GE Energy

IGCC & CCS
Hydrogen Fueled Gas Turbines

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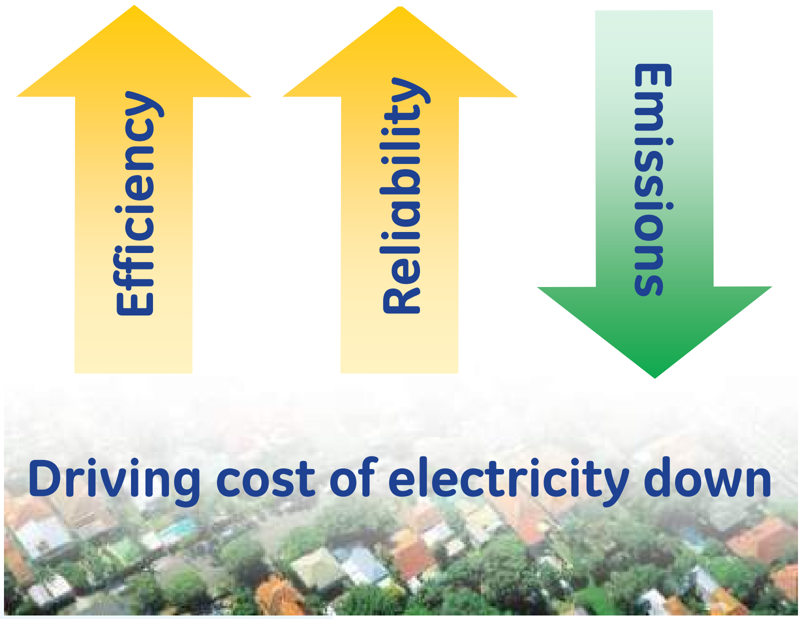
Global power generation requirements

Diverse

- Nuclear
- Coal
- Gas
- Wind
- Oil
- Geothermal
- Biomass
- Hydro
- Solar

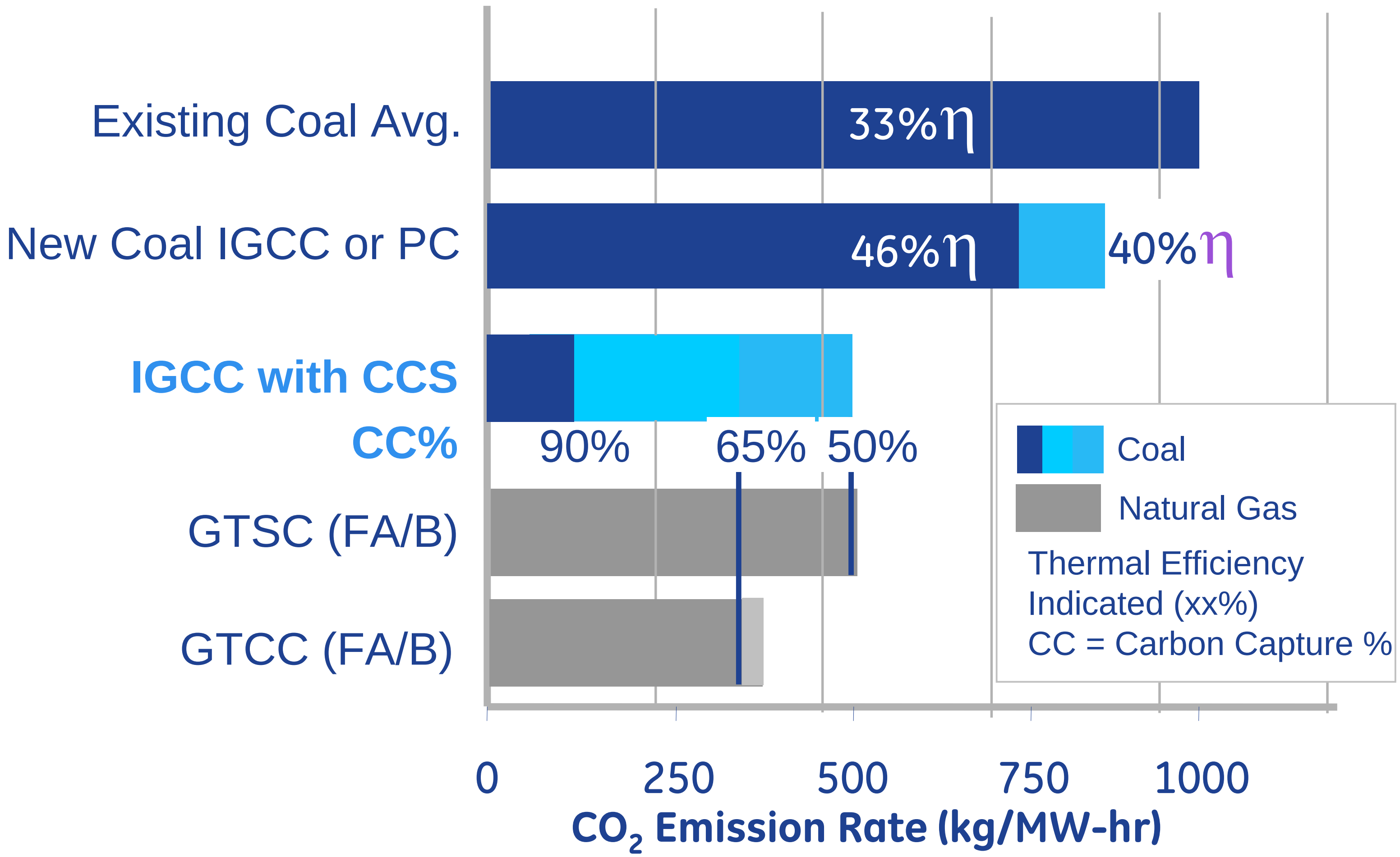
+

Efficient



Affordable, reliable & environmentally responsible

Carbon Footprints of Fossil Power



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References: DOE NETL; EIA; IEA and GE Internal Data

Technology Readiness for CCS

Process	Description	Oxidant	Status/Avoided Cost
Pre-combustion Capture - IGCC	Shift & CO_2 Scrub H_2 gas turbine	O_2 partial oxidation Air post combust	Ready for deployment - $32/ton[1]
Post-Combustion Capture - Amine	Once-through, open cycle	Air	Ready for deployment - $68/ton[1]
Post-Combustion Capture - Ammonia	Refrigerated Flue Gas Chilled Ammonia	Air	Slipstream Pilot
Oxy-combustion	Full CO_2 recycle CO_2 working fluid	O_2	Pilot
Chemical Looping	Me/MeO oxidation/reduction	O_2	Early Development
AZEP	High temperature membrane O2	O_2	Early Development

[1] Avoided cost; Ref: Cost and Performance Baseline for Fossil Energy Plants, DOE NETL 2007-1281, May, 2007

