Lünen – State-of-theArt Ultra Supercritical Steam Power Plant Under Construction

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Abstract

Clean and cost-effective power generation is of paramount importance to cope with the challenges imposed by an increasing energy demand throughout the world. Investment cost and fuel costs are the main contributors to the cost of electricity. In recent years, costs associated with CO_2 emissions have attracted more and more attention due to its political awareness.

The efficiency of the power plant as one key value affects both the fuel costs and the amount of CO_2 emitted to the environment. As coal is more abundant in many parts of the world, coal prices are less volatile and more stable than natural gas prices. But larger CO_2 emissions increase the need for more efficient coal-based power generation.

Ultra supercritical (USC) steam power plants meet notably the requirements for high efficiencies to reduce both fuel costs and emissions as well as for a reliable supply of electric energy at low cost. Recent developments in steam turbine technology and high-temperature materials allowed for significant efficiency gains. Siemens has more than fifteen years of experience with ultra supercritical steam turbines and continues to optimize associated designs and technologies.

This paper presents Siemens products and solutions for ultra supercritical steam power plants and their application in the 800 MW Trianel Power project in Lünen. Several German and European municipal utility companies hold a share in Trianel Kohlekraftwerk Lünen GmbH & Co. KG. Advanced steam parameters (280 bar / 600 °C / 610 °C), a net efficiency above 45 % (LHV basis, hard coal), and specific CO_2 emissions well below 800 g/kWh are characteristic features of this turnkey project which reflects the state-of-the-art in USC power plant technology.

Experiences gathered in the development and execution of this advanced coal-based power plant project in Germany will be summarized from a customer and a supplier perspective. Commissioning of the power plant in Lünen is scheduled for fall 2012.

Introduction

Coal-based power generation is still a fundamental part of energy supply throughout the world. Reliability, security of supply, low fuel costs, and competitive cost of electricity make a good case for coal-fired steam power plants. Requests for sustainable use of existing resources and concerns about the effect of CO_2 emissions on global warming have strengthen the focus of plant engineers and the power industry on more efficient energy conversion processes and systems.

Applying proven state-of-the-art technology while striving for cost-optimal efficiencies are key customer requirements in any new power plant project. Optimizing the combustion process, increasing the steam parameters, reducing the condenser pressure and improving the internal efficiency of the steam turbines are some of the well known levers for raising the overall plant efficiency. Due to the efficiency penalties associated with carbon capture and storage (CCS) such improvements are more than ever needed to ensure a sustainable generation of electricity based on coal.

Siemens steam plant SPP5-6000 (1x800) is designed to meet these challenges with today's technology. Trianels' hard coal fired steam power plant in Lünen/Germany is the first application of this advanced 800 MW reference power plant design with ultra supercritical steam parameters. Several others are about to follow.

This paper describes the objectives and the approach of the municipal utilities to put this power plant project into practice. Technical details of the plant layout and the key plant components will be presented and discussed. Two examples illustrate the efforts of the project team to improve the efficiency and flexibility of the power plant. A summary of recent developments in project execution will shed some light on the current challenges imposed on procurement and cost estimation.

Trianel Power Project in Lünen

In the course of the liberalization of the German electricity market several municipal utilities joined forces in 1999 to set up Trianel, a new company for providing electricity to municipal energy providers at low cost. Independence-minded this cooperation also aims at the European market and transnational synergies. By close cooperation of municipal stakeholders the Trianel group became firmly established in the liberalized energy market. Today, Trianel is the largest and most powerful platform for independent European municipal utilities. A total of 46 shareholders and several associated partners provide electricity, gas, and services at all levels of the entire value chain.

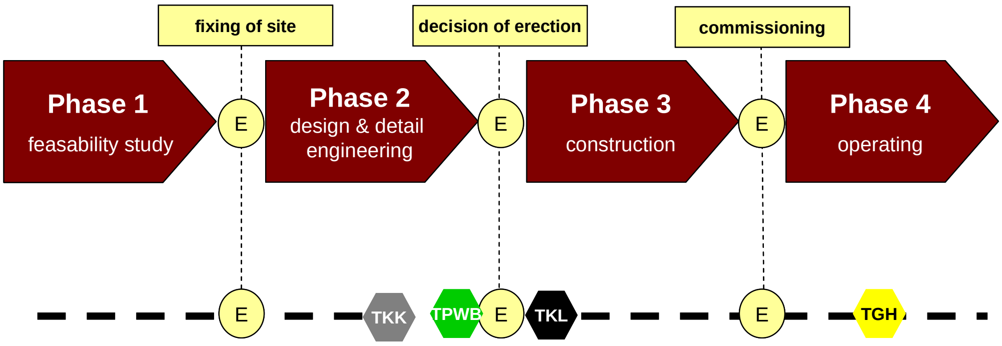


Figure 1 Trianel Project Development. 2x400 MW CCGT power plant Hamm-Uentrop (TGH), 750 MW coal-fired power plant Lünen (TKL), 400 MW offshore wind park Borkum (TWB), 750 MW coal-fired power plant Krefeld (TKK).

Following the commissioning of an advanced combined cycle power plant in Hamm-Uentrop (2x400 MW, η>57 %) in October 2007, Trianel is now developing additional power plant projects to achieve a sustainable and environmentally friendly power generation portfolio (Figure 1): The advanced hard coal fired steam power plant in Lünen (TKL) is currently under construction. Planning an additional steam power plant in Krefeld (TKK) has progressed considerably. Furthermore, the 400 MW offshore wind park Borken (WB) shall be put into operation prior to the year 2012. When completed, the power generation portfolio of Trianel will rely on natural gas (43 %), hard coal (41 %), and wind power (16 %). Independent generation of electricity is the main driver for the municipal utilities to cooperate in Trianel whose expertise in project development will assist these partners in achieving their task.

