The FutureGen of Carbon Capture & Sequestration

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Battelle

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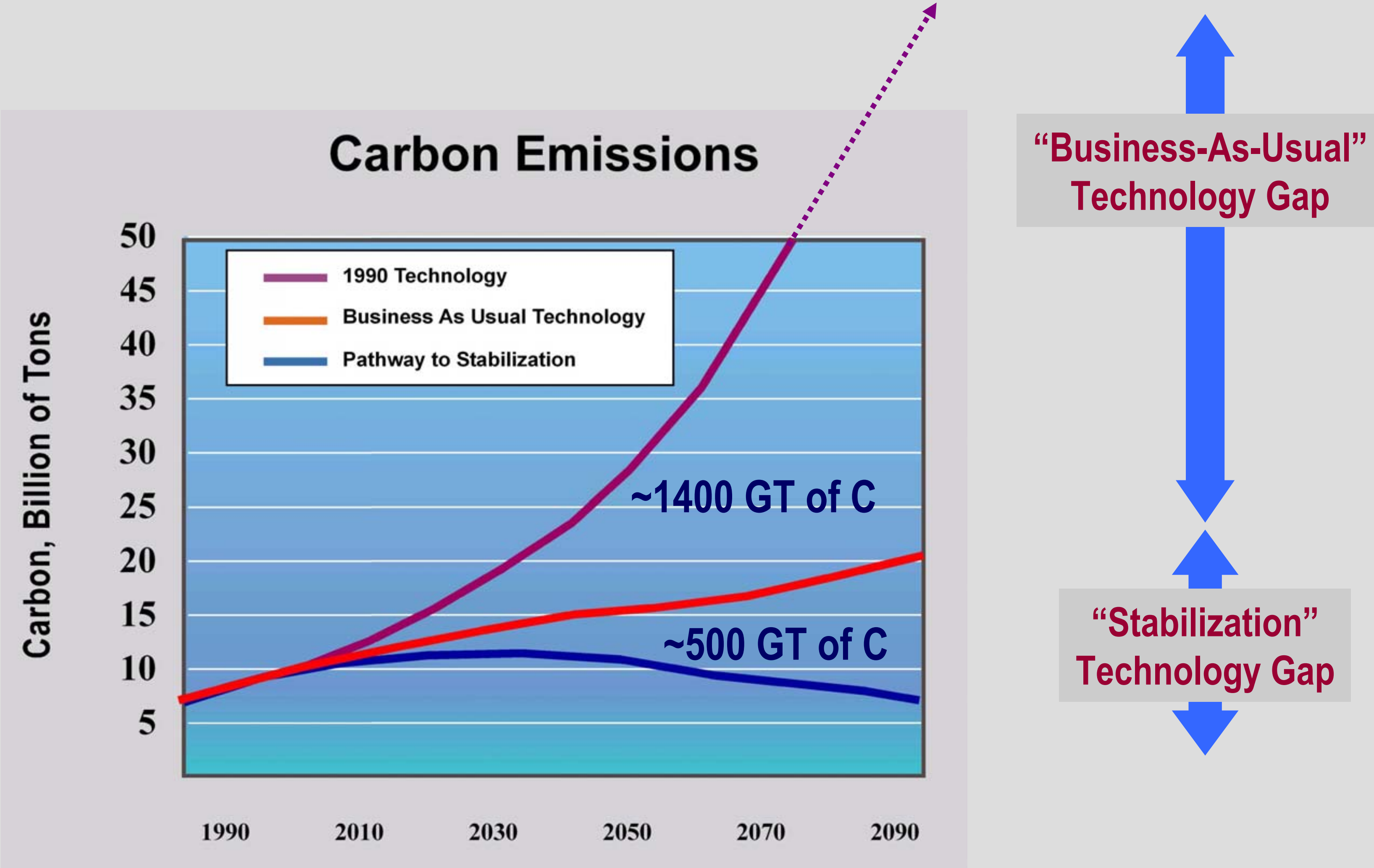
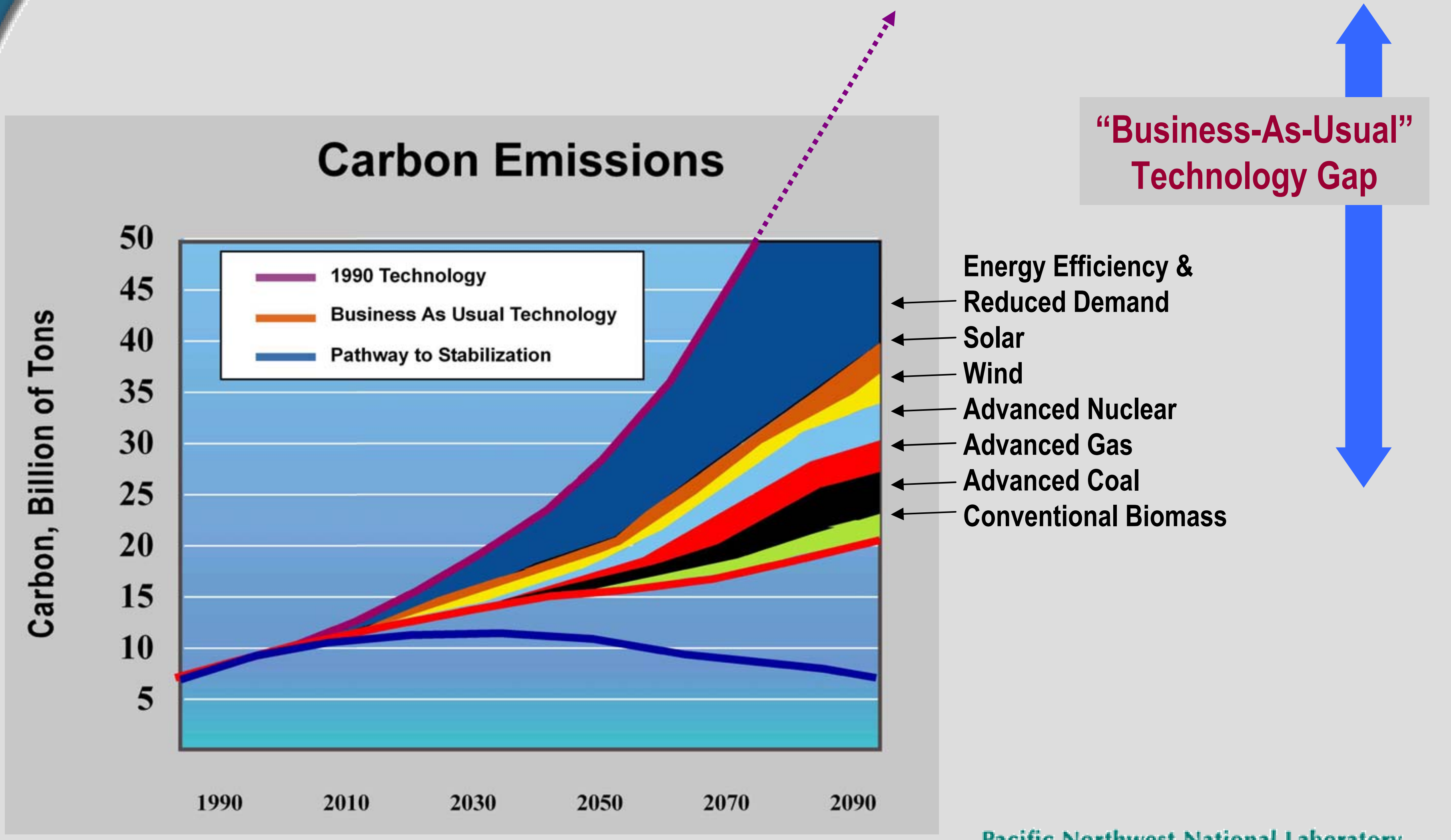