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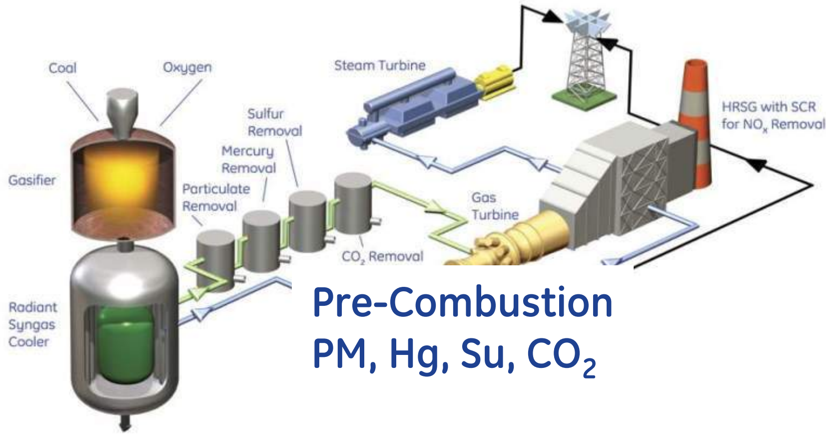
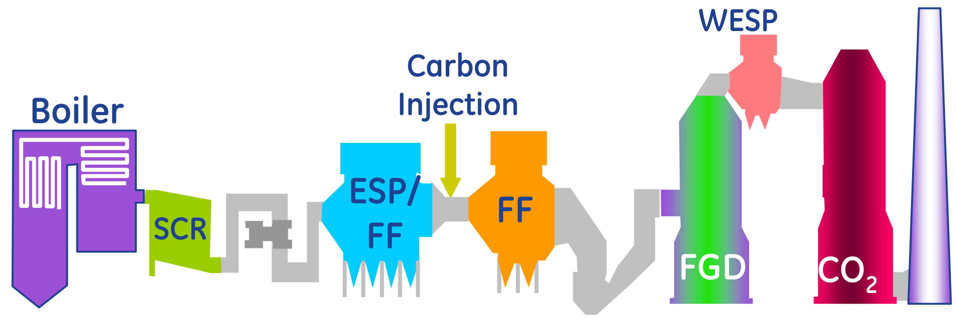
IGCC vs. Pulverized Coal for CCS

Pollution Prevention vs. Pollution Control





IGCC

- Gasification cleans fuel
  small fuel volume

- CO_2 concentration in syngas is high
  ~15% without shift
  40%-50% with single shift
  ~90% with 2 stage shift

Pulverized Coal

- PC cleans the flue gas
  100 times the gas volume of IGCC

- CO_2 concentration is low
  ~14% with no improvements

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Gasification Options

- Heavy Oil
- Asphalt
- Vacuum Residue
- Petroleum Coke
- Coal
- Natural Gas

GE's Gasification Technology

Coal to Liquid
- Syngas + Fischer Tropsch
- Wax + Diesel

Refinery Polygeneration
- Hydrogen
- Steam
- Power

Electricity

Chemicals
- Ammonia
- Methanol

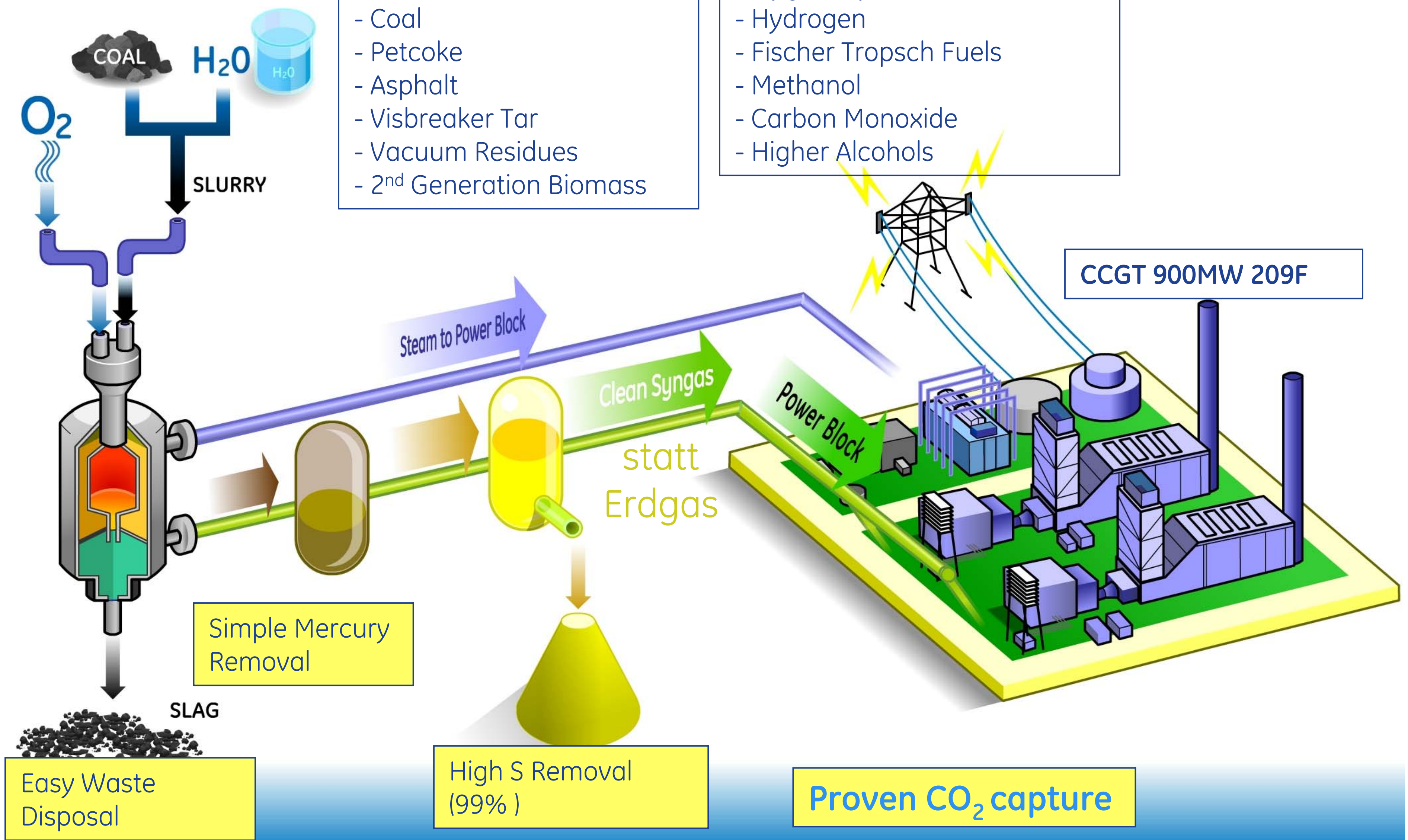
Substitute Natural Gas
- SNG

…since > 50 years !