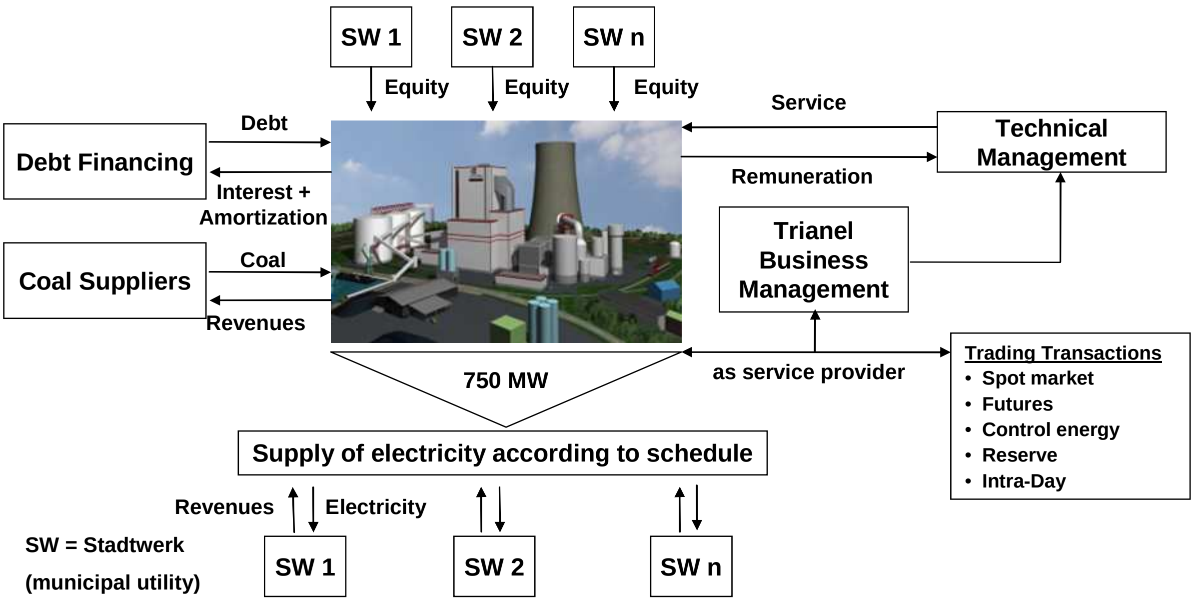


Figure 2 Project structure

Cost-effective growth by investing in power plants is an appealing approach for municipal utilities. Economies of scale favor large-scale power generation projects. Due to the significant capital requirements for such projects, the market entry barrier for a new power supplier is relatively high. Partners achieve a critical size by pooling of interests and will be able to finance power plant projects together that cannot be realized alone. This is the Trianel approach. High operational flexibility without sacrificing cost-effectiveness or plant performance is a prerequisite for a power plant in the Trianel concept (Figure 2). In Lünen, this requirement is fully met.

Table 1 Project history

Date	Activity/Event
10/2005	Project start (feasibility study)
02/2006	Selecting and clearing of site (Stummhafen Lünen)
04-11/2006	Concept planning; Request for proposals
12/2006	Reservation agreement for steam turbine, HP piping, boiler pressure parts and erection capacity slots
02/2007	Permissioning initiated
09/2007	Public hearing
09/2007	Engineering, Procurement and Construction (EPC) contract signed; Detail engineering started (EPC contract phase 1)
02/2008	Project financing: Underwriter/arranger selected and assigned
04/2008	Coal supply contract for 20 years signed
May 6, 2008	First part of the immission control permission accorded (BImschG, Federal Immissions Control Act) →(advance notice “Vorbescheid” and first outline planning permission “1. Teilgenehmigung”
May 8, 2008	Investment decision (29 municipal utilities involved)
July 26, 2008	Financial closing: Financial contract signed
August 1st,2008	Notice to proceed (NTP); Construction started (EPC contract phase 2)
11/2012	Beginning of commercial operation (COD)

In fall 2005 Trianel announced its commitment to build an advanced coal-fired steam power plant in Lünen (Table 1). Two years later the engineering, procurement and construction (EPC) contract was signed with a consortium of Siemens Energy Sector and Trianel Boiler Consortium Lünen (TBCL). Detailed engineering started immediately while Trianel focused efficiently on project financing and approval planning. Trianel received the permission for construction and operation of the power plant on May 6, 2008, took the final investment decision two days later and achieved financial closing in July 2008. Notice to proceed (NTP) was given to the consortium partners Siemens and TBCL on August 1, 2008. Construction is under way and progress can be followed via a webcam which is linked to the webpage of Trianel. Commissioning of the power plant is scheduled for fall 2012. Upon recently Trianel has changed the name of the project company to Trianel Kohlekraftwerk Lünen GmbH & Co. KG.

Proven state-of-the-art technology is used for the advanced 800 MW steam power plant in Lünen-Stummhafen to boost efficiency and cut emissions. Meeting the requirements of the municipal utilities who joint forces in Trianel, the power plant is optimized both in technical and economic terms. A high net efficiency will be achieved due to the high steam parameters, advanced components and optimized processes.

The power plant is located on a greenfield site just outside Lünen, 15 km north of Dortmund in North-Rhine Westphalia, Germany. It will use international low sulfur bituminous coal delivered by river barges on the “Datteln-Hamm-Kanal”. The power plant will operate in baseload mode. Estimated 1.4 billion Euros are needed to cover the total capital requirements of the power plant and its associated infrastructure.

Protection of the Environment

The Lünen power plant will meet the most stringent environmental protection requirements of the German authorities and will have among the lowest environmental emissions of any coal-fired power plant in Germany.

The flue gas cleaning system includes equipment for removing nitrogen oxides (SCR reactor), particulates (electrostatic precipitators) and sulfurous components (flue gas desulfurization unit). Typical emissions limits are as follows:

- SOx 200 mg/Nm3
- NOx 200 mg/Nm3
- CO <200 mg/Nm3
- Particulates 20 mg/Nm3

Completely enclosed conveyor belts will supply the fuel from the ship unloading station to the closed coal silos and next to the coal bunkers of the steam generator. Such a complex coal handling system avoids emissions of respirable dust to a large extent.

Clean flue gas is supplied to the natural-draft wet cooling tower. Large amounts of moisturized air in the cooling tower ensure that the emissions are highly diluted before they are rejected to the environment.

Noise emissions measured above background levels at a distance of 0.5 km from the power plant site will be no greater than 60 dB(A) during the day and 45 db(A) during the night, whereby the proportionate noise rating level generated exclusively by the Power Plant has to be 10 dB (A) lower at these immission points.

Due to the high efficiency of the overall plant, specific CO_2 emissions are well below 800 g/kWh. Technologies for removing CO_2 from the exhaust gas of coal-fired steam power plants are still under development. Several small-scale postcombustion CO_2 capture pilot plants based on different CO_2 solvents are in operation (e.g., the Castor project in Esbjerg) or have been announced (e.g., [4]). Significant efficiency penalties, tougher requirements for flue gas desulfurization, and solvent degradation in oxygen-rich exhaust gases are some of the difficulties associated with postcombustion CO_2 capture that need to be addressed. In the light of tremendous research and development efforts these obstacles shall be overcome in the future. Siemens is an active player in the quest for cost-effective capture ready design options, advanced CO_2 solvents and integrated CO_2 capture systems [4]. Trianel has already considered additional space for a CO_2 capture plant in the Lünen project, to be in principle prepared for future CO_2 removal requirements.

