Parallel session
Producing more with less: Efficiency in Power Generation

CO2-REDUCTION TARGETS CALL FOR APPLYING BAT; A NEW 800 MW COMBINED CYCLE POWER PLANT SOUTH OF GRAZ

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ABSTRACT

Seeing the problem of increasing electricity demand in Austria combinded with the targets to reduce CO2 emissions and the fact that older power stations will be closed, Verbund has decided to start the project work for a 800MW gas fired combined cycle power plant south of Graz.
The project targets are to realize a power plant according to best available technology.
In the presentation the state of the art of combined cycle power plants will be presented on basis of this new Verbund project. Also the environmental effects of the technology change (partial replacement of existing units by new units using BAT) will be presented.

1 Short description of Austrian Thermal Power / ATP

ATP is a company of the Verbund Group, which operates thermal power plants. In 2003 ATP produced 5,97 TWh electricity, of which 91 % from coal and 9 % from oil. The installed capacity amounts 1901 MW, from this capacity 756 MW are already in cold standby. Because of the closing of a coal mine another 330 MW unit will be transferred to cold standby in 2006. By this the capacity of ATP power stations will be reduced to 850 MW in total. To compensate this reduction in capacity and in order to fulfill the future requirements regarding CO2-reduction, ATP is planning to build a new 800 MW combined cycle plant (CCGT) south of Graz at the site of the existing power plant Mellach.

power station	status of plant	fuel	capacity in operation year 2000 (MW)	capacity in operation year 2008 (MW)
Dürnrohr	operation	coal	405	405
Mellach	operation	coal	246	246
Werndorf 2	operation	oil , gas	164	164
Voitsberg 3	operation 2006 cold stand	lignite	330	
St.Andrä2	cold stand by since 2004	coal, biomass	124	
Korneuburg	cold stand by since 2000	oil , gas	285	
Werndorf 1	cold stand by since 1999	gas	110	
Zeltweg	cold stand by since 2001	coal, biomass	137	
Pernegg	closed	oil	100	
			1901	**815**

Table: ATP Power stations

2 Overall environment for new power plants

The European Energy Market is characterized by the following facts:

- Fully liberalized electricity market
- Reduction of non profitable generating capacity
- Building activity of new generating capacity on a very low level
- Over-aging of existing power stations
- Increasing electricity demand
- Restrictions on the CO2-emissions

These facts will cause the need of new generating capacities by the end of this decade. The realization period of a power plant lies between 5 and 7 years, therefore in case a power plant should be ready in 2010 the process of detailed planning has to be started.

Environment for power plants in Austria

- During the previous decade the electricity consumption in Austria has increased by 2,3 % annually. For the next years an increase of 1,6 % per annum is expected. At the same time a decrease of hydropower electricity production is expected as a consequence of the EU-directive 2000/60/EG (Wasserrahmenrichtlinie).
- The electricity production in Austria has a concentration in the northern part of Austria. The fact that the power stations which were brought to cold standby are located mainly in the South and due to restrictions in the transport capacity of the grid the need of new generating capacity is given specially in the south.
- *Based on 1990 CO2-emissions Austria has to reduce CO2-emission by 13 % until* 2010. Between 1990 and 2002 CO2-emissions have increased app. 10 %. To reach the goal 2010 set by the government the emissions have to be reduced by app. 23 %. The CO2-allocation for ATP for the period 2005 - 2007 amounts 3,3 million tons per year, to compare, the CO2 emission value 2003 was 5 Million tons. Because neither electricity production based on the purchase of C02-certificates nor switching from coal to oil and gas seems not to be profitable at existing electricity price level, CO2-reduction can only be achieved by reduction of generation. Therefore, to keep the production on the existing level, it is necessary to invest in new generating capacities and to use the best available techniques for new plants. The average CO2-emission of ATP power plants amounts at the moment 0,84 tons per MWh, specific emissions of new gas fired combined cycle plants are by the factor 2,3 lower or in other words 0,36 tons per MWh.

