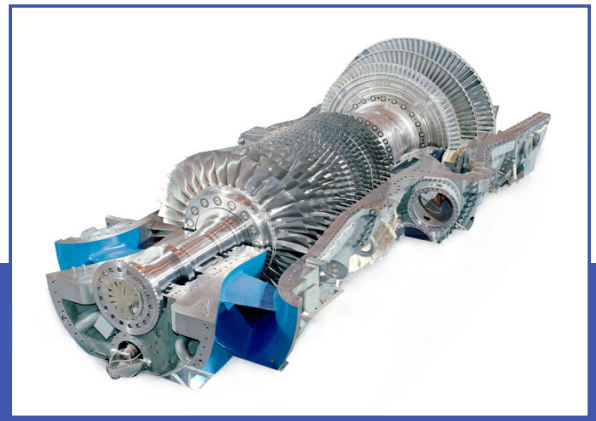
GE
Energy

# IGCC Cleaner Coal --Ready for Carbon Capture

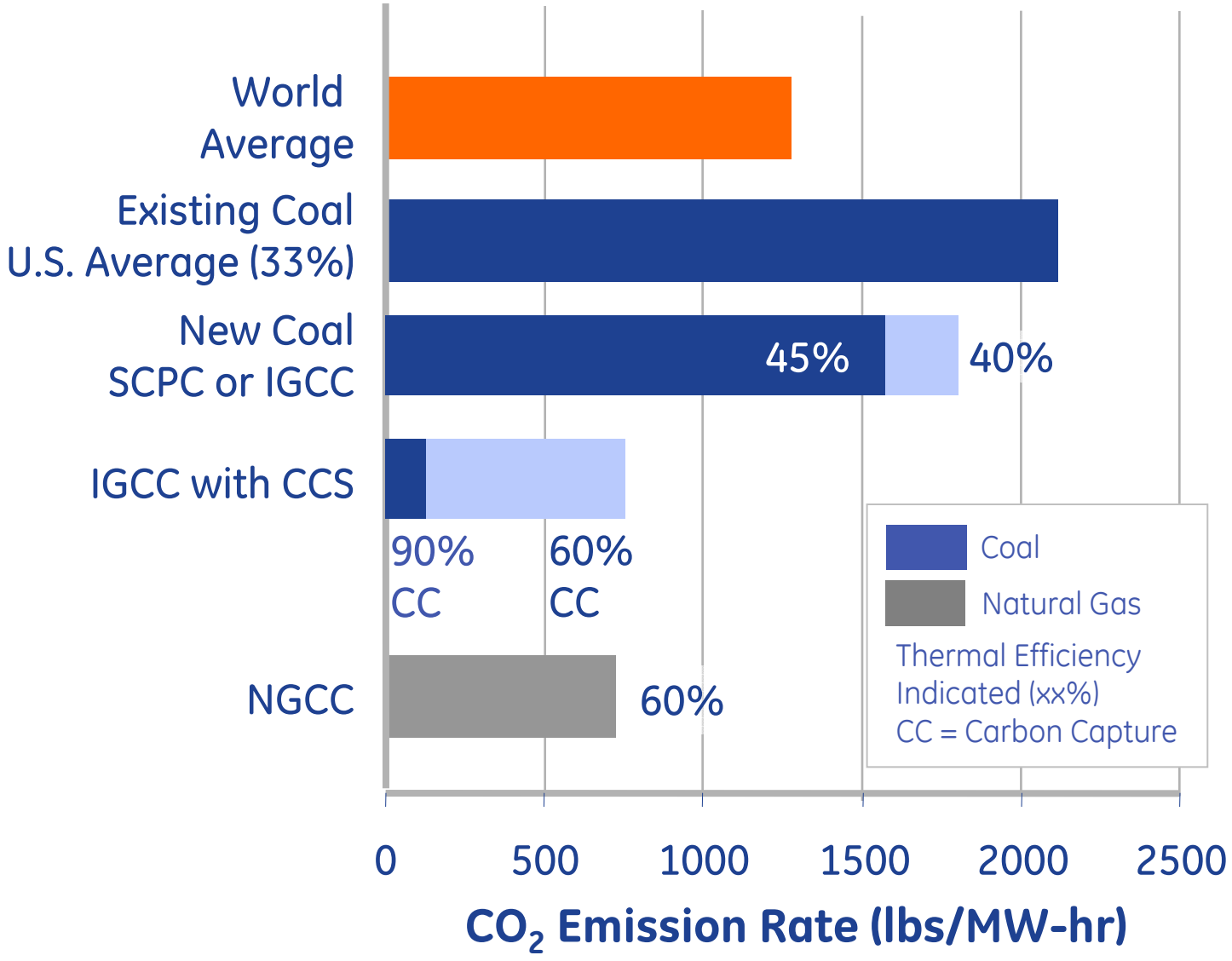


**Norm Shilling**
GE Energy

May 8, 2007

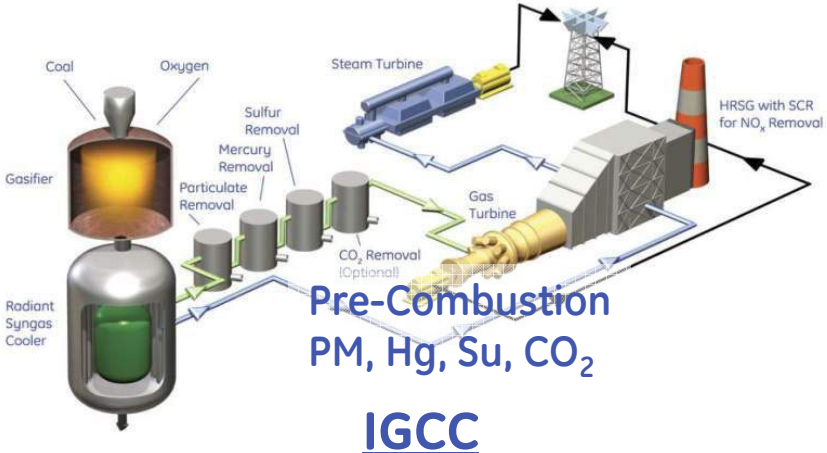
imagination at work

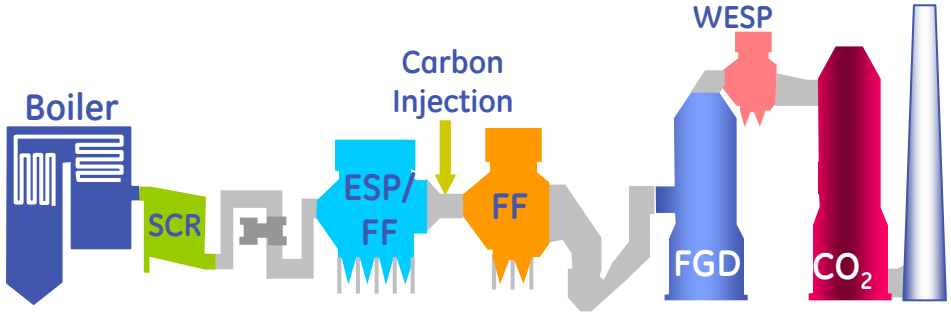
# $CO_2$ Production with Today's Fuels



# IGCC - Cleaner By Design

## Pollution Prevention vs. Pollution Control




### IGCC

- Gasification cleans the coal before it is burned instead of cleaning up the pollution after it is produced.
