HANNOVER MESSE
20.–24. APRIL 2009

SIEMENS

State of the Art Combined Cycle & Steam Power Plants

Dr. Harald Kurz
Director Solutions Marketing 50Hz

April 22nd, 2009

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State of the Art Combined Cycle & Steam Power Plants

- Market Environment
- What means ‚State of the Art‘?
- Energy Efficiency and Emissions
- State of the Art Combined Cycle Power Plant and its relating Gas Turbine
- State of the Art Steam Power Plant and its relating Steam Turbines
- Outview

Renewables are gaining in importance – but fossil fuels will continue to be the mainstay

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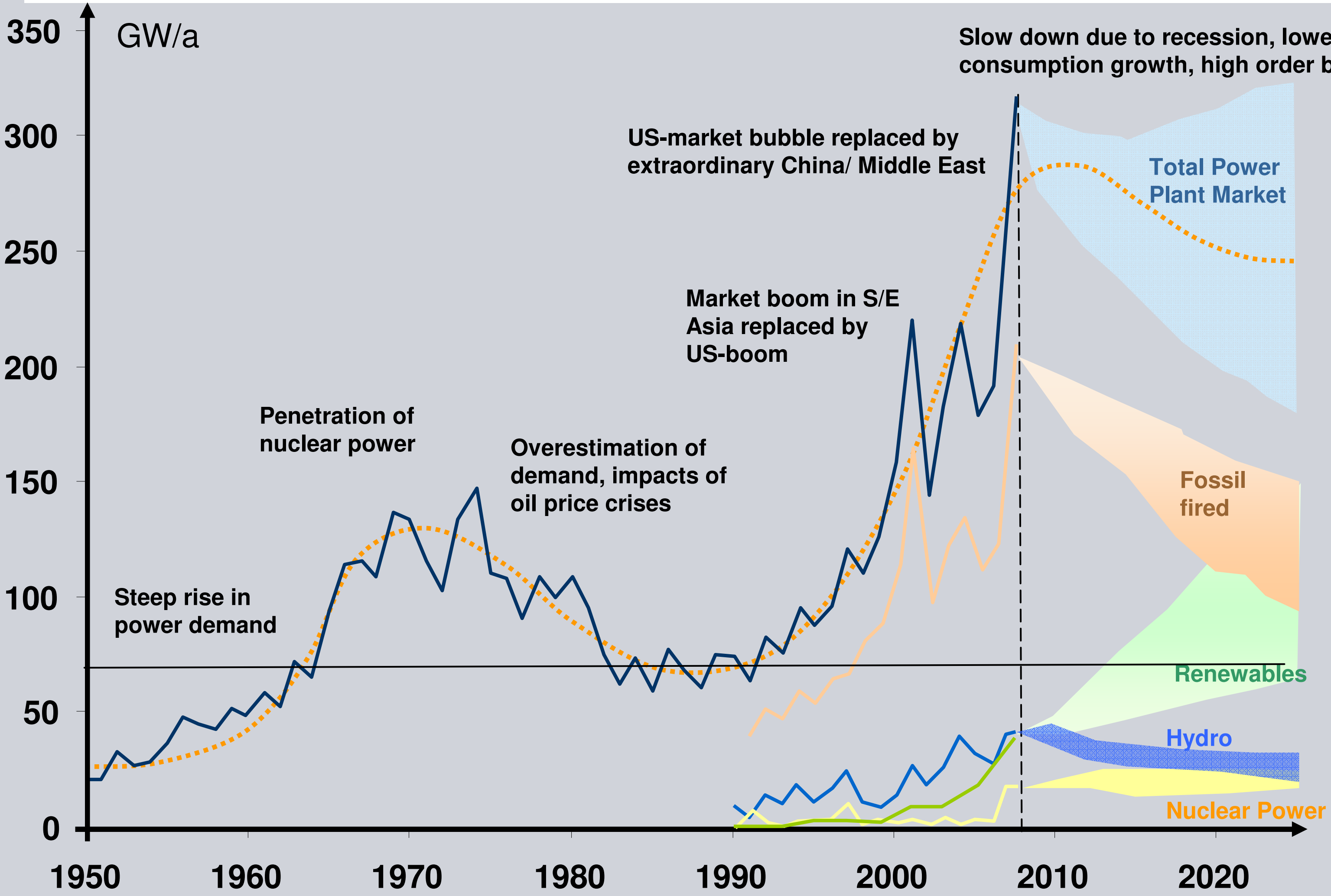

Drivers, Uncertainties

- Economy growth
- Energy prices
- Ecology awareness
- Power plant types
- Commodity prices
- Liberalization
- Customer behavior
- Replacements
- Regional markets
- Grid extension
- Production capacity

Siemens Energy Sector – Answers for energy supply

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Energy products and solutions - in 6 Divisions

Oil & Gas

Fossil Power Generation

Renewable Energy

Energy Service

Power Trans-mission

Power Distribution

today‘s presentation

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Siemens Energy Sector – Answers to the multifaceted market requirements

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Influencing factors	Energy market requirements	Energy Sector – Products and solutions
Increasing energy demand worldwide	**Reliable supply** ▪ Fast response to load changes ▪ Provision of base- intermediate- and peak-load generating capacities ▪ Long-distance transmission of large amounts of electricity, grid staibility ▪ Technologies for difficult-to-access and unconventional oil and gas deposits	▪ High-performance, reliable gas turbines for fast response to load changes ▪ High-voltage DC transmission (HVDC), reactive-power compensation ▪ Whisper transformers, energy automation systems ▪ Systems for underwater recovery of oil and gas, unmanned pumping stations
Power supply in urban and rural areas Climate change	**Climate and environmental protection** ▪ Reduction of CO_2, NO_x, SO_x etc. ▪ Efficient use of fossil fuels ▪ Low-loss energy transport ▪ Noise control and environmental protection today's presentation	▪ High-efficiency power plants (CCPP) ▪ Renewables: wind (on- and offshore), solarthermal ▪ HVDC and ultra high-voltage systems ▪ Whisper transformers, gas-insulated lines ▪ CO_2 compressors for Carbon capture and storage (CCS)
Scarcity of fossil fuels	**Cost-effectiveness** ▪ High efficiency ▪ Low lifecycle costs ▪ High security of investment / profitability ▪ Low O&M and service costs	▪ High-efficiency CC and coal-fired power plants ▪ Switchgear with 25-year maintenance intervals ▪ Cost-saving service solutions ▪ Highly profitable E-LNG solutions (Electric Liquefied Natural Gas)

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State of the Art Combined Cycle & Steam Power Plants

Energy Efficiency and Carbon Capture & Sequestration (CCS) are key solutions to reaching emission reductions targets