3 State of the art of gas turbines and CCGT plants

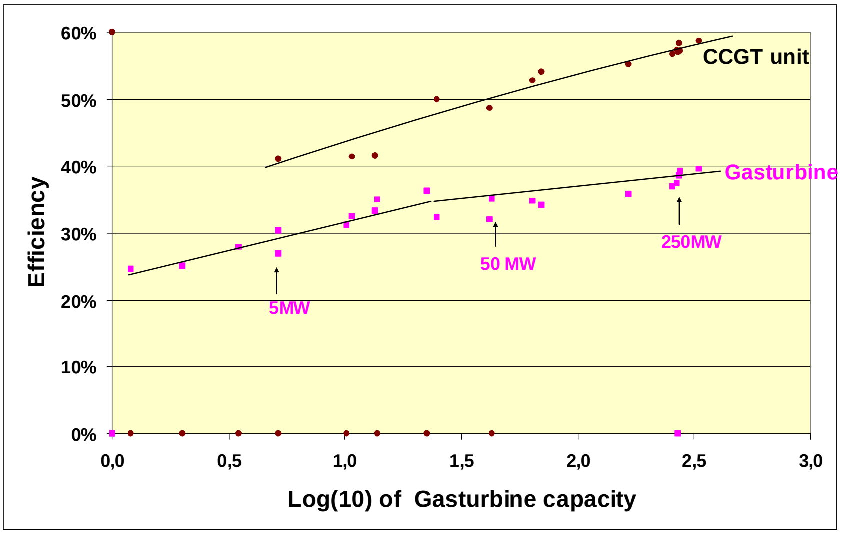
The main component of a CCGT unit is the gas turbine. The development of gas turbines is done by the producers. Planners of power stations normally can only choose between standardized gas turbines from different producers. Also CCGT plants are offered by the producers in standardized packages. This is different to conventional power plants which can be optimized in size and design according to specific needs. In the following the performance of gas turbines and CCGT plants is described from the view of an user and potential buyer, not from the view of a producer.

Efficiency of gas turbines and CCGT plants

The efficiency of CCGT increases with the scale. Reasons for this are:

- Specific losses of small machines are higher than specific losses of big machines
- By economical reasons in small machines complex-high tech solutions are more difficult to realize than in bigger machines
- The need to keep the specific costs for operation and maintenance low, also for small machines, forces to have a more conservative design of these machines

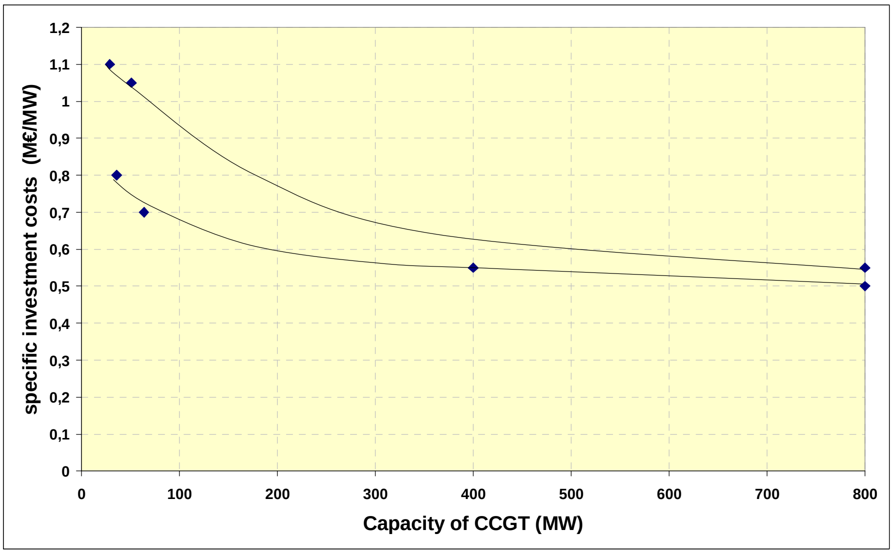
The following graph shows the efficiency of new gas turbines and CCGT units, the operational efficiencies in long time operation are 1 to 2 %-points lower. Big CCGT units (400 MW class), depending on local conditions, are reaching a net-efficiency in the range of 57 % to 59 % while best efficiencies of 30 MW CCGT units are lower than 50 %.



