Is IGCC a Viable Option for Biomass?

Workshop IEA Bioenergy Task 33, Lucerne, 26 October 2016

Gasification applications:
Power w/o and w/ CCS, chemicals, poly-generation

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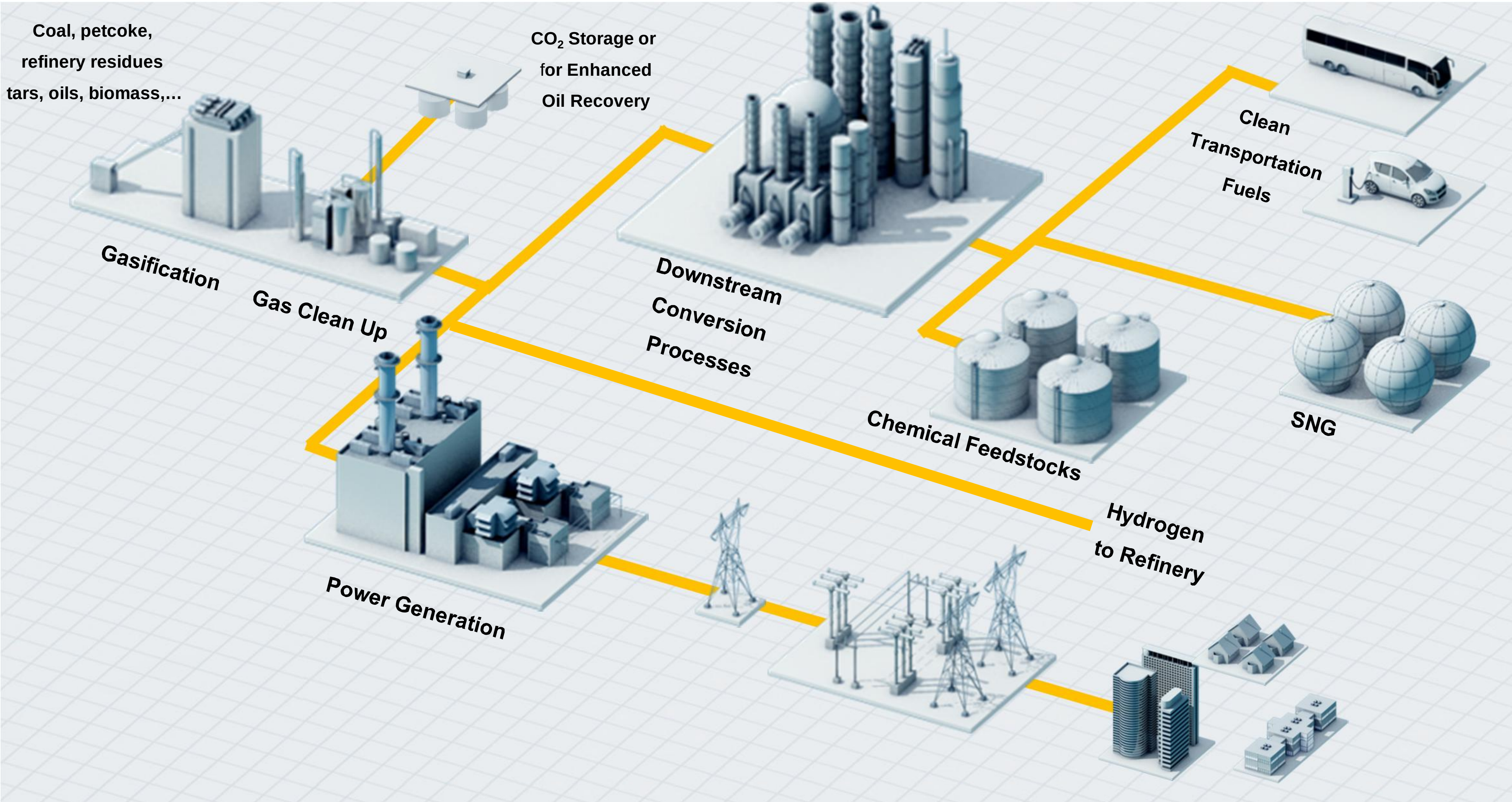
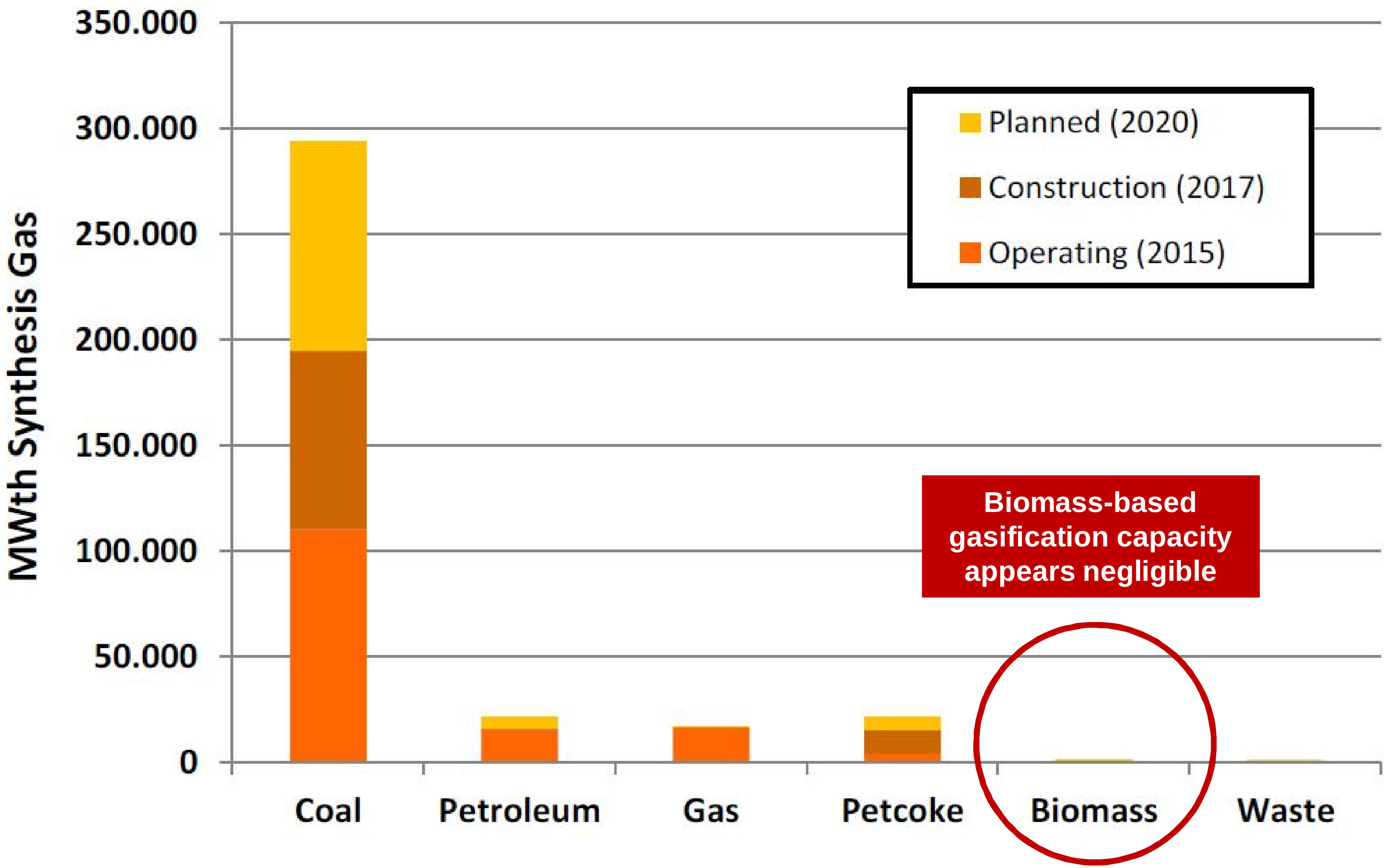
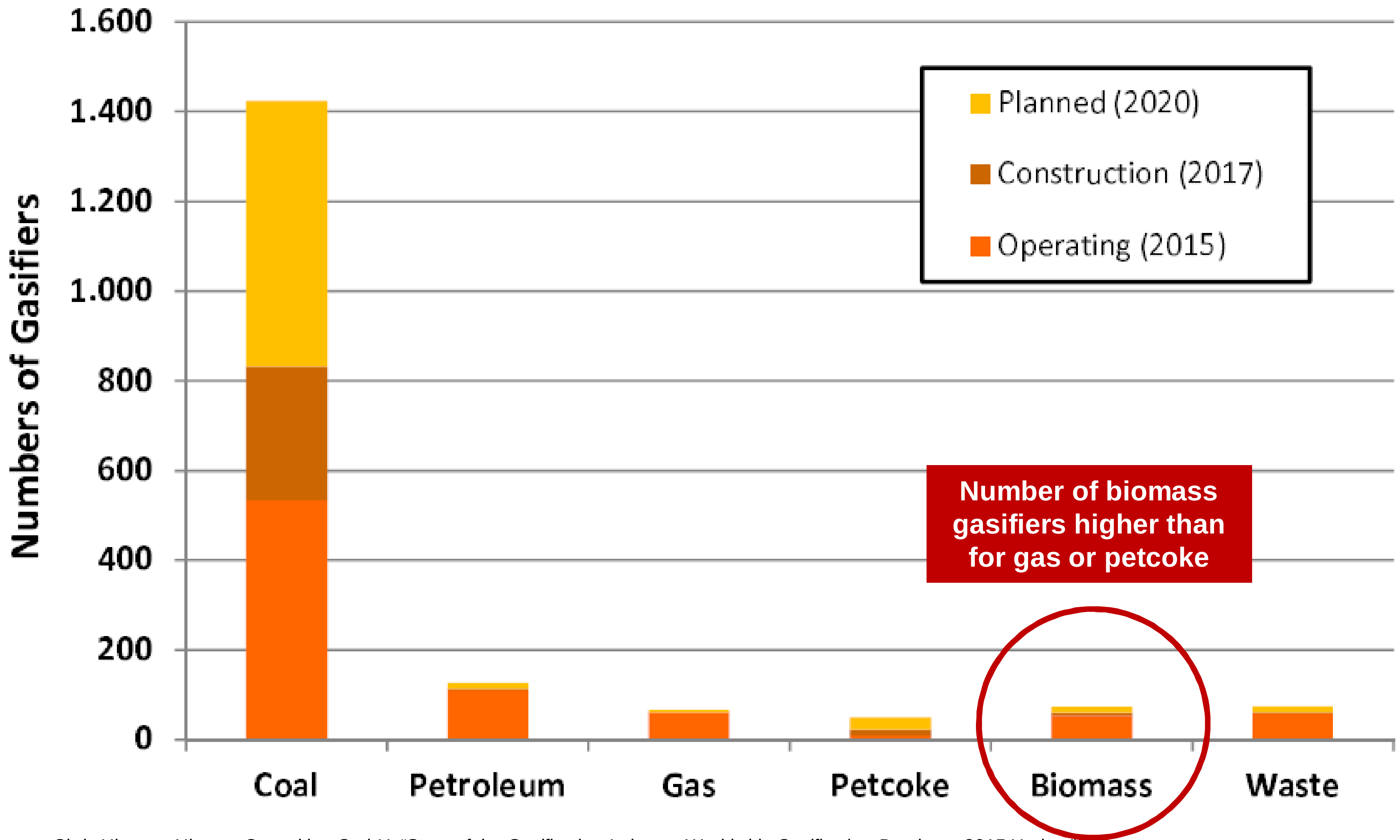