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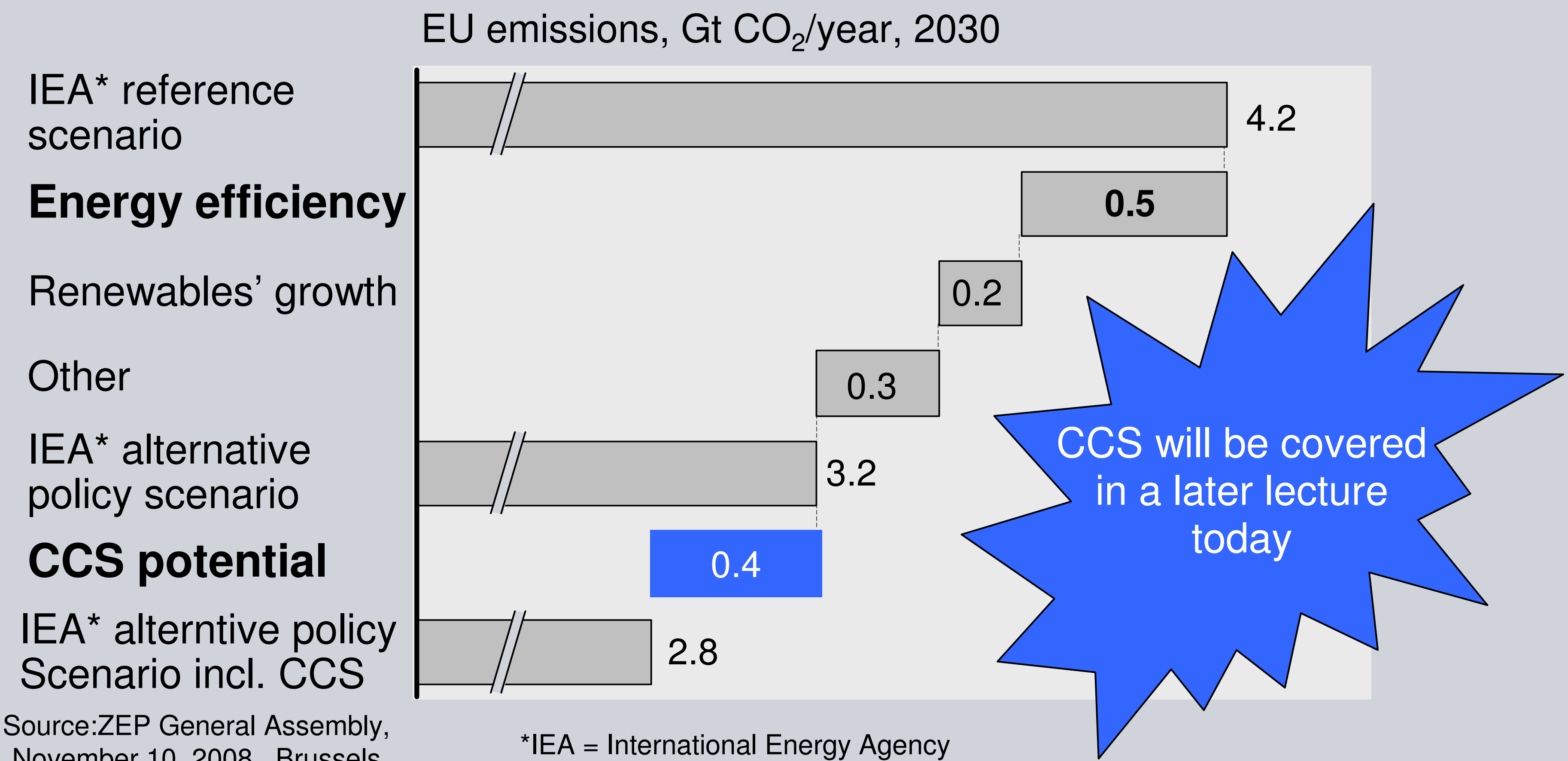

Source:ZEP General Assembly, November 10, 2008 , Brussels

*IEA = International Energy Agency

It is globally accepted by now that CCS is indispensable for reaching global carbon emissions reduction targets.

State of the Art with regard to efficiency...

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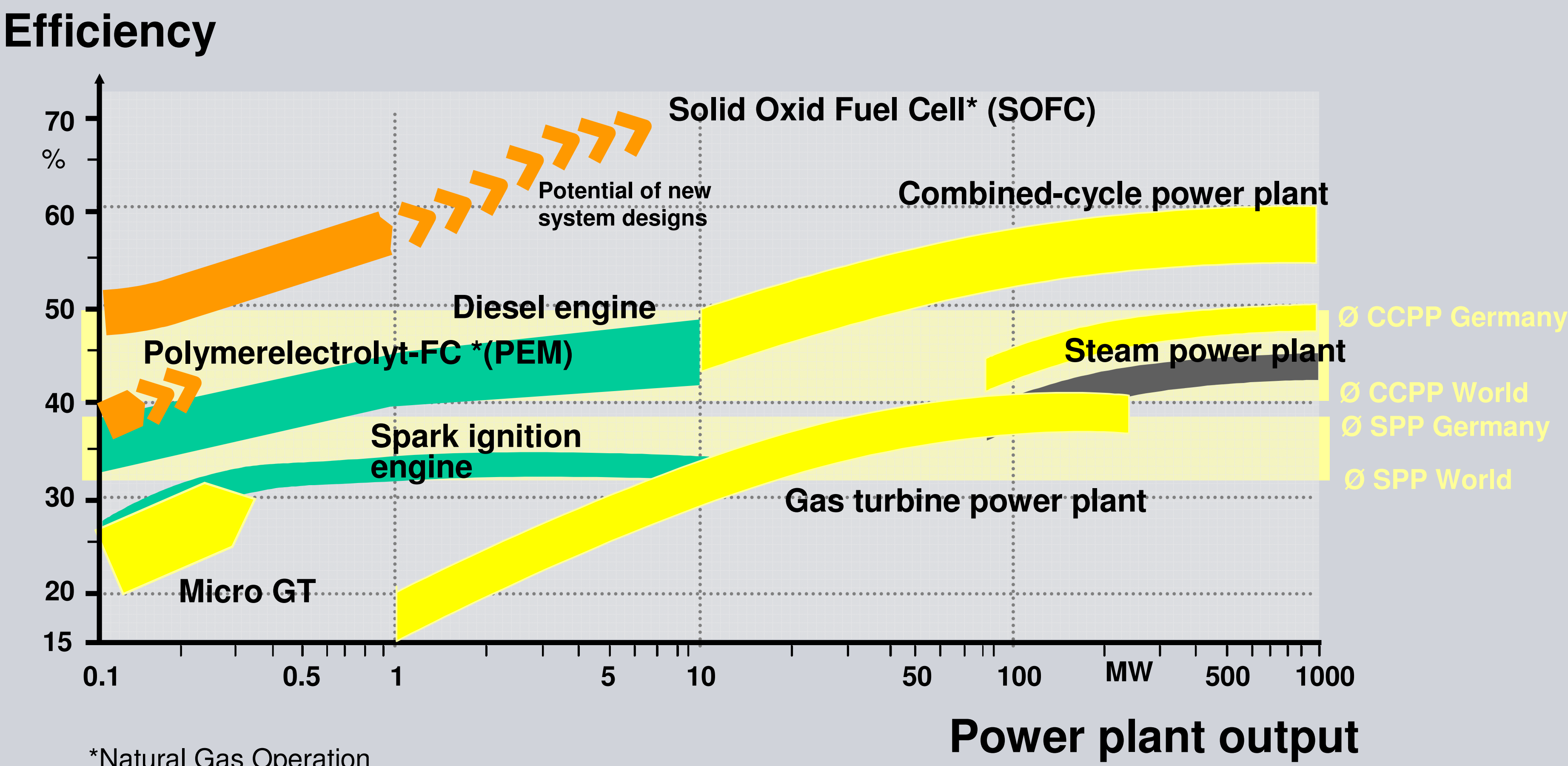

*Natural Gas Operation

There is a lot of efficiency improvement potential for the averagely installed Gas and Steam Power Plant

Efficiency is key driver:
Siemens technology efficiency milestones

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Steam Power Plants

Reference plant Germany, 600 MW

Combined Cycle Power Plant

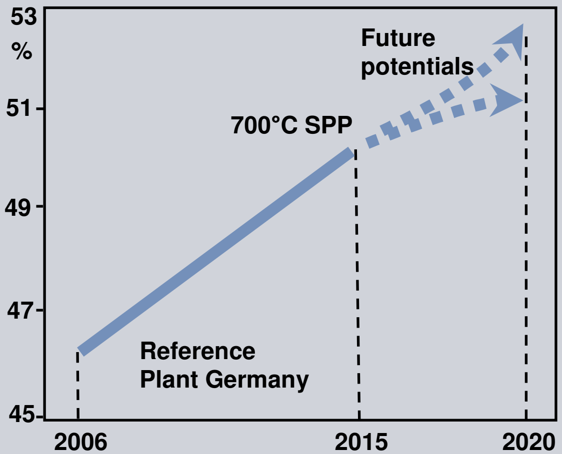
CCPP Irsching 4, 530 MW

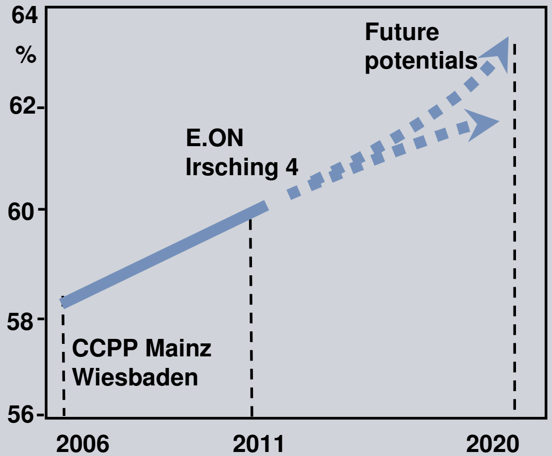
Integrated Gasification Plant

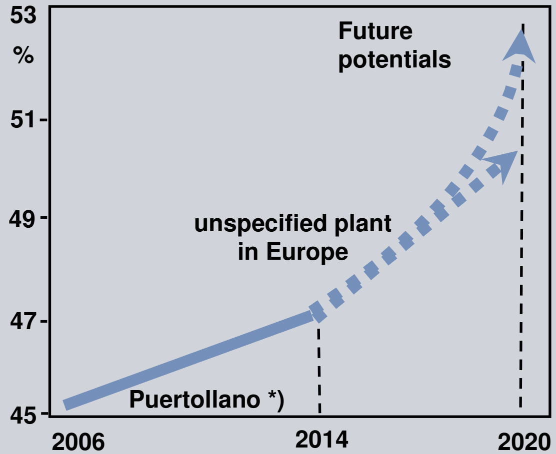
Puertollano, 320 MW

*) coal quality depending

Development of efficiency (net)







