



**“Fortuna”, an Advanced Large and Highly Flexible
CHP Project as Measure to Reduce Emissions
and to Increase Affordability**

Flux50 Brussel – 25 May 2018

Piet Van der Biest

Siemens Power & Gas Division

Agenda

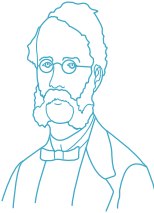
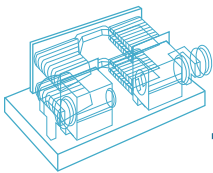
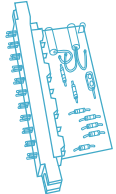
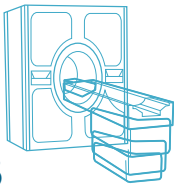
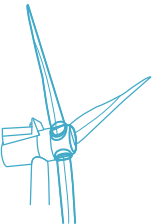
- Introduction
- Specifics of German Market
- CHP Fortuna – Customer and Plant Configuration
- CHP Fortuna – Course of the Project
- CHP Fortuna – Results

www.siemens.com/fortuna

www.swd-ag.de

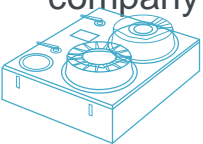
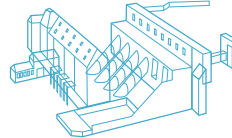



Siemens has always driven technological and social progress

Electrification – Automation - Digitalization

<p>1816 – 1892</p> 	<p>1866</p> 	<p>1959</p> 	<p>1983</p> 	<p>2012</p> 
<p>Company founder, visionary and inventor</p>	<p>The dynamo makes electricity part of everyday life</p>	<p>SIMATIC makes Siemens a leader in automation technology</p>	<p>First magnetic resonance imaging scanner goes into operation</p>	<p>Test operation of the world's largest rotor for offshore wind turbines</p>

Werner von Siemens

Siemens innovations over the past 170 years

<p>1847</p> <p>Pointer telegraph lays the foundation of Siemens as a global company</p> 	<p>1898</p> <p>Foundation of Siemens Belgium</p>	<p>1925</p> <p>Siemens electrifies the Irish Free State with a hydroelectric power plant</p> 	<p>1975</p> <p>Breakthrough of high-voltage direct current (HVDC) transmission</p> 	<p>2010</p> <p>TIA Portal takes automation a stage further</p> 	<p>2017</p> <p>MindSphere, the cloud-based operating system for the Internet of Things</p> 
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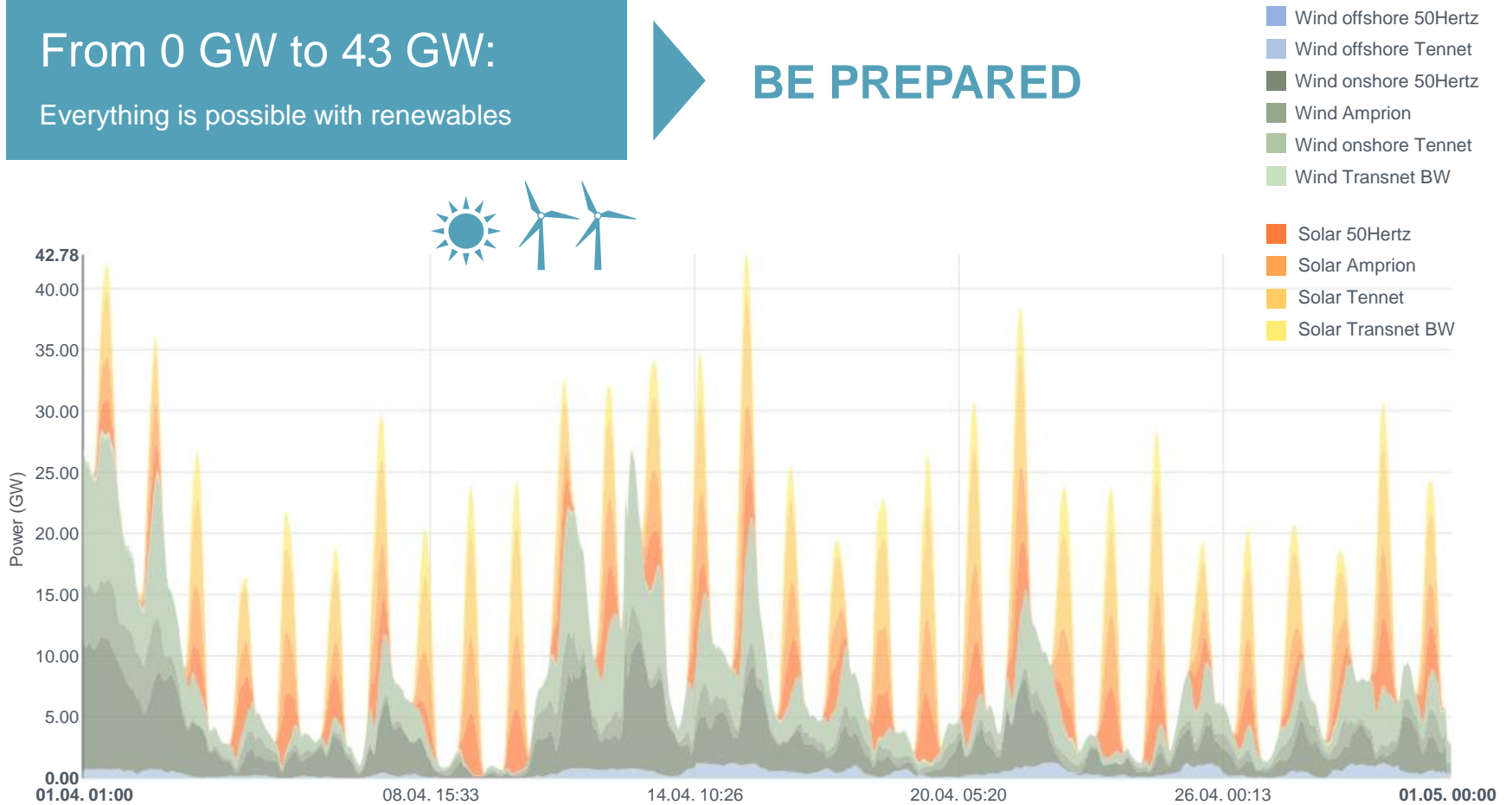
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Electricity production in Germany in April 2015

From 0 GW to 43 GW:
Everything is possible with renewables

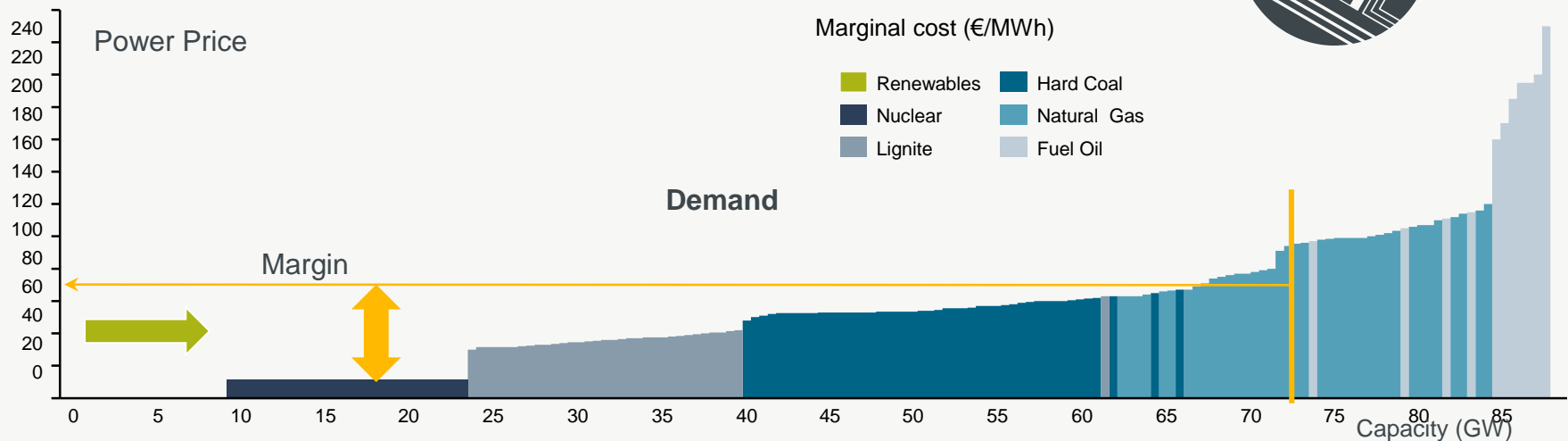
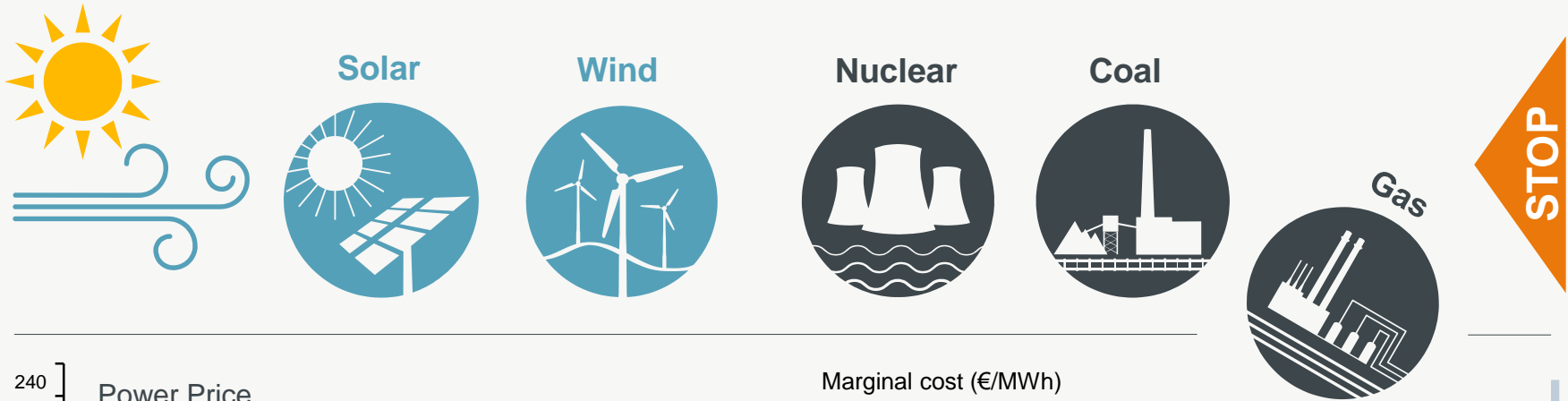


