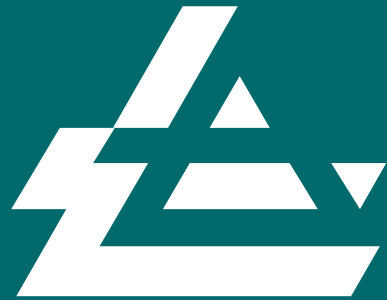


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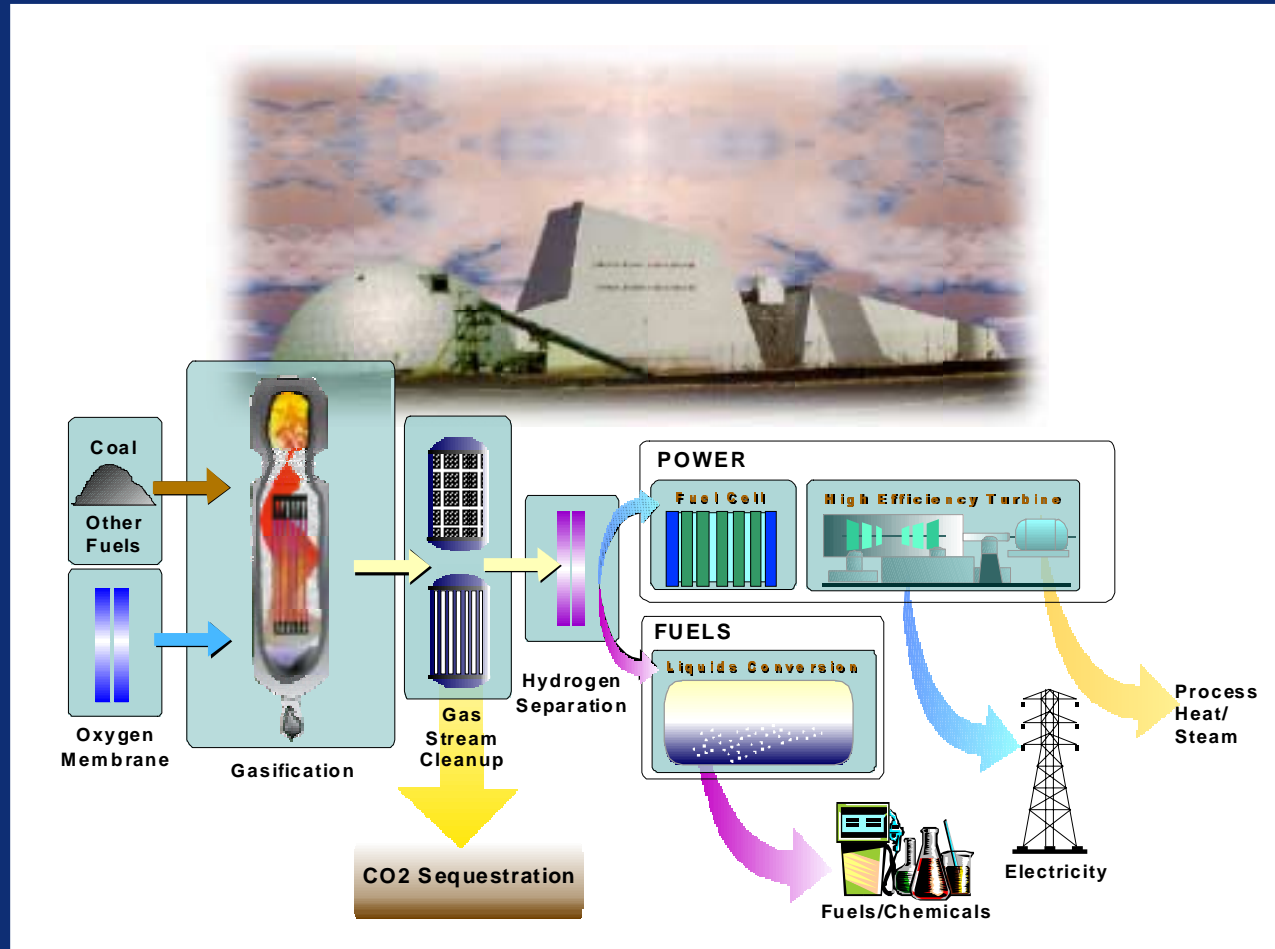


