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**PRODUCTS** 

# New Gas Turbine Integration Options for ITM Oxygen in Gasification Applications

VanEric Stein

Phil Armstrong

Ted Foster

*Air Products and Chemicals, Inc.*

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# Cryogenic Distillation is state-of-the-art for tonnage oxygen

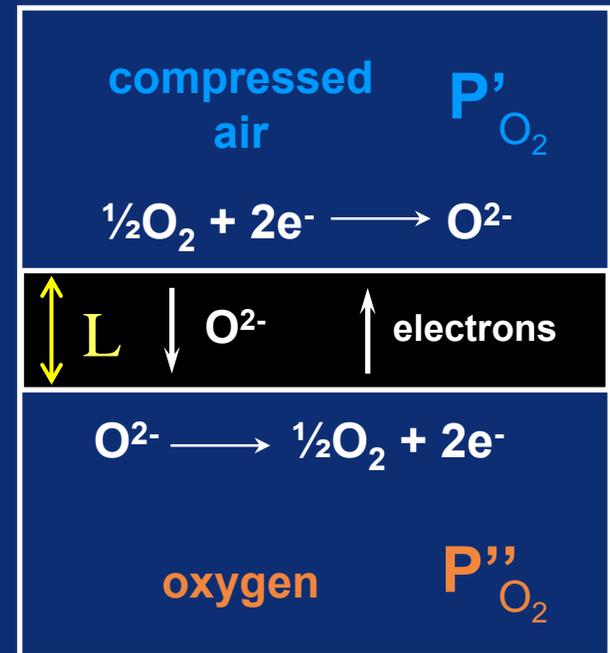


- Mature, reliable technology
- Energy intensive
- Requires 100's of equilibrium stages
- Represents ~15% of IGCC capital cost
- Consumes ~15% of IGCC gross power output

# Ion Transport Membranes (ITMs) produce high-purity oxygen at high flux

- Mixed-conducting ceramic membranes (non-porous)
- Typically operate at 800-900 °C
- 100% selective for O<sub>2</sub>

- O<sub>2</sub> flux  $\propto \frac{1}{L} \ln \left( \frac{P'_{O_2}}{P''_{O_2}} \right)$