BE PREPARED



Source: Fraunhofer ISI <https://www.energy-charts.de/power.htm>, Last update: 2015-10-14 12:15pm

Renewables continuously pushing merit order jeopardizing the business for CCPPs



We need innovative solutions to secure sustainable, clean & flexible power

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Location: Düsseldorf

Customer: Stadtwerke Düsseldorf (SWD)

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- Located in the west of Germany
 - Population (beginning of 2015): 619.651
 - Seventh most populous city in Germany
 - Larger Urban Zone population of 1.5 million
- **SWD** founded 150 years ago
 - Supply of gas, electricity and district heating
 - Ambitious climate goals; carbon neutrality by 2050 (towards 2 ton CO₂/capita)
 - Lausward power plant situated in Düsseldorf harbor near the city center
 - Power plant in operation since 1957

Standard reference sheet CCPP Fortuna, Lausward

**“Fortuna”
Düsseldorf
SCC5-8000H 1S**

Customer	Stadtwerke Düsseldorf
Total Power Output	603,8 MW net
Plant efficiency	61.5 % net
GT Type	SGT5-8000H
ST Type	SST5-5000
Generator Type	SGen5-3000W
Date of order	May 2012
1st comm. operation	Jan. 2016



- ✓ District heating 300MWth
- ✓ ~ 85 % fuel efficiency
- ✓ CO₂-Emissions 230 g/kWh in heating operation
- ✓ Hot start in <25 min to full load
- ✓ PAC 19 days early

District Heating Storage

“Fortuna” Düsseldorf District Heating Functionality

District Heating Output 300 MW_{th}

CHP efficiency ~ 85 %

Storage capacity 36 Mio liter

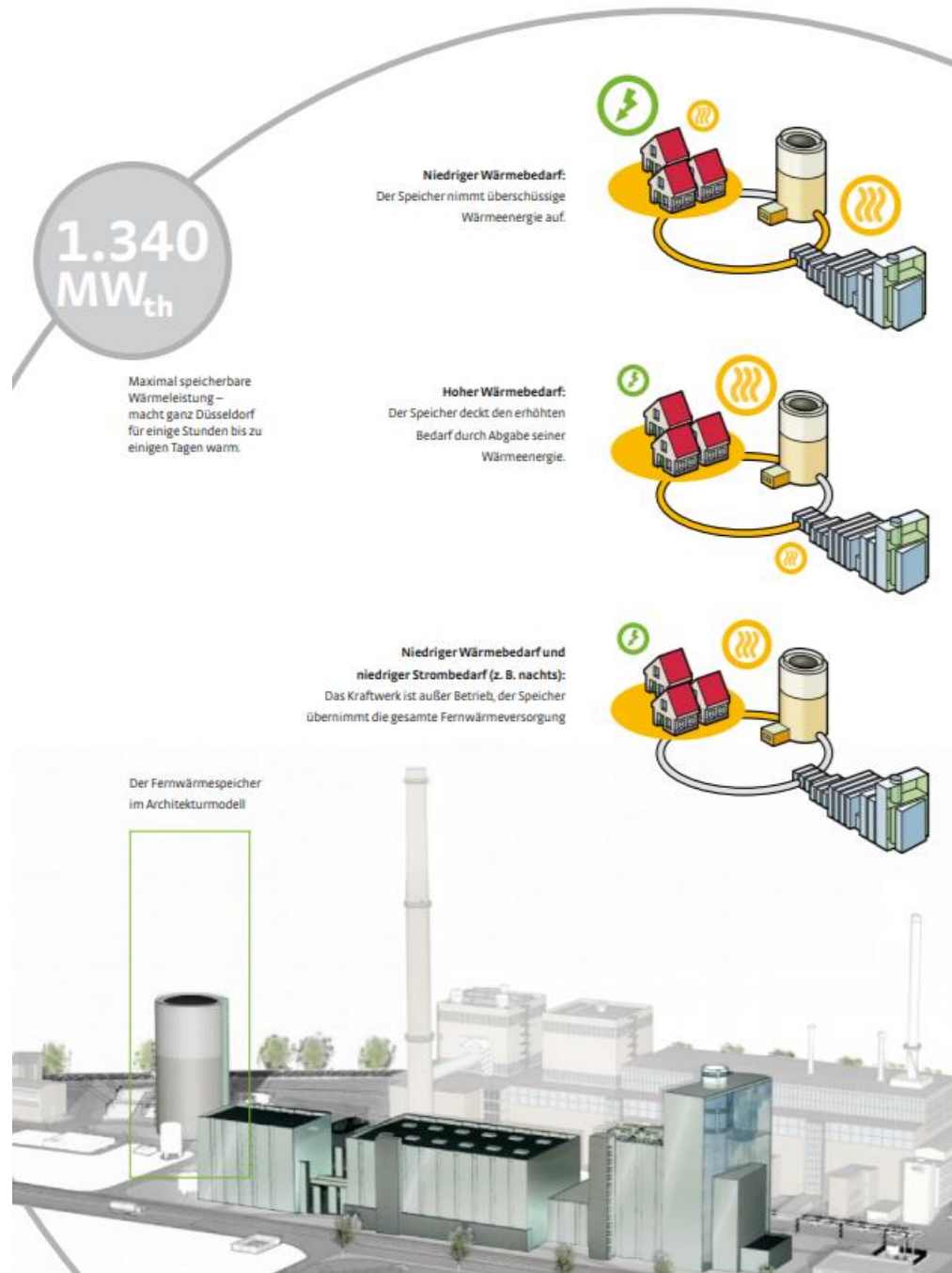
1.340 MW_{th}

**General data on the district heating
of Stadtwerke Düsseldorf :**

Overall capacity 855 MW_{th}

Piping 234 km

Source : SWD-AG.DE



LAUSWARD Unit F (Fortuna)

Key Figures / Main Data

Plant configuration

- Combined Heating Plant (CHP) SCC5-8000H in single-shaft-arrangement.
- Fuel: natural gas (L-gas; lower heating value = 40660kJ/kg)
- River water cooling (Rhein) and closed cooling water circuit
- District heating (DH) < 50 ... 300 MW_{th} with 3 heating condensers

Ambient Conditions

Air

- Design **12° C** (-20 ... +40° C)
- Design **1013 hPa** (978 ... 1040 hPa)
- Design **75 % rH** (29 ... 98 % rH)

Cooling water (Rhein)

- Design **14° C** (1 ... 30° C)

Main components

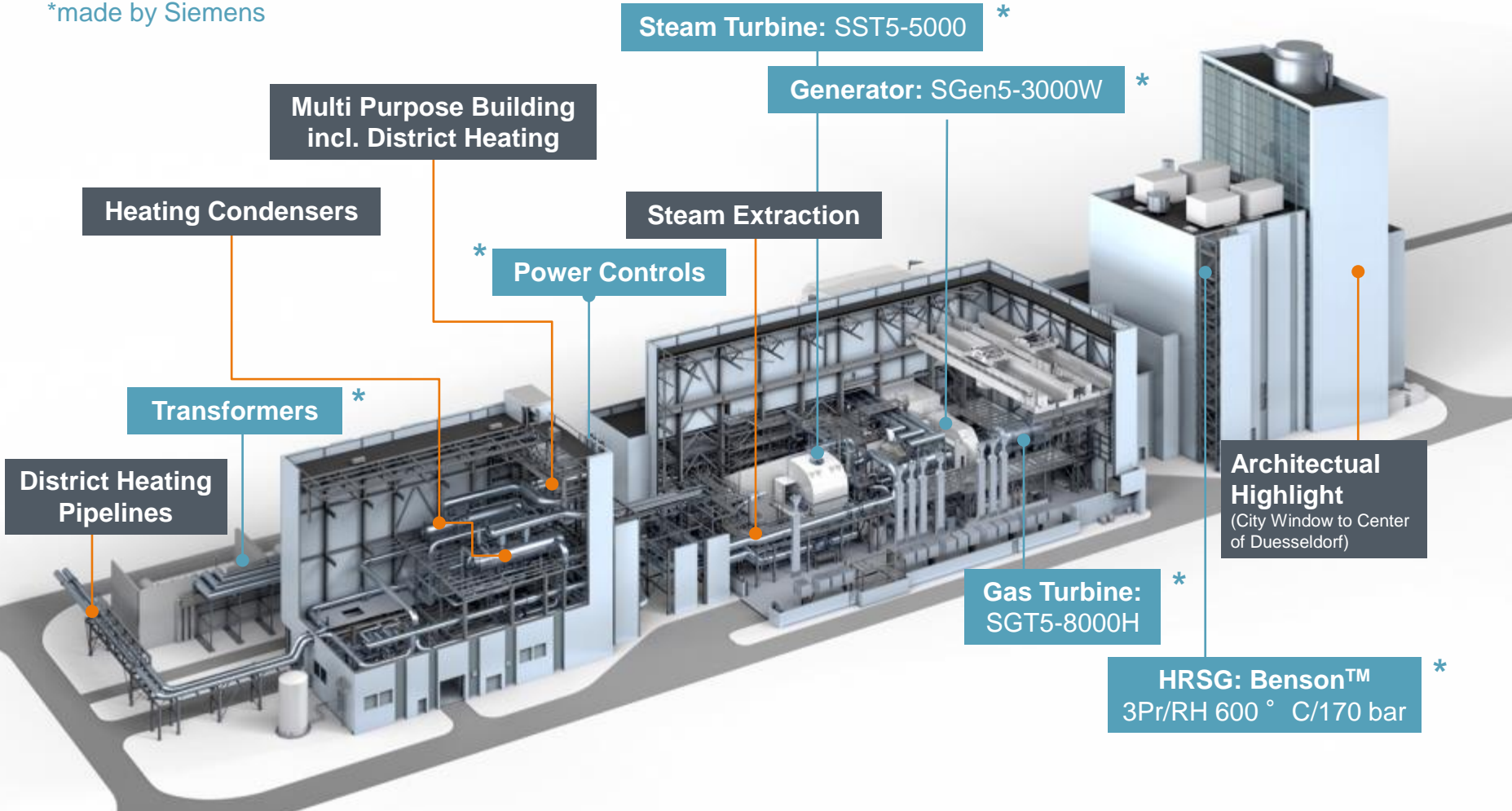
- Gas turbine SGT5-8000H
- Generator SGen5-3000W
- Steam turbine SST5-5000 (HP, IP and LP)
- Condenser
- HRSG 3P-RH, BENSON (HP) in horizontal arrangement
- Auxiliary steam generator 7 MW_{th}

