The SCC5-8000H 1S Lausward Block F: "The First CHP to Extract 300MWth of District Heating from a Single Power Plant Unit in Combined Cycle Operation"
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Introduction

The strive for efficient use of primary energy combined with reducing the greenhouse gases (GHG) is a key element in the EU-Policy for decarbonization.

The energy sector is expected to offer a high potential for contributing to the aim of the EU to reduce the CO2 emissions by 20 – 25% in comparison with the 1990 value. Electrical energy is not only considered as a key enabler of decarbonization (e.g. use of electric cars instead of fuel driven vehicles), but also as a major driver for keeping industrialization within Europe at high level by the EU-policy makers.

After the Fukushima nuclear disaster Germany has decided to abandon nuclear power plant technology by 2022 and enforce its Energy Transition. Driven by the introduction of a variety of subsidies for renewable energy sources, Germany has seen a rise in the installation of Photovoltaic and Wind plants, which already exceeded the projected figures by far. This in consequence has led to additional financial burdens and increase in electricity prices for consumers. Therefore, the German government is searching for ways to restructure the built-out of renewables to achieve a better balance between renewable built-out and improving the power grid, without substantially loosing speed in the Energy Transition “Energiewende”.

Besides the fact that Germany has achieved its CO2 aims defined in the Kyoto protocol, the CO2-emissions generated by its power industry have continuously risen over the last two years. The reasons for that can be mainly attributed to the very low Carbon prices and the rise of shale gas in the US and subsequently to the decreased coal prices on the world market. This resulted in extended usage hours of coal fired power plants due to the decreased marginal costs of these generation facilities. Combined Cycle Power Plants (CCPP) are, therefore, under substantial economic pressure. This leads to the conclusion that only those CCPPs with a high efficiency and flexible operation characteristics will have a positive business case in the future, provided that the current market conditions prevail.

It is yet to be seen if the shale gas boom will have a long-lasting downward effect on the worldwide gas and oil prices. Irrespective thereof, natural gas will remain one of the important and widely available primary energy sources to be used in power generation for the next decades to come.

For the EU-policy makers, keeping the energy infrastructure at internationally competitive level in terms of prices and greenhouse gas emissions will be of vital importance to maintain not only the prosperity of its member states, but also to ensure the achievement of environmental goals.
How the Combined Cycle Power Plants can play an important role in reducing CO2 footprint of the energy industry will be explained in the next chapters.
Europe’s Road to Decarbonization, part 1

In its roadmap for moving to a competitive low carbon economy in 2050, the European Commission has reconfirmed several strategies to achieve substantial reduction in greenhouse gases (see Figure 1 below).

![Europe's Road to Decarbonization](image)

Figure 1: EU-Policy for Decarbonization

Among those policies are the promotion of Renewable Energy Sources (RES) and the legislation to promote Combined Heat and Power (CHP).

The rise of RES has resulted in additional economical and technological challenges, with the first being closely connected to the payment of subsidies and the subsequent effects on the electricity prices. The latter – the technological challenges – are concerned with the integration especially of large centralized RES into the power grid, with the constraints to grid overloading and grid frequency stability problems and in the future the usage/implementation of storage capacities to make efficient use of the excess of renewable energy feed-in.

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1 EU – Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Roadmap for moving to a competitive low carbon economy in 2050, COM(2011) 112 final, Brussels, 8.3.2011
The anticipated future power generation mix as shown for an exemplary week in June 2020 (see Figure 2) indicates that due to the fluctuating feed-in of RES, substantial load gradients need to be mastered by the non-renewable fleet.

**Figure 2: Effect of RES on non-renewable fleet**

In order to summarize this section, it can be stated that not only efficiency in terms of fuel, but also flexibility will be a main driver for power plant operations and developments in the future.
Combined Heat and Power

Based upon the EU Combined Heat and Power legislation, Germany has introduced its CHP-legislation “KWK Gesetz” in 2009, which was revised in 2012 to further promote CHP and achieve 25% of power generation from the CHP-Plants (see Figure 3 below).

With the latest revision of the CHP-legislation, the subsidy was increased from 1.8 to 2.1 ct/kWh CHP-Power. Furthermore, the subsidy receipt period was flexibilized to 30,000 Full Load Operating Hours (FLOH), instead of the formerly limit of 6 years/ 30,000 (FLOH). For most CHP this will extend the subsidy receipt period beyond 6 years.