Development of ITM Oxygen Technology for Combustion or Gasification Applications

Phil Winkler

Evolution of Combustion Technology to Support
National Energy Needs
January 15, 2002

Vision 21 includes ceramic membranes for low-cost oxygen

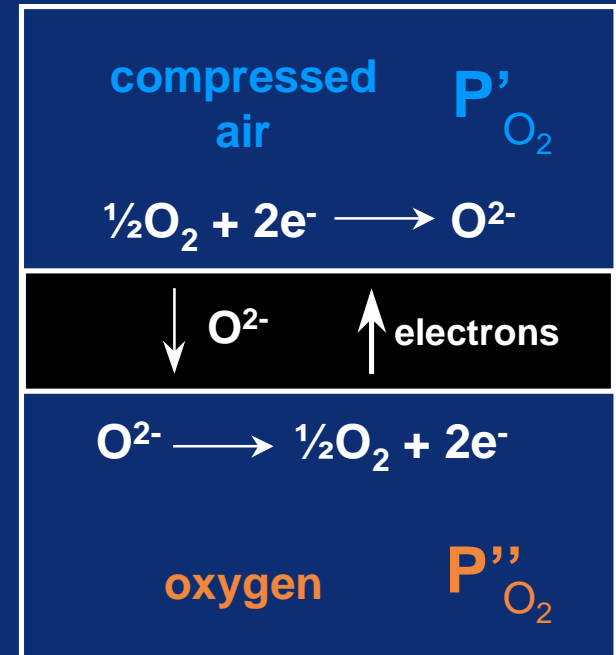


ITMs