Source: Siemens Energy ST MOP

State of the Art Combined Cycle & Steam Power Plants

- Market Environment
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- **State of the Art Combined Cycle Power Plant and its relating Gas Turbine**
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Our basis for State of the Art Power Plants: Reference Power Plants (RPP) = pre-engineered Power Plants

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Operating Costs	Plant Operation	Financials
Electricity Price	**Power Output**	**Investment Volume**
Fuel Price	**Efficiency**	**Payment Schedule**
Personnel Costs	**Availability/Reliability**	**Lead time**
Consumables	**Emissions**	Debt/ Equity Ratio
Insurance	Load Regime	Interest Rate
Maintenance		Income Tax

Increased customer value by optimised key factors

Example - Fossil power generation: Combined cycle power plants

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Combined-cycle power plants belong to the most energy efficient fossil-fired power generators. The new gas turbine from Siemens in Bavarian town Irsching is expected to set a new efficiency record: over 60 percent.

Key features	- High efficiency due to combination of gas and steam turbines - Further efficiency enhancements possible thanks to higher combustion temperatures and innovative turbines
Environ-mental value	- Only 345 g CO2-emissions per kilowatt hour, compared to 578 in average power generation worldwide - Significant emissions reduction anticipated (gas turbine Irsching)
Customer value	- Low fuel consumption* - Low operating costs* - High flexibility and availability *Compared to conventional fossil-fired power plants

2% Pt. efficiency increase => CO_2 saving compared to 9.500 cars with 20.000 km/a

The worlds biggest Gas Turbine and the relating most efficient Combined Cycle Power Plant (CCPP)

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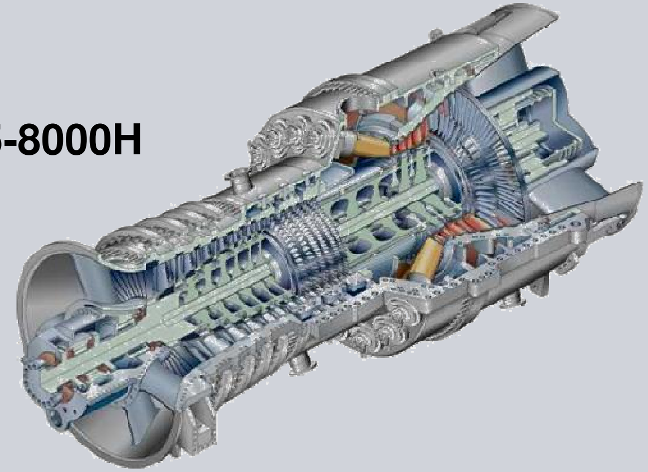
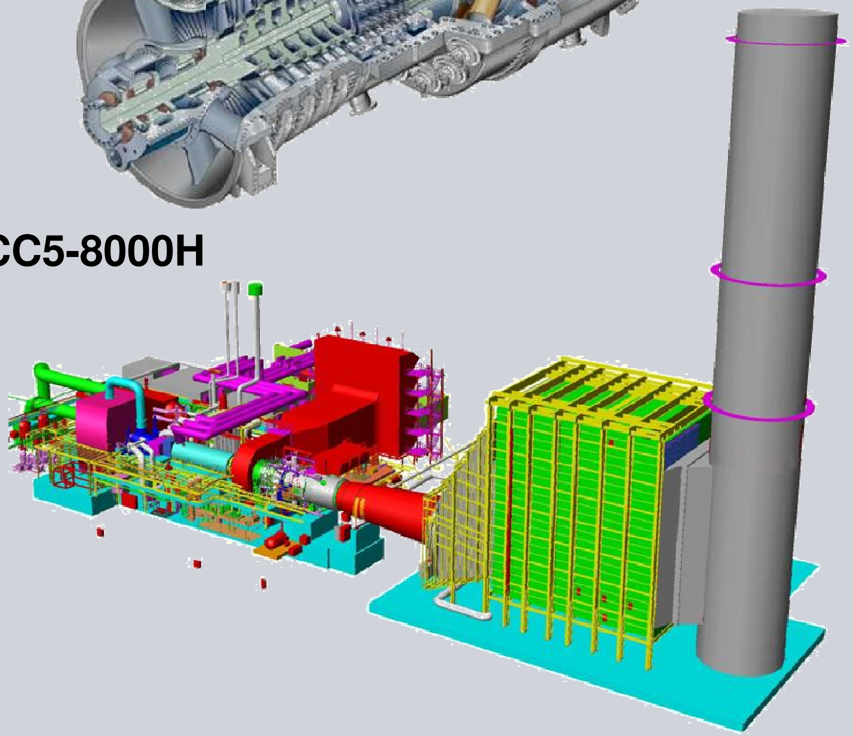
Gas turbine	SGT5-8000H
Steam turbine	SST5-5000
Generator	SGen5-3000W
Fuel	nat. gas, #2
GT / CC output	340 / 530 MW
GT / CC efficiency	> 39% / ≥ 60 %
Pressure ratio	19.2 : 1
Exhaust mass flow	820 kg/s
Exhaust temperature	625 °C
Turn down	50%
HRSG/WS-Cycle	3Pr-RH, Benson 600°C / 170 bar

SGT5-8000H



SCC5-8000H



The world biggest Gas Turbine

SGT5-8000H power data in comparison

SGT5-8000H

Porsche 911 Turbo
420 PS (309 kW) at 6.000 1/min

Boeing 747-400

1 Gas Turbine blade = 10 Porsche

1 Gas Turbine = 1100 Porsche or 13 Boeing 747-400 engines

1 CCPP = 1715 Porsche or 20 Boeing 747-400 engines

Some State of the Art Gas Turbine features of the SGT5-8000H

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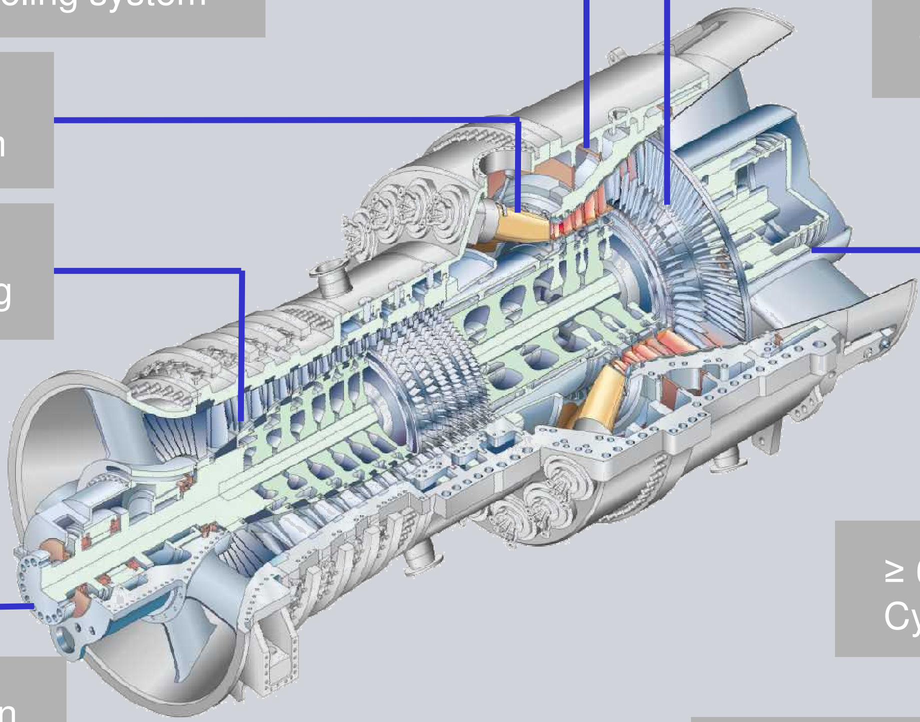
High cycling capability due to advanced blade cooling system