- $CO_2$ concentration in syngas is high (40%-50%)
- The IGCC Cleaner Coal option increases fuel diversity, reduces emissions, and increases siting and permitting flexibility.

### Pulverized Coal

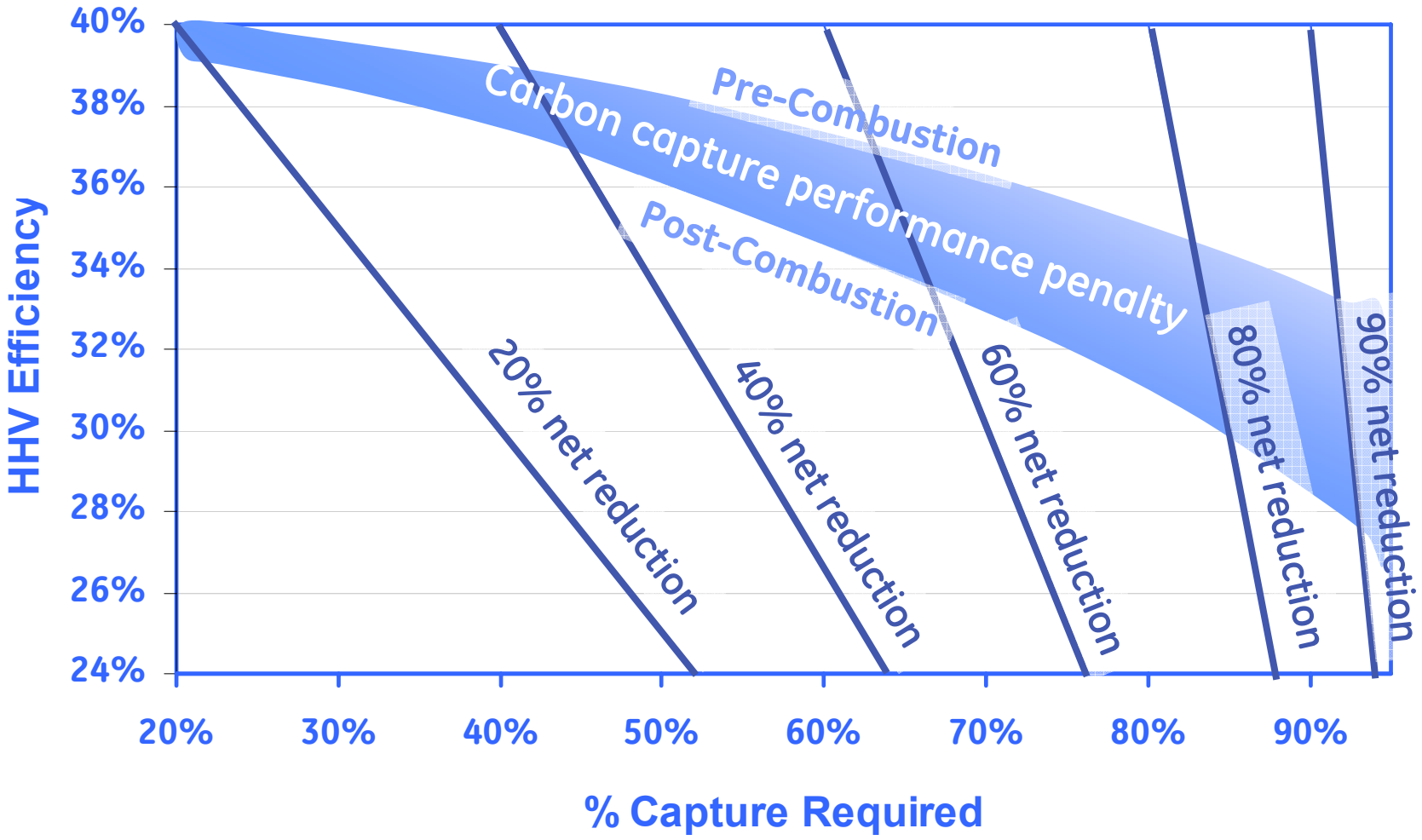
- Removing pollutants requires treating 100 times the gas volume of an IGCC plant.
- $CO_2$ concentration is low (~14% - 1/3 that of syngas)
- Higher criteria & HAPS emissions than an average IGCC plant
- Limestone sulfur removal adds 3%-4% to $CO_2$ emissions

