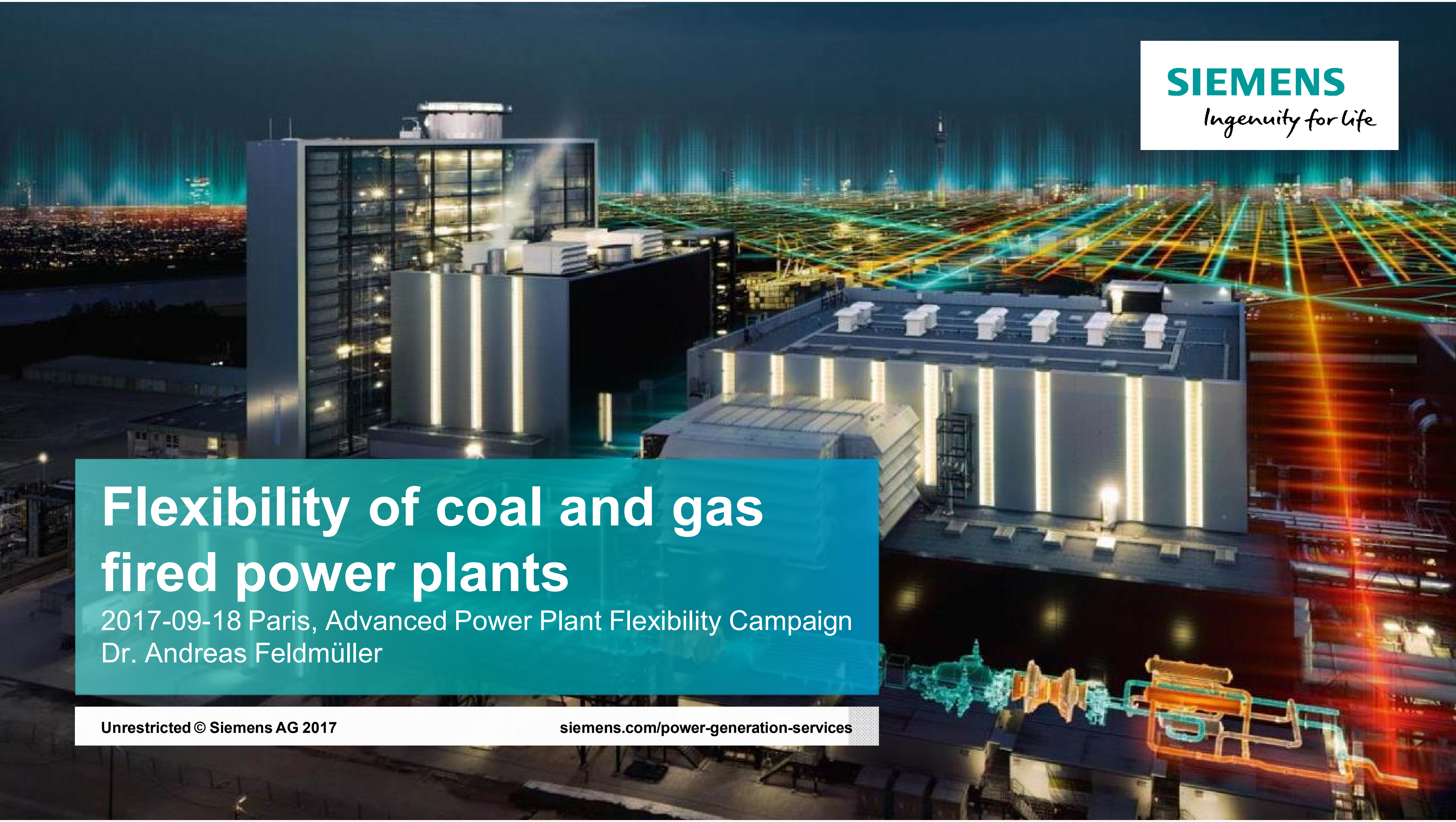

Flexibility of coal and gas fired power plants

2017-09-18 Paris, Advanced Power Plant Flexibility Campaign

Dr. Andreas Feldmüller

siemens.com/power-generation-services

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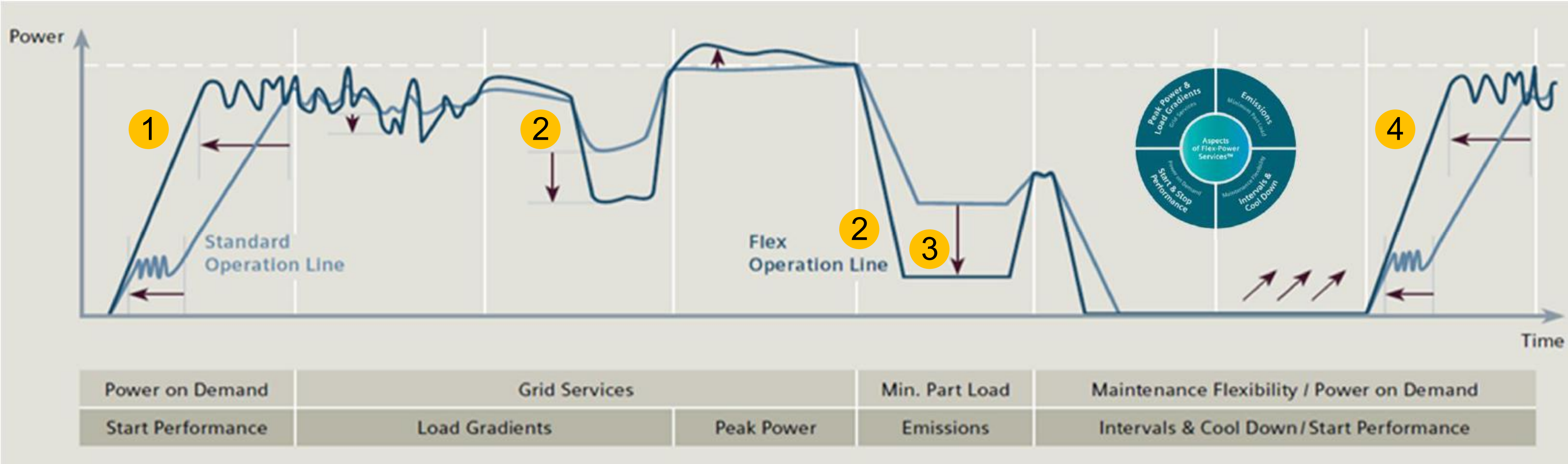
Key aspects of flexible power plant operation