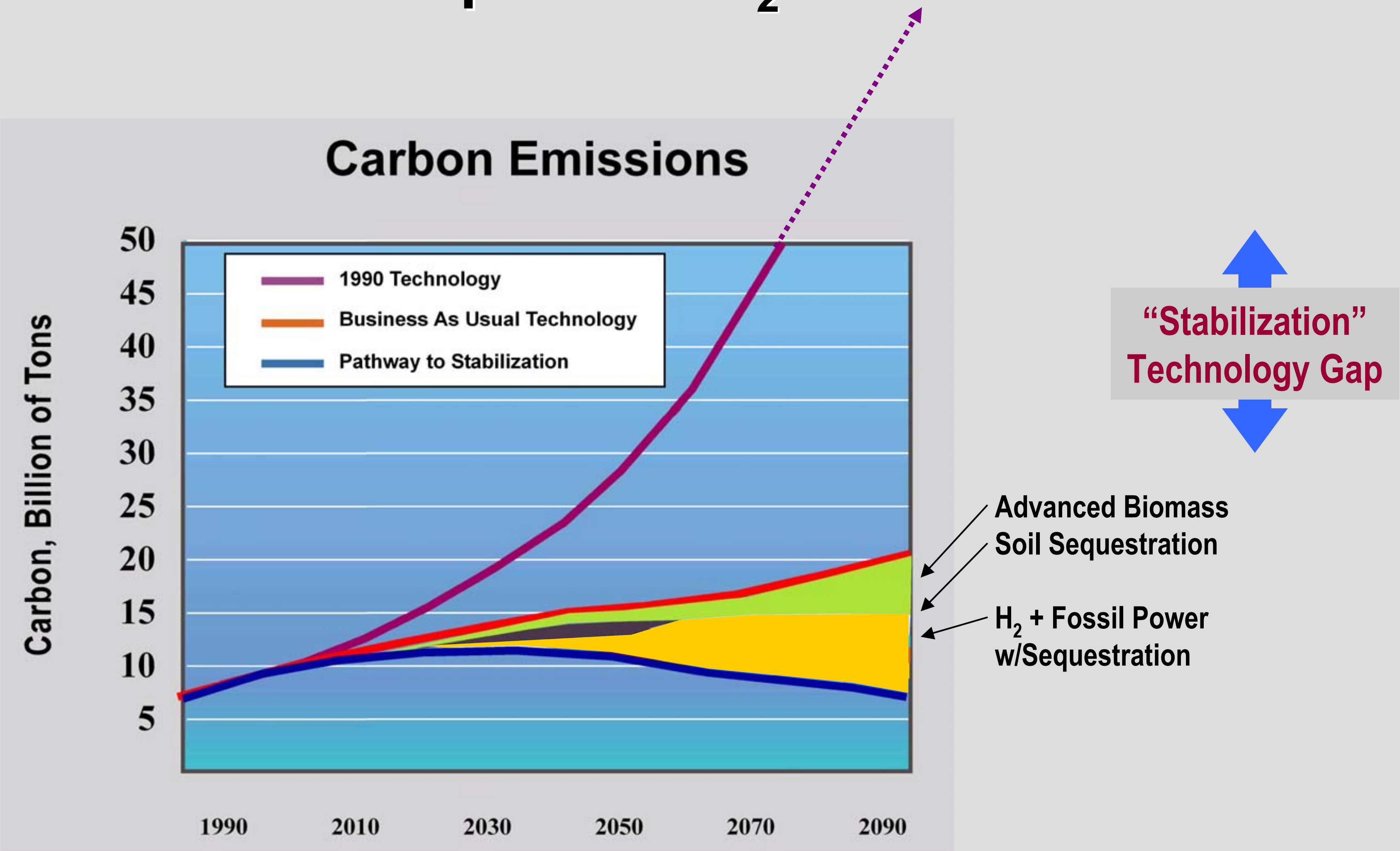
Commitment to Stabilization Requires Closing TWO "Technology Gaps"