# Carbon Capture Technology

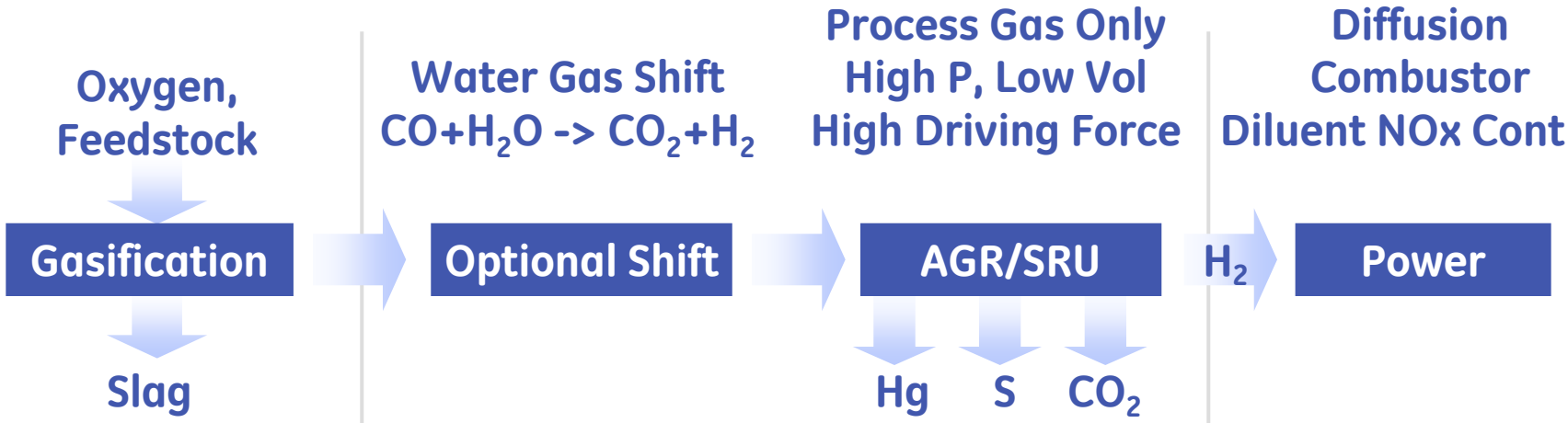
| | Pathways | Technologies | $CO_2$ $/MT[1] |
|---|---|---|---|
| Today | Post-Combustion | • Amine Scrubbing | $40[1] |
| | Pre-Combustion | • IGCC | $19[1] |
| Developing | Post-Combustion | • Oxy-Combustion | ~$30[1] |
| | | • Chilled Ammonia | -- |
| | | • Chemical Looping | -- |
| | Pre-Combustion | • Membranes $O_2/CO_2/H_2$ | -- |
| | | • High efficiency shift | -- |
| | | • Pre-mix $H_2$ combustor | -- |