Graph: Efficiency of gas turbines and CCGT units

Specific investment costs of CCGT units

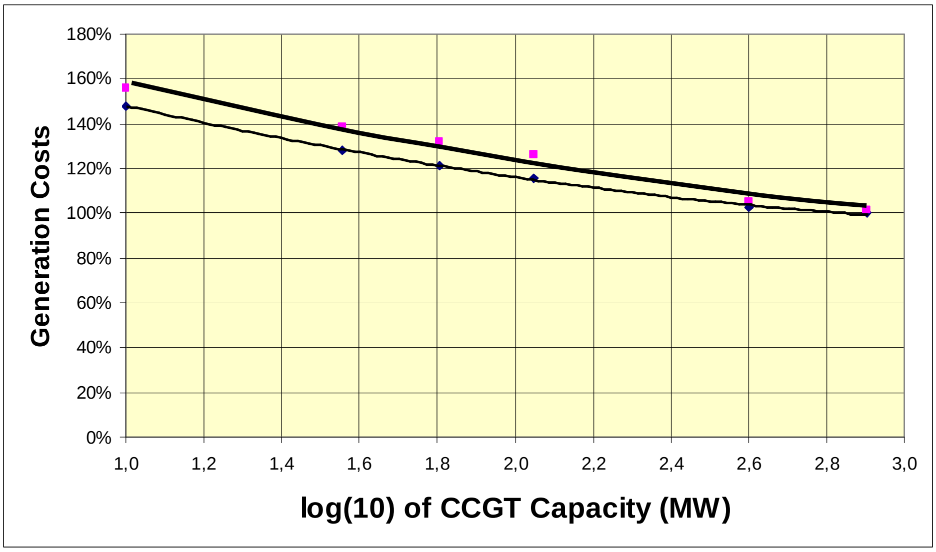
The specific investment costs of CCGT units are decreasing with increasing size, small units have higher specific investment costs than bigger ones. The need to be competitive in the liberalized electricity market forces to choose large unit sizes.



Graph: Specific investment costs of CCGT units

Electricity generation costs of CCGT units

As shown above bigger CCGT units have better efficiencies and lower investment costs. Therefore the electricity generating costs of CCGT plants are decreasing significantly with the scale. The generation costs of a small 10 MW CCGT are 50 % to 60 % higher than those of a 800 MW CCGT. This statement is valid only for CCGT units operating in condensing mode, not for combined heat and power production.



Graph: Relative electricity generation costs of CCGT plants

<u>State of the art of large gas-turbines (250 MW class)</u>

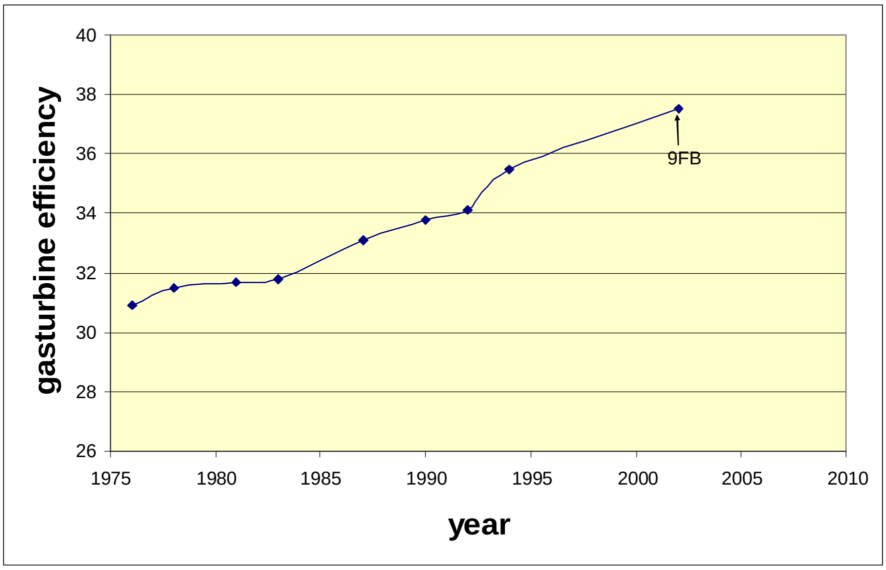
Large gas turbines are offered from four suppliers:
Alstom
General Electric
Siemens
Mitsubishi (at the moment not generally in Europe, not in Austria)