Primary feedstocks for gasification



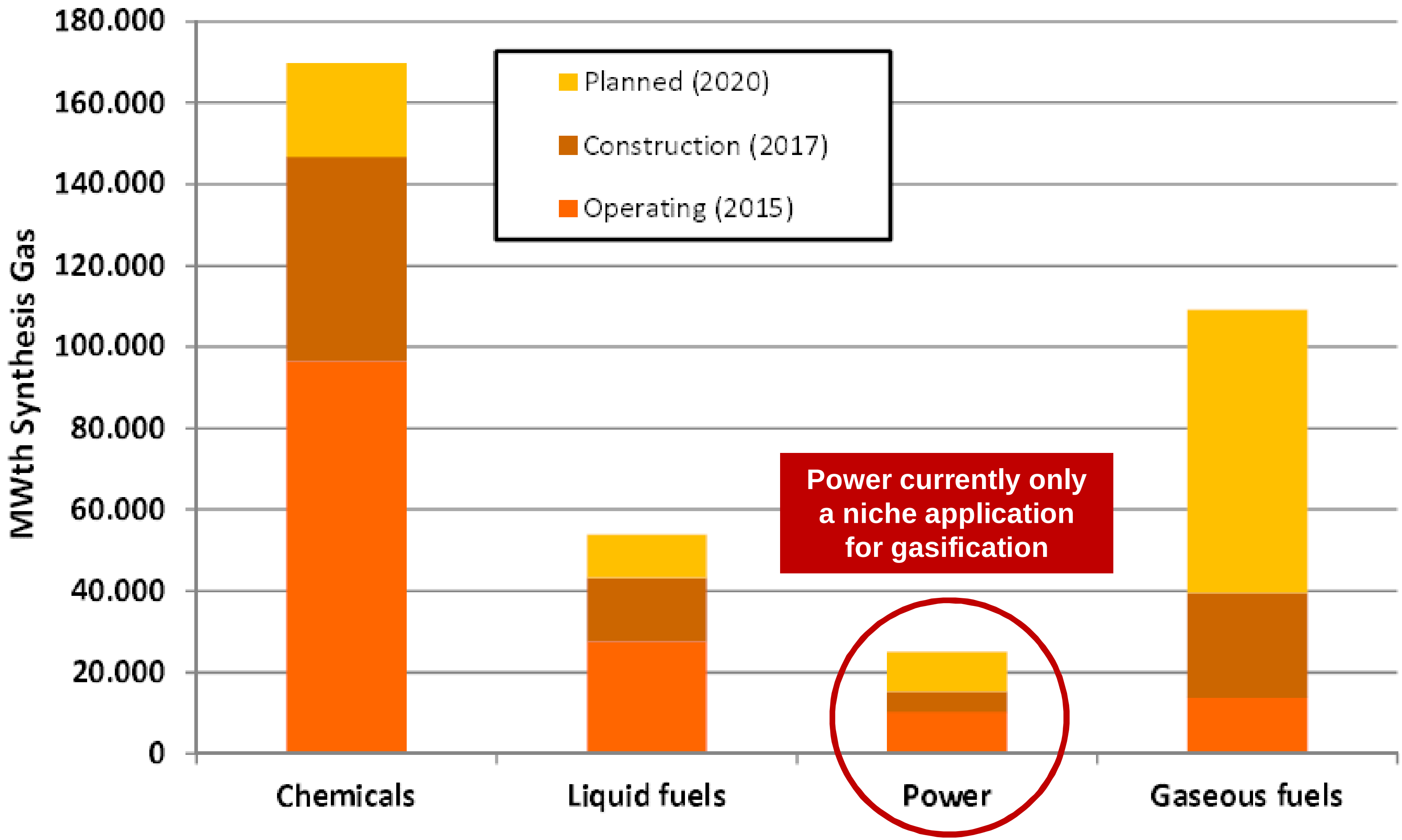
Source: Chris Higman, Higman Consulting GmbH, "2016 Status of the Gasification Industry", presented at the "ACI Gasification 2016 Conference", Rotterdam, 23rd March 2016

Number of gasifiers by primary feedstock



Source: Chris Higman, Higman Consulting GmbH, “State of the Gasification Industry: Worldwide Gasification Database 2015 Update”, presented at the “Gasification Technologies Conference”, Colorado Springs, 14th October 2015

