The ENERGY COUNCIL
2008 Annual Meeting

Advances in Coal-Fired Power Generation

Oklahoma City, Oklahoma

September 27, 2008

Ben Yamagata

Executive Director

CURC

CURC
COAL UTILIZATION RESEARCH COUNCIL SM

Focus of the Presentation --

1. **Importance of Coal**
2. **Challenges to the use of Coal**
3. **Technology innovation & use**
4. **Next Steps**

What is CURC?

- Coal Utilization Research Council
- Based in Washington D.C.
- 60+ members & Membership includes .....
- Focused upon coal related technology development and use

CURC COAL UTILIZATION RESEARCH COUNCIL SM

Importance of Coal

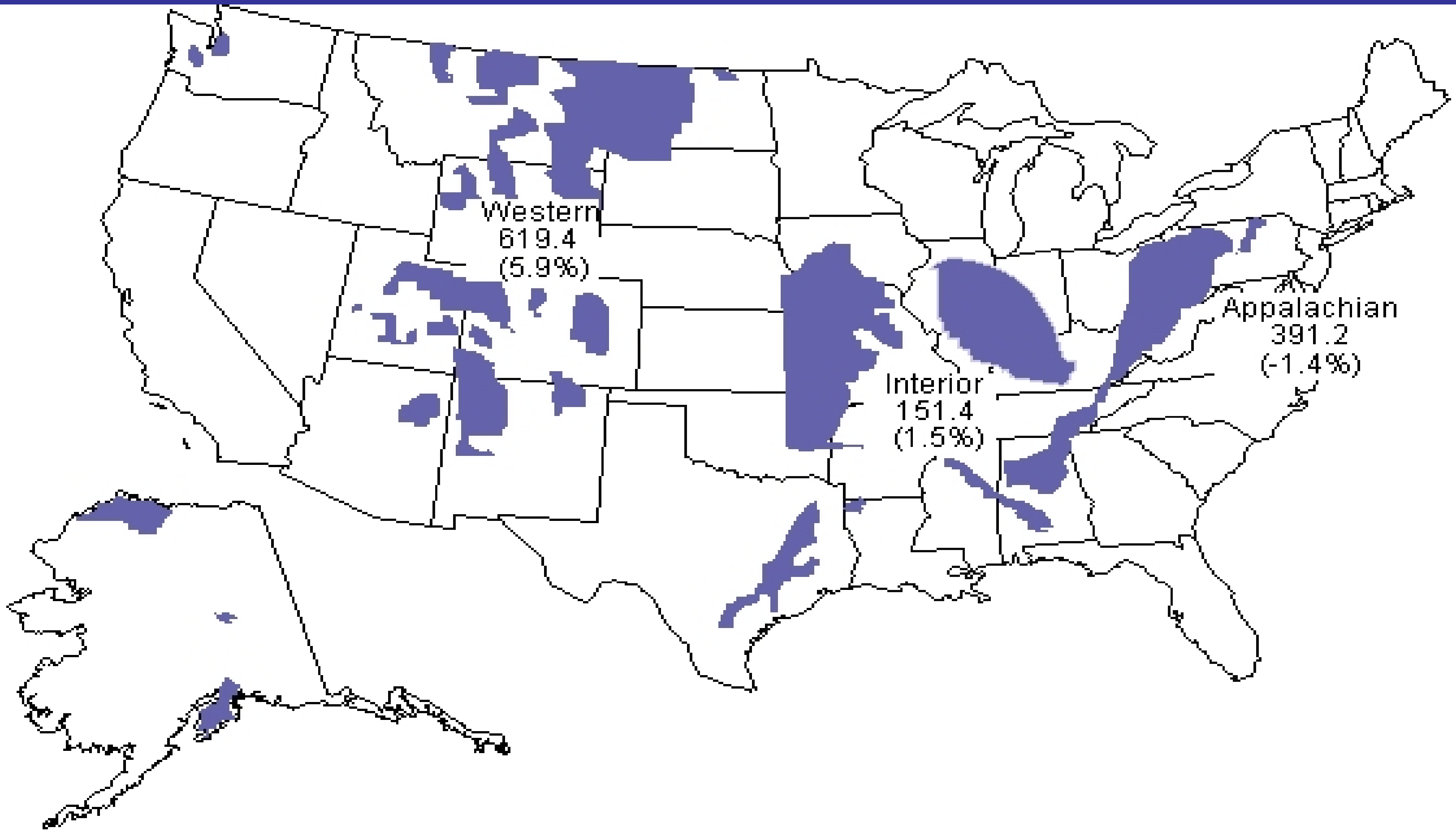
In the United States

and

Throughout the World

Coal is Plentiful & Disbursed Throughout the U.S.

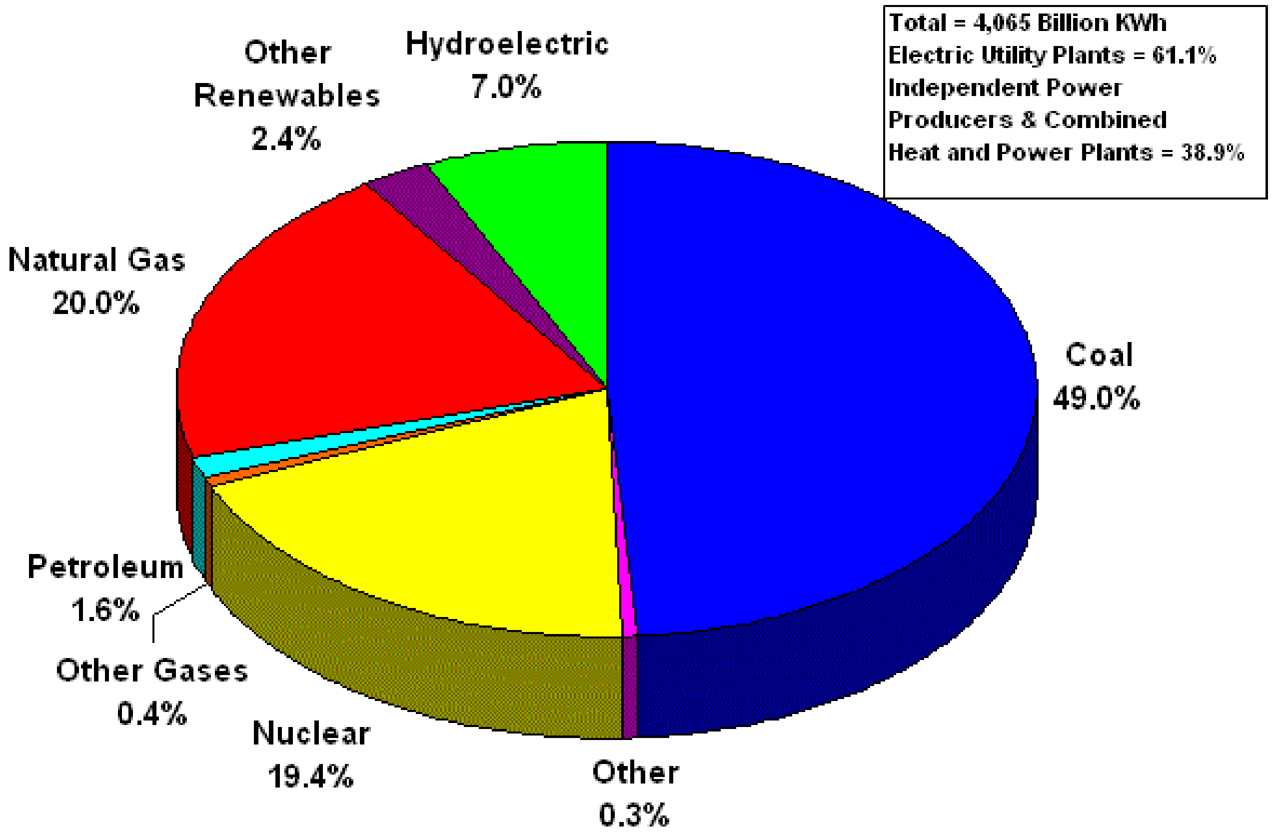
U.S. Total: 1,162.8 Million Short Tons (2.8% increase above 2006)



- Source: Energy Information Administration, Annual Coal Report, 2006, DOE/EIA-0584(2006) (Washington, DC, October 2007).

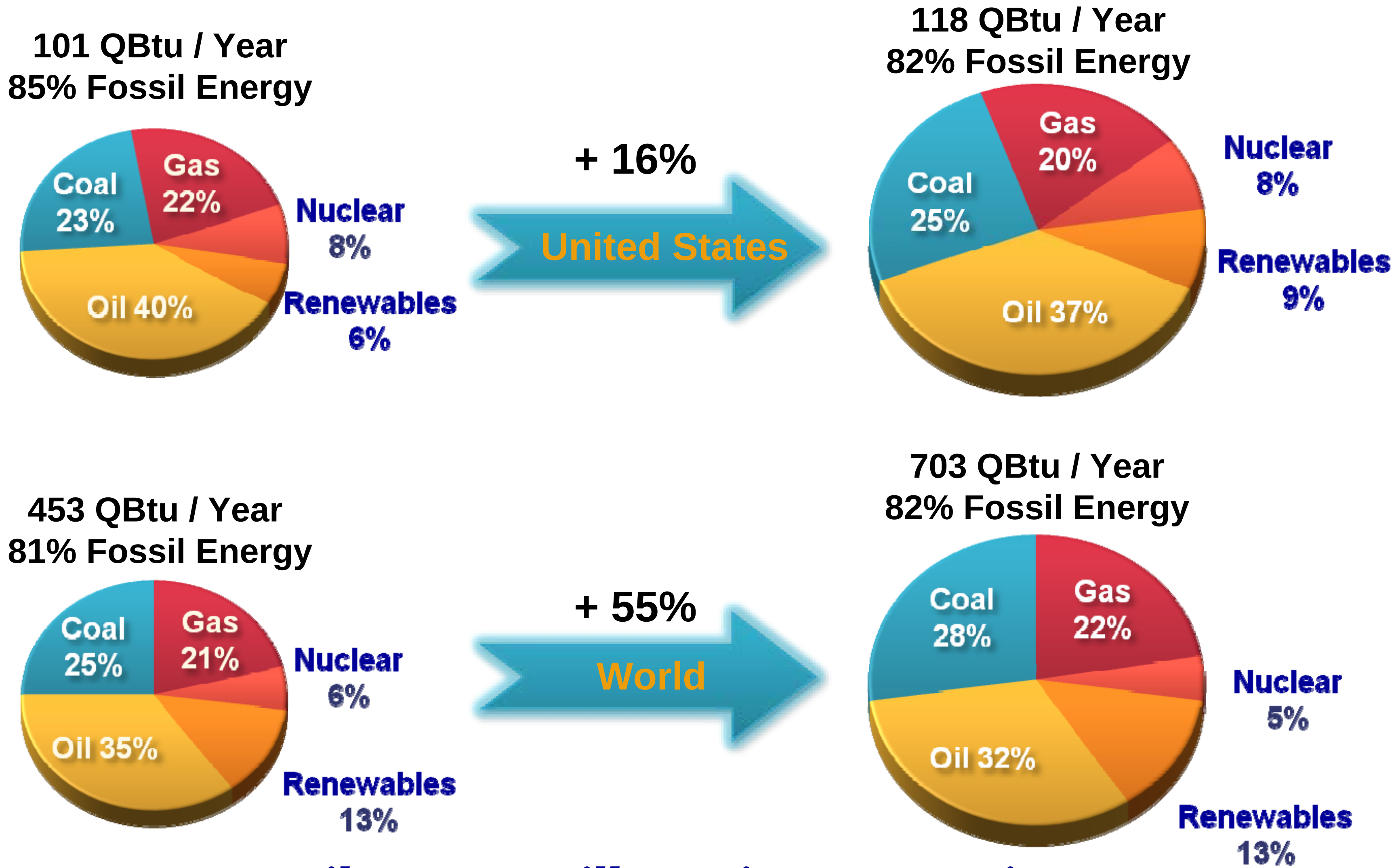
CURC
COAL UTILIZATION RESEARCH COUNCIL SM

U.S. Electric Power Industry Net Generation, 2006



- **Sources:** Energy Information Administration, Form EIA-906, "Power Plant Report;" and Form EIA-920 "Combined Heat and Power Plant Report."