Power Plant Design

Scope of Supply

For Lünen, Siemens, as the EPC consortium leader, is responsible for overall planning, supply of the steam turbine generator set, the mechanical and electrical equipment including the entire instrumentation and control system, the transformers and switchgear as well as various auxiliary and supporting systems. Siemens is also responsible for construction, installation and commissioning.

Trianel Boiler Consortium Lünen (TBCL) consisting of IHI and AE&E supplies the once-trough type steam generator, the air quality control equipment (electrostatic precipitators, SCR reactor including the ammonia supply system, and flue gas desulphurization unit), the coal feed and ash removal system, and the auxiliary boiler.

Trianel is responsible for the construction of a 380 kV line connecting the new power station to the electric grid (substation Lippe, distance to site about 5-6 km) and for coal unloading, coal storage and coal transport equipment.

State-of-the-Art Technology

Lünen is the first project based nearly exclusively on Siemens SSP5-6000 (1x800) reference power plant (RPP) for advanced steam power plants in the 800 MW class. Since the early 1990s Siemens has been working on RPP concepts both for steam power plants and combined cycle power plants. Reducing investment costs by making use of modular pre-engineered RPP designs and at the same time providing sufficient flexibility to accommodate specific needs arising from customer requirements are major driving forces for all these development efforts.

Table 2 Key technical features

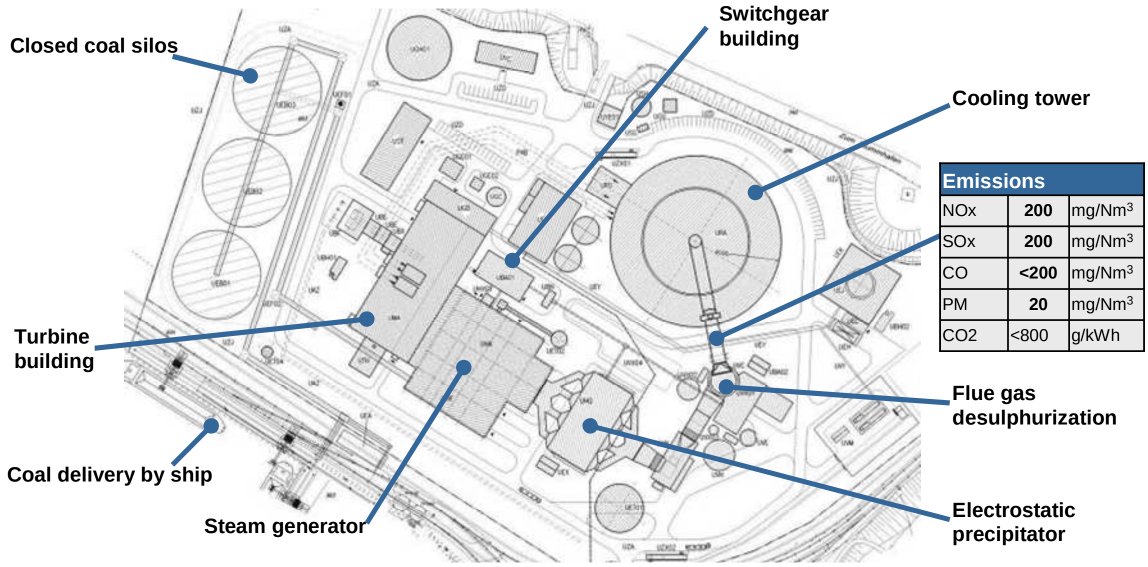
Gross power output:	813 MW (rated output; 50 Hz); single unit
Net efficiency (LHV basis)	~45.6% (@ design point),
Steam generator:	Tower-type once-through boiler with vertical evaporator tubing
Gas cleaning	Selective catalytic reactor (DeNOx), electrostatic precipitators (particulate matters), and wet limestone flue gas desulphurization (SOx)
Steam parameters	280 bar/600°C/610°C steam parameters at boiler outlet
Steam turbine	SST5-6000 with single reheat and two double-flow LP turbines (4x12.5 m^2 exhaust annular area)
Generator	SGen5-3000W, water/hydrogen-cooled
Feedwater preheating	9-stages: 3 high-pressure FWPH (header-type) with one external desuperheater, 5 low-pressure FWPH (plate-type); feedwater heaters A1 & A2 are located in the condenser neck as a duplex heater
Final feedwater temperature	308°C
Feedwater pump concept:	2 x 50 % electric motor-driven feedwater pumps
Condenser	dual-pressure serial condenser operating at 30 and 45 mbar respectively
Flue gas discharge:	via the natural-draft wet cooling tower
Distributed control system	SPPA-T3000 power plant automation system.

The main focus of the SPP5-6000(1x800) is the turbine building where all mechanical components of the water steam cycle as well as all electrical equipments are optimized around the steam turbine generator set. The design is based on materials and technology that are available today and have proven reliability in use. Only a few modifications were required to adapt the SPP5-6000(1x800TI) reference power plant design to the specific customer needs. Optimized for cost-effectiveness and environmental performance, Lünen shows the technical features summarized in Table 2. A single-line concept for both the air and flue gas path is applied to minimize investment costs.

Plant Layout

Lünen is a good example of the SPP5-6000 (1x800) concept in practice. Its turbine building with the turbine generator at a floor level of 17m with no floor below the basement and with overall dimensions of 91x38x41 m shows a clear affinity with the reference power plant design. Lünen is also adopting the heater bay concept with the main components of the high and low pressure feedwater preheating line arranged within an annex of the turbine hall. The annex is located between the turbine building and the boiler island.

General layout planning attached particular importance to a compact and economic design (Figure 3). The arrangement of the steam turbine and the boiler results in short steam lines and a short electrical run to the switchyard. The side arrangement of the cooling tower in relation to the electrostatic precipitator allows efficient routing of the flue-gas exhaust system through the cooling tower, while at the same time optimizing the circulating water system.



Emissions		
NOx	200	mg/Nm^3
SOx	200	mg/Nm^3
CO	<200	mg/Nm^3
PM	20	mg/Nm^3
CO2	<800	g/kWh

Figure 3 General arrangement drawing

Figure 4 illustrates the compact cost-effective plant design in the turbine building which also allows for good accessibility during maintenance. Header-type high-pressure feedwater heaters and the separate desuperheater are located in-front of the high-pressure steam turbine. The turbine floor level is on 17 m. No basement exists in the turbine building to minimize construction efforts. The main components of the feedwater system including the feedwater tank, boiler feed pumps and low-pressure feedwater heaters are placed in the heater bay which forms an integral part of the main structure. The central switchgear building is nearby the turbine building and accommodates the central control room.