Considering the current low spark spread for CCPP in Germany, only CCPPs with CHP are likely to demonstrate a positive business case due to the available subsidies for CHP-Power. For example, the subsidies may reach up to EUR 200 Million for a CCPP with 270MWth district heating.

Also, the introduction of subsidies for cold and heating storages may have a positive impact on the success of CHP plants, given that the storages will add value to the operational flexibility of CCPPs, e.g. the heating storage can be loaded when the CCPP is running in low load operation (little power demand) and the storage can be unloaded in times of peak power prices, with the CCPP preferably running in pure condensing mode to obtain maximum benefits from the power market.
The success of CHP with CCPP, not only in Germany, will depend upon a series of factors, including:

1. Economic concerns, such as the market structure and prices for natural gas and electricity (spark spread).
2. The future of the EU Emission Trading System (ETS).
3. The availability of heat sinks (district heating or process steam requirements).
4. The investment in infrastructure to bring the “heat” to its consumers, e.g. built-out of district heating networks.
5. Competitiveness of other power generation technologies, especially the traditional “substitutes”, e.g. coal fired power plants.

There is no doubt that CCPPs with and without CHP are and will be key corner stones of the future energy mix, but its immediate advance to substitute coal fired power plants is hampered by the overall economic situation. Therefore short-term developments in CCPP technology will focus on effective integration of CHP requirements.
**CCPP with Combined Heat and Power Technology (CHP)**

The Combined Heat and Power Technology are largely driven by the process demands, e.g. district heating applications or process steam extraction.

Virtually each CHP Plant is customized to provide the most benefit in terms of:

- Satisfying the process parameters to the extent possible, without using back-up facilities or add-ons, such as duct firing
- Reaching a high fuel utilization factor (a value above 80% is an indication for a good CHP-quality)
- Minimizing the power loss factor, which provides an indication about the quantity of electricity “lost” due to the extracted steam not taking part in the electricity generation process

With an increase in steam export to a district heating system or to process plants, the fuel utilization factor increases but the net electrical efficiency decreases due to the “lost” steam, as shown in Figure 4:

![Figure 4: Interdependency between Fuel utilization and Electrical efficiency](image)

As could be seen above, an increase in fuel utilization for district heating applications, can be achieved by using an innovative multiple steam extraction. This is due to the fact that the multiple steam extraction can be fine-tuned to account for the most important load cases.

Obviously, the extraction stages correspond to steam-extraction-points within the water-steam-cycle of the power plant. The typical extraction points are shown in the Figure 5 below.
Figure 5: Steam extraction points in water-steam-cycle

For district heating applications lower calorific steam should be used to minimize power losses. This may result in extracting steam from the low-pressure section of the steam turbine for this kind of application. For process steam applications, the steam extraction points must be selected to ensure the necessary physical properties of steam: pressure and temperature.
The SCC5-8000H 1S Lausward Block F, Düsseldorf / Germany

Düsseldorf’s local utility, Stadtwerke Düsseldorf (SWD), is running an extensive district heating network on both sides of the Rhine river. With its three generation centers Flingern, Garath, and Lausward, SWD provides yearly approx. 1.4Mill. MWh of district heating power over its 200km network to its customers. In future SWD wants to use its district heating upgrade potential by increasing the system capacity by 15MWth/a.3

For its project SCC5-8000H 1S Lausward Block F, SWD was looking for state-of-the-art power plant technology to ensure SWD’s competitiveness on the market, by increasing its share of self produced electricity and to produce district heating at lowest costs. Siemens met those requirements by offering the SCC5-8000H 1S based upon its high efficient gas turbine SGT5-8000H. The gas turbine is arranged in a single-shaft configuration combined with a steam turbine SST5-5000 which is equipped with three steam extraction points as shown in Figure 6 below.

Figure 6: Steam extraction points in water-steam-cycle, SCC5-8000H 1S Lausward Block F

Using these steam extraction points, the power loss factor is as low as 0.16 for the important load case of 150MWth district heating.

3 „Attraktive Effizienz“, ZfK March 2013, page 14
The power plant can extract in total 300MWth, which is approx. 75% of the maximum district heating demand of Düsseldorf. No further auxiliaries such as duct firing are needed to achieve this outstanding performance, especially in respect to eco-friendliness and security of supply.