Energy Demand Today | Energy Demand 2030

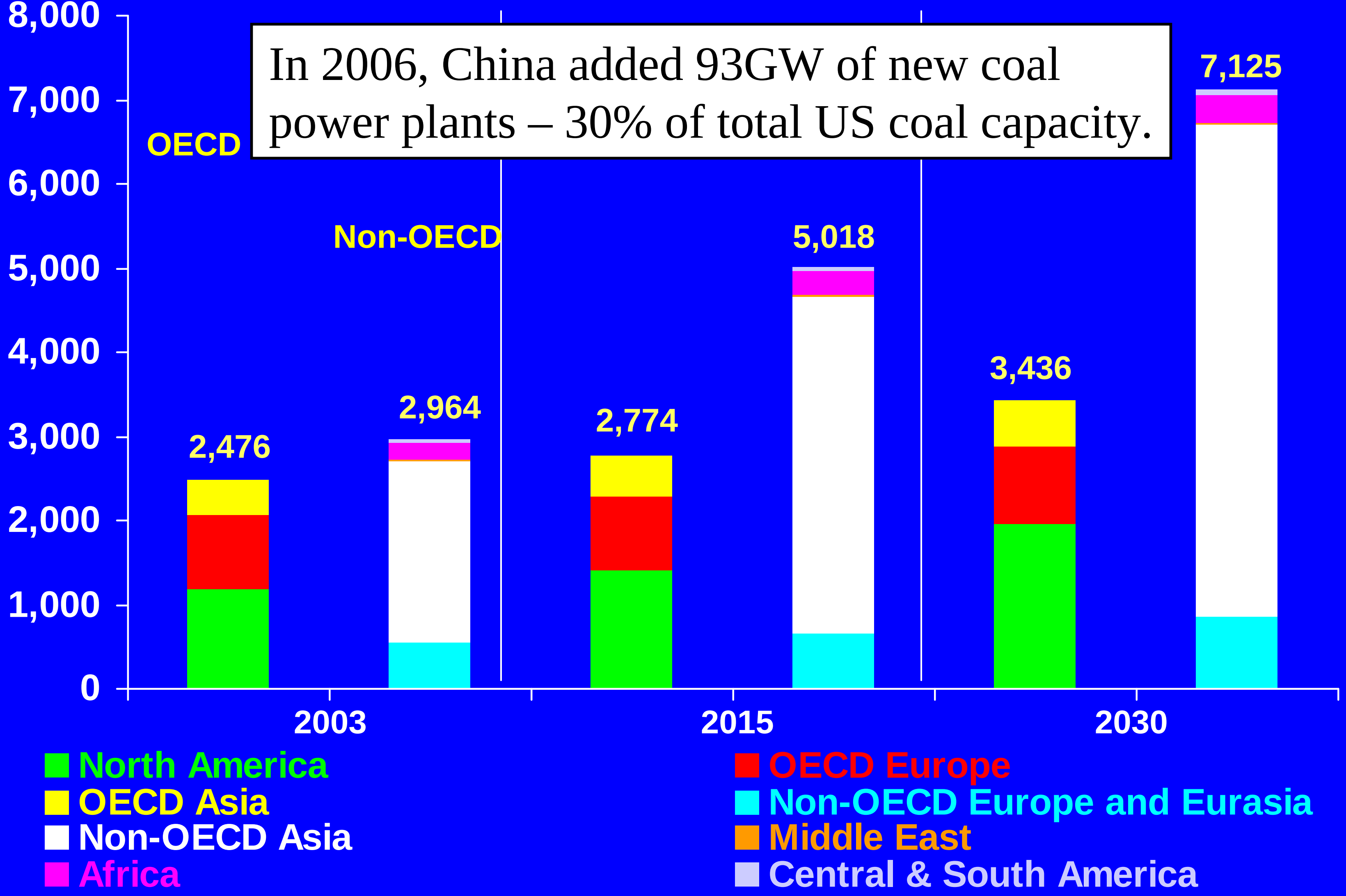


Fossil Energy Will Continue to Dominate

U.S. data from EIA, Annual Energy Outlook 2008 revision; world data from IEA, World Energy Outlook 2007

World Coal Consumption,

2003, 2015, and 2030 (million short tons)

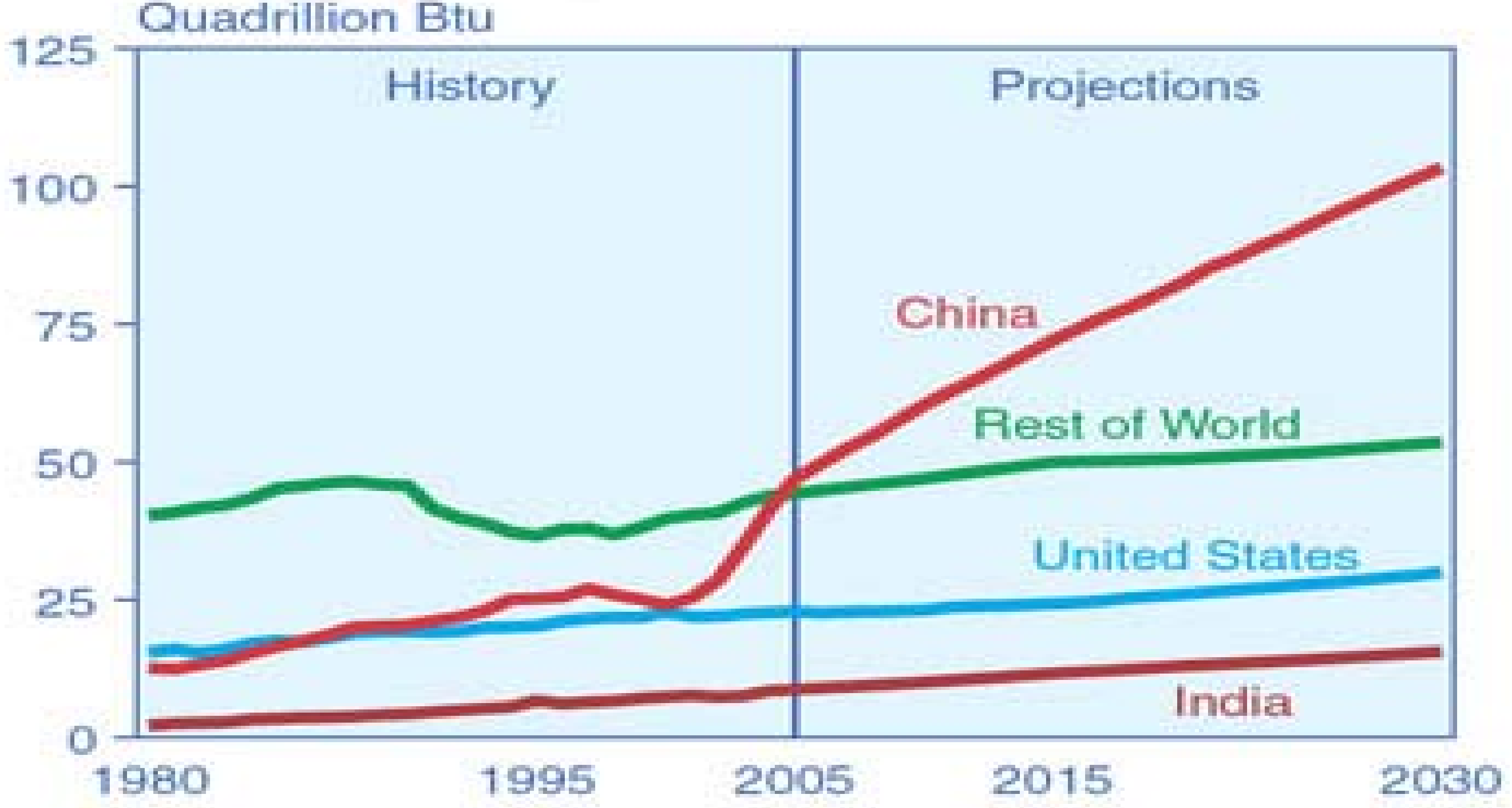


In 2006, China added 93GW of new coal power plants – 30% of total US coal capacity.

International Energy Outlook 2006

OECD = Organization for Economic Cooperation and Development

Figure 13. Coal Consumption in Selected World Regions, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2008).

Challenges to the Use of Coal

Traditional Air Pollutants

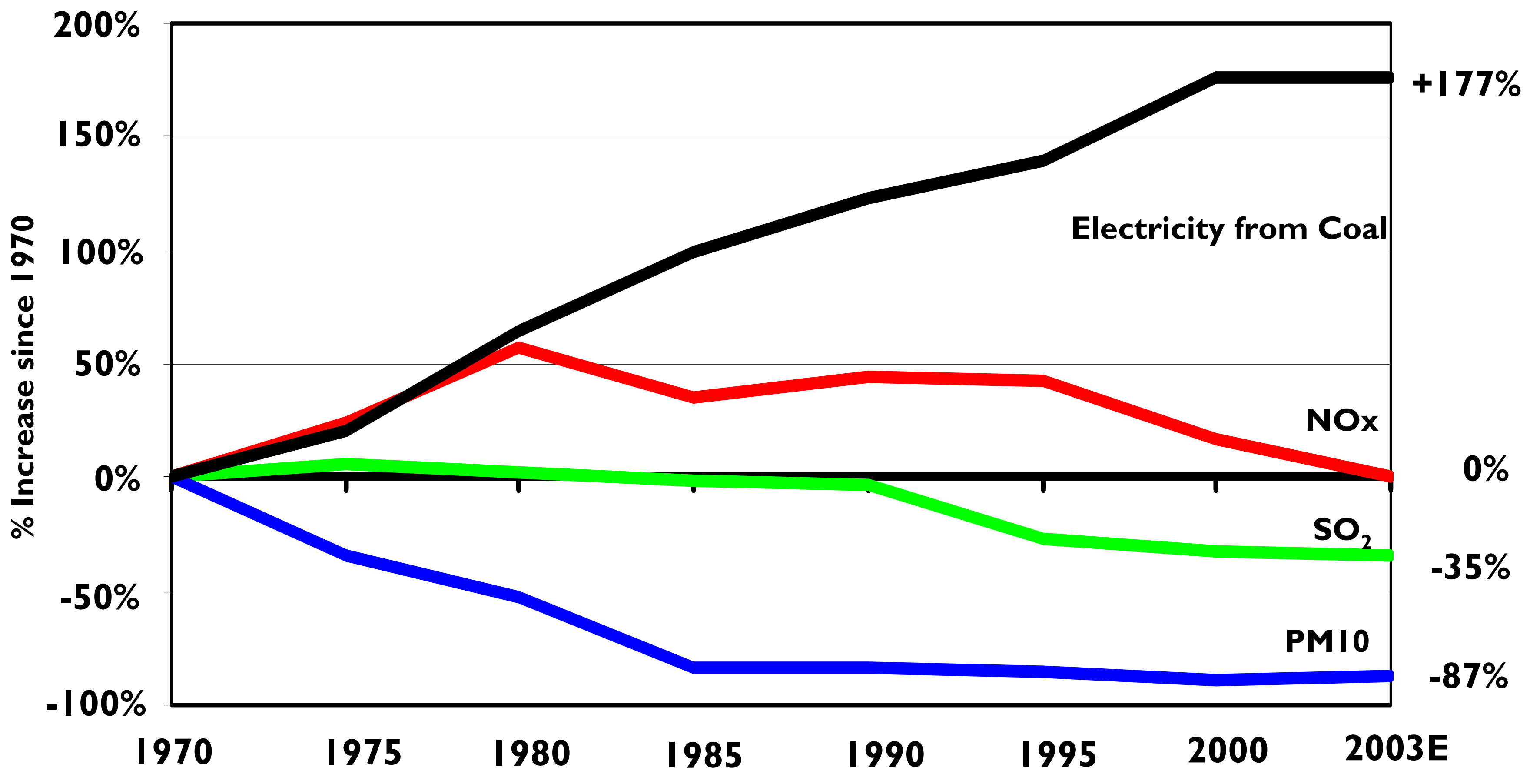
and now

Carbon Dioxide (CO_2)