Gasification capacity by application



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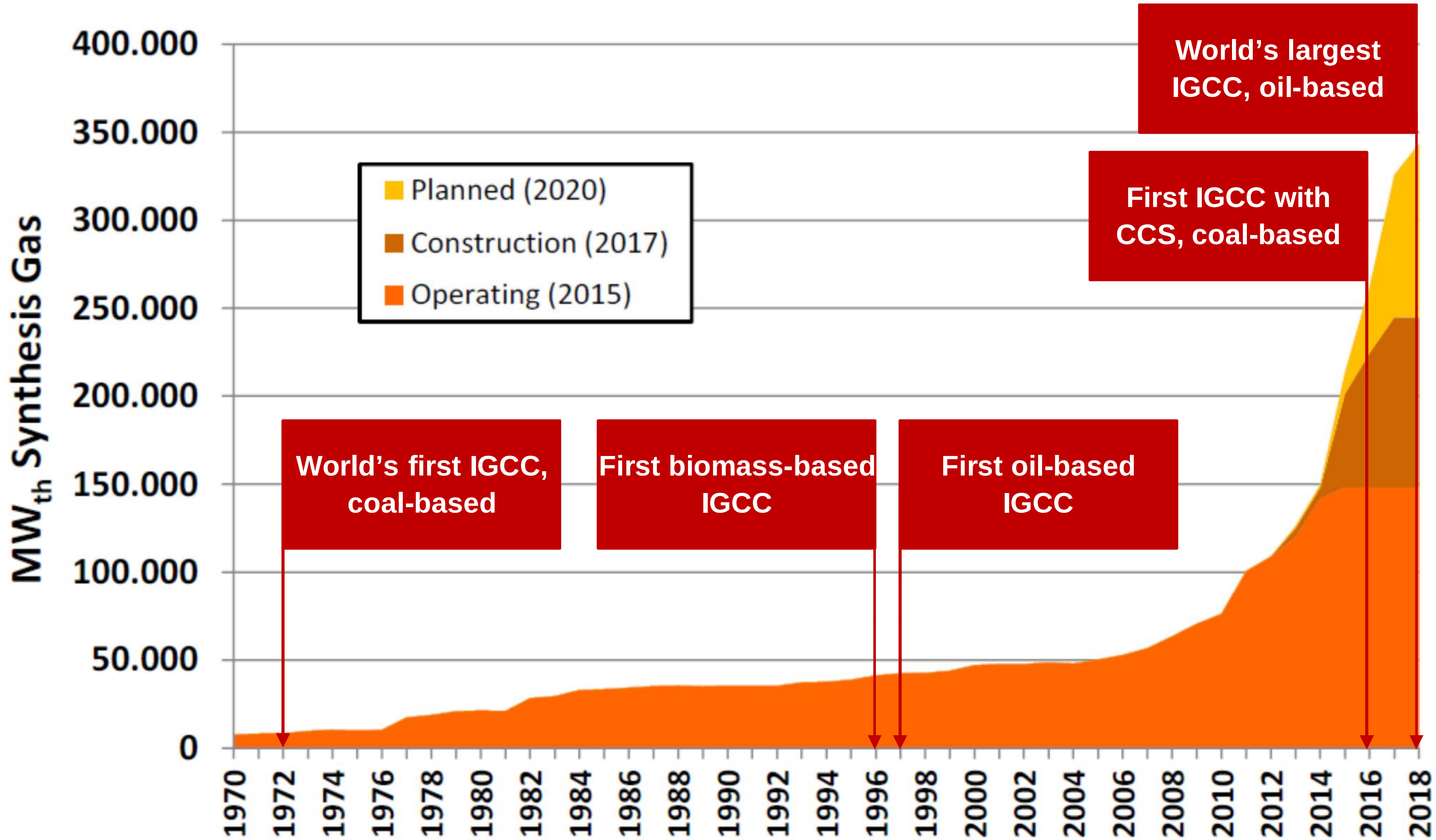
Cumulative worldwide gasification capacity and growth (total for all applications)



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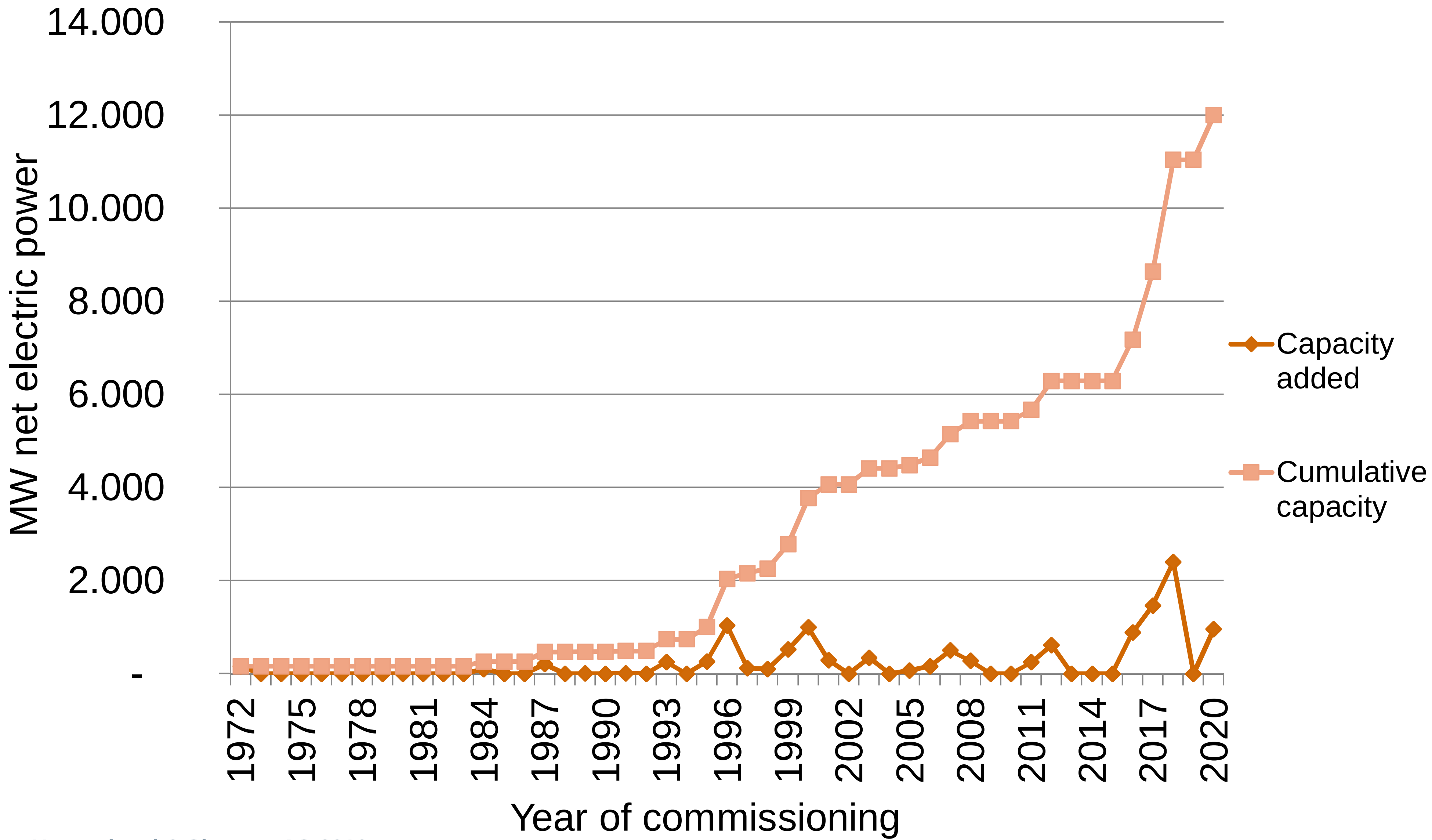
Cumulative global IGCC net power capacity and yearly capacity additions



Cumulative global IGCC net power capacity and contribution of projects with Siemens GT technology