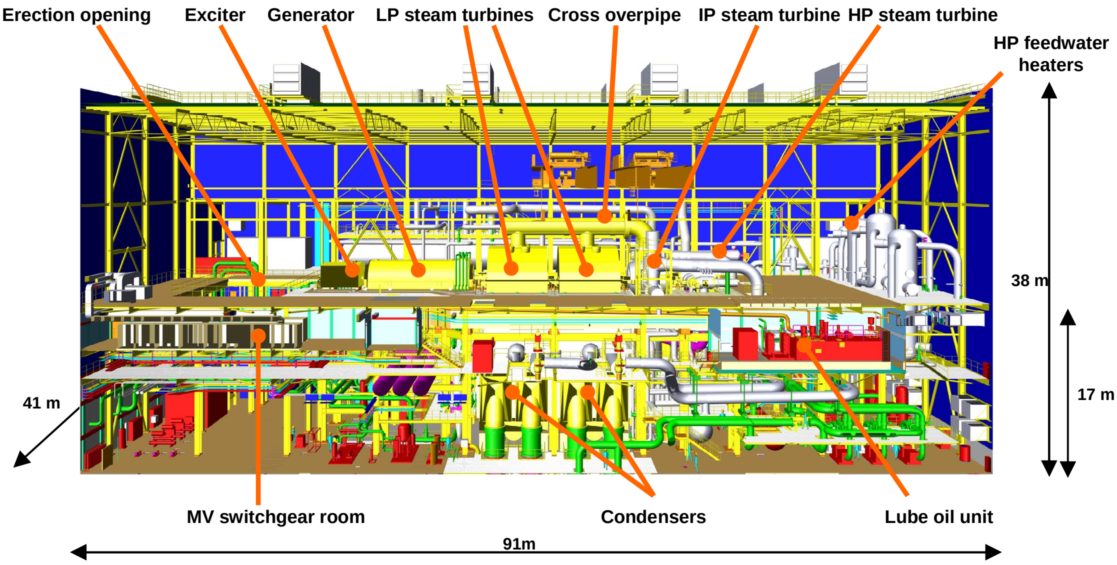


Figure 4 Turbine building in Lünen

Turbine-generator

For the 50 Hz market, Siemens offers full speed tandem compound turbo-sets for steam power plants (SPP) with ultra supercritical steam parameters in the gross power output range of 600 to 1200 MW per unit. The steam turbine set SST5-6000 used in Lünen is a four-casing design with separate HP, IP, and two LP turbines (Figure 5). It is installed on the turbine floor (+ 17 m) on a spring-mounted foundation decoupled from the overall structure. A push rod concept permits parallel axial thermal expansion of LP rotor and inner casing. This reduces clearances between rotor and casing and improves the efficiency.

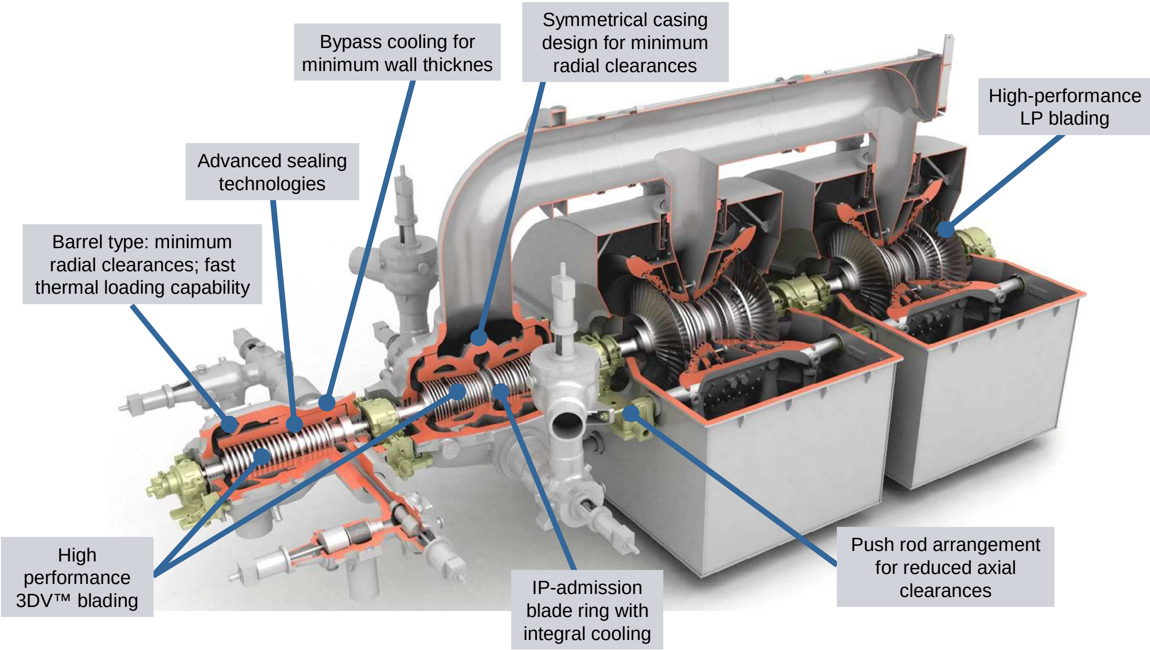


Figure 5 SST5-6000 Steam turbine

High parameter values for the main steam (270 bar, ~600°C) and reheat steam (60 bar, ~610°C) at the turbine inlet pose special requirements on both the design and the materials. For example, the HP cylinder is designed as barrel-type turbine and has an inner casing. Ultra supercritical steam conditions usually require the use of thick-walled components. The rate of heat transfer into these components is often the limiting factor for the duration of the start-up process. In order to remove this restriction, a special feature has been developed for HP turbine modules: An internal bypass cooling system that allows for a more flexible operation (start-up / load changes). In a nutshell, a small amount of cooling steam passes through radial bores into the small annulus between the inner and outer HP casing (Figure 6).