Traditional Air Pollutants and their control

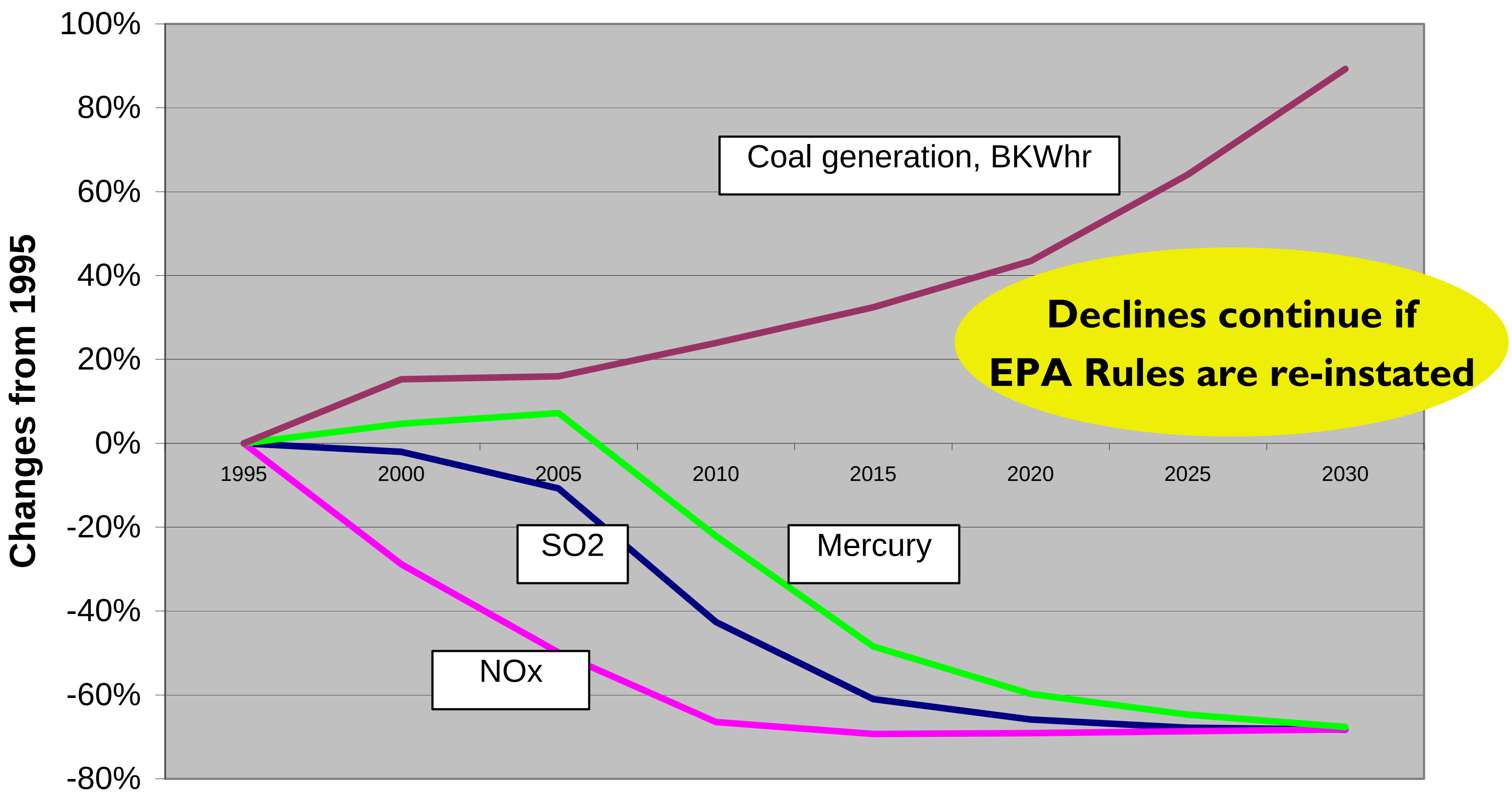
- Traditional pollutants include:
  - Fine particles derived from the ash in coal
  - Sulfur dioxide
  - Nitrogen oxides
  - Mercury, found in trace amounts in coal
- Power plants use separate control technologies designed specifically to reduce each of these pollutants

Changes in Coal-Based Electricity & Emissions
Since 1970 Coal increasingly clean



Source: EIA Annual Energy Review 2003 (Sept. 2004), EPA National Emissions Inventory Trends (Dec. 2004)

Generation Increases but Emissions Decline



The world is changing…

“Arctic ice could disappear almost completely in the latter part of the century”

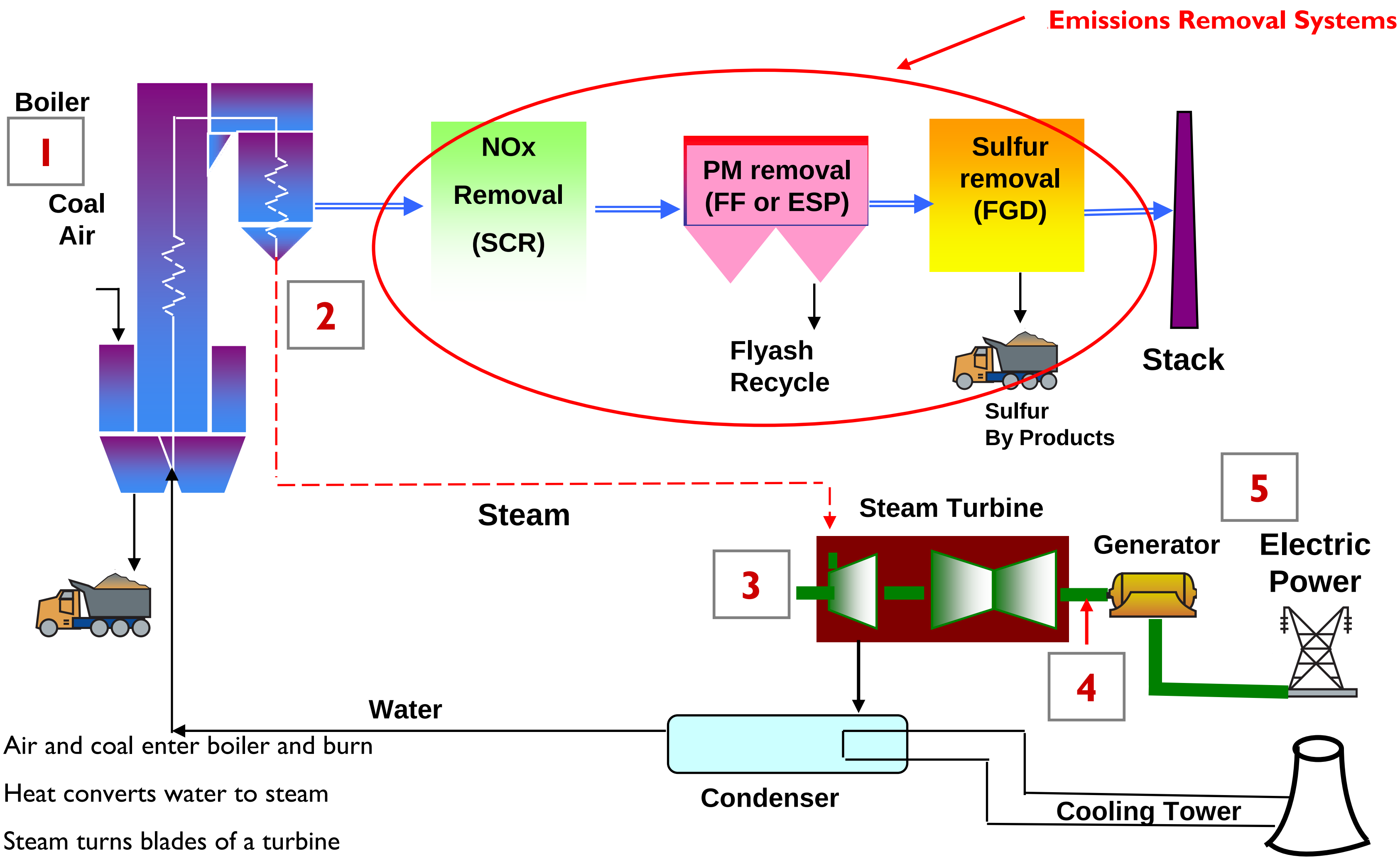
IPCC, AR4

Technology Innovation & Use

How do we use coal today?