Advanced **ULN** combustion system

Evolutionary 3D-compressor blading

Four stage turbine with advanced materials and thermal barrier coating



≥ 60% Combined Cycle efficiency

Proven rotor design, Hirth serration and central tie rod

Integrated combined cycle process for economy and low emissions

Technology Lever:
Combustor design

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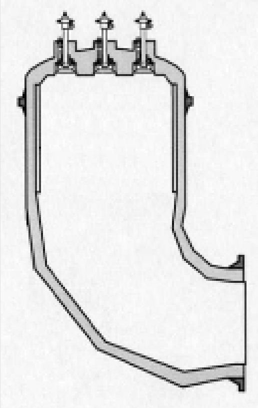
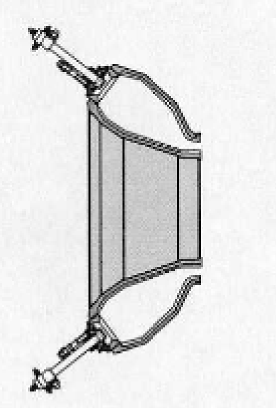
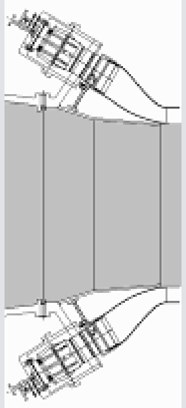
Combustion Chamber



silo

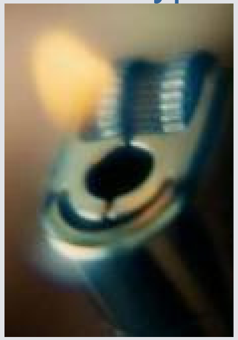


annular



can annular

Burner Type

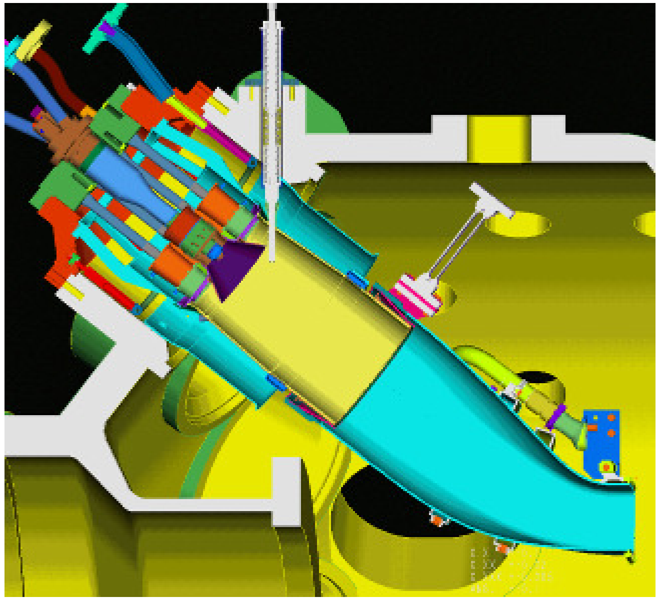


Diffusion Burner:
>250ppm NOx

Hybrid Burner:
15-25ppm NOx

DLN/ULN Burner:
<15-25ppm NOx

example: 8000H Combustor



Technology Lever:
Cooling & Leakage Air Reduction

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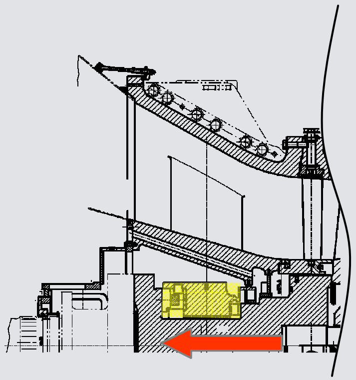
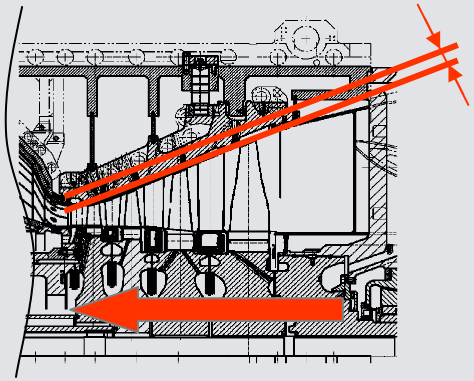
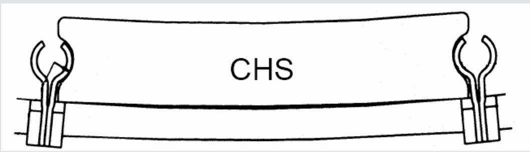
example: Hydraulic Clearance Optimization

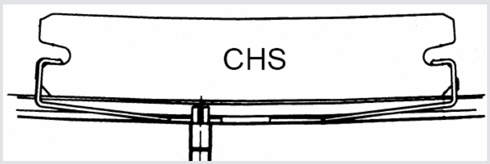

compressor bearing


turbine clearances

example: tile holders for ceramic heat shields



old design



new design with less cooling air consumption

Technology Lever:
Aerodynamical blade design compressor and turbine

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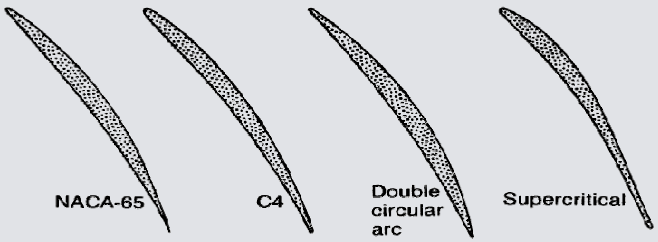
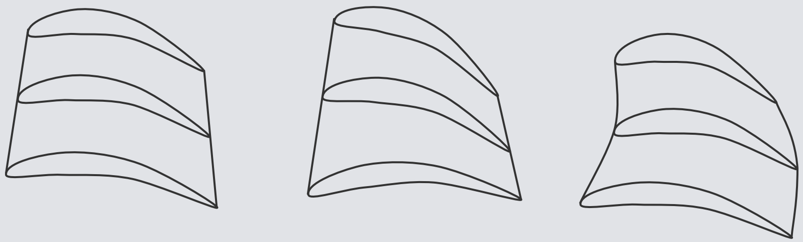
Blade profile



aus Cumpsty, N.A.: Compressor Aerodynamics

Blade shape



3D-Aero Blading Design


example: 4000F turbine blade

Technology Lever:
Mechanical turbine blade design

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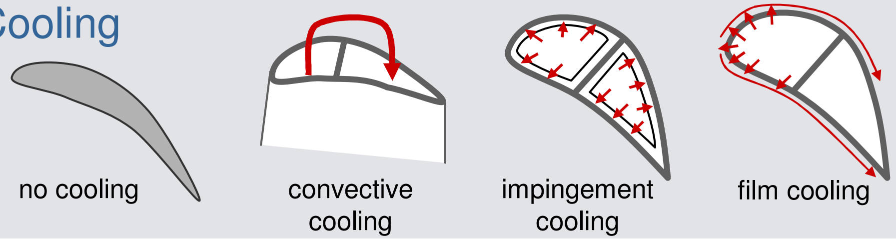
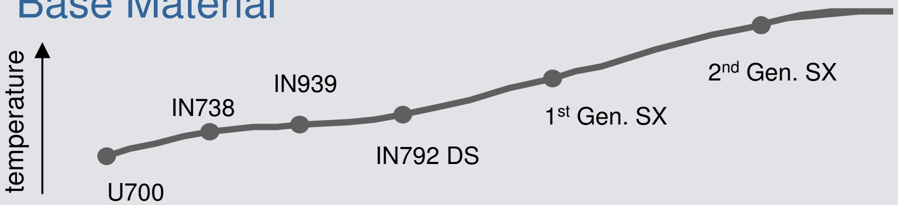
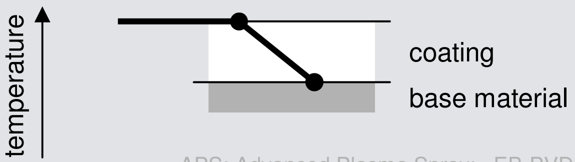
Cooling



Base Material



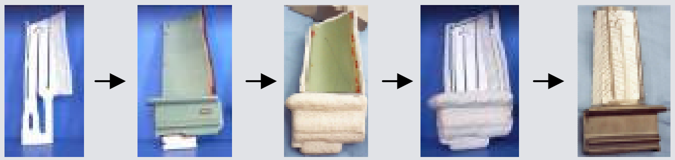
Coatings



- MCrAlY: SICOAT
- 2231TBC: e.g. ZrO_2+Y_2O_3
- Coating Technologies: APS, EB-PVD