		available gas-turbines				in development / in test	
Producer		Alstom	Siemens	GE	Mitsubishi	GE	Mitsubishi
Type	--	GT 26	V94.3A	GE 9FB	701F3	GE 9H	701H
Gasturbine capacity	MW	274	276	269	270,3		334
Gasturbine exhaust temp.	°C	630	585	622	586		587
CCGT capacity (ISO)	MW	405	407	412	397,7	480	483
GT-efficiency at 100% load	%	Mean value = 38,7					39,5
CCGT-efficiency at 100% load	%	Mean value = 57,9				60	60

Table: Technical data of available gas turbines and CCGT units

The table shows that the capacity of CCGT units from Alstom, General Electric and Siemens are in a narrow range, at ISO conditions between 405 MW and 412 MW. Mitsubishi and General Electric have also gas turbines with 480 MW, the GE machine is still in test condition. It is expected that with these new machines of the 480 MW class a CCGT efficiency of 60 % can be reached. The efficiencies shown in the table are given for new machines and direct cooling. When cooling towers are used for cooling (indirect cooling) the net efficiency of CCGT is app.0,7 %-points lower.

The following graph shows the development of gas turbine efficiency during the last 30 years on example of the GE machine Frame 9 (data were taken from literature). The GE Frame 9 machine is the worldwide most spread gas turbine with high capacity. The graph shows a continuous, nearly linear increase of efficiency since 1975, the extrapolation of this graph shows that in 2010 a gas turbine efficiency of app. 40 % could be state of the art.



Graph: Development of GT-efficiency

The design measures causing the efficiency increase of gas turbines will not be explained in this paper, the main parameters are listed below:

optimized compressors
smaller clearances between rotor and casing to reduce losses
high fireing temperatures

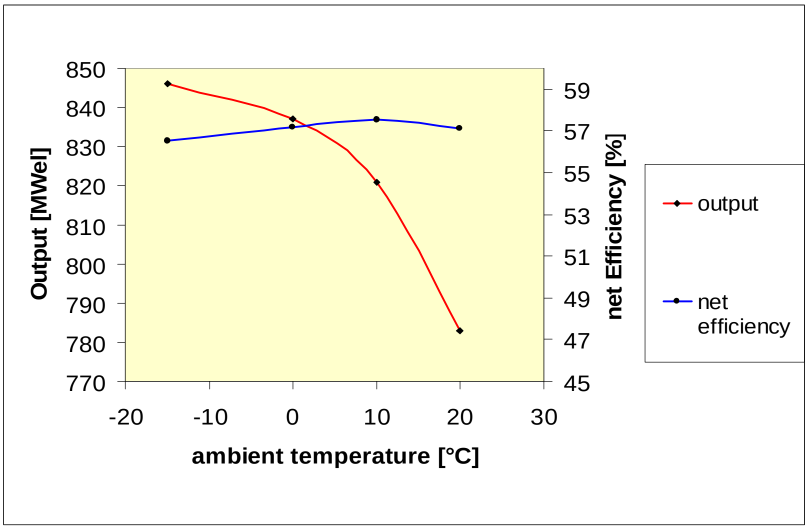
cooling of turbine blades with air
coating of turbine blades
single crystal turbine-blades

Some special features of the manufacturers to increase efficiency are:

- Change axial positioning of turbine runner at continuous operation and start to reduce clearance between rotor and casing — Siemens
- Sequential combustion — Alstom
- Cooling of compressed air — Alstom
- Use of steam instead of air to cool turbine blades — Mitsubishi und GE

<u>Influence of ambient temperature on gas turbine capacity and efficiency</u>

The output of a gas turbine depends on ambient conditions, air pressure and air temperature, the drop of gas turbine output between 0 °C and 30 °C is almost 10 %. The influence of ambient temperature to the efficiency is rather low. In the following graph this dependence is shown (typical example).