[1] The Future of Coal, MIT 2007 Coal Energy Study, same technology basis

# Efficiency & Net $CO_2$ Reduction



# Carbon Removal…a Proven Process




## Proven Gasification

- 62 GE licensed gasification units operating worldwide
- 12 with solid feedstock

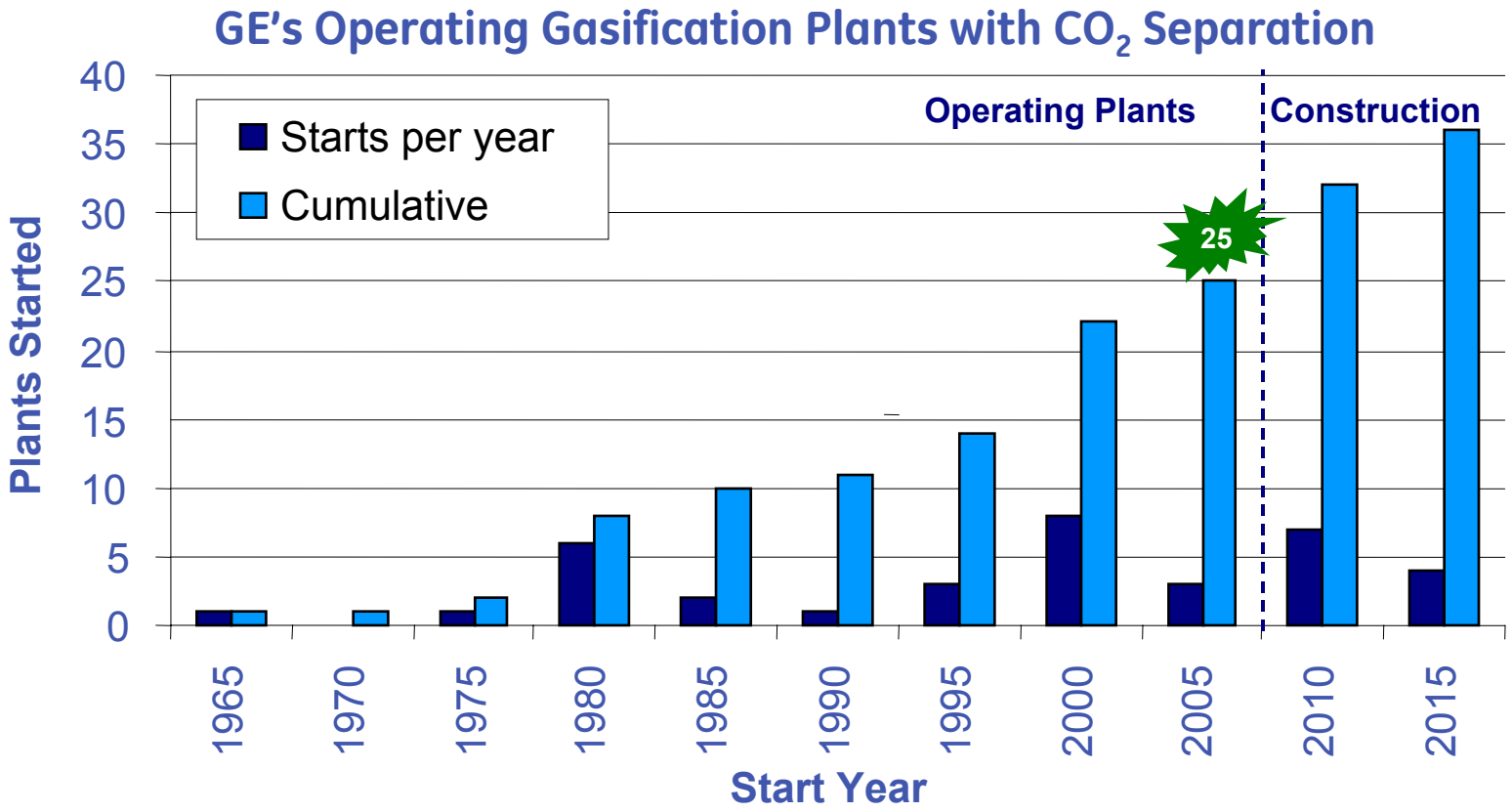
## Proven Process Technology

- 25 GE licensed gasification units operating worldwide using shift reaction to produce $H_2$
- 8 with solid feedstock
- 25 GE licensed units operating worldwide using AGR technology to remove $CO_2$ from shifted syngas
- 8 with solid feedstock

## Proven Turbines

- 25 GE gas turbines operating at 50%+ $H_2$
- F-class combustion validation up to 90% $H_2$