1 Hot start-up time

2 Ramp rate

3 Minimum Load

4 Cold start-up time

Operational flexibility of power plants has increased
Example: Lignite-fired power plants

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Lignite-fired Power Plants	VDE (ETG) April 2012 (0)			Agora Energiewende, Fichtner June 2017 (1)		Neurath (Germany) (6)	Belchatow (Poland) (1)	Boxberg R (Germany) (1)
	Commonly used	State-of-the-art power pl.	Optimization potential	Commonly used	State-of-the-art power plants	Commissioned 1975, modernized	Commissioned 2011	Commissioned 2012
Average ramp rate [% Pnom per min]	1	2,5	4	1-2	2-6	2,4 (potential 3,2)	2-6	4,6-6
Minimum Load [% Pnom]	60	50	40	50-60	35-50	43 (potential: 35)	45	35
Hot start-up time [min]	360	240	120	240-360	75-240		140	75-85
Cold start-up time [min]	600	480	360	480-600	290-480		360	290-330

(0) VDE-Studie "Erneuerbare Energie braucht flexible Kraftwerke - Szenarien bis 2020“, Autoren ETG-Task Force Flexibilisierung des Kraftwerksparks

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants

(6) RWE AG, Siemens AG, PowerGen Europe 2013

New plants and **plant modernizations** lead to increasing operational flexibility of the installed fleet!

Flexibility of coal and gas fired power plants - comparison
Minimum Load

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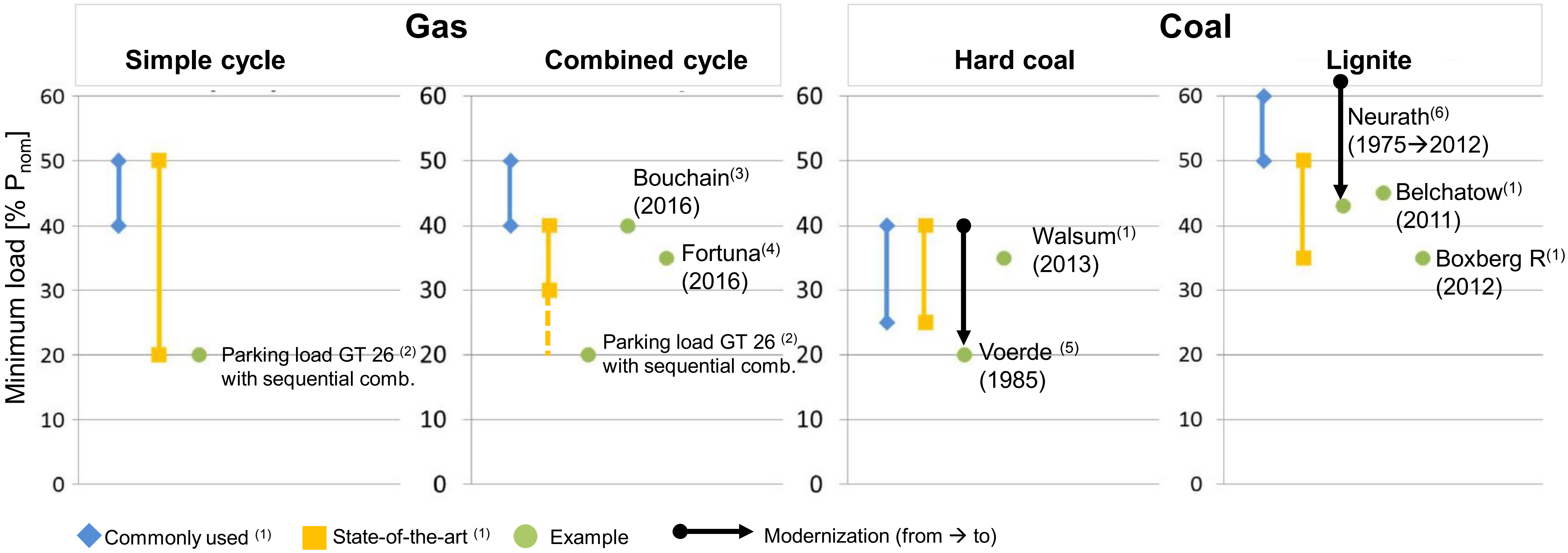
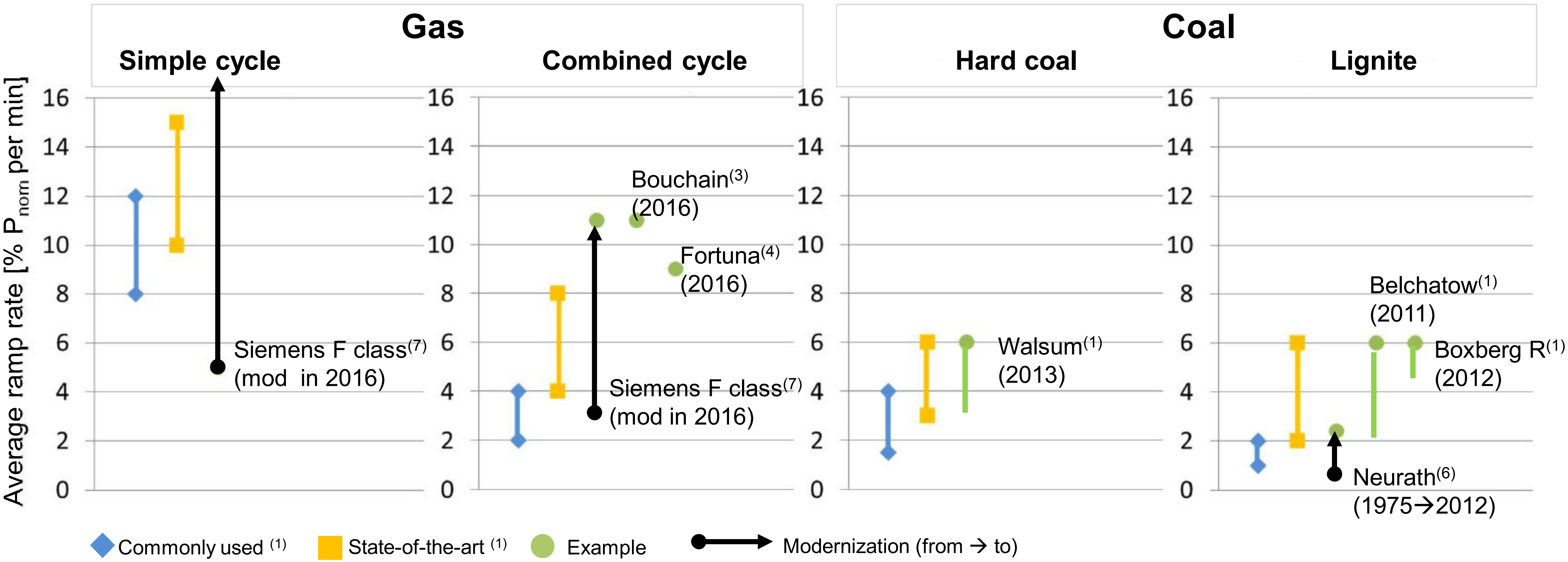