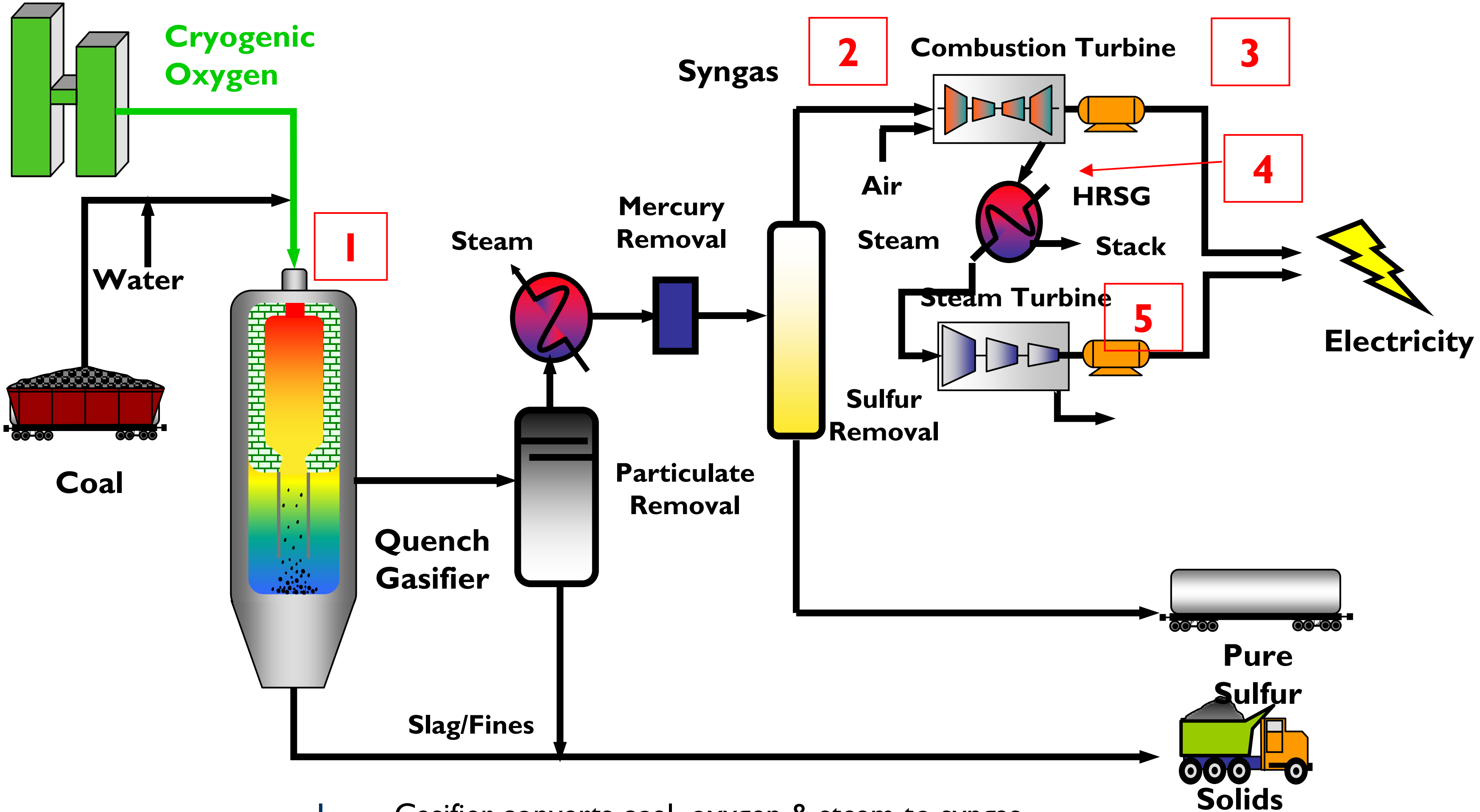
How will we use coal tomorrow?

How Does a Pulverized Coal Plant with Emissions Removal Systems Work?



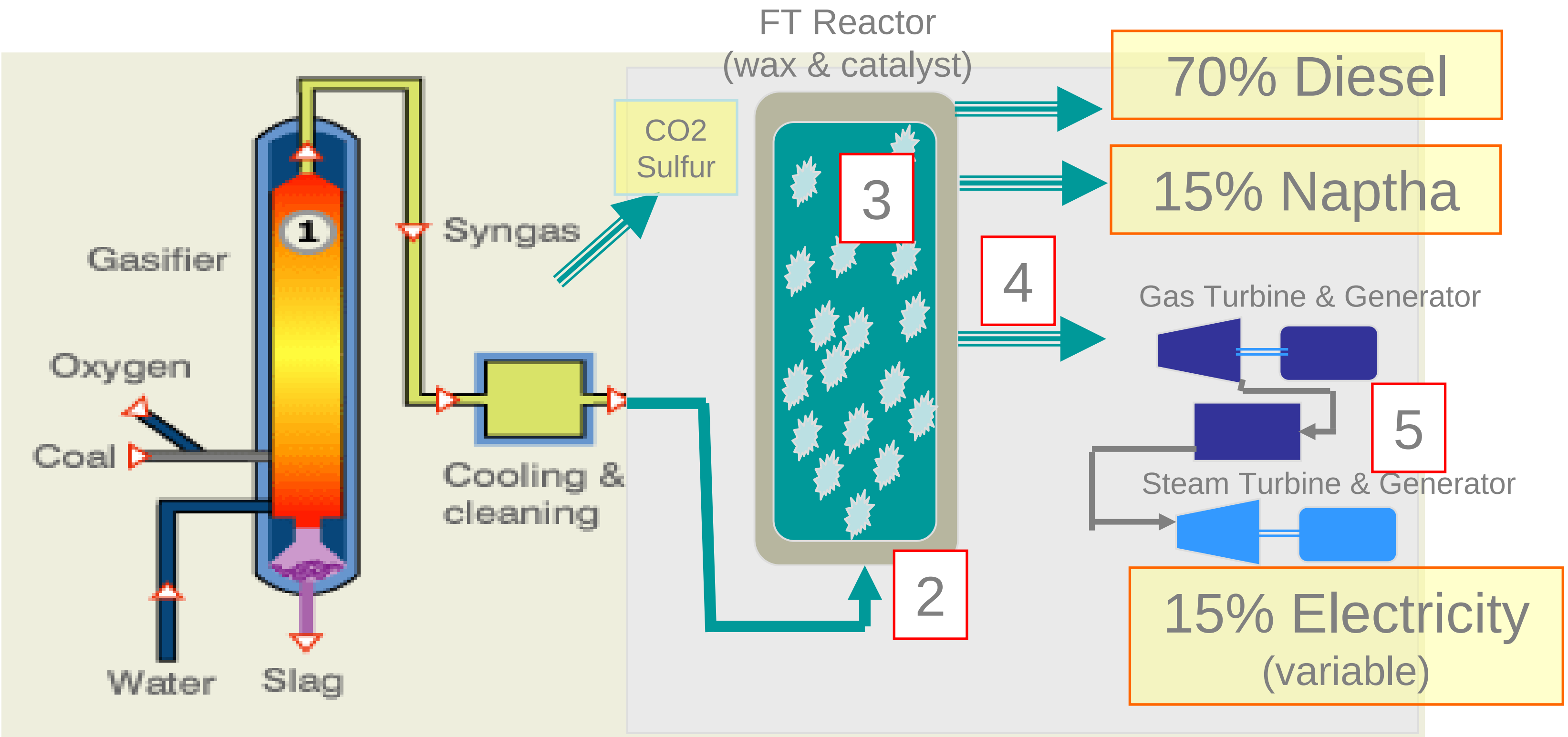
1. Air and coal enter boiler and burn
2. Heat converts water to steam
3. Steam turns blades of a turbine
4. Turbine shaft turns generator
5. Generator makes electricity

How Does An IGCC Power Plant Work?



1. Gasifier converts coal, oxygen & steam to syngas
2. Cleaned syngas (SO_x, Hg, PM removed) is burned
3. Combustion gases expand in gas turbine, generates power
4. Waster heat generates steam (HRSG)
5. Steam expands in steam turbine, generates more power

Coal-to-Liquids (CTL) Using Fischer-Tropsch



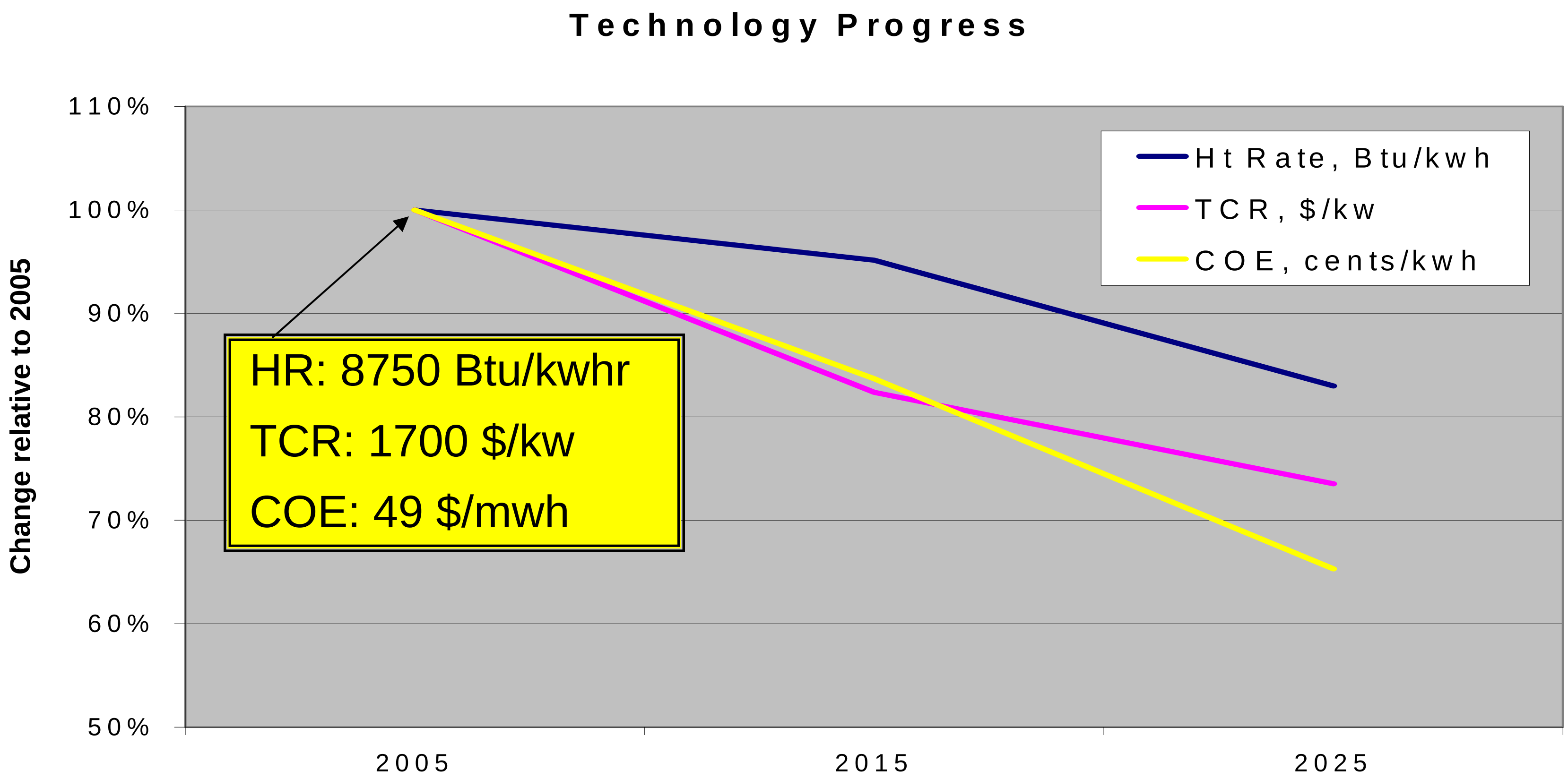
1. Gasifier converts coal, <u>oxygen</u> & steam to syngas
2. Cleaned syngas goes to FT conversion unit
3. Catalyst in FT unit changes syngas to diesel and naptha (10,000 BPD)
4. Unreacted synthesis gas burned in combustion turbine/generator
5. Waste heat makes steam, drives steam turbine/generator (110 MW total)

Emission Performance: An order of magnitude reduction for traditional pollutants by 2025.