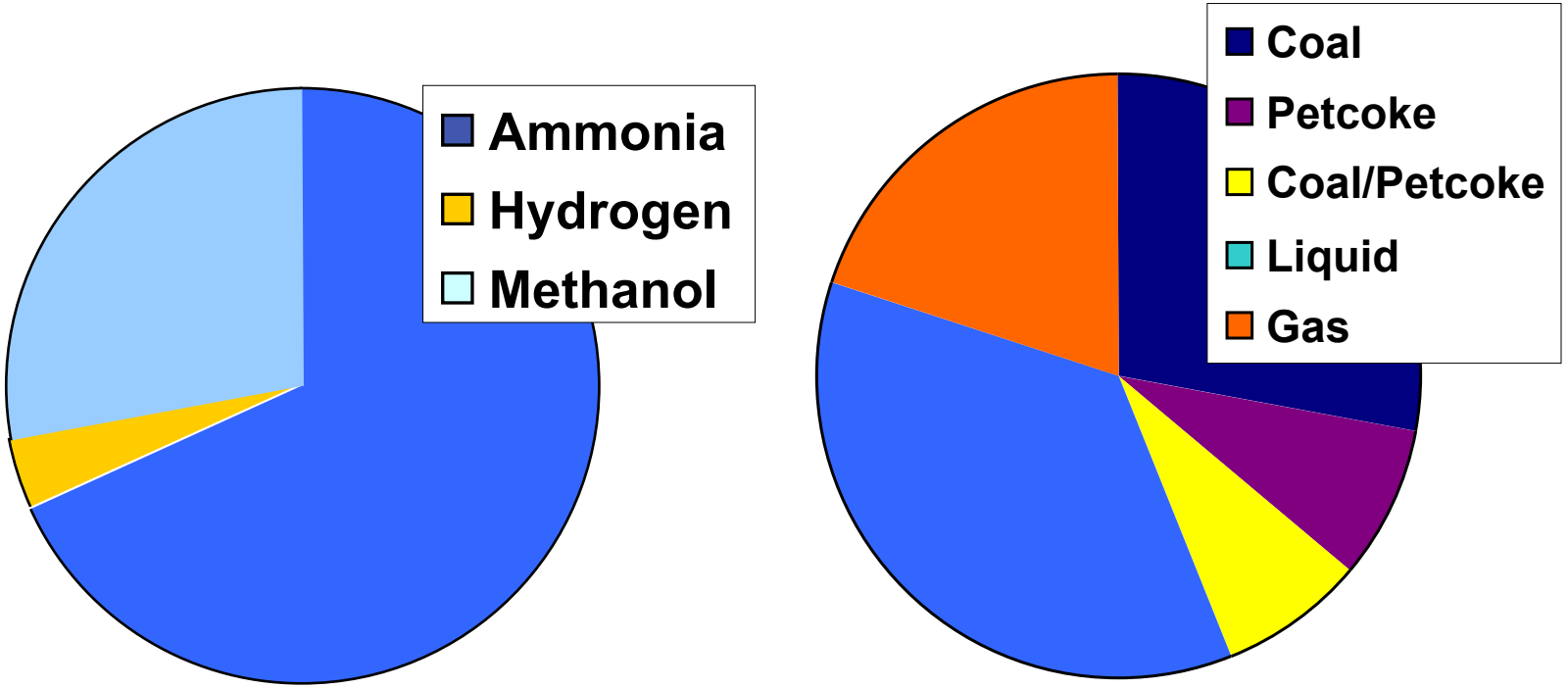
# Proven Gasification/$CO_2$ Capture




## Gasification w/ $CO_2$ Capture is over 50 yrs old

- First GE gasification plant w/ CO2 removal: Spencer Chemical, 1953
- 25 operating plants (8 solids) over last 40 years