(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants (2) Alstom, VGB PowerTech 9/2011

(3) GE Power, EDF, PowerGen Europe 2016 (4) GAS TURBINE WORLD May - June 2016 (5) Siemens references (6) RWE AG, Siemens AG, PowerGen Europe 2013

Flexibility of coal and gas fired power plants – comparison
Ramp rate



(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants (3) GE Power, EDF, PowerGen Europe 2016

(4) GAS TURBINE WORLD May - June 2016 (6) RWE AG, Siemens AG, PowerGen Europe 2013 (7) Siemens AG, Power Gen Europe 2017,

Flexibility of coal and gas fired power plants – comparison
Hot start-up time

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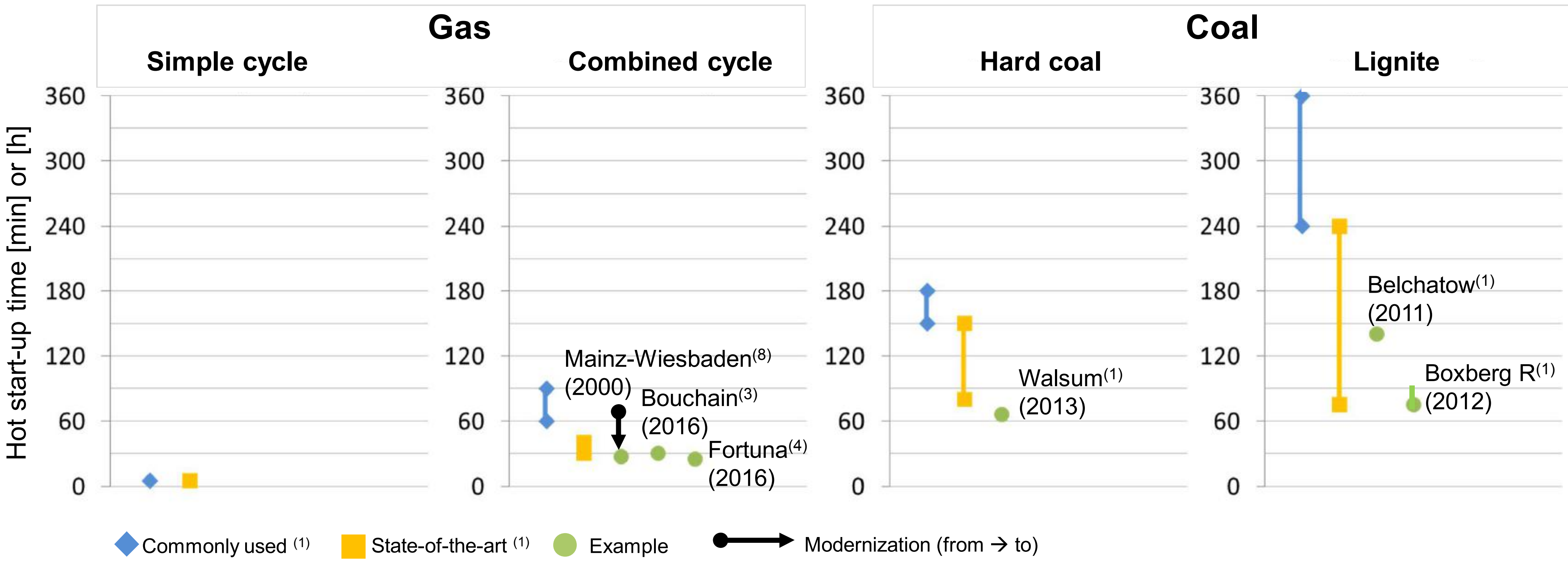

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants (3) GE Power, EDF, PowerGen Europe 2016
(4) GAS TURBINE WORLD May - June 2016 (8) KMW AG, Siemens AG, Power Gen Europe 2015

Flexibility of coal and gas fired power plants - comparison
Cold start-up time

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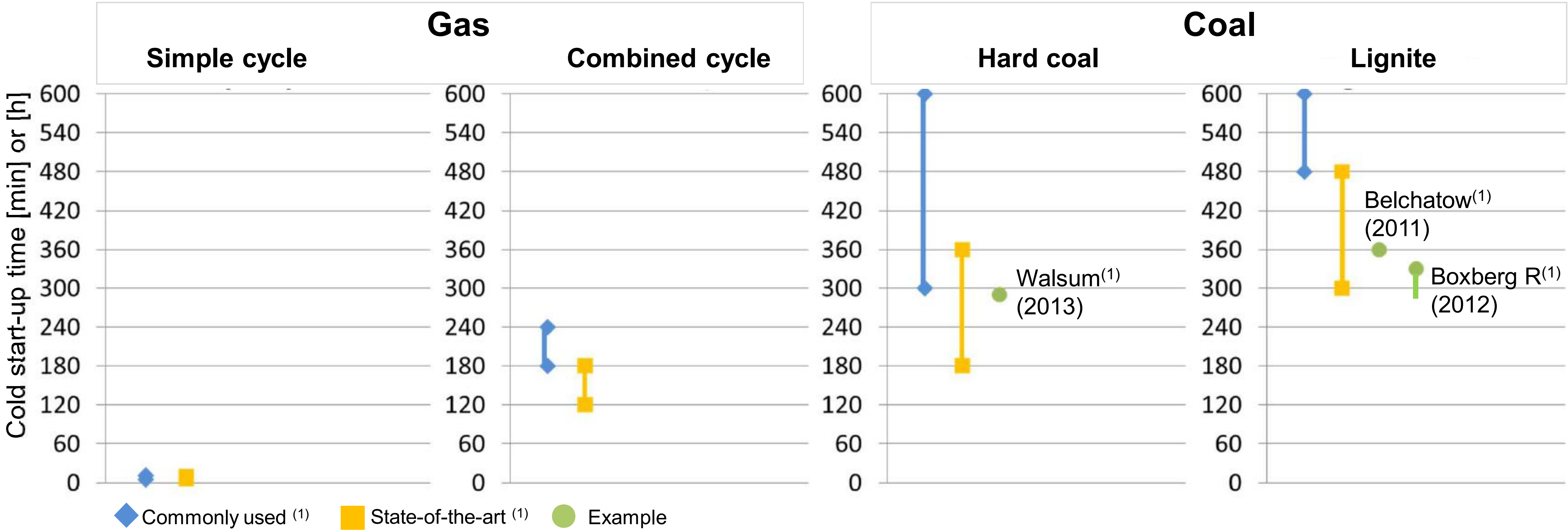