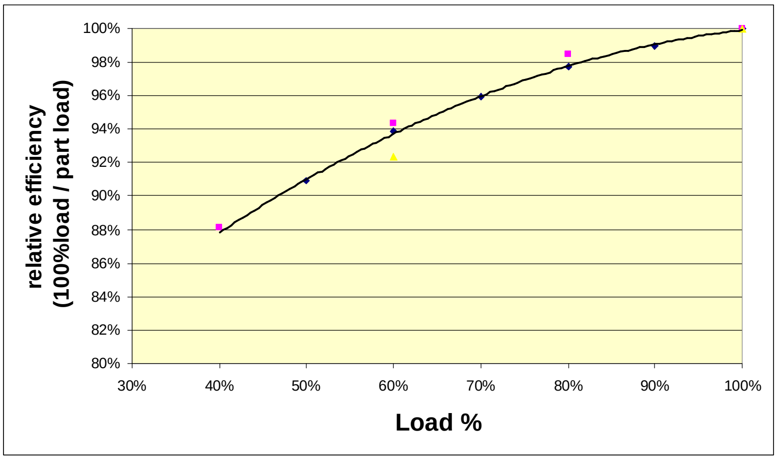


Graph: Typical example for the dependence of GT-output and efficiency

Part load efficiency of CCGT plants

The efficiency of CCGT units at partial load is lower than efficiency at 100 % load.

At 50 % CCGT load the efficiency is app. 10 % lower than at full load (depends on the GT supplier).



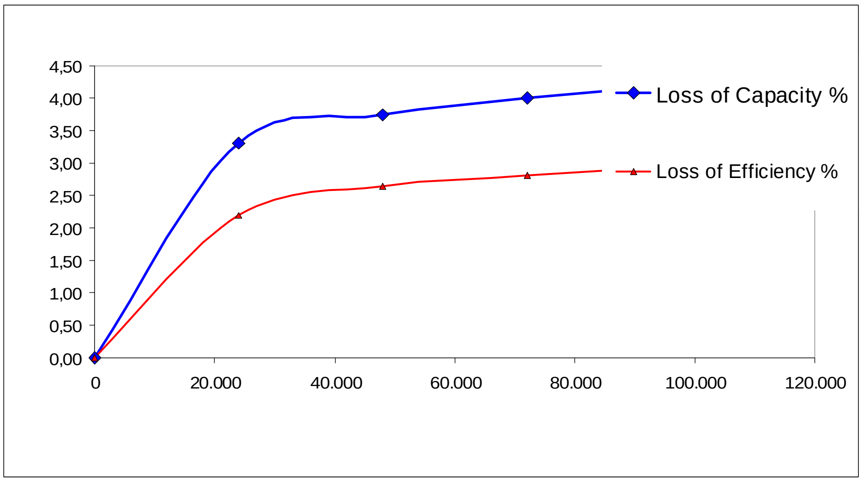
Graph: Influence of load factor to the CCGT efficiency

Though low load factors are no problem for gas turbines the ability of running at low load is limited because of increased NOx-emission values at low load. When emission limit values of LCP directive are applied, CCGT units can be operated between 40 % and 50 % load, when emission limits of Austrians legislation are applied the min load lies in the range of 50 % to
60 %.

Aging of gas turbine output and efficiency

Previous mentioned capacity and efficiency data are data of new plants which are guaranteed by suppliers at the beginning of commercial operation.
During operation the capacity and efficiency are decreasing. Reasons are

- Increase of internal losses
- Coarsening of compressor and turbine blades
- Dirt on the surface of compressor and turbine blades



Graph: Loss of GT-Capacity and -Efficiency during operation

By regular maintenance one part of the capacity and efficiency degradation can be recovered, another part can't be recovered. The graph shows the remaining (non recoverable) part of degradation.

The efficiency loss of the gas turbine leads to higher exhaust temperatures of the gas turbine. Therefore a part of this loss can be compensated in the steam process.

After 30.000 operating hours of a CCGT, the expected efficiency of the CCGT is app. 1,5 % points lower than the guaranteed efficiency of the new plant.