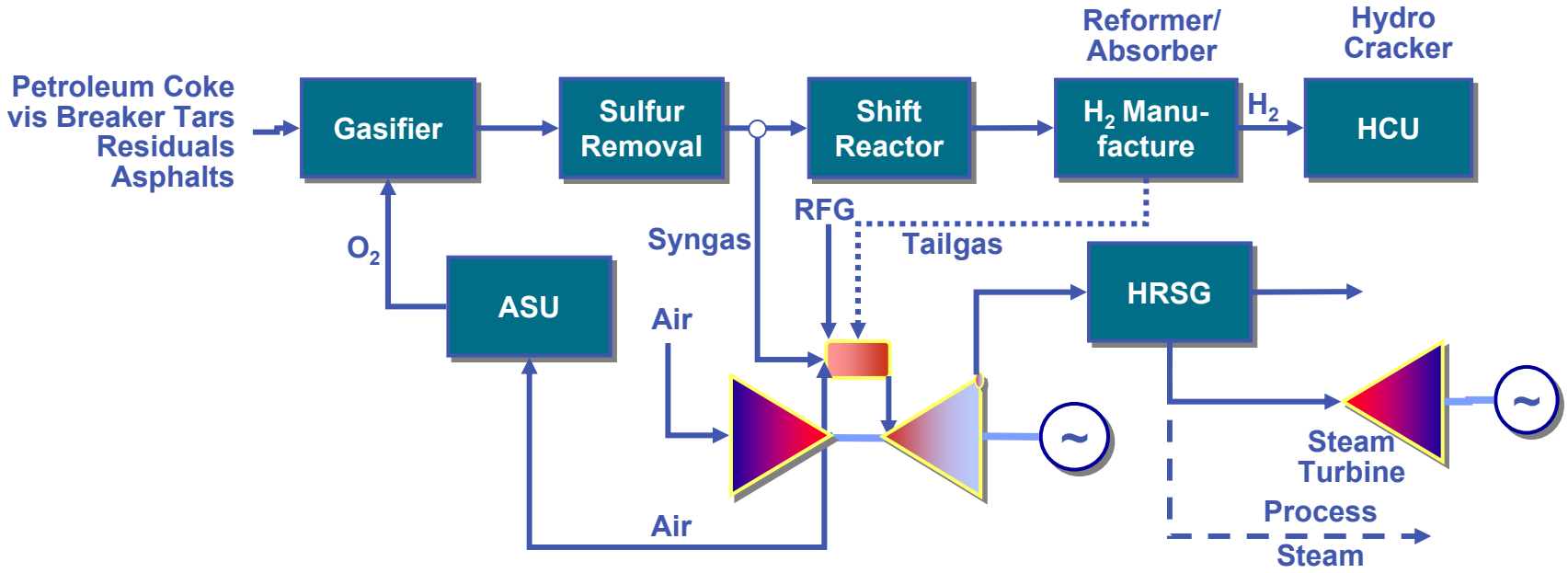
# Gasification Capture Experience




## Capture+Shift Equivalency to CC

- Ammonia Plant => 90% $CO_2$ Capture
- Methanol Process => 70% $CO_2$ Capture

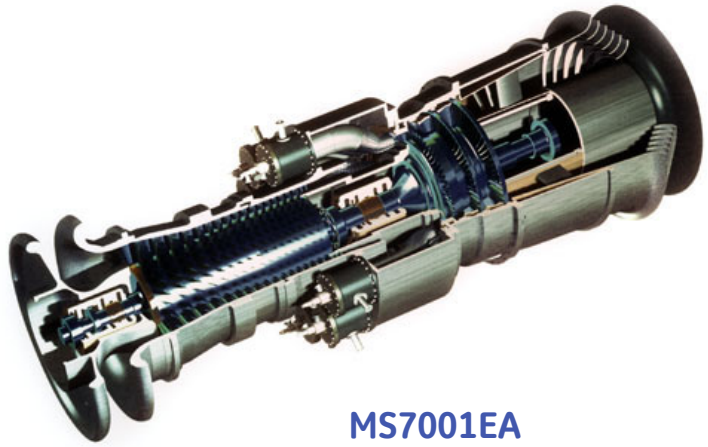
# $H_2$ in Refinery IGCC



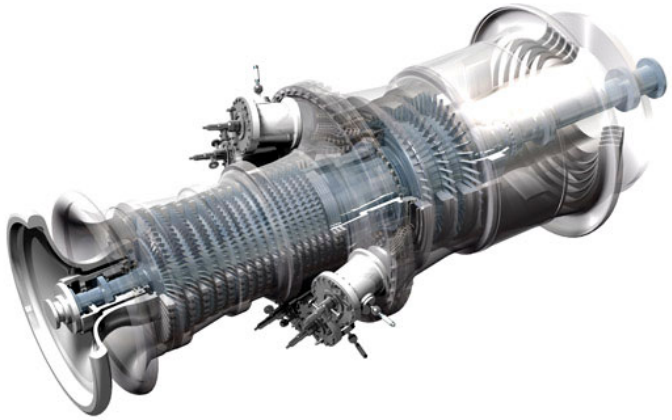
# Proven Hydrogen Turbines

| Site | Model | No. | Gas | Features |
|---|---|---|---|---|
| ExxonMobil Singapore | MS6241FA | 2 | IGCC | 44.5% H2 |
| Georgia Gulf | MS7001EA | 3 | Blend | Methane+50% H2 |
| SUV Vresova | MS9001E | 2 | IGCC | 46.8% H2 |
| BASF/ Geismer | MS6001B | 1 | PG | Up to 80% H2 |
| Koch Refinery | MS6001B | 1 | RFG | 12% to 50% H2 |
| Daeson Korea | MS6001B | 1 | PG | up to 95% H2 |
| Shell Int'l | MS5001P | 1 | RFG | 60% H2, propane |
| Reutgerswerke | MS3002J | 1 | PG | 60% H2 |
| Tenerife | MS6001B | 1 | RFG | ~70% H2 |
| Cartagena | MS6000B | 1 | RFG | 66% H2 |
| San Roque | MS6000B | 2 | RFG | 70% H2 |