Main components

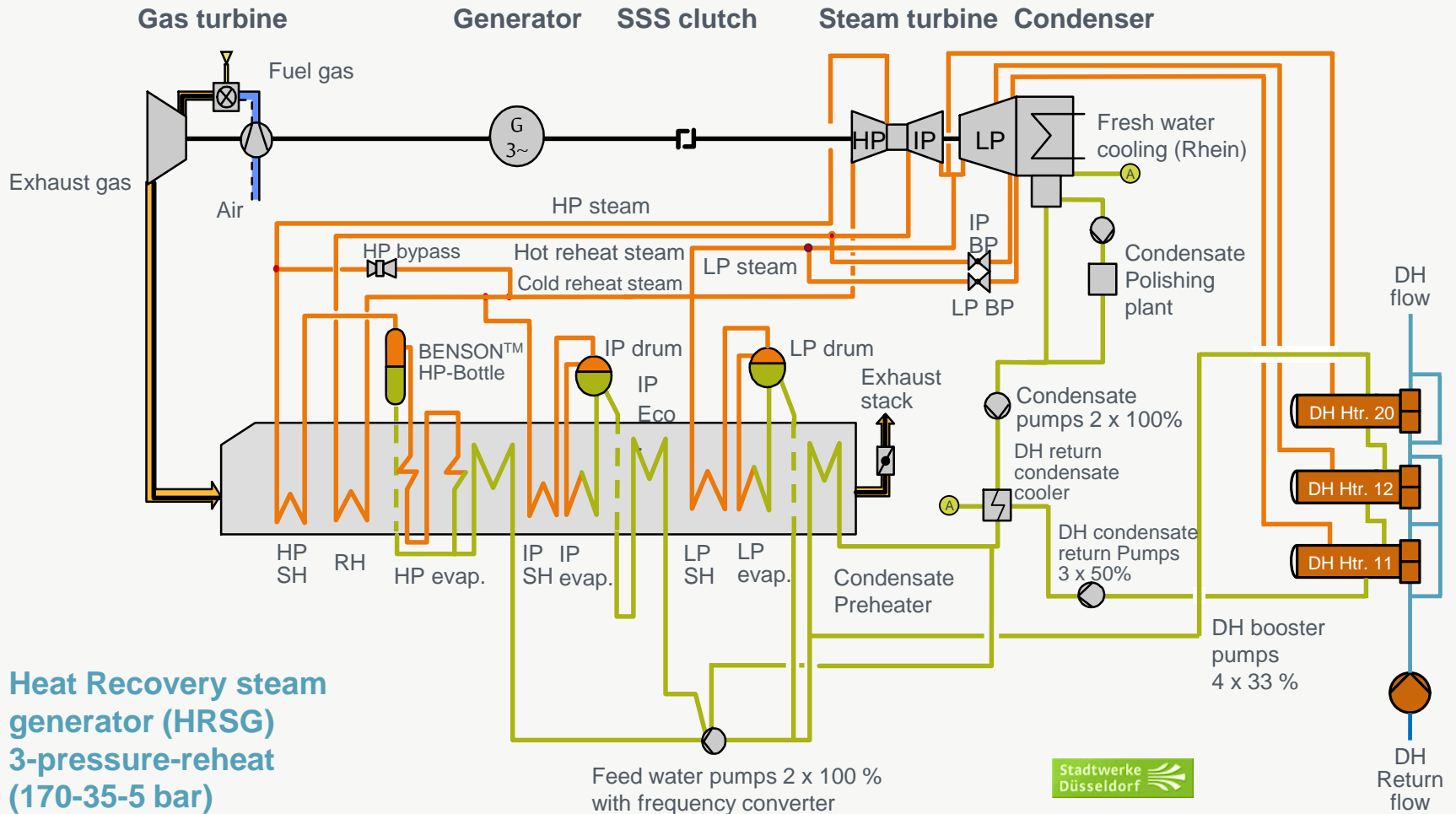
- Gas compressor BORSIG , Type T-Jet 45
- Condensate polishing plant
- 2 x 100 % feed water pumps (speed controlled)
- 2 x 100 % condensate pumps
- 3 x 50 % closed cooling water pumps (PGB)
- 4 x 33 % DH booster pumps
- I&C system Siemens SPPA-T3000

Plant layout - Unit Fortuna

*made by Siemens



Water-Steam-Cycle with 3-pressure HRSG



**Heat Recovery steam generator (HRSG)
3-pressure-reheat
(170-35-5 bar)**



SGT5-8000H gas turbine

Key features and customer benefits

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Rotor

- Proven rotor design (Hirth serration, central tie rod, internal cooling air passages): For world class fast (cold) start and hot restart capability
- Easy rotor destacking on-site: Disc assembly with Hirth serration and central tie rod

Compressor

- Four stages of fast acting variable-pitch guide vanes (VGV) allowing for improved part load efficiency and high load transients
- Evolutionary 3D blading
- Rotating blades replaceable without rotor destack or lift

Bearings

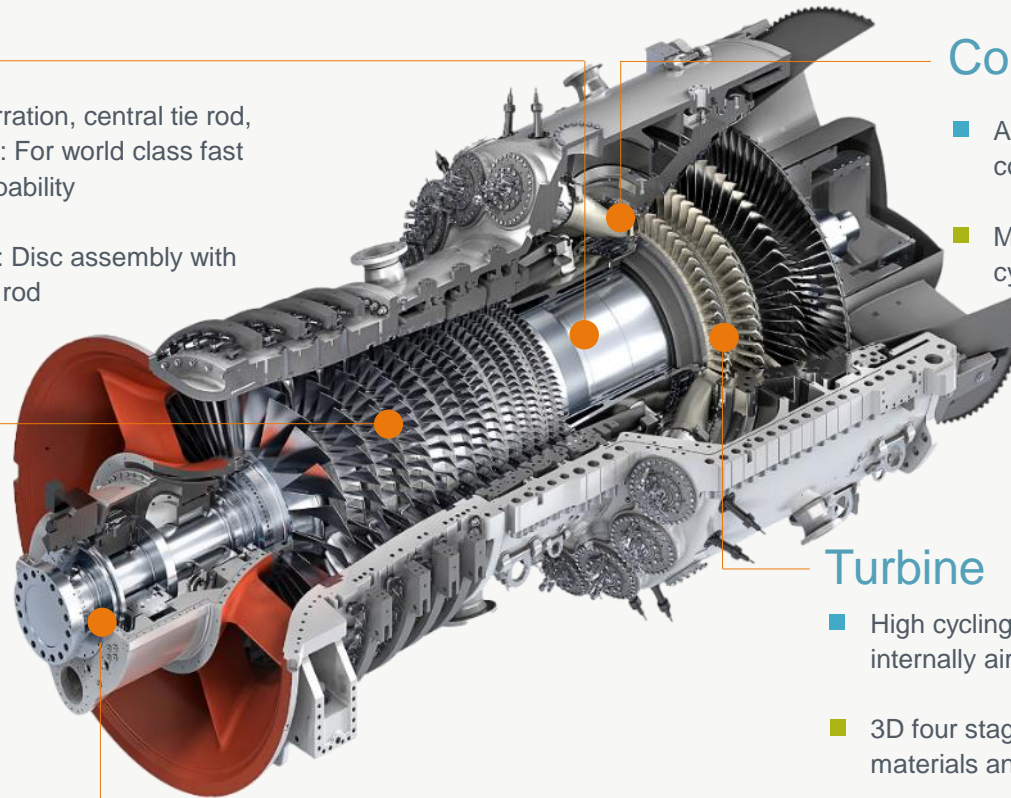
- Active clearance control with
- Hydraulic Clearance Optimization (HCO) for reduced degradation

Combustion

- Advanced can annular combustion system
- More than 60% combined cycle efficiency

Turbine

- High cycling capability due to fully internally air cooled turbine section
- 3D four stage turbine with advanced materials and thermal barrier coating
- Shorter outages: All turbine vanes and blades replaceable without rotor lift; vane 1, blade 1 and 4 replaceable without cover lift