(Represents best integrated plant technology capability)

PC and IGCC Systems	Year	
	2005	2025
Emissions		
PM, lbs/MWhr	0.09	0.01-0.02
SO2, lbs/MWhr	0.8-0.3 (90-99%)	0.07-0.01 (98-99.9%)
NOx, lbs/MWhr	0.5-0.4	0.2-0.1
Mercury, %	80-90%	98-99%
CO2, lbs/MW-hr	1770-1940	1410-1670
Efficiency Btu/kWh (HHV)	38-39%	44-49%

Technology Progress over time – cheaper, efficient, cleaner



Necessary Technologies

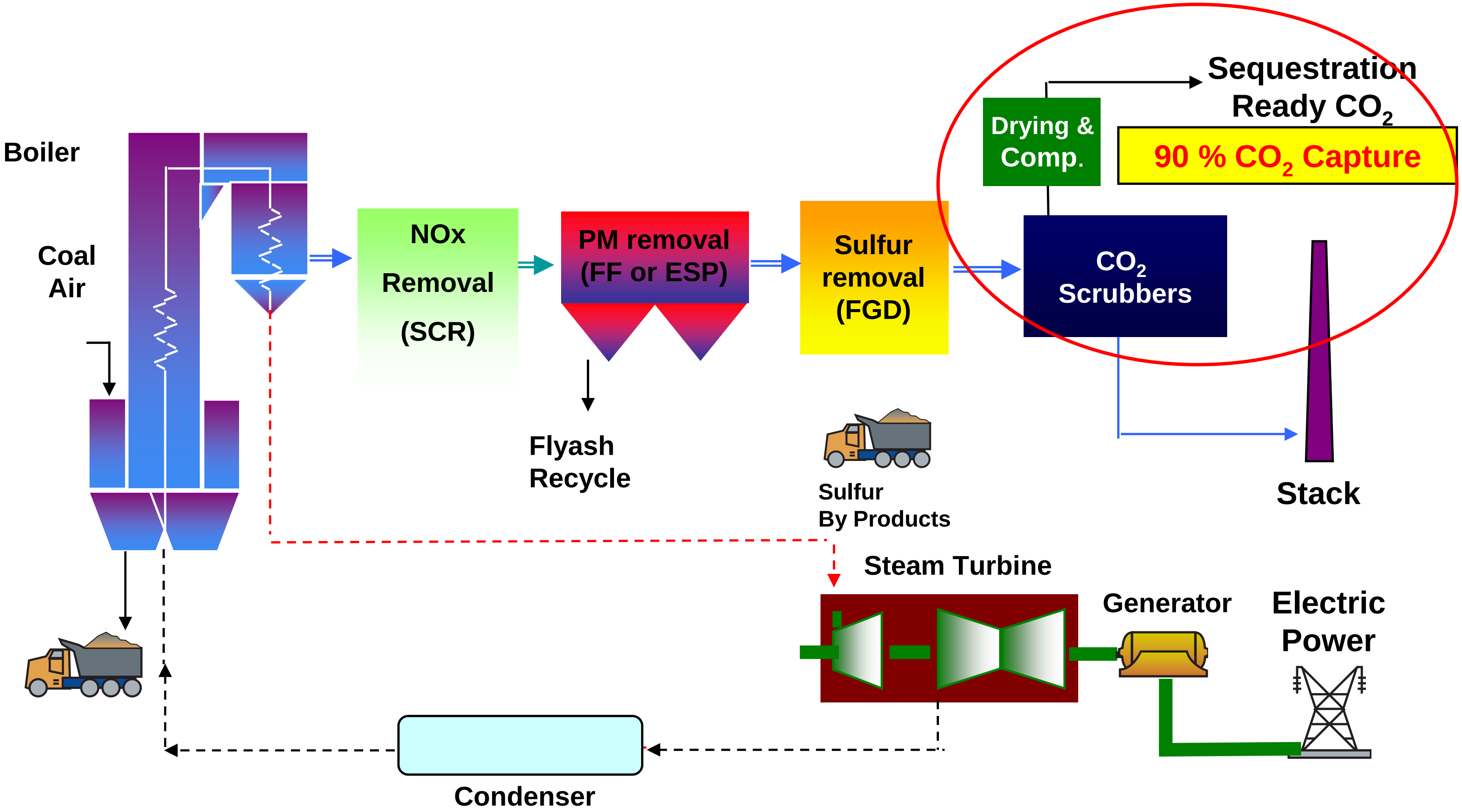
IGCC

- -Improved refractory (no spare gasifier reliability)
- -Gasifier scale-up
- -G to H Class CTurbine
- -ITM Oxygen
- -Warm gas cleanup
- -CO2/Slurry feed or dry feed
- -Fuel Cell hybrid

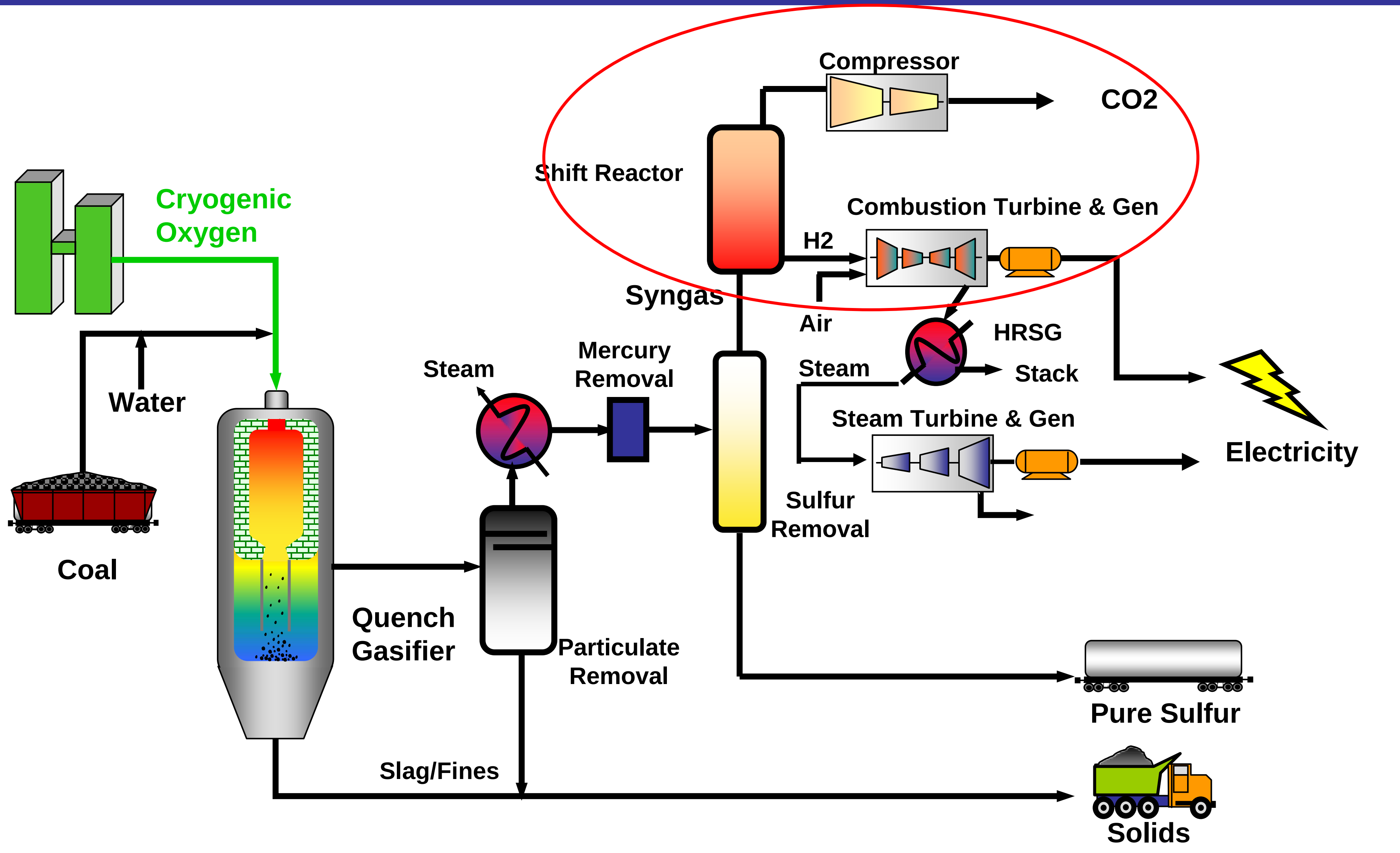
PC

- -1150 F Supercritical
- -Materials
- -5000 psig / 1450 F USC
- -Materials

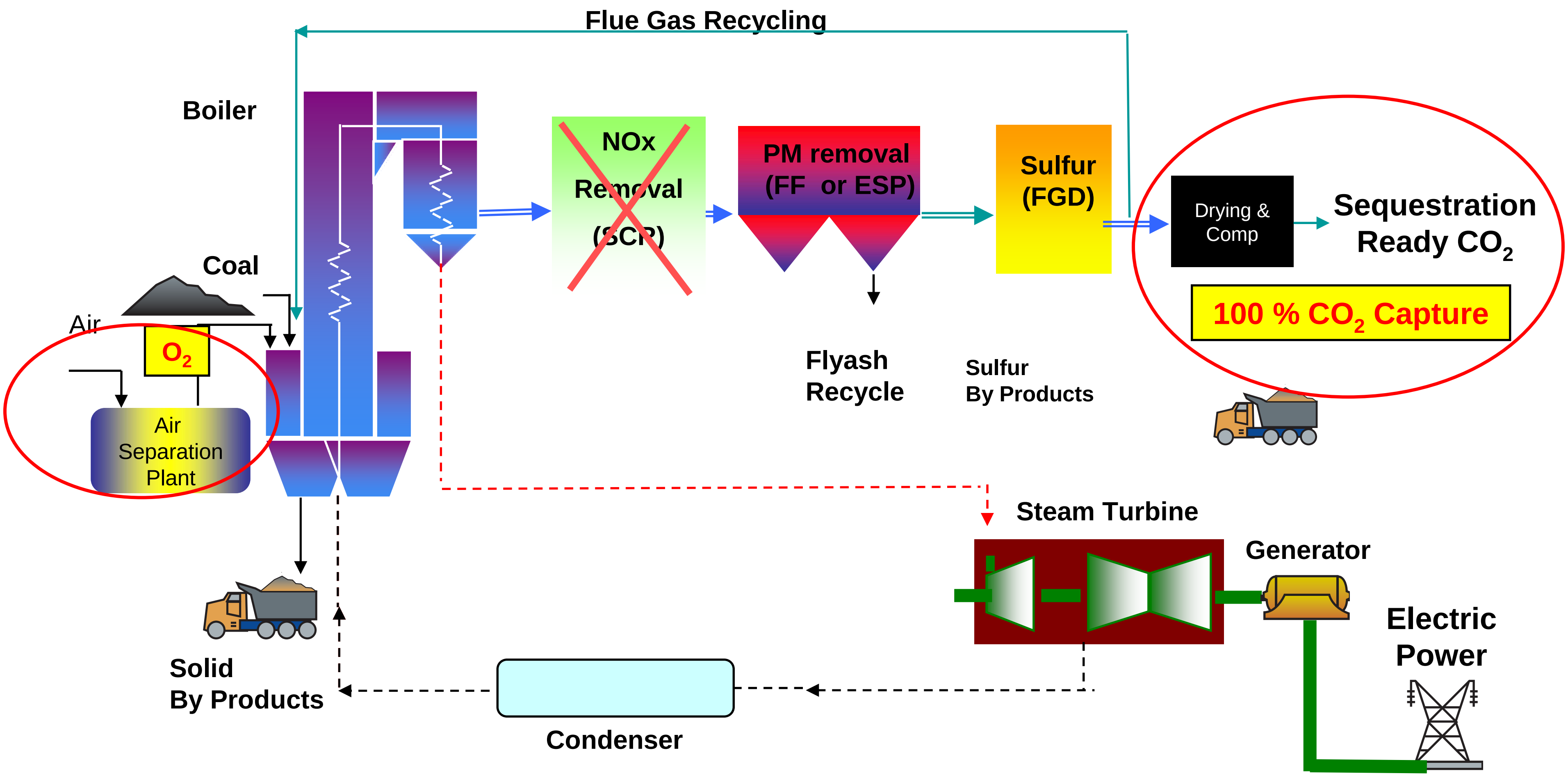
Pulverized Coal Plant With Carbon Capture