WG=Waste Gas; RFG=Refinery Gas; Steel=COG+BFG; TG=Tail gas



MS7001EA



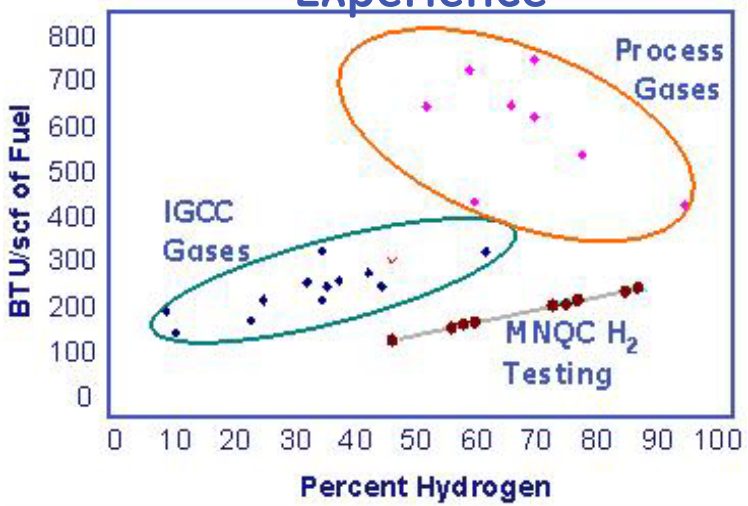
MS6001B

| Site | Model | No. | Gas | Features |
|---|---|---|---|---|
| Antwerpen | MS6000B | 1 | RFG | 78% H2 |
| Puertollano | MS6000B | 2 | RFG | Up to 60% H2 |
| La Coruna | MS6000B | 1 | RFG | Up to 52% H2 |
| Rotterdam | MS6000B | 1 | RFG | 59% H2 |
| AGIP/ Milazzo | MS5001P | 1 | RFG | 30% to 50% H2 |
| Cochin Refineries | MS5001P | 1 | RFG | 50% H2 |
| Mobil/ Paulsboro | MS5001P | 2 | RFG | 20% to 60% H2 |
| Uhde NUP | MS3002J | 1 | TG | ~60% H2 |
| Donges | GE10 | 1 | RFG | 76% H2 |
| Zarqa Refinery | PGT10 | 1 | RFG | 82% H2 |

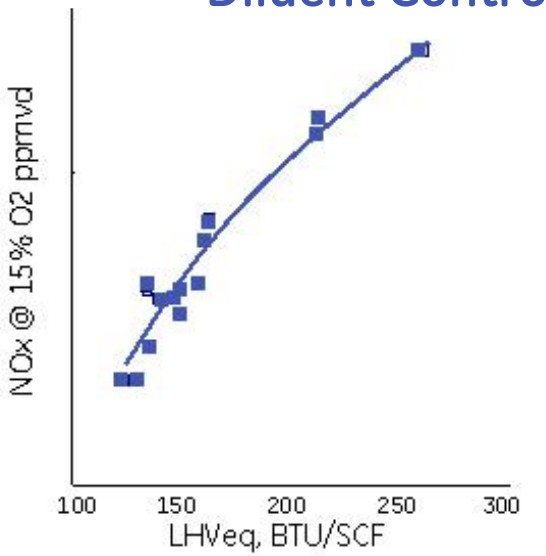
# F-Class Combustor - Proven for $H_2$

- Diffusion flame technology
- Diluent addition used to control NOx ($N_2$ or steam)
- Typically achieves 15ppm NOx (with diluent)
- FA & FB combustion validation completed


## Experience



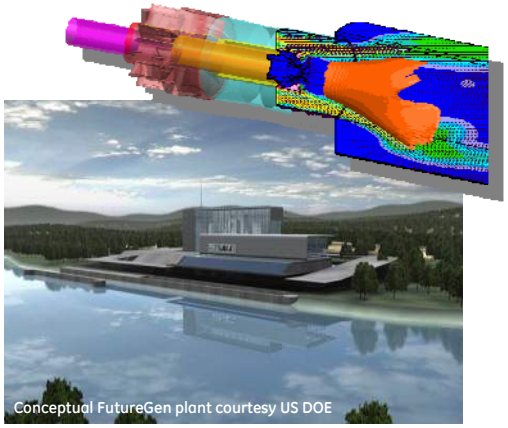

## Diluent Control



# IGCC & CCS Combustion Landscape

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

GE PG7321FB-H2



Conceptual FutureGen plant courtesy US DOE

# Storage

| Pathways | Technologies | $CO_2$ $/Ton |
|---|---|---|
| **Geological** | • Compression into oil & gas reserves, saline aquifers, or deep coal seams | **$5-10** |
| **Terrestrial** | • Forest preservation<br>• Algae<br>• Microbes | **$50**<br>**$120**<br>**NA** |
| **Ocean** | • Deep ocean injection<br>• Hydrates for permanence | **$50** |