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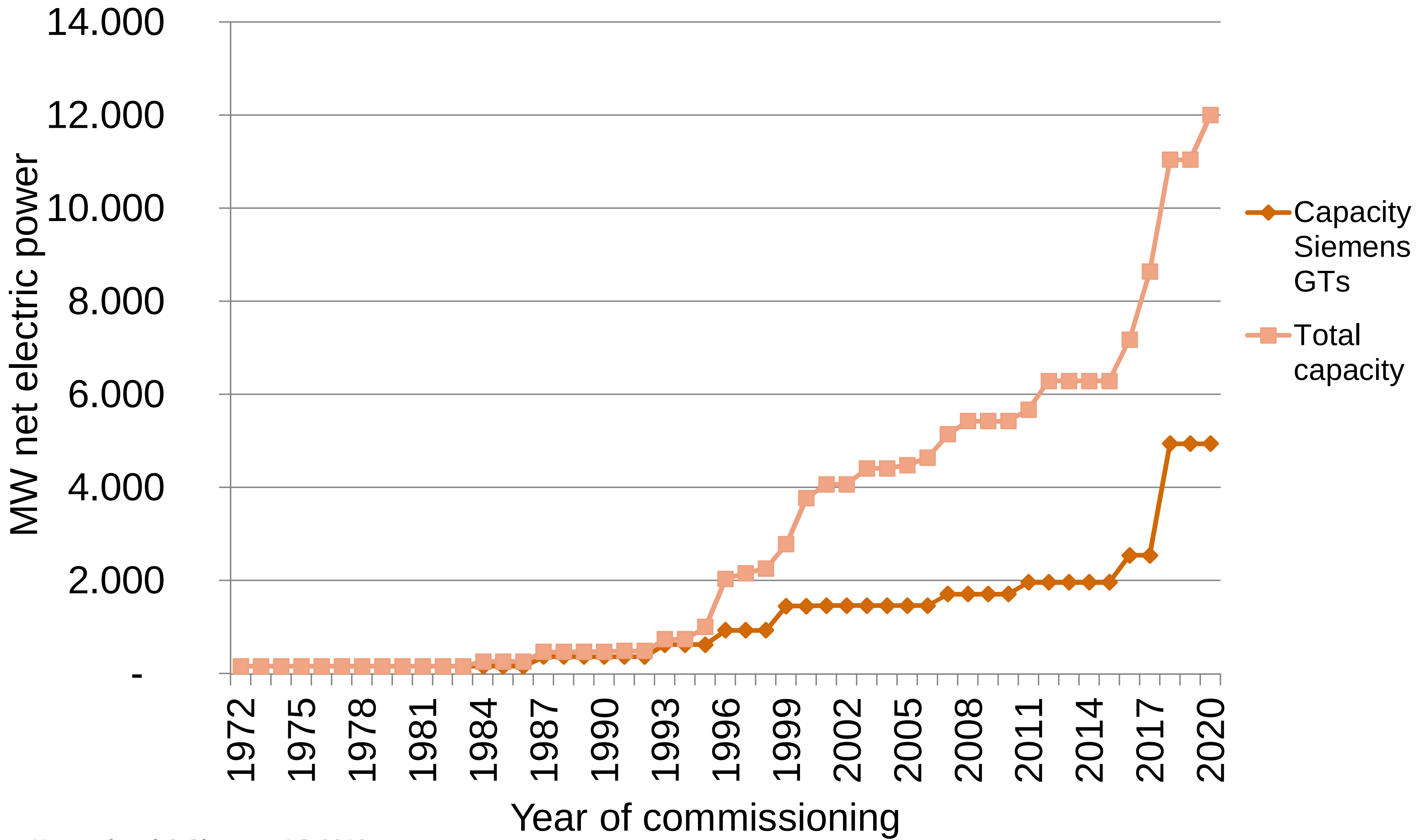

Integrated Gasification Combined Cycle (IGCC): simplified interface diagram and Siemens scope

(example for power only application, w/o CCS)

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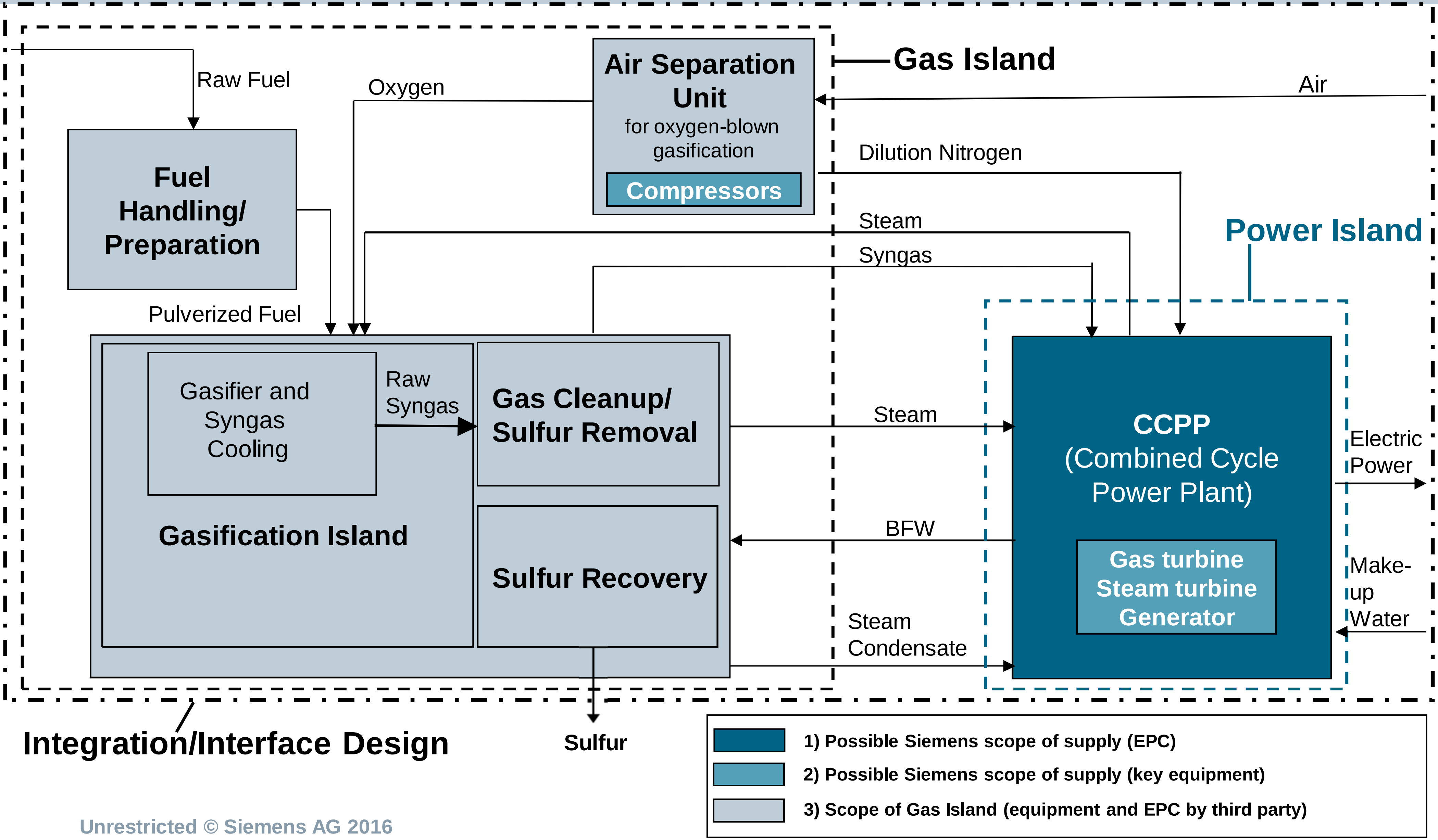