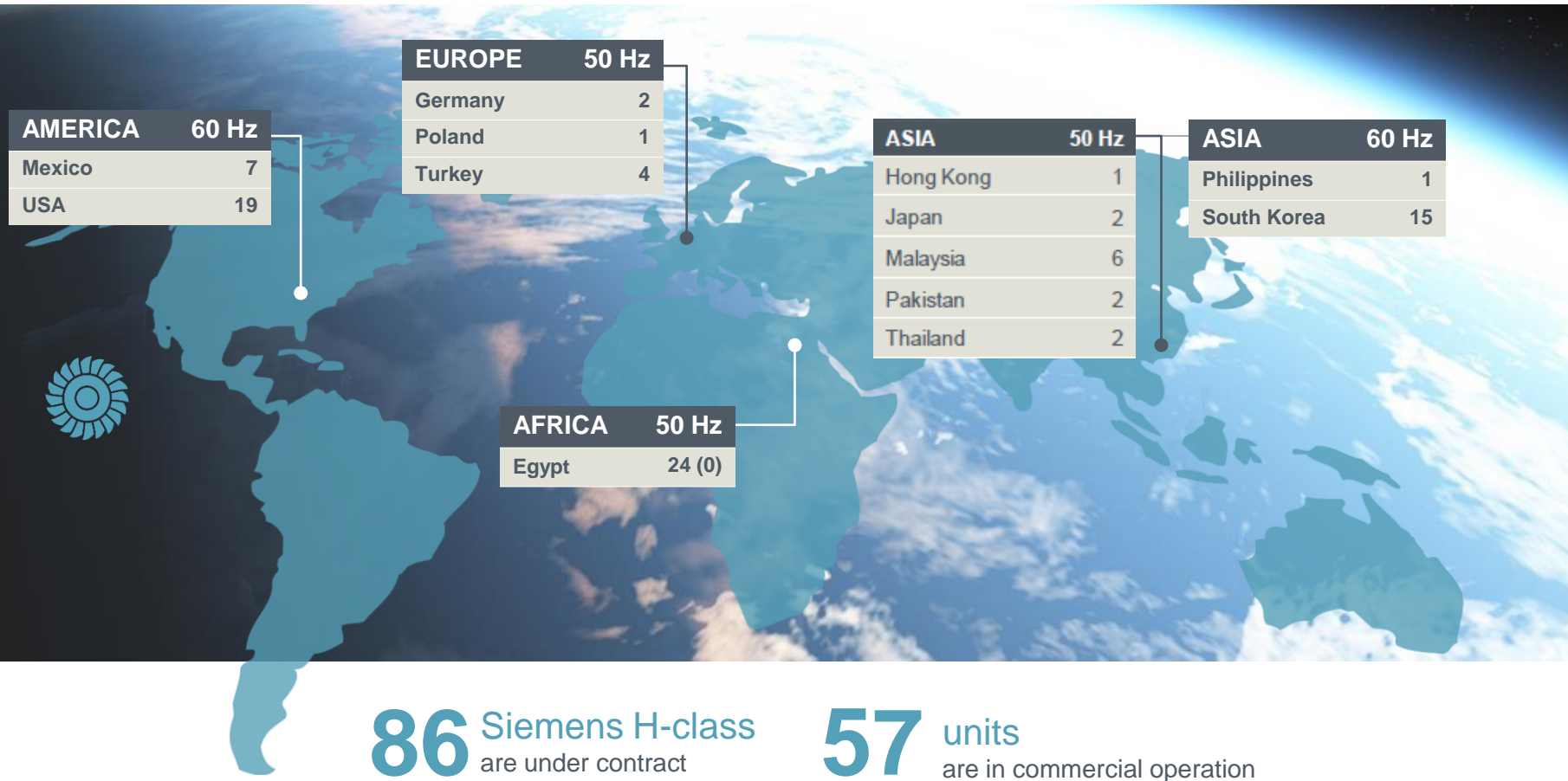
■ Flexibility

■ Performance

■ Serviceability

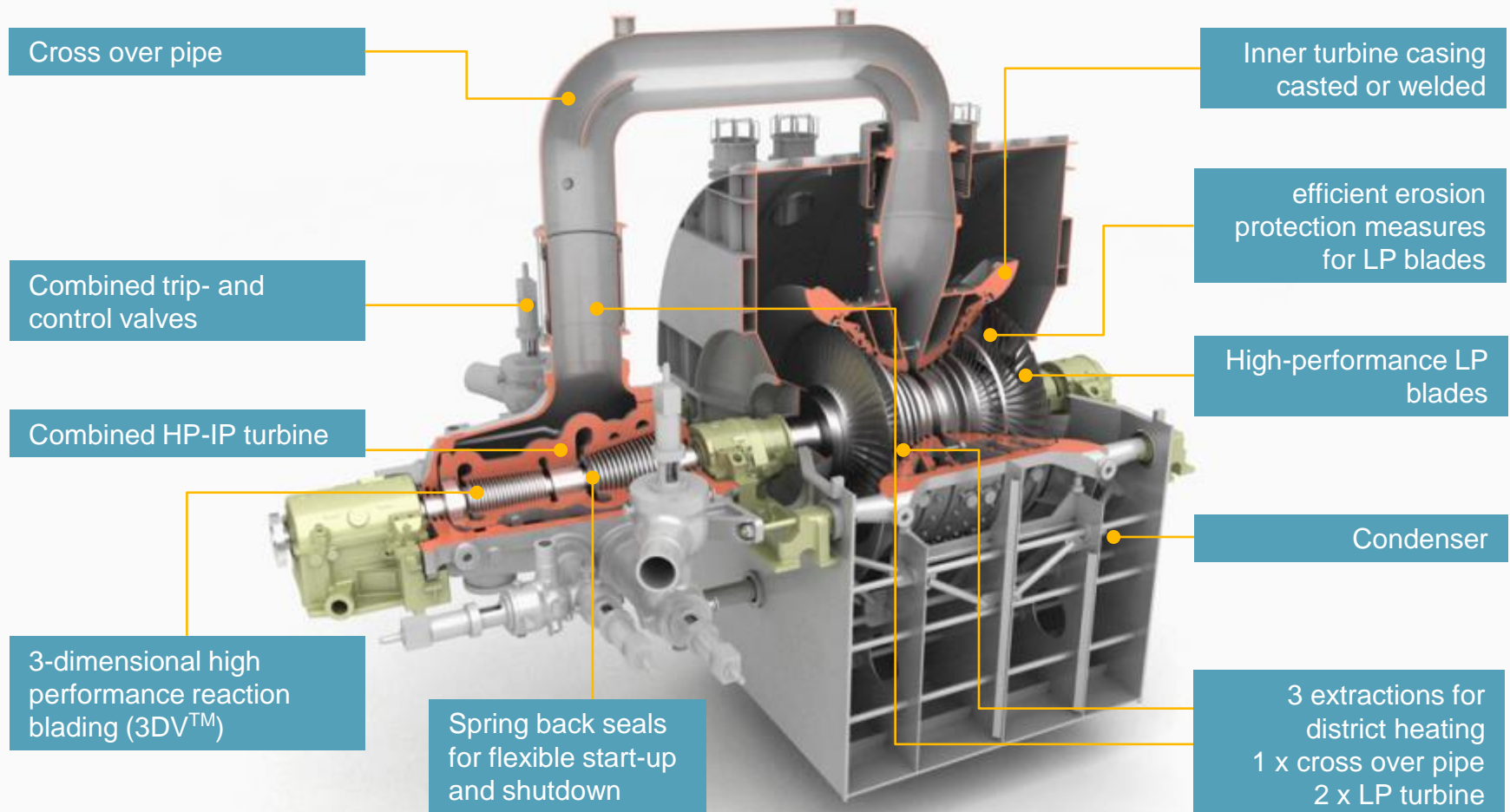
SGT-8000H series – more than 650,000 fired hours