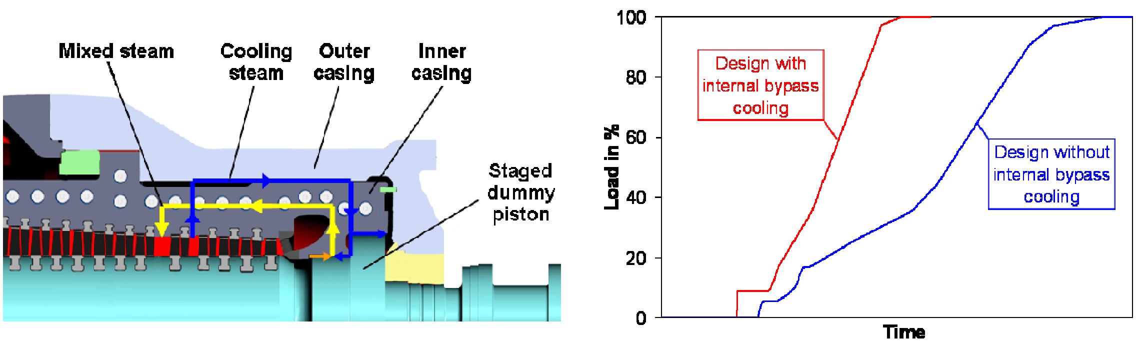


Figure 6 HP turbine: Internal bypass cooling system and reduced start-up time [3].

This approach effectively protects the inner surface of the outer casing (which would be exposed to main steam temperature without the internal bypass cooling). As a consequence it was possible to reduce the wall-thickness of the outer casing and thus enable faster heat-up of the casing. An improved starting performance is the main customer benefit of this innovative concept. Components exposed to high temperatures such as the HP inlet barrel as well as HP/IP rotors and inner casings are made of 9-12%CrMoV steel.

Siemens advanced 3DV™ technology (3-dimensional design with variable reaction levels) for HP/IP blades is used in Lünens' steam turbine generator set. With 3DV™ blades the stage reaction and stage loading for each row is optimized to gain highest HP and IP efficiencies. Stage reaction describes the split of pressure drop and velocity increase between stationary and moving blades, and is defined by the ratio of the enthalpy drop through the moving blade row to the enthalpy drop through the whole stage.

Both low-pressure turbines are double-flow designs. Free-standing 1150 mm steel last stage blades (LSB) provide an annular area of 12.5 m^2 per flow.

A comprehensive technical description of specific steam turbine features is given in references [1]-[3].

Table 3 shows a reference list of large scale USC steam turbines manufactured by Siemens. Steam parameters have increased only slightly over the last years bur gross power output capacity has increased considerably compared to the first large scale USC application in Isogo, Japan. Chinese power suppliers favor higher electrical outputs, European customers very often consider 800 MW an optimum unit size.

Table 3 References of Siemens ultrasupercritical steam turbines [3]

Plant	Country	Gross power output	Main steam	Reheat steam	Commercial operation
Isogo	Japan	1 x 600 MW	251 bar / 600°C	610°C	2001
Yuhuan	China	4 x 1000 MW	262 bar / 600°C	600°C	2007
Wai Gao Qiao 3	China	2 x 1000 MW	270 bar / 600°C	600°C	2008
Westfalen	Germany	2 x 800 MW	275 bar / 600°C	610°C	2011
Eemshafen	Netherlands	2 x 800 MW	275 bar / 600°C	610°C	2012
Lünen	Germany	1 x 800 MW	270 bar / 600°C	610°C	2012
Mainz	Germany	1 x 800 MW	273 bar / 600°C	610°C	2013

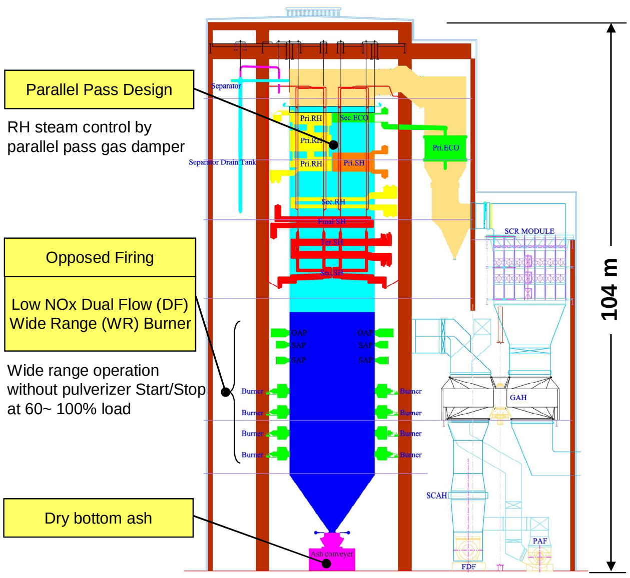
The generator in Lünen is a SGen5-3000W series (two-pole), directly coupled to the turbine. It has direct water-cooled stator windings, a hydrogen-cooled rotor, static excitation, a two-channel digital voltage regulator and the necessary auxiliary systems (i.e. seal oil, hydrogen- and water units).

High-Energy Piping

High-energy piping costs have a significant share in the total capital expenditures. Main steam and hot reheat piping is made of P92 (X10CrWMoVNb9-2) each with four lines at the steam generator outlet that are already merged to two lines in the boiler island. The cold reheat piping (16Mo3) consists of a single line at the turbine outlet that is split to two lines at the boiler inlet. Feedwater piping is a single line made of WB36. Recent trends in piping costs will be discussed in Section “Project Execution”.

Steam generator

The once-through steam generator manufactured by IHI Corporation has a tower design. Selected technical data are summarized in Figure 7. Key features include: low NOx dual flow wide range burner, control of the reheat steam temperature by a parallel pass damper, a Ljungström-type air preheater, and dry bottom ash removal. About 600 kg/s ultra supercritical main steam (280 bar/600°C at boiler outlet) are generated. At design conditions, more than 94 % of the coal energy (LHV basis) is transferred to the water/steam cycle.



Boiler Parameter	Value
Boiler Manufacturer	IHI Corporation
Main steam flow	2,160 t/h
Main steam press.	280 bar
Main steam temp.	600 degC
Reheat steam temp.	610 degC
Minimum load (Coal)	Approx. 25%
Accessory of Boiler	**Type**
Mill	IHI-VS Mill x 4
Burner	IHI-DF WR burner x 32
Gas Air Heater	Ljungstrom type x 1
Forced Draft Fan	Axial type x 1
Primary Air Fan	Centrifugal type x 1
Bottom Ash Extractor	Dry type x 1

Figure 7 Characteristic design features of the steam generator in Lünen (source: IHI).

