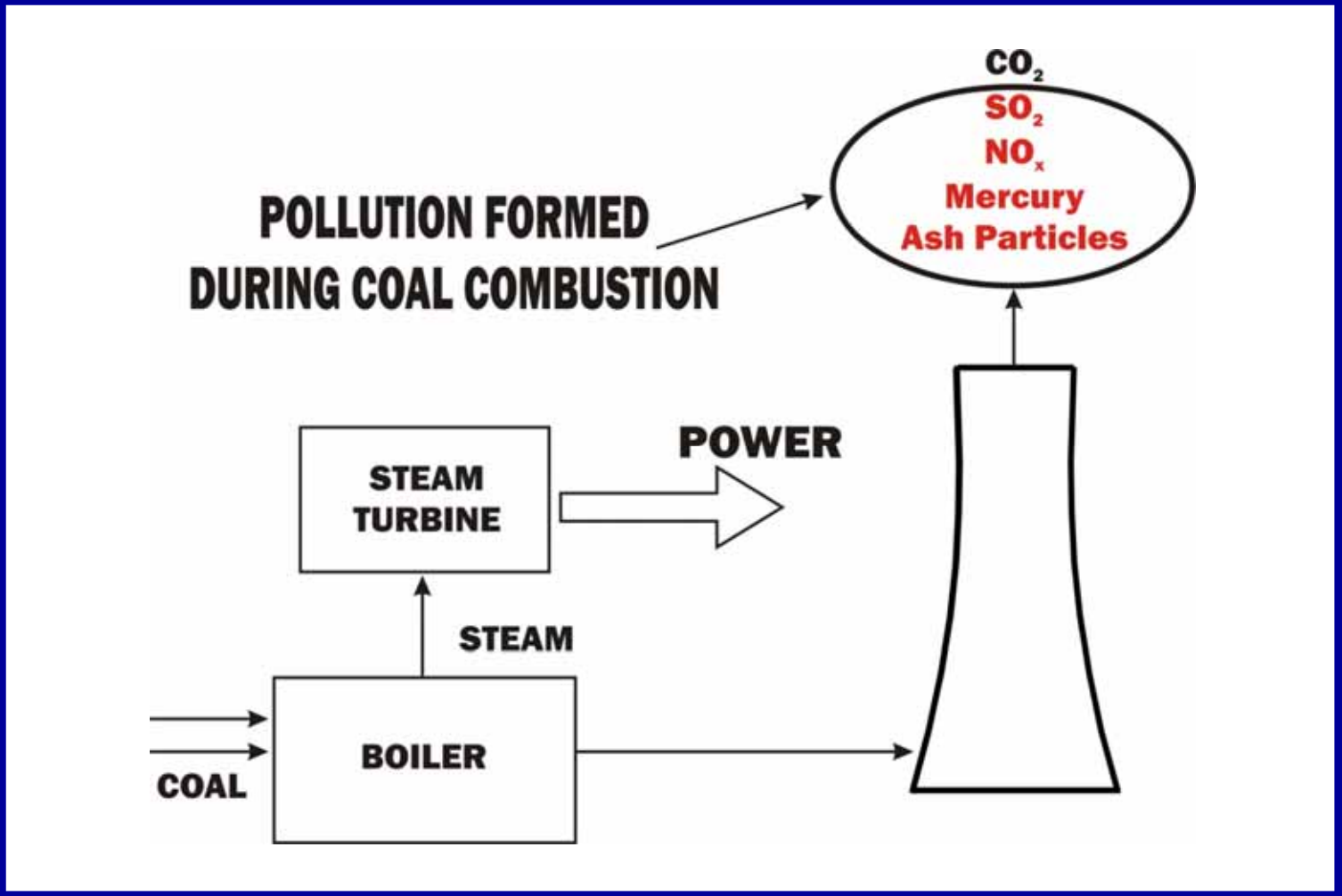
ELECTRIC POWER FROM COAL WITH CARBON CAPTURE AND SEQUESTRATION

by
Dr. Edward Levy
Director, Energy Research Center
Lehigh University

QUICK COAL FACTS

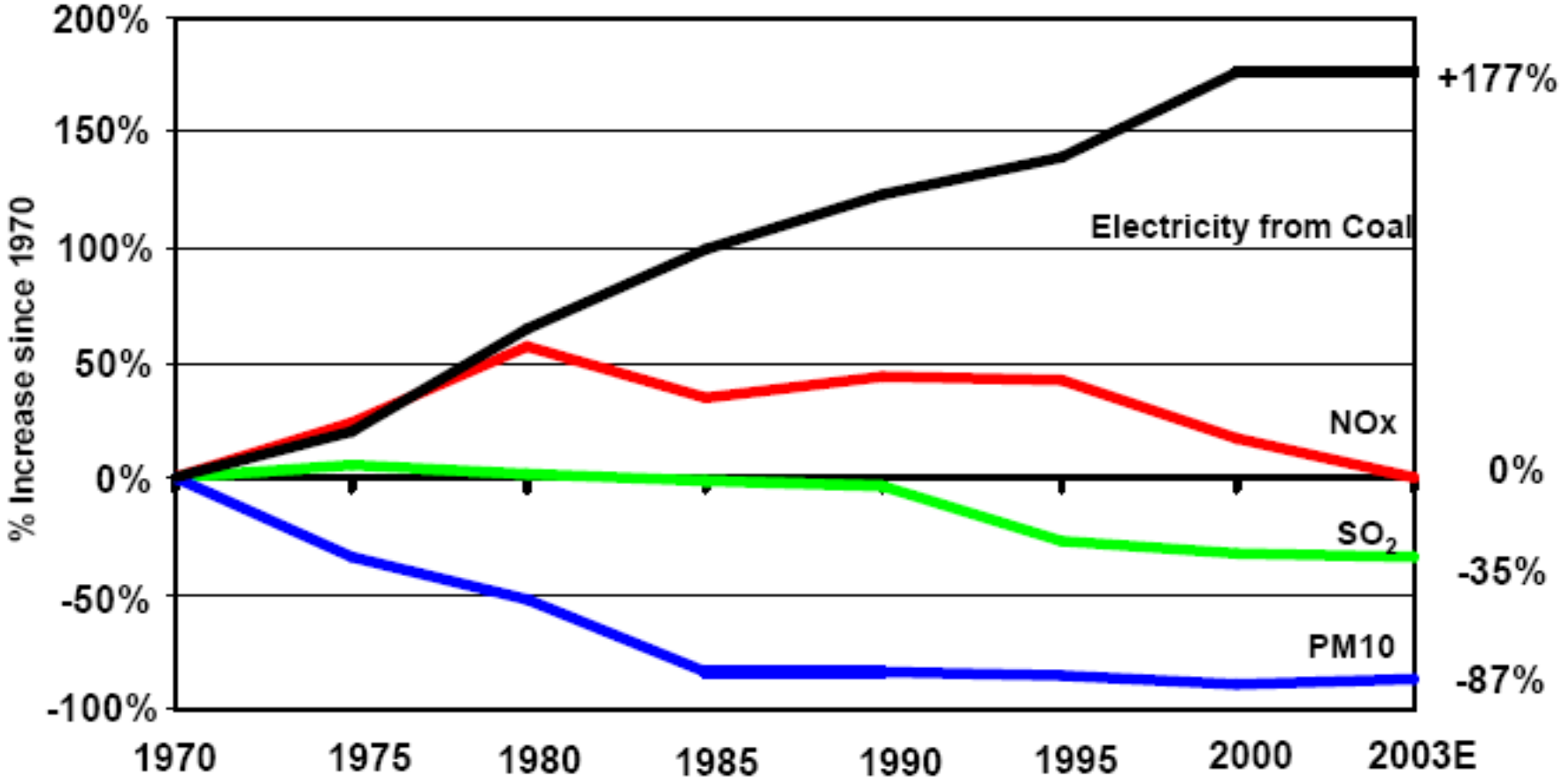
- There are 1471 Coal-Fired Electric Generating Units in the U.S.
- 50.4% of U.S. Electric Generation (MW/hr) is from coal.
- 22% of Energy Consumed in the U.S. is from coal.
- U.S. Coal Reserves are Estimated to Last 250 Years

STACK EMISSIONS FROM COAL-FIRED POWER PLANTS

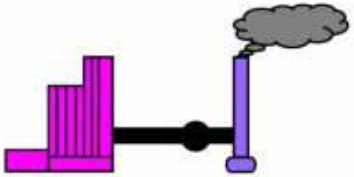


Emissions are declining

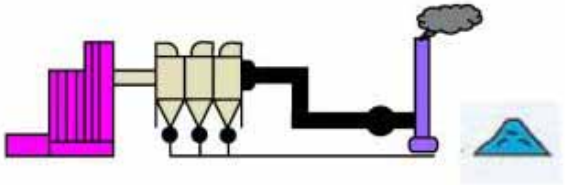
Changes in Coal-Based Electricity & Emissions Since 1970



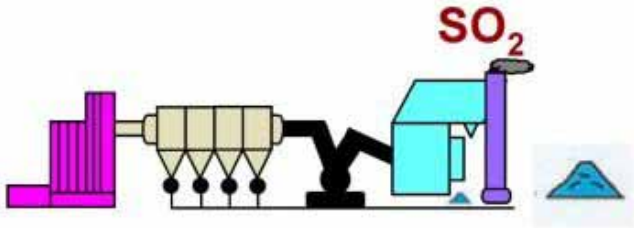
Source: EIA Annual Energy Review 2003 (Sept. 2004), EPA National Emissions Inventory Trends (Dec. 2004)



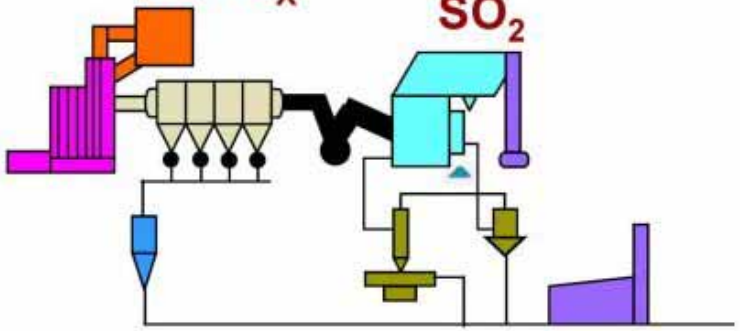
1950s



1970s

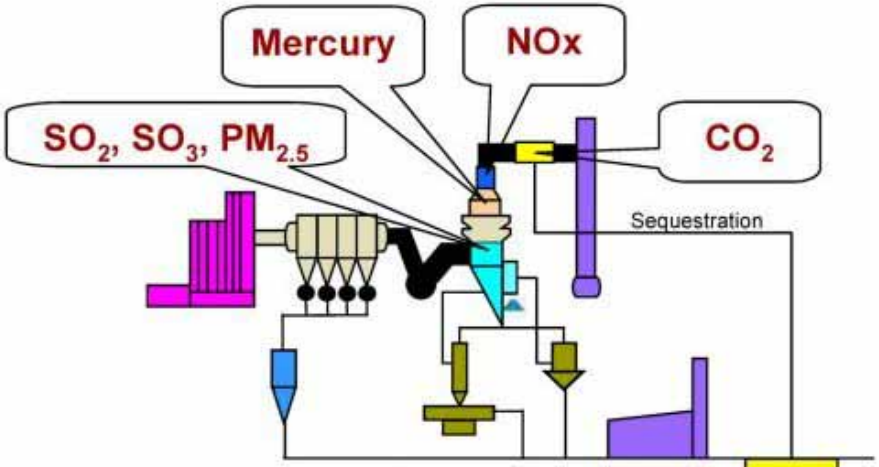


1980s



1990s

End Product Recovery and Utilization

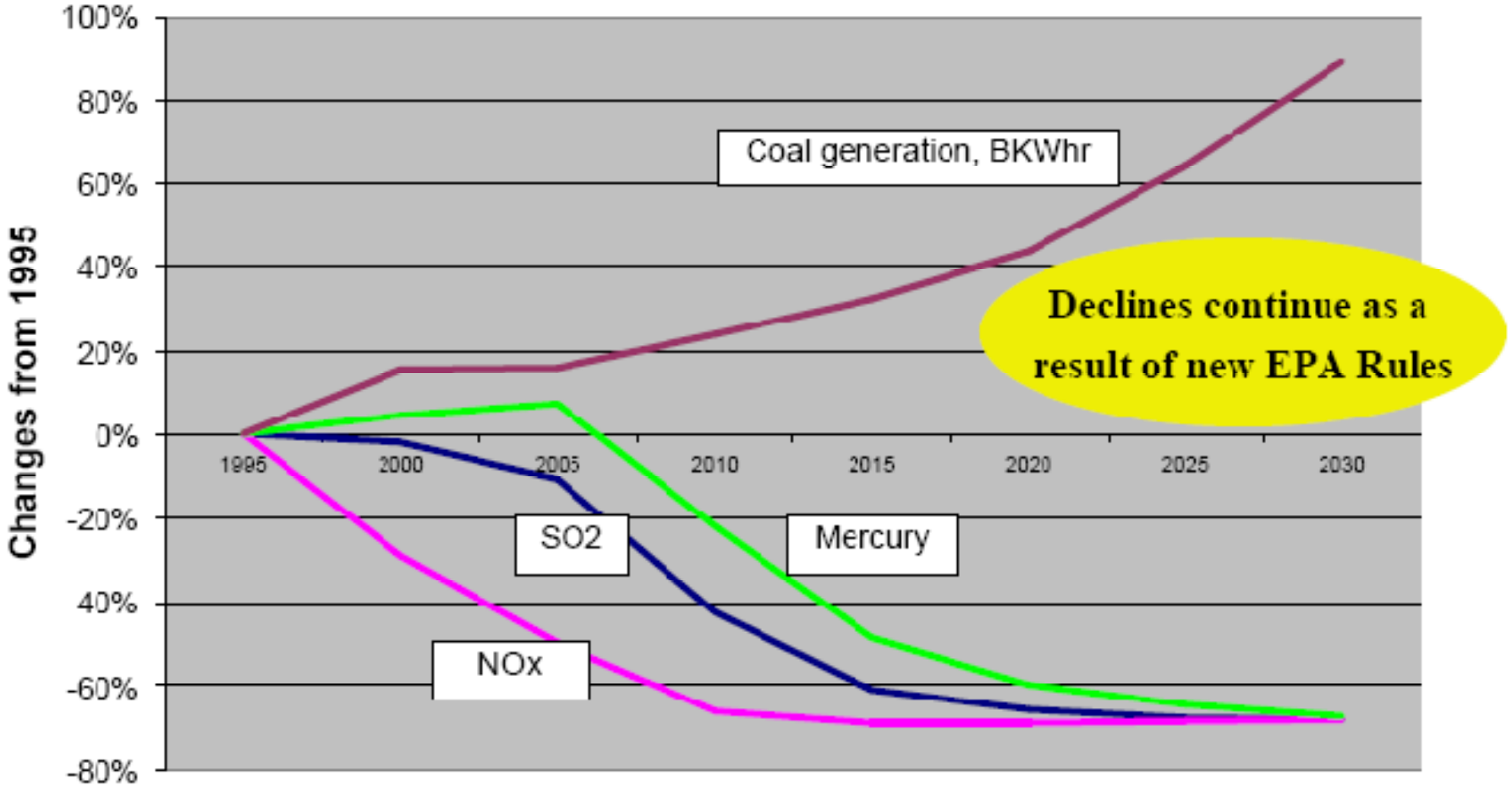


2000-2020

End Product Recovery, Utilization and CO_2 sequestration

Emission Limits Continue To Be Reduced

And Emissions will Continue to Decline even more while Generation increases through 2030



CURC
COAL UTILIZATION RESEARCH COUNCIL
www.coal.org

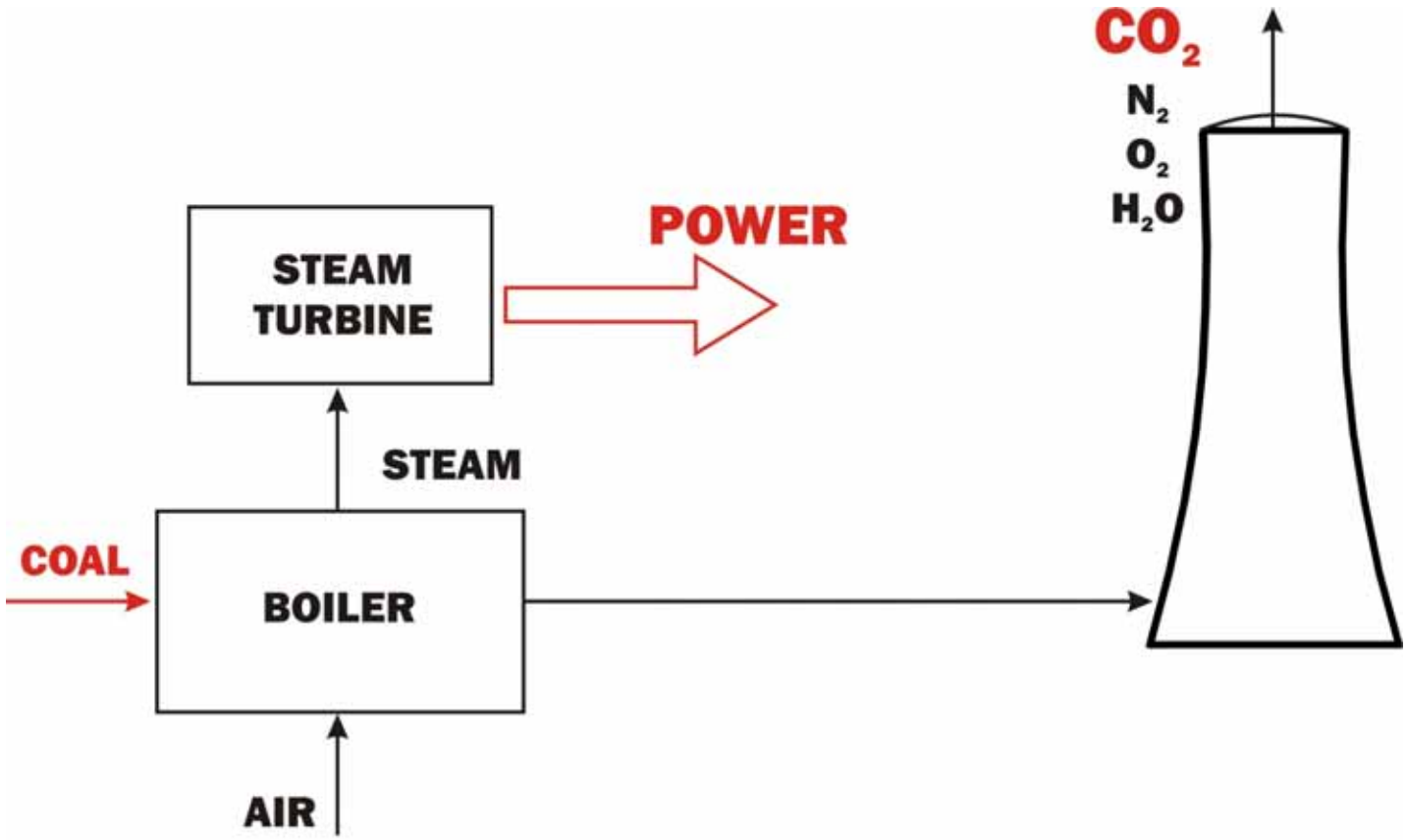
COAL AND GLOBAL WARMING

- 32.7 % OF CO_2 GENERATED IN U.S. IS FROM COAL-FIRED POWER PLANTS

- TOP PRIORITY:

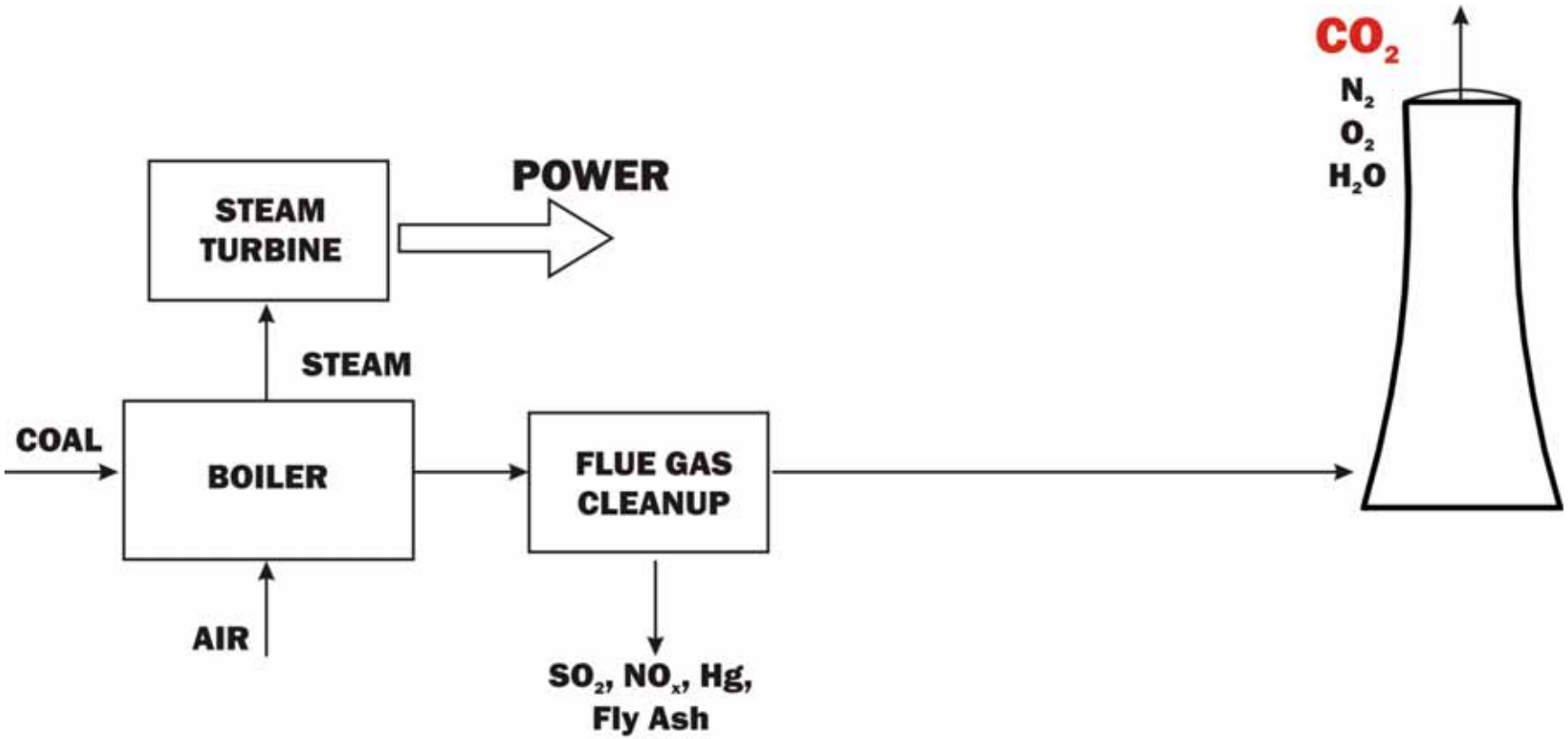
  DEVELOP TECHNOLOGY TO REDUCE CO_2 EMISSIONS FROM COAL-FIRED POWER PLANTS

CO_2 EMISSIONS AND POWER PLANT GENERATION EFFICIENCY



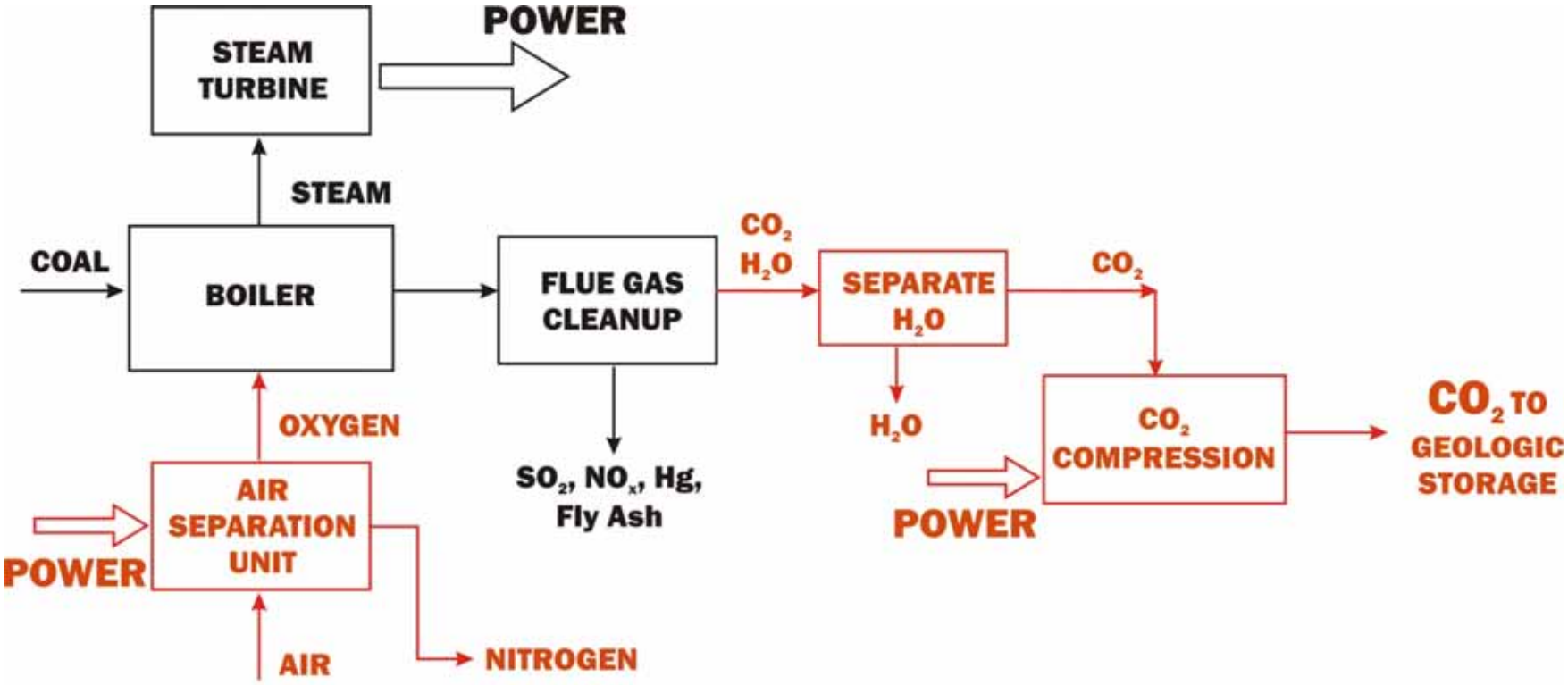
Higher Efficiency Results in Less CO_2

- **An increase in efficiency from 35 to 45%, would decrease CO_2 emissions by 22%!**



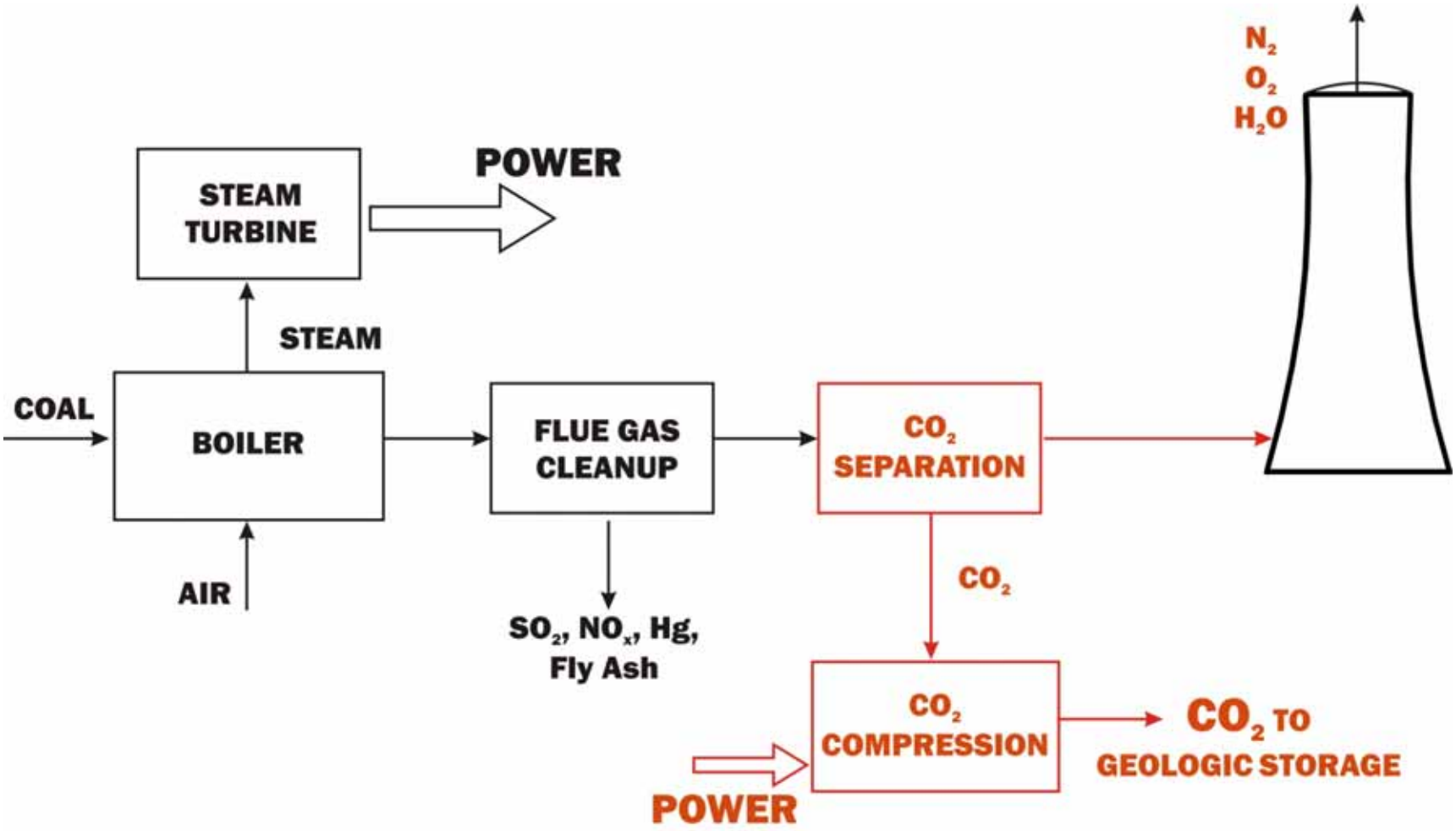
CONVENTIONAL STEAM POWER PLANT

CARBON CAPTURE METHODS

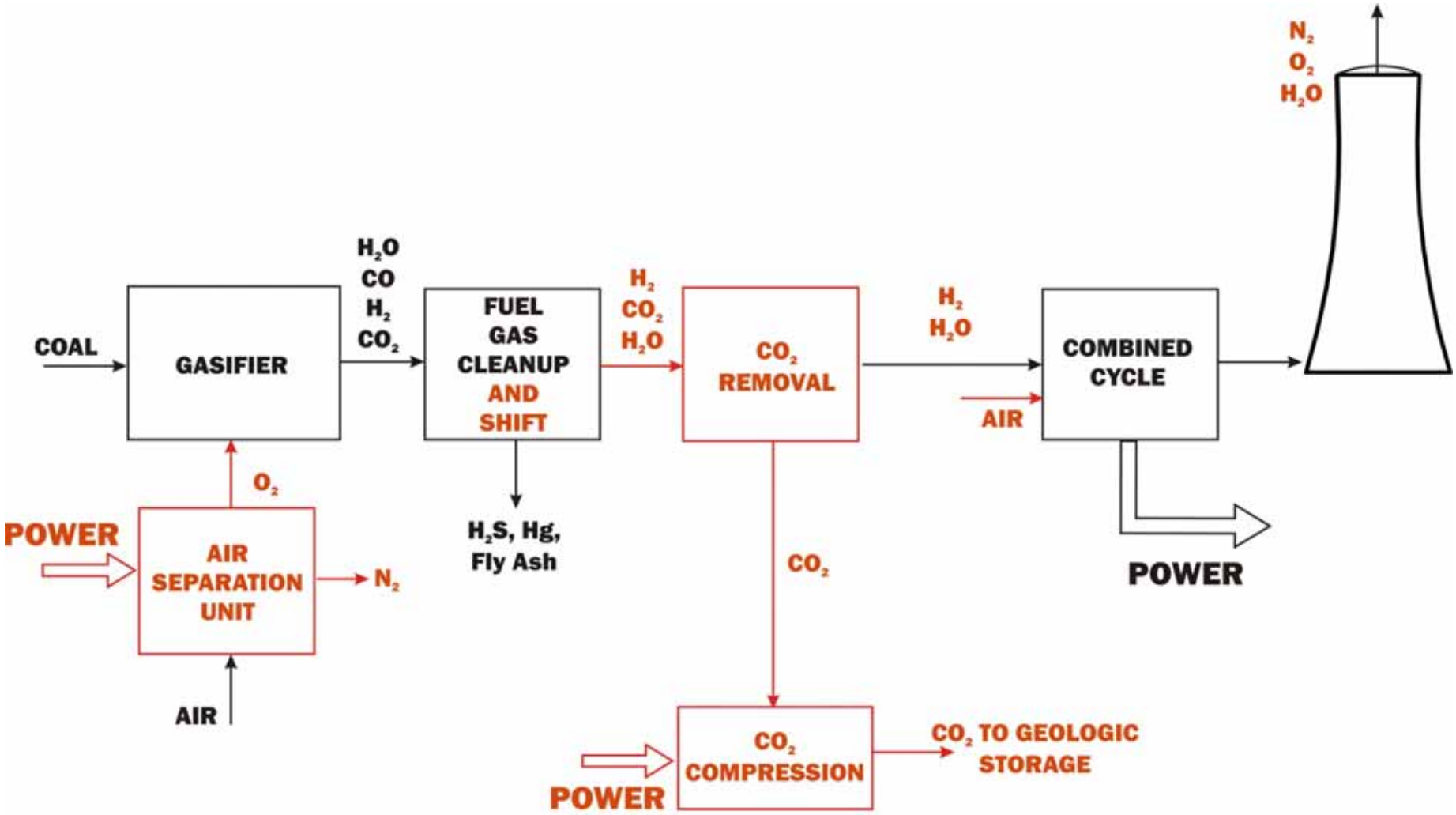


STEAM POWER PLANT WITH OXY-COMBUSTION

CARBON CAPTURE METHODS



STEAM POWER PLANT WITH POST-COMBUSTION CAPTURE



INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) WITH CO_2 CAPTURE

CO_2 SEQUESTRATION

WHAT WILL WE DO WITH THE CAPTURED CO_2?

- ENHANCED OIL RECOVERY
- COAL BED METHANE RECOVERY
- INJECTION INTO DEEP SALINE AQUIFERS

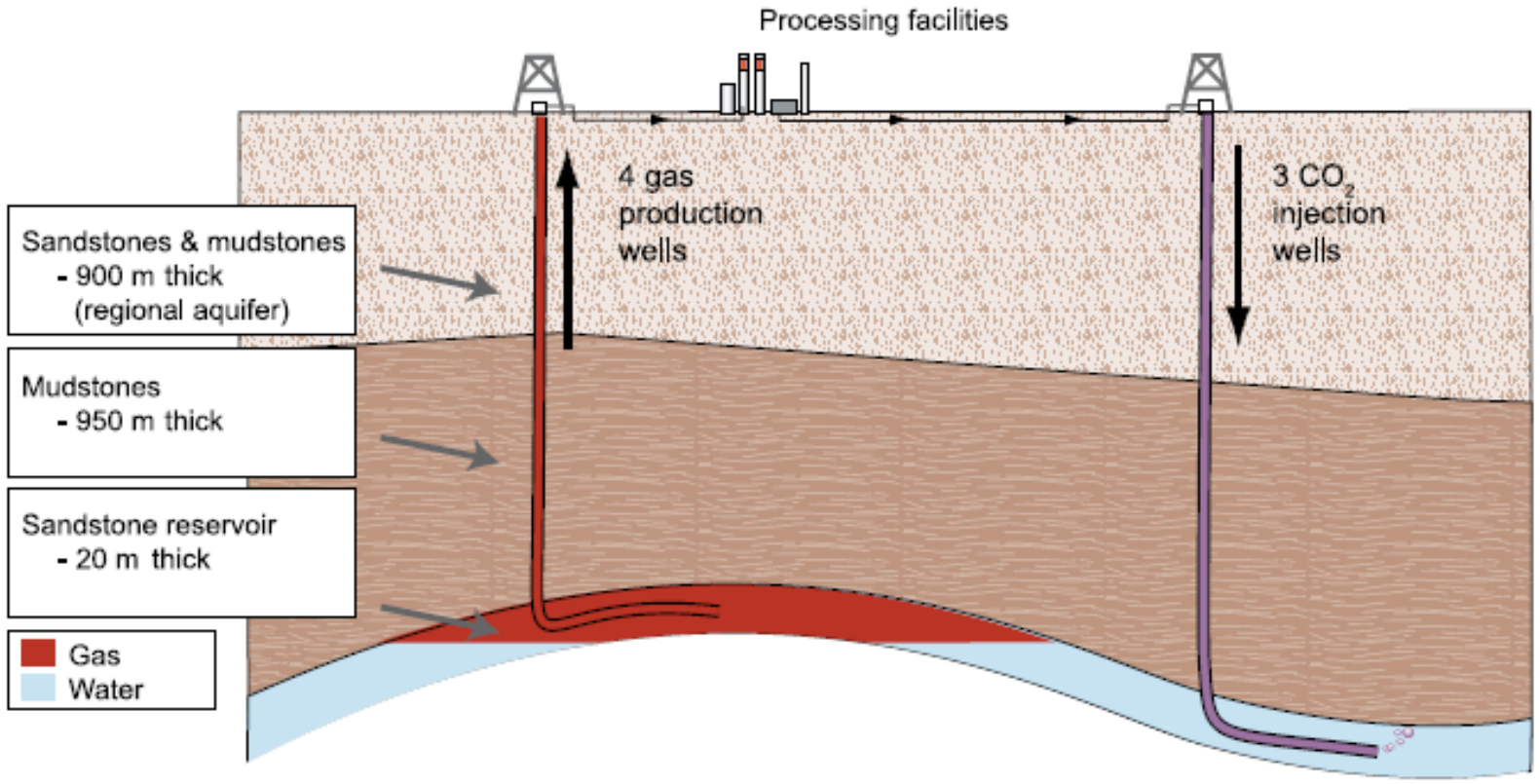
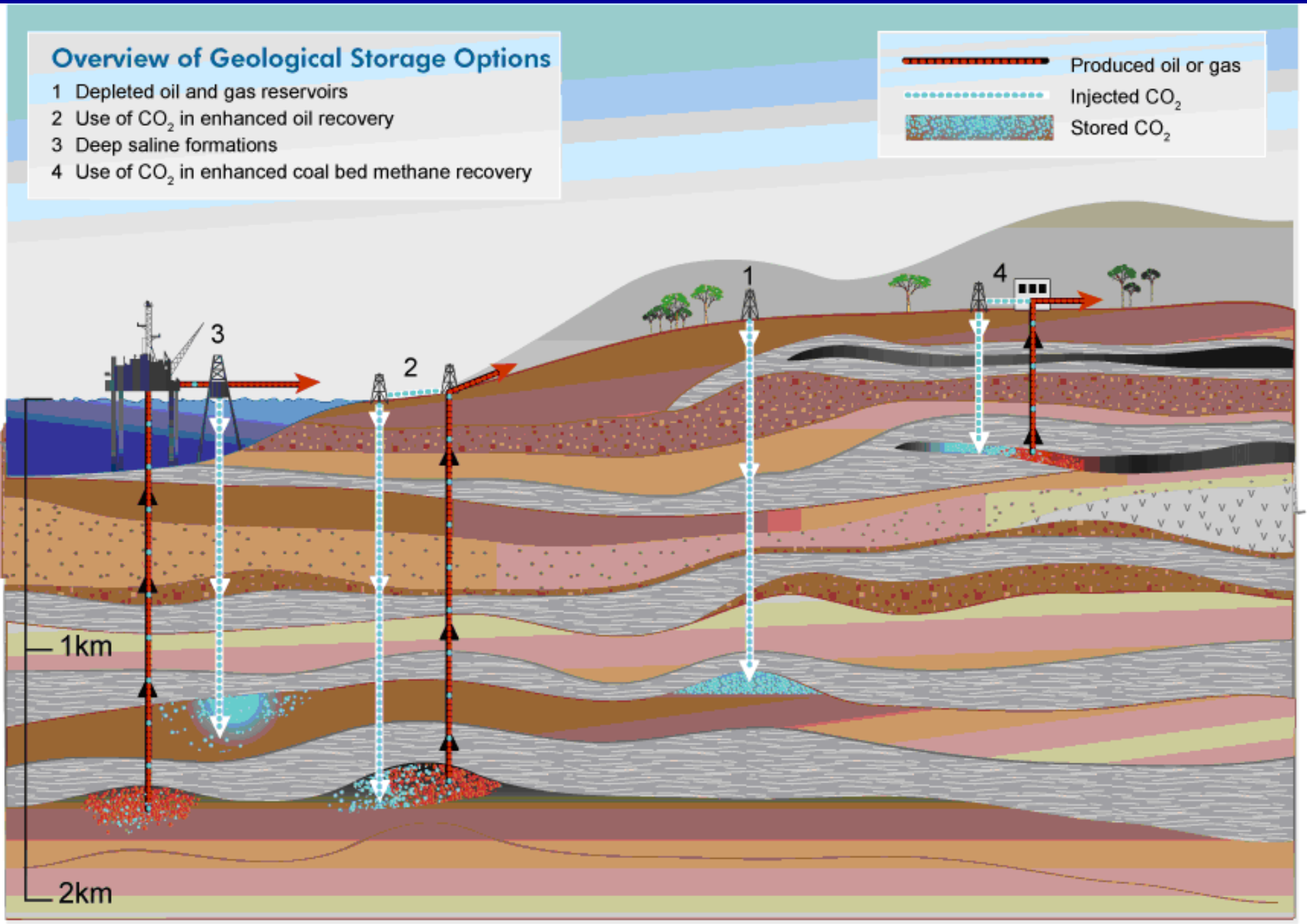


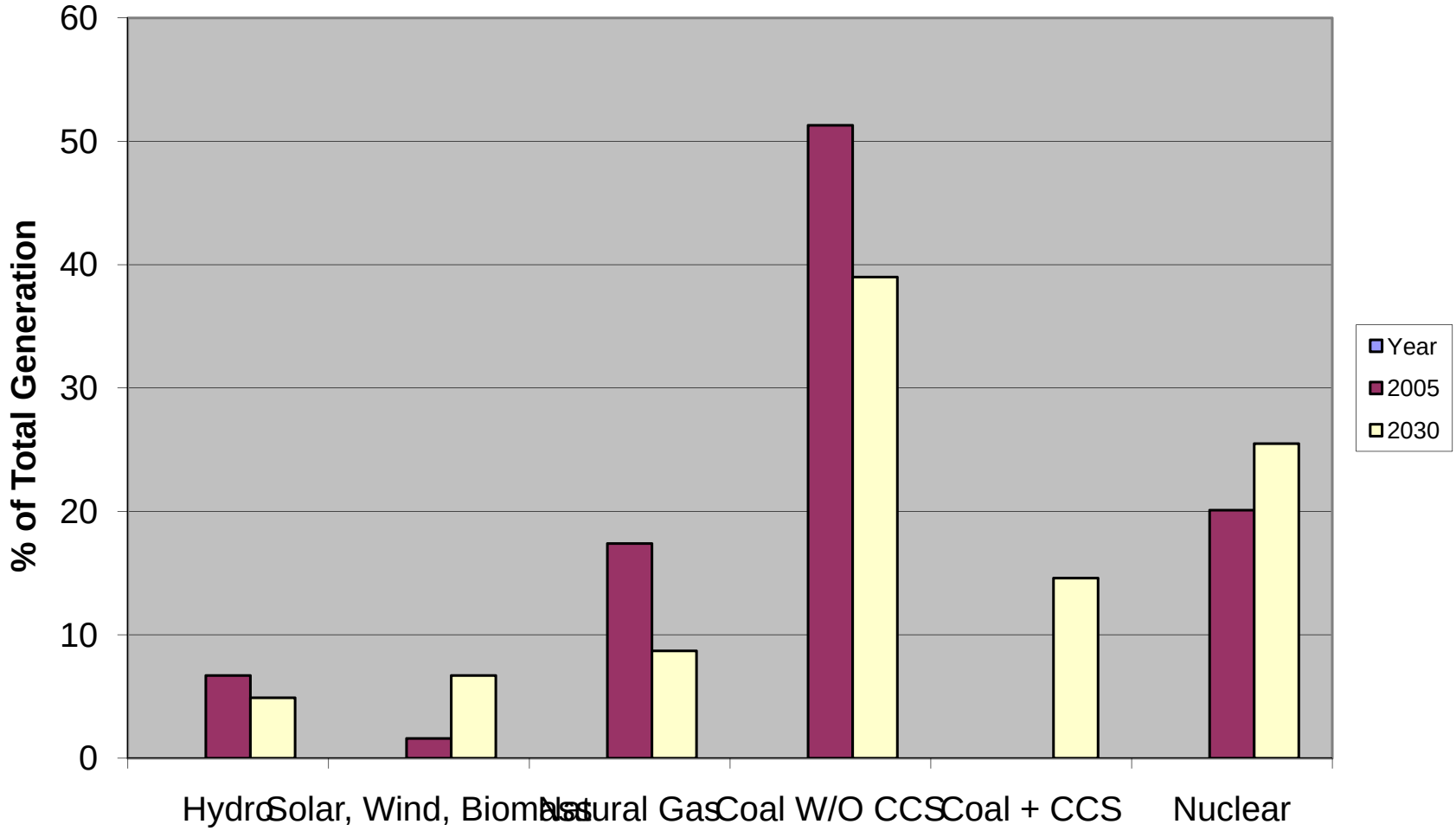
Figure 5.5 Schematic of the In Salah Gas Project, Algeria. One $MtCO_2$ will be stored annually in the gas reservoir. Long-reach horizontal wells with slotted intervals of up to 1.5 km are used to inject CO_2 into the water-filled parts of the gas reservoir.


Overview of Geological Storage Options
1 Depleted oil and gas reservoirs
2 Use of CO_2 in enhanced oil recovery
3 Deep saline formations
4 Use of CO_2 in enhanced coal bed methane recovery
Produced oil or gas
Injected CO_2
Stored CO_2
1
2
3
4
1km
2km

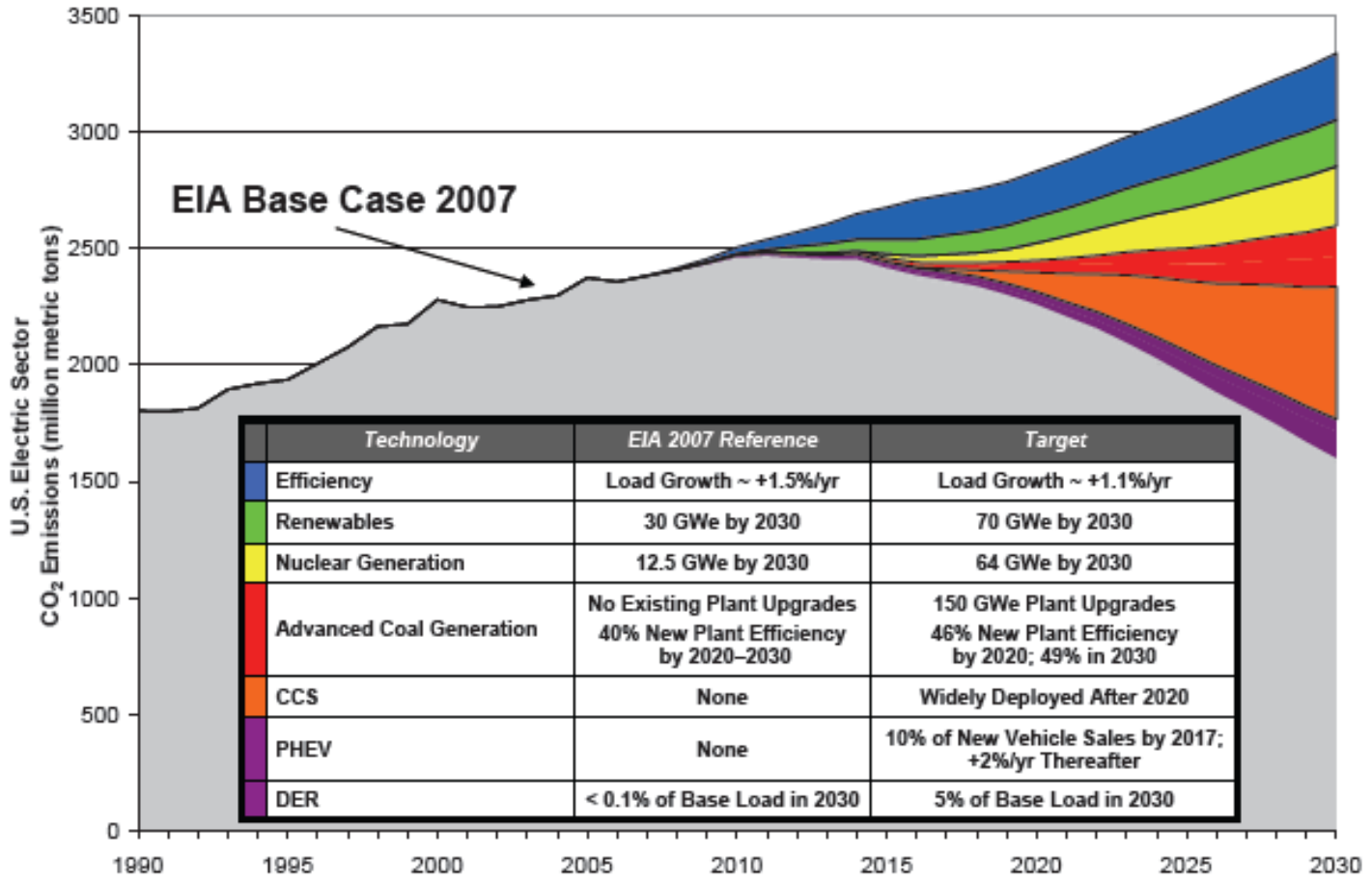
WHERE DOES COAL WITH CCS FIT INTO THE FUTURE GENERATION MIX?

- **Total U.S. Generation of Electricity is Projected to Increase Significantly Between 2005 and 2030**
- **(A 44% Increase in One Plausible Scenario)**
- **Contributing Factors Are Population Growth, Use of Plug-in Electric Vehicles, and Demand Side Conservation**
- **All Generation Options Will Be Needed to Meet the Demand**

PROJECTED U.S.ELECTRICITY GENERATION



CO_2 Reductions … Technical Potential*



Technology	EIA 2007 Reference	Target
Efficiency	Load Growth ~ +1.5%/yr	Load Growth ~ +1.1%/yr
Renewables	30 GWe by 2030	70 GWe by 2030
Nuclear Generation	12.5 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Existing Plant Upgrades 40% New Plant Efficiency by 2020–2030	150 GWe Plant Upgrades 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Vehicle Sales by 2017; +2%/yr Thereafter
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

** Achieving all targets is very aggressive, but potentially feasible.*

EPRI ELECTRIC POWER RESEARCH INSTITUTE

RESEARCH NEEDS

INCREASE POWER PLANT EFFICIENCY

- Increase Steam Temperatures and Pressures
- Develop Innovative Efficiency Improvement Techniques
- Develop Improved Sensors, Controls and Process Optimization Techniques

INCREASE POWER PLANT EFFICIENCY

- **Increase Steam Temperatures and Pressures** (Materials Science, Mechanical Engineering)
- **Develop Innovative Efficiency Improvement Techniques** (Mechanical Engineering, Chemical Engineering, Materials Science)
- **Develop Improved Sensors, Controls and Process Optimization Techniques** (Mechanical Engineering, Computer Science, Chemical Engineering, Electrical Engineering Physics, Materials Science)

OXY-COAL COMBUSTON

- Develop Low Cost Methods of Generating Oxygen
- Optimize Process Operating Conditions
- Develop Sensors and Controls
- Develop Ferrous Alloys for Oxy-Combustion Environment
- Develop Improved CO_2 Compression Processes

POST COMBUSTION CO_2 CAPTURE

- Improved CO_2 Capture Processes
- Sensors, Controls and Process Optimization
- Materials
- CO_2 Compression

INTEGRATED GASIFICATION COMBINED CYCLE

- Gasification Processes
- CO_2 Capture
- Hot Gas Cleanup
- Materials
- Sensors, Controls, and Process Optimization
- CO_2 Compression

POWER PLANT POLLUTION CONTROL

- Acid Rain Gases
- Mercury
- Capture of Fine Particles
- (Improved Processes, Instrumentation, Controls, Process Optimization, Materials)

CARBON SEQUESTRATION

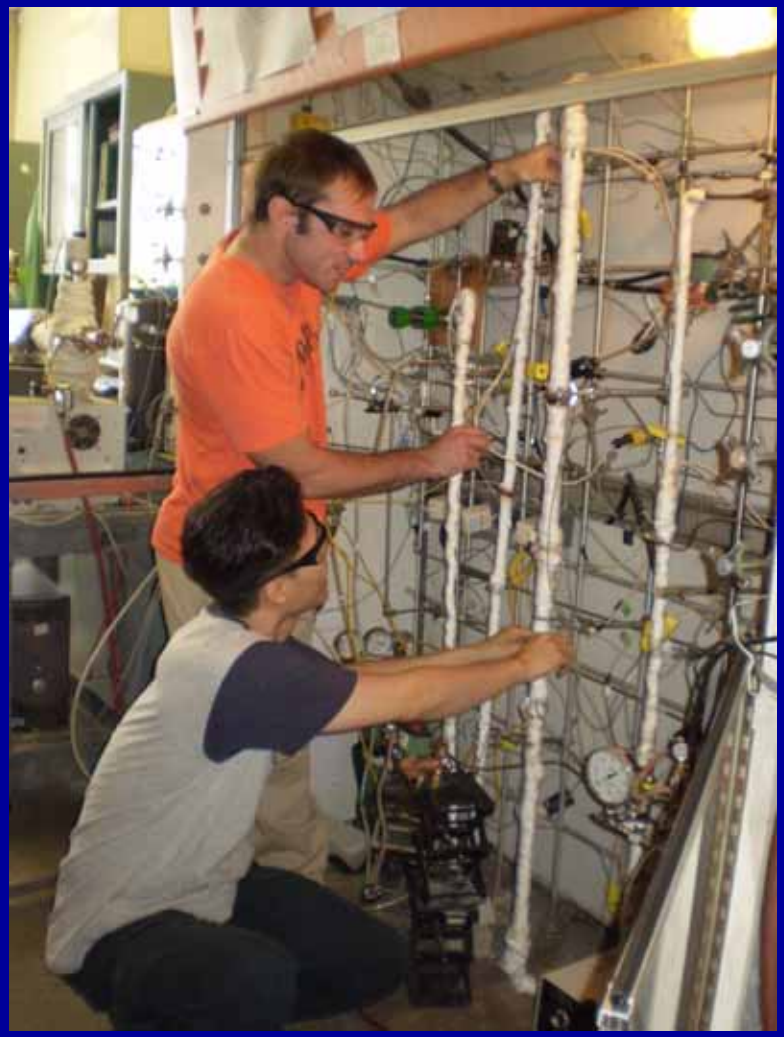
- What Happens to CO_2 After Injection?
- Chemical Reactions in Geologic Formations
- Sensors/Monitoring/Controls
- Public Policy Dimensions of Geologic Sequestration

EXAMPLES OF RESEARCH AT LEHIGH'S ENERGY RESEARCH CENTER

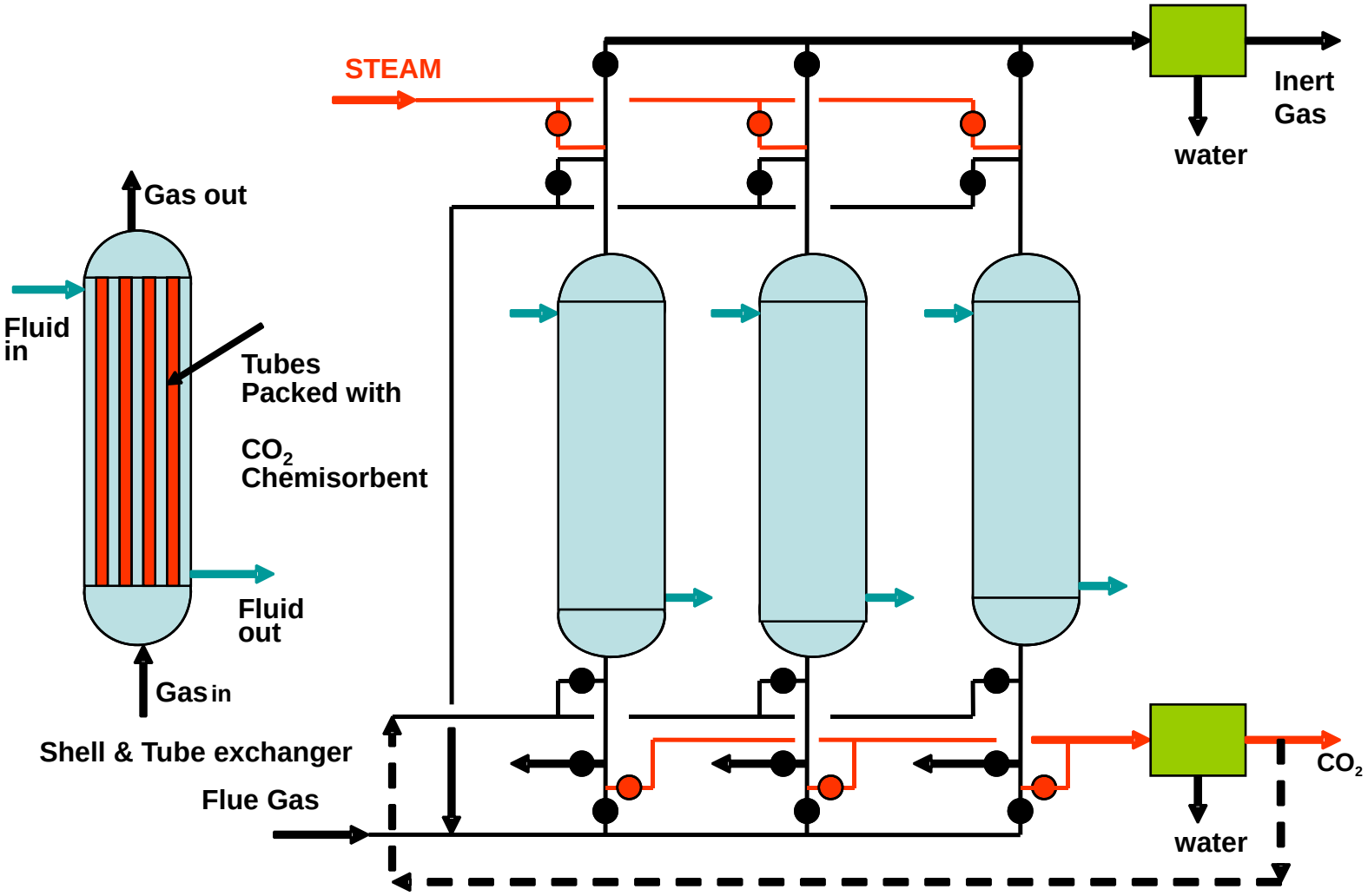
CO_2 RECOVERY FROM FLUE GAS: Chemisorptive Carbon Capture

(S. Sircar and H. Caram)

- Use Solid Sorbents to Separate CO_2 from Flue Gas
- Constraints – Temperature Range, Sulfur Poisoning, Energy Costs
- Laboratory Experimentation and Fundamental Modeling



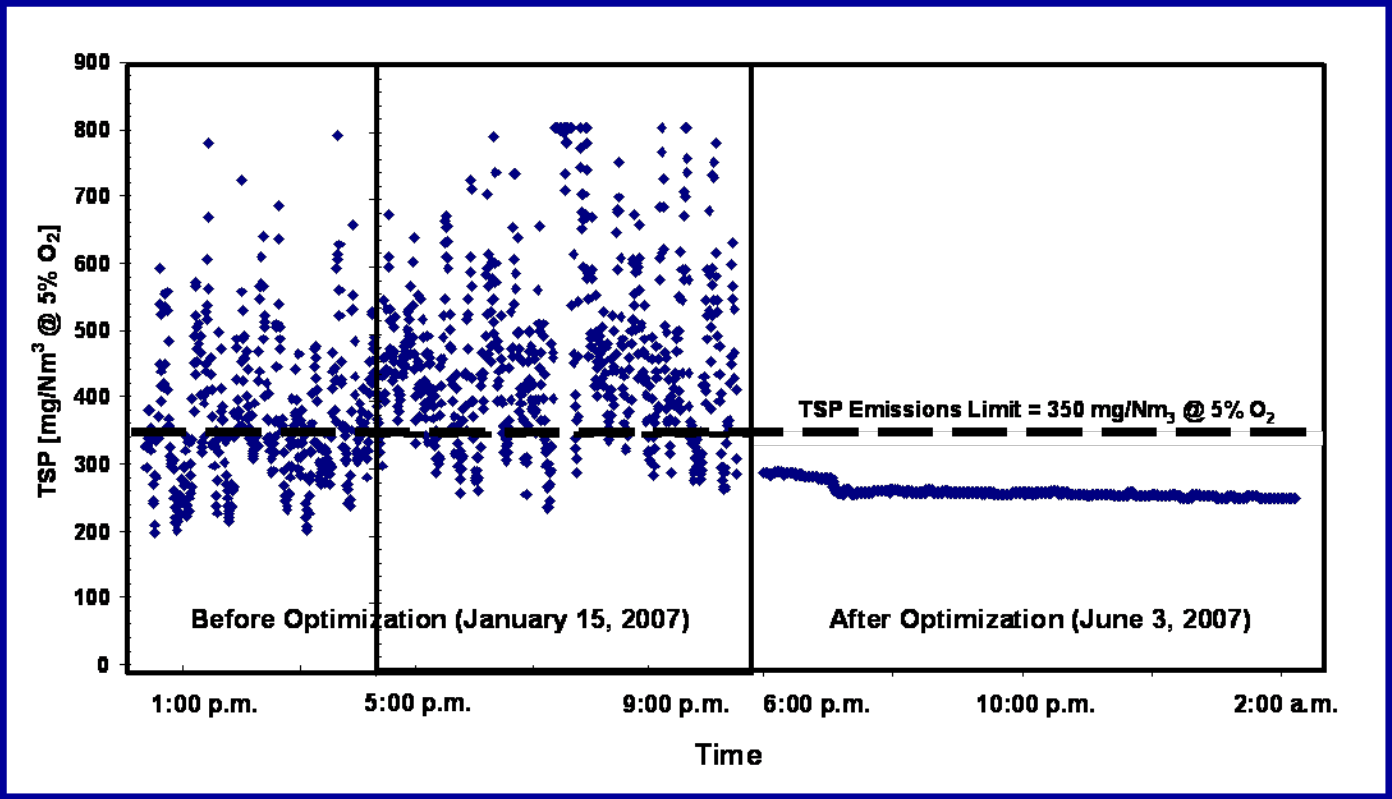
HIGH PURITY TSA PROCESS



PROCESS OPTIMIZATION AND CONTROL USING ARTIFICIAL INTELLIGENCE (AI)

(C. Romero and N. Sarunac)

- Increase power plant thermal efficiency.
- Reduce power plant emissions.
- Extend component life.
- Reduce operating costs.

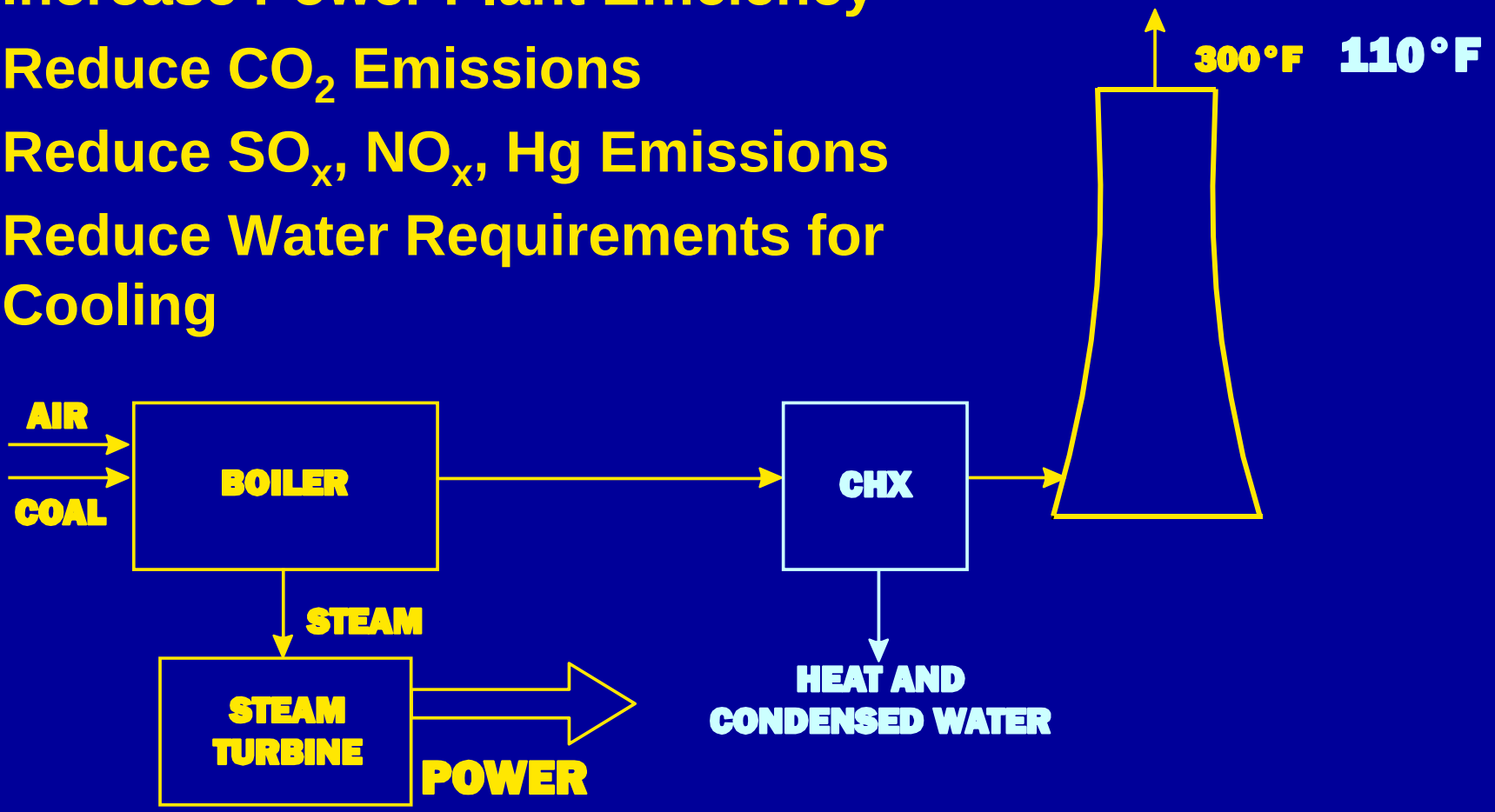


REDUCE FLUE GAS EXIT TEMPERATURE IN COAL-FIRED POWER PLANTS

Use Condensing Heat Exchangers

(E. Levy and H. Bilirgen)

- Increase Power Plant Efficiency
- Reduce CO_2 Emissions
- Reduce SO_x, NO_x, Hg Emissions
- Reduce Water Requirements for Cooling



- Theoretical Modeling
- Laboratory Experimentation
- Tests at Power Plant
- Develop CHX Design Methodology
- Optimize Heat Exchanger Design

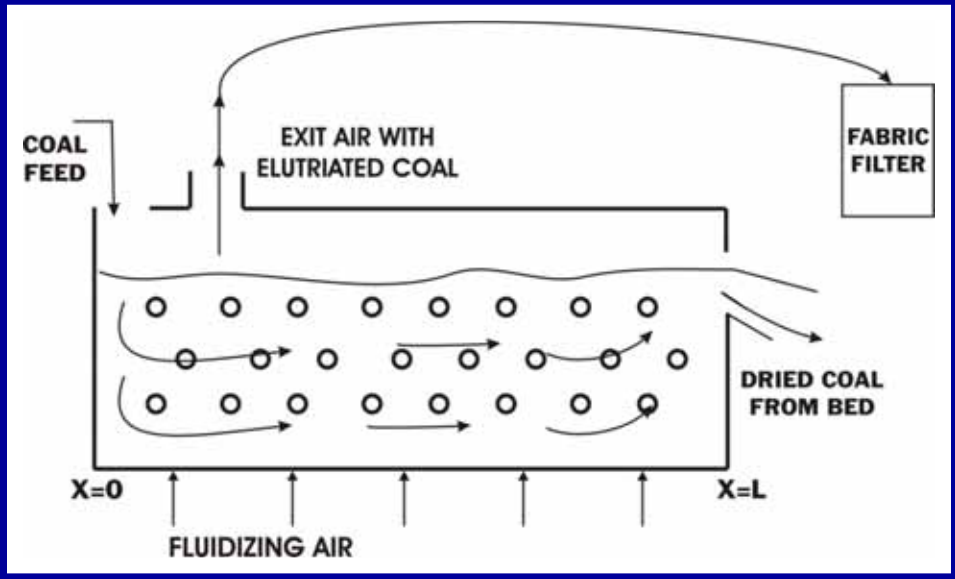
USE POWER PLANT WASTE HEAT TO PRE-DRY HIGH MOISTURE COAL

(N. Sarunac and E. Levy)

- Increase Power Plant Efficiency
- Reduce Stack Emissions
- Reduce CO_2

Coal Creek Station
North Dakota Lignite

- Data Base On Drying Kinetics
- Theoretical Model of Drying Process
- Design Commercial Scale System
- Evaluate Impacts on Plant

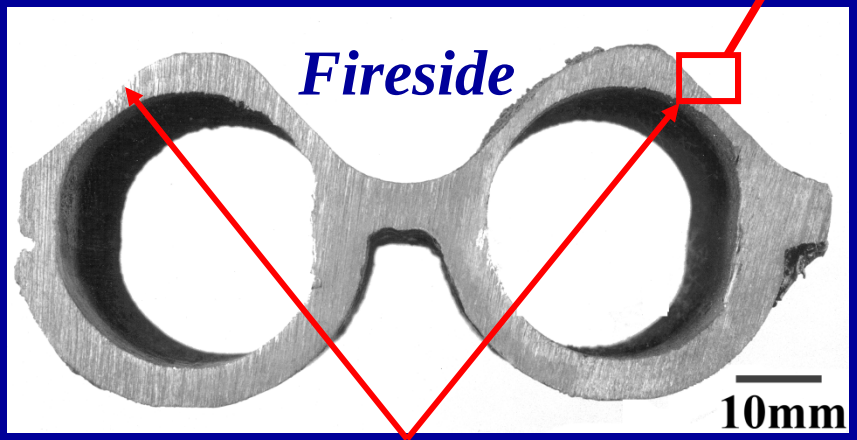


PREVENTING BOILER TUBE CORROSION

(J. DuPont and H. Nied)

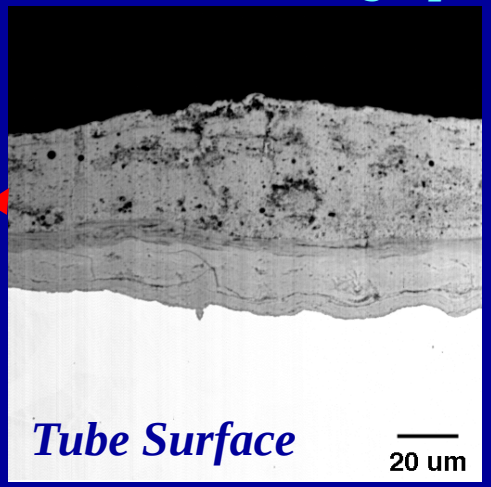
High Efficiency-Low Emissions Boilers are Subject to Aggressive Tube Corrosion and Cracking

- Determine Failure Mechanisms
- Develop Protective Weld Overlay Coatings
- Develop Welding Procedures
- Carry Out Both Laboratory and Long-Term Field Tests

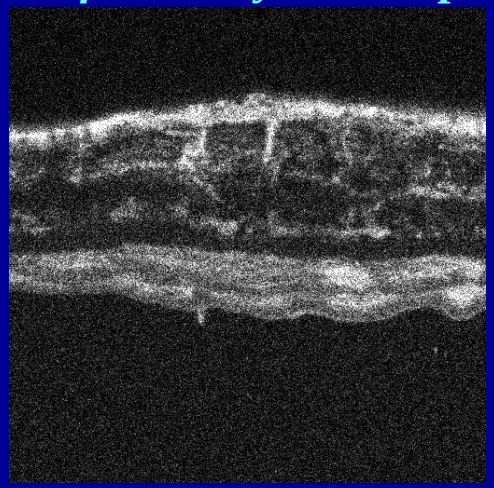


Excessive Wall Thinning

LOM Photomicrograph



Sulfur X-Ray Dot Map



Thank you!!

Questions?