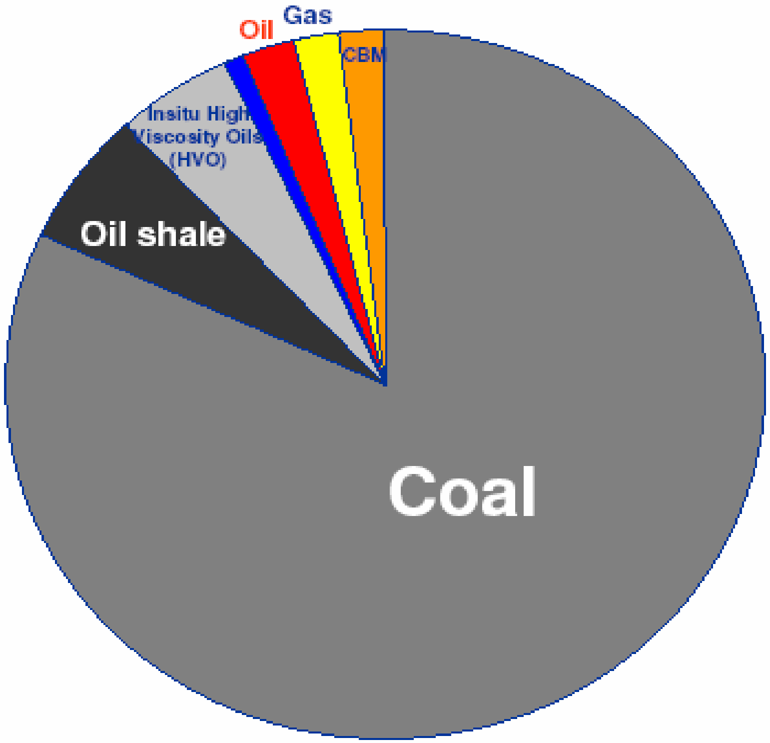
Air Pollution from Electric Power Generation

Pulverized Coal Combustion (PC)
Integrated Gasification Combined Cycle (IGCC)
Co-Generation (Combined Heat & Power = CHP)

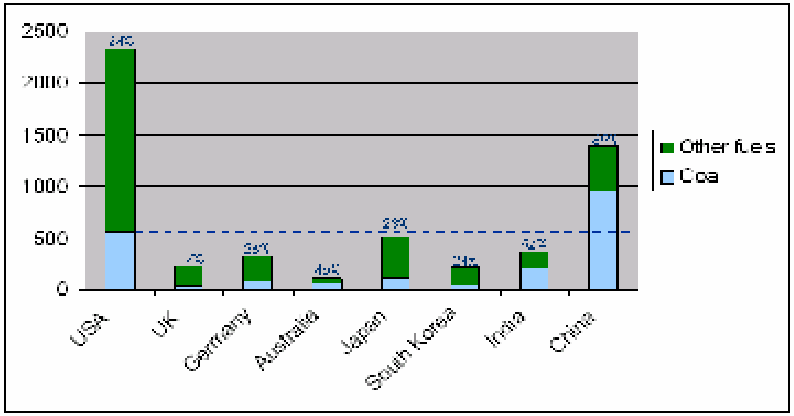
By
Michael J. Pilat
Professor of Civil Engineering
November 13, 2007

Coal is an abundant and important source of energy

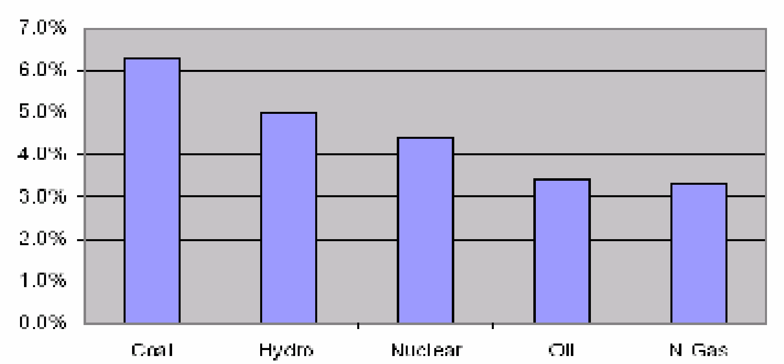
World's fossil fuel reserves
(excl. hydrates)



Consumption by fuel (million tonnes oil equivalent) 2004



Growth rate of Global Consumption by fuel 2004



Coal

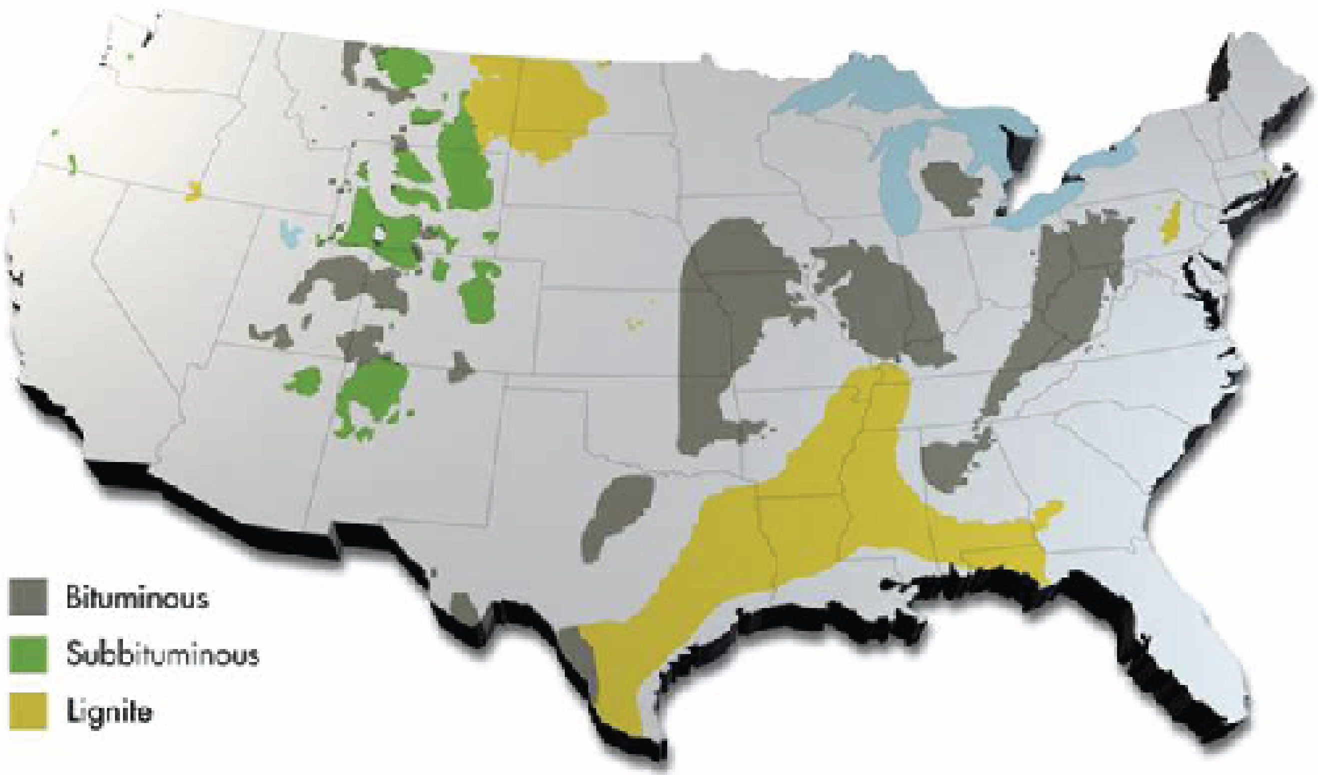
In U.S. economy, coal accounts for about 25%of primary energy consumption

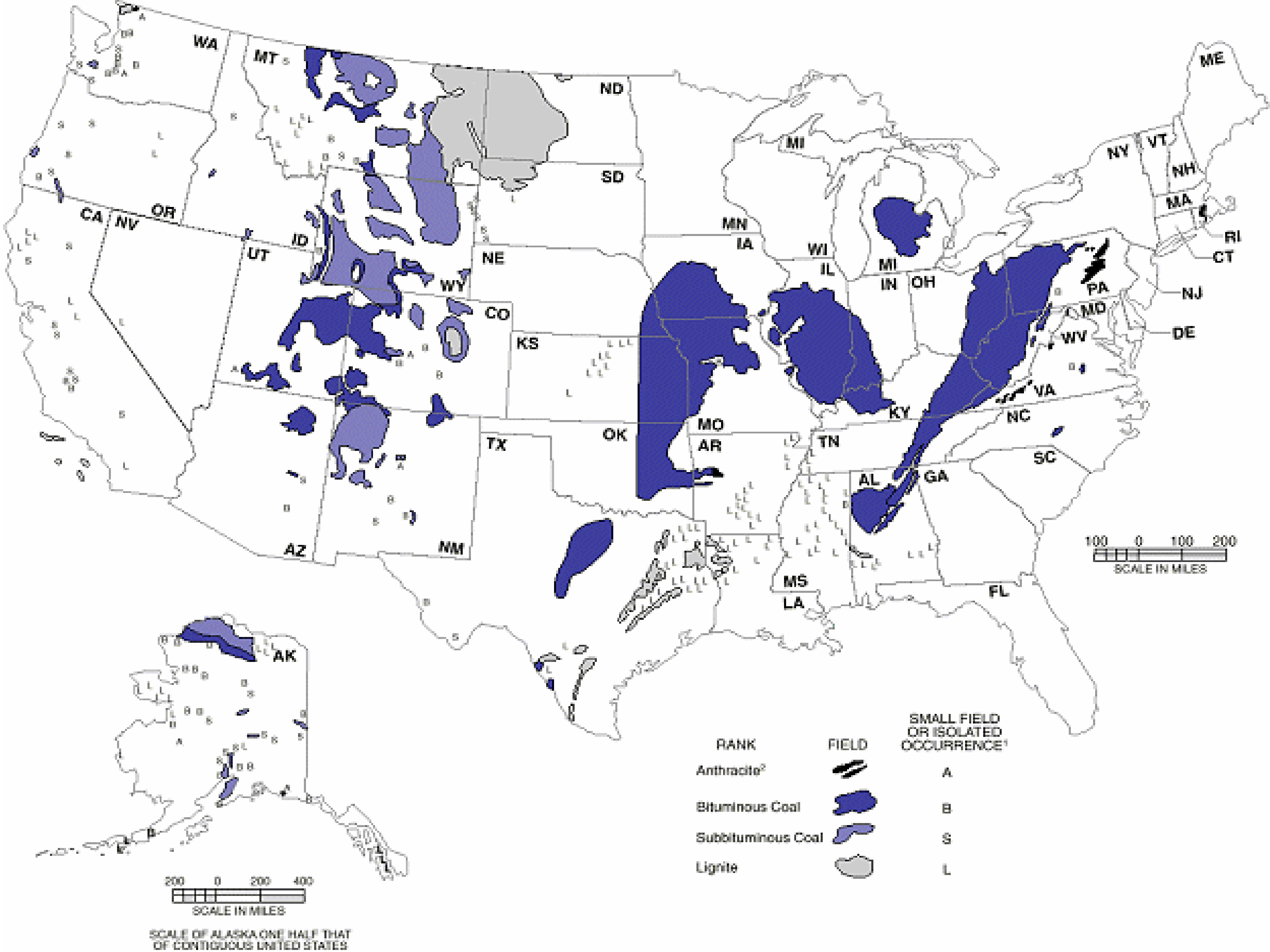
Total US coal consumption will increase from 1.05 to 1.44 billion short tons between 2001 and 2025, an average increase of 1.3 % per year

Coal is predicted to be the primary fuel for US electricity generation through 2025.

74 gigawatts (76,000 MW) of new coal-fired generating capacity may be constructed in US between 2001 and 2025. Centralia coal fired power plant has 1400 MW generating capacity.

U.S. Coal Basins




WA
MT
ND
SD
MN
WI
MI
ME
NY
VT
NH
MA
RI
CT
NJ
PA
DE
MD
WV
OH
IN
IL
IA
NE
CO
KS
MO
KY
VA
NC
TN
SC
GA
AL
MS
LA
FL
AR
OK
TX
NM
AZ
UT
NV
CA
OR
ID
WY
AK
100 0 100 200
SCALE IN MILES
200 0 200 400
SCALE IN MILES
SCALE OF ALASKA ONE HALF THAT OF CONTIGUOUS UNITED STATES
RANK
FIELD
SMALL FIELD OR ISOLATED OCCURRENCE[1]
Anthracite[2]
A
Bituminous Coal
B
Subbituminous Coal
S
Lignite
L

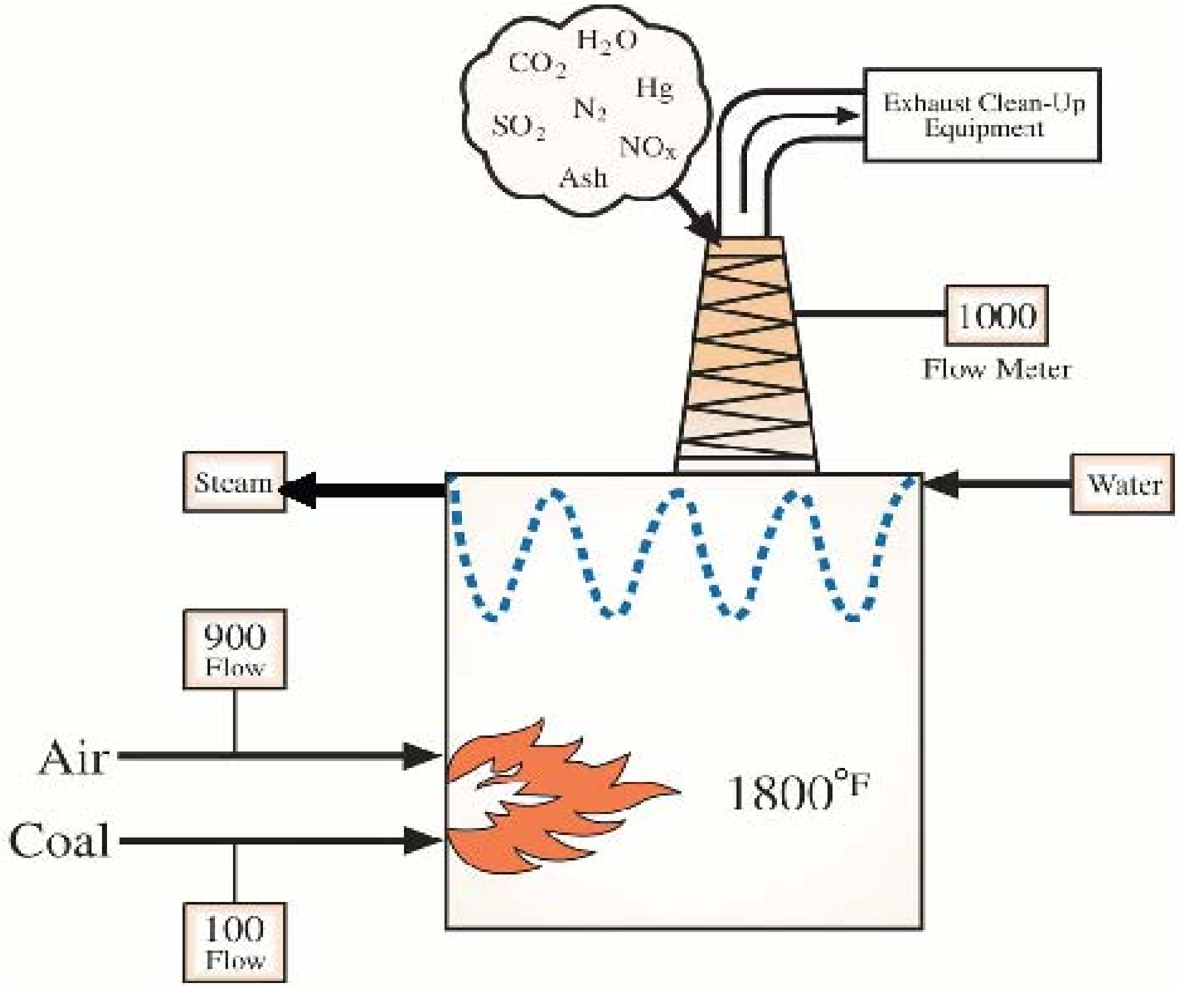
- **New Pulverized Coal Power Plants Are:**

  Energy systems with 50 – 60 year lifetimes;

  Most carbon-intensive energy system investments;

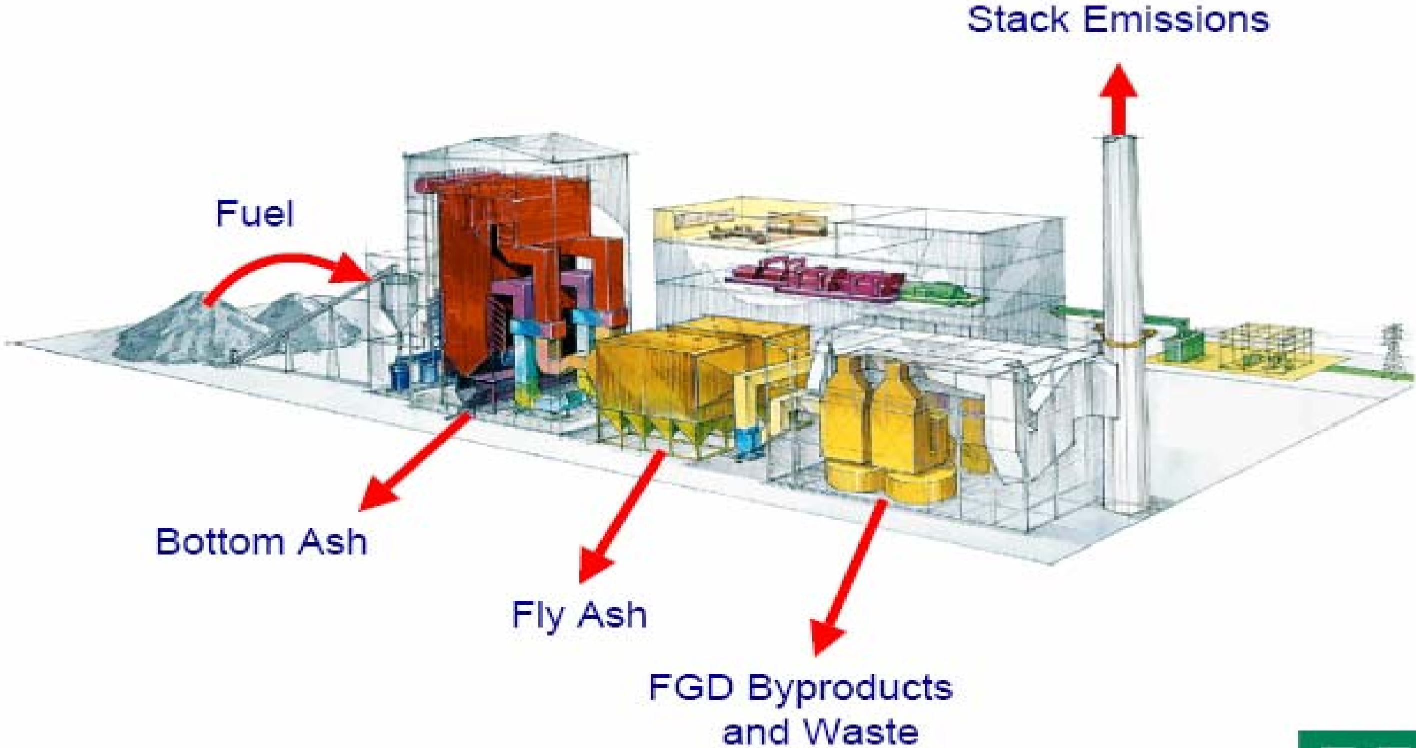
  Some Say Difficult to add CO_2 capture to pulverized coal fired power plant - but PowerSpan has demonstration project at First Energy Coal-Fired 50 MW Power Plant at Shadyside Ohio to go on-line in 2008 with CO_2 injection into geologic formations for CO_2 sequestration.

- **Large numbers of new PC power plants are projected to be built over the next 25 years – *primarily in China and India.***


CO_2
H_2O
Hg
SO_2
N_2
NOx
Ash
Exhaust Clean-Up Equipment
1000
Flow Meter
Steam
Water
900
Flow
Air
Coal
100
Flow
1800°F

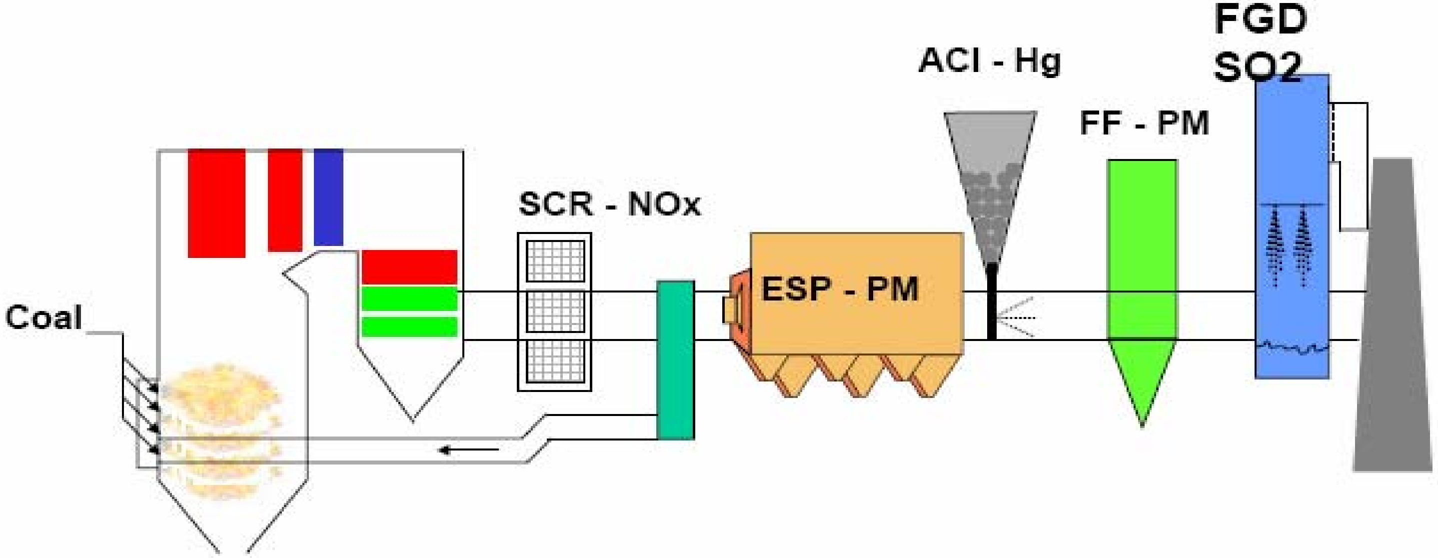
Coal Boiler

Power Plant Emissions



Energy and Environmental Strategies

Flue Gas Path

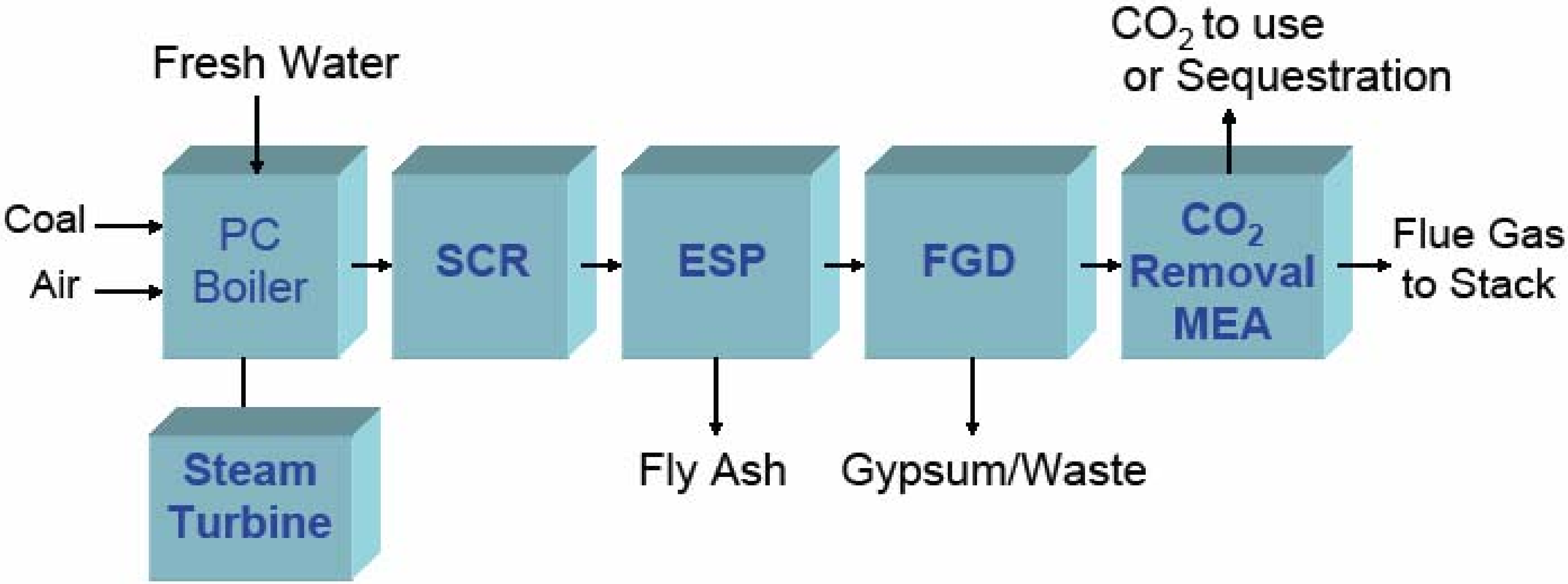


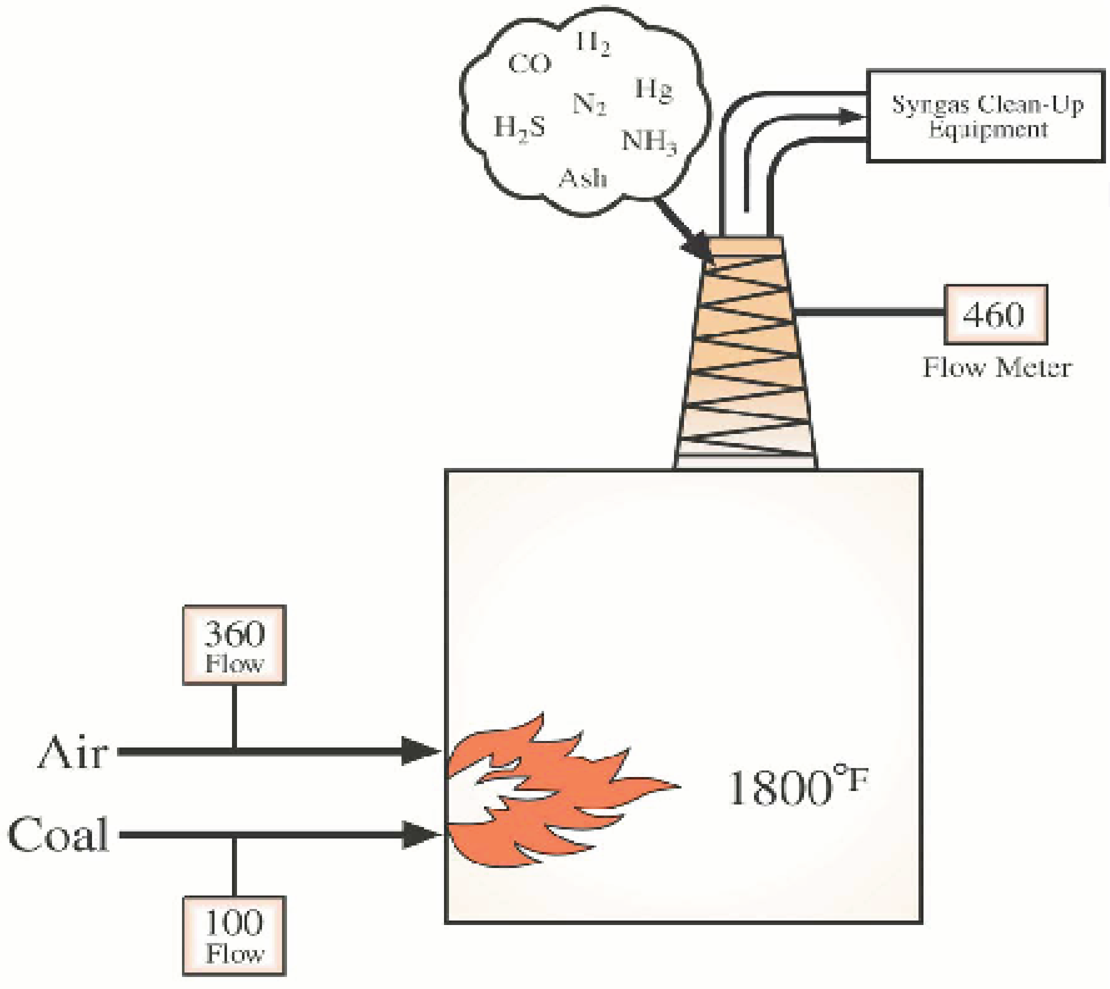
Energy and Environmental Strategies


Centralia Coal Fired Power Plant

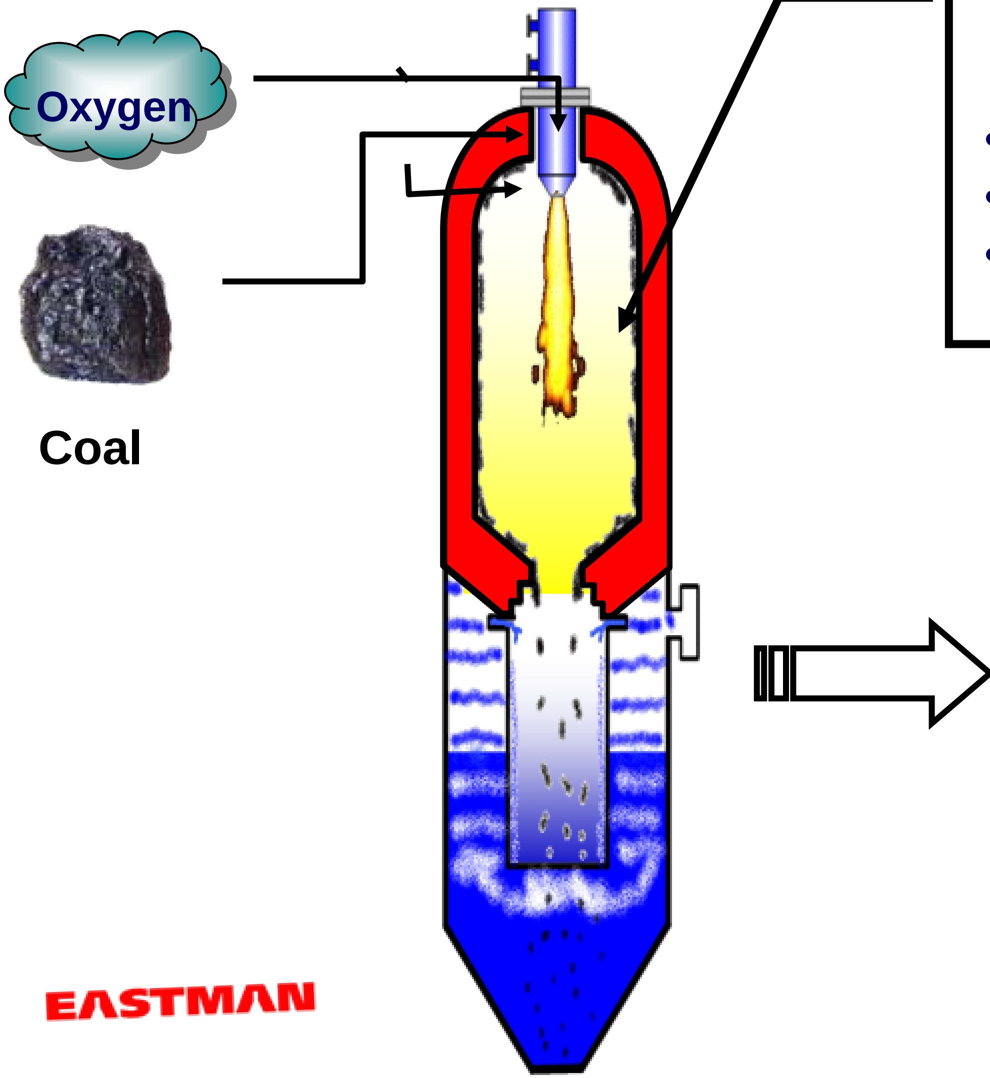
Centralia Coal Fired Power Plant

Pulverized Coal (PC) with CO_2 Removal





Coal Gasifier
with Air



Extreme Conditions:

- Up to 1,000 psig or more
- Nominal 2,600 Deg F
- Corrosive slag and H_2S gas

Products (syngas):

CO (Carbon Monoxide)

H_2 (Hydrogen)

[CO/H_2 ratio can be adjusted]

By-products:

H_2S (Hydrogen Sulfide)

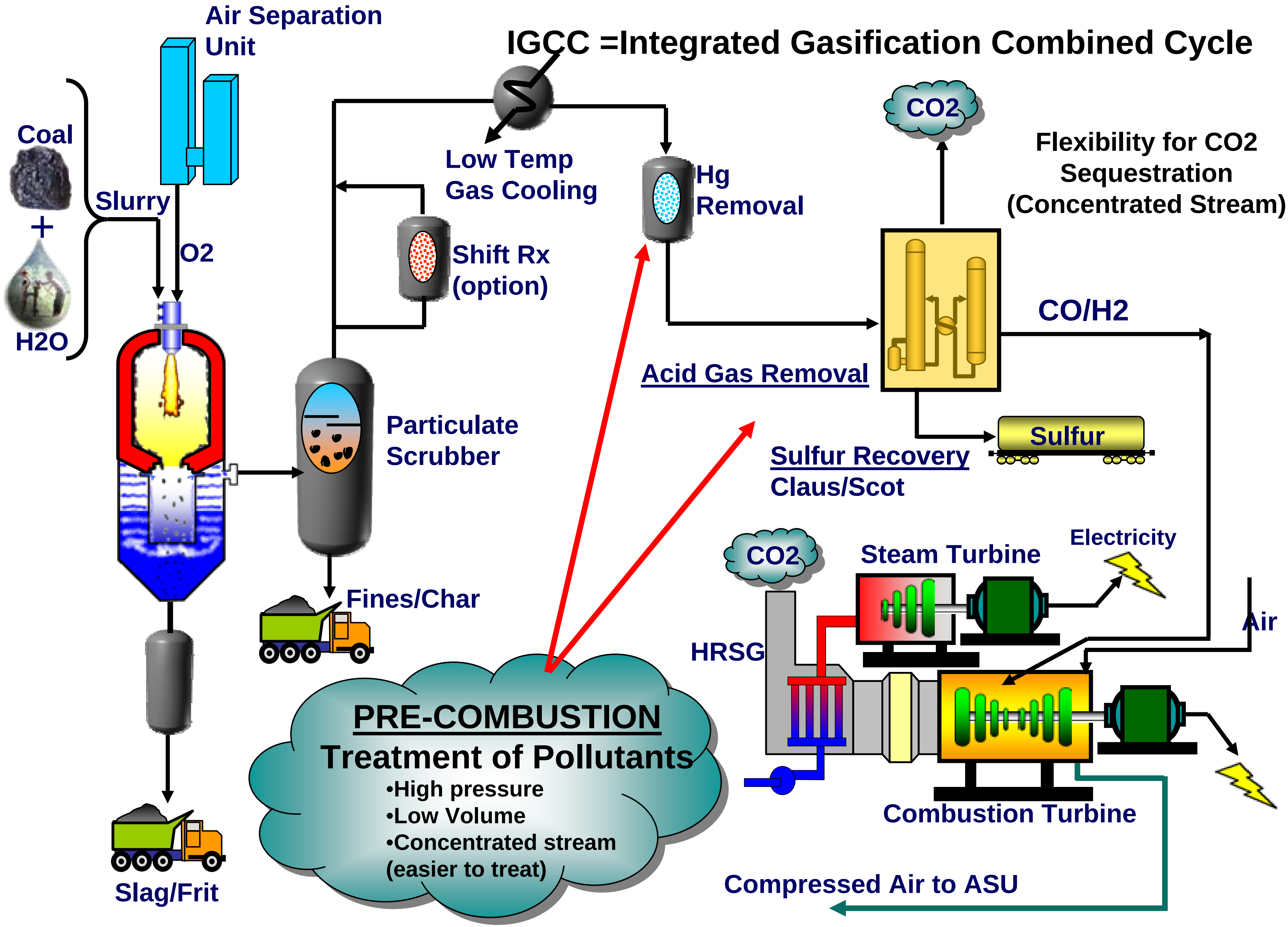
CO_2 (Carbon Dioxide)

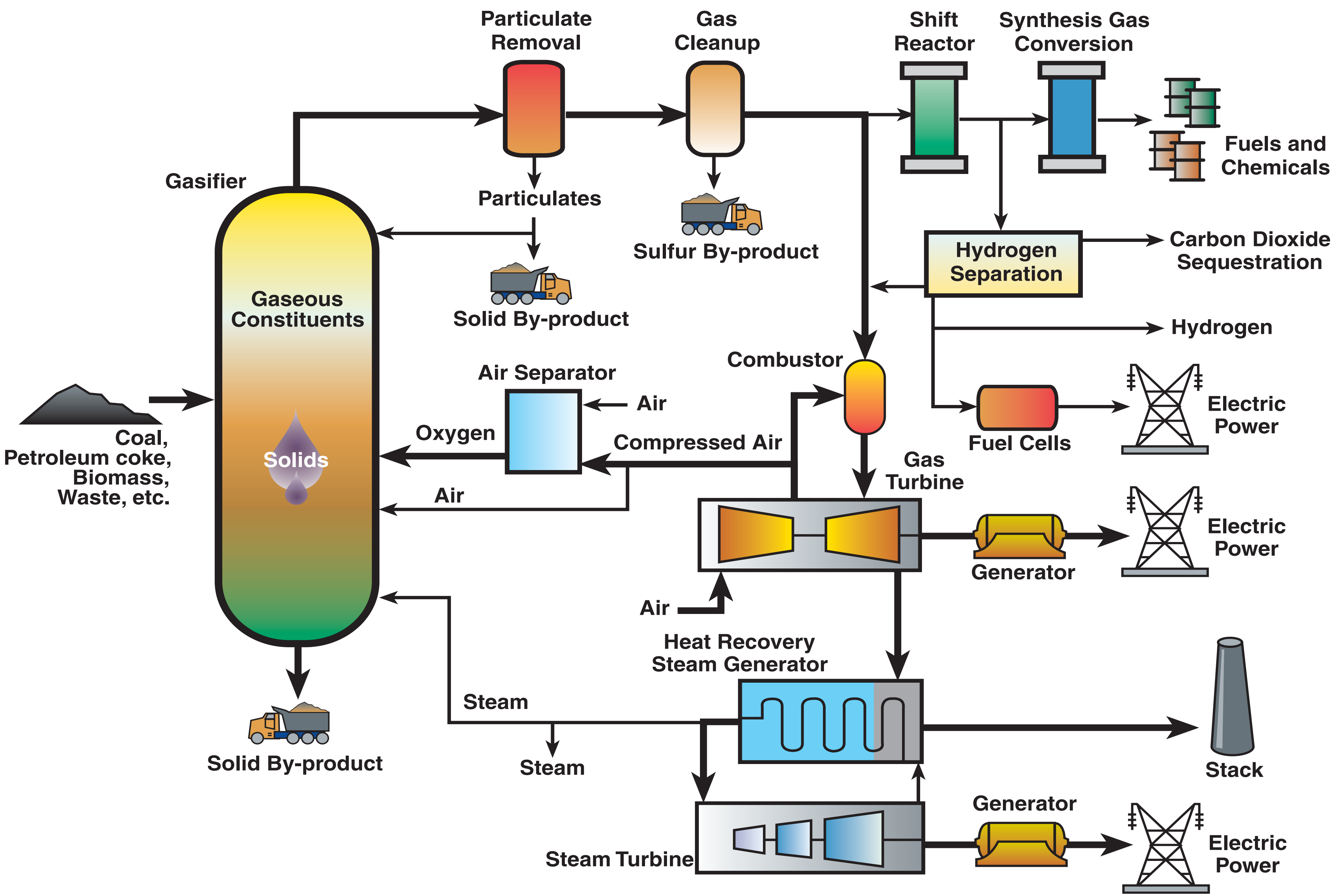
Slag (Minerals from coal)

EASTMAN

Coal Gasification

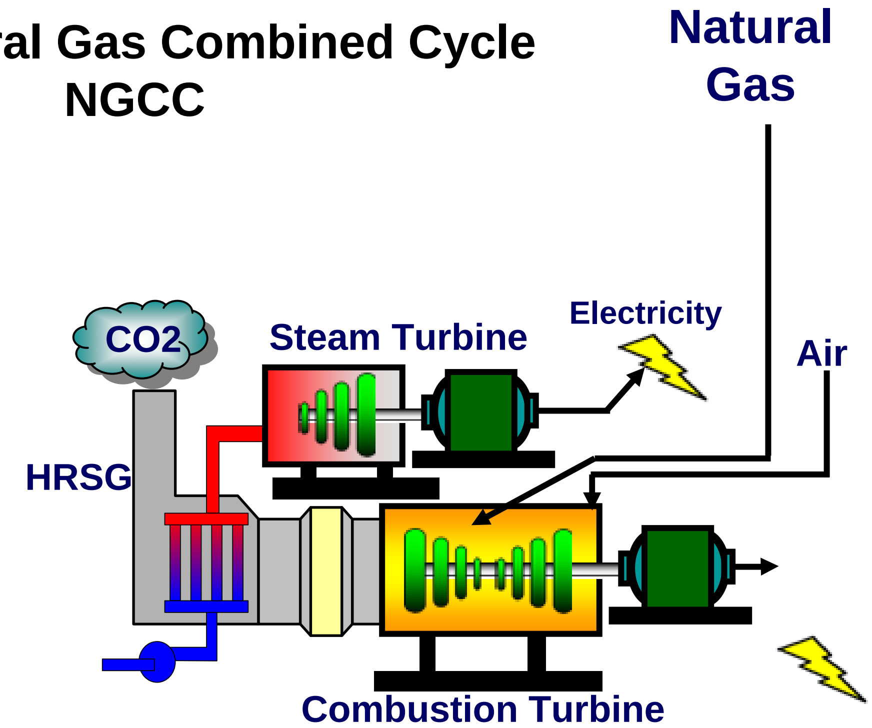
IGCC =Integrated Gasification Combined Cycle





IGCC = Integrated Gasification Combined Cycle

Natural Gas Combined Cycle
NGCC

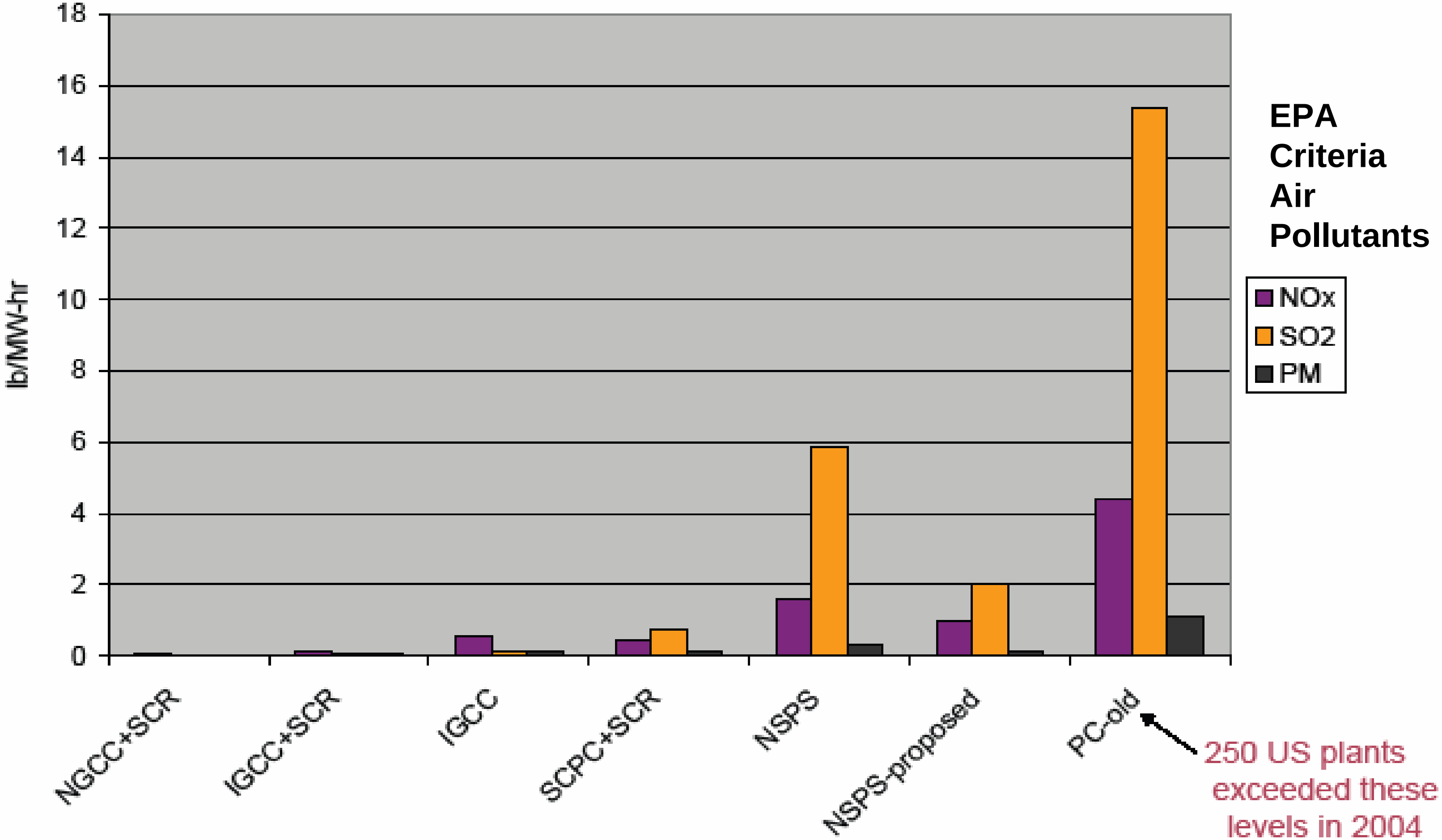


Integrated Gasification CC plant produces "Syngas" which replaces Natural Gas in this "Combined Cycle" Power Plant

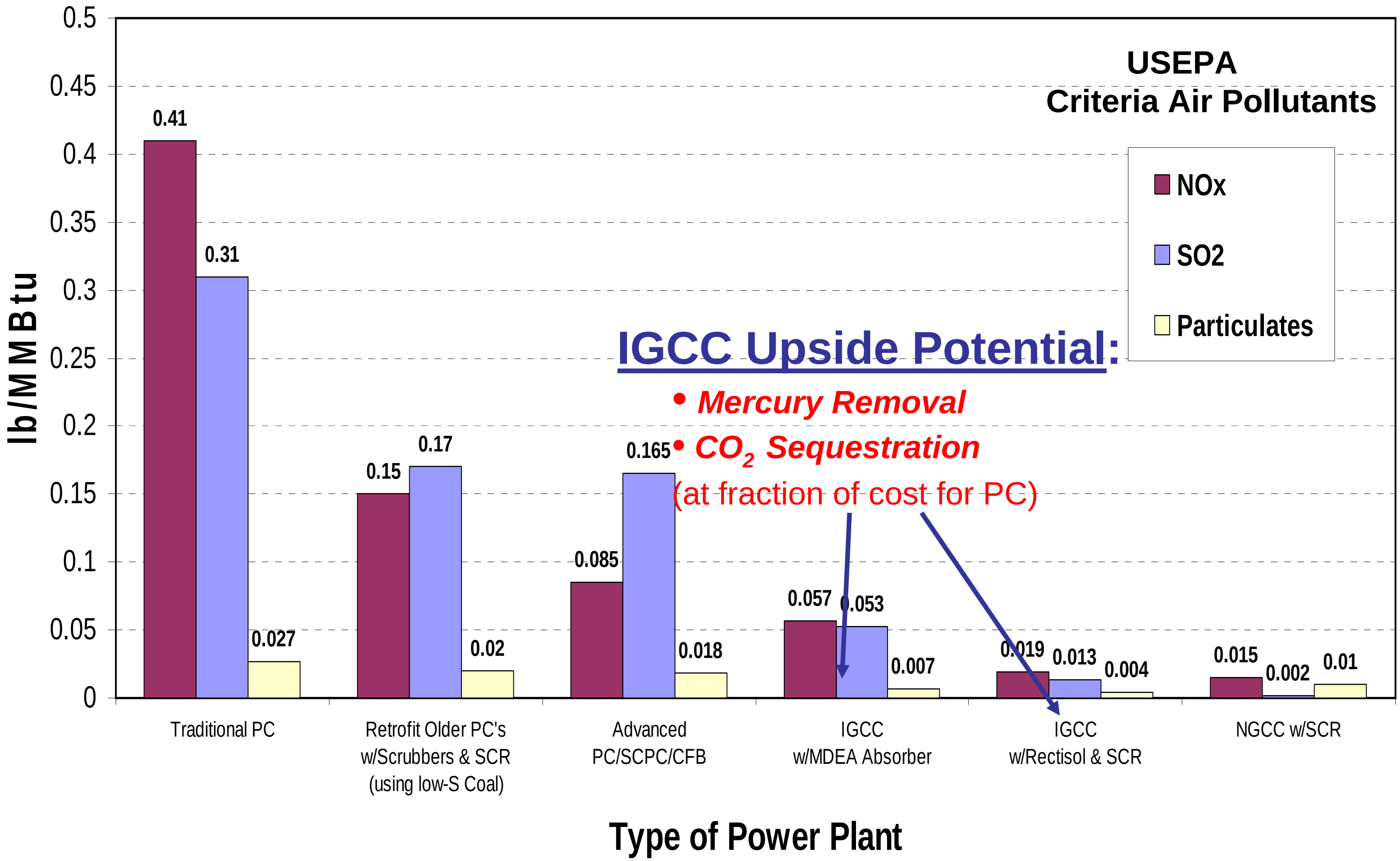
Most US Electric Power plants built in last 15 years have been Natural Gas Combined Cycle plants (NGCC).
Plants built at Goldendale, Tacoma, Centralia, Sumas, Washington.

Combust natural gas in jet engine turbine, exhaust gases heat water in Heat Recovery Steam Generator (HRSG), make steam which drives steam turbine.

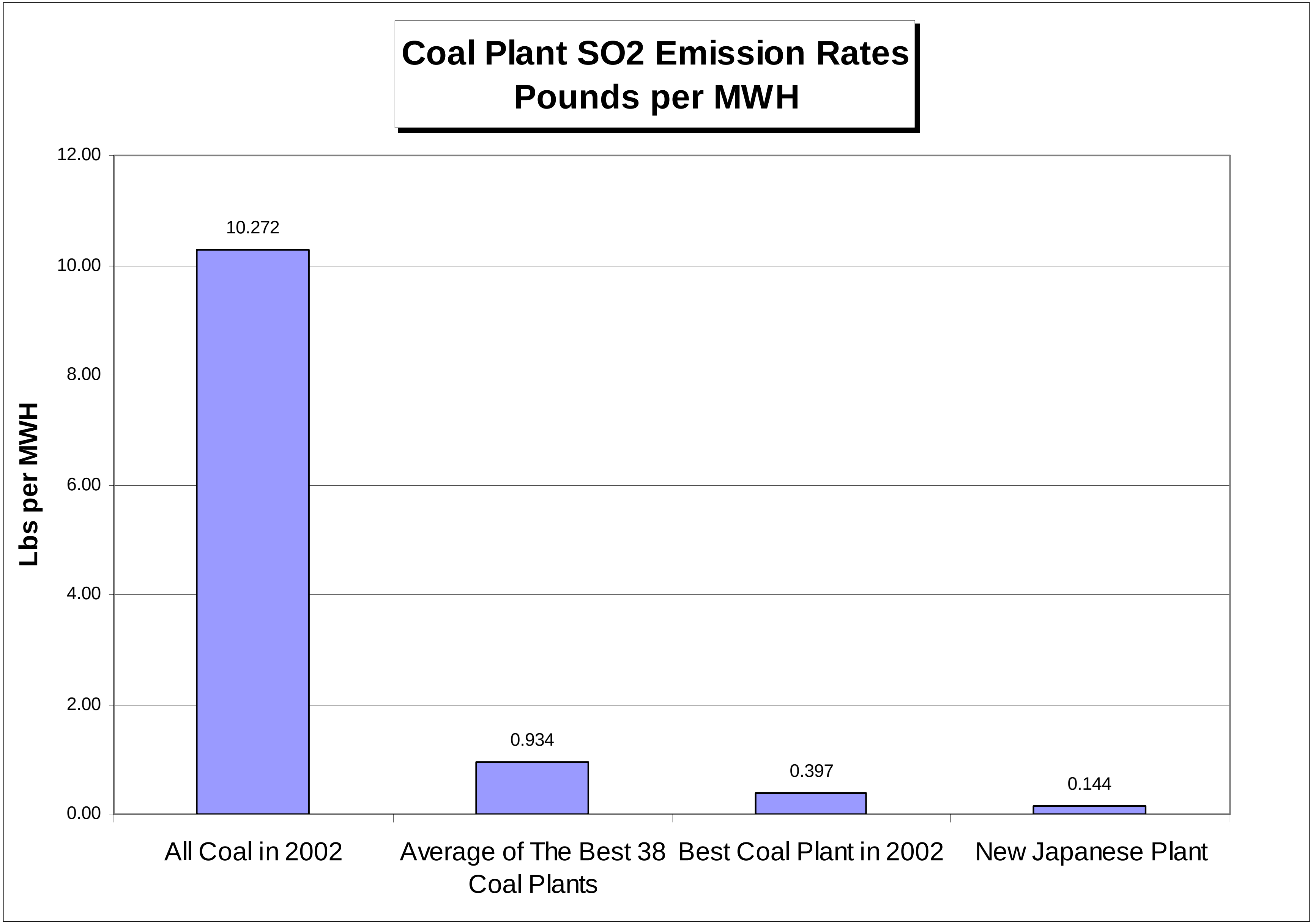
Emissions Comparison with Older Coal Plants and Federal Standards

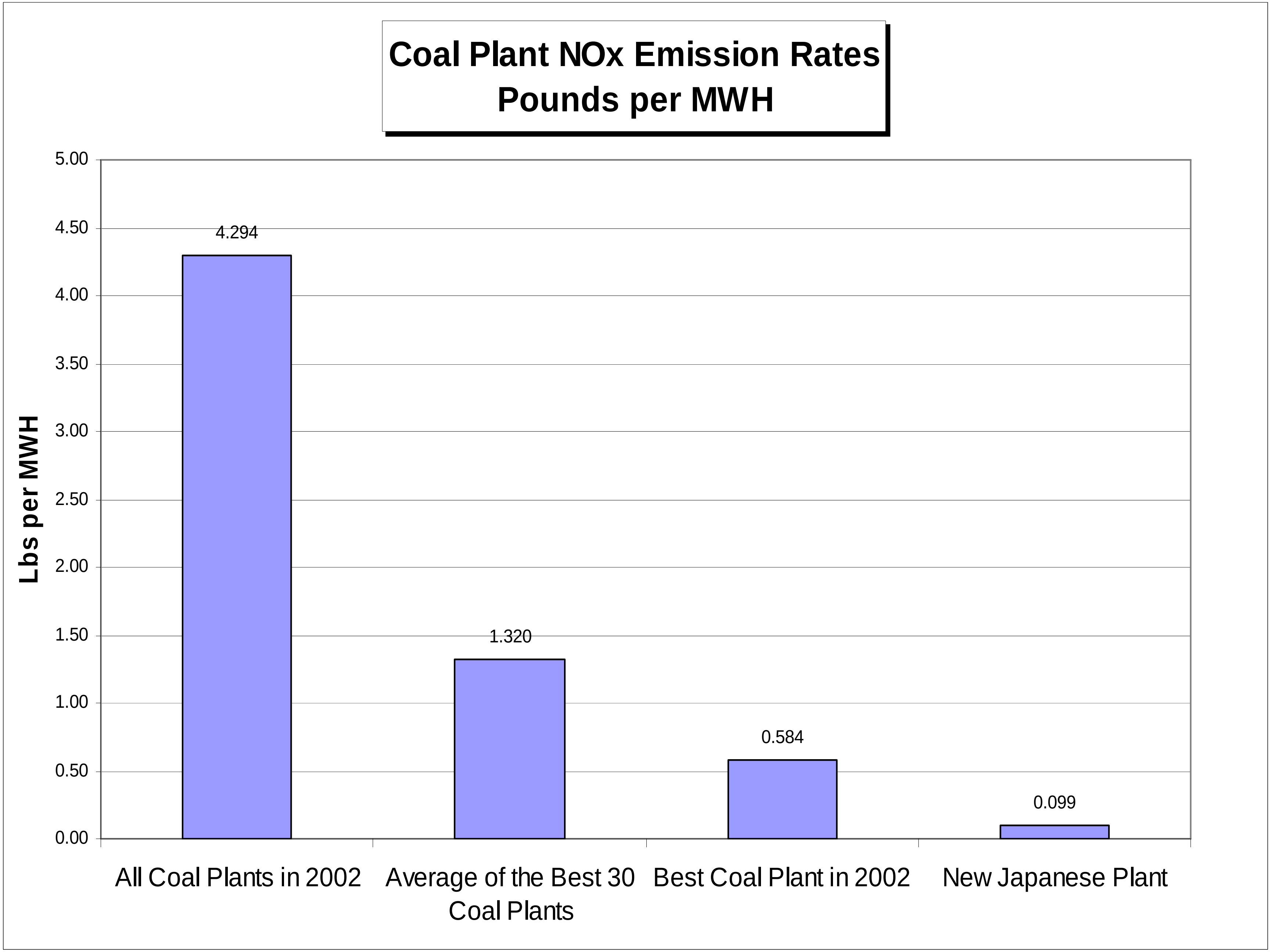


Power Plant Typical Emissions by Technology Type



PC =Pulverized Coal Boiler, SCR = Selective Catalytic Reactor for NOx control, NGCC = Natural Gas Combined Cycle (combustion & steam turbines)


Coal Plant SO2 Emission Rates
Pounds per MWH
Lbs per MWH
12.00
10.00
8.00
6.00
4.00
2.00
0.00
10.272
0.934
0.397
0.144
All Coal in 2002
Average of The Best 38 Coal Plants
Best Coal Plant in 2002
New Japanese Plant


Coal Plant NOx Emission Rates
Pounds per MWH
Lbs per MWH
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
4.294
1.320
0.584
0.099
All Coal Plants in 2002
Average of the Best 30 Coal Plants
Best Coal Plant in 2002
New Japanese Plant

- Solid Wastes

Less Volume: IGCC produce about half the solid wastes of conventional coal plants.

Better Form: IGCC solid wastes are less likely to leach toxic metals than fly ash from conventional coal plants because IGCC ash melts and is vitrified (encased in a glass-like substance).

- Water Use

Less Water: IGCC units use 20%-50% less water than conventional coal plants and can utilize dry cooling to minimize water use.

Combustion vs Gasification

	Combustion	Gasification
Carbon	CO_2	CO
Hydrogen	H_2O	H_2
Nitrogen	NO, NO_2	NH_3 or N_2
Sulfur	SO_2 or SO_3	H_2S or COS

Existing Coal-based IGCCs

Puertollano (Spain)

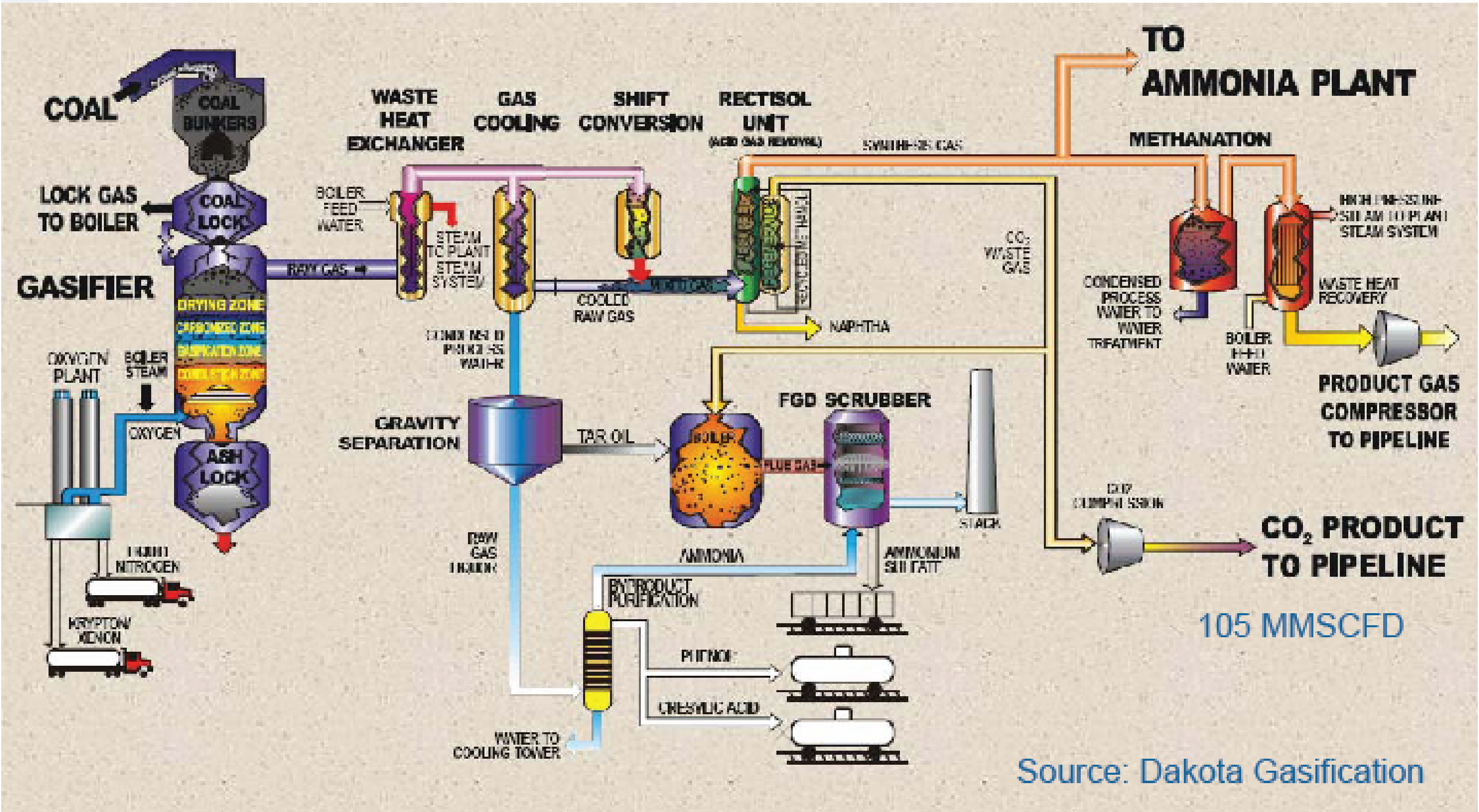
Wabash (Indiana)

Polk (Florida)

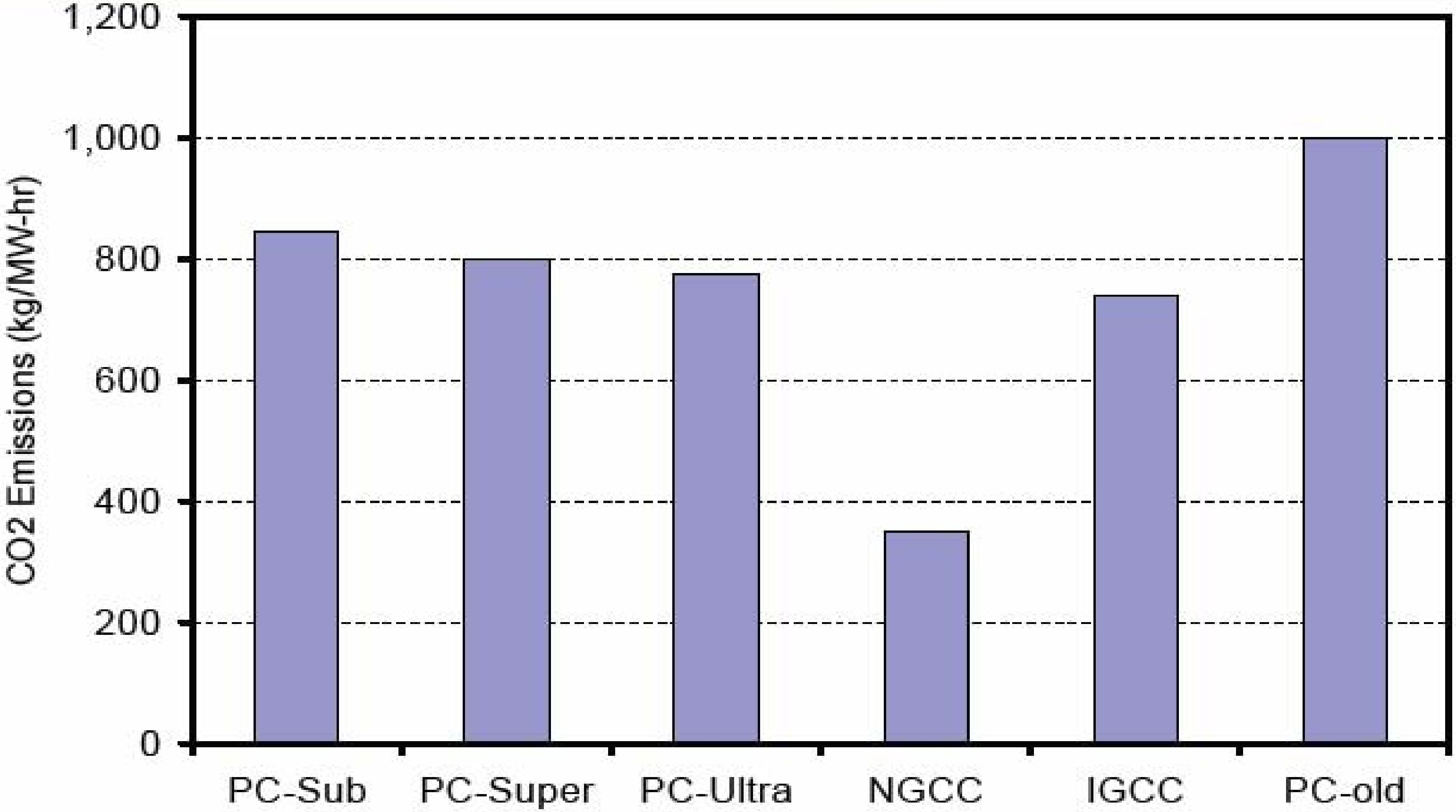
Buggenum (Netherlands)

Great Plains Synfuels Plant

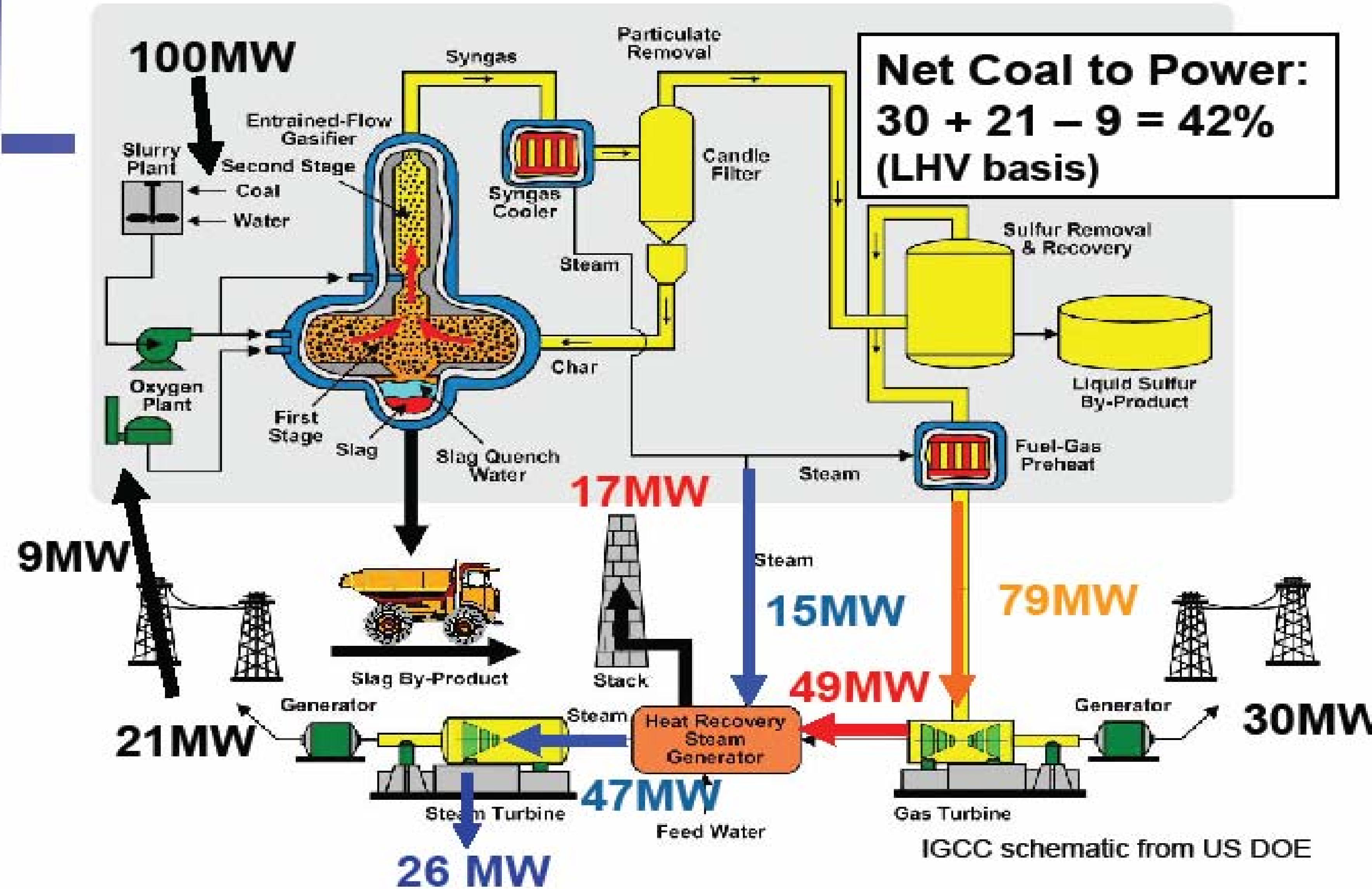
Uses water-gas shift and recovers CO_2 for enhanced oil recovery



CO_2 Emissions without CO_2 Capture



Net Coal to Power:
30 + 21 – 9 = 42%
(LHV basis)



IGCC schematic from US DOE

Current Shell Coal Gasification Business Footprint

SCGP technology

NUON

Buggenum, The Netherlands

253MW IGCC Power Plant (1994)

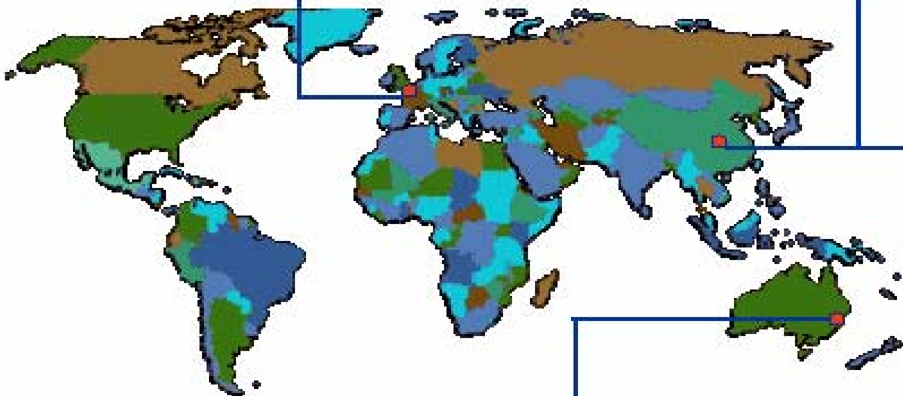
SCGP technology in equity play

China

Yueyang Sinopec and Shell Coal Gasification Co Ltd (50:50 JV)

Syngas for fertiliser plant.

Under construction



SCGP licensing deals won

China

6 Syngas for Fertiliser production

7 Syngas for Methanol and related products

1 Syngas for Hydrogen production

All projects under work in progress

SCGP licensing bid won

Stanwell Corporation

Rockhampton, Australia

Power Plant with CO_2 sequestration

Project to attain FID

POWERSPAN

ECO Technology (What it does)

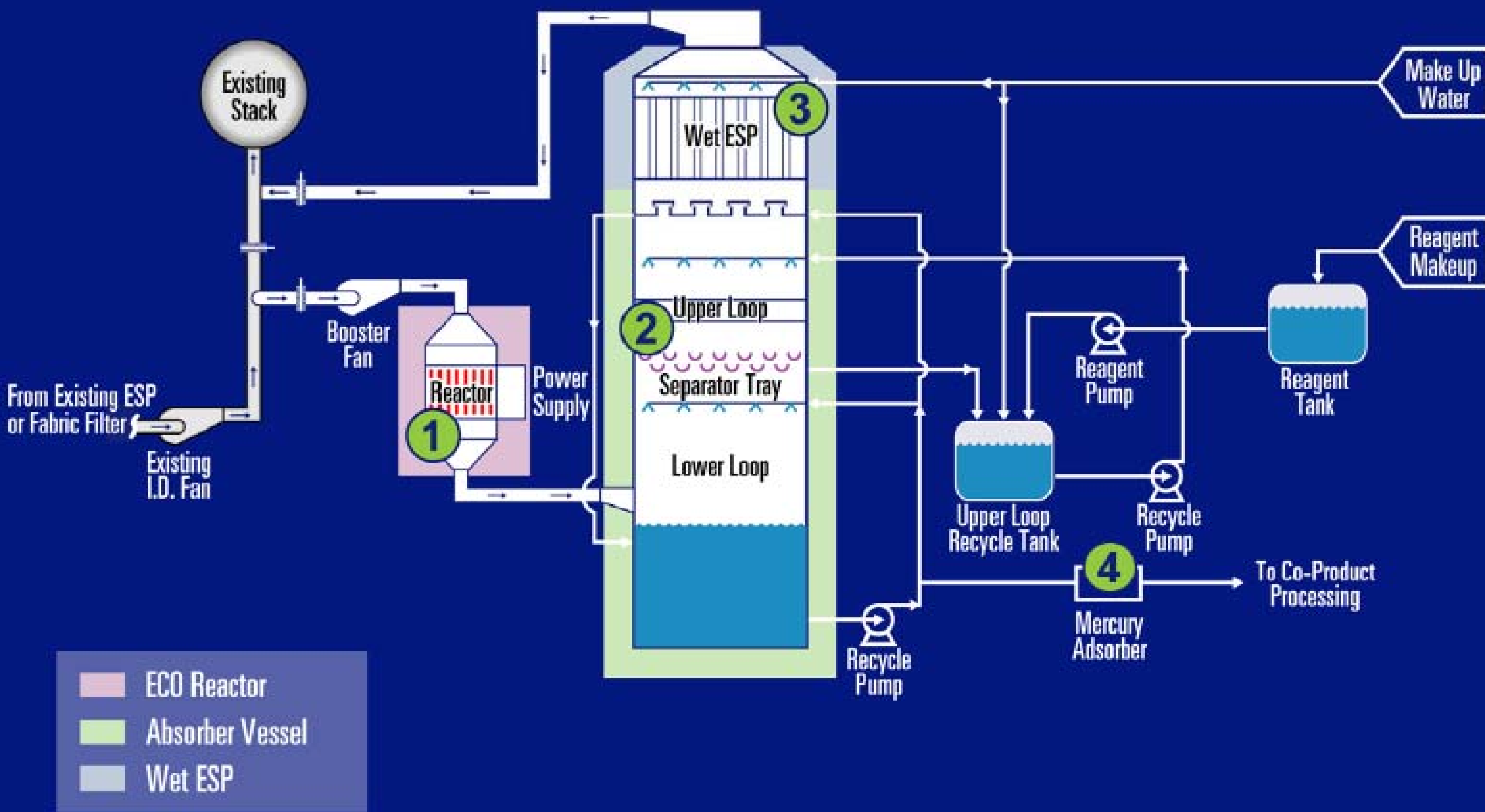
- Multi-pollutant Control Process
  - SO_2
  - NO_x
  - Hg
  - Fine particulate matter ($PM_{2.5}$)
  - Hazardous Air Pollutants (HAPs)
- Installs after existing particulate control device
  - Reduces impact on plant
  - No impact on ash
- Produces saleable fertilizer
  - Hg in compact container
  - No discharge streams

POWERSPAN

ECO Technology (How it does it)

- Three gas processing steps
  - Dielectric barrier discharge reactor
  - Ammonia-based absorber tower
  - WESP
- Mercury filtering in liquid stream
  - Mercury collected in compact charcoal bed
- Co-product processing
  - Ammonium sulfate
  - Nitrogen market can readily absorb

ECO® Process Flow




FirstEnergy's
R. E. Burger Plant
Site of Commercial
Demonstration Unit

POWERSPAN

Performance

- SO_2 removal routinely >98%
  - Inlet concentrations up to 2200 ppm
- NOx r/m consistent up to 73% - depends on coal S
  - Higher sulfur fuel improves scrubbing
  - Lower NOx improves performance
  - New Test Loop has demonstrated 90% r/m
- Hg Removal 80 to 85%, with 1.5 ug/Nm^3 ave outlet
  - Inlet concentrations up to 12 ug/Nm^3
  - Completed 168 days of 180-day extended run

POWERSPAN

Powerspan CRADA with DOE on CO_2 Removal

- Cooperative research and development program on CO_2 capture with ammonia (NH_3)
- Lab tests show NH_3 has several advantages over commercially available amine (MEA) process:
  - higher CO_2 loading capacity
  - lower energy consumption for regeneration
  - lower cost reagent
  - 88% CO_2 removal achieved with 10% ammonium carbonate solution

POWERSPAN

ECO® Capability

- Emission levels like natural gas plants.
  - ECO® has capability of near zero emissions; 1-2 ppm outlet SO_2/NO_x; particulates < 0.005 lb/MMBtu.
  - Equivalent to or better than IGCC.
- No waste streams – byproducts recycled.
  - Ash can be sold, ECO® converts SO_2 to ammonium sulfate fertilizer, no landfill waste or waste water, captured Hg can be isolated.
- Over 90% CO_2 capture and sequestration could be economically achieved.
  - Ammonia process shows potential for >90% CO_2 capture and sequestration at <$15/ton (DOE study).

Burger Commercial Unit

- 50 MW ECO at FirstEnergy's Burger Plant, operating >3 yrs
- 180-day performance test completed successfully; ECO® demonstrated as BACT
- EPRI-sponsored study concluded ECO® as reliable as conventional technology (>99% available)
- FirstEnergy ordered ECO for Bay Shore Unit 4, 215 MW
- AMP-Ohio announced ECO commitment for new Meigs County Plant, 2 x 500 MW (CO_2 capture a major driver)

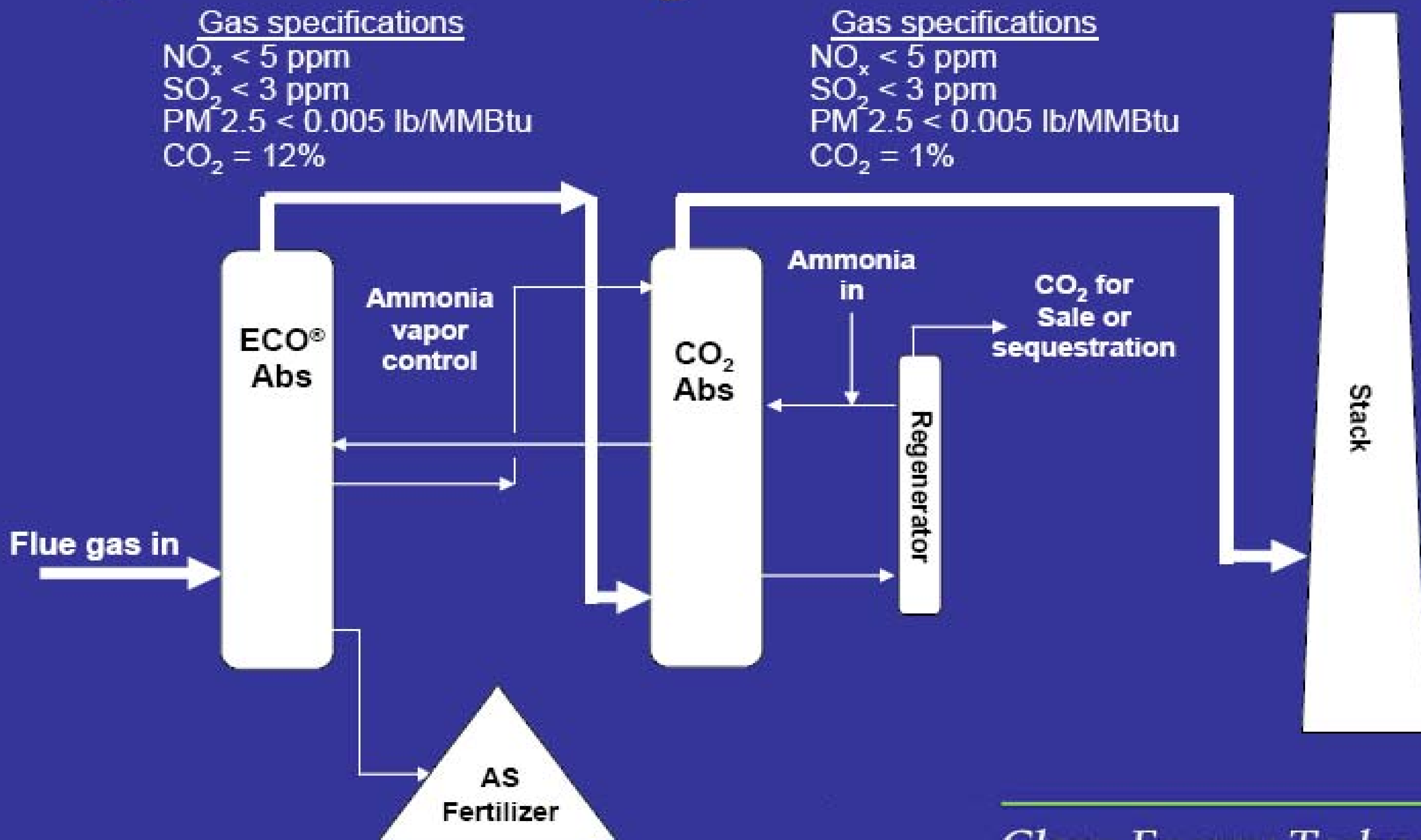
POWERSPAN

Powerspan CO_2 Research with US DOE

- Joint research and development program on CO_2 capture with ammonia (NH_3).
- NH_3 has several advantages over commercially available amine (MEA) process:
  - higher CO_2 loading capacity,
  - lower energy consumption for regeneration,
  - lower cost reagent.
- Powerspan and DOE testing shows >90% CO_2 capture with ammonium carbonate solutions:
  - Powerspan testing done under commercial absorber conditions (time, flows, temperatures).

POWERSPAN

Integrated $ECO^{®}$-ECO_2 Installation



Clean Energy Technology

POWERSPAN

Summary of CO_2 Capture Costs

- DOE Studies on CO_2 Capture with Ammonia, MEA, Oxy-Fuel and IGCC indicate:

CO_2 Capture Cost Comparison	MEA	Oxy-Fuel	IGCC	ECO
Cost of Electricity (cents/kWh)	8.2	7.4	6.74	5.34
\$/ton CO_2 Avoided	47	32	18	11

Clean Energy Technology

POWERSPAN

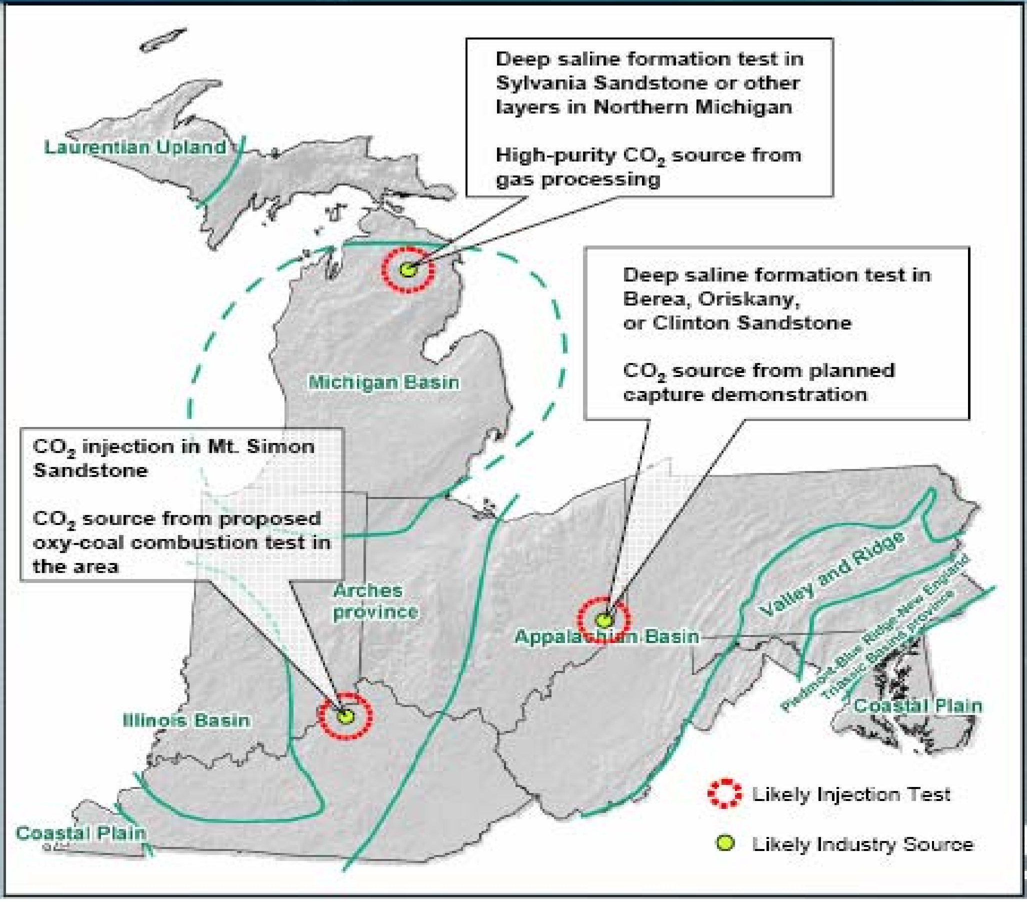
ECO_2 Development Plans

- Conduct pilot tests of CO_2 capture:
  - Integrated with ECO® process at FirstEnergy's Burger Plant planned for early 2008 – sequester CO_2 on site with DOE / MRCSP project
  - 20 ton/day CO_2 / 1 MW equivalent
- Evaluate process performance and economics for scale-up
- Conduct commercial scale test of ECO_2 with CO_2 sold for enhanced oil recovery (up to 2,000 ton/day - 100 MW equivalent, 700K tons /yr)

Clean Energy Technology

Phase II Candidate Geological Field Demonstrations and CO_2 Sources

- The primary CO_2 injection sites, including the R.E. Burger Plant site, are shown on the map
- Additional locations may be characterized for injection feasibility in saline formations, oil/gas fields, coal seams, and organic shales
- Additional possible sources of CO_2 include ethanol plants, gas processing, and commercial suppliers



The R.E. Burger Plant Field Demonstration

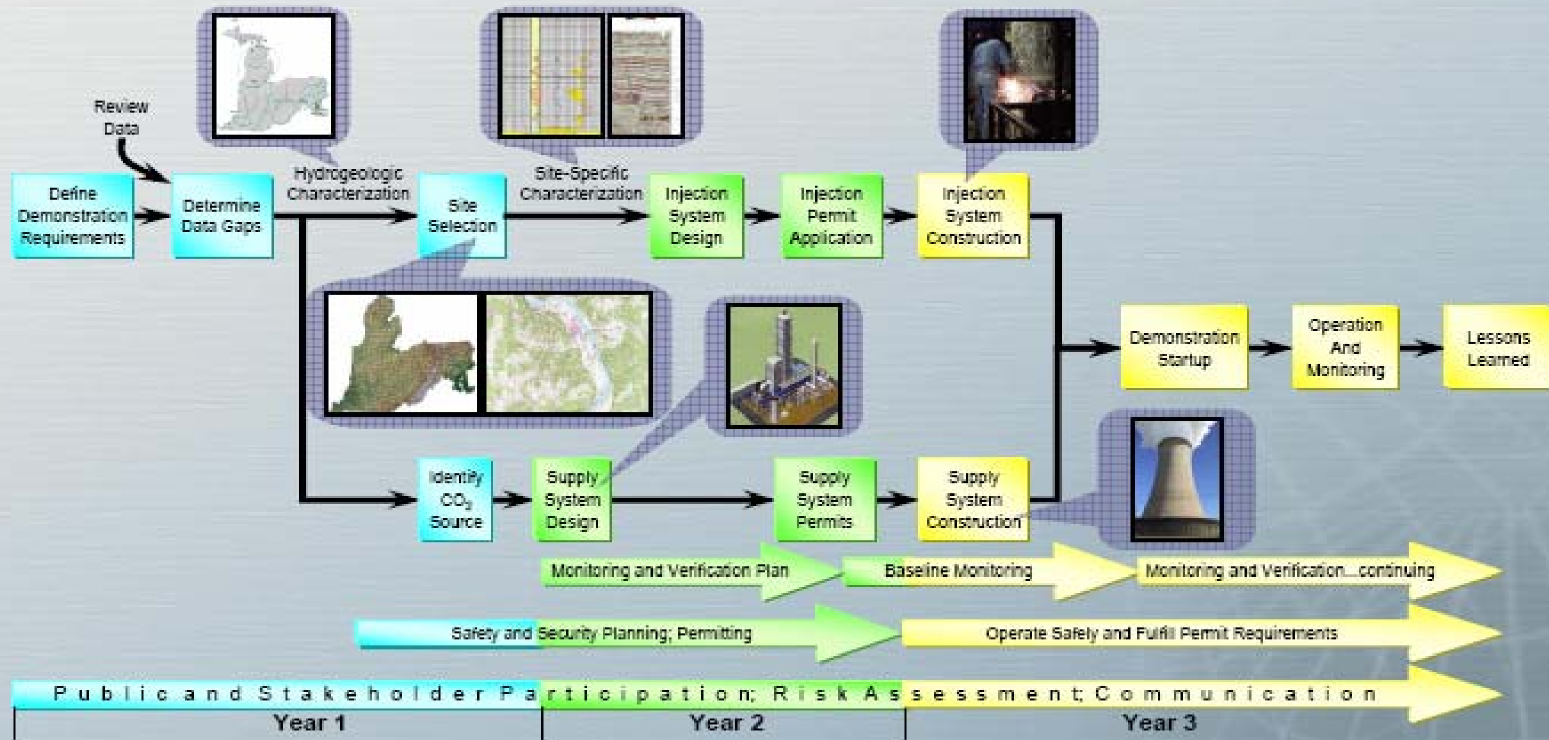
- FirstEnergy's R.E. Burger Plant in Shadyside, Ohio located in the Appalachian Basin region is one of the potential sites for geologic storage demonstration
- The site is being assessed by MRCSP to confirm suitability for injection
- Several potential injection formations, such as Berea, Oriskany, Clinton and Rose Run sandstones underlie this region, along with thick containment zones
- Some possibility exists for enhanced oil or gas recovery in the area
- Planned tests would assess the continuity and injectivity, operational approaches and monitoring mechanisms in one or more of these sandstone formations

Other Advantages of the R.E. Burger Plant Site

- R.E. Burger Plant is currently the site for Powerspan's Electro-Catalytic-Oxidation™, or ECO technology test, designed to reduce NO_x, SO_2, fine particulates and mercury emissions
- Under an R&D agreement (CRADA) with DOE, Powerspan will pilot test a CO_2 capture technology integrated with their multi-pollutant ECO technology currently operating at the R.E. Burger Plant
- CO_2 captured during this planned pilot test will be used for the injection demonstration, based on technical and economic feasibility analysis

Battelle
The Business of Innovation

Key Steps in Developing CO_2 Storage Demonstrations



POWERSPAN

Is Gasification the Best Solution for Coal?

- Coal gasification (IGCC) is more expensive and less reliable than supercritical pulverized coal plants
- DOE studies on IGCC versus super critical PC plants with ammonia based CO_2 capture estimates:
  - SCPC plants cost of electricity ($53.4/MWh), is 20% less than IGCC ($67.4/MWh)
- Most new coal plants in US are PC based

Key Point: ECO_2 could be installed on current or new coal plants and be economically preferable over IGCC for coal-based plants with CO_2 capture

POWERSPAN

Summary of CO_2 Capture Costs

- DOE Studies on CO_2 Capture with Ammonia, MEA, Oxy-Fuel and IGCC indicate:

CO_2 Capture Cost Comparison	MEA	Oxy-Fuel	IGCC	ECO
Cost of Electricity (cents/kWh)	8.2	7.4	6.74	5.34
\$/ton CO_2 Avoided	47	32	18	11

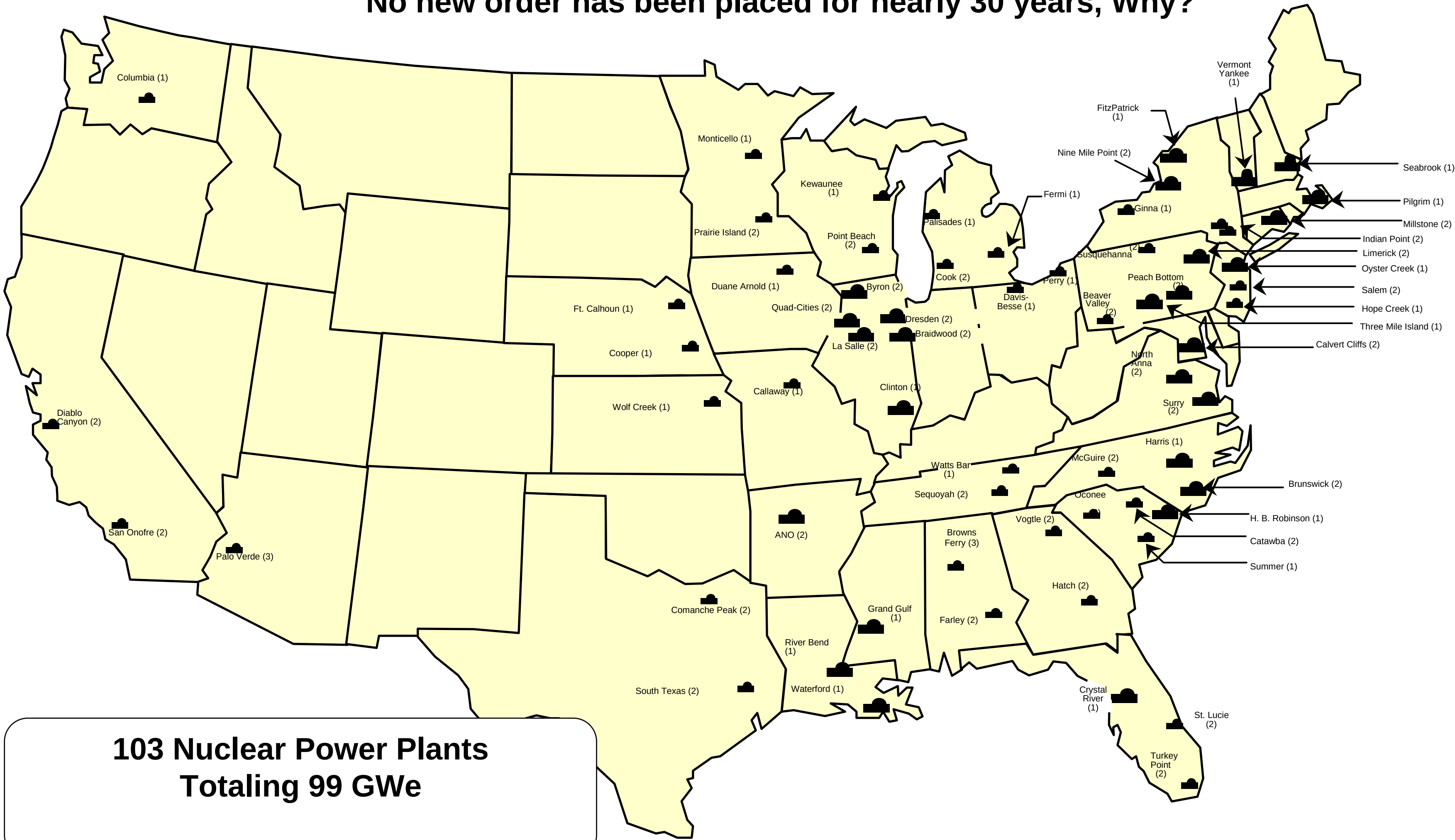
POWERSPAN

Summary

- Coal is economically attractive and available; short term use will grow in US and world-wide
- Technology is available today to make coal-fired electricity generation as clean as gas (for conventional pollutants SO_2, NOx, Hg, PM)
- It is too early to anoint IGCC as the future of coal in a carbon constrained world – early studies indicate ammonia capture (ECO_2) is the winner
- Although stronger regulations would accelerate technology development, EOR opportunities provide near term motivation – capital for CO_2 capture ($50/bbl oil justifies $30/ton CO_2)

Nuclear Power Plants in US

No new order has been placed for nearly 30 years, Why?



103 Nuclear Power Plants
Totaling 99 GWe

Trojan Nuclear Power Plant, Rainier Oregon

Portland General Electric (PGE) Began construction Feb 1970, commercial operation began May 1976.

Had 35 year license which was to expire 2011.

Problems with construction errors, steam tube cracking, etc.

Some radioactive leaks.

Dec. 1992, PGE staff scientists said Trojan may be unsafe to operate.

1978 Oregon vote prohibited PGE from charging ratepayers costs for electrical power plants not providing power to customers.

But Oregon Public Utility Commissions allowed PGE to continue to charge ratepayers for costs of Trojan plant even though it closed in Jan, 1993. Class action lawsuit says PGE must pay customers for unlawful profits.

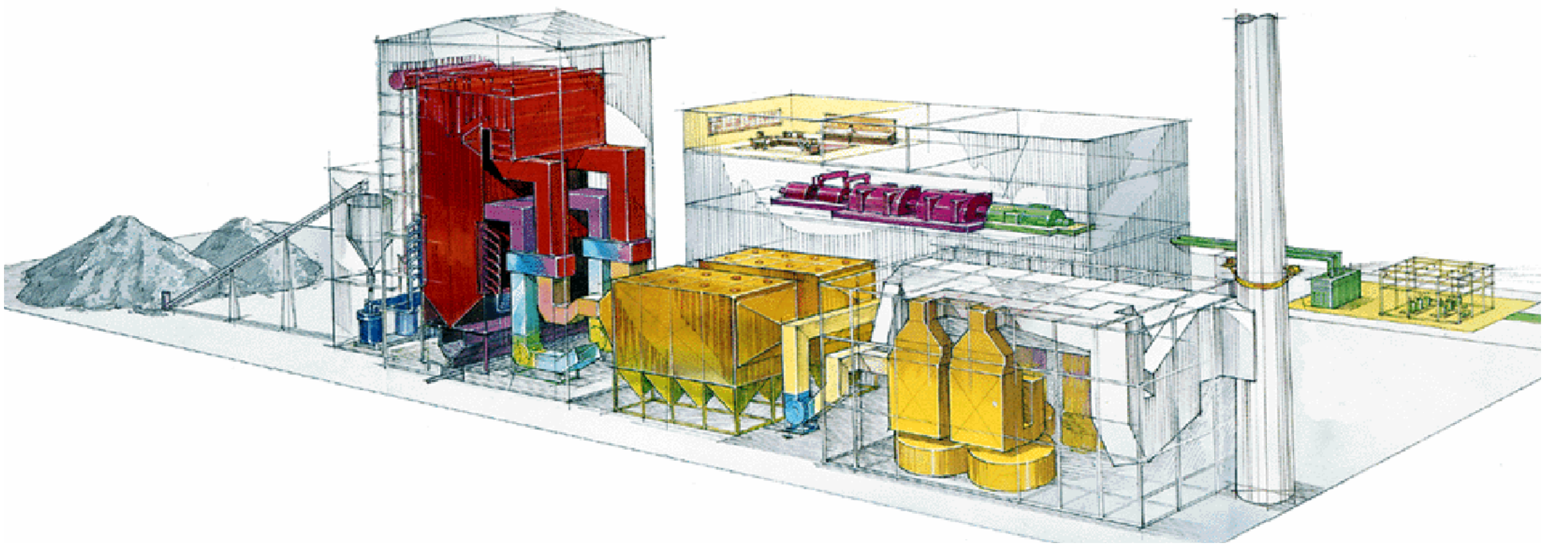
Pilat Opinion is that PGE shut down Trojan in Jan 1993 because the cost for electric power generation was too high compared to hydropower and coal power plant power.

The Trojan 499 ft high cooling tower was demolished on May 21, 2006.

If new Nuclear power plants were economically feasible in the Western US, the Oregon Trojan site would have been a possible site for a new plant because the nuclear plant infrastructure was already there.

Why are some in the US Federal Government "lobbying" for the construction of new Nuclear Power Plants in the United States?

- **An IGCC places the chemical plant in the *front end* of plant.**
- **In contrast, a conventional coal power plant is less efficient because it places a chemical plant at the *back end*, attempting to capture pollutants after combustion and much dilution.**
- ***But, the capital costs of a IGCC plant are about 20% greater than for a***
- ***Conventional coal power plant & a IGCC is more complicated to operate.***



- Electric Utiltity Industry Culture
  - **IGCC is a chemical plant. Power companies understand combustion, not chemical process plants.**
  - **Perceived and actual technical and financial risk.**
- **Why build an IGCC if you can get a permit for a conventional coal plant?**

Is IGCC BACT? (BACT = Best Available Air Pollution Emission Control Technology)?

Best Available Control Technology (BACT) and IGCC

If a conventional coal power plant is proposed for construction in US, should IGCC be evaluated as an alternative option in the permit to construct review by the State Governments (such as Wash Dept of Ecology) and EPA?

States

Yes:	**Illinois, Montana, New Mexico**
No:	**Wisconsin, West Virginia**
Undecided:	**Many states**

Federal Government

May issue an opinion through permit appeal federal court decision.

Pilat Opinion: IGCC will not be ruled as BACT for a coal fueled power plant.
Why? 1) Not any full-sized electric utility IGCC coal fueled power plants operating in US. 2) Court more likely to decide that as long as coal fueled power plant reduces criteria air pollutants (PM, SOx, CO, NOx, Hg) to BACT emission levels, methodolgy for emission reduction is choice of power plant.

Montana has large coal reserves and intends to develop "clean" coal fueled power plants and Governor wants IGCC built in Montana.

Pilat Concluding Observations on Coal Fired Power Plants

- **IGCC power plants are being proposed (NW Energy has proposed a coal-fueled power plant in Kalama, Washington, possibly an IGCC plant)**
- **IGCC plants *claim to* be cleaner than conventional coal-fired power plants but this implies that CO_2 is absorbed, collected, and not emitted into atmosphere.**
- **Capital Costs of IGCC are significantly greater (20%) than that of conventional coal-fired power plants.**
- **Regulatory crossroads - Is IGCC BACT for producing electricity from coal?**
- **With the increased cost of natural gas, natural gas fueled turbine electric generating station electric power costs are greater than from conventional coal power plants (but they take less time to permit and construct, lower capital costs).**
- **US Electric utilities reluctant to propose construction of new nuclear power plants because of high capital costs and they are not able to pass these costs onto the rate payers (which was possible prior to 1978 when electric utilities were monopolies and less expensive electric power was not allowed to be transmitted long distances).**
- **Some funding for "environmental concerns" about air pollutant emissions from conventional coal fired power plants has been provided by companies and/or groups having competing electric power generation equipment or processes which produce more expensive electric power; such as the natural gas company Chesapeake Energy of Oklahoma City which funded the "Texas Clean Sky Coalition" to lobby against the construction by TXU of the new coal fired power plants in Texas.**

Electric Utility Monopolies

Prior to deregulation which started in 1978, US Electricity was supplied by regional monopolies (Seattle City Light, Puget Sound Power & Light, Washington Water Power, Pacific Power & Light, etc.)

State Utility Commissions regulated the electricity cost to the ratepayer and the electric rates were related to the utilities % return on their capital investment.

This encouraged electric utilities to purchase high capital cost power plants such as nuclear power plants (high capital cost, low fuel cost) rather than low capital cost power plants (oil or natural gas fueled turbine generators).

Washington Public Power Supply System, WPPSS, (changed name to Energy Northwest) started construction in 1972 to build some large nuclear power plants but decreased power needs, poor engineering and construction, increased costs, and the loss of their monopoly resulted in the largest default on municipal tax exempt bonds in US history ($2.25 billion). The Columbia Nuclear Power Plant north of Richland on the Hanford site is a 1200 MW reactor and was completed in 1984.

Impact of Emissions from Distributed Electrical Generation on Air Quality in the Sydney Basin

This section concludes that Distributed Electrical Generation results in reduced CO_2 greenhouse emissions compared to central electrical power generation by coal fired power plants.

Aim of the Australian Study

Assess the possible Air Quality impacts and Greenhouse Gas abatement from significant Electric Distributed Generation deployment in the Australian market.

What is Distributed Generation (DG)?

- DG is small scale electricity generation **at**, or **close**, to the point of use

  Currently, most on-site generators are “emergency” units exempt from air pollutant emissions requirements.

- **The U of Washington has 10 megawatts of diesel engine electrical generation at U of W power plant to furnish UW Hospital with emergency power when needed.**

Central Generation
Coal Fired Power Plant

Distributed Generation
Internal Combustion Engine

Fossil-Fueled Distributed Generation Engines?

Toxic ?

Noisy ?

Dirty ?

Smelly ?

Diesel Engines with no air pollution control equipment emit particulate air pollutants and NOx

Natural Gas Engines are relatively clean.

Overview

Distributed Generation Systems

Regulators

Scientists and Engineers

Environment

Who will own the distributed electric generation installations?

Will Electric Utilities Lose Their Monopoly?

Fossil-Fueled DG Systems

- **Internal Combustion (IC) Engine fueled by: Diesel or Natural Gas**
- **Natural Gas Turbine (common in US for large electrical generation facilities)**
- **Internal Combustion Engine Fueled by Natural Gas with Waste Heat Utilization**

  (Co-Generation)

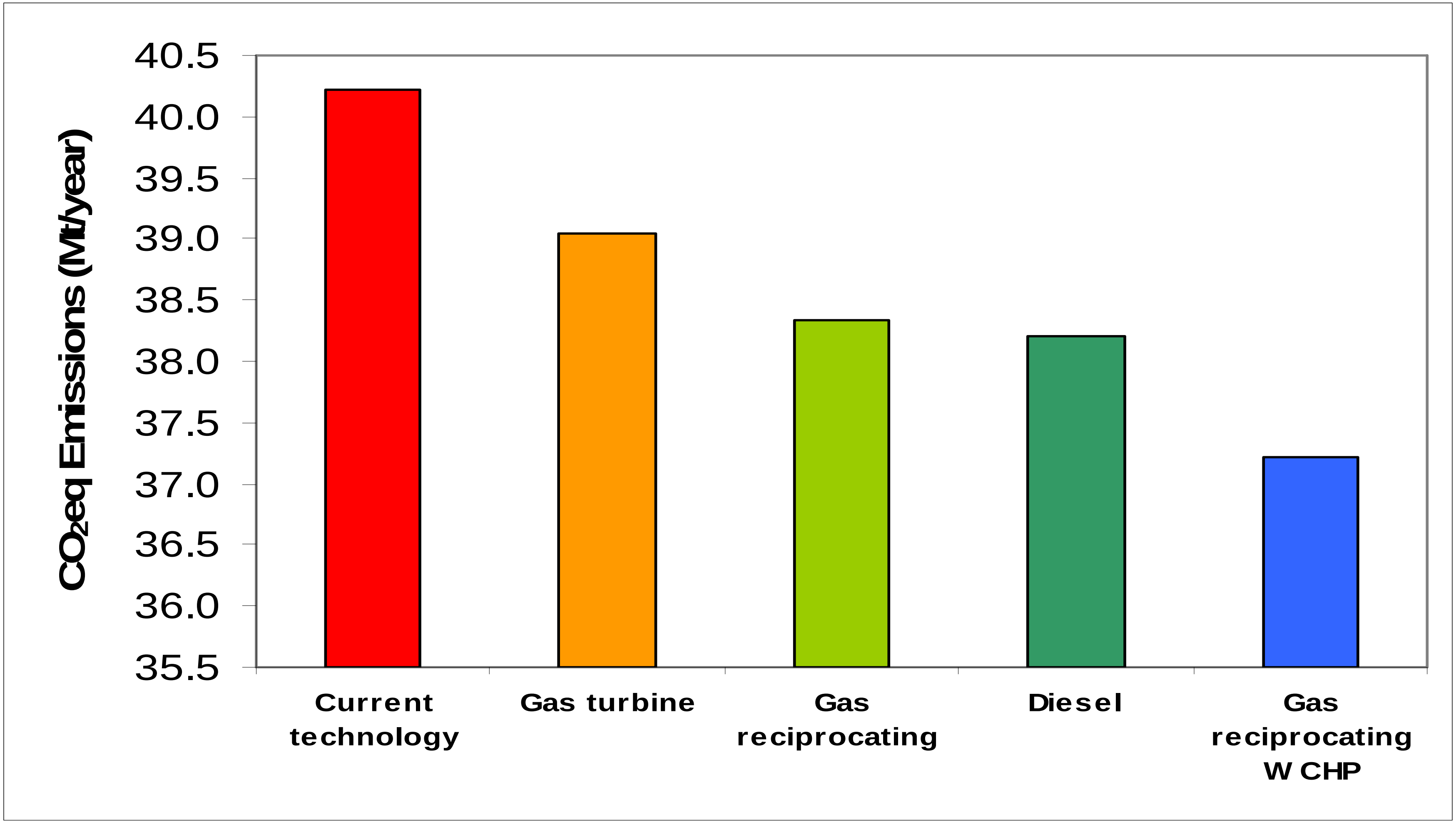
Regulatory Agencies - implications of DG

- Fossil fueled DG technologies increase of air pollutant emissions at the point of use. These emissions may have a positive or negative impact on both local and regional air quality.

Methodology Used in the Study

- 2001-2002 NSW annual electricity consumption was scaled down to Sydney based on Sydney-NSW population ratios.
- Of total Sydney electricity consumption, 15% was assumed from DG - (based on tripling the existing DG)
- The amount of electricity from DG equates to approximately 500 MW

Changes in Emissions of CO_2 depend on the technology adopted



CHP = Combined Heat & Power

Conclusions

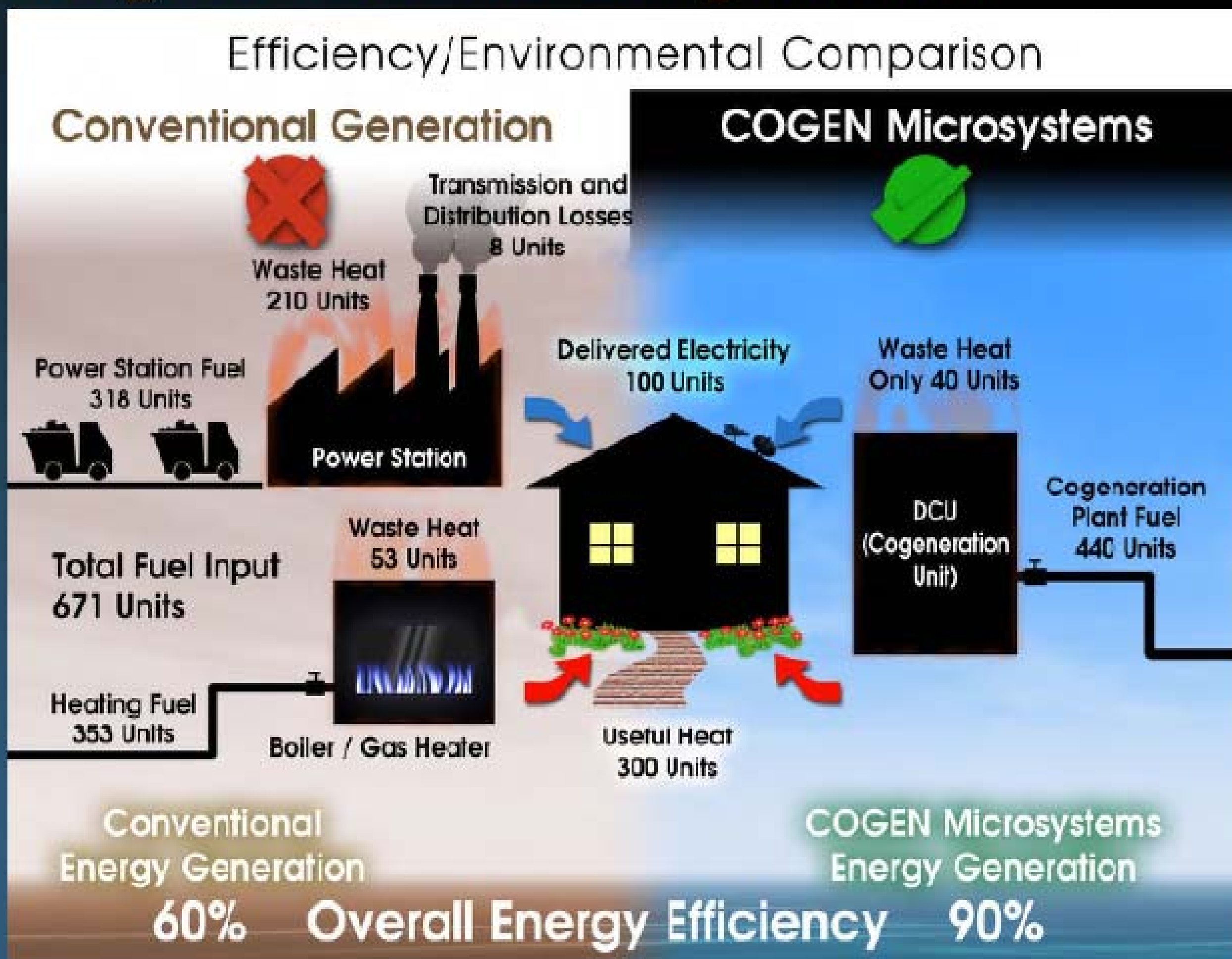
- **Distributed Electrical Generation technologies reduce CO_2 emissions relative to centralized electrical power plants**
- **DG Natural Gas reciprocating engines with waste heat utilization (i.e. cogeneration) found to produce the highest greenhouse gas savings followed by diesel engines, gas engines (without waste heat utilisation), and gas turbines.**

Why is Distributed Electrical Generation not Used in the US?

U of W Power Plant has space for 2nd 5 megawatt Steam Turbine to generate Electricity but it has never been installed? Why?

COGEN
Microsystems

Cogeneration comparison



COGEN Microsystems

What's the big deal?

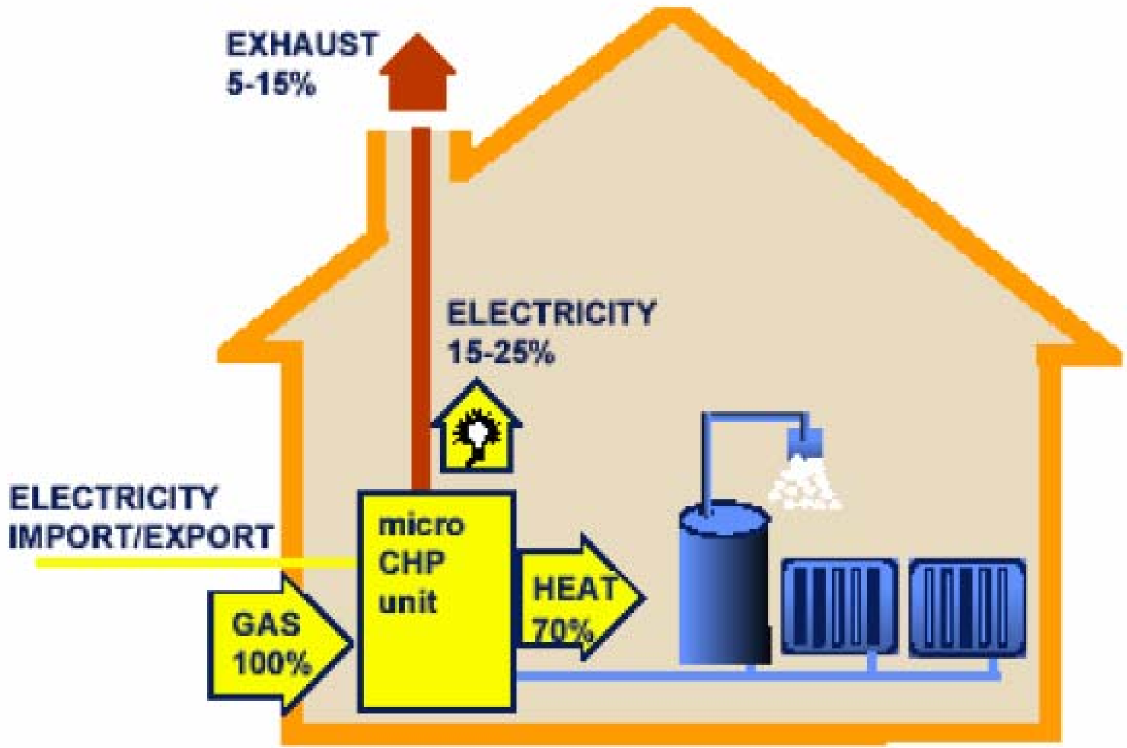
- Saves energy; home example:

	CONVENTIONAL	COGEN
Fuel Input	671	440
Heat losses	-263	-40
Distribution losses	-8	0
Energy delivered to home	400	400
Efficiency	59.6%	90.9%

- Reduces Greenhouse emissions.
- Takes the strain off the distribution grid and generation capacity.
- Blackout protection.

Typical energy split

COGEN Microsystems

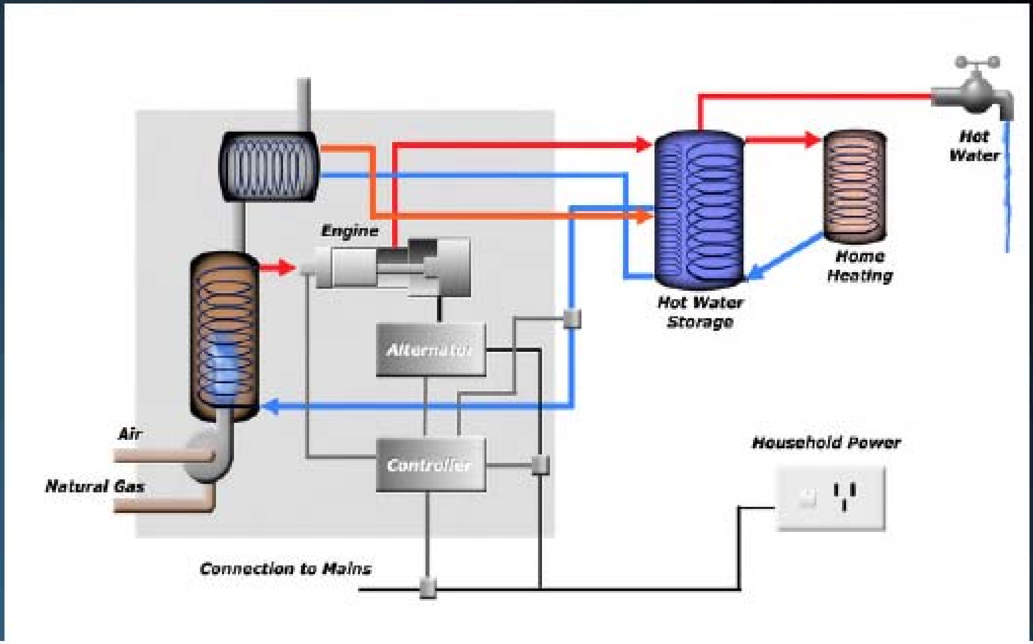


Micro CHP replaces boiler in conventional central heating system

Our CHP control system

COGEN Microsystems

- Our patented control system maximises the benefits of micro cogeneration in the home.
- Controls alternator to interface directly to the grid. No inverter required.
- "Standalone" mode for blackouts.
- This technology applies to all heat engines – we have valuable IP (US Patent now granted, others pending) that competitors will want to use.



COGEN
Microsystems

Tri-generation – the next step

- A Micro Cogeneration system combined with a desiccant cooling and humidity control system provides air conditioning – important for markets with warmer climates eg Australia.
- Tri-generation systems - heating, cooling and power generation - take the strain of existing electricity infrastructure by reducing peak (summer) demand. This is a major issue in many states of Australia and overseas (eg California).
- Household air conditioning, power generation and hot water all powered by natural gas with 90% overall thermal efficiency.

1. Honda (cont)

COGEN Microsystems

Honda MCHP1.0 Specifications

Fuel		Natural Gas (Japan 13A)
Output	Electricity	1Φ 200V/100V 50/60Hz 1 kW
	Heat	3.25 kW
Power supply		Grid interconnection
Heat recovery		Max. 80℃ Hot coolant
Efficiencies (LHV)	Electricity	20%
	Heat	65%
Dimension (L x W x H)		640x380x940 mm
Operation Weight		82 （ｋｇ）
Operation Noise		44 （ｄＢ（Ａ）／１ｍ）
Emission (NOx)		Max. 60ppm
Engine	Type	Liquid cooled 4-stroke OHC vertical single cylinder
	Displacement	163 cm^3
Starting system		Starter Generator

Table 1 Specifications

1. Honda (cont)

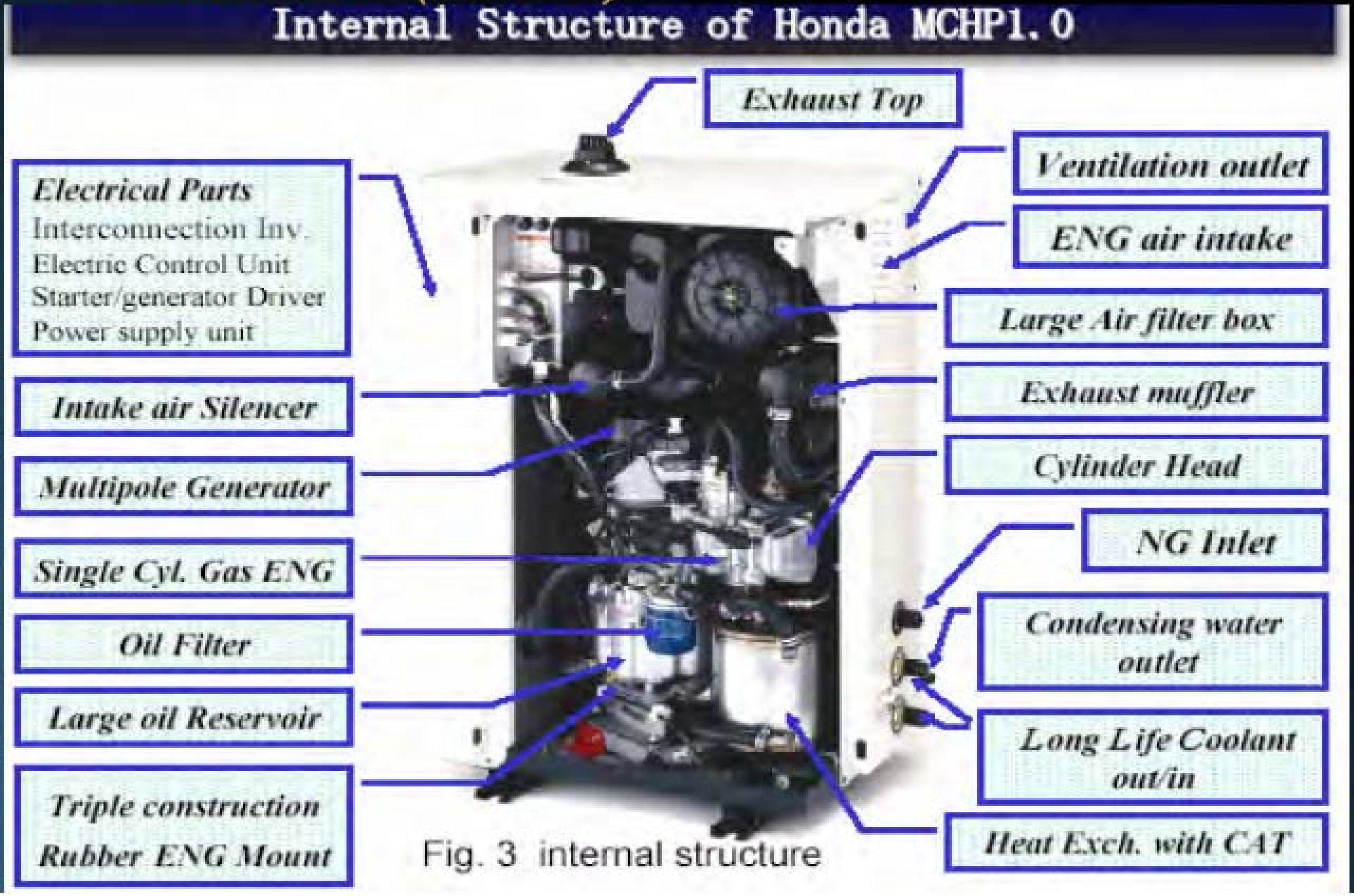