(1) Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants

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Hot start-up of a combined cycle power plant

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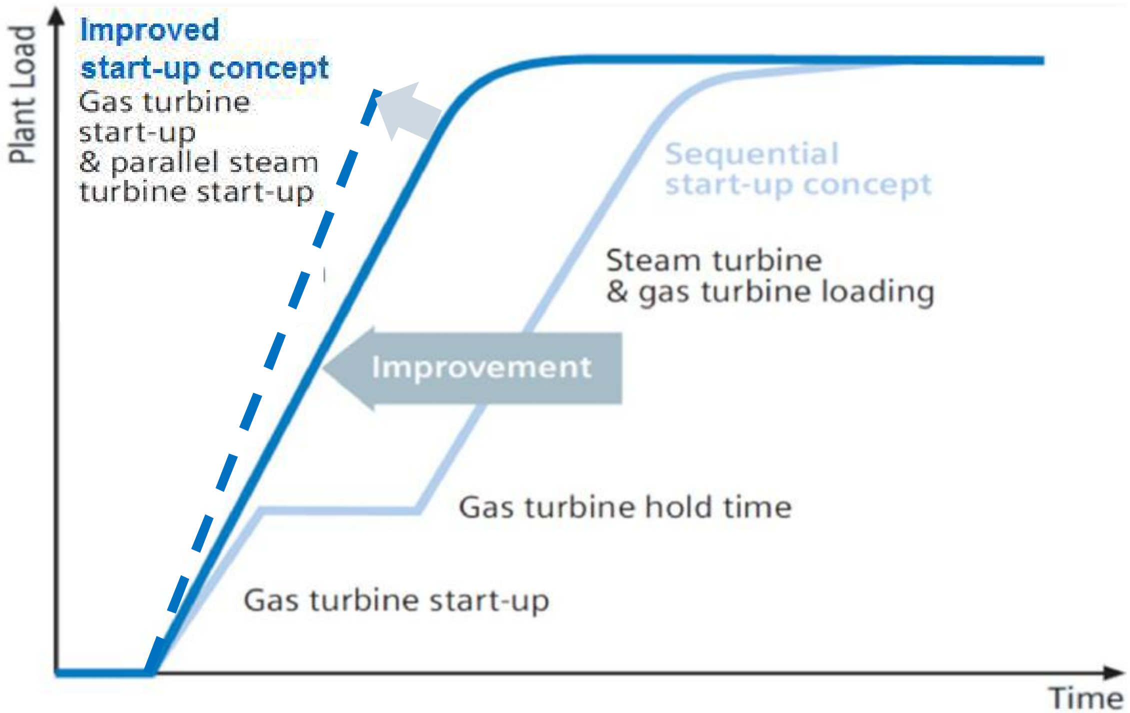

- Improved concept (Hot start on the Fly, a fully integrated and automated start-up process)
- Further potential by increased start-up gradients of GT and ST

Improvement potentials gained from **start-up concept, component capabilities** and **automation**

Fast load ramps of steam power plants – frequency support with the water steam cycle