Integrated Gasification Combined Cycle Power Plant: IGCC in Principle

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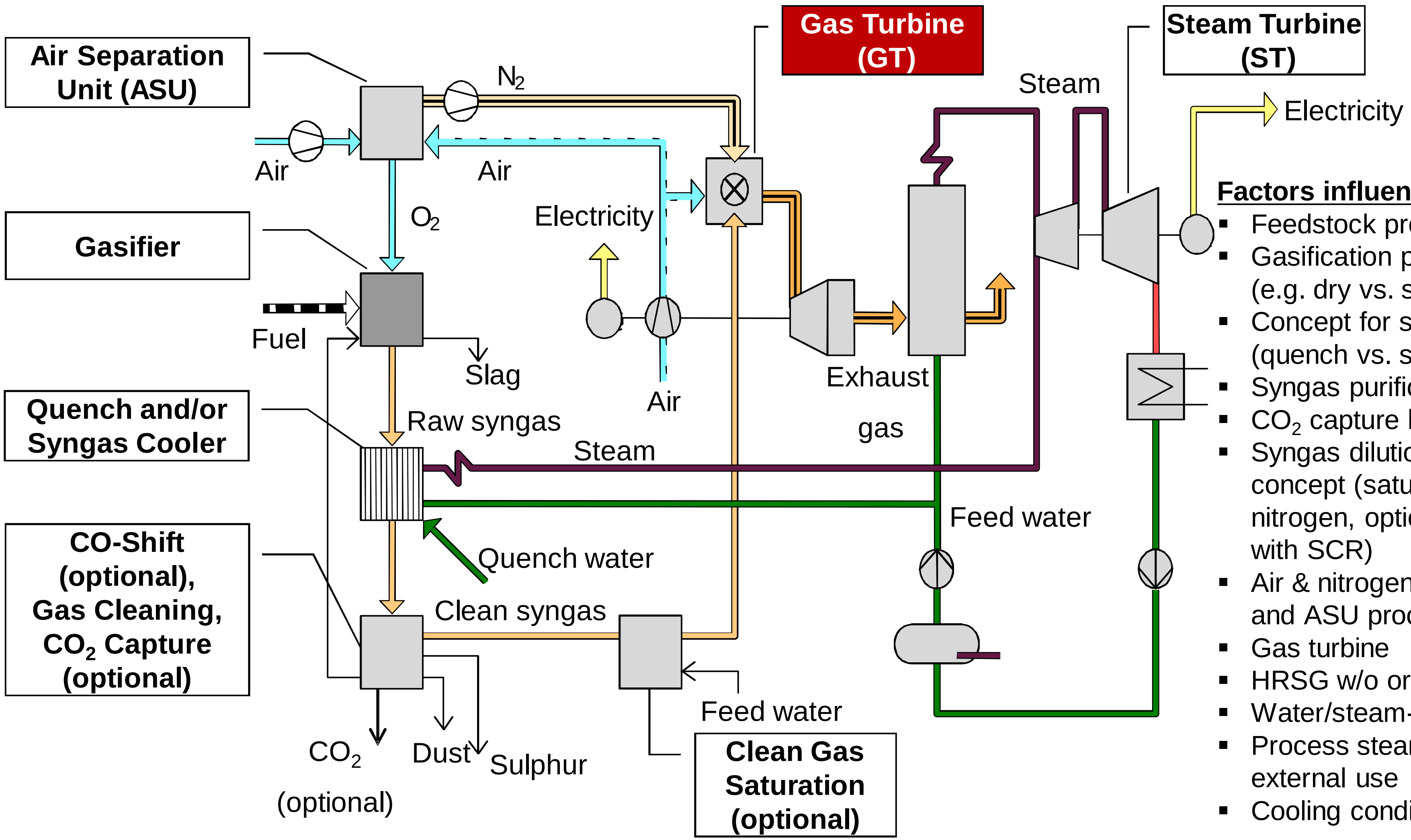

Factors influencing performance:

- Feedstock properties
- Gasification process (e.g. dry vs. slurry-fed systems)
- Concept for syngas heat recovery (quench vs. syngas cooler)
- Syngas purification process
- CO_2 capture level (0% to 90%)
- Syngas dilution and NOx reduction concept (saturation and/or nitrogen, optional combination with SCR)
- Air & nitrogen integration concepts and ASU process
- Gas turbine
- HRSG w/o or w/ duct firing
- Water/steam-side interfaces
- Process steam extraction for external use
- Cooling conditions

IGCC plant solutions need proper integration design for the interfaces and a robust plant design with implementation of the lessons learned.

Power and Gas Division: Organizational structure

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Division	Power and Gas				
Business Units	Large Gas Turbines, Generators (PG GT)	Distributed Generation (PG DG)	Steam Turbines (PG SU)	Energy Solutions (PG ES)	Dresser-Rand (PG DR)
Business Fields	▪ Gas turbines from 100 to 400 MW ▪ Electrical generators from 25 up to 2,235 MVA	▪ Industrial gas turbines from 5 to 54 MW ▪ Aeroderivative gas turbines from 4 to 66 MW	▪ Steam turbines from 45 kW to 1,900 MW ▪ Steam turbines for industrial applications & power generation	▪ 50 Hz and 60 Hz gas turbine power plant solutions ▪ CHP*, Desalination, IGCC**, Repowering ▪ Integrated solar combined cycle ▪ HRSG*** ▪ DCS****, Turbine Controls ▪ I&C and Electrical for small hydro power	▪ Reciprocating compressors, turbo compressors and compressor trains ▪ Gas engines ▪ E-houses and modules ▪ Distributed LNG ▪ Power generation for Oil & Gas ▪ Related services

* Combined heat and power ** Integrated gasification combined cycle ***Heat recovery steam generator ****Distributed Control Systems

The Siemens gas turbine portfolio: The right engine for every requirement

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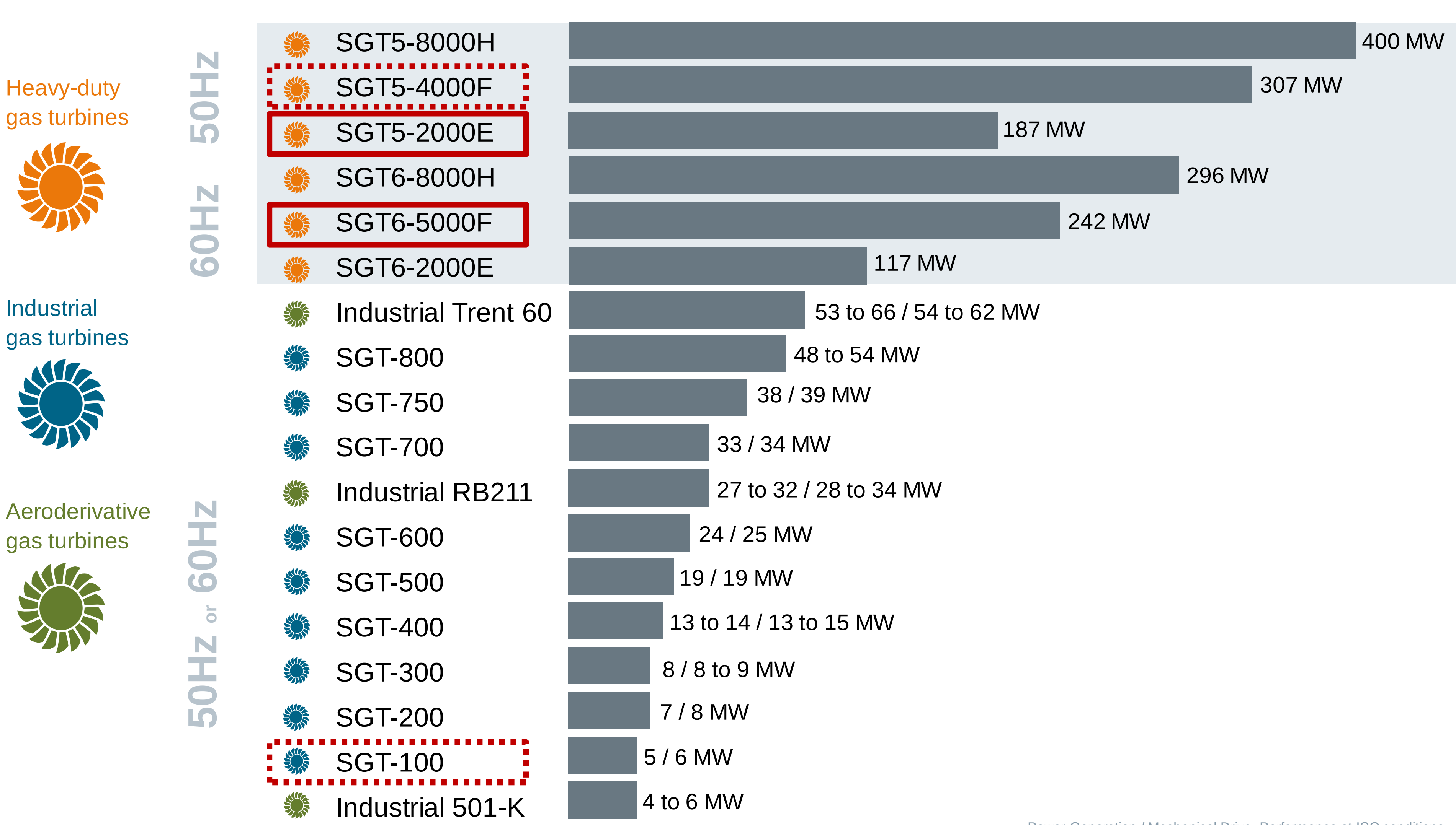