By using the 3 stage steam extraction layout, the most efficient way to balance steam export with district heating demand is achieved without the need for quenching high calorific steam from other upstream steam extraction sources.

This means that with increased district heating demand, the steam is extracted accordingly from the relevant sources, e.g. for a low to medium heating demand, only extraction from the LP section of the steam turbine is used. With increased heating demand, further steam is extracted from the cross-over-pipe between the IP and LP Section of the steam turbine. Subsequently at full district heating load, most of the steam is taken from the latter source.

This high level of steam extraction results in a fuel utilization factor of approx. 85%, meaning that 85% of the fuel is converted into heat and power. This demonstrates the high quality of the CHP process.
Another outstanding feature of the SCC5-8000H 1S Lausward Block F is the achievement of over 61% Net Electrical Efficiency by using the state-of-the-art water-steam-cycle features, such as 600°C life steam temperature and the Benson® design for the Heat Recovery Generation System (see Figure 7 below).

Based upon this high efficiency, SCC5-8000H 1S Lausward Block F will keep its competitive advantage in Germany’s Merit-Order system.
The road to decarbonization, part 2

Obviously, an increase in efficiency and a high fuel utilization factor results in low specific CO2 emissions per electrical kilowatt-hour produced.

Based upon Siemens’ SGT5-8000H, the SCC5-8000H 1S produces specific CO2-emissions as low as 325g CO2/kWh net.

ECONOMICS:
Highest fuel efficiency in CHP Plant by Siemens

Lausward
Düsseldorf

SCC5-8000H 1S

<table>
<thead>
<tr>
<th>Customer</th>
<th>Stadtwerke Düsseldorf</th>
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<tr>
<td>Total el. Power Output</td>
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<tr>
<td>Plant efficiency</td>
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<td>ST Type</td>
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<td>Generator Type</td>
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Special features
✓ District heating 300 MWth
✓ 85 % fuel efficiency
✓ CO₂ Emissions less than 325 g/kWh

Figure 8: Summary Design Features of SCC5-8000H 1S Lausward Block F

This exceptionally low value in comparison with coal fired power plants results from a change to relatively low carbon fuel (natural gas) and from the higher power plant efficiency.
The following Figure 9 summarizes this aspect.

**Siemens high efficient H-class CCPP solution enables significant CO₂ emissions reduction**

**Figure 9: Specific CO2 Emissions per Power Plant Type (fossil fuel)**

The SCC5-800H 1S Lausward Block F will produce approx. one-third of the CO2 emissions of one state-of-the-art lignite plant. Comparing total emissions by using a typical lignite plant size of 1100MW, this results in yearly CO2 savings of 5 Mill. tons.

If the comparison is extended by including the maximum district heating production of 300MWth then the CO2 savings are even greater.

Therefore, the SCC5-800H 1S with CHP are the most preferable fossil plant solution to meet the ambitious EU CO2 limits.
Summary

Energy efficiency and the fuel switch from coal to natural gas are the key elements to reduce the CO2 footprint of the energy industry. The latest generation of CCPPs already achieves an efficiency level beyond 60% and is therefore the most efficient fossil fired power plants. But there are still ways to increase the energy efficiency of a CCPP even further by implementing e.g. combined heat and power capabilities (CHP). Stadtwerke Duesseldorf and Siemens signed the contract to start building the Lausward CHP plant in July 2012, providing a contribution in meeting the city’s climate and CHP targets set by the state and German governments. In addition to the outstanding, “world record” efficiency level over 61% net in condensing mode operation, the Lausward CHP plant can export up to 300MWth to the local district heating network. No further auxiliaries such as duct firing are needed to achieve this outstanding performance, especially in respect to eco-friendliness and security of supply.

The configuration provides the most efficient way to extract steam to the district heating system corresponding ideally to the respective load demand and will set a landmark for future power generation in Germany and elsewhere. It emphasizes the central role of CHP engine as part of the German energy transition (Energiewende) debate. Based on Siemens experience with the H-class design this paper presented the outperforming advantages of the Lausward CHP Block F in regard to heat extraction, fuel utilization of approx. 85%, and the optimized cycle design selected to reduce electricity losses at extraction point to a minimum.
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