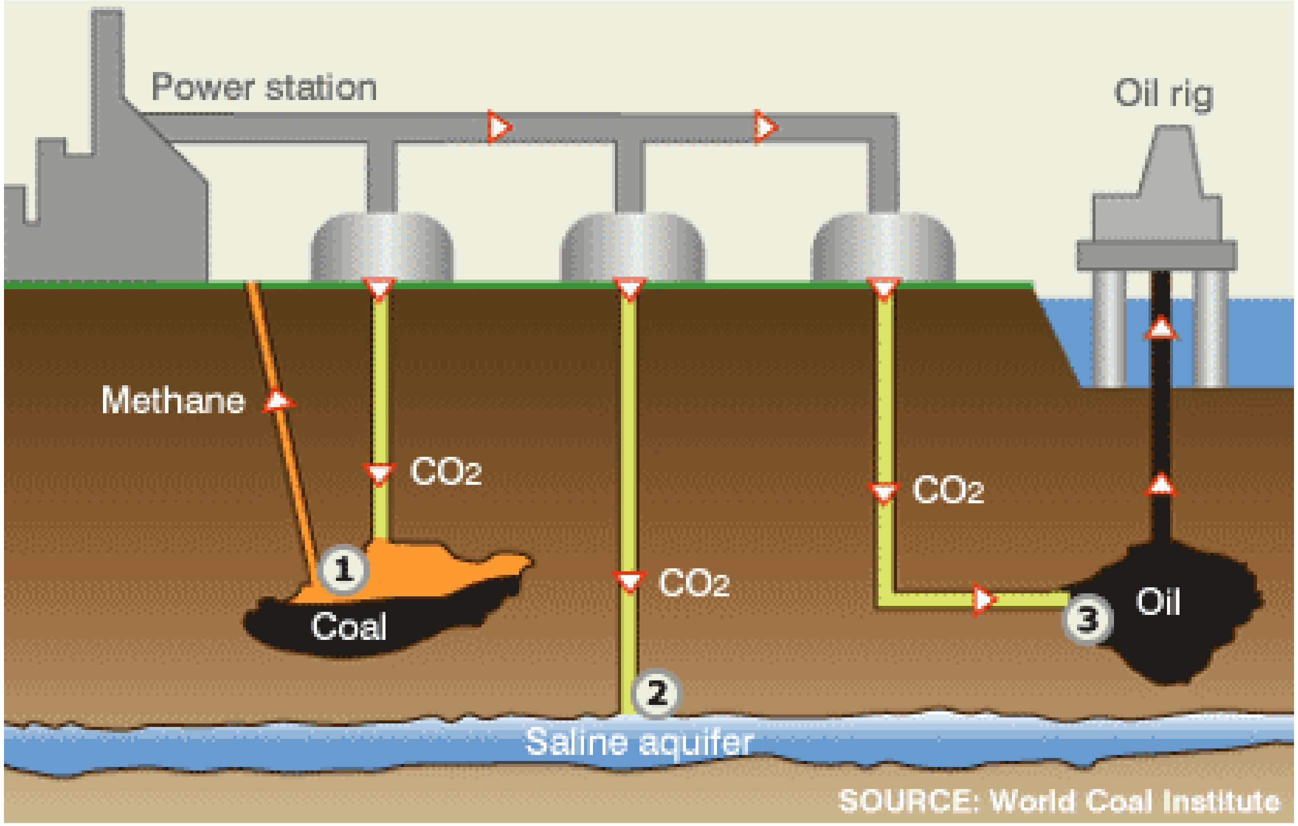
IGCC With Carbon Capture



Oxy-coal Combustion Plant With Carbon Capture



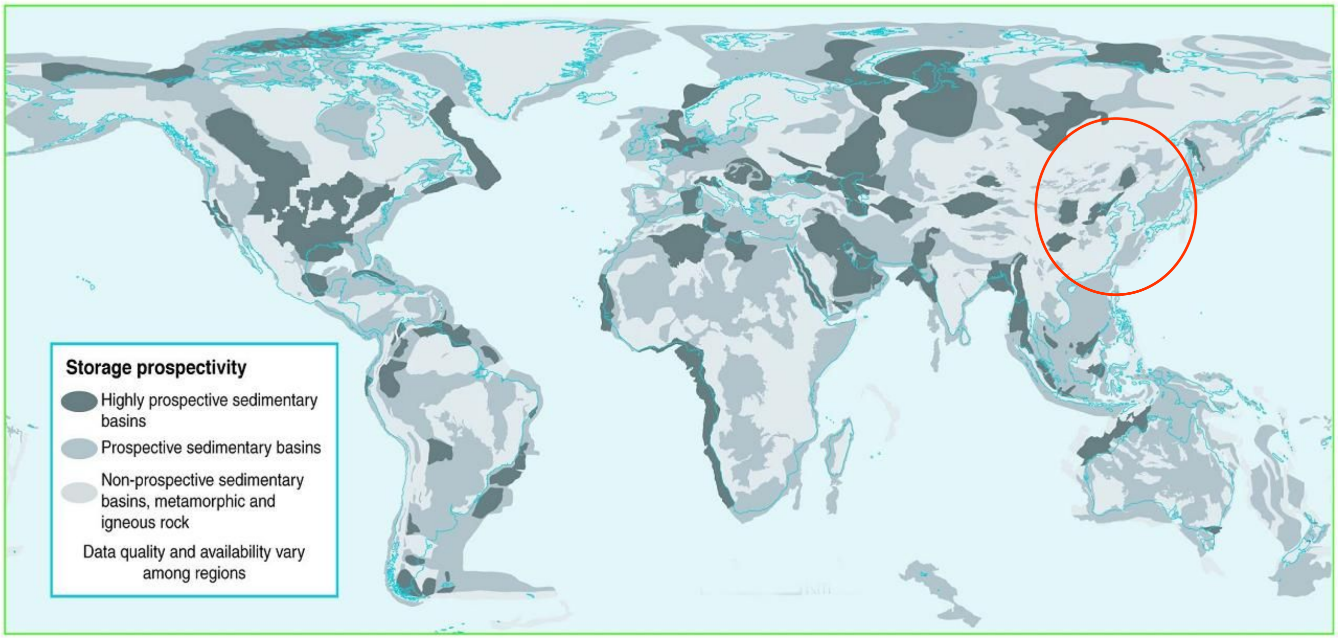
What Can We Do Once We Capture The CO_2?



1. Methane production from unmineable coal seams
2. Injection into deep saline formations (2 miles down)
3. Enhanced Oil Recovery (EOR)

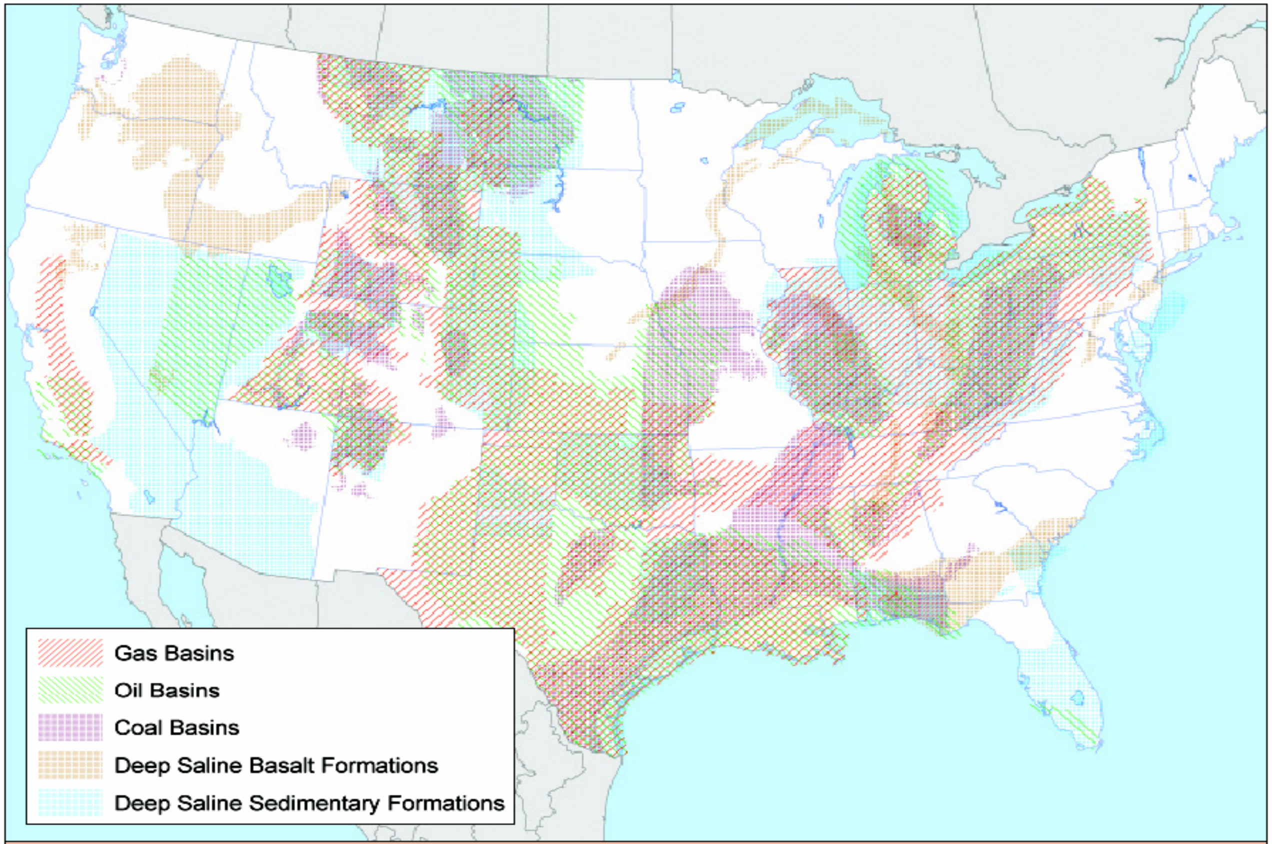
Sequestration sites are plentiful in N. America, but may be scarce in Asia

Prospective areas in sedimentary basins where suitable saline formations, oil or gas fields, or coal beds may be found.



SRCCS Figure TS-2b

Even in the US, some areas are remote from likely disposal sites



▲ Early estimates of CO_2 storage capacity in the United States reveal a very large, widely distributed and perhaps extremely valuable resource with which to cost effectively address climate change.

Source: CO2 Capture & Geologic Storage, Battelle/GTSP, 2005.