**Cost = capture + storage + transport**

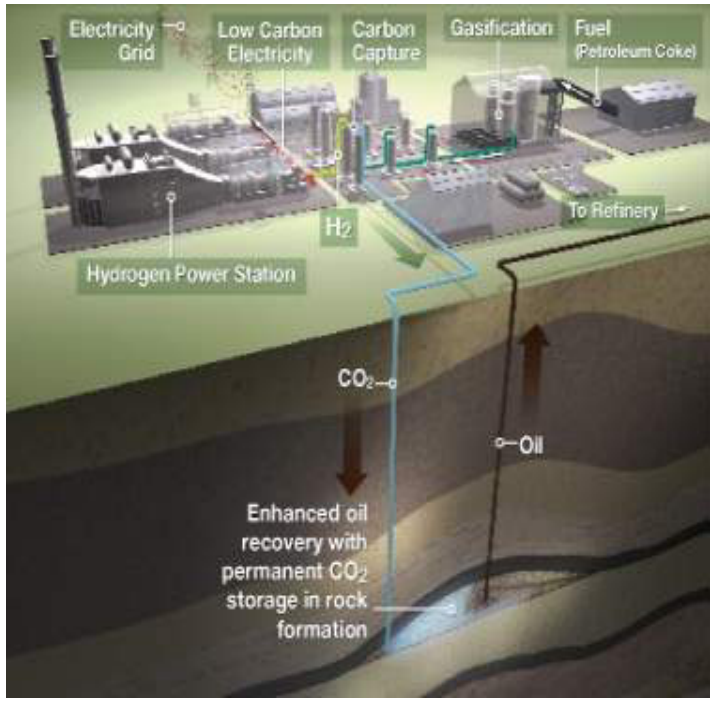
# Status of $CO_2$ use for EOR in the US[1]

## *A lot has been safely done in the past.*

- Approximately 80 $CO_2$-EOR projects:
  - Natural $CO_2$
  - 3000 miles of $CO_2$ distribution pipelines in Permian Basin (U.S.)
  - Enhanced oil recovery efficiency ranges from 11 to 15%
- Multiple oil reservoirs available for $CO_2$-EOR.
- $CO_2$-EOR projects have been limited by $CO_2$ quantity.

[1]U.S. Dept. Of Energy (Feb. 2006)

# GE and BP Accelerating Low Carbon Power Generation




**Carson Hydrogen Power Project**

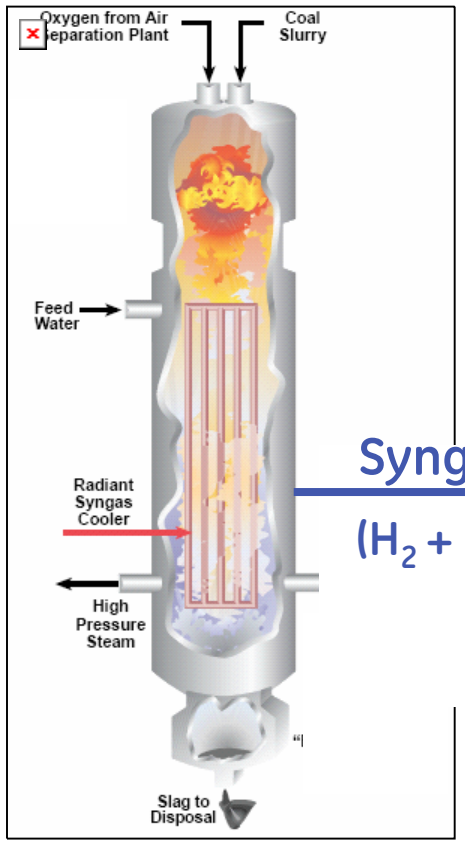
## Hydrogen Power Projects

- Utilize advantaged fossil fuels (coal, petcoke)
- Produce high H2 fuel gas to burn in gas turbines
- Capture $CO_2$ (~90%)
- Utilize $CO_2$ for Enhanced Oil Recovery (EOR)
- Future storage in Saline Aquifers

## Value Through Collaboration

- Combine technology company with an operations company
- Leaders in gasification, power and CCS
- 10+ projects over next decade
- Carson, CA is first gasification project

# Gasification – Multiple Coal Solutions




Gasification Technology

Syngas

$(H_2 + CO)$

- IGCC
  - Carbon Capture → Hydrogen
  - Polygen → Hydrogen
  - Greenfield
  - Refueling
  - Site Repowering
- Refineries
  - Hydrogen
  - Steam
  - Power
- Chemicals
  - Methanol
    - Formaldehyde
    - MTBE
    - Acetic acid
    - Amine
    - DME
  - Ammonia
    - Urea
    - Ammonia nitrate/sulfate
  - Oxochemicals: Butanol, Ethylhexanol
- Coal to Liquids → Cleaner Diesel

# Summary

- New coal capacity build depends on economic feasibility of carbon capture
- IGCC with pre-combustion capture is proven and ready to provide low $CO_2$ power from coal
- IGCC provides the lowest avoided cost of $CO_2$ capture today
- Key IGCC pre-combustion capture projects in development
- Advances in gasification, separation and hydrogen combustion will maintain IGCC leadership for CCS

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# IGCC Cleaner Coal --Ready for Carbon Capture

## Q&A

imagination at work