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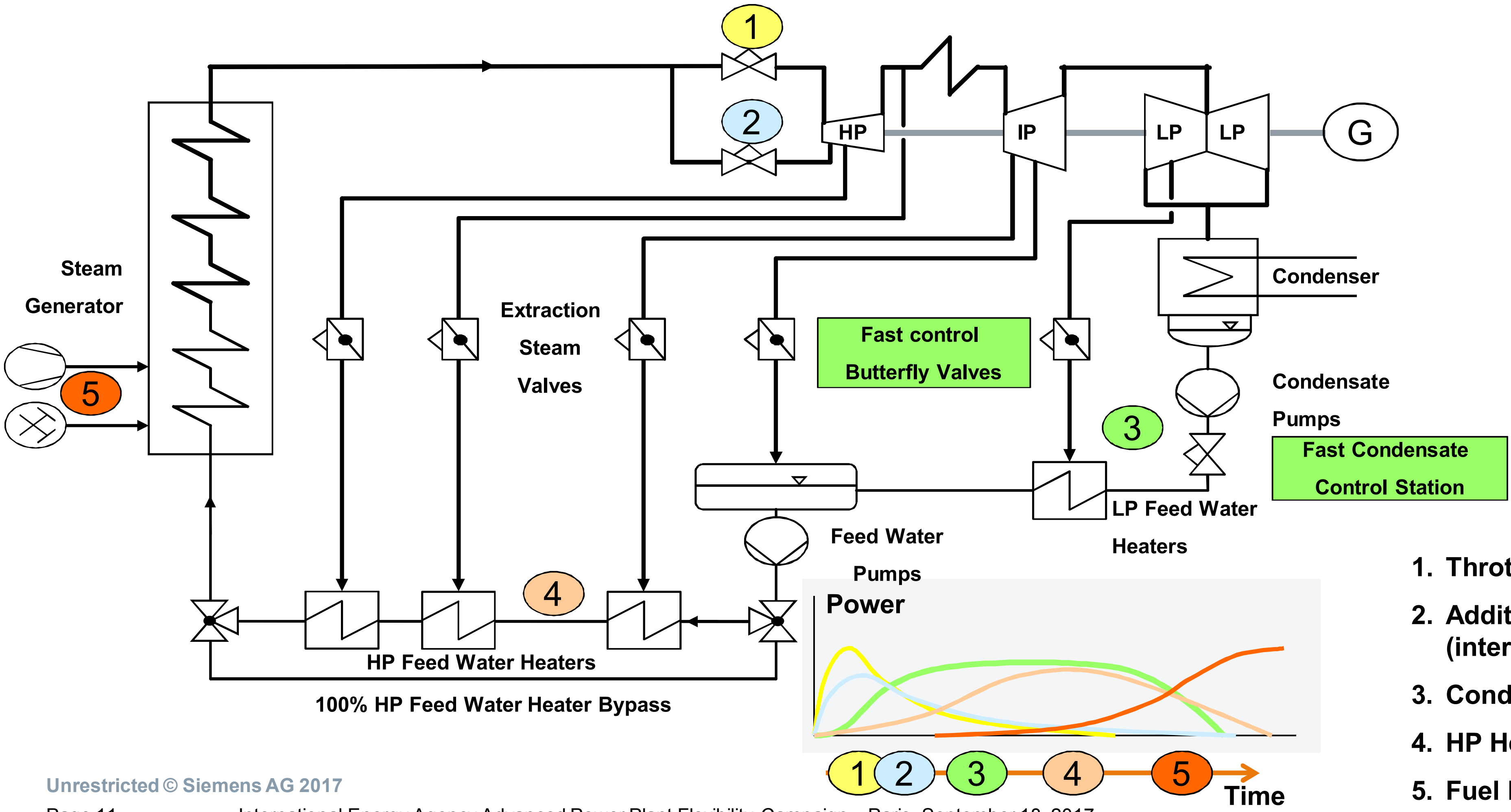
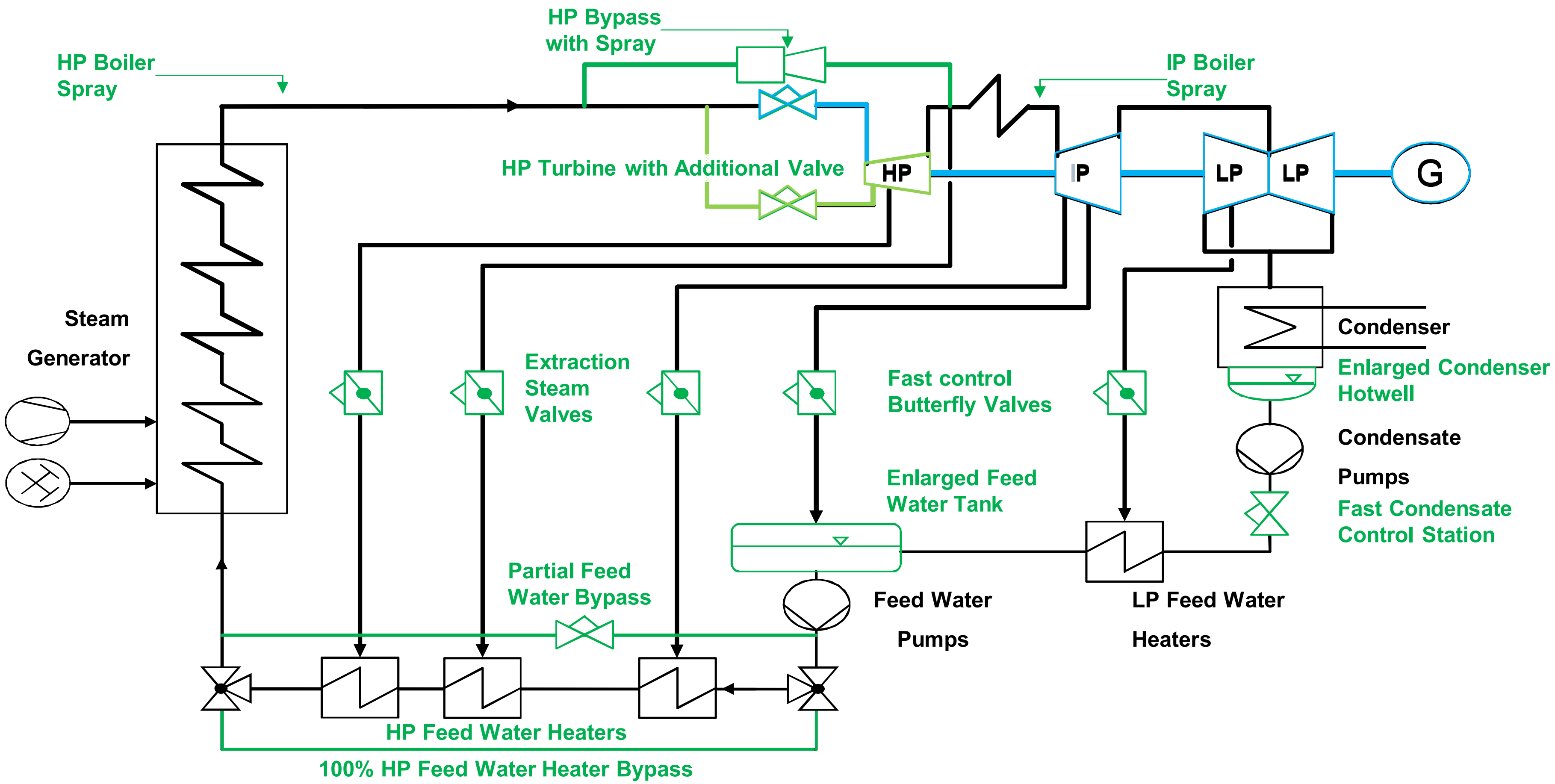