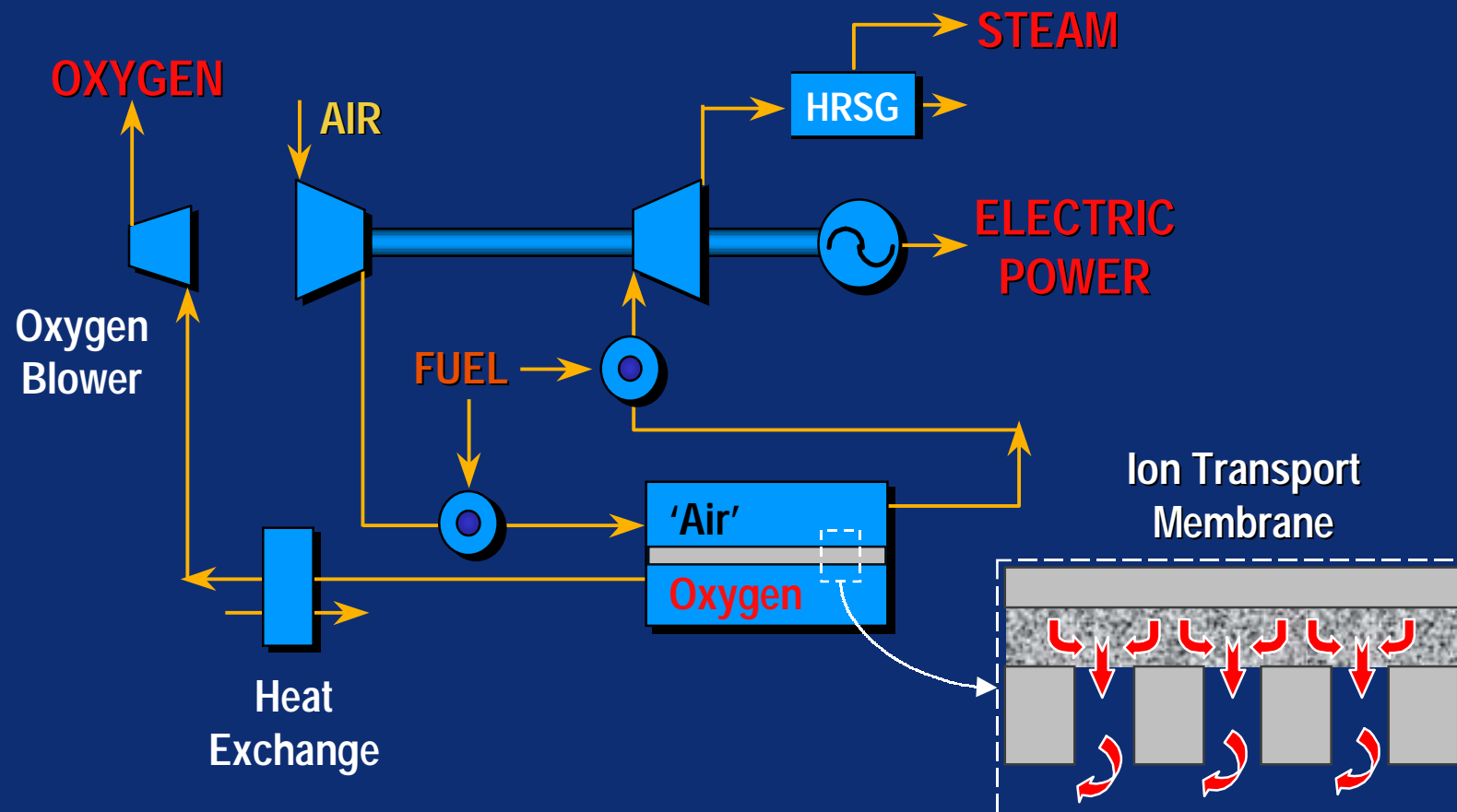
Ion Transport Membranes produce high-purity oxygen

- Mixed-conducting ceramic membranes (non-porous)
- Typically operate at 800-900 °C
- Crystalline structure incorporates oxygen ion vacancies
- Oxygen ions diffuse through vacancies
- 100% selective for O₂