With regard to the steam generator, the overall plant efficiency is improved by:

- optimizing the heating surface arrangement,
- raising the final feedwater temperature to 308°C,
- keeping the excess air coefficient in the firing system less than 1.2,
- controlling the reheater outlet temperature without water injection,
- reducing the exhaust-gas temperature downstream of the air preheater to 120°C, and
- minimizing pressure drops.

The boiler can be operated in once-through mode in the load range between approx. 35 to 100%. Under design conditions, heat transfer to the water/steam cycle reduces the temperature of the flue gases to approx. 350°C at the outlet of the economizer. Preheating the combustion air decreases the temperature of the exhaust gases even further before they are supplied to the electrostatic precipitators. It should be noted that the values of the process parameters and the boiler efficiency depend on the coal being burnt.

The evaporator in the furnace consists of a spiral pass with smooth tubes and vertical water walls in the upper furnace section. Opposed firing is arranged on 4 burner levels with low NOx wide range burners. Flame characteristics can be adjusted with respect to the boiler design, load and coal quality. This improves flexibility and enables the operation from 60% to 100 % load (at design conditions) without mill start/stop.

A special feature of the boiler design is the control of the reheater outlet temperature without spray water injection in normal operation. This is achieved by a parallel design of reheater 1 and superheater 1/economizer 2 and the use of gas dampers in the upper convective part of the steam generator.

Water/steam cycle

The simplified process flow diagram shown in Figure 8 once again establishes a close relationship between Lünen and Siemens SPP5-6000(1x800) reference power plant. Examples include the steam parameters, redundancy concepts for the main pumps, control concepts, and design of the feedwater preheating line.

Important features of the water/steam cycle include (see Table 2):

- Frequency control through condensate throttling,
- Condensate polishing in bypass loop with a separate 1 x 100% condensate polishing pump,
- Steam bypass system including a 4x25 % HP bypass station with safety function and a 2x30 % LP bypass station.

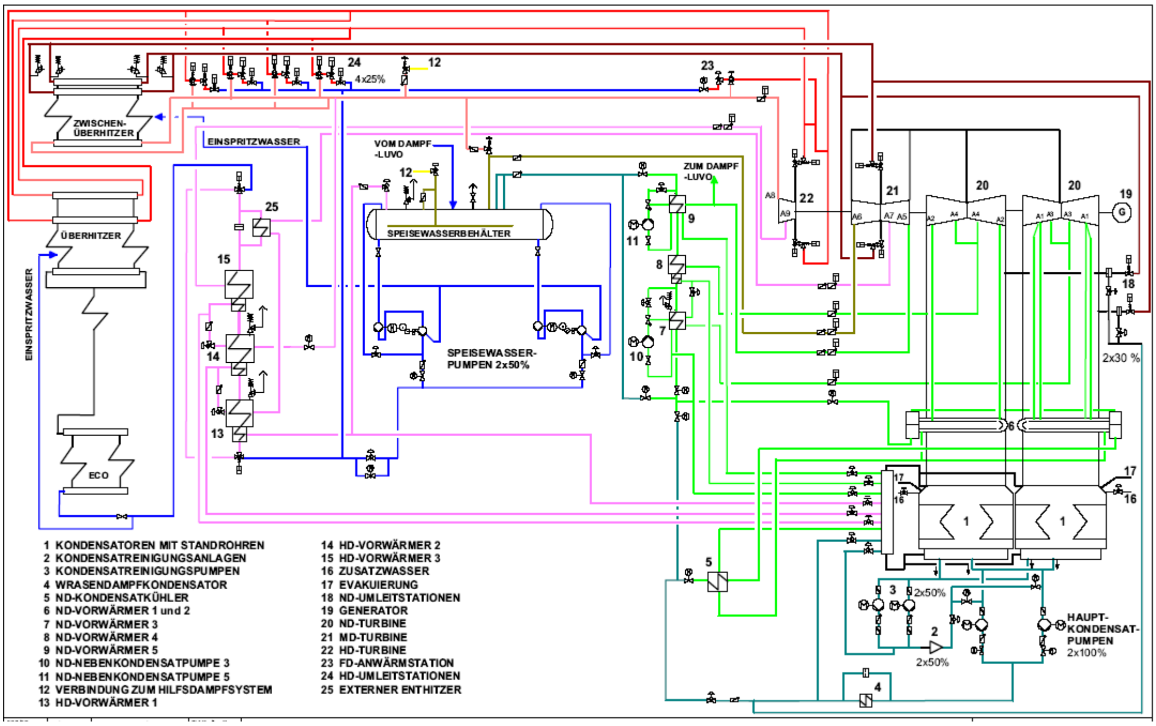


Figure 8 Water/Steam cycle

Thermodynamic Performance

For the given ambient conditions at the power plant site (+9°C, 80 % relative humidity, 18°C cooling water temperature) the plant concept is designed for a net efficiency of 45.6 % based on the lower heating value.

Key levers for improving Lünens' overall plant efficiency have already been addressed in the paper: high steam parameters, optimized processes, and highly-efficient energy conversion in key plant components. Optimizing the cold end of the water/steam cycle shows also some potential for improvement. Once again this is a trade-off between capital expenditures and fuel costs (efficiency) and needs to be evaluated for the given boundary conditions.