Business-As-Usual Gap
Extraordinary Improvement is Built into BAU

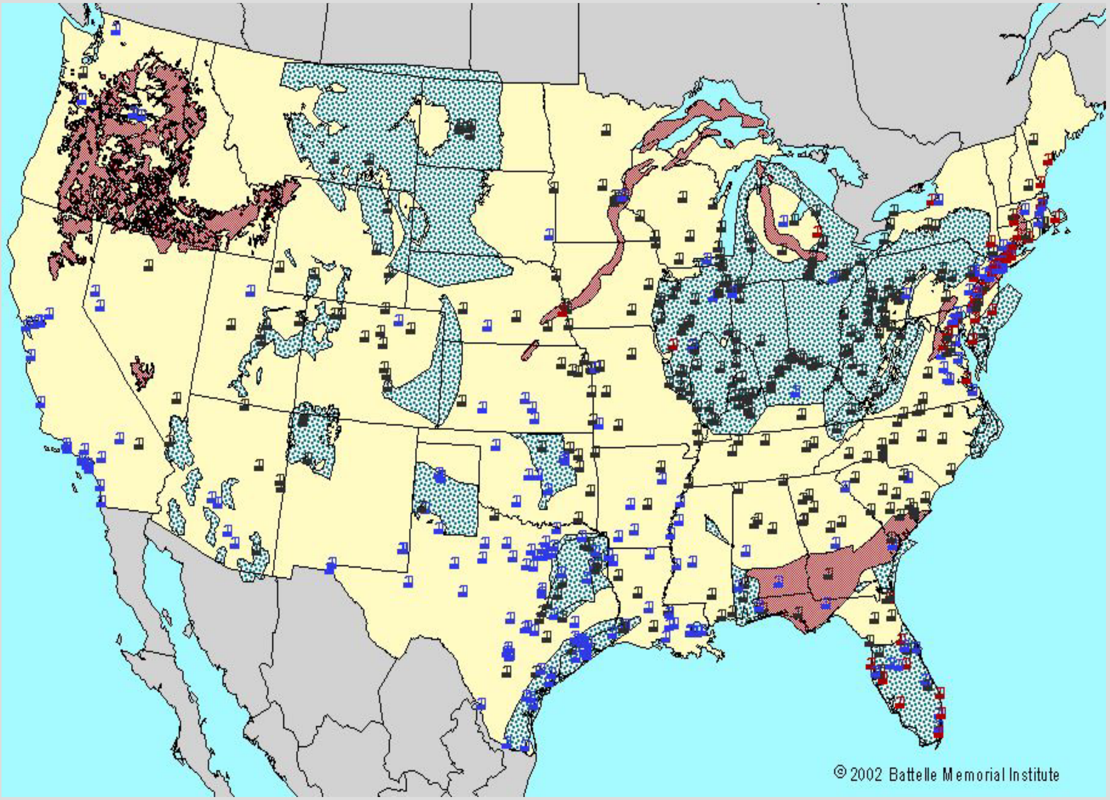


Role of Carbon Sequestration in Atmospheric CO_2 Stabilization



Geologic Sequestration

- Deep saline formations
- Depleted oil/gas reservoirs
- Coal-bed methane
- Basalt



President Bush Launches FutureGen

"Today I am pleased to announce that the United States will sponsor a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant. This project will be undertaken with international partners and power and advanced technology providers to dramatically reduce air pollution and capture and store emissions of greenhouse gases."