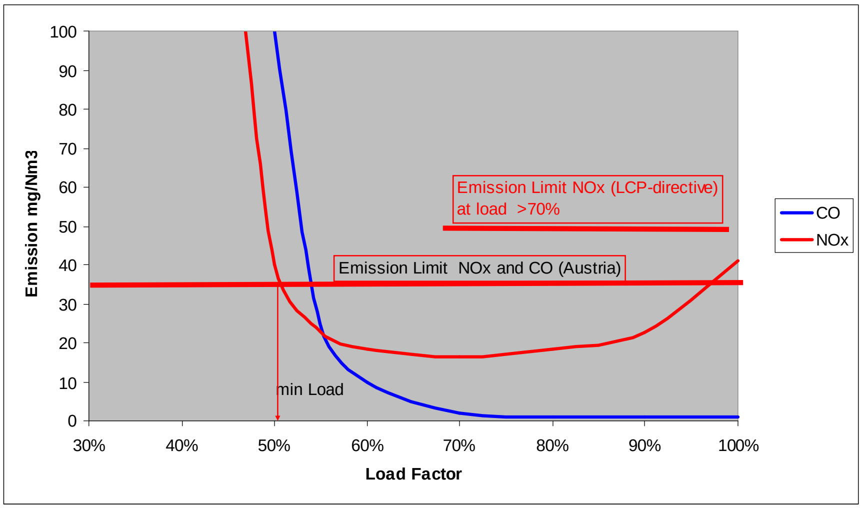
<u>Influence of cooling to CCGT efficiency</u>

The cooling system has an essential influence on the efficiency of the steam process. A decrease of the cooling water temperature by 10 °C improves the CCGT efficiency by app.0,5 %. At typical climatic conditions in Austria for a 400 MW CCGT unit the difference between cooling tower cooling and direct cooling amounts app. 7 MW in capacity, the difference in efficiency is about 0,7 %.

<u>Emissions</u>

Emission limit values according to LCP-directive are:
NOx	50 mg/Nm³ if annual average of CCGT efficiency is lower than 55 %
NOx	75 mg/Nm³ if annual average of CCGT efficiency exceeds 55 %
Taking into consideration the lower part load efficiency of CCGT and the efficiency degradation it seems to be difficult to reach an annual average of efficiency of 55 % with state of the art CCGT units (net efficiency 57 – 59 % in new condition at full load).
Die NOx-limit values are to keep in the load range > 70 % load. No limit if load < 70 %
CO:	No limit value in LCP regulation

Austrian regulation stipulates a lower emission limit value for NOx, 35 mg/Nm³, this limit is not dependent on the load factor.
CO: Austrian regulation stipulates max. 35 mg/Nm³ at nominal load (normally 100 % load).



Graph: Typical values of NOx and CO emission depending on the load

The graph shows a typical example of NOx-and CO-emission of a gas turbine (250 MW class).

All suppliers of gas turbines guarantee that the NOx-emission value does not exceed the limit value 50 mg/Nm³ stipulated by the European LCP-regulation. Non of the suppliers guarantees that the NOx-emission does not exceed 35 mg/Nm³. Therefore to keep the Austrian emission limit the installation of a SCR seems to be necessary. The installation of a SCR is technically state of the art, but is worsening the competitiveness of the plant.

A heavy burden is that in Austria NOx limit value must be kept also at low load. The NOx-emission limit value limits the operational load range. By this the possibility of load reduction in off peak hours is limited. This has an enormous negative effect to the economy of a plant, frequent shut downs of the plant during night hours will be the consequence. It is sure that in some cases the higher NOx-emissions during stop and start of the plant will overcompensate the positive environmental effect of low NOx-emission limits. So the total environmental effect of the low Austrian emission limit at low load could be negative.

In a common liberalized electricity market different emission limit values in European countries are disturbing competition and will boost the intentions to build power stations in neighbor countries having less strengthened environmental limits.

4 The 800 MW CCGT project „Mellach"

In the period 2000 to 2006 ATP intends to convert a capacity of app. 1200 MW (6 power stations) from operational to cold stand by status. Due to future restrictions of CO2-emissions it is intended to substitute this generation capacity with modern CCGT units according to the state of the art.