- $$j_{O_2} \propto \ln\left(\frac{P'_{O_2}}{P''_{O_2}}\right)$$



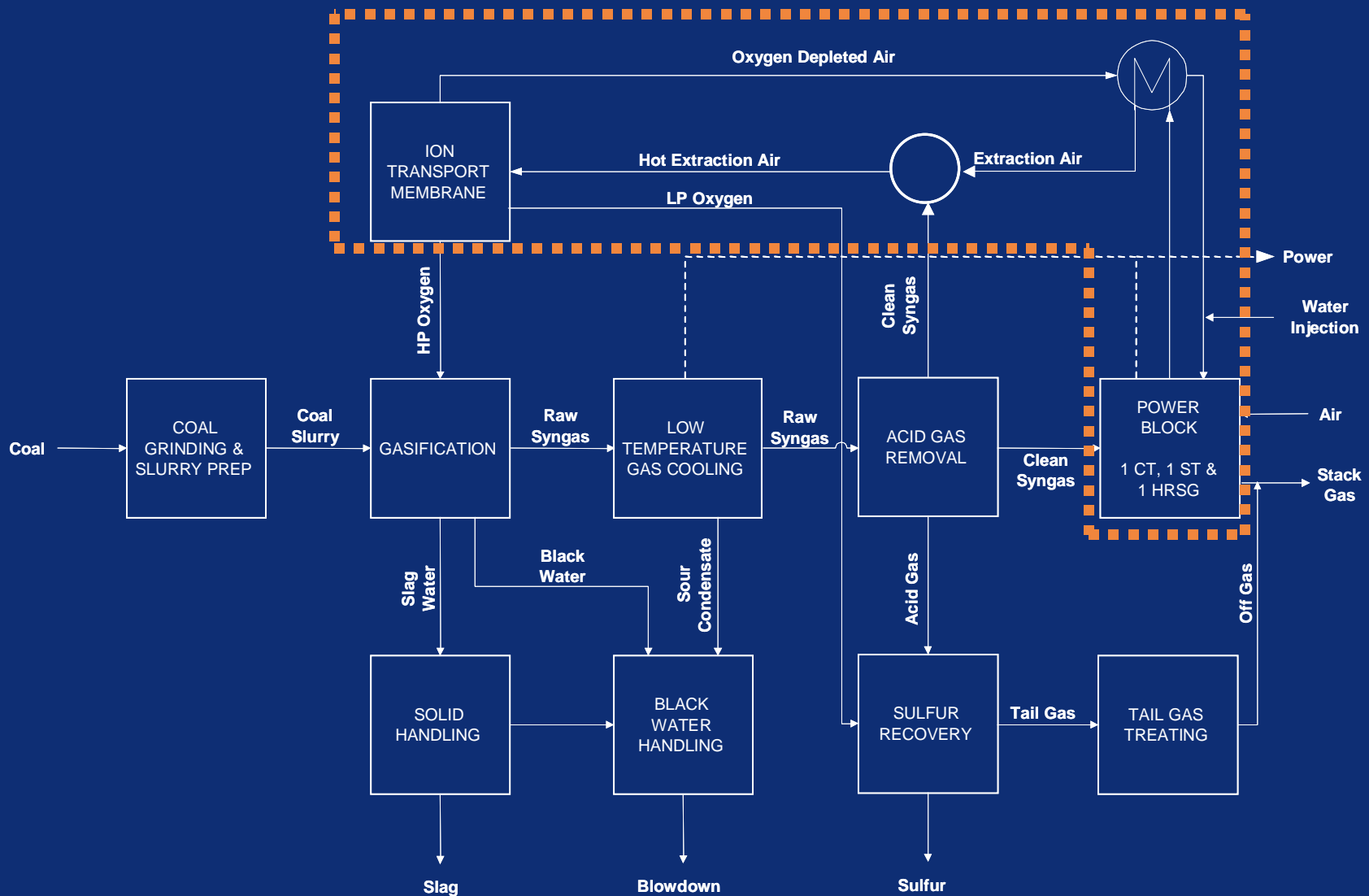
ITM Oxygen integrates well with power generation cycles



ITM Oxygen offers benefits to advanced energy technologies

- Gasification applications
 - IGCC study with ChevronTexaco
- Combustion applications
 - CO₂ Capture Project (oxy-fuel boilers)

IGCC Study with ChevronTexaco



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IGCC Study Design Basis

- **Single-train high-pressure Texaco quench gasifier (950 psig)**
 - eastern U.S. coal
 - raw syngas expander
 - conventional fuel gas cleaning and SRU
- **Siemens Westinghouse W501G - 60 Hz (272 MW)**
- **100% air / N₂ integration of ASU / ITM Oxygen**
- **HRSG and reheat steam turbine (1800 psig)**
- **ISO ambient design conditions**

ITM Oxygen shows significant benefits for IGCC

	ITM Oxygen	Cryo ASU	Δ (%)
IGCC Net Power (MW)	438	409	+7

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Oxygen Power Req't (kWh/ton)	147	235	- 37

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Total IGCC Cost (\$,000)	447,000	448,000	-----
IGCC Specific Cost (\$/kW)	1,020	1,094	- 7