Office of the Press Secretary
February 27, 2003

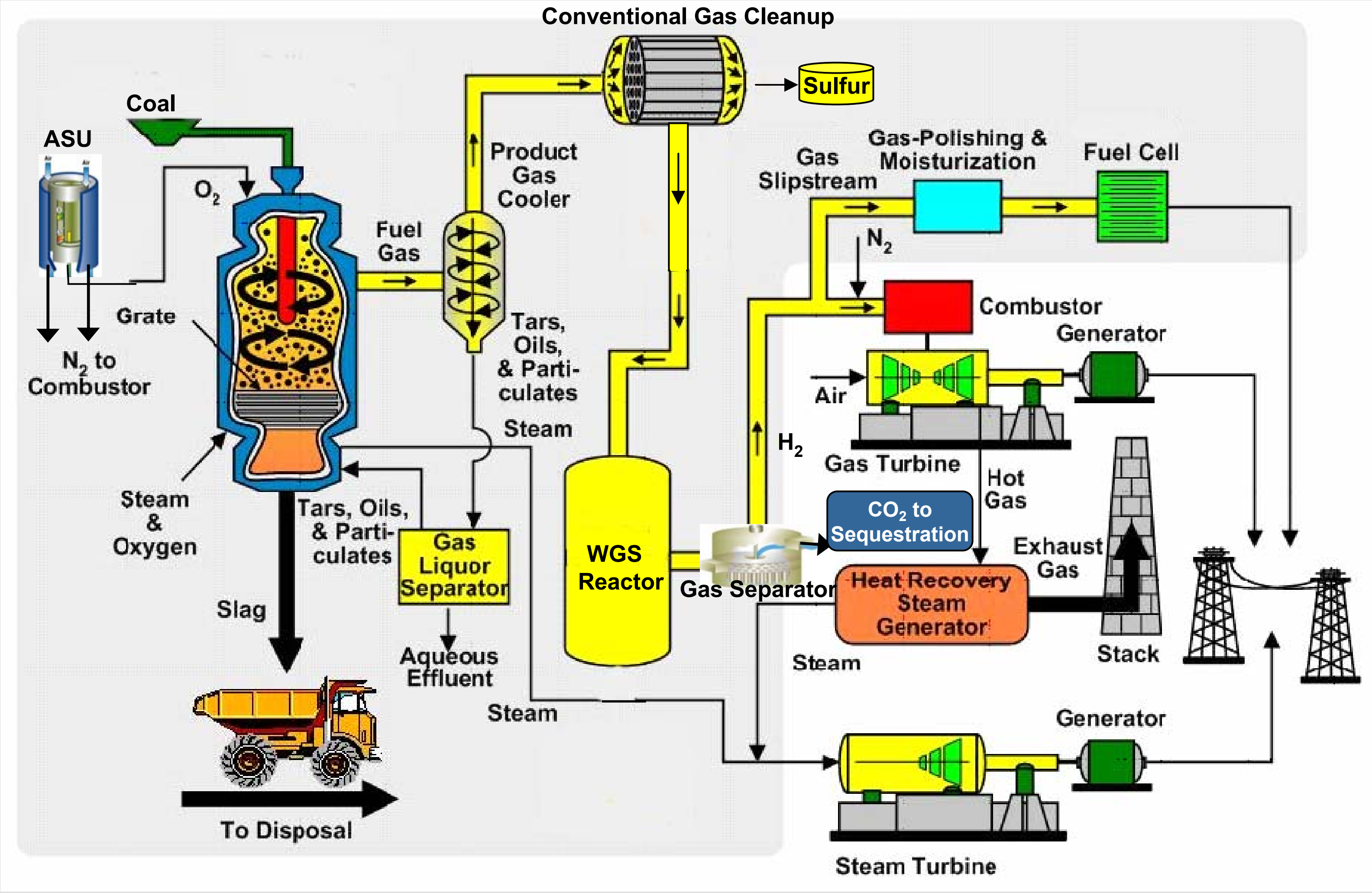
FutureGen Benefits

- Expand options for use of coal in power generation and transportation sectors
- Reduce costs of meeting possible future CO_2 emissions limits
- Unique platform to test new H_2 technologies and geologic sequestration methods

Key Aspects of FutureGen

- Nominal 275 MWe Plant
  - ≈1 MMT CO_2 generated per year
  - >50% net efficiency
- Coal Gasification
  - H_2 production
    - Onsite electrical generation
      - Gas turbine
      - Fuel cells
      - Hybrids
    - Petrochemical feedstock
    - Transportation grade fuel
  - **CO_2 Capture (90% target)**

Hydrogen Production from Coal with Integrated CO_2 Capture



Pre-combustion CO_2 Capture

- Advantages
  - Much higher CO_2 concentration in gas stream than in post-combustion
  - Higher operating pressure
    - More compact equipment
    - Greater driving force for CO_2 separation
- Disadvantages
  - Most designs require air separation unit for O_2 production
    - Current ASU technologies primarily cryogenic
    - Oxygen production 12-15% of capital cost of IGCC plants; consumes 10% of gross power production
  - Scientific research and commercially available CO_2 separations systems mostly targeted at low CO_2, post-combustion flue gas streams

Petronas Fertilizer Co. Amine Scrubber

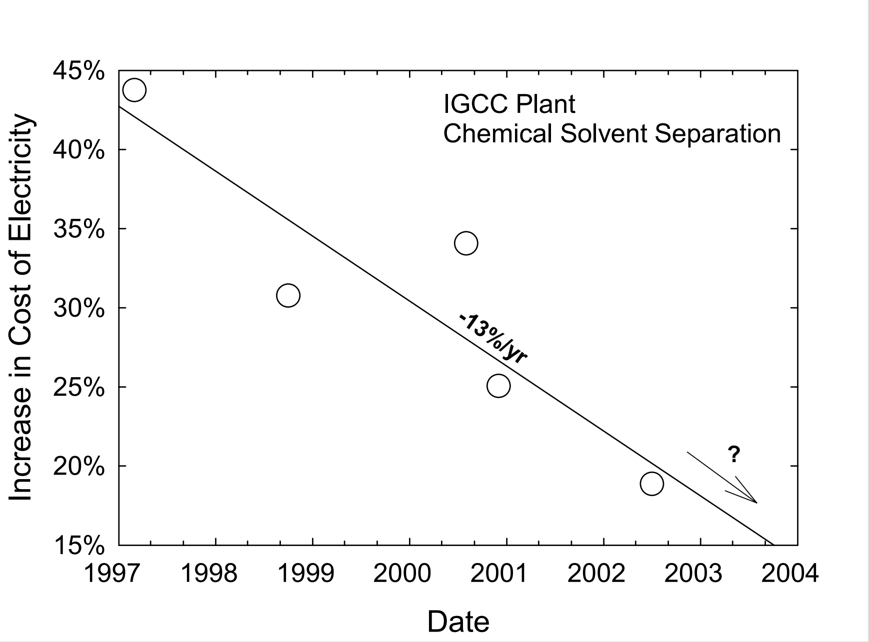
Kansai Electric Power Company
Mitsubishi Heavy Industries Ltd