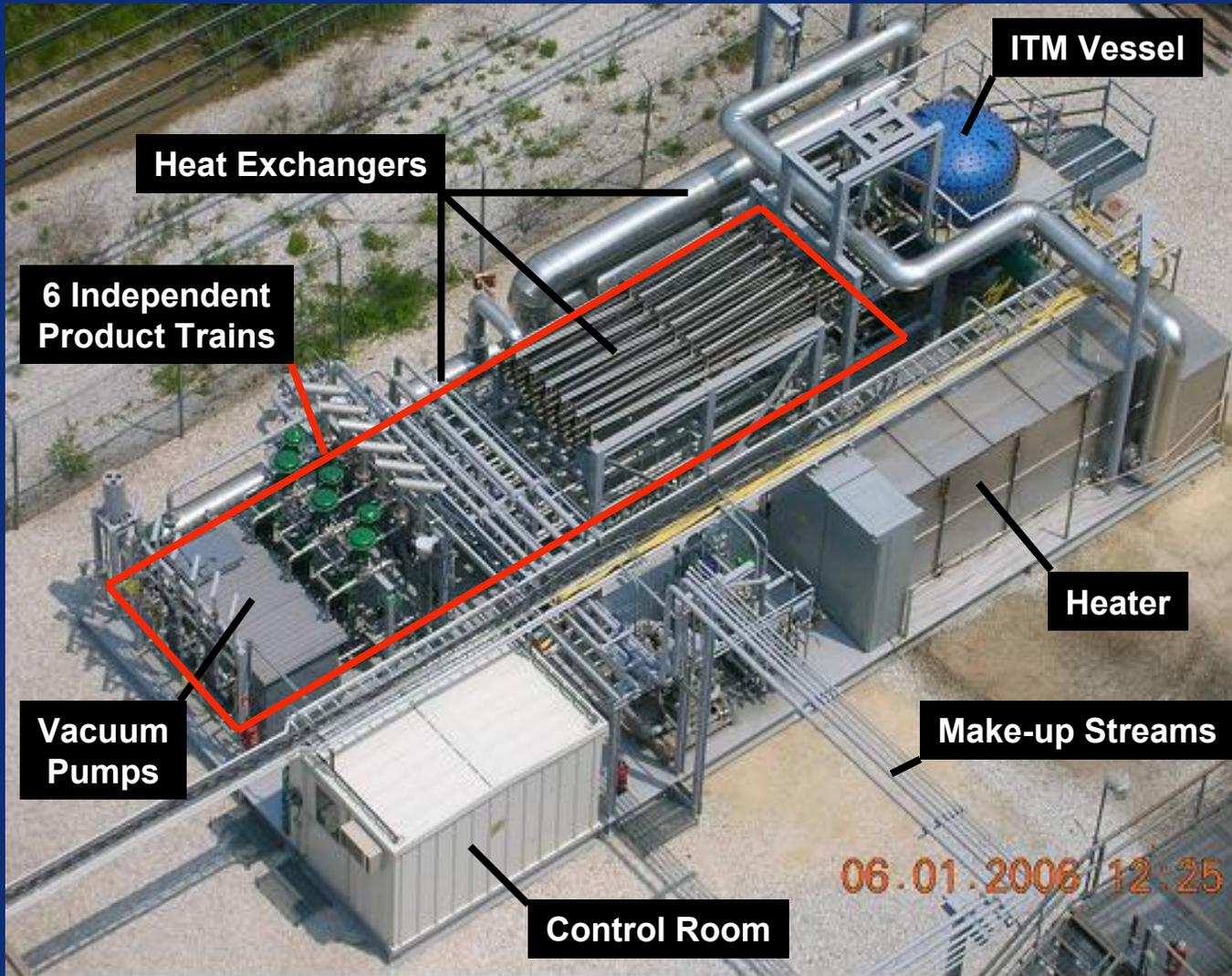


# We are building ½-ton/day commercial-scale ITM modules ...

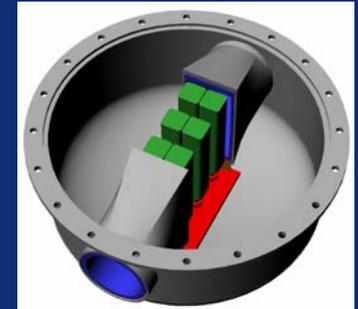
- Single-stage air separation yields **compact** designs
- **Low  $\Delta P$**  on the air side
- **All-ceramic** construction
- **High-temp** process has better **synergy w/ gasification systems**