APS: Advanced Plasma Spray; EB-PVD:Electron Beam Physical Vapor Deposition

Manufacturing



Casting:
- conventional
- directional solidification
- single crystal casting

Technology Development Success Stories: Advanced High Temperature Coating Systems

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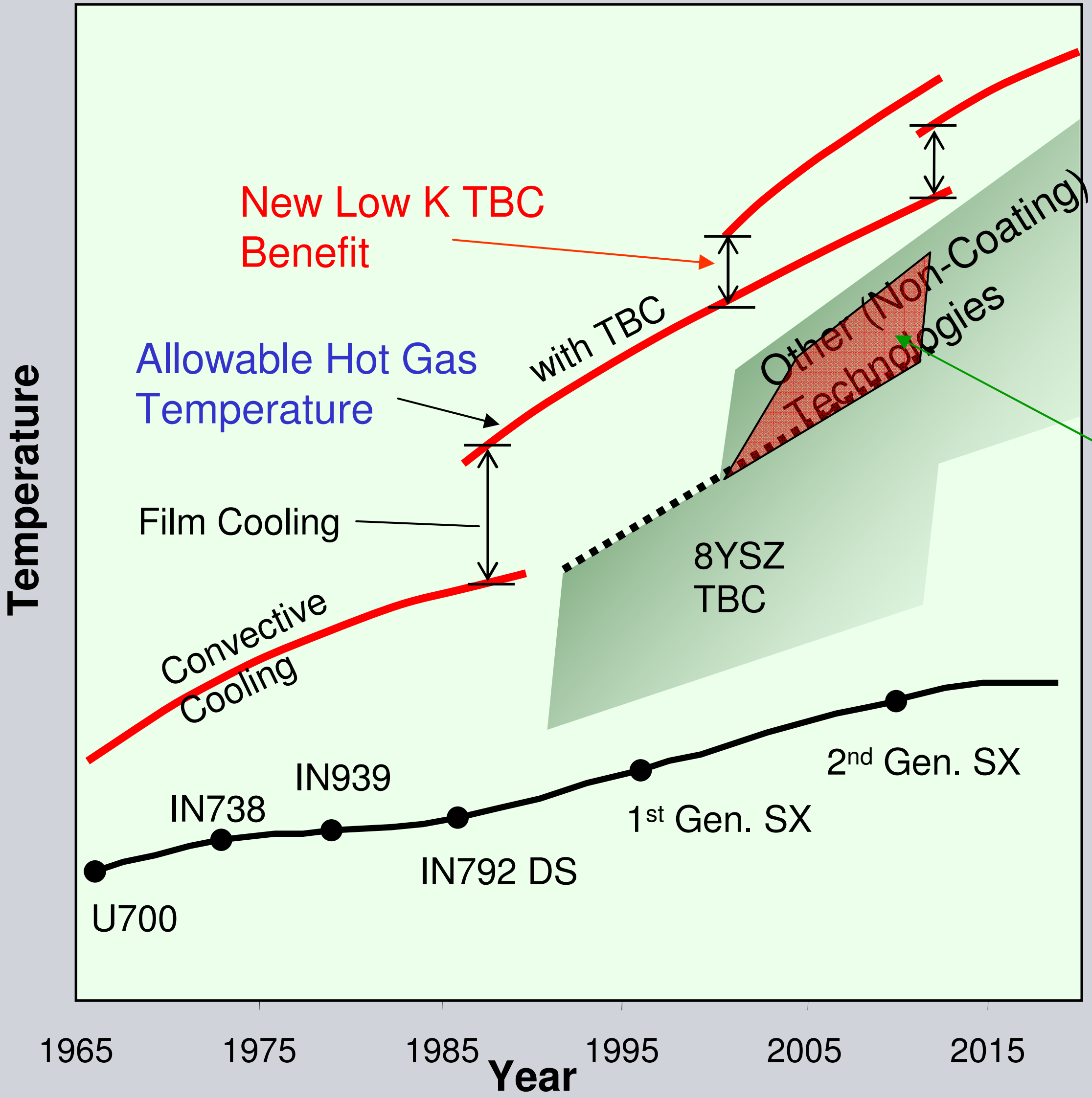

Siemens "Class 1" low K TBCs 1st generation implemented and in production

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- **State of the Art Steam Power Plant and its relating Steam Turbines**
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State of the Art:
Some References for High Steam Parameters

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1x600 MWel / Main Steam: **251 bar** / **600 °C**
Reheat Steam: **610°C**, Condenser: **0.0507 bar**

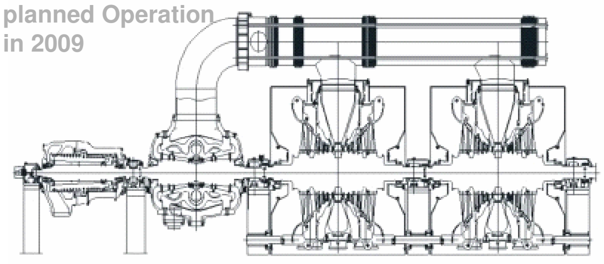
1x1025 MWel / Main Steam: **265 bar/576 °C**
Reheat Steam: **600°C**, Condenser: **0.0291/0.0368 bar**

2x900 MWel / Main Steam: **250bar** / **538 °C**
Reheat Steam: **566°C**, Condenser: **0.049/0.0368 bar**

4x1000 MWel / Main Steam: **262.5 bar** / **600 °C**
Reheat Steam: **600°C**, Condenser: **0.054/0.044 bar**

1x750 MWel / Main Steam: **250 bar** / **540 °C**
Reheat Steam: **560°C**, Condenser: **0.2 bar ACC**

planned Operation
in 2009



Waigaoqiao 3, China

1x1000 MWel / Main Steam: **270 bar** / **600 °C**
Reheat Steam: **600°C**, Condenser: **0.054/0.044 bar**

Largest Ultra- Supercritical Steam Turbines recently built by Siemens with excellent operating records

...the relating State of the Art Steam Turbines SST-6000

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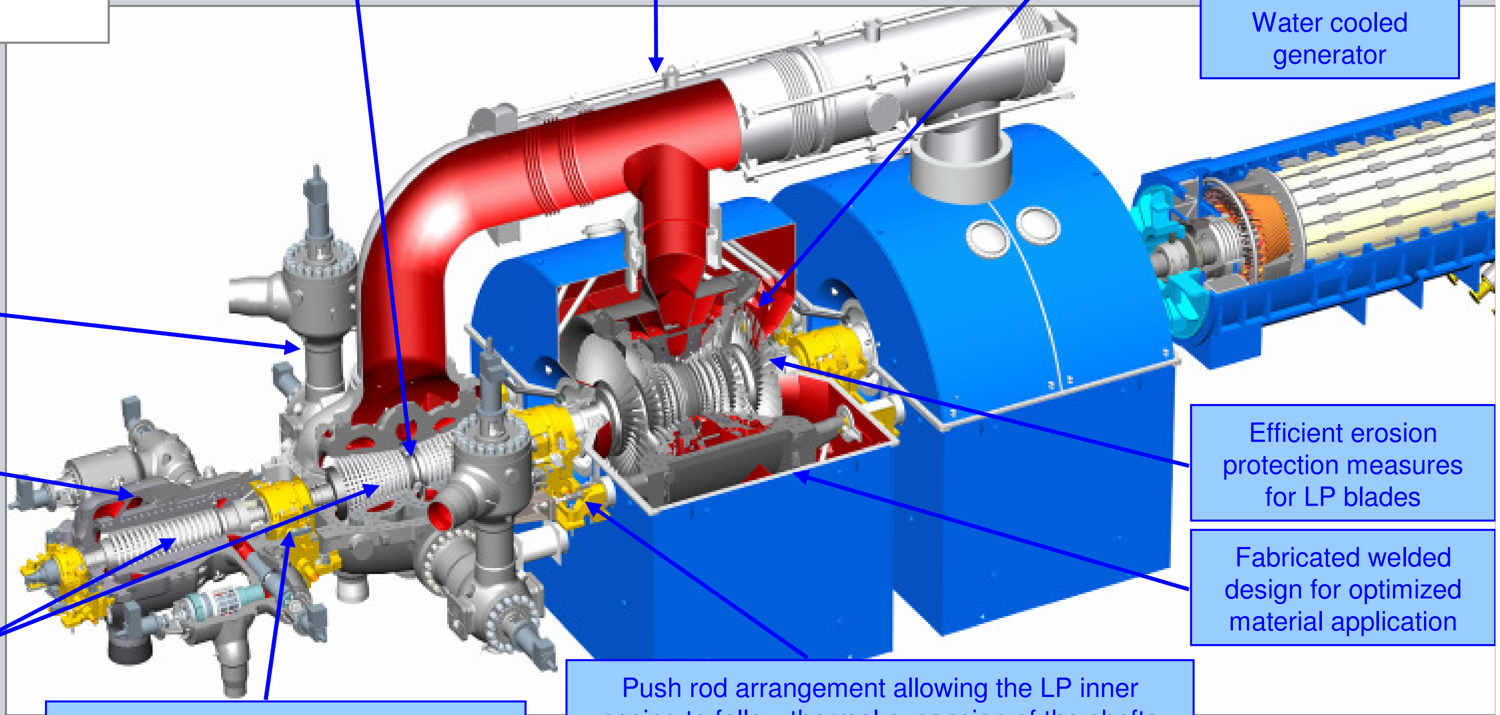
Rating 50 Hz / 60 Hz
300 MW to 1200 MW