Power Generation / Mechanical Drive, Performance at ISO conditions

Gas Turbines with syngas references

Syngas experience with predecessors of current Gas Turbine version

Heavy-Duty Gas Turbines

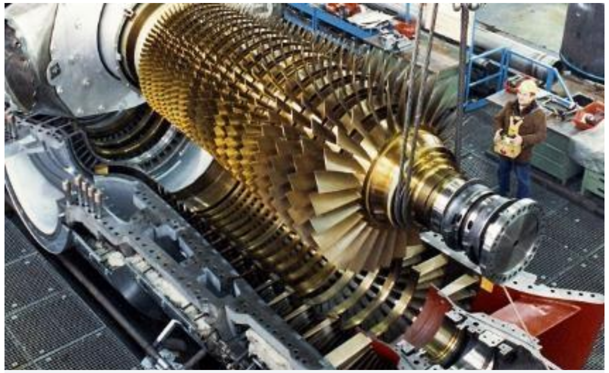
SGT5-8000H (up to 400 MW)
Highly efficient, flexible, proven

SGT5-4000F (up to 307 MW)
Trusted operational excellence

SGT5-2000E (up to 187 MW)
Reliable, robust, fuel flexible

SGT6-8000H (up to 296 MW)
Highly efficient, flexible, proven

SGT6-5000F (up to 242 MW)
Reliable, fuel flexible and powerful



SGT6-2000E (up to 116 MW)
Reliable, robust, fuel flexible

Future syngas application

Gas turbines with syngas/ IGCC references

SGT-2000E gas turbines series provide solutions for the full gas range

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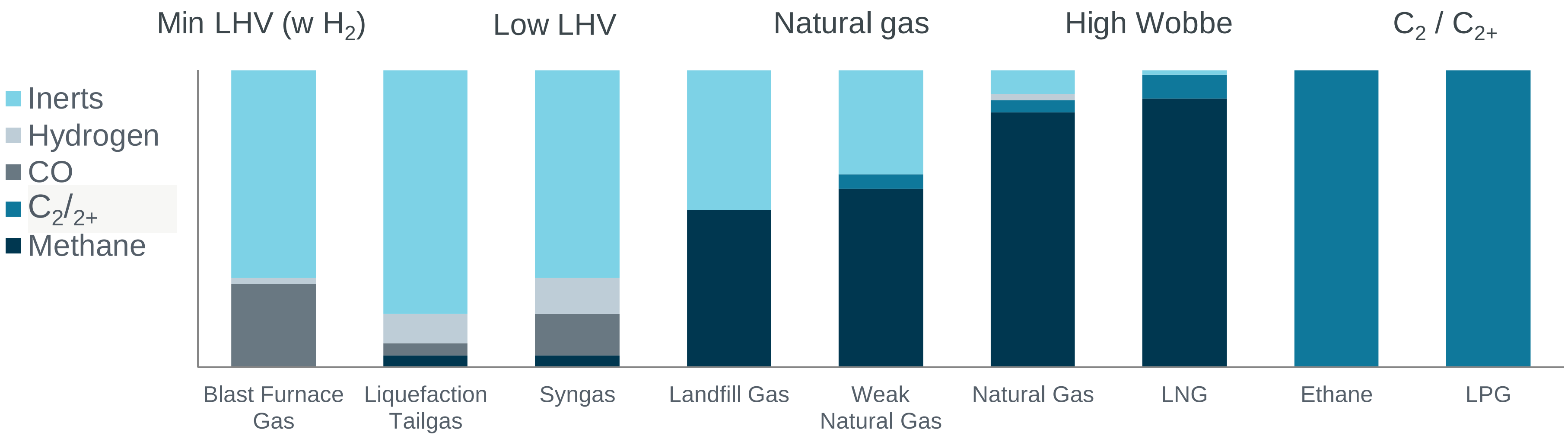
LHV/Wobbe Index increasing

H_2/CO-containing low LHV fuels



Compressor	**modification**	**standard**	
Combustor	**modification**	**standard**	**modification**
Turbine		**standard**	
Fuel system	**modification**	**standard**	**modification**

Standard combustion system covers wide Wobbe range for fuels w/o H_2/CO. Hydrogen-containing syngas and steel mill gases require special solutions.

Special conditions for combustion of syngas or H_2-containing fuels in gas turbines

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- Higher stoichiometric combustion temperature
- Smaller volumetric calorific values
- High flame speed

↓

- Large increase in volumetric fuel flow rates
- Increased overheating potential

↓

- Fast homogeneous mixing of fuel and air within shortest possible time
- Elimination of any flow separation
- High gas flow velocity to compensate increased flame speed

Fuel Properties	CH_4	H_2	CO
LHV [MJ/kg]	50.3	119.9	10.1
[MJ/m³]	33.9	10.2	12.6
Flame speed in air [cm/s]	43	350	20
Stoich. comb. temp. [K]	2227	2370	2374
Density [kg/m^3_{STP}]	0.72	0.09	1.25
Specific heat [kJ/kgK]	2.18	14.24	1.05
Flammability limits [vol %]	5 - 15	4 - 75	12.5 - 74

Syngas and steel mill recovery gas operation requires diffusion-type combustion with fuel "dilution" for control of NOx emissions and flame speed.

Siemens syngas burner technology: SGT5-2000E(LC) gas turbine

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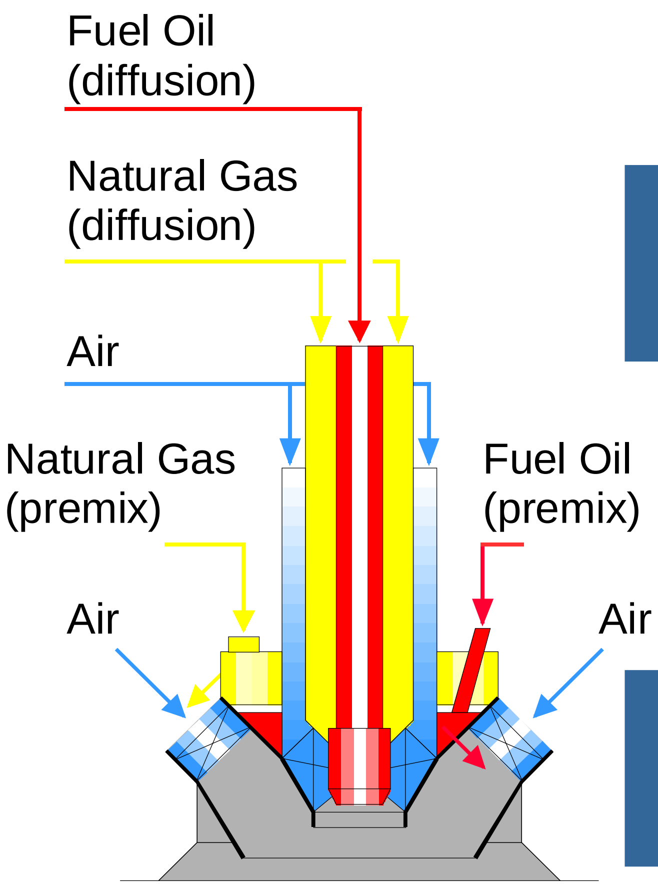
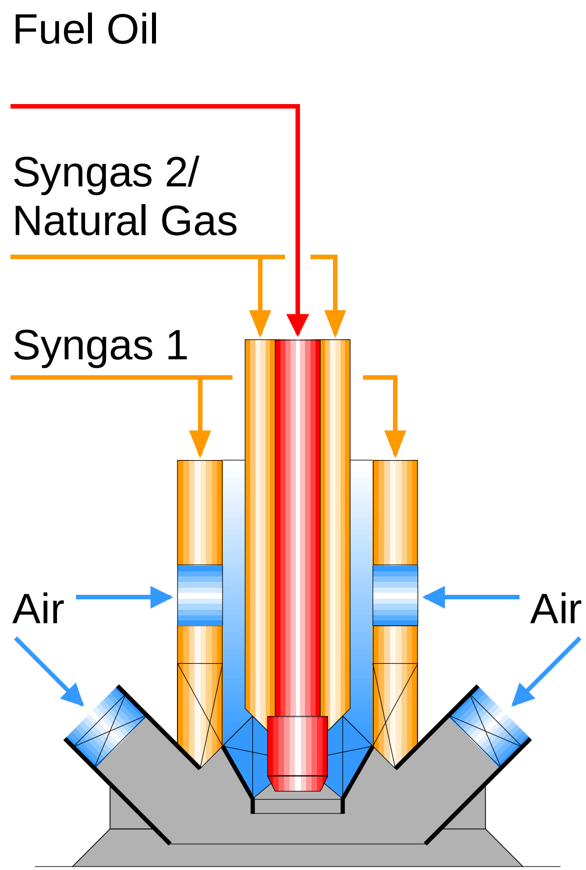
<u>Regular multi fuel burner</u>