Pre-cleanup Gas Compositions

	CO_2	H_2	O_2	N_2	H_2O	H_2S	SO_x (ppm)	NO_x (ppm)
PC/NGCC	3-14%	neg	1-8%	60-80%	5-20%	neg	2-2000	100-500
IGCC	20-40%	40-60%	neg	1-5%	1-10%	1-10%	neg	neg

Costs for Carbon Capture

Reference	Date	ΔCOE
IEA Greenhouse Gas R&D Programme	1997	44%
SFA Pacific	1998	31%
MIT	2000	34%
Parsons Energy Inc.	2000	25%
IEA Greenhouse Gas R&D Programme	2002	18%
PSA		279%
TSA		306%
Cryogenic		47%
Gas Separation Membrane		143%
Gas Absorption Membrane		58%

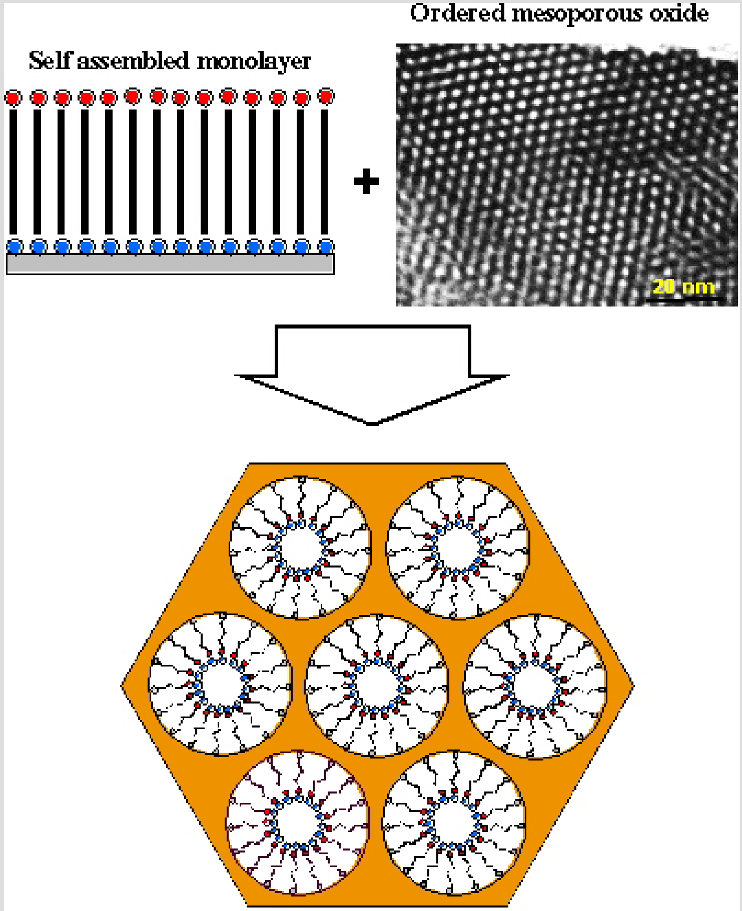


R&D Needs

- Operating temperature <800 ^{o}F
- Lower capital costs
- Higher efficiency
- Produce both high pressure hydrogen and CO_2

New Capture Technologies

- Membranes
  - Catalytic
  - Ion transport
  - Facilitated transport
  - Polymeric
  - Ceramic
  - Nanocomposites
- Clathrates
- Carbon nanotubes/carbon-carbon composites
  - Electrical swing adsorption
- Ordered mesoporous oxides/aerogels



Self assembled monolayers on mesoporous oxides (SAMMS)

State of Science?

Keyword(s)	ISI Web of Science	Information Bridge	Google
Fuel Cell	4311	1239	468000
CO_2 Capture	171	80	1100
CO_2 Capture +syngas	81	47	137
Cold Fusion	798	37	504000