Fleet experience on four continents

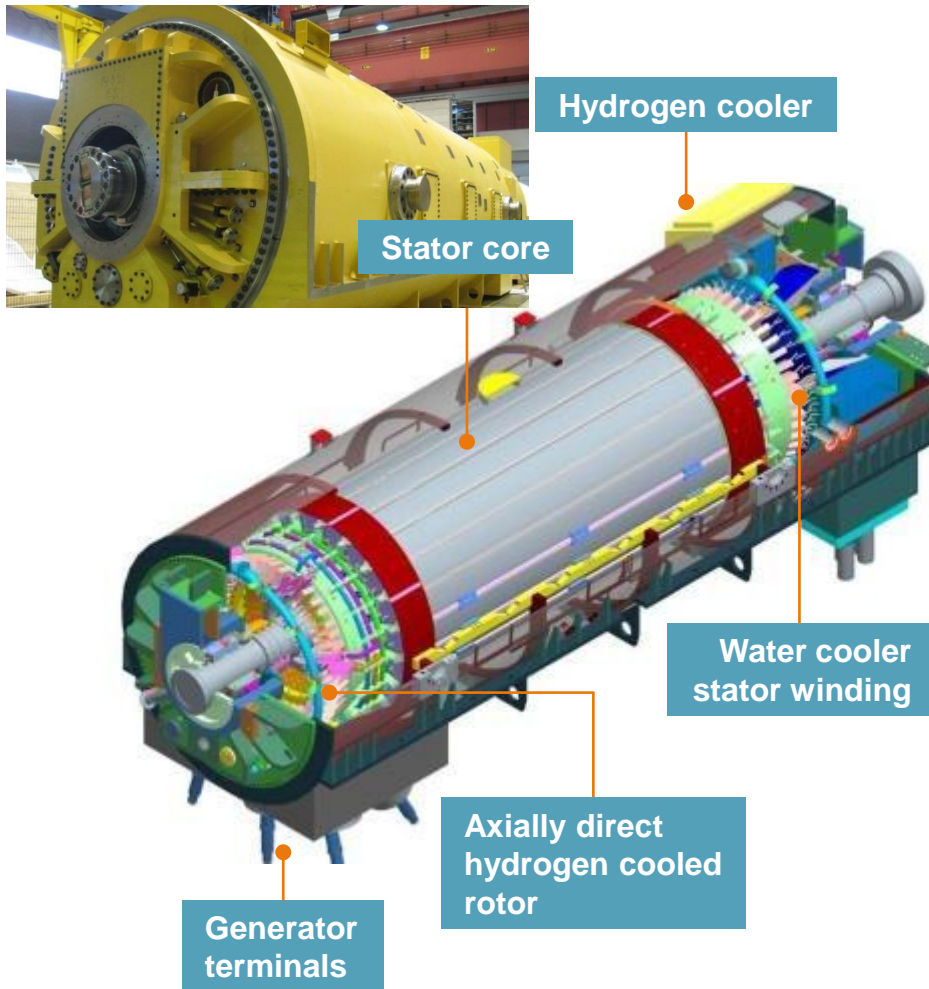


July 2017

SST5-5000 for steam power plants and CCPP 50 / 60 Hz: main parts



Generator SGen5-3000W



Technical Data

- Apparent Power: 760 MVA
- Voltage : 21 kV \pm 5 %
- Power factor: 0,80

Features

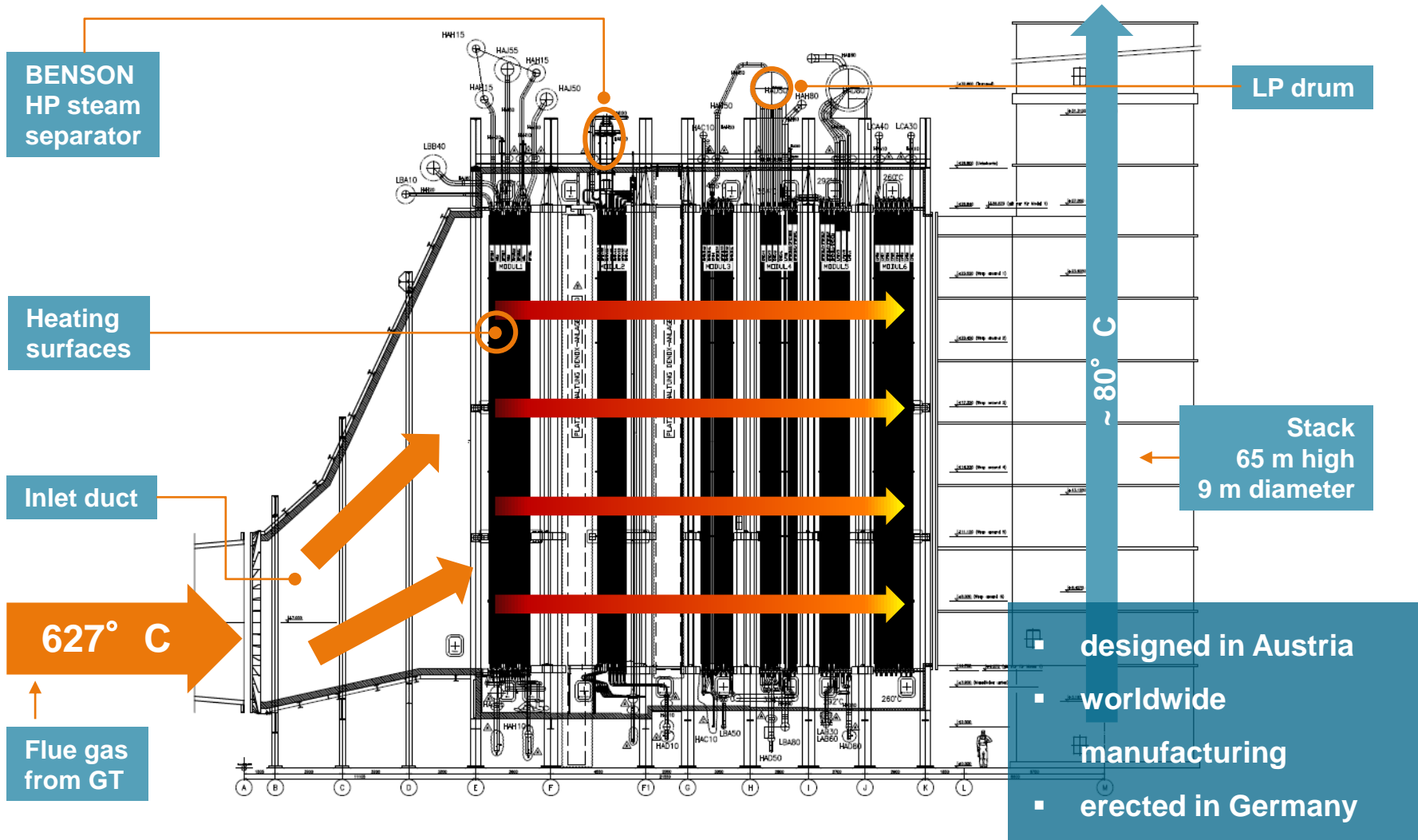
- Water cooled stator winding
- Axially direct hydrogen cooled rotor winding
- Stator insulation system MICALASTIC®
- World class efficiency

References

- Reliable design based on an experience of 100 units installed
- > 99 % reliability in 12 months average
- Generator operated at Irsching 4

Heat Recovery Steam Generator (HRSG) Cross section

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CHP Fortuna – Course of the project

All milestones on track – 29 Months

- March 2012 Dismantling of old flue gas filter ✓
- May 29th 2012 Contract signature with Siemens ✓
- July 10th 2012 “Vorbescheid” granted ✓
- July 31st 2013 Site responsibility with Siemens ✓
- May 30th 2014 Placement of gas turbine ✓
- April 4th 2015 First fire of gas turbine ✓
- Aug. 13th 2015 2 Million working hours w/o incident ✓
- Sept. 9th 2015 Test run with world records ✓
- Jan. 26th 2016 **Start of commercial operation** ✓



The “Fortuna” project is benchmark in Health & Safety

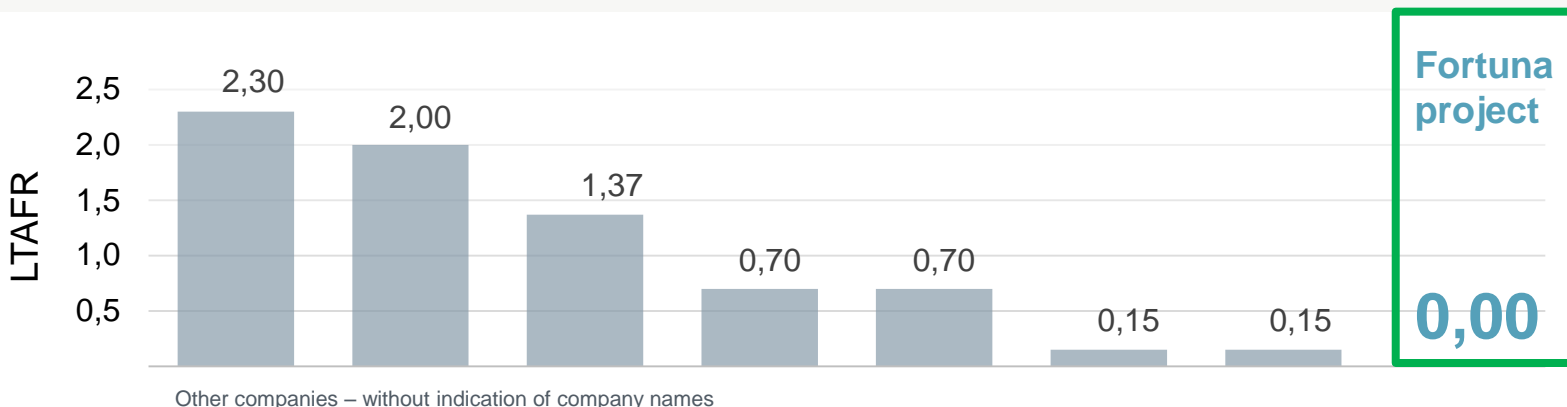
Working time without loss-time incident

2,148,561
man hours

- Equals **1500** people over one year
- Or equals **40** people over their whole working life



Zero harm culture at Siemens: Safety as a mindset.



But any accident is one too many.

$$LTFAR = \frac{LTAs \times 1,000,000}{\text{Manhours worked}}$$

LTAs = Lost Time Accident

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Records and Achievements in Lausward