ITM Oxygen is a three-phase development effort

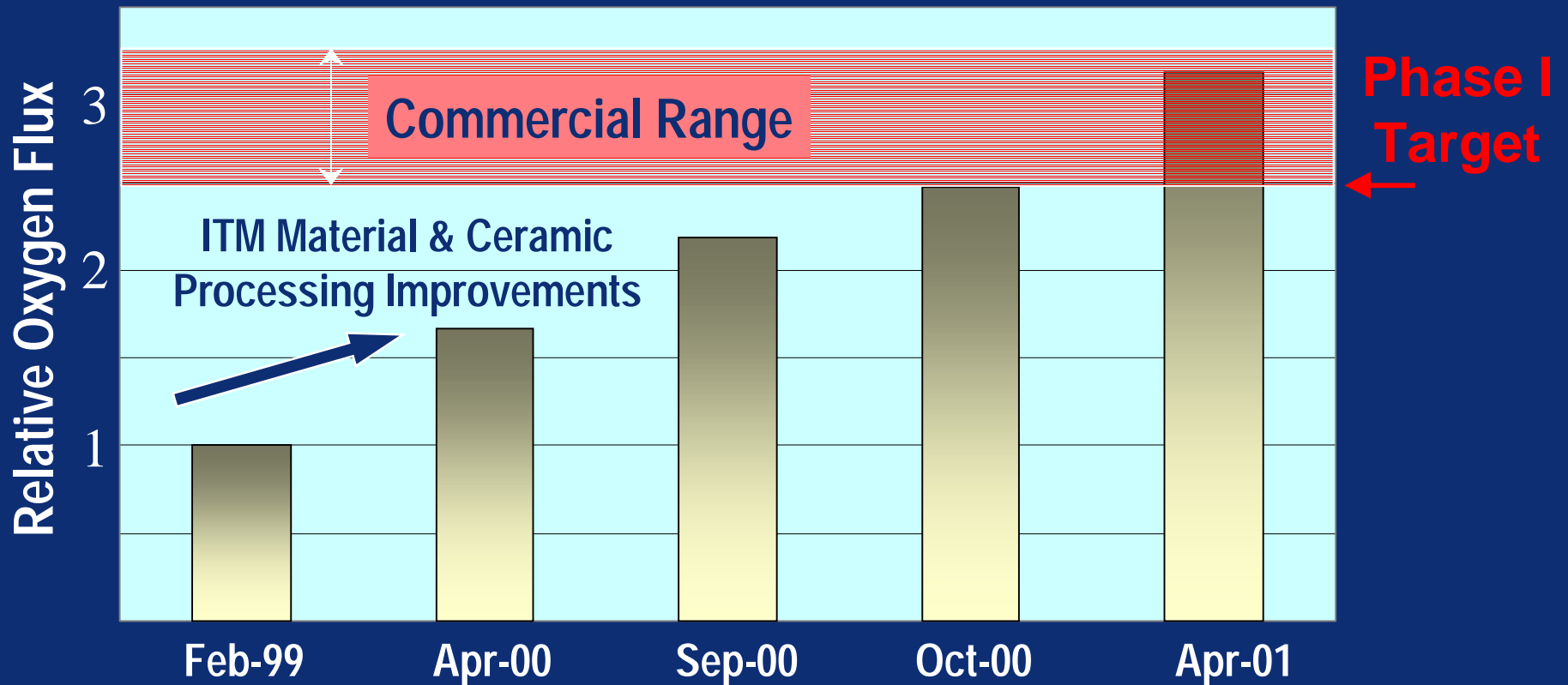
- **Phase I** - proof of concept
 - ceramic fabrication scale-up
 - process concept validation tests at lab-scale

Ceramic Fabrication scaled-up in component size and volume



Oxygen flux from sub-scale membranes meets target

subscale membrane assemblies at
T and P_{O_2} typical for full process conditions