Steam conditions SPP
up to 300 bar / 600°C / 600°C
up to 4350 psi / 1110°F / 1110°F



Optimized blades and increased exhaust areas for highest efficiencies

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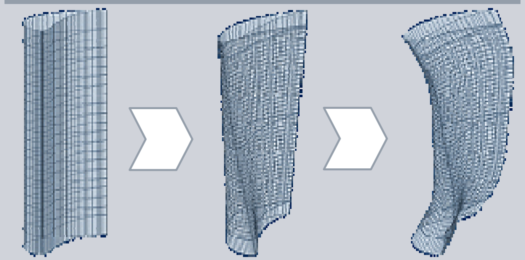
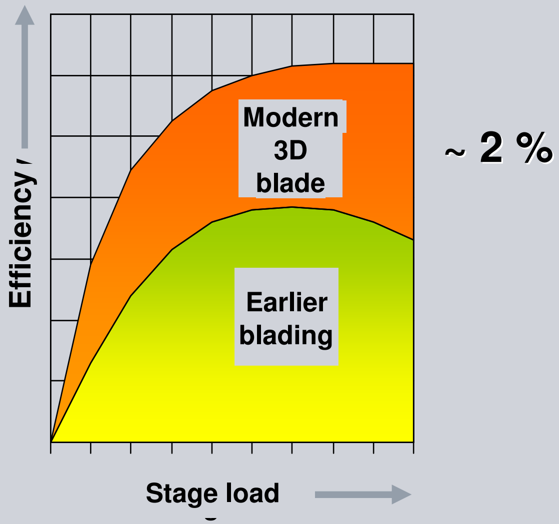
HP & IP blades



3D blading



Last row blades

Interlocked blades
- Titanium forged blades
- Interlocked shroud
- Midspan snubber
- Side entry roots

Free standing blades
- Steel forged blades
- Side entry roots

Highlights and design details

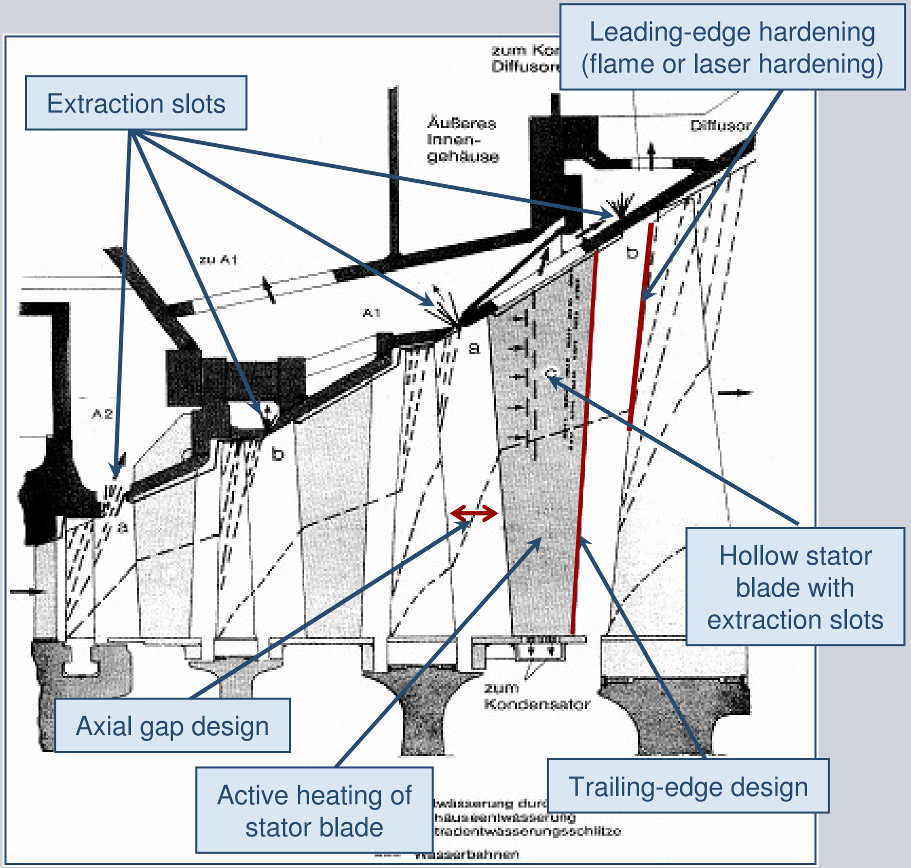
Additional measures against erosion

Design features

- Proven methodology for prediction of erosion impact and selection of optimum protection level and relevant features (not all features are applied at the same time)
- Minimized trailing-edge thickness for reduced droplet size
- Flame hardening or laser hardening of moving-blade inlet edge
- Moisture-extraction slots at outer flow contours
- Hollow guide vanes with moisture-extraction slots on blade surface
- Hollow guide vanes with internal heating system to evaporate surface moisture

Customer benefits

- Improved reliability and life time
- Reduced ageing
- Optimum protection level for each application



Sealing –
labyrinth with abradable coating

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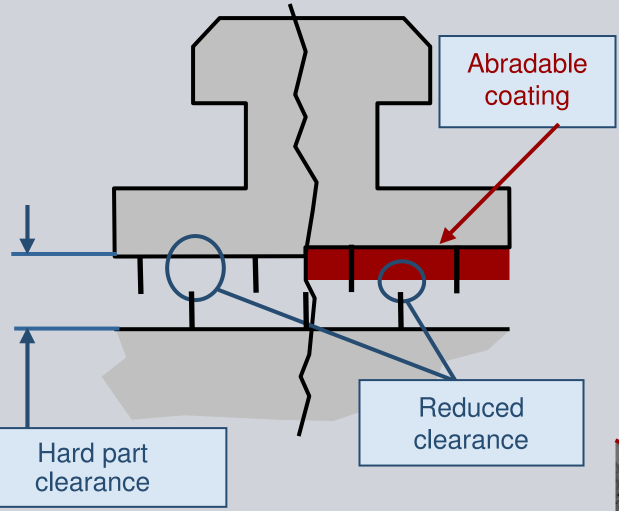
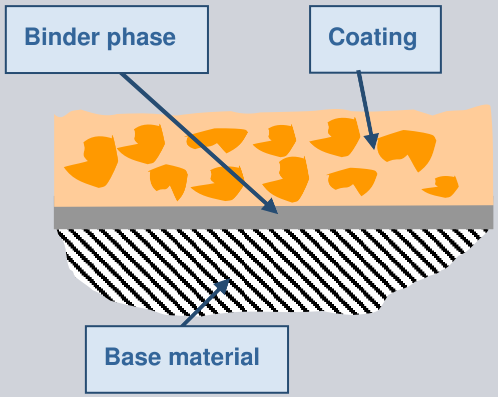
Design features