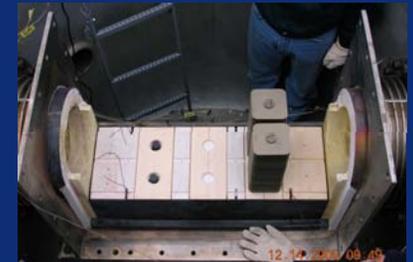
# ... and testing them in pilot plant



ITM Vessel Internals



2 Modules Installed



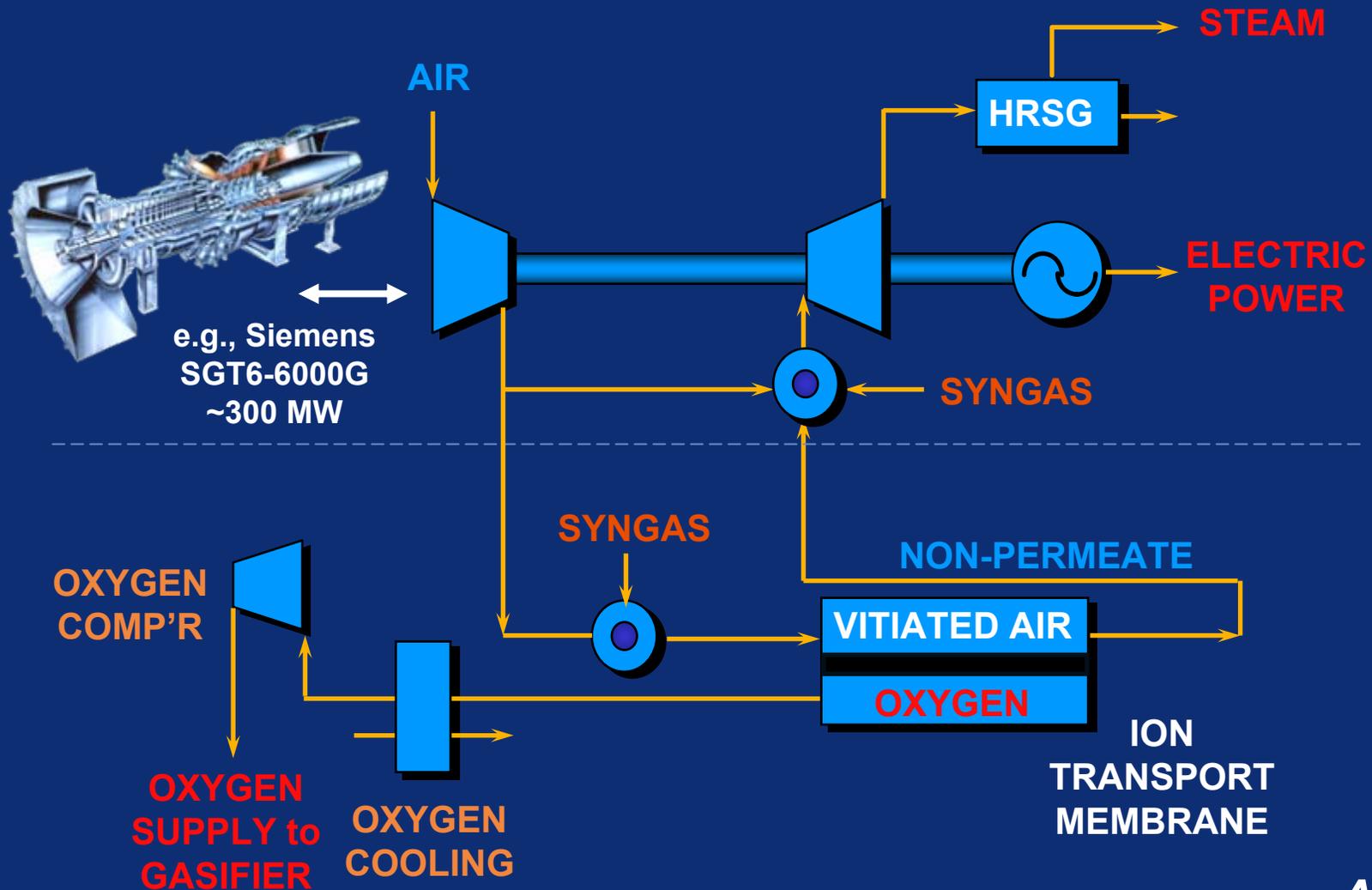
Flow Duct Installed



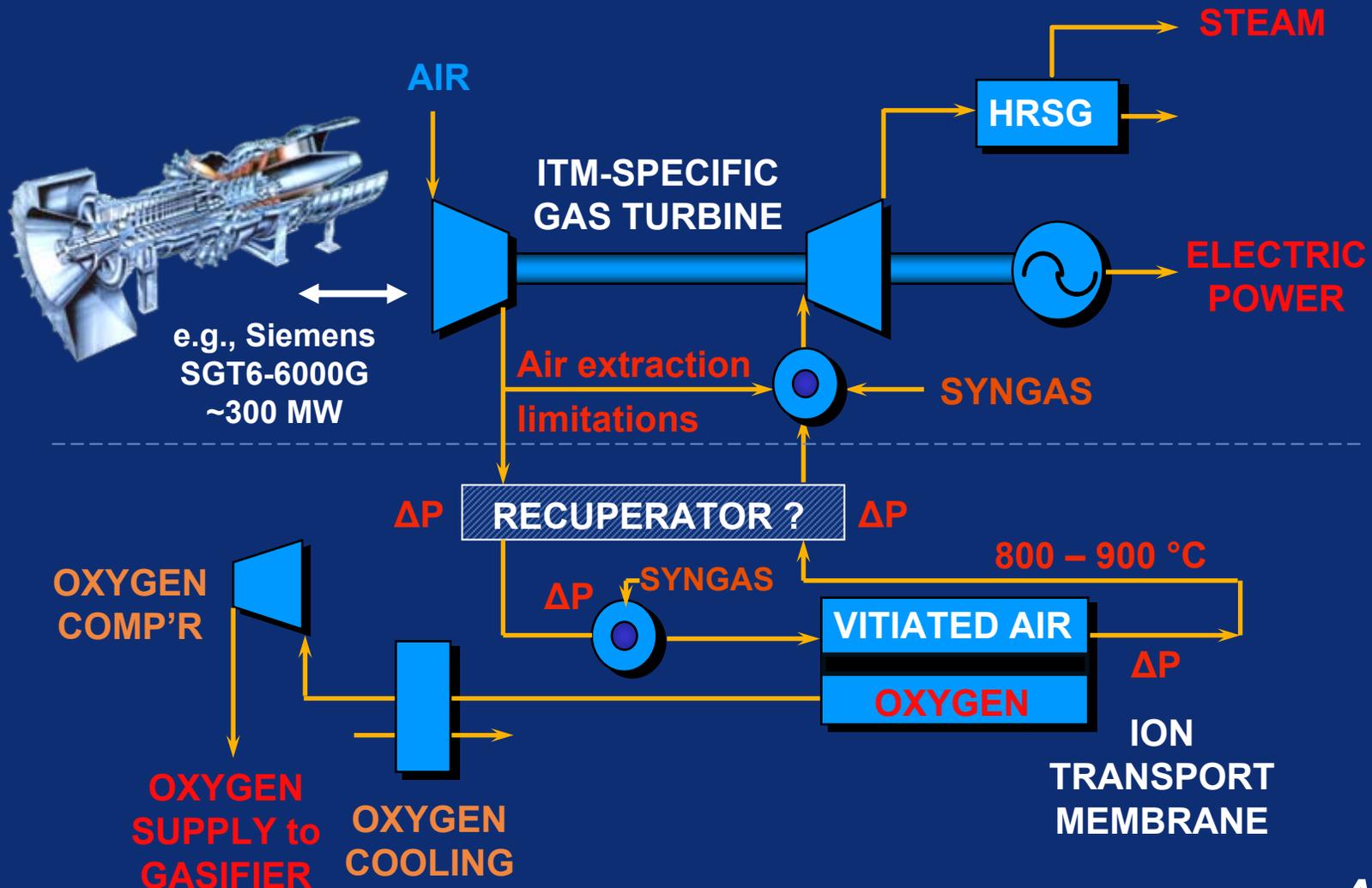
# Initial pilot plant testing highly successful

- Several trials with 1/2-ton/day modules during the last year
- Demonstrated **>99% oxygen purity** from commercial-scale module and seal
- Oxygen **flux** consistently **met or exceeded expectations** and has remained **steady over multi-week tests**
- Just completed retrofit of **advanced control system** to improve reliability during startup/shutdown cycles