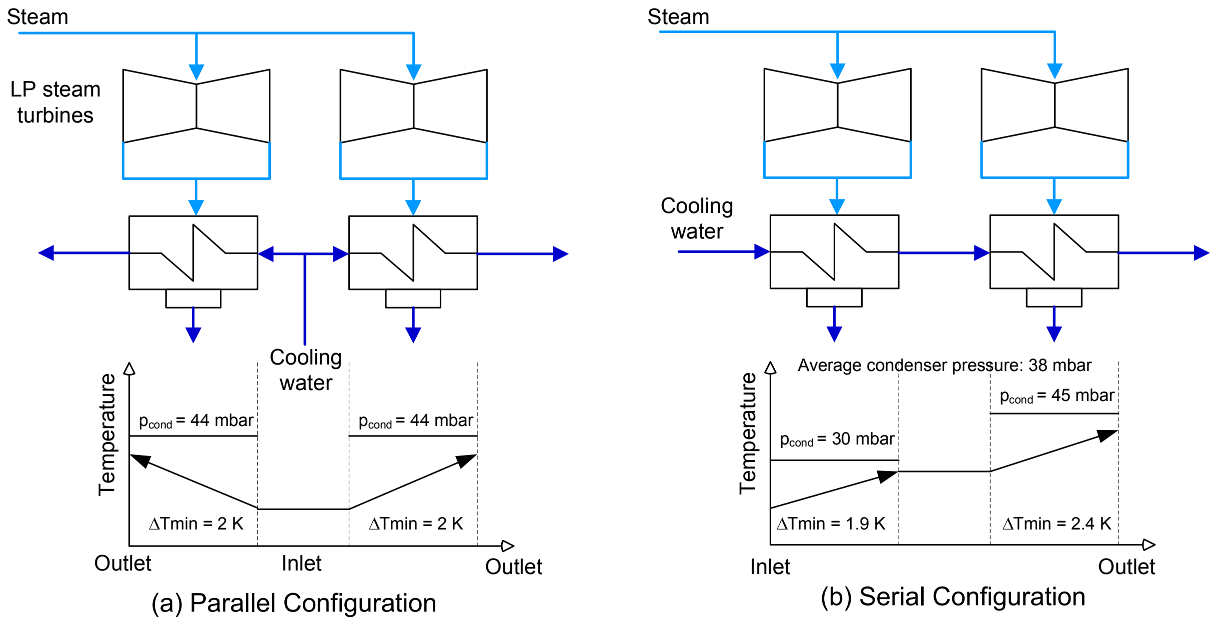


Figure 9 Parallel and serial condenser configuration

In Lünen, the cooling water flows in series through the condensers of the two LP turbines. Figure 9 illustrates the differences in the temperature profiles of the cooling water and the condensing steam for a parallel and a serial configuration of the condensers. In a parallel configuration the cooling water mass flow rate is equally split between the two condensers. Both LP turbines expand to the same condenser pressure since the temperature profiles in the condensers are identical. In case of a serial arrangement, the total cooling water mass flow rate will pass through each condenser. Different condenser pressures are achieved. Assuming equal mass flow rates of for the cooling water in both configurations, the average condenser pressure in the serial arrangement is lower. In general, the lower the condenser pressure the higher the efficiency of the overall plant.

Exhaust losses of the LP steam turbines for given last stage blades, pressure losses on the cooling water side and investment costs of a larger heat transfer area in the condensers need to be carefully evaluated before a decision for a serial condenser configuration shall be taken. For Lünen, it turned out to be the most economic solution.

Operational flexibility is a core requirement for cost-effective power plant operation. In addition frequency control is an important task.

Frequency control - Condensate Throttling

Condensate throttling is applied in case of a high decrease in grid frequency (Figure 10). If the grid frequency requires high power demand and the unit is in modified sliding pressure operation, the turbine control opens the governor valves to raise the load by using the steam storage capacity of the boiler (except if the valves are fully open already). Simultaneously the main condensate control valve is throttled to a calculated position allowing a reduced condensate mass flow flowing through the LP feedwater heaters. Considering a certain time respond, the extraction steam mass flows of the LP feedwater heater and the deaerator / feedwater tank are reduced. The surplus steam remains in the turbine and generates additional power. The resulting load increase depends on the amount of pre-set throttling of the governor valves of the turbine, the throttling of the main condensate control valve and the actual unit load. By means of additional fast acting valves in the regarding extraction steam lines the response time behavior can be optimized.

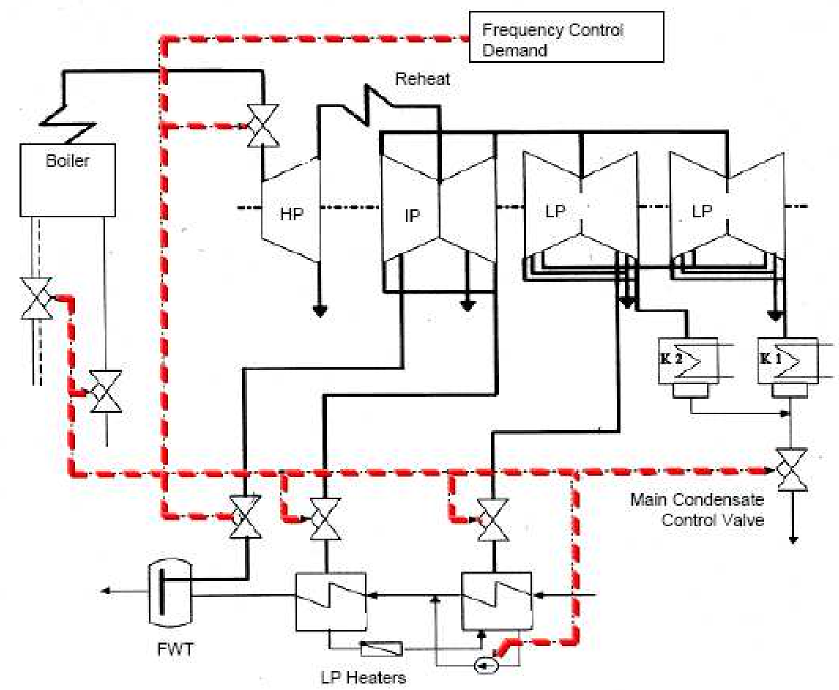


Figure 10 Principle of condensate throttling

This condensate throttling serves as compensator for the transient time behaviour of the boiler. The accumulated condensate is stored in the condenser hotwell or a separate condensate collecting tank. Parallel to the above mentioned measures the firing rate of the boiler is increased to meet the load requirements. The feeding of the boiler is continued and increased. So the level of the feedwater storage tank is decreased accordingly.

During this time the condensate flow reduction is gradually released and has reached steady state conditions again. Refilling of the feedwater storage tank is initiated by releasing the condensate control valve to control the level of the hotwell or condensate collecting tank. The maximum allowable condensate mass flow is monitored and the refill flow is limited to a maximum value. Due to the increased condensate flow through the LP feedwater heaters and into the deaerator the steam extraction from the affected turbine extractions is increased. The generator output decreases correspondingly. To compensate this influence the boiler-firing rate is increased. However the maximum allowable superheater outlet flow is limited to 100% BMCR (Boiler Maximum Continuous Rating).

Project Execution

Construction of the power plant started in August 2008 shortly after the notice to proceed (NTP) was formally approved. The overall time schedule for Lünen from NTP to CoD (commercial operation date) covers 51 months. Figure 11 exemplifies the construction sequence of some key components and technical teams.