1. Throttling
2. Additional Valve (interstage valve)
3. Condensate Stop
4. HP Heater
5. Fuel Increase

Overall optimization of steam power plant to improve plant frequency support



HP turbine with additional HP valve for peak and part load

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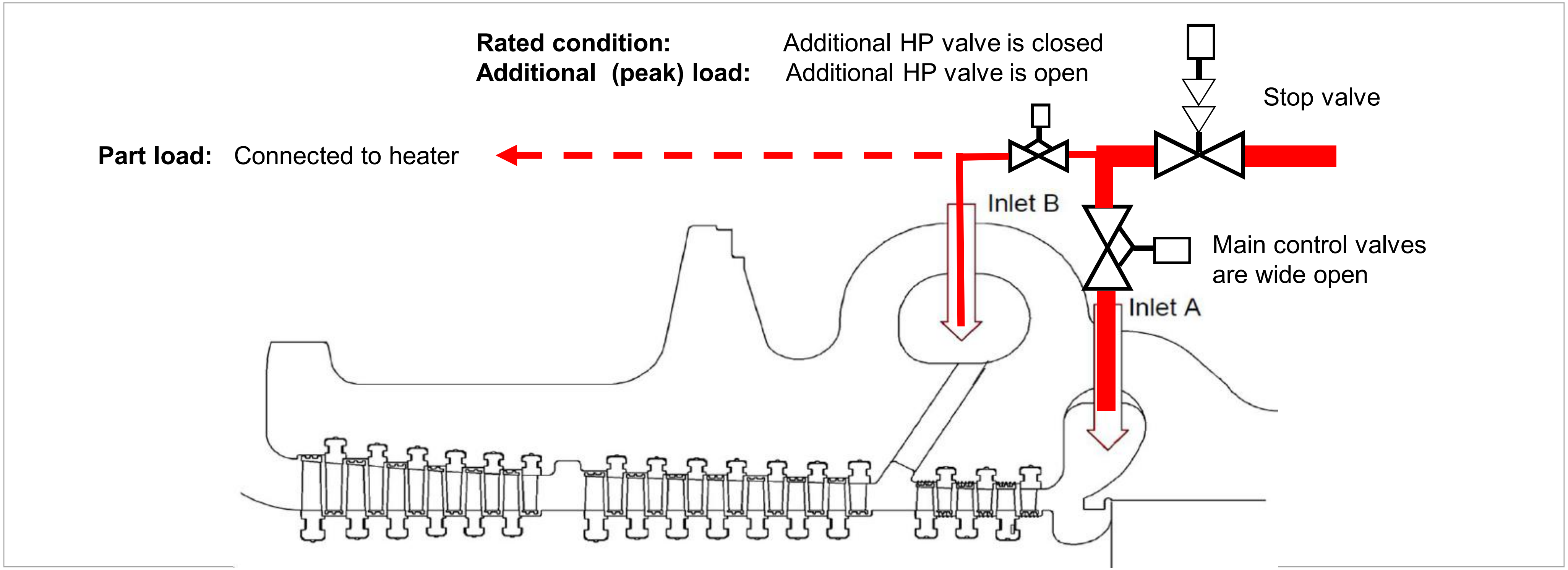
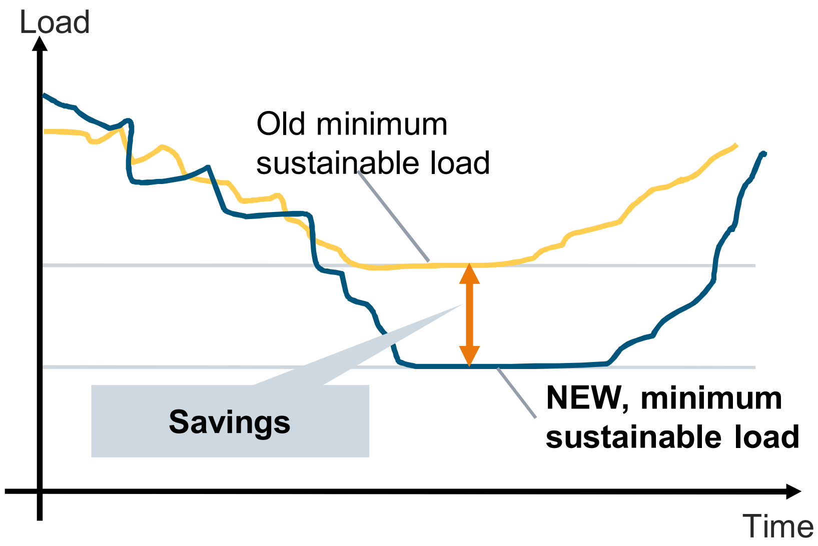


HP turbine with additional HP valve to increase

- HP swallowing capacity for frequency response
- Feed water temperature at part load

Controls modernization to reduce minimum load

Minimum Load Reduction



- Use of robust state space controller for unit control
- Adaptation, optimization and setting of lower-level controls for new minimum load level
- Adaptation or addition of control sequences, burner and mill scheduler
- Provision of additional instrumentation where necessary
- Modifications, additions or replacement of original DCS as necessary

- Faster response to increased load demands as unit does not need to be shut down
- Avoidance of unnecessary start-ups and shutdown

Content

Results at CCPP Mainz-Wiesbaden - Power station 3
Hot start-up time reduced to 27 minutes

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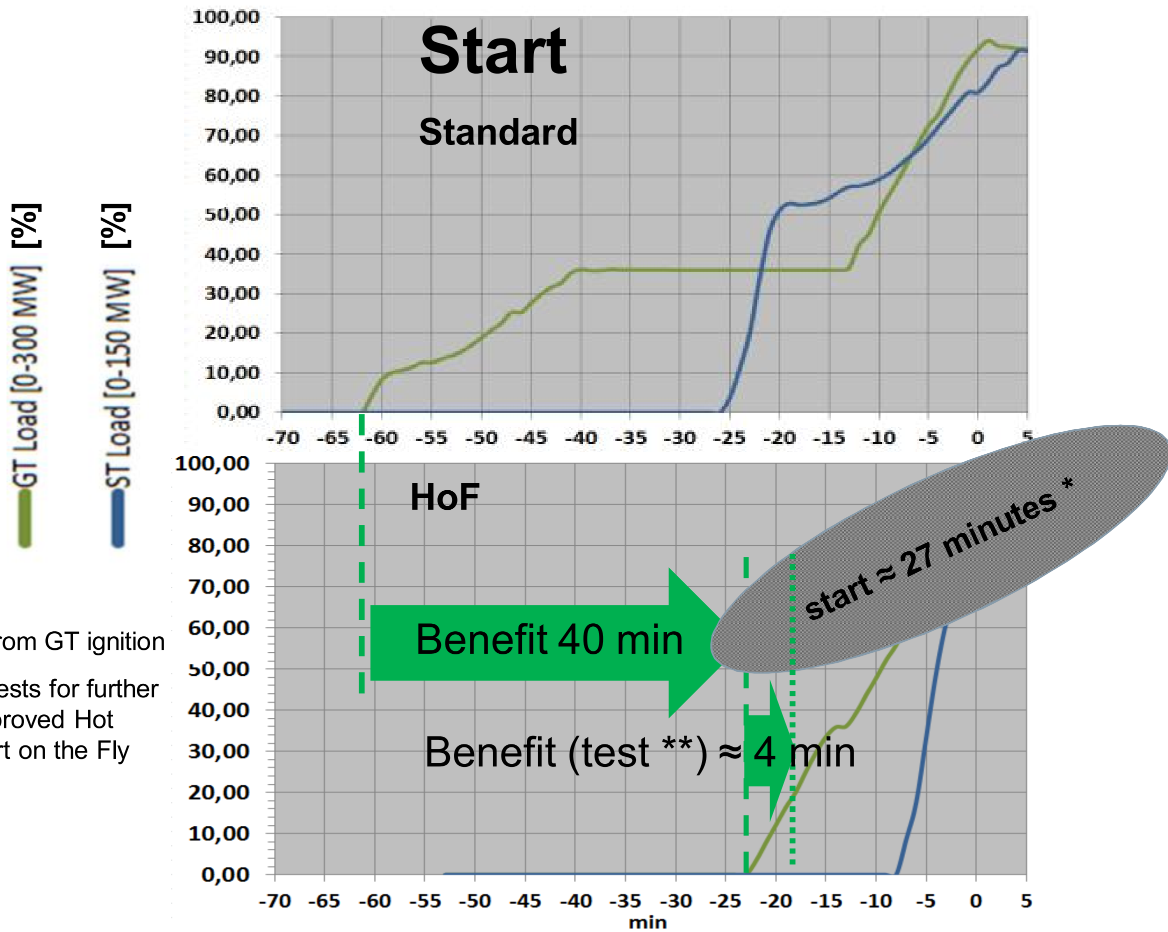
- Combined Cycle
- SCC5-4000F
- Multi shaft
- ≈ 440 MW
- Built 2000