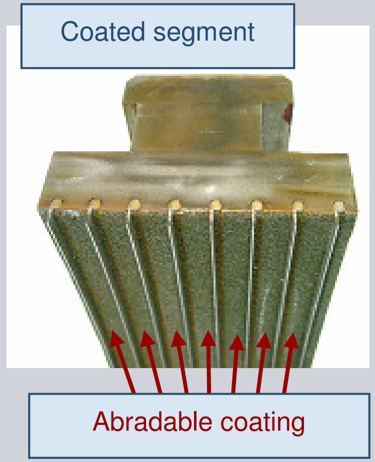
- Coating applied to standard seal segments (thickness about 0.6 mm)
- Reduced leakage flow due to reduce clearances (about 20% less than uncoated labyrinth)
- Favorable coating behavior during contact: fin cuts groove into coating without damage to fin or significant heating, at negligible torque
- Suitable for large pressure drops
- Increased clearance between hard parts for additional operating safety
- Applicable to various types of seal segments, especially
  - balance piston
  - dummy piston

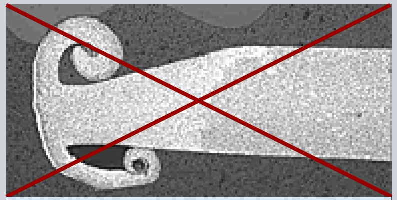
Customer benefits

- Increased efficiency and power output
- Increased operational safety
- Proven design









Hard rub

Rub with coating

Sealing – brush seals

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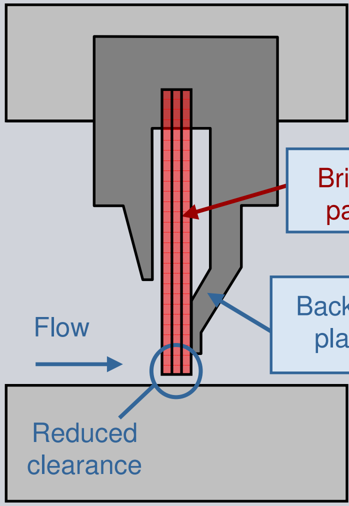
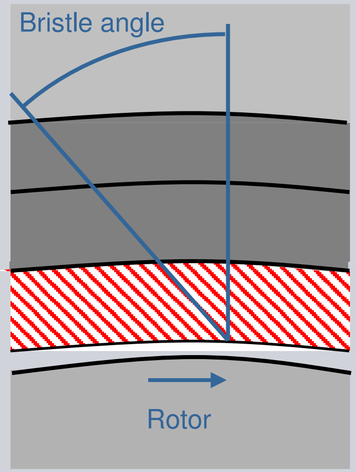
Design features

- Bristle pack allows very tight clearances
- 50-70% reduction in leakage flow compared to standard labyrinth
- Bristles give way in transient operation
- Backing plate of brush element is positioned further away from rotating parts than standard seal fins to increase operating safety
- Brush seal is used as add-on in current labyrinth seals
- Used for low and moderate pressure drops, i.e.
    - Gland seal (inserted in segments, HP/IP)
    - Gland seal (inserted in casing, LP)

Customer benefits

- Increased power output and efficiency
- No impact on operational safety





2-stage brush segment

2-stage brush segment

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Steam Turbines for 700°C SPP – the next generation of big steam power plants

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Goal:
- > 50% net efficiency
- 700°C, 350 bar

State of the art:
- 46% net efficiency
- 600°C, 250 bar

approx. 7% less fuel consumption and CO_2

The way there:

- New materials and design concepts (innovative components: HP and IP turbines and valves)
- Component test facility COMTES700 at Scholven since 2005
- Engineering study NRWPP700 since 2006 (financing through NRW and 700°C partners)
- Demo plant 550 MW

Siemens preferred solutions for CO_2 capture

More on this topic will be covered by a later lecture today at 16:00

IGCC / Pr… capture

Gasifi… …ability
for n…

- T…
- …
  hy…
- Mastering hi…
  complexity with “Sie…
  execution offer”.

Post-combustion carbon capture

Scalable market introduction, Demoplants with slipstreams, minimize upgrade risk in process trains

…ncement potential for solvents, scrubbing …d for integration into the power plants

…sil fired power plants

…t based process …ous


Siemens Fuel Gasifier


Siemens IGCC in Puertollano (E)


Siemens scrubbing process test lab


Post-Combustion ca… capture plant design

Siemens solutions will be ready for the implementation in the upcoming CCS demonstration projects.

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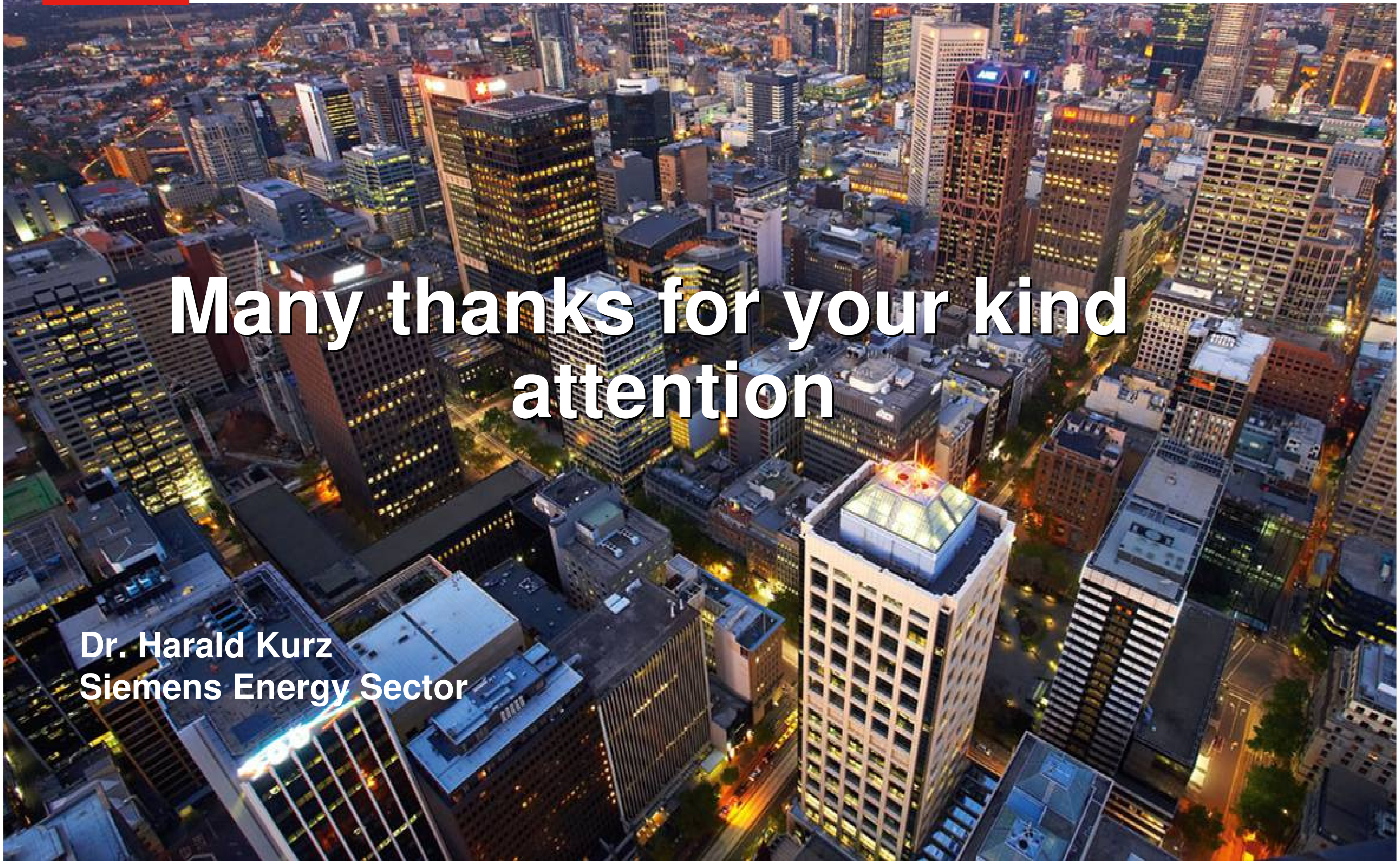
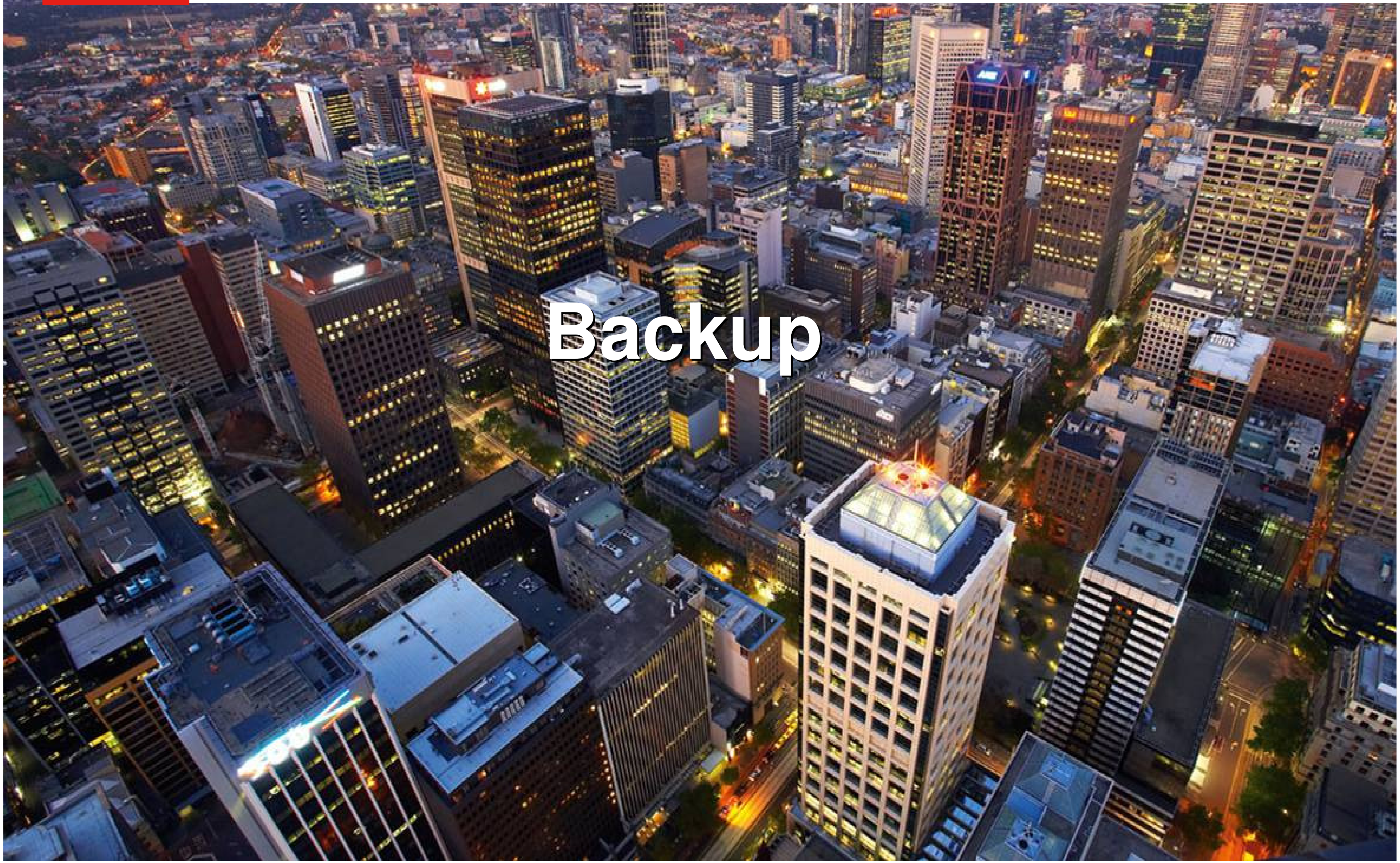