CO₂ emissions
230 g CO₂/kWh_{el.+th.}

Net efficiency
61.5%

CCPP Power output
603.8 MW_{net}

GT Power output during
commissioning 422 MW
proven

300 MW_{th}
district heating

Handed over 19 days
ahead of schedule

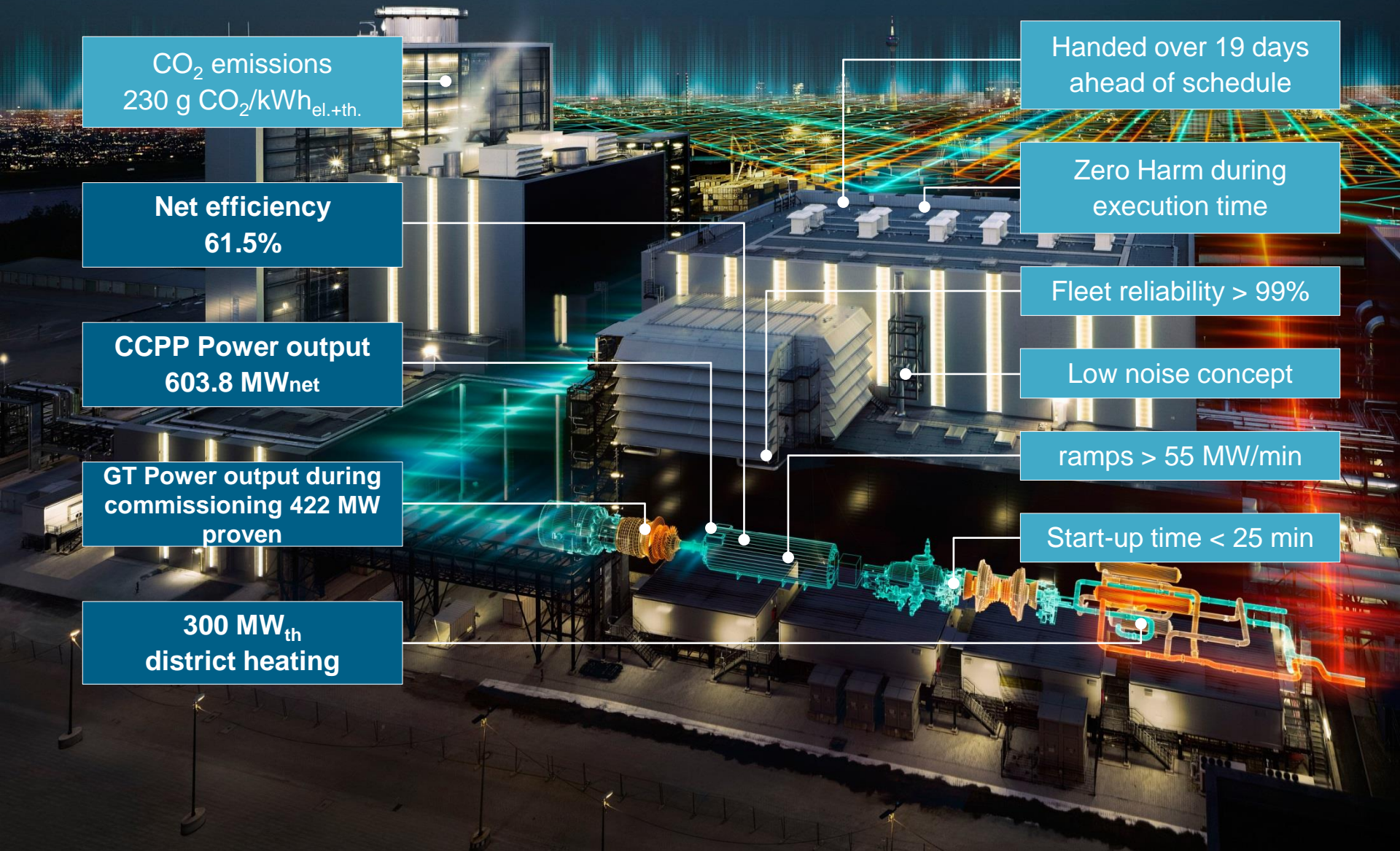
Zero Harm during
execution time

Fleet reliability > 99%

Low noise concept

ramps > 55 MW/min

Start-up time < 25 min



Emission compliant turndown demonstrated at Fortuna with new *Clean Range* system



Clean Range system:

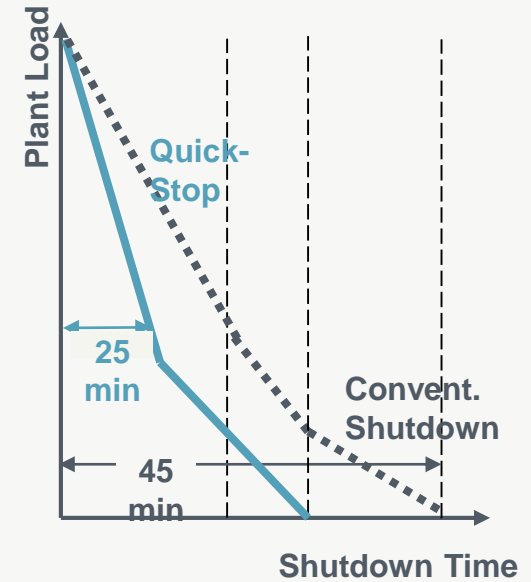
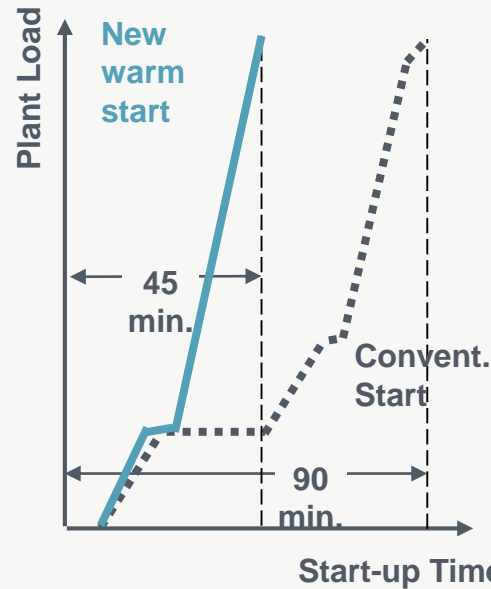
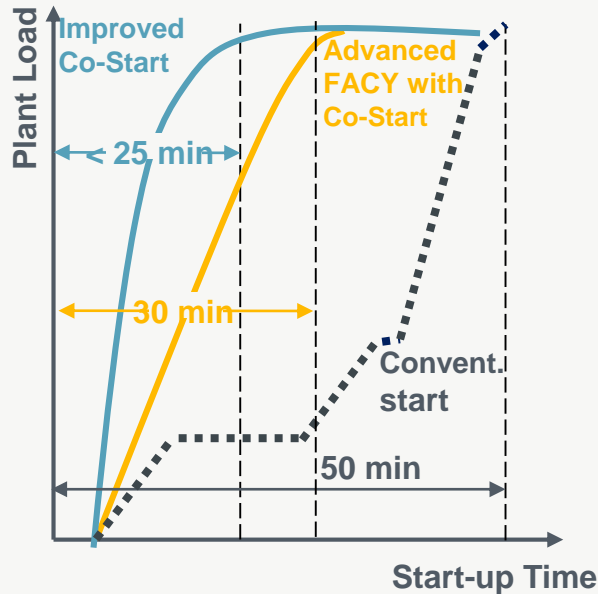
Turndown significantly improved down to 28%:

- CO & NO_x emission compliant during clean range operation
- Further turndown potential in evaluation
- Lower fuel consumption at low load operation
- Extension of load range
- Higher frequency response capability
- Increased operating flexibility
- Reliable heat extraction even in times of low electricity demand/production
- Simple Cycle performance at low load

Reduced start-up and shut down times while expected number of starts and component fatigue at similar level

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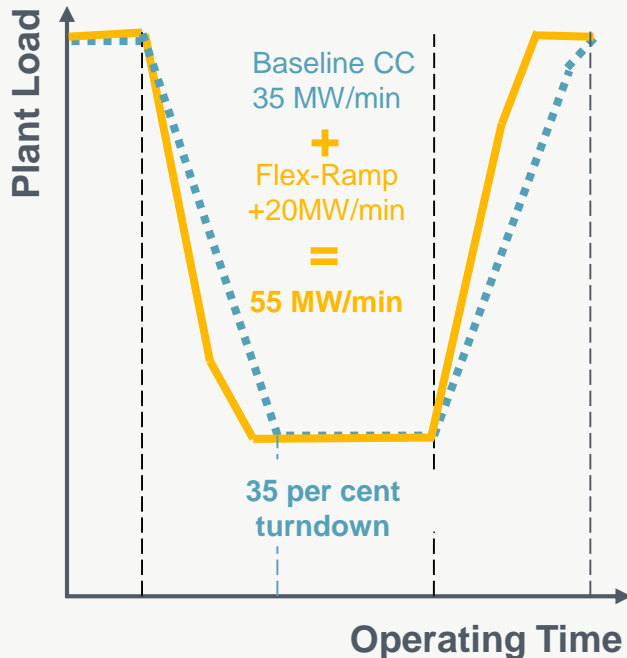


Start-up time	50 min	30 min	25 min
Fuel [kg]	32.600	20.000	16.050
Fuel [MWh]	420	260	210
Delta [%]	100	62	50

Start-up time	90 min	45 min
Fuel [kg]	55,900	29,700
Fuel [MWh]	720	380
Delta [%]	100	53

Start-up time	45 min	30 min	20 min
Fuel [kg]	31.200	22.200	13.000
Fuel [MWh]	420	290	170
Delta [%]	100	71	42

Flex-Ramp: Increased plant load ramp-rates for higher grid services revenues



Flex-Ramp concept:

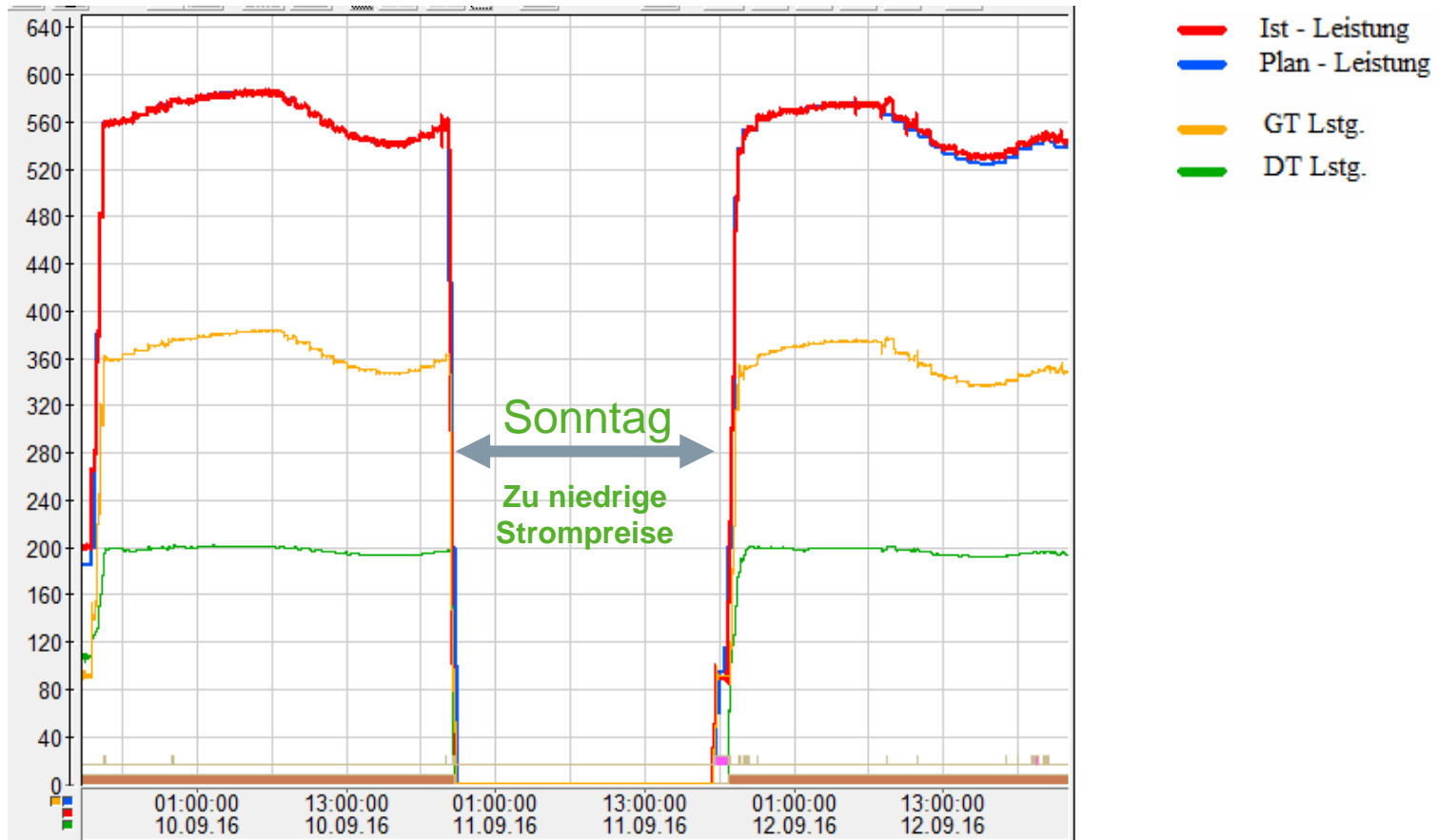
Steam turbine output added to GT ramp rate using new control logic (no hardware modification required)

- **Ramp-up:** Additional steam production based on HRSG stored energy (open high pressure bypass results in high pressure drop with immediate additional steam production); Additional steam routed to intermediate pressure steam turbine
- **Ramp-down:** Faster load decrease by intermediate pressure bypass station control (steam to condenser)

Feature	Current	Flex-Ramp
Load Change in 5 min	± 200 MW	± 275 MW
CC load change: ~40% - 100%	-375 MW / 11 min +340 MW / 8 min	- 375 MW / 7 min +360 MW / 6 min
Max. Ramp Rate	35 MW/min	55 MW/min