IGCC … Flexible & Env. Friendly

Feedstock
- Coal
- Petcoke
- Asphalt
- Visbreaker Tar
- Vacuum Residues
- 2nd Generation Biomass

Polygen Options
- Hydrogen
- Fischer Tropsch Fuels
- Methanol
- Carbon Monoxide
- Higher Alcohols



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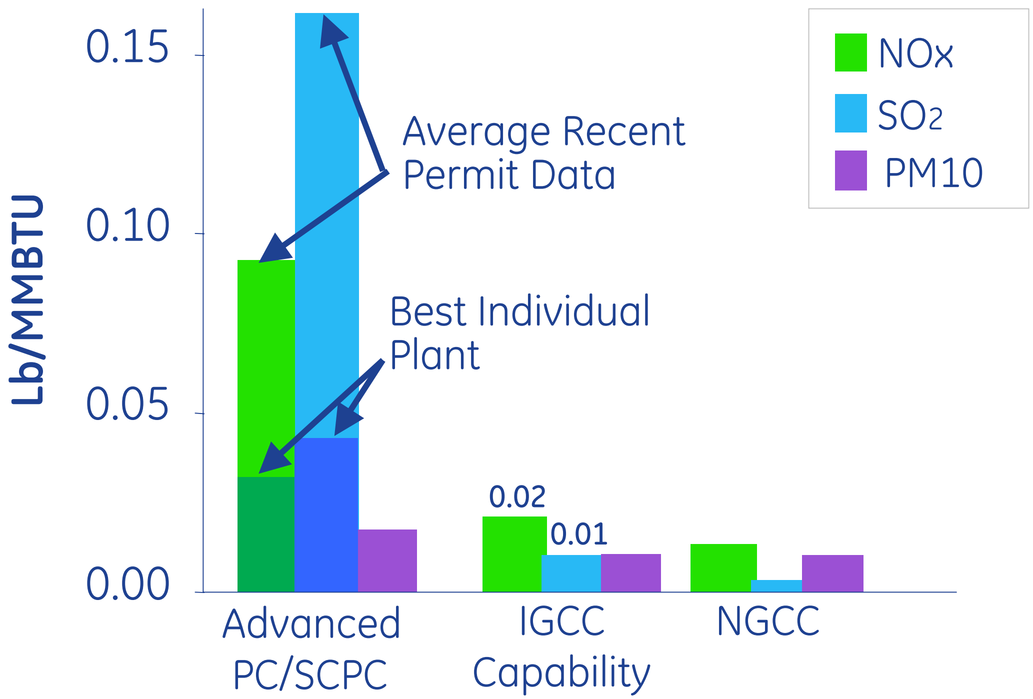
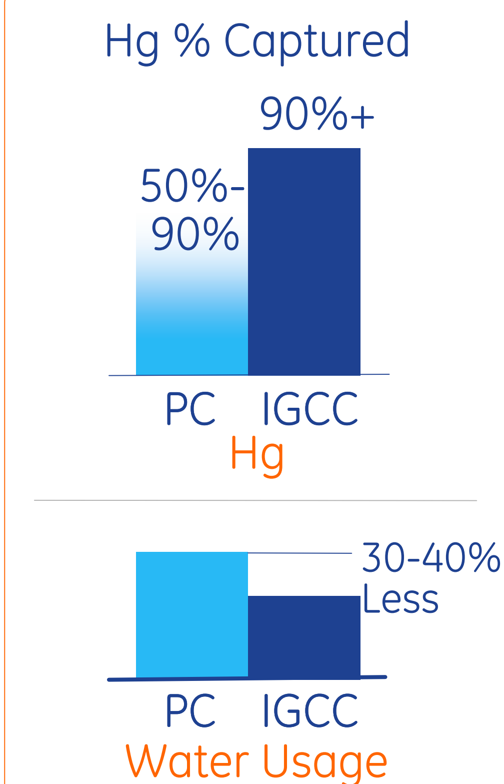
IGCC: Cleaner By Design



Source: GE internal data, average of 30 permits granted, applications and publicly reported emissions



IGCC Benefits - Environmentally Cleaner

- 33% less NOx
- 75% less SO_2
- 50% less PM_{10}
- 90% + Hg removal
- 30% less water
- CO_2 capture ready

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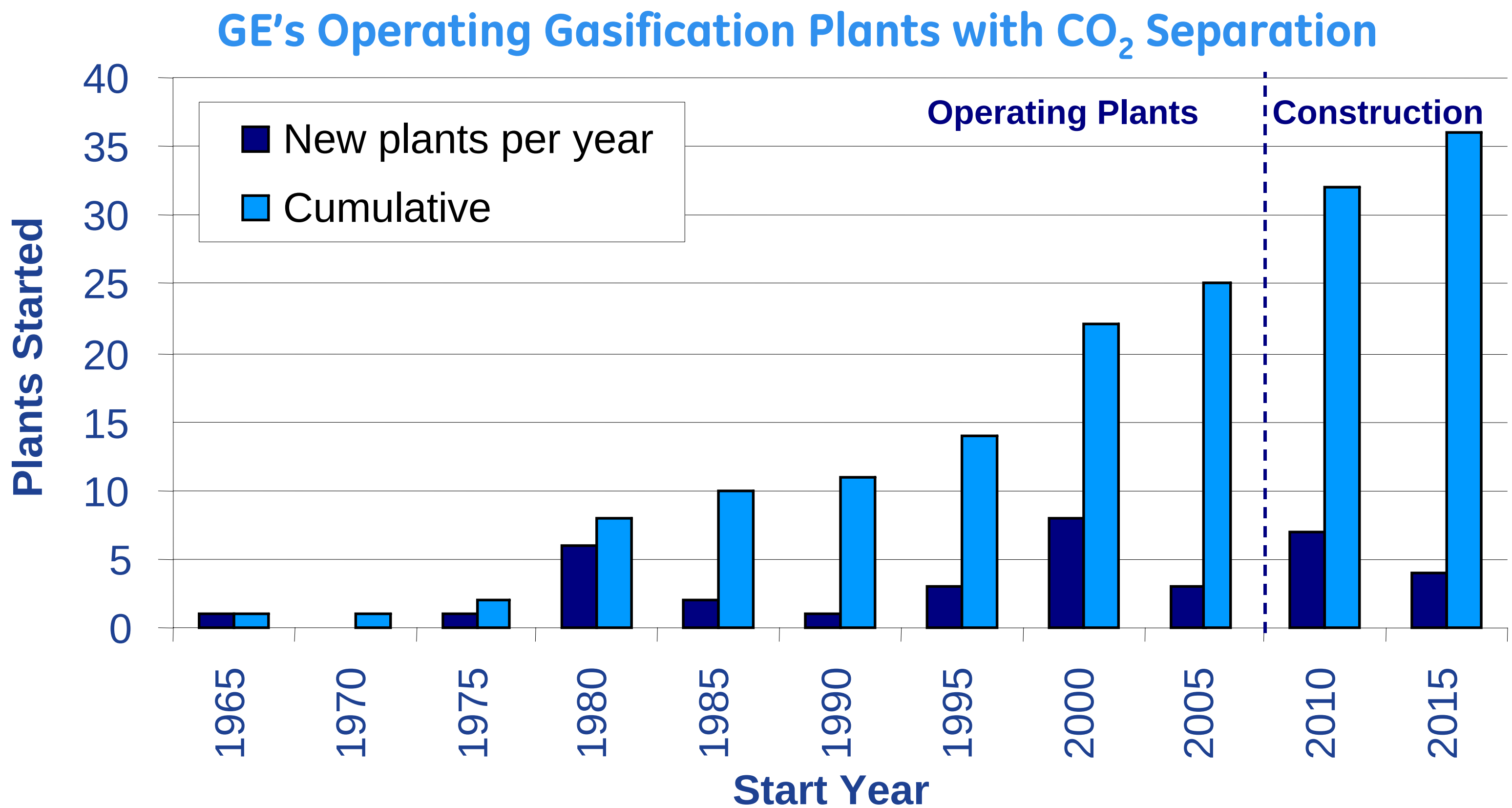
CO_2 Removal from Syngas (De-Carbonization)