Many thanks for your kind attention

Dr. Harald Kurz
Siemens Energy Sector

Backup



There are many measurements which gives indications for 'State of the Art'...

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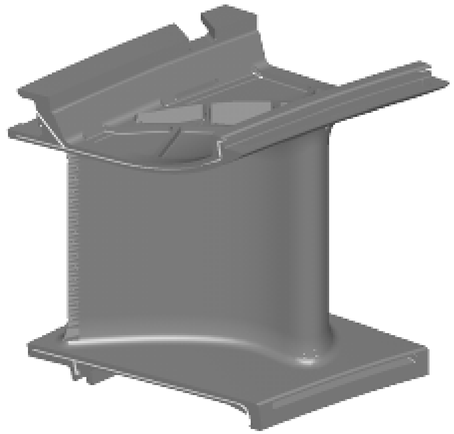
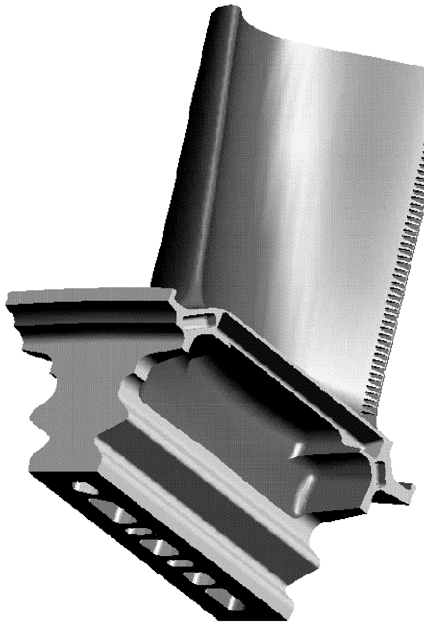
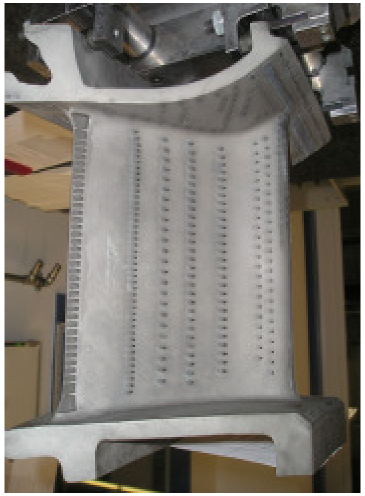
Business Drivers	Customer Requirements	Core Competencies
Engine Performance Reliability / Availability / Maintainability (RAM) Market / Competitiveness	▪ Power ▪ Efficiency ▪ Emissions ▪ First Cost ▪ Life Cycle Cost ▪ Capital Cost ▪ Maintenance Cost ▪ Operational Costs ▪ Time-to-Market ▪ Operational Flexibility ▪ Fuel Flexibility ▪ Cycling Capability ▪ Upgradeability ▪ Regulatory Compliance ▪ Product Integrity ▪ Robust Design ▪ Proven Design Features	▪ Aerodynamics ▪ Coatings ▪ Code Development ▪ Combustion ▪ Diagnostics ▪ Dynamic Integrity ▪ Engine Operations ▪ Heat Transfer / Cooling ▪ Materials ▪ Mechanical Integrity ▪ NDE Technology ▪ Probabilistic Design ▪ Sealing Technology ▪ Secondary Air Systems ▪ Thermodynamics

SGT5-8000H first turbine stage improved design for highest efficiency

- Largest single-crystal stage to date
- Contoured shroud of vane
- Thin wall casting
- Airfoil and shrouds are highly impingement-cooled
- Highly film-cooled airfoils







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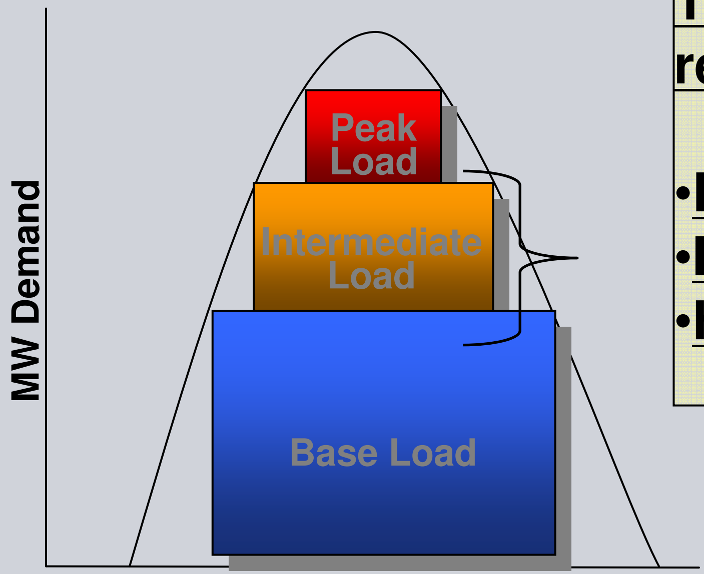
State of the Art requires high Operational Flexibility...



Market Requirement

This range of operation requires flexibility

- **Faster starts**
- **Increased turndown**
- **High part load performance**

Our Solution

Air Cooled engine with Less Complexity
No external engine dependencies for cooling
No ties to water-steam cycle for cooling
IF THE ENGINE IS TURNING, THERE IS COOLING

Disclaimer

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