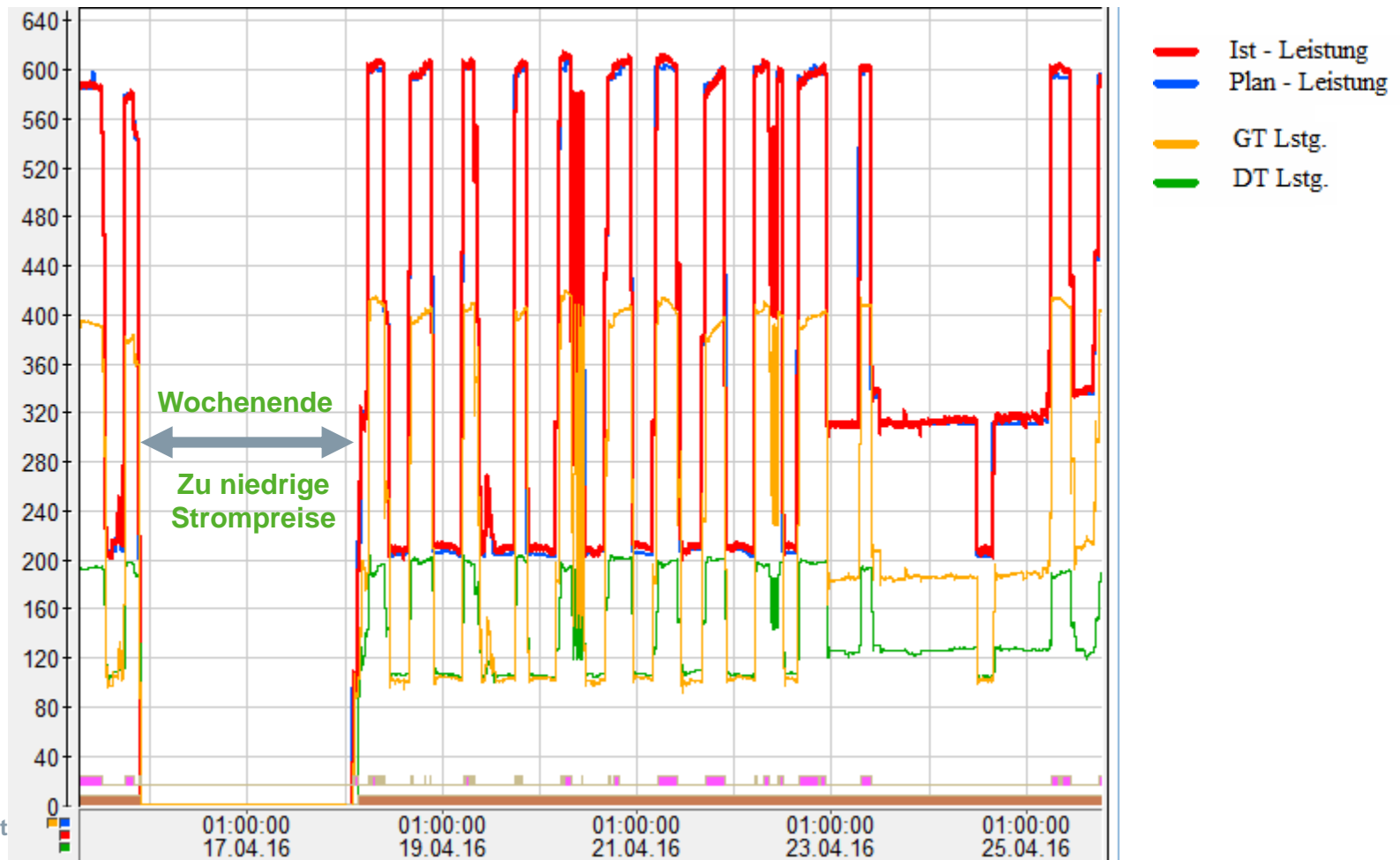
Operational Experience

Summer Operation



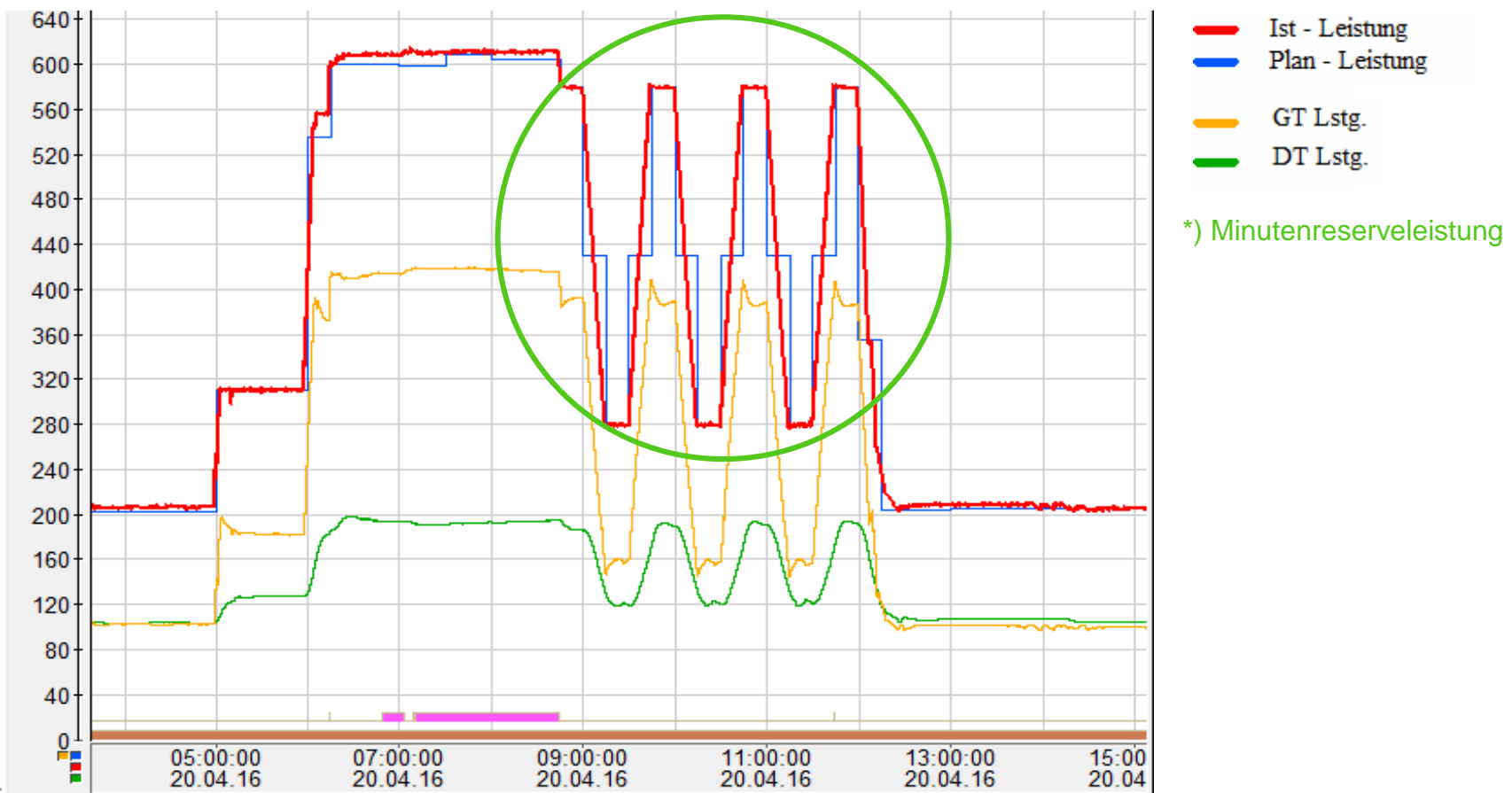
Operational Experience

Typical Springtime Operation



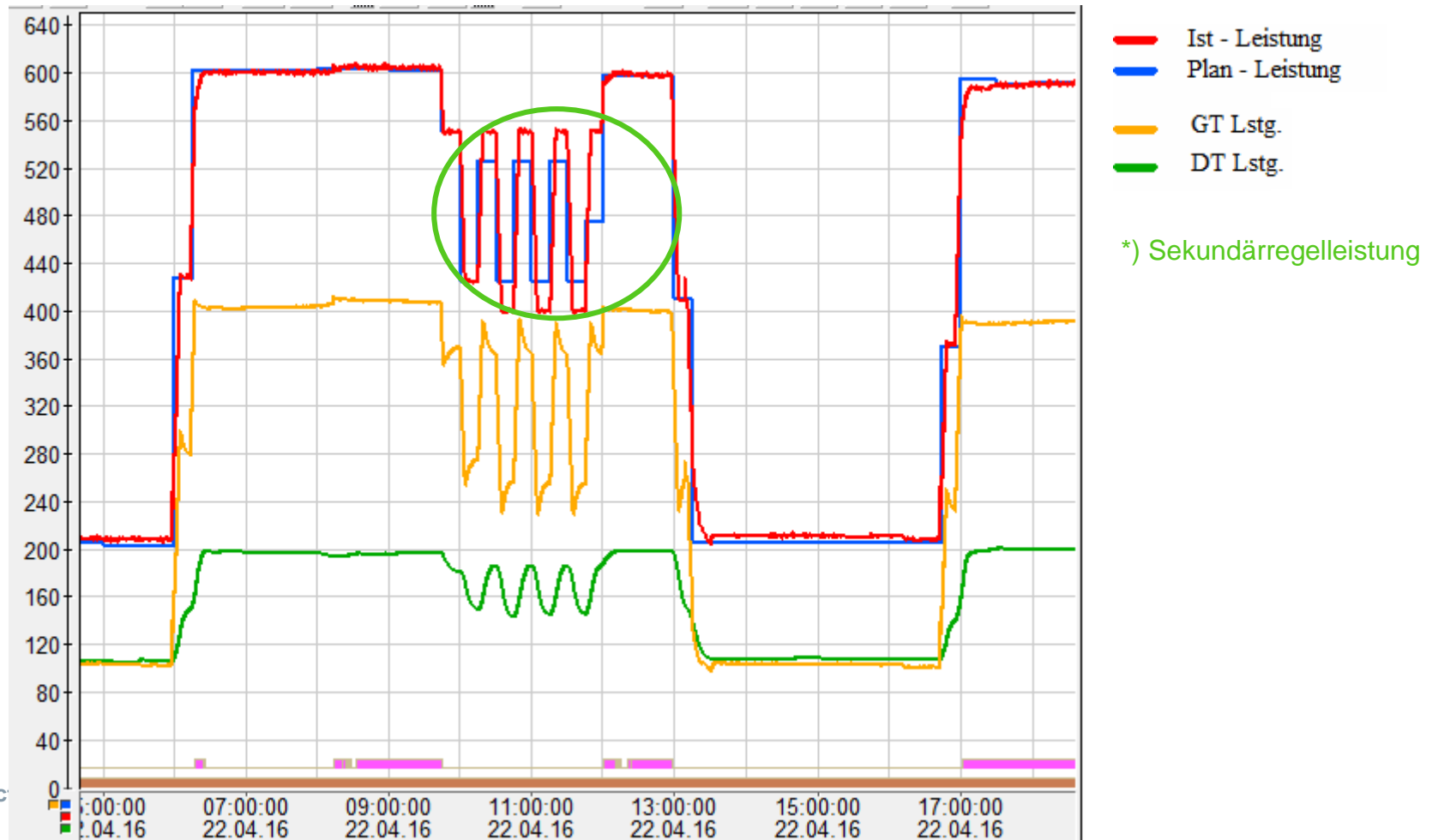
Operational Experience

- Nachweis der Präqualifizierung von 300 MW MRL*) -



Operational Experience

- Nachweis der Präqualifizierung von 150 MW SRL *) -



Emissions SCC5-8000H general

Emission Limits		World Bank ^{5, 6}	EU ^{5, 7}	SGT5-8000H
Gas ¹ nat. gas	NO _x	25 ppm	25 ppm	< 25 ppm
Fuel oil No. 2 ²		80 ppm	25 ppm	45 – 74 ppm
Fuel oil No. 6 ²		146 ppm	n. a.	n. a.
CO nat. gas / fuel oil 2		No restrictions	80 ppm	10 ppm ¹ - 80 ppm ⁸
PM fuel oil No. 2 ²		n. a.	n. a.	<10 ppm (only contractual requirements)
UHC ⁴ nat. gas		No restrictions	No restrictions	4 ppm (fuel gas) for start-up only 0 ppm >40 % GT load

Performance Data

Net power output [MW]	>600
Net efficiency [%]	>60
Net heat rate [kJ/kWh]	<6000
Pressure ratio	19.2
(ISO ambient conditions)	

Other important information

CO2 320 – 350 g/kWh ¹ (depending on gas quality)

¹ at base load & ISO Conditions (at 15% oxygen in dry exhaust gas)

² according to ASTM

³ w/o fuel bound nitrogen

⁴ unburned Hydrocarbons

⁵ Status Oct. 2015

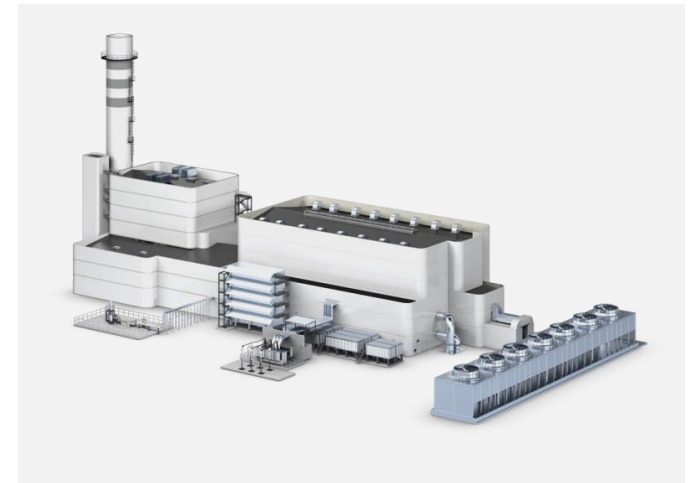
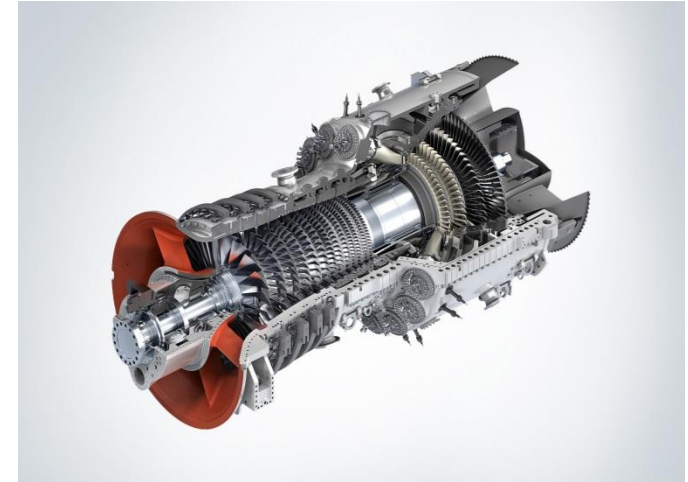
⁶ Compliance = 95% of hourly averages per anno meet limit

⁷ Monthly averages

⁸ Emission conform Min load <35%

Key Data of Siemens SGT-8000H series

SGT-8000H	50 Hz	60 Hz
ISO base power output (MW)	400	296
Efficiency (%)	40.0	40.0
Heat rate (kJ/kWh Btu/kWh)	8,999 8,530	8,999 8,530
Exhaust mass flow (kg/s lb/s)	869 1,915	640 1,410
Exhaust temperature (°C °F)	627 1,161	630 1,166
Physical Dimensions	50 Hz	60 Hz
Weight (t lb)	445 981,000	289 637,000
Length x Height x Width (m)	12.6 x 5.5 x 5.5	10.5 x 4.3 x 4.3
Length x Height x Width (ft)	41 x 18 x 18	34 x 14 x 14
Combined Cycle Plant, 1S	50 Hz	60 Hz
Net power output (MW)	600	440
Net efficiency (%)	> 60	> 60
Combined Cycle Plant, 2x1	50 Hz	60 Hz
Net power output (MW)	1,200	880
Net efficiency (%)	> 60	> 60



Lausward „Fortuna“: all contractual parameters exceeded, proven in operation

	Contractual values ¹	Demonstrated	Status
Power output (net) ²	597,1 MW	603,8 MW	✓
Efficiency (net, LHV) ²	61,4%	61,5%	✓
District heating extraction	300 MWth	300 MWth	to be measured
Fuel Utilization rate	-	~ 85%	to be measured
NOx emissions ²	25 ppm	< 25 ppm	✓
hot Co-start ³	< 40 min	< 25 min	✓
warm Co-Start	-	45 min	✓
PAC before contractual date	0 days	19 days	✓

¹ Lausward reference site conditions

² At base load

³ Max. shutdown time period of 8 hours

■ World records

Contact page



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