Gasification with CO_2 Capture is over 50 yrs old

- First GE gasification plant with CO_2 removal: Spencer Chemical, 1953
- 33 of 63 gasification plants (12 with solids feedstock)

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GE IGCC plant under Construction

630MW IGCC Plant

- Duke Energy IGCC, Indiana 5 coal
- NTP in 2007, COD in 2012
- Detailed engineering near completion
- Construction on-track
- Core components shipping in 2009
- 7F Syngas turbines ship in 2010

Successful siting & permitting

- Sited & permitted next to aging PC facility

Duke Energy
Edwardsport site construction, January 2009

" We have an opportunity to make history with the Edwardsport plant. The facility could very well be one of the cleanest coal-fired power plants in the world. It will produce nearly 10 times as much energy as the existing Edwardsport plant with much less environmental impact." - Jim Turner, President & COO, U.S. Franchised Electric and Gas-Duke Energy

Duke Energy press release, Jan. 25, 2008

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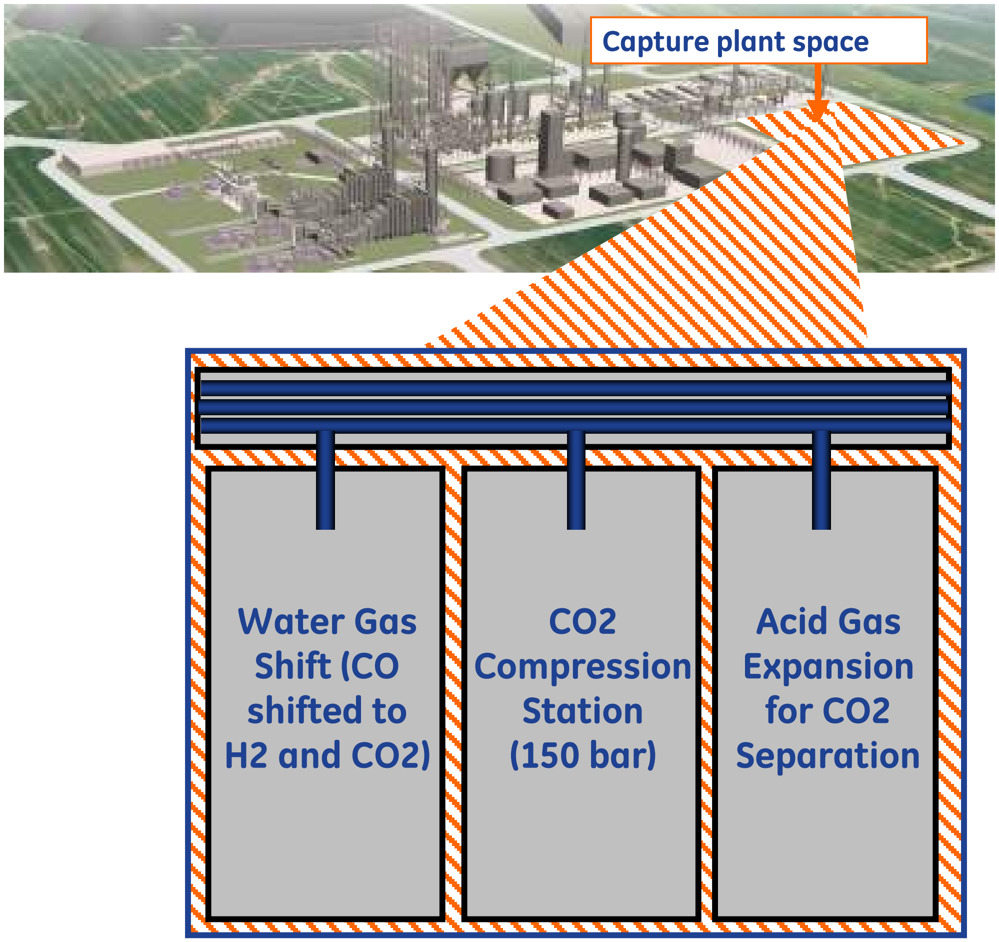
Carbon capture ready … more than a space



Capture ready features

- Designed for now or later addition of "carbon capture island"
- Plot space for AGR expansion, shift unit/s, CO_2 compression
- AGR system already captures CO_2 for recycle … expandable for future
- No gas turbine hot gas path modification
- NG CO_2 equivalence (50% - 65% capture)

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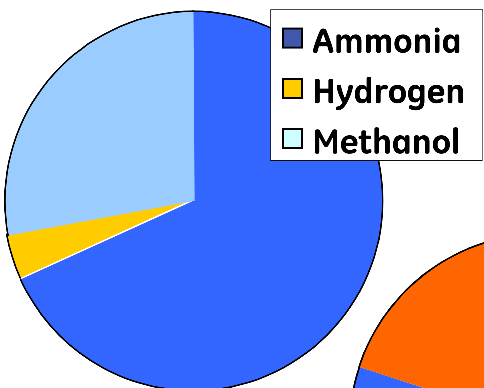
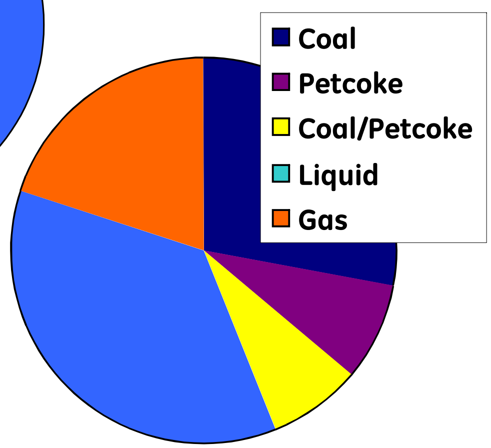
IGCC systems proven for carbon capture