Concept with 2 syngas passages

Optimized syngas nozzle design

<u>Syngas burner</u>



Flexible and proven syngas burner for low calorific syngas and steel mill recovery gas

Heavy-duty gas turbines
Fuel compositions for 50 Hz syngas references

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Project	Buggenum (Netherlands)	Puertollano (Spain)	Priolo Gargallo (Italy)	Servola (Italy)	Tianjin (China)
Application	IGCC (coal-based)	IGCC (coal-based)	IGCC (oil-based)	Steel mill gas CCPP	IGCC (coal-based)
Fuel type (Diluent)	Diluted syngas (H_20 and N_2)	Diluted syngas (H_20 and N_2)	Diluted syngas (H_20)	Steel mill gas mixture (H_20)	Diluted syngas (H_20 and N_2)
Fuel composition					
H_2	12,3 Vol.-%	10,7 Vol.-%	31,7 Vol.-%	9,0 Vol.-%	15,3 Vol.-%
CO	24,8 Vol.-%	29,2 Vol.-%	28,5 Vol.-%	16,3 Vol.-%	33,7 Vol.-%
CO_2	0,8 Vol.-%	1,9 Vol.-%	3,2 Vol.-%	13,6 Vol.-%	1,1 Vol.-%
N_2	42,0 Vol.-%	53,1 Vol.-%	0,9 Vol.-%	41,0 Vol.-%	9,0 Vol.-%
CH_4	----	----	----	14,6 Vol.-%	0,5 Vol.-%
C_nH_m	----	----	----	----	----
Ar	0,6 Vol.-%	0,6 Vol.-%	----	----	0,1 Vol.-%
H_2O	19,1 Vol.-%	4,2 Vol.-%	36,0 Vol.-%	5,5 Vol.-%	40,3 Vol.-%
O_2	0,4 Vol.-%	0,3 Vol.-%	----	----	----
Fuel heating value (LHV)	*4,3 MJ/kg*	*4,2 MJ/kg*	*9,1 MJ/kg*	*7,2 MJ/kg*	*6,6 MJ/kg*

Syngas composition and LHV of diluted fuel depends on application.

Industrial gas turbines
Fuel heating values (LHV) for syngas references

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Syngas from small-scale air-blown gasification applications:

- Värnamo (biomass) 4.5 MJ/Nm^3
- HRL (lignite) 4.0 MJ/Nm^3
- ARBRE (biomass) 5.0 MJ/Nm^3

Syngas LHV in same order as for nitrogen/steam-diluted fuels at large-scale coal-based plants with oxygen-blown gasification.

General considerations for application of syngas as gas turbine fuel

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- The fuel has to meet the typical gas turbine fuel purity requirements.
- Due to the hydrogen content in the fuel, syngas has to be combusted in diffusion-type burners.
- Depending on the syngas composition, dilution with nitrogen and/or steam may be required for reactivity and/or NO_x emission control.
- In case of low LHV and/or low fuel reactivity, natural gas may need to be added.
- In any case a project/fuel-specific evaluation is needed from combustion point of view.
- Especially the lower LHV design limits have to be checked in conjunction with fuel composition and reactivity, respectively.

Gas turbine fuel purity requirements

Contaminants for which limit values in low ppm range are defined e.g. include

- Sodium (Na)
- Potassium (K)
- Vanadium (V)
- Lead (Pb)
- Calcium (Ca)
- Particulates/Dust
- Hydrogen Sulfide (H_2S)/Total Sulfur (S)

Contaminants for which limit values in ppb range are defined e.g. include

- Iron (Fe)
- Nickel (Ni)
- and related Carbonyls ($Ni(CO)_4$, $Fe(CO)_5$)

Fuel purity requirements are defined for standard fuels with high LHV.
Limit values have to be corrected for syngas applications with LHV ratio.