# ITM Oxygen integrates well with gas turbine power cycles

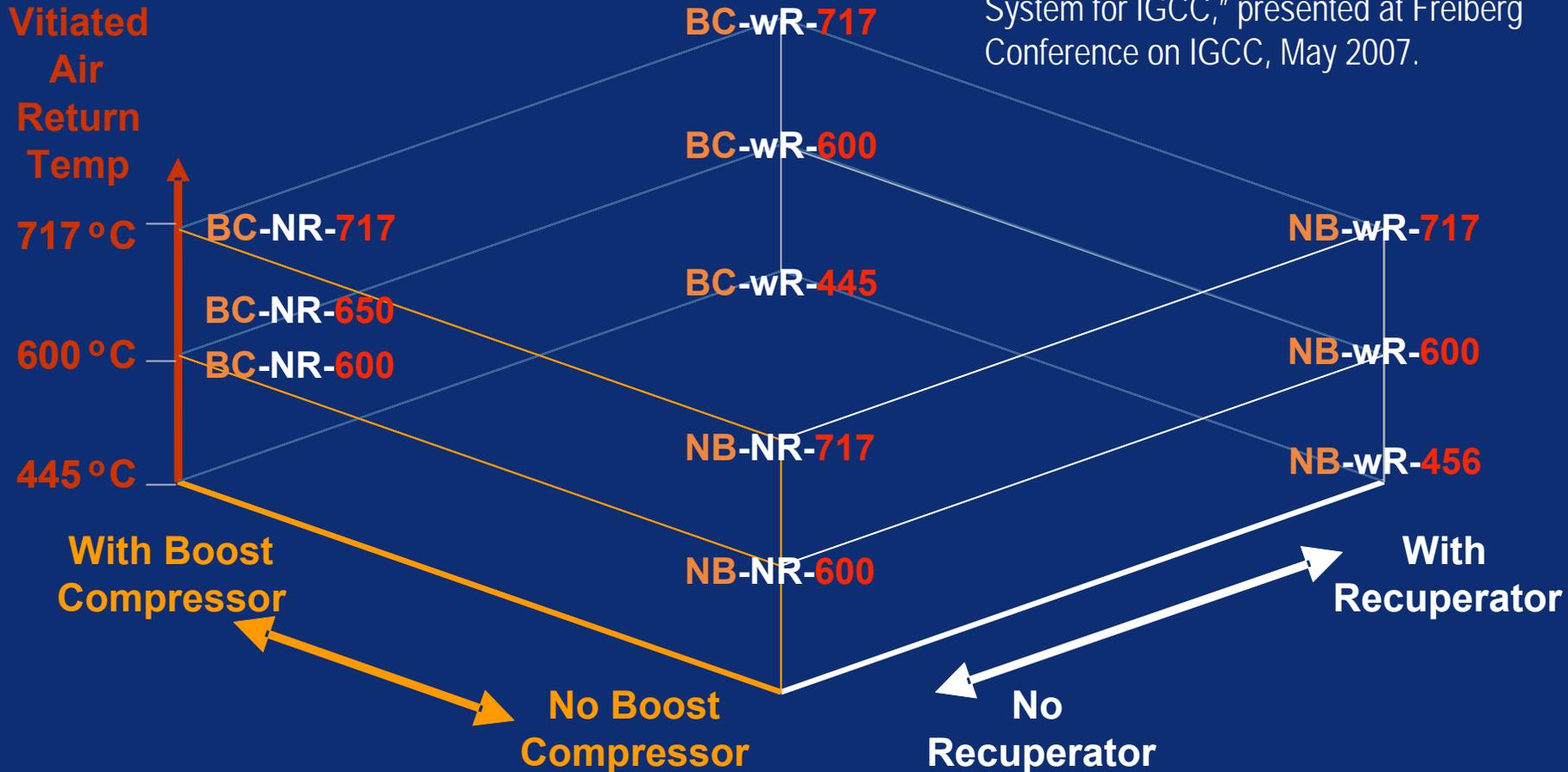


# Full integration with advanced gas turbine poses challenges ...

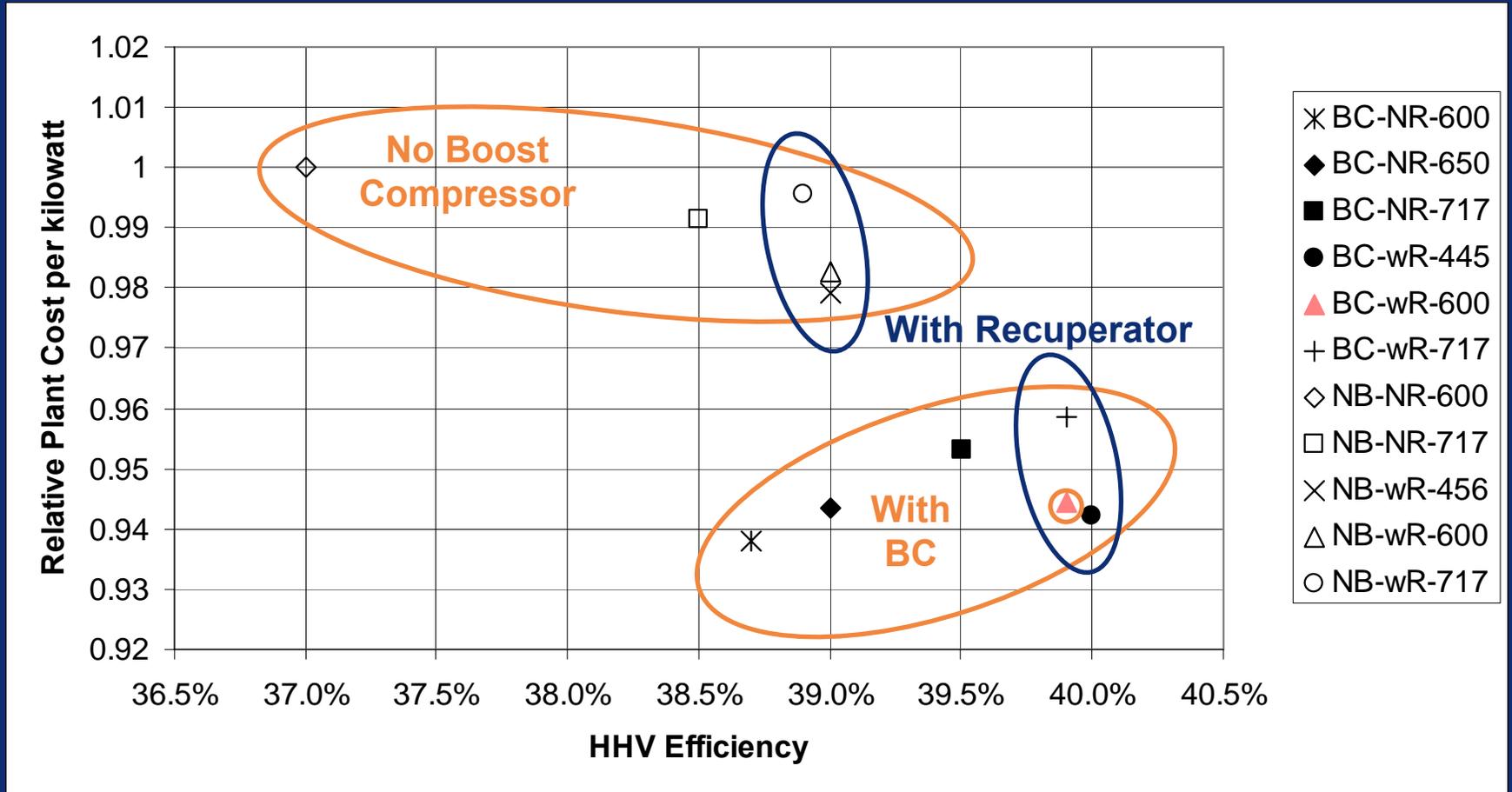


# Multi-dimensional evaluation determined optimum configuration

Ref: "Integrated ITM Oxygen – Gas Turbine System for IGCC," presented at Freiberg Conference on IGCC, May 2007.



# Boost compressor / recuperator yields best overall IGCC

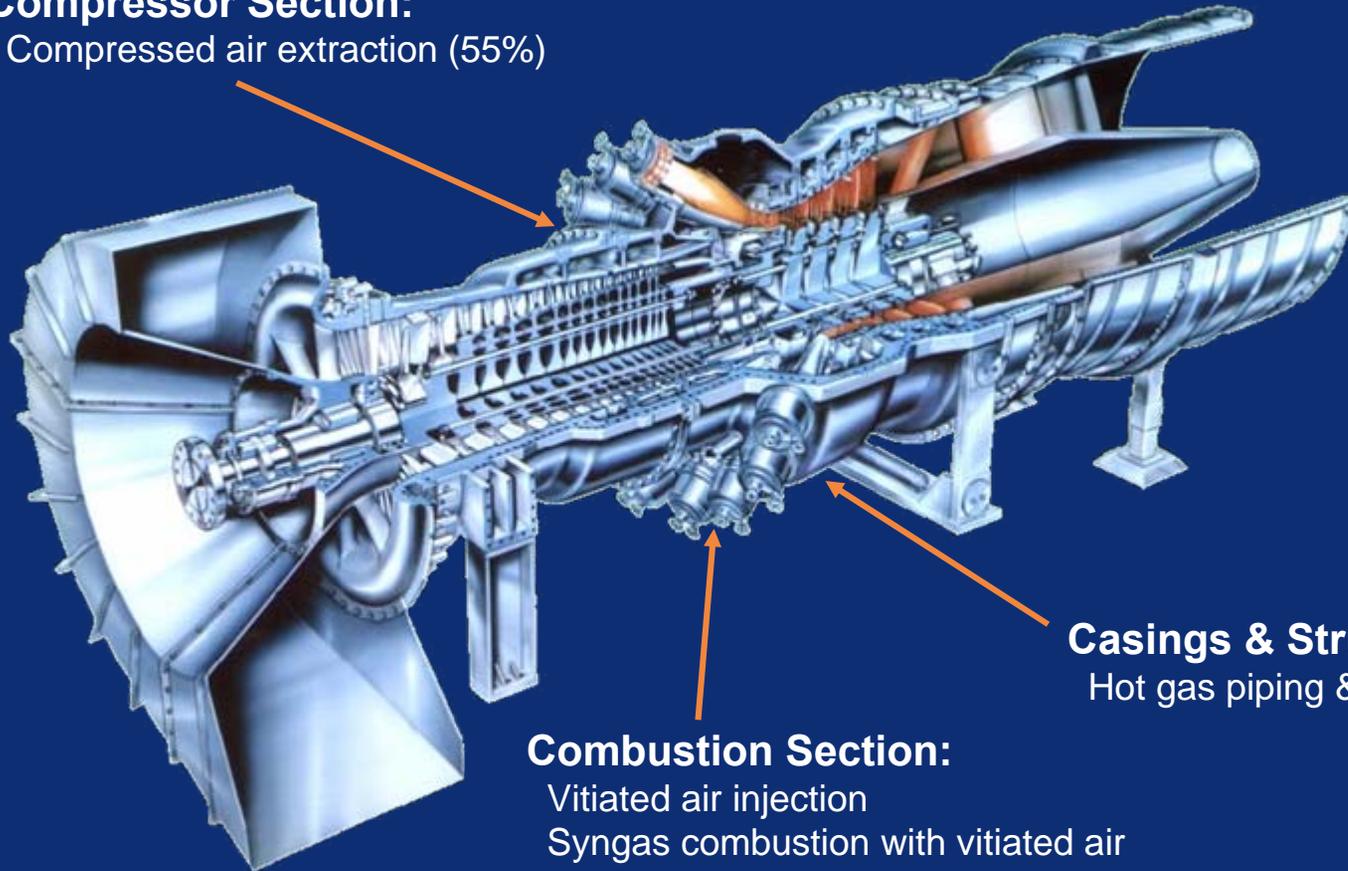




# SGT6-6000G gas turbine modifications for ITM Oxygen

## Compressor Section:

Compressed air extraction (55%)