Storage Options
(theoretical potentials)

Total projected coal use: 2050 – 2100 =>

330 GT CO_2 (US)

Reservoir	**Global GTCO2**	**US GTCO2**
Deep Saline	9500	3630
Depleted NGas	700	35
Depleted Oil/EOR	120	12
Deep Coal Seams (ECBM)	140	30
Deep Saline –Basalt	Unknown	240

Sources: CO2 Capture & Geologic Storage, Battelle/GTSP, 2005; 1.5%/yr extrapolation from EIA/AEO-2006.

What's Next?

Operating Presumptions ---

Coal will remain a key energy resource for the generation of electricity

Mitigating climate change will succeed only if CCS is successful

To succeed CCS will require “public support” through every phase of technology development from basic R&D, demonstration, early deployment (i.e. “first adopters”), and long(er)-term commercial utilization

IF CCS is the path forward to insure the continued use of coal then --

- What needs to be done?
- How long will it take?
- How much will it cost?
- How will it be paid for?

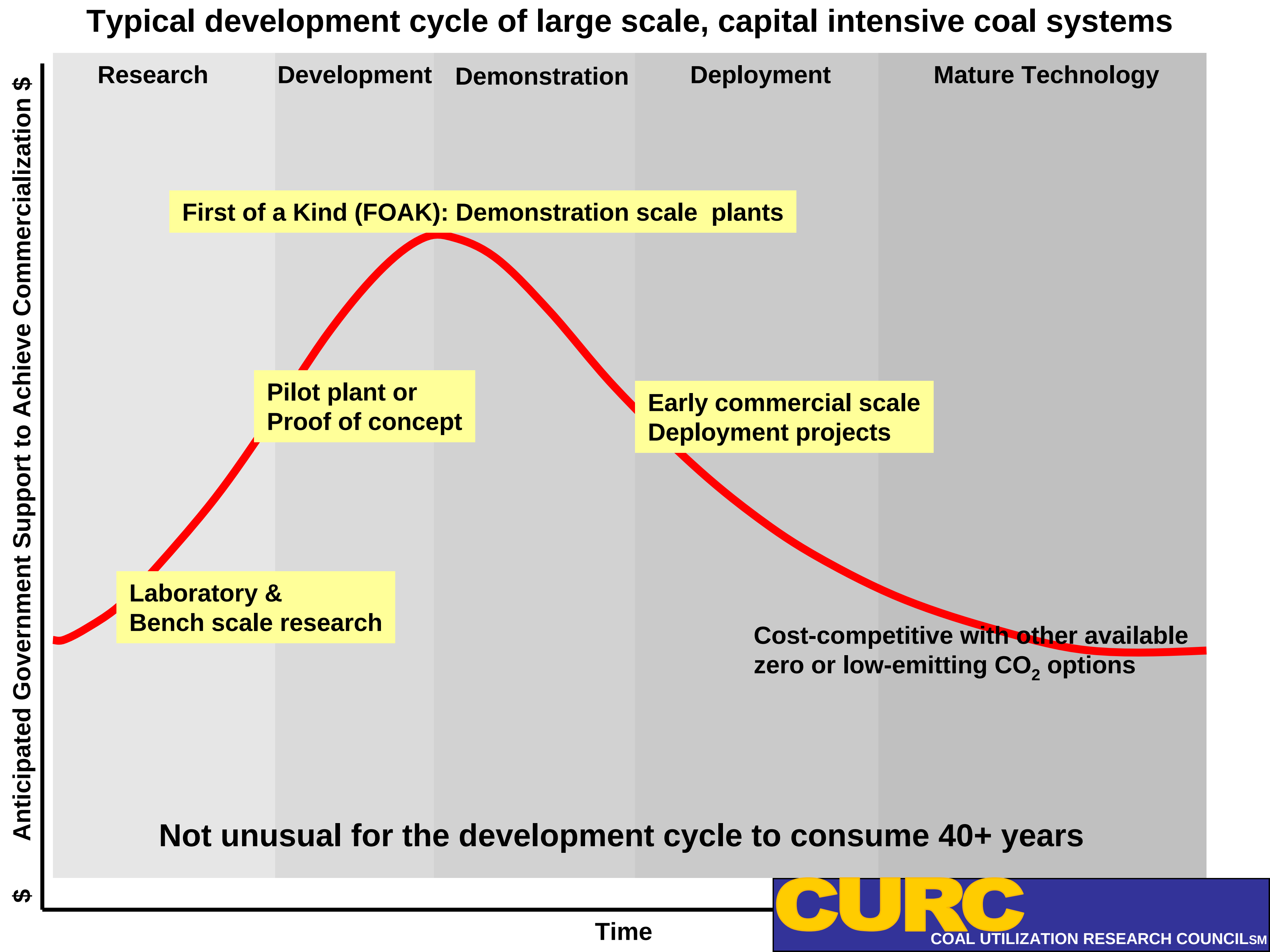
What needs to be done?

- Develop, demonstrate & deploy CCS technology
  - What is CCS technology?
    - CO_2 capture
    - CO_2 transportation
    - CO_2 injection & long-term storage
    - CO_2 monitoring & verification

~ 80% of total CCS costs (CO2 capture)

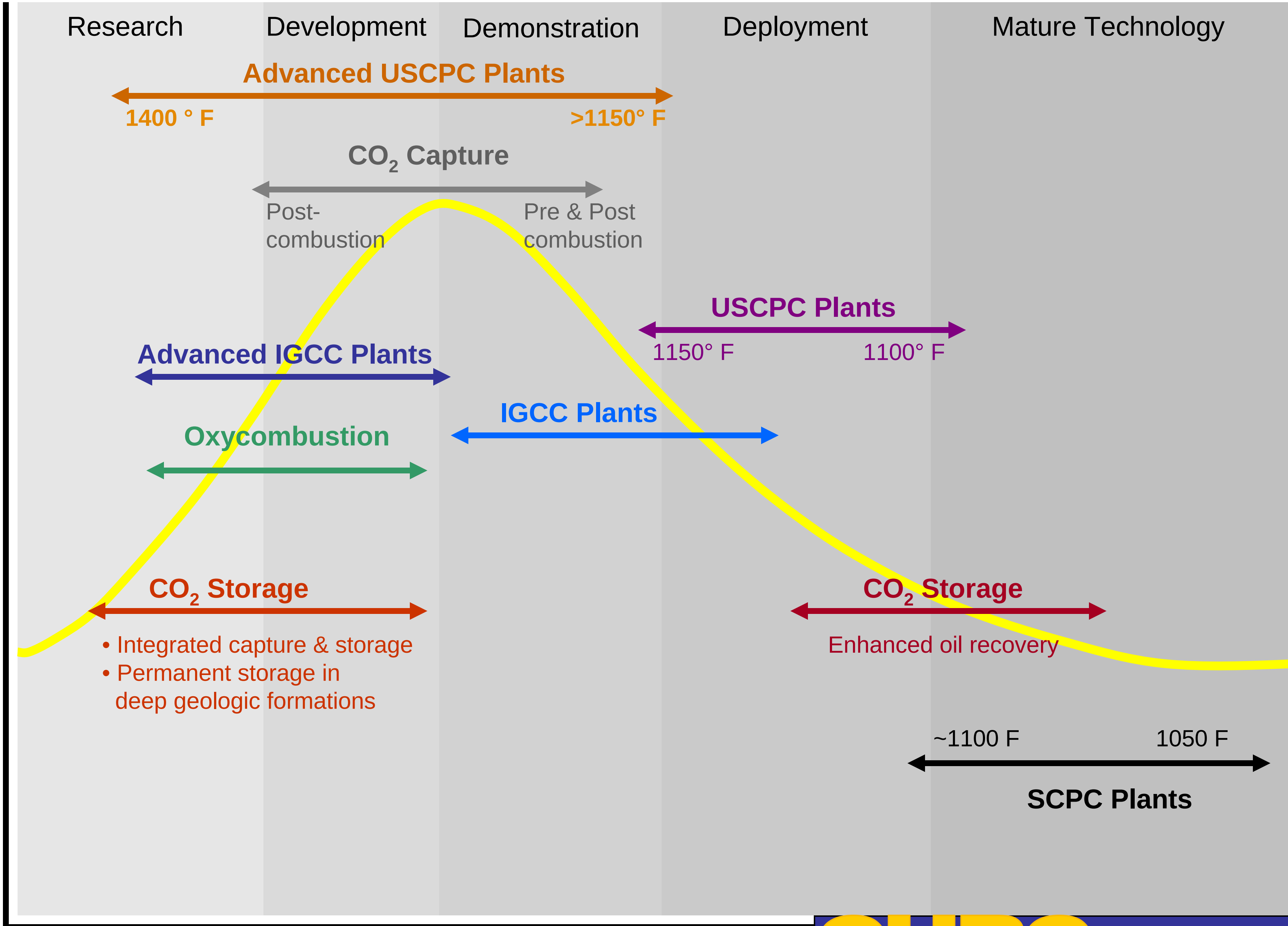
~ 20% of total CCS costs (transportation, injection & storage, monitoring & verification)

- Increase the efficiency of coal-based power plants
  - The greater the efficiency in converting coal to useful energy the less CO_2 emitted
    - Each 1% increase in efficiency = ~2.5% decrease in CO_2
    - Increasing efficiency reduces costs for CCS because less coal used
    - Increased efficiency = more energy/unit of coal