Preliminary studies of ATP have shown that highest efficiency and lowest investment costs can only be reached with CCGT units in the range > 400 MW. Furthermore the investigation has shown that a 800 MW unit consisting of two widely independent 400 MW units with common infrastructure at one site would be the best solution for ATP.

a) Selection of site

At the beginning of the investigation in total five different sites were investigated, this investigation has shown that Mellach site would be the most preferable site for a CCGT.

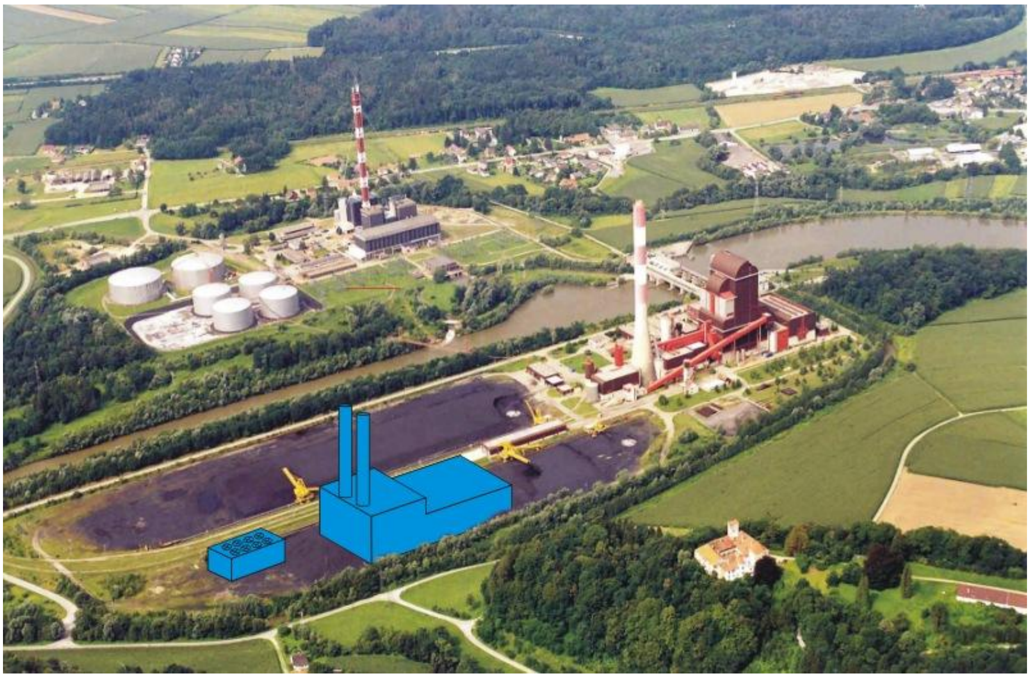
The evaluation criteria which have led to the decision of Mellach have been

- Situation of the grid (capacity demand is especially given in the south of Austria)
- Grid connection
- Gas supply (supply lines)
- Cooling water
- Possibility to supply district heat
- Personal and infrastructure synergies with existing industries (power stations)

b) Positioning of the CCGT at the site of the coal power plant Mellach

The CCGT unit will be erected on the eastern part of the coal yard of Mellach power plant (Mellach is hard coal fired, nominal capacity 246 MWel). The remaining coal yard is sufficient for future operation of the plant.

The vicinity of the new CCGT to the existing plant will enable to have a common use of infrastructure and personnel (common management, common workshops and stores, common ammonia storage, common water treatment …).



c) Supply of district heat to the city of Graz

From the power stations Werndorf 2 (164 MW, oil fired) and Mellach (246 MW, coal fired) in total app. 800 GWh/a, max. 250 MW district heat is supplied to the city of Graz. In future when the CCGT is in operation, it is not intended to use Werndorf plant for base load in winter time. The district heat supply from Werndorf plant will be substituted with district heat from the CCGT plant.

To have a redundancy in district heat supply the new CCGT will have the ability to supply min. 250 MW district heat (this is 100 % of existing supply).