- Hot Start on the Fly (HoF) is the standard start up process after overnight stop
- Highly predictable start up time of 27 minutes (+/- 2 minutes)

Reference: PowerGen Europe 2015,
From base to cycling operation - innovative operational concepts for CCPP,
Dr. Andreas Feldmüller & Florian Roehr, Siemens AG,
Thomas Zimmerer, Kraftwerke Mainz-Wiesbaden AG



* from GT ignition

** tests for further improved Hot start on the Fly

Results at RWE Neurath Unit D
Load gradient tripled, Minimum load reduced by 40%

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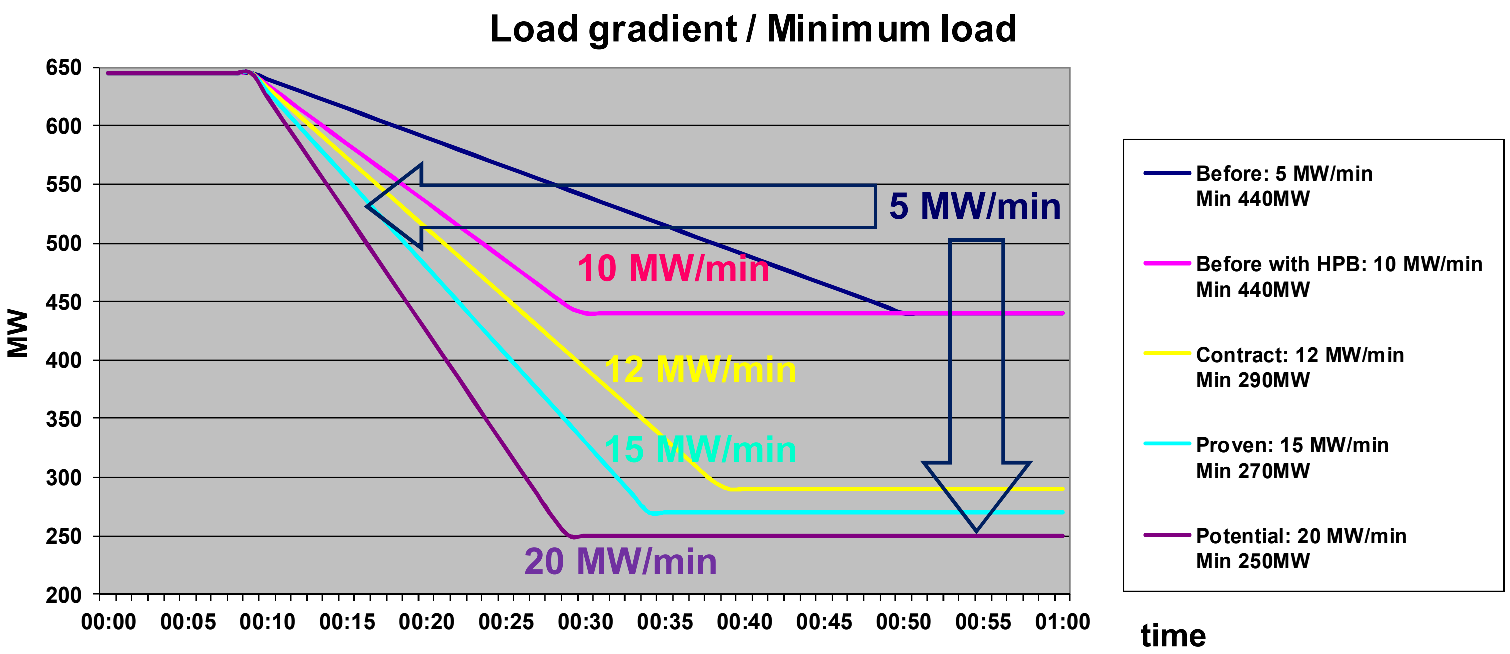
- 630 MW, tangential, lignite-fired, built 1975
- Boiler design for base load
- Fuel changed massively compared to design



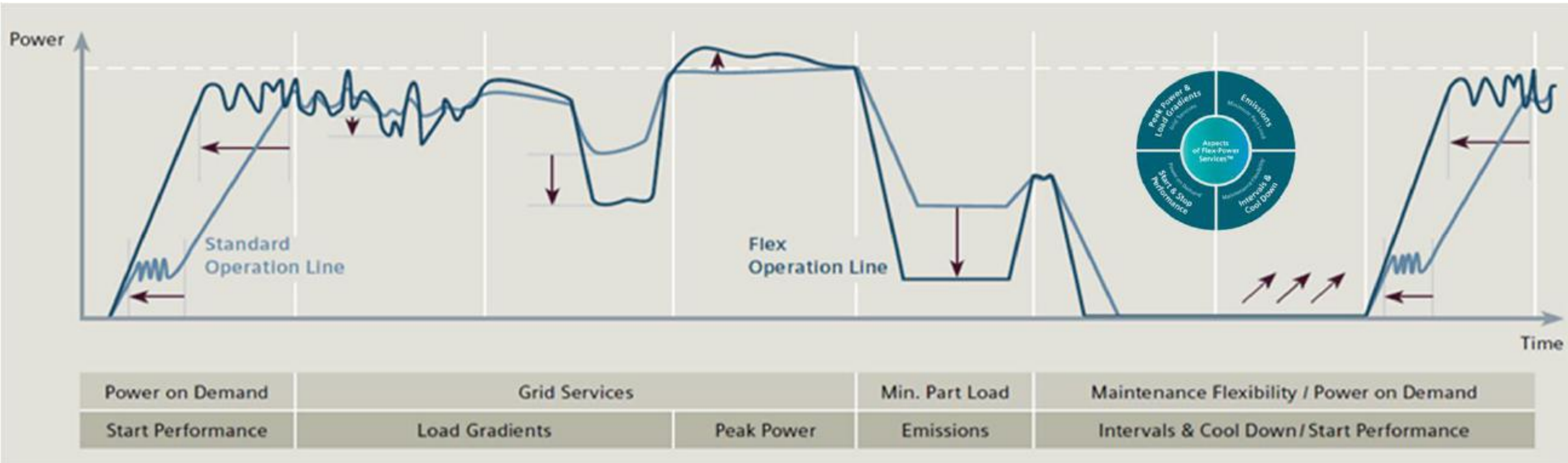
Reference: PowerGen Europe 2013
A Vision Becomes Reality, One of the most flexible lignite fueled units of the World - Achieved by a DCS Retrofit
Björn Pütz & Thomas Schröck, RWE AG, Annette Barenbrügge & Bernhard Meerbeck, Siemens AG