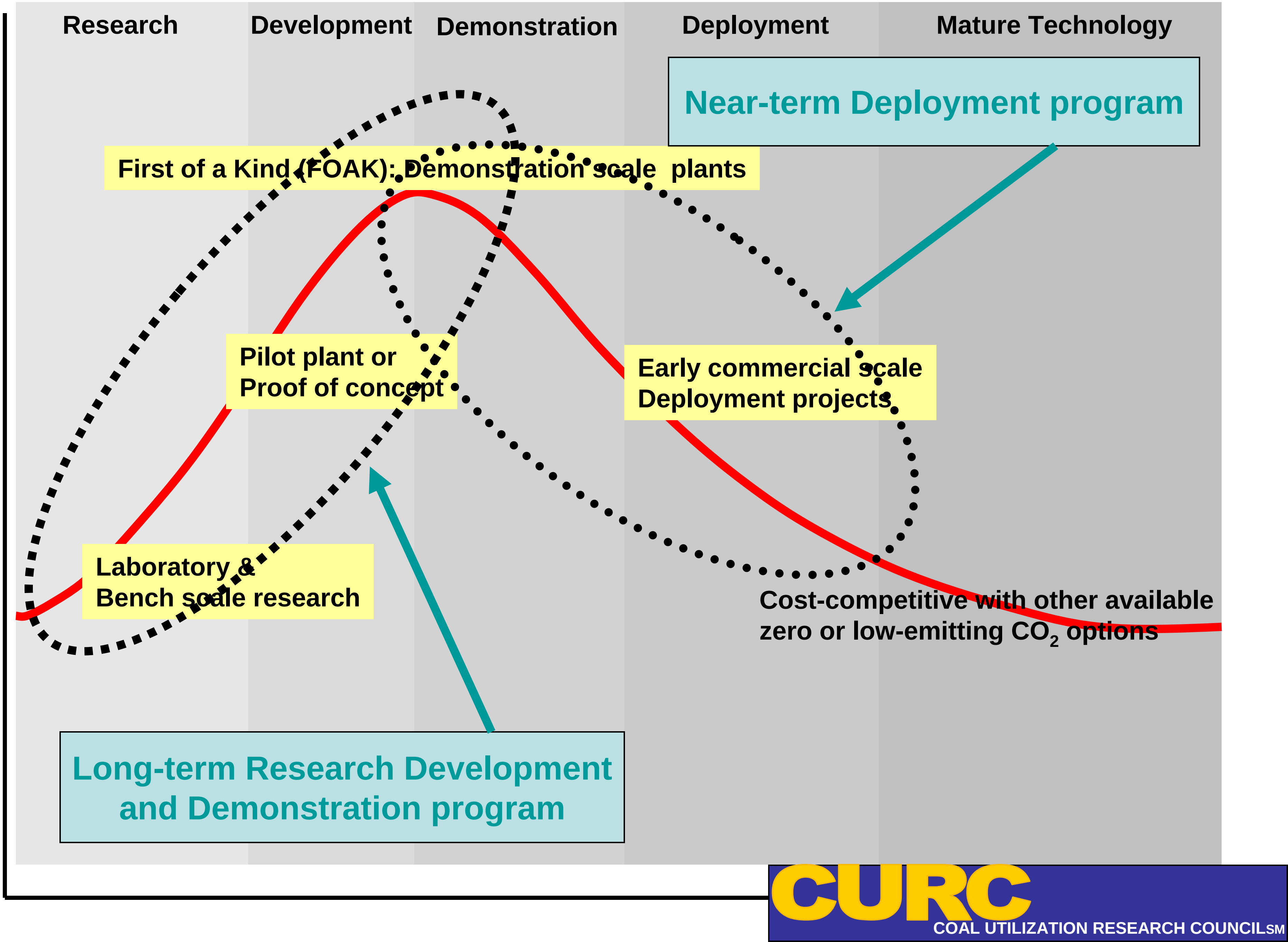
Typical development cycle of large scale, capital intensive coal systems
Research
Development
Demonstration
Deployment
Mature Technology
First of a Kind (FOAK): Demonstration scale plants
Pilot plant or
Proof of concept
Early commercial scale
Deployment projects
Laboratory &
Bench scale research
Cost-competitive with other available
zero or low-emitting CO_2 options
Not unusual for the development cycle to consume 40+ years
Anticipated Government Support to Achieve Commercialization $
$
Time
CURC
COAL UTILIZATION RESEARCH COUNCIL SM

Chart depicts approximate level of maturity of various technologies in 2008

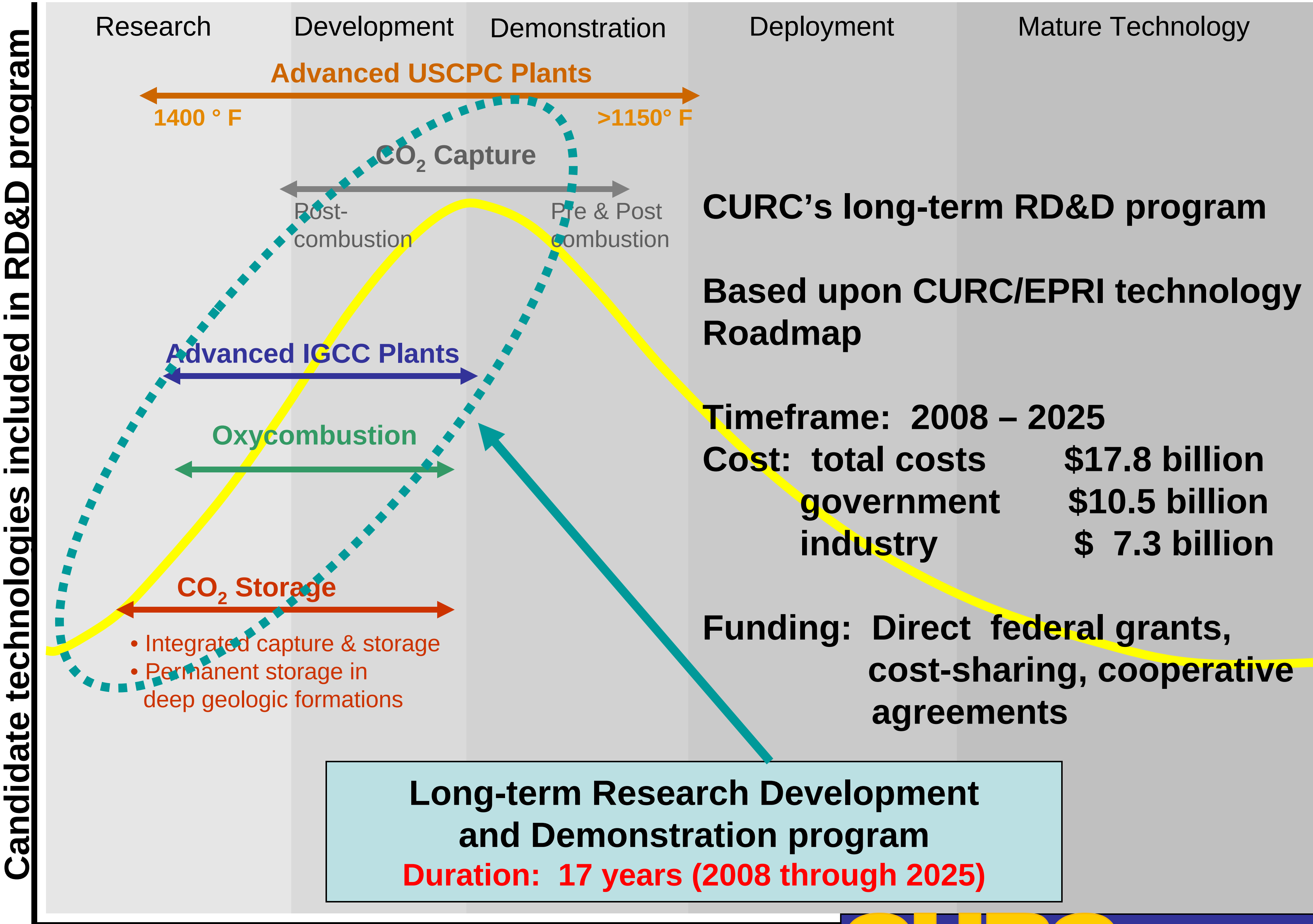


CURC COAL UTILIZATION RESEARCH COUNCIL℠

Typical development cycle of large scale, capital intensive coal systems

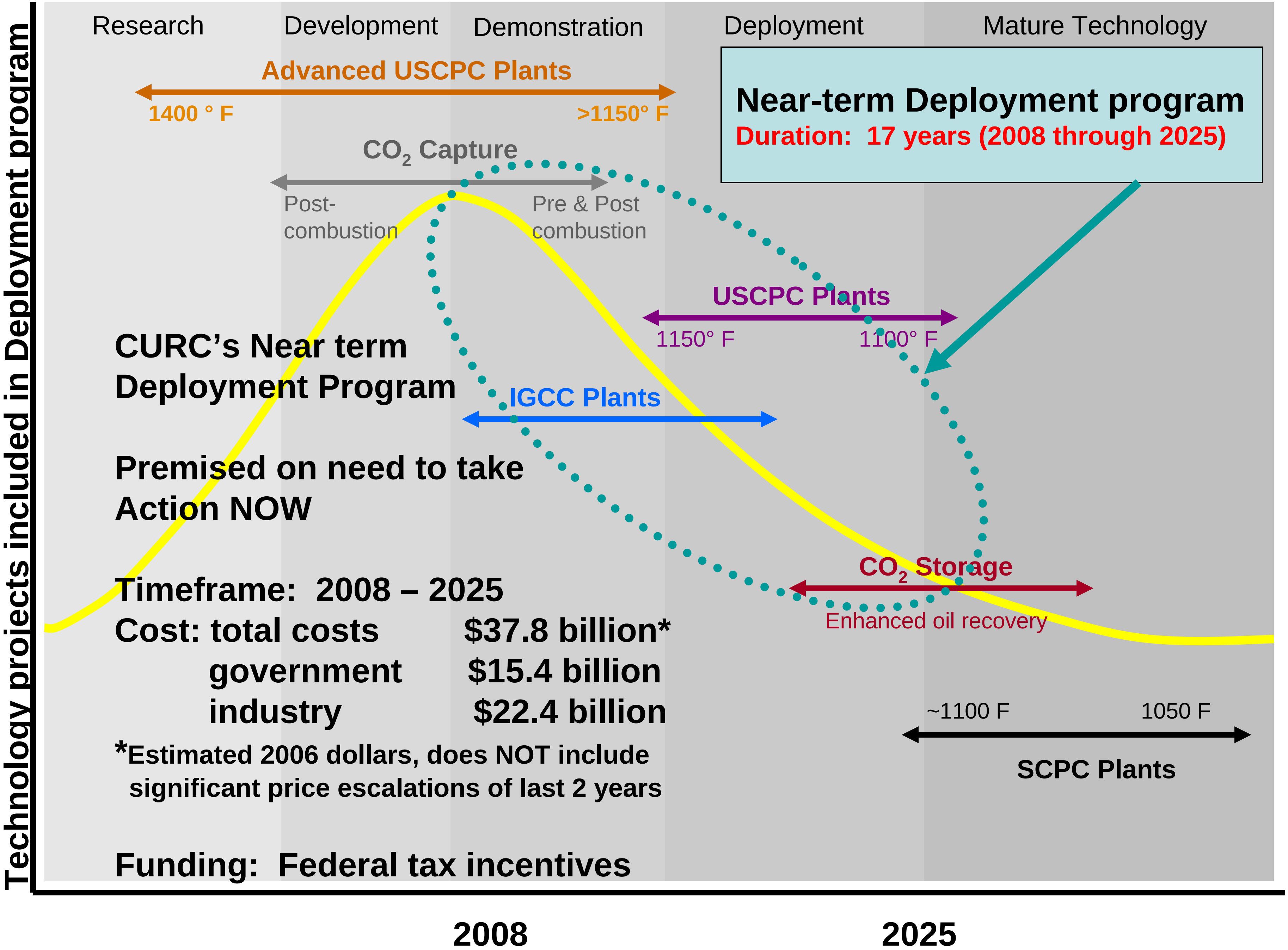


Various advanced coal & CO_2 capture and storage technologies that would be focus of RD&D Program



COAL UTILIZATION RESEARCH COUNCIL[SM]

Approximate level of development of various advanced coal technologies & CO_2 capture and storage



Summary of the Discussion

Coal is Vital to U.S. ENERGY SECURITY

One half of Nation's electricity needs

200 + years of domestic supply

Affordable source of electricity

Electricity grows 25% by 2030 – 80% of that demand is projected to come from COAL

CURC COAL UTILIZATION RESEARCH COUNCIL SM

Summary of the Discussion

If World is to address climate change – CCS must succeed

Intergovernmental Panel on Climate Change concluded 99% of CO_2 can be stored in “appropriately selected and managed geological reservoirs and 99% of the CO_2 will remain permanently stored in those reservoirs for over a 1000 years

Summary of the Discussion

Four major barriers to success

1. All of the pieces of capture technology exist -- integration and experience

2. **Require experience and confidence in storing large volumes of CO2**

3. **Current costs are too high – nearly double the cost of electricity – learn by doing**

4. **Absence of a define regulatory structure to govern the storage of CO2**

For additional information

www.coal.org

Ben Yamagata at:

bny@vnf.com
202-298-1857

COAL UTILIZATION RESEARCH COUNCIL℠