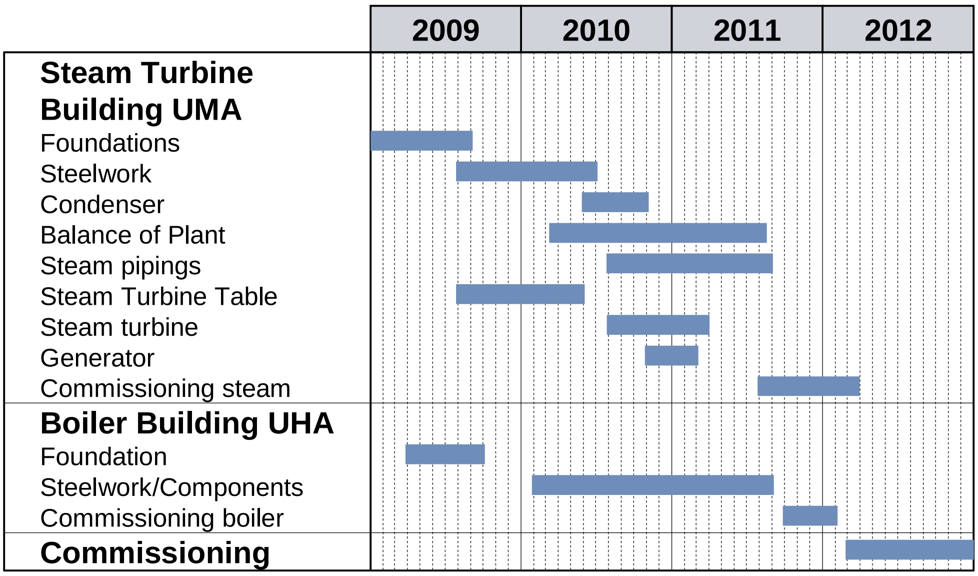
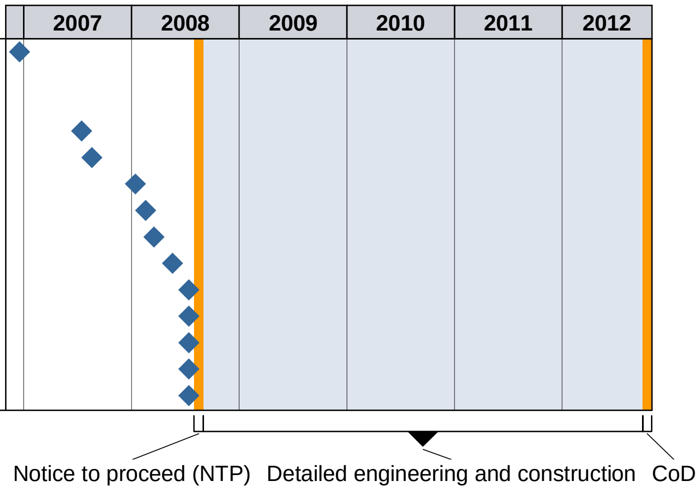


Figure 11 Simplified project time schedule (excerpt).

Project execution is faced with several challenges. For example, the delivery time for many plant components has significantly lengthened in recent years due to the large amount of power plant projects throughout the world and the limited number of suppliers. As Table 4 points out some equipment and components even had to be ordered before notice to proceed was given!

Table 4 Point in time for ordering critial components relative to "Notice-to-Proceed" (NTP) and "Commercial operation date" (COD).

Commitment / Order placed for …
Reservation agreement for steam turbine, HP-Piping, boiler pressure parts including HP-piping and erection capacity slots
HP-Preheater
HP-Piping
Cooling tower (Mechanical Eng.)
Cooling tower (Civil Eng.)
Main contract for Civil Eng.
Feedwater pumps
Feedwater tank
Main condensate pumps
Main cooling water pumps
Unit transformer / Auxiliary transformer
LP-Preheater



Prices for several materials used in the construction of the advanced power plant have changed significantly since the EPC contract was signed in September 2007 (Figure 12). While the price for P91 which is used as a reference here for the high-pressure piping material P92 (see Section "High Energy Piping") is still rising, some materials such as carbon steel WB36 and copper are currently less expensive. Prices for concrete reinforcing steel and heavy profiles which are used in construction (e.g., cooling tower, steelwork) showed a relatively sharp rise and fall in 2008 and are currently on the level of October 2007 again.

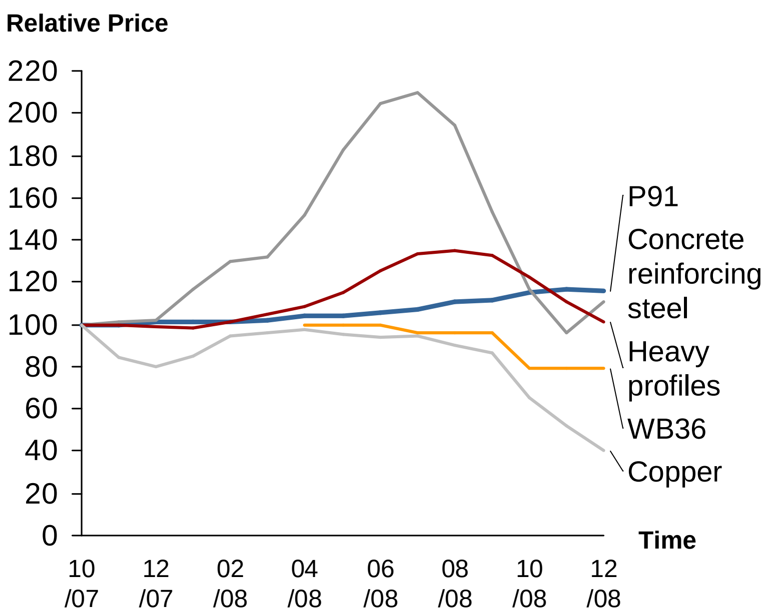


Figure 12 Recent price trends for selected materials (Data sources: DStatis, London Metal Exchange, ThyssenKrupp).

Future price trends are difficult to predict. Estimating and calculating equipment prices are still a challenge – both for EPC contractors and customers. Even if recession will result in lower material prices, the high backlog of orders of many players in the supply chain might prevent that this drop in prices will significantly reduce the total capital requirement of power plants in the near future. It is to be feared that a possible delay in the development and implementation of new power plants will cause a new accumulation of projects as soon as the economy recovers.

Conclusions

- Joining forces is a road to success for municipal utilities in a competitive market.
- Close cooperation between the customer and the EPC consortium lead by Siemens is the key to success for efficient approval planning.
- Extensive knowledge of an experienced power plant supplier is required to select the most cost-effective design options for the given project-specific boundary conditions.
- Ultra supercritical steam parameters, optimized key plant components and processes are prerequisites for high overall plant efficiencies, low emissions and the sustainable use of energy resources.
- Proven and reliable state-of-the-art technology is applied to ensure low life cycle cost.
- The construction of Trianels' advanced steam power plant is on schedule.

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