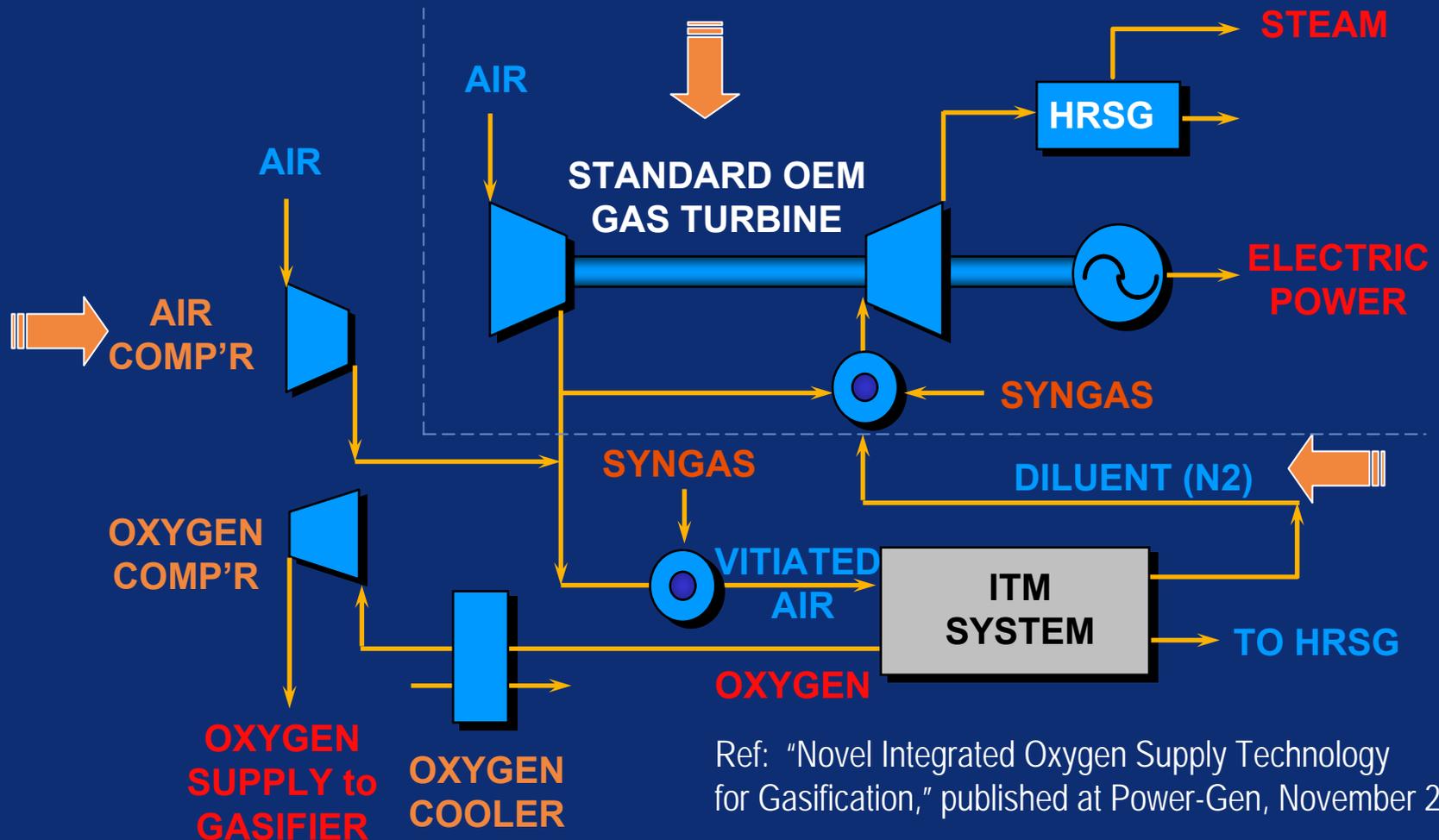


**Casings & Structural:**  
Hot gas piping & manifolding

## Combustion Section:

Vitiated air injection  
Syngas combustion with vitiated air

# Partial integration with standard GT also achievable ...



# ... while preserving significant benefits for IGCC

- Integration with **modified ITM Oxygen cycle** can reduce **IGCC specific capital cost by 9%** and increase efficiency by 1.2%, with **25% capital savings in oxygen production**