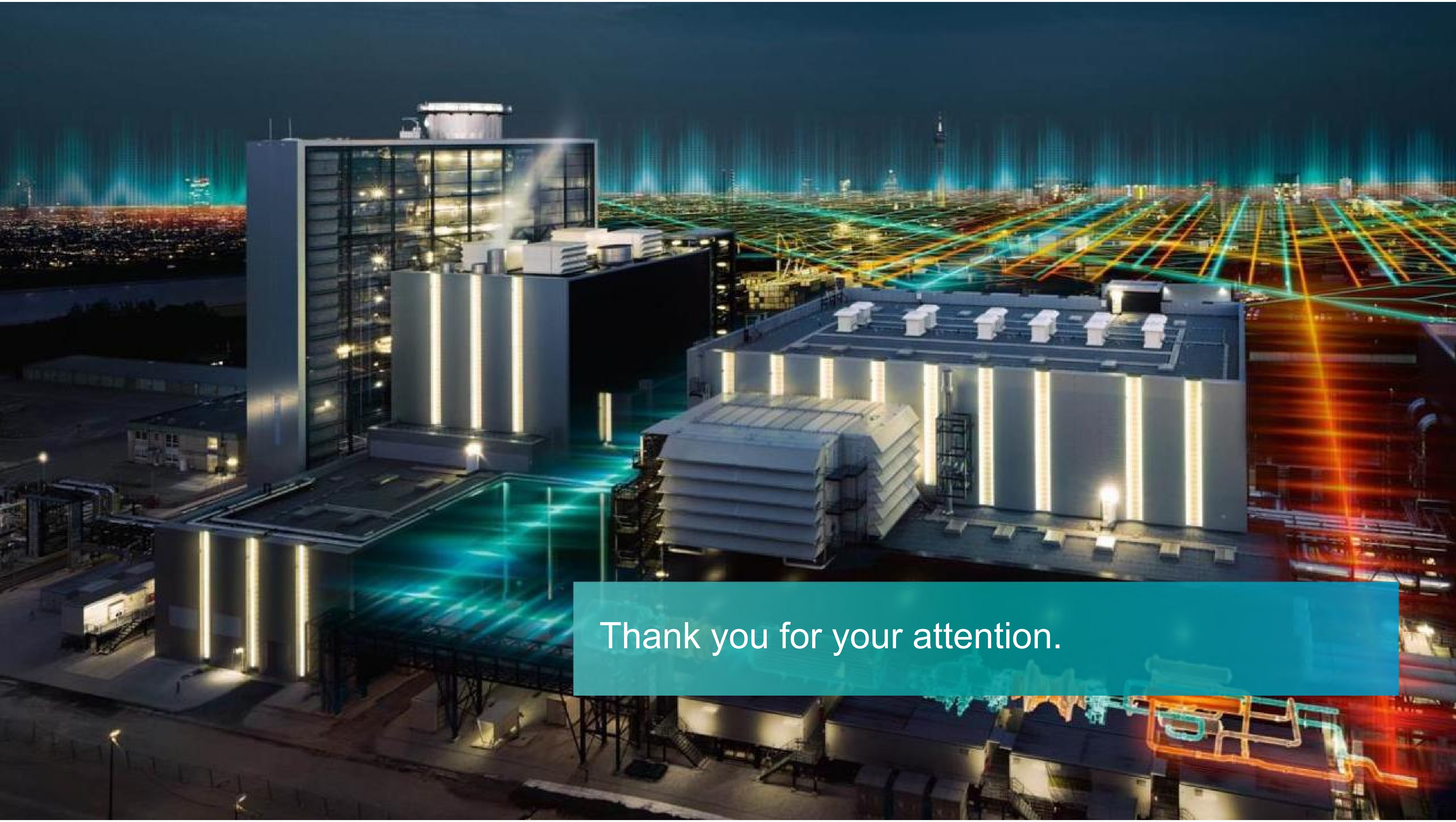
- Installation of a new robust state-space unit control
- Fully automatic mill shut-on and shut-off
- Optimisation of all subordinated controllers, e.g. air, feedwater, fuel

Content

Conclusions

- Operational flexibility of power plants has increased in the last years
- New plants and plant modernizations lead to increasing operational flexibility of the installed fleet
- Large improvements could be achieved by plant modernizations





Thank you for your attention.

Flexibility of coal and gas fired power plants – comparison
Details of the references

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(0) VDE-Studie "Erneuerbare Energie braucht flexible Kraftwerke - Szenarien bis 2020“, Autoren ETG-Task Force Flexibilisierung des Kraftwerksparks, April 2012

(1)Fichtner, Agora Energiewende (2017): Flexibility in thermal power plants – With a focus on existing coal-fired power plants

(2)Alstom, Christoph Ruchti, Hamid Olia, Peter Marx, Andreas Ehrsam and Wes/ey Bauver, Combined cycle plants as essential contribution to the integration of renewables into the grid, VGB PowerTech 9/2011, page 84

(3)PowerGen Europe 2016, Laurent Cornu (GE Power), Olivier Pohlenz (EDF), First Commercial Application of GE’s HA Technology. Overview of the Bouchain Power Plant Construction, Start-Up and Commissioning Phases

(4)GAS TURBINE WORLD May - June 2016, Junior Isles, Block Fortuna sets three world records, page 16-20

(5)Siemens references

(6)PowerGen Europe 2013, Pütz & Schröck (RWE AG), Barenbrügge & Meerbeck (Siemens AG), A Vision Becomes Reality, One of the most flexible lignite fueled units of the World - Achieved by a DCS Retrofit

(7)Power Gen Europe 2017, Eisfeld, Feldmüller, Röhr (Siemens AG), CCPP improvements in a business environment of intermittent power generation

(8)PowerGen Europe 2015, Feldmüller & Roehr (Siemens AG), Zimmerer (Kraftwerke Mainz-Wiesbaden AG), From base to cycling operation - innovative operational concepts for CCPP

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