Global syngas/IGCC projects incorporating Siemens GT or CCPP technologies

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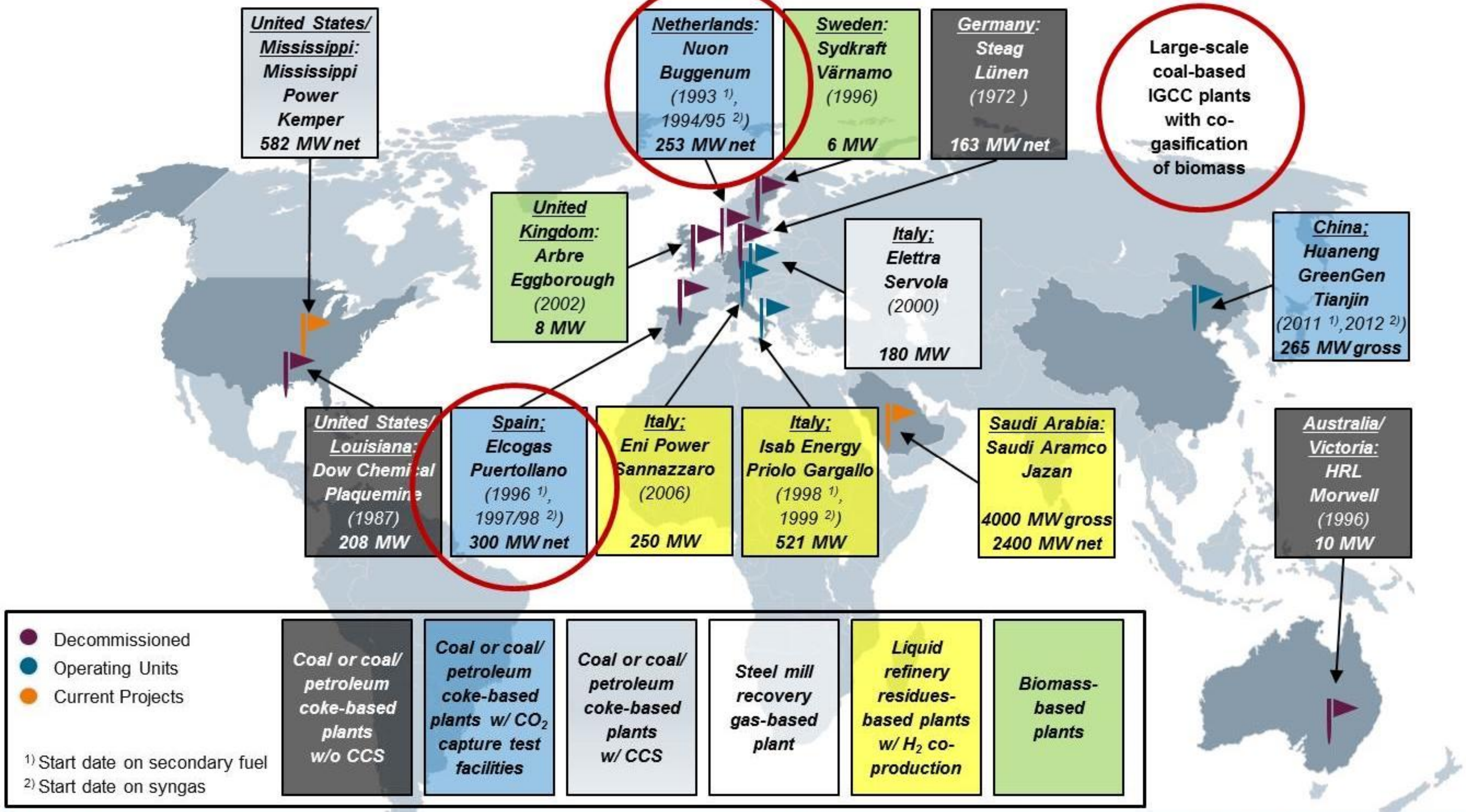
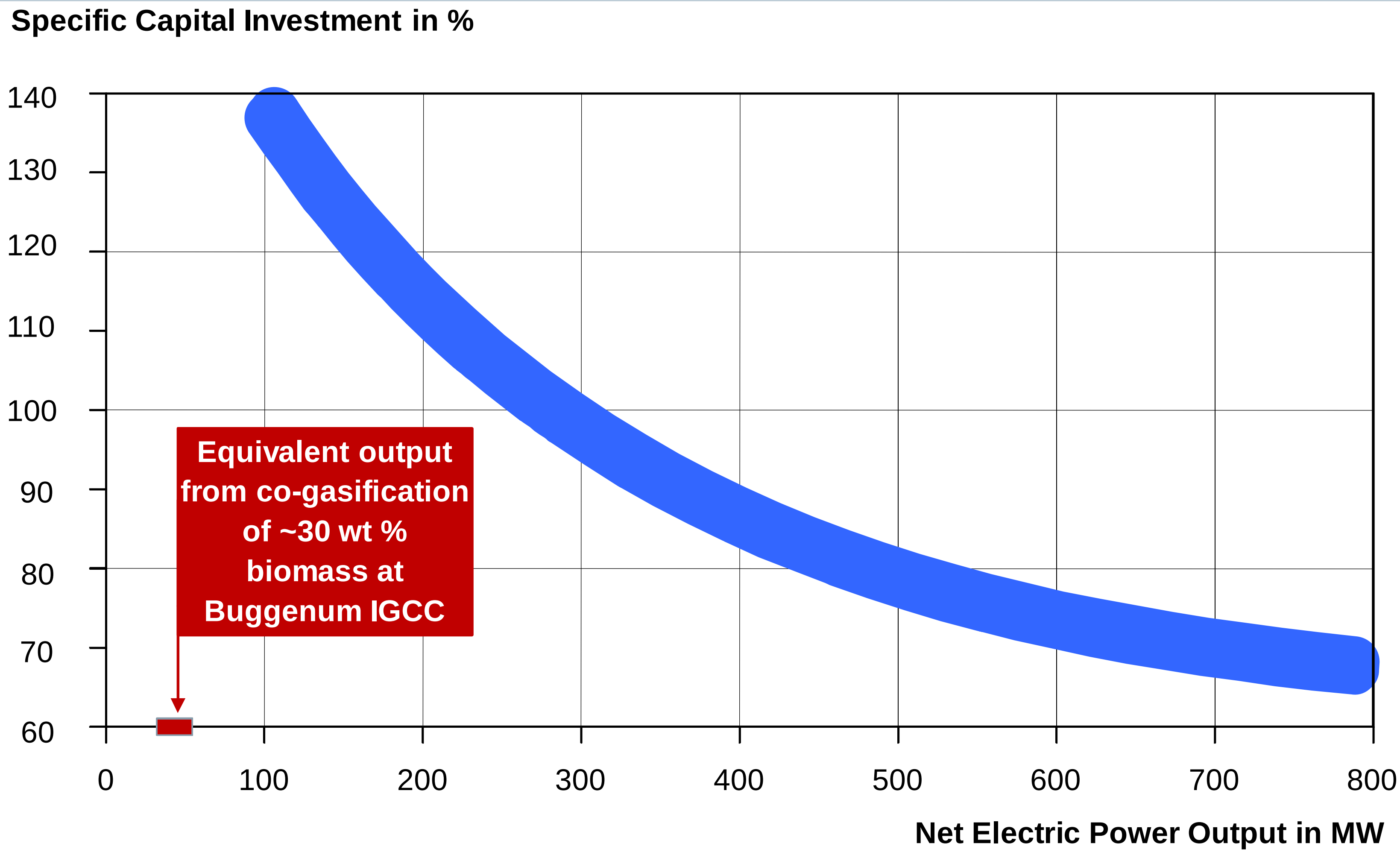


From world's first to world's largest IGCC power plant: more than 40 years of experience with applications for coal and refinery residues.

Indicative influence of plant size on relative CAPEX of coal-based IGCC power plants



Larger units contribute to reduction of IGCC specific costs.

Guascor engines for syngas application
Syngas quality requirements and references

DRESSER-RAND
A Siemens Business

Biomass

Gasification & Gas Cleaning

Syngas

Fuel LHV range 4,7- 14 MJ/Nm^3

Fuel mainly containing CO and H_2

Typical Impurities: Tars, solid particles, sulfur, ammonia,…

San Juan de los Olivos (Argentina)

- **Location:** Argentina
- **Combined output:** 0,5 MWe
- **Model (Tech):** SFGLD 360 (Syngas)
- **Power per engine:** 500 kWe
- **Number of engines**: 1
- **Const. year:** 2013
- **Client:** San Juan de los Olivos

Dordtech plant (UK)

- **Location:** UK (Wales)
- **Combined output:** 6,3 MWe, 5 MWth
- **Model (Tech):** SFGLD 560 (Syngas)
- **Power per engine:** 700 kWe
- **Number of engines**: 9
- **Const. year:** 2014
- **Client:** Dordtech

Aliaga Rice husk plant (Philippines)

- **Location:** Philippines
- **Combined output**: 646 kWe
- **Model (Tech):** SFGLD 560 (Syngas)
- **Power per engine:** 646 kWe
- **Number of engines.** 1
- **Const. year:** 2016
- **Client:** Aliaga

Syngas Requirements:

LHV	4,6-14 MJ/Nm^3
C4+BTEX	< 10% of total LHV
O_2	< 2% Vol.
H_2S	< 70 mg/MJ
H_2	< 40% of total LHV
Gas Humidity	< 60%
Ethylene	< 12% of total LHV
Acetylene	< 5% of total LHV
NH_3 Ammonia	<1,5 mg/MJ
Tar Oils and tar 1 ring 2 rings 3 rings >3 rings	Condensates not allowed <1,500 mg / MJ < 200 mg / MJ < 3 mg / MJ 0 mg / MJ
Dust-solid particles	< 5µm

Guascor SFGLD engine series specially developed to work with lean gases from biomass gasification.

Conclusions and outlook for IGCC applications

- In general, IGCC power plants are still a niche application for gasification and in the power industry.
- **Coal-based** IGCC still has significant development potential
- …but needs incentives in competition with SPP for power only applications.
- …and is more attractive in combination with co-production of higher value products.
- **Refinery residues-based IGCC** plants are commercially applied on (very) large scale
- …typically co-produce hydrogen and process steam for refinery supply.
- …future application depending on refinery capacity additions and/or upgrades.
- **Biomass-based IGCC** so far with very limited experience in small-scale units
- …co-gasification of biomass in large coal-based plants may be more attractive
- …co-firing of syngas in boilers or use of syngas in gas engines expected to be commercially more viable for small-scale gasification plants.
- …higher value (chemical) products may be more attractive than power.

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