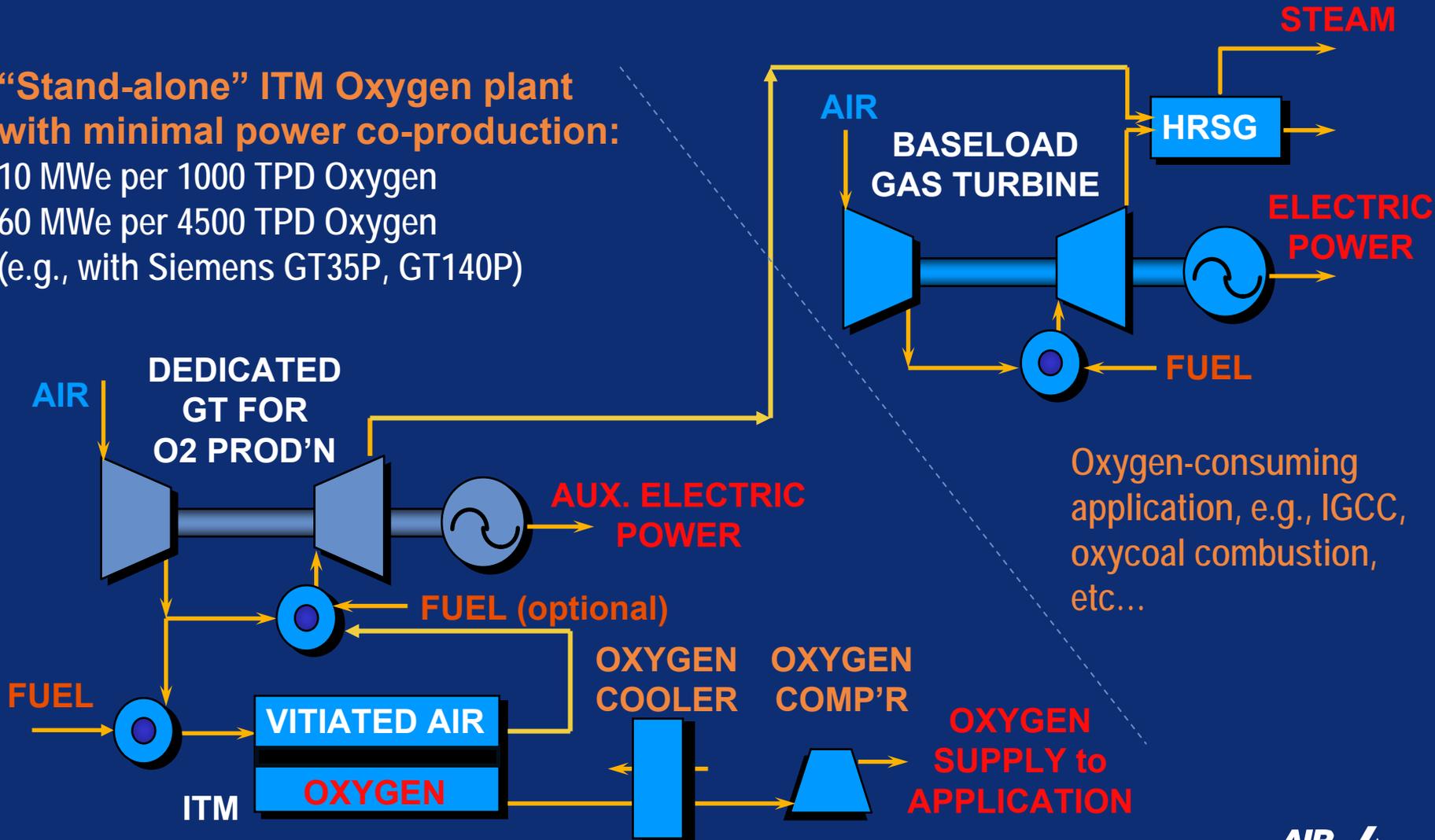
<b>2-on-1 GE 7FA+e design basis</b>	<b>Cryo O2</b>	<b>ITM O2</b>	<b>Δ ( %)</b>
<b>IGCC Net Output (MW)</b>	543	627	+ 15
<b>IGCC Net Efficiency (% HHV)</b>	38.4	38.9	+ 1.2
<b>Oxygen Plant Cost (\$/sTPD O<sub>2</sub>)</b>	25,000	18,700	- 25
<b>IGCC Specific Capital Cost (\$/kW)</b>	1,500	1,368	- 9

- ITM Oxygen plant capacity: 4,550 sTPD oxygen + 13,200 sTPD diluent

# Minimal integration using dedicated ITM GT offers flexible flowsheet

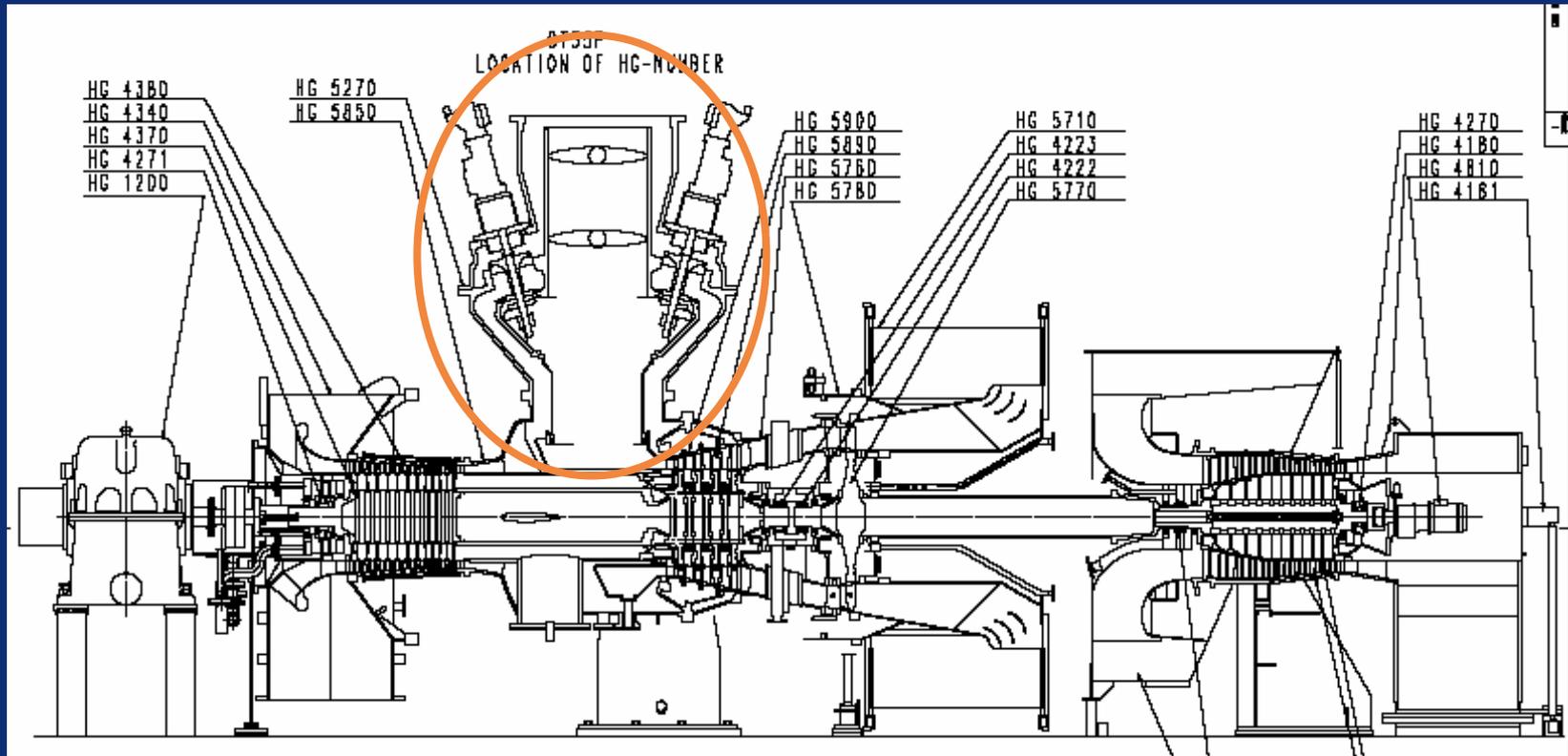
**“Stand-alone” ITM Oxygen plant with minimal power co-production:**

10 MWe per 1000 TPD Oxygen  
 60 MWe per 4500 TPD Oxygen  
 (e.g., with Siemens GT35P, GT140P)



Oxygen-consuming application, e.g., IGCC, oxycoal combustion, etc...

# GT35P/GT140P developed for full air extraction and off-board combustion

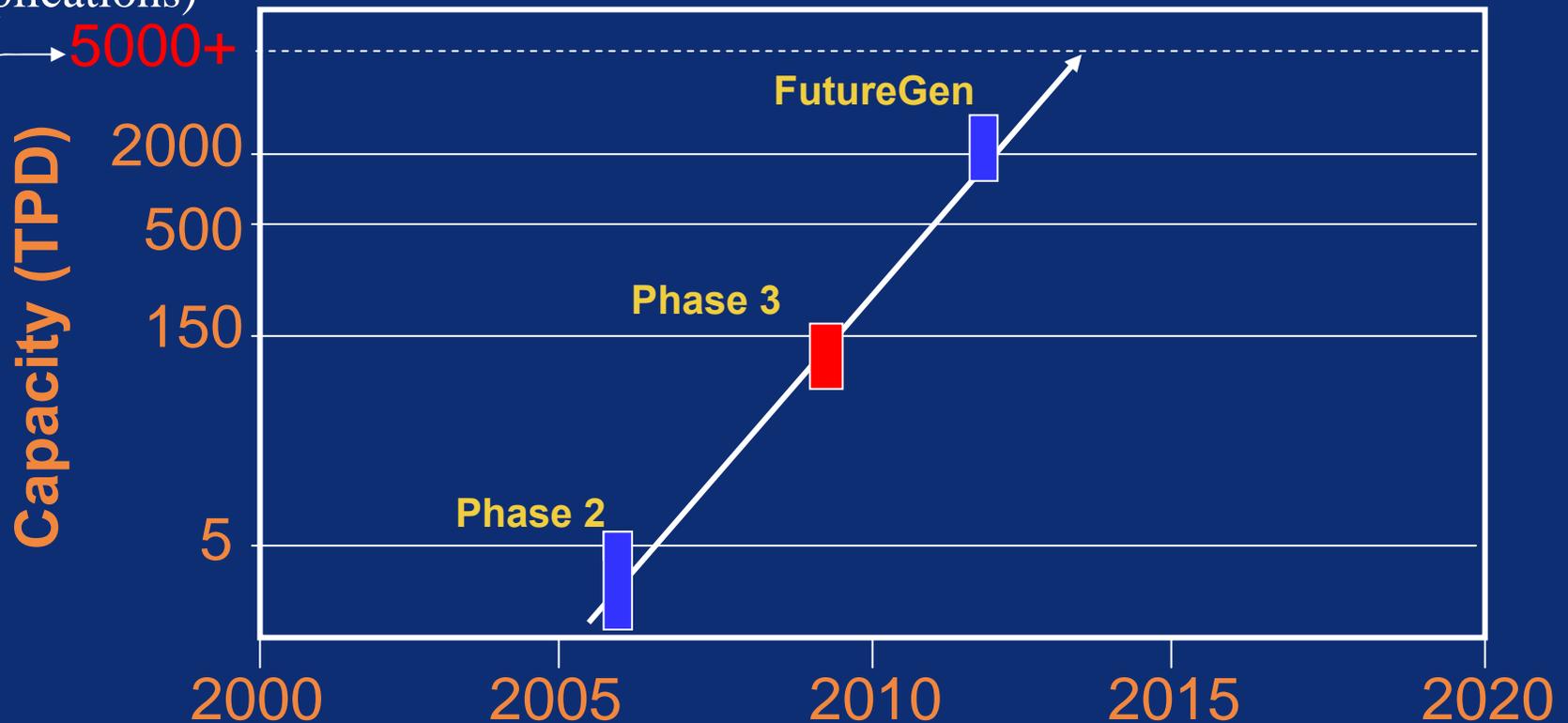


- 6 GT35P PFBC installations world-wide ('89-'98)
- 1 GT140P PFBC installation ('99)

# ITM dev't plan meets FutureGen schedule and market timing

(large energy applications)

5000+



# The future remains bright for ITM Oxygen

- **Commercial-scale ITM Oxygen modules** are being **built and tested** successfully
- **Conceptual full integration** with SGT6-6000G **maximizes ITM benefits** while minimizing GT design / development impact
  - **Partial integration** with standard OEM gas turbine **preserves significant benefits**
  - **Minimal integration** using dedicated ITM GT **offers good early entry prospects**
- Air Products and the DOE are accelerating development of ITM Oxygen to reach **large-tonnage scale for FutureGen** plant

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[www.airproducts.com](http://www.airproducts.com)

[ITM@airproducts.com](mailto:ITM@airproducts.com)

Phone: 610-481-4475

Fax: 610-706-7420