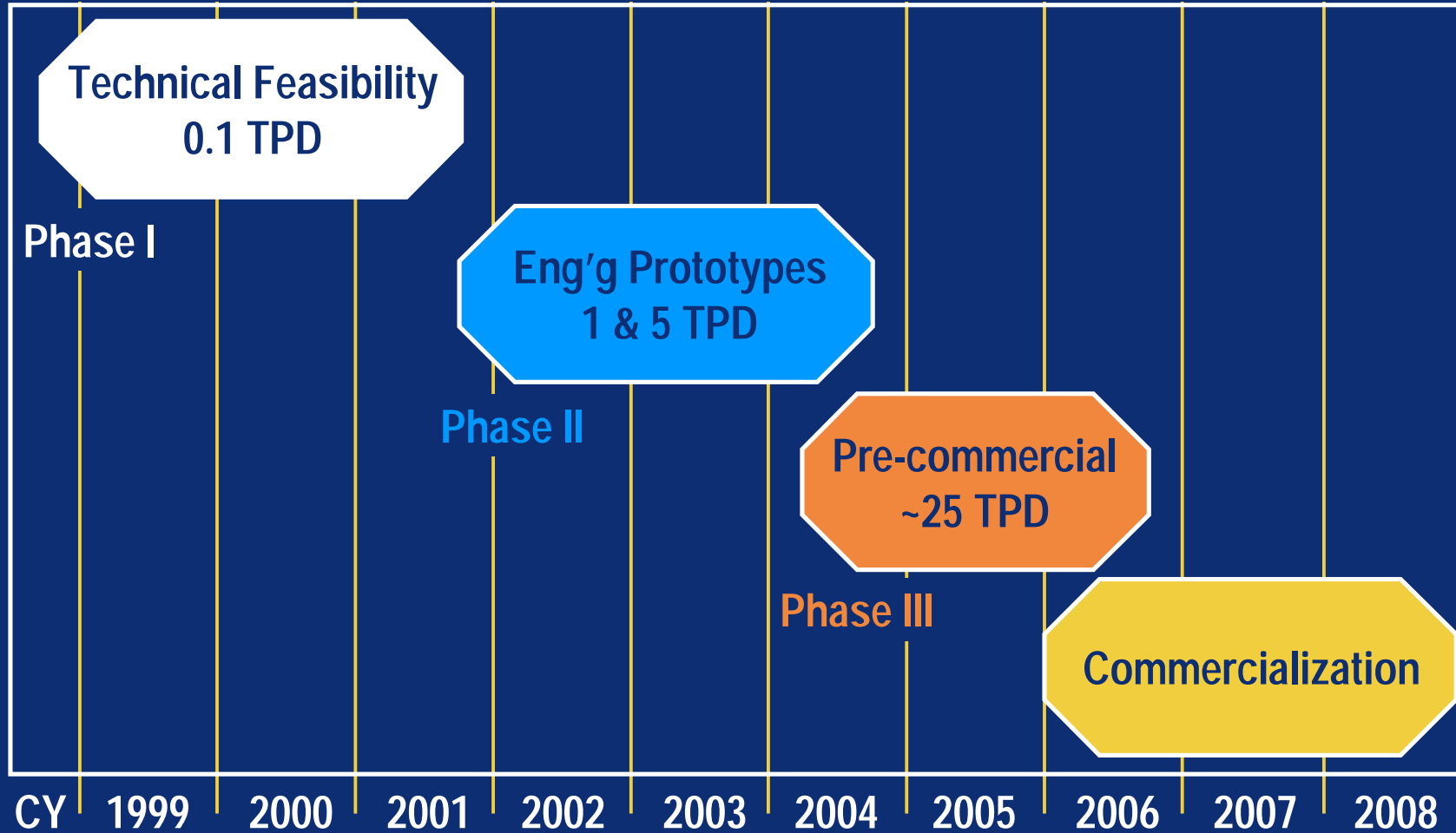


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ITM Oxygen is a three-phase development effort

- Phase I - proof of concept
 - ceramic fabrication scale-up
 - process concept validation tests at lab-scale
- Phase II - scale-up to 5 TPD
 - design, construction, testing of 5 TPD unit
 - engineering, cost, scale-up data for Phase III
- Phase III - 25 TPD pre-commercial demo unit
 - fully integrated with gas turbine
 - tested at suitable field site

Commercialization begins 2006



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