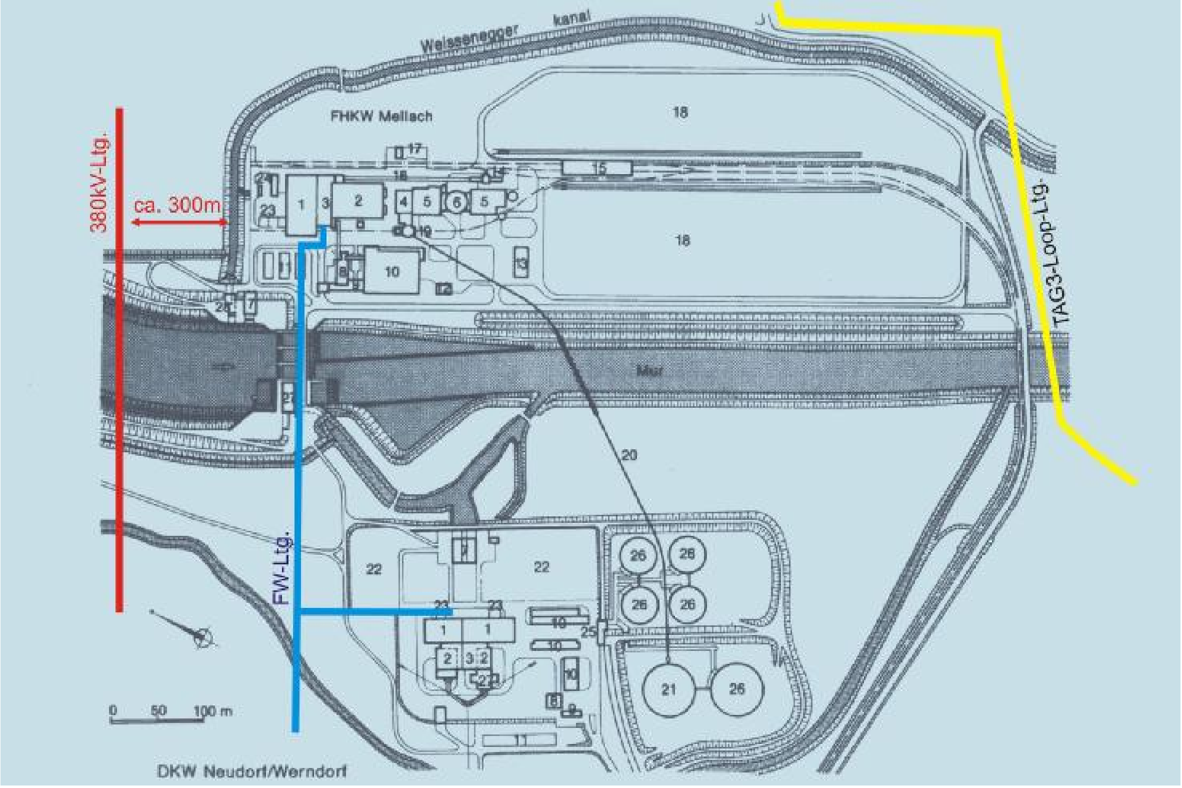
Net capacity of CCGT	800 MW
capability of district heat supply	250 MW
Net efficiency in condensing mode	58%
Net efficiency when supplying 250MW of distric heat	70%

Table: Technical data of CCGT

d) Gas supply and grid connection

The Trans-Austria-Gaspipeline (TAG), the main connection from Russia to Italy is routed directly along the power station area, also the main tapping point of Styrian gas network to the TAL pipeline is situated very near to the power station. Therefore the gas connection line to the CCGT will be very short.

The connection point to the grid will be the grid substation Zwaring in app. 5 km distance to the plant. If the new planned 380 kV transmission line from Rothenturm to Zwaring will be realized in time the CCGT will be connected directly to this new 380 kV line.



e) Emissions

The emission limits according Austrian regulations for the CCGT are:
NOx 35 mg/Nm³
CO 35 mg/Nm³ (at nominal load)
Dust 5 mg/Nm³

The new CCGT unit will be able to keep this emission limits, to keep the NOx-limit a SCR unit will be installed. The expected operational NOx-value is 20 mg/Nm³.

The specific CO2-emission of the new plant will be 0,36 to/MWh.

f) Project time table

Preliminary project investigations were done early 2003, at the moment the basic planning and environmental impact analysis are in work. It is planned to submit the project to the authority for approval beginning of next year. If approval is reached end of 2005 commissioning of the plant could commence mid 2008.