33 Gasification Plants
Shift+Capture Experience

- Ammonia Plant
- Methanol Process
- Refinery Hydrogen

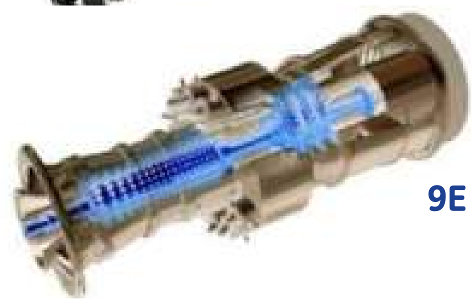




28 GT Turbines
high H_2 (>50%) Experience


6B


7EA


9E


F-class

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B/E-class High Hydrogen Experience

Project / Site	GT Model	No. Units	Fuel Gas	Features
Geismer, US	MS6001B	1	PG	up to 80% H2
Refinery, US	MS6001B	1	RFG	12 - 50% H2
Korea	MS6001B	1	PG	up to 95% H2
Tenerife, Spain	MS6001B	1	RFG	~70% H2
Cartagena, Spain	MS6001B	1	RFG	66% H2
San Roque, Spain	MS6001B	2	RFG	70% H2
Antwerpen, Belgium	MS6001B	1	RFG	78% H2
Puertollano, Spain	MS6001B	2	RFG	up to 60% H2
La Coruna, Spain	MS6001B	1	RFG	up to 52% H2
Rotterdam, NL	MS6001B	1	RFG	59% H2
Schwarze Pumpe, GER	MS6001B	1	IGCC	62% H2
Vresova, CZ	MS9001E	2	IGCC	46.8% H2
Fawley, UK	MS9001E	1	RFG	~50% H2
Georgia Gulf, US	MS7001EA	3	Blend	Methane + 50% H2
Milazzo, ITA	MS5001P	1	RFG	30 - 50% H2
Ref., India	MS5001P	1	RFG	50% H2
Paulsboro, US	MS5001P	2	RFG	20 - 60% H2
Ref., Int'l	MS5001P	1	RFG	Propane + 60% H2
Reutgerswerke, US	MS3002J	1	PG	60% H2
NUP	MS3002J	1	TG	~60% H2
Donges, US	GE10	1	RFG	76% H2
Refinery, Jordan	PGT10	1	RFG	82% H2

RFG = Refinery Gas, TG = Tail Gas, PG = Process Gas, IGCC = Syngas

→ Fleet Leader
avg. 90% H_2
more than 10 yrs
more than 75,000 hrs

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F-class Hydrogen Experience

	PSI Wabash	Tampa Polk	Exxon Singapore	Valero Delaware
Turbine	7FA	7FA	2x6FA	2x6FA
H_2 (% vol)	24.8	37.2	44.5	32.0
CO	39.5	46.6	35.4	49.5
CH_4	1.5	0.1	0.5	0.1
CO_2	9.3	13.3	17.9	15.8
N_2+Ar	2.3	2.5	1.4	2.2
H_2O	22.7	0.3	0.1	0.4
LHV BTU/ft^3	209	253	241	248
kJ/m^3	8,224	9,962	9,477	9,768
T_{fuel} F/C	570/ 300	700/ 371	350/ 177	570/ 299
H_2/CO Ratio	0.63	0.80	1.26	0.65
Diluent	Steam	N_2	Steam	H_2O/ N_2
Equiv BTU/ft^3	150	118	116	150
kJ/m^3	5,910	4,649	4,600	5,910

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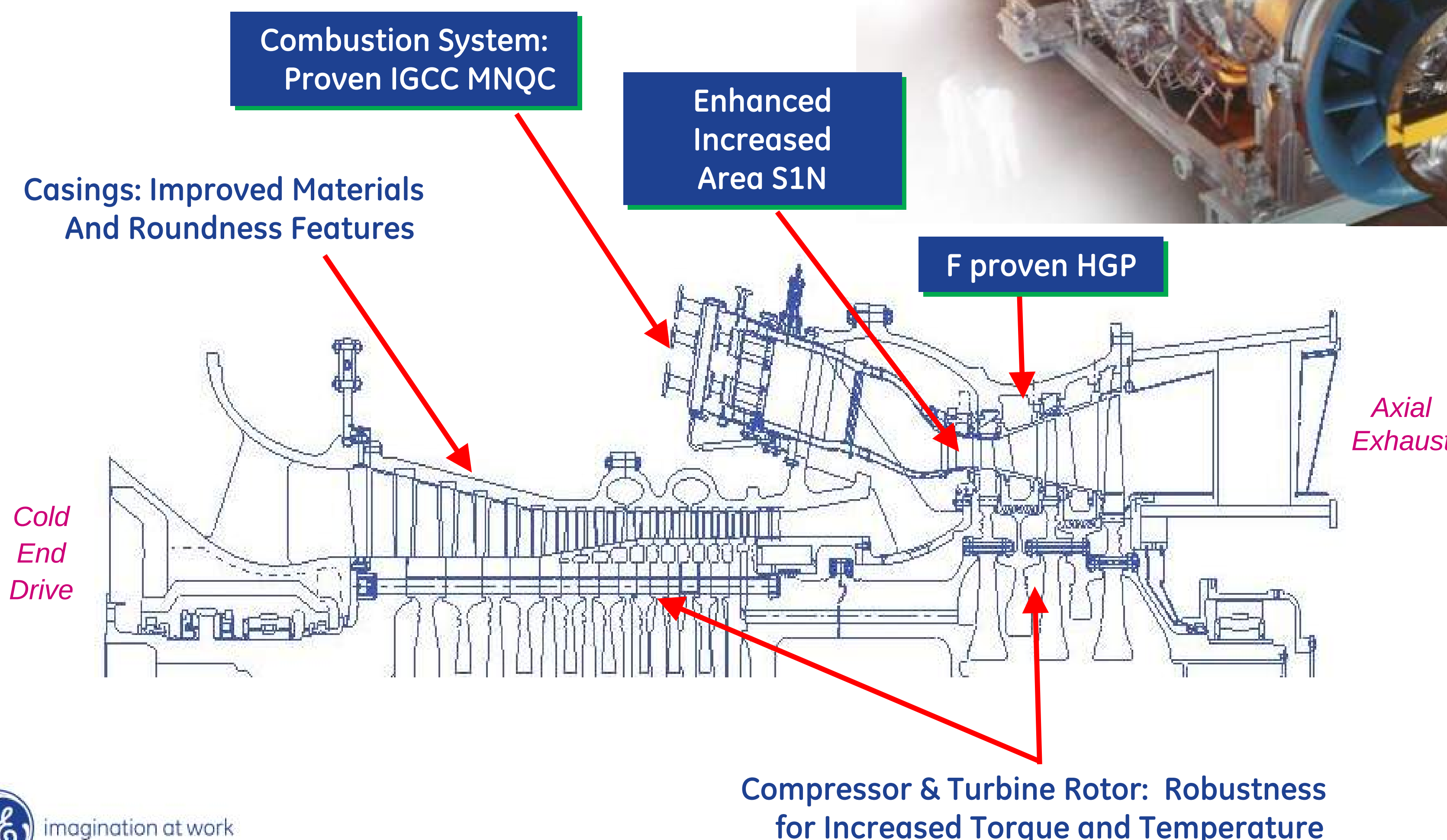
IGCC 7F/9F Syngas Product Features Summary



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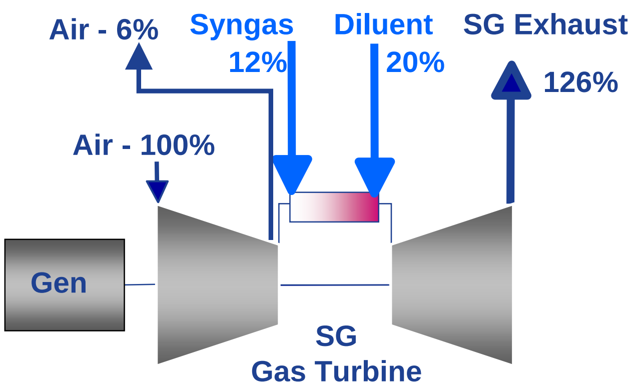
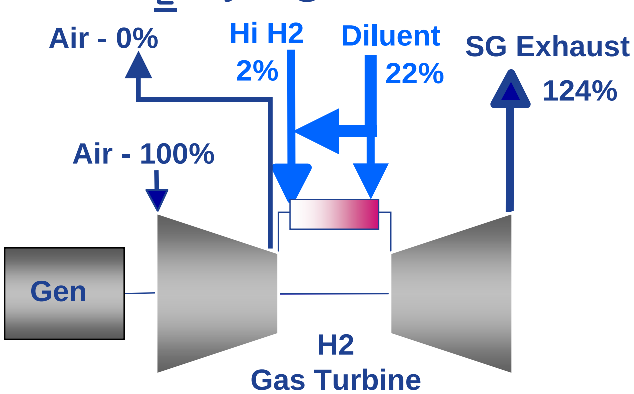
Maintaining GT Output on Syngas Fuels

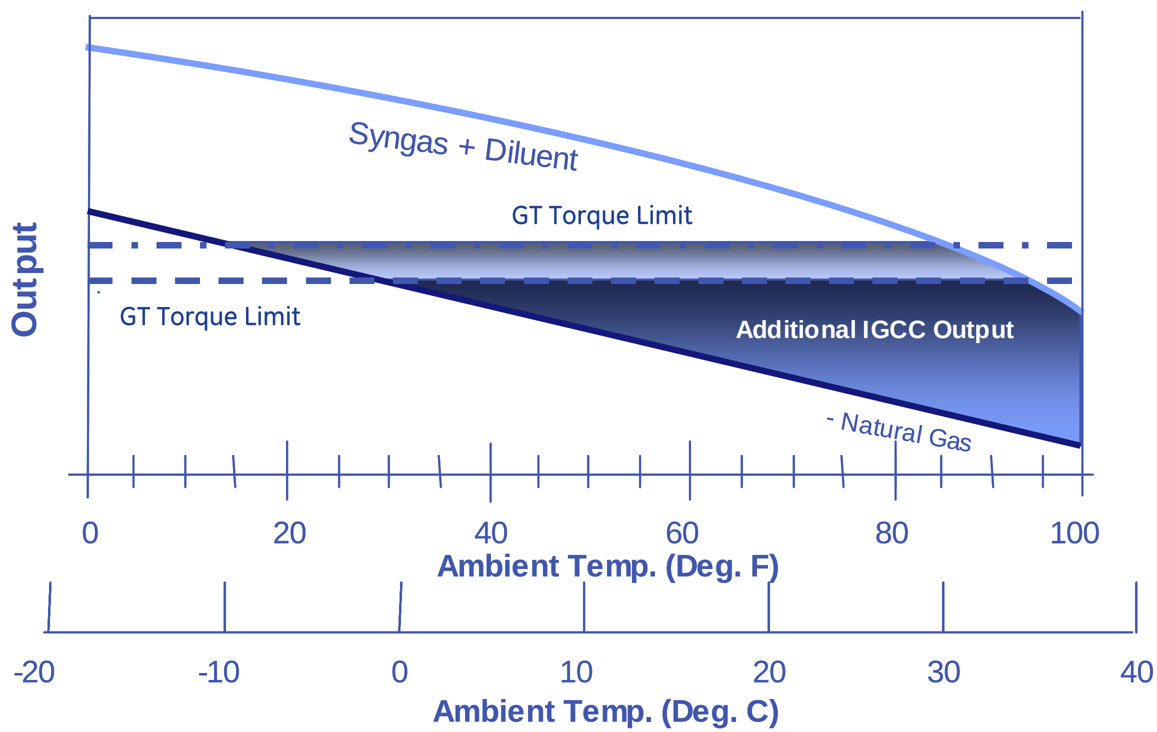
Un-shifted Syngas GT



Hi H_2 Syngas



Gas Turbine Output vs. Ambient Temperature



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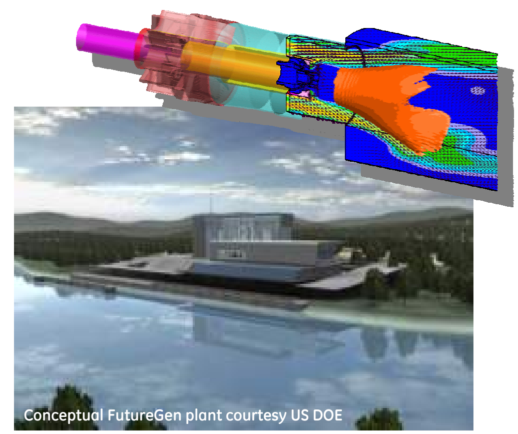
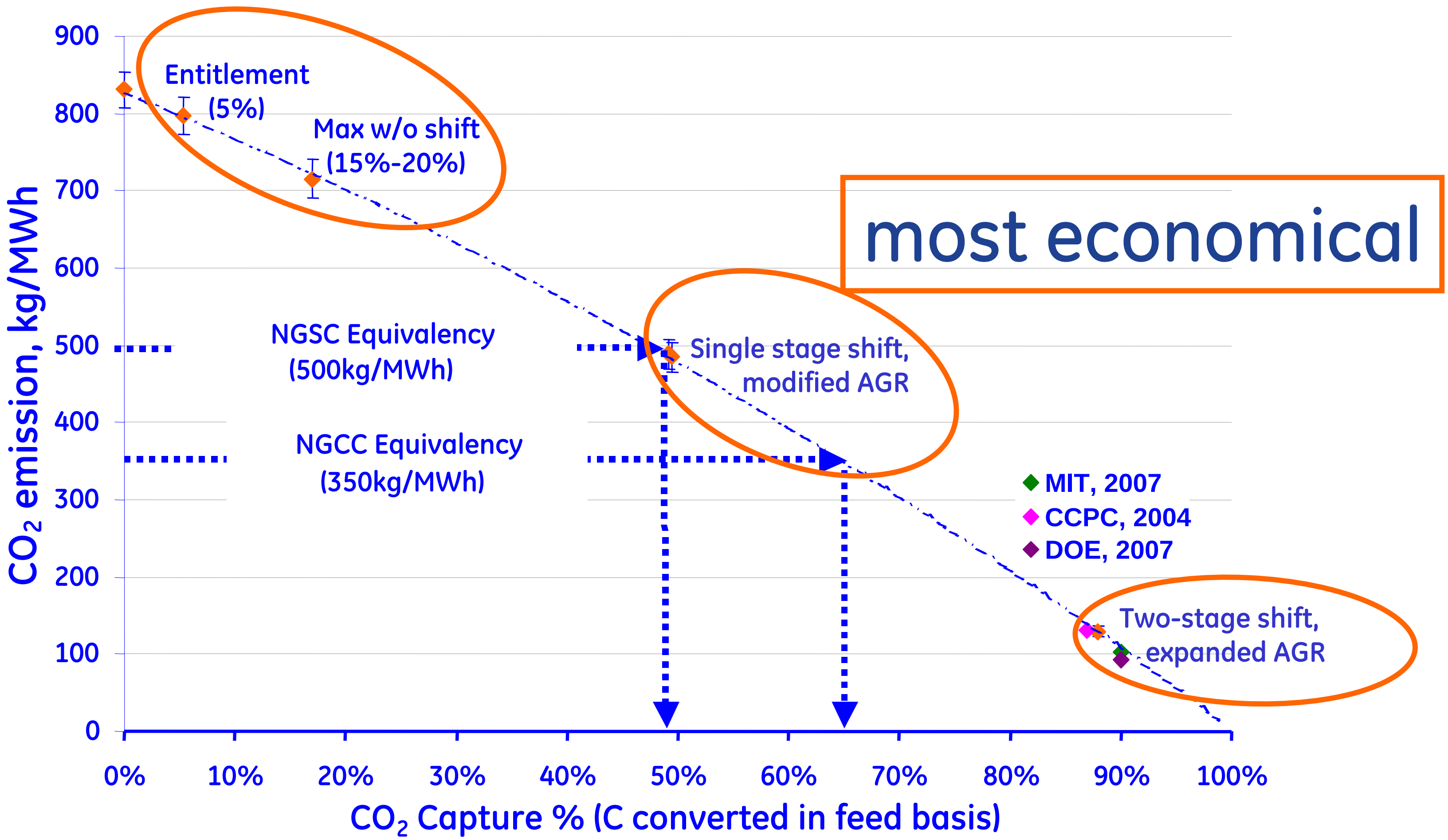
IGCC & CCS Combustion Landscape

Objective	Approach	Capability
Cleaner Energy from Coal	*Today*	
	IGCC with Carbon Capture	• High-H_2 GT fleet • Successful operation • Diffusion flame • Diluent for NOx
	Future	
	Advanced Separation & Gasification Technology	• Advanced pre-mix combustion • Membranes -- O_2, CO_2, H_2 • DOE program



Criteria for Carbon Capture Levels



Fuel Price for COE in $/mmBTU

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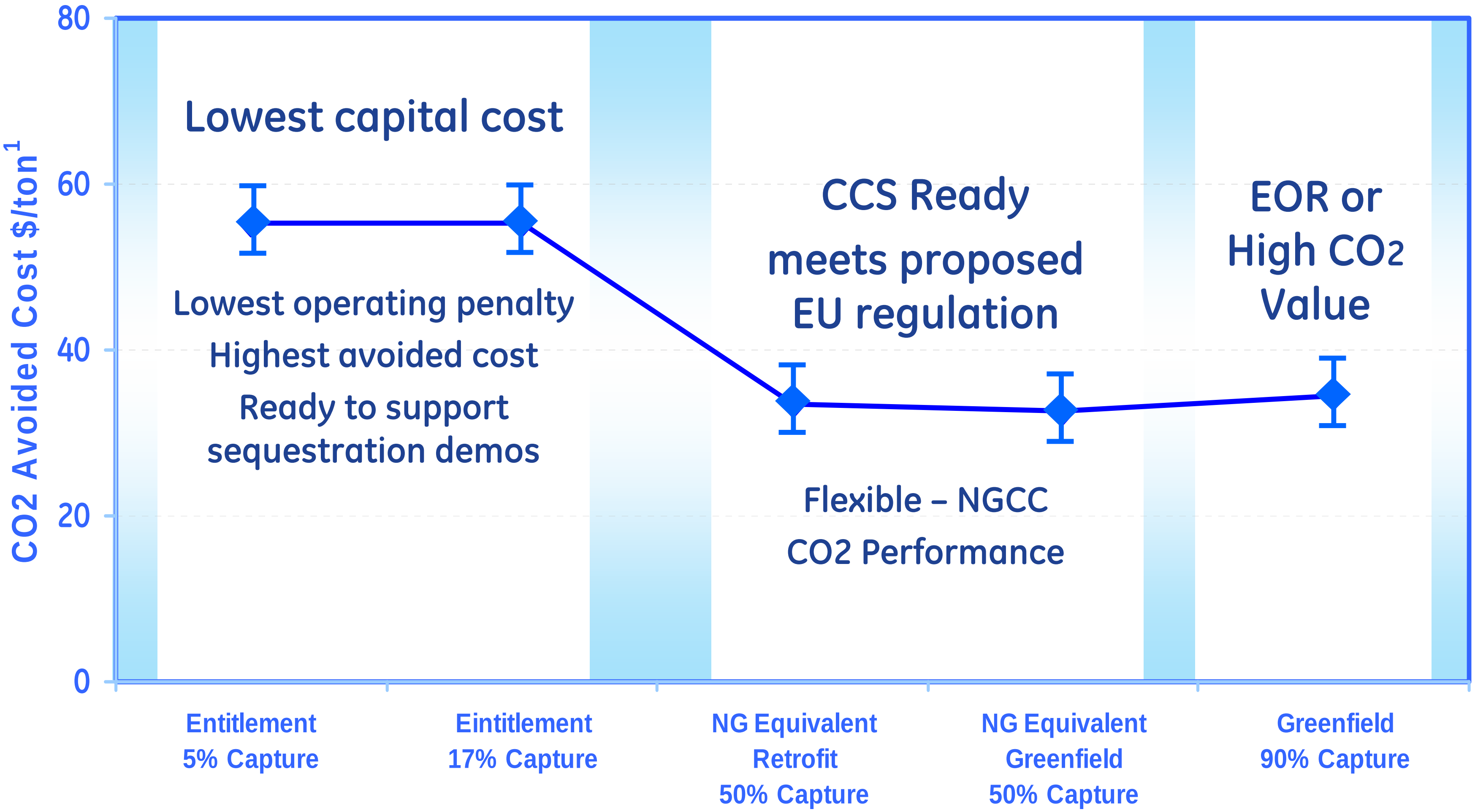
IGCC flexibility for carbon value



[1] Capture with compression to 150 bar, excludes T&S

$$\text{CO2 Avoided Cost (\$/ton)} = \frac{COE_{cc}(\$/MWh) - COE_{base}(\$/MWh)}{CO2_{base}(ton/MWh) - CO2_{cc}(ton/MWh)}$$

Source: GE Energy internal data

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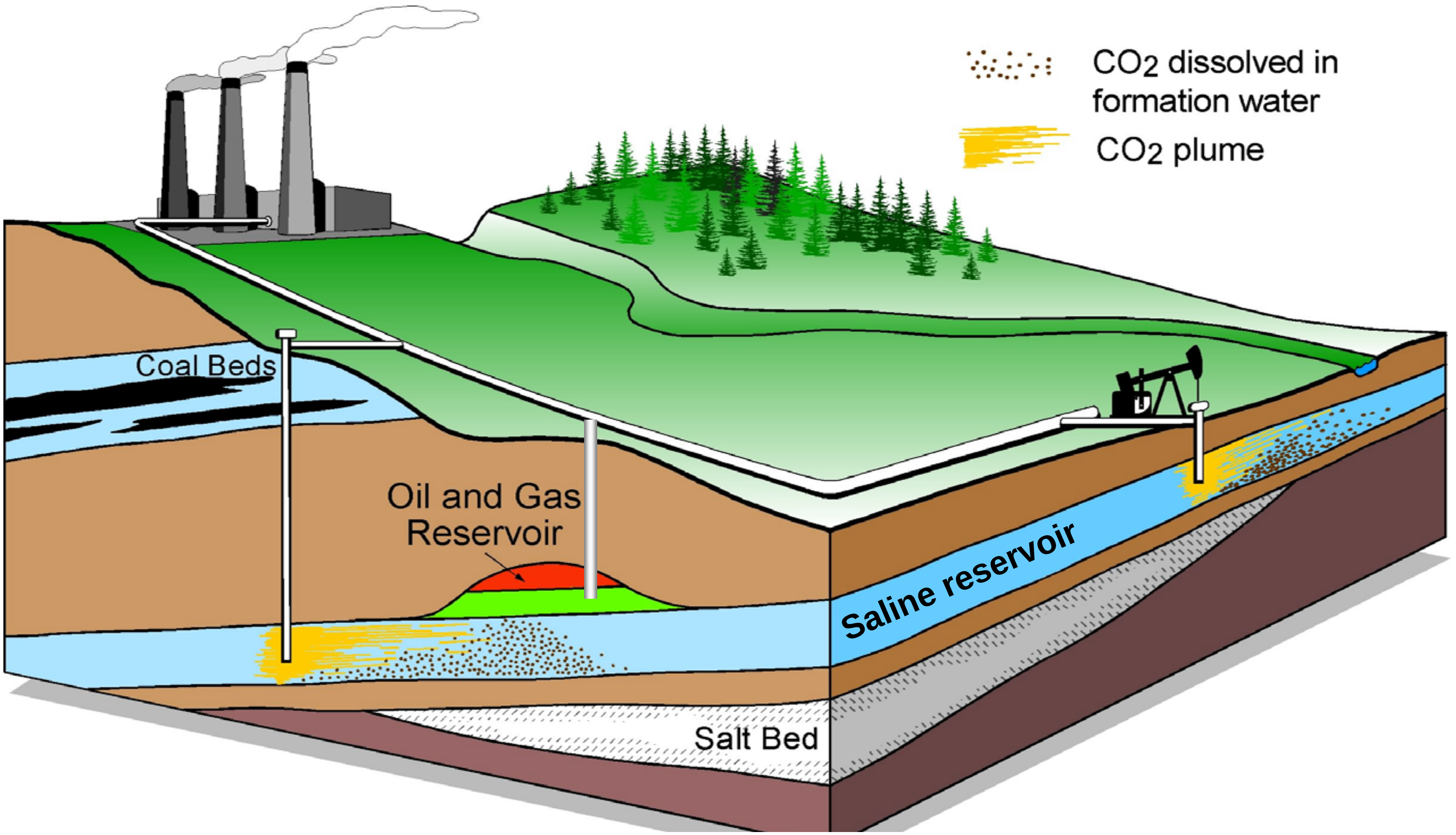
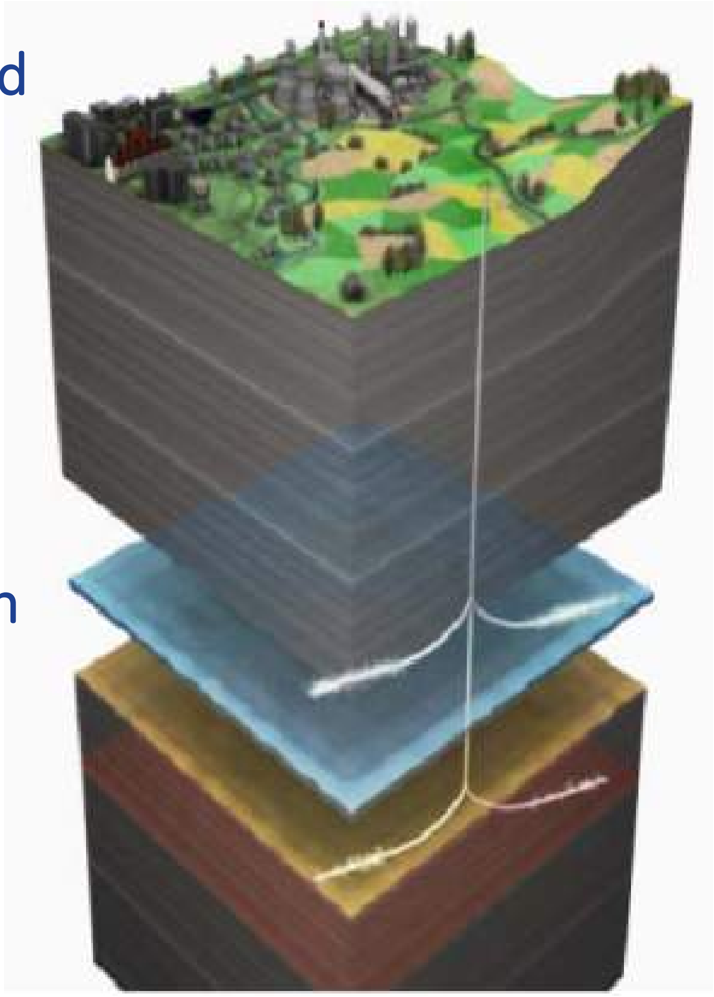
The Technology of CCS



GE and Schlumberger

- May 2008: alliance agreement announced
- To accelerate the use of "cleaner coal" technology
- GE: Experience in IGCC, carbon capture
- Schlumberger: Geologic storage expertise and capabilities for site selection, characterization & qualification
- Technical & commercial certainty for moving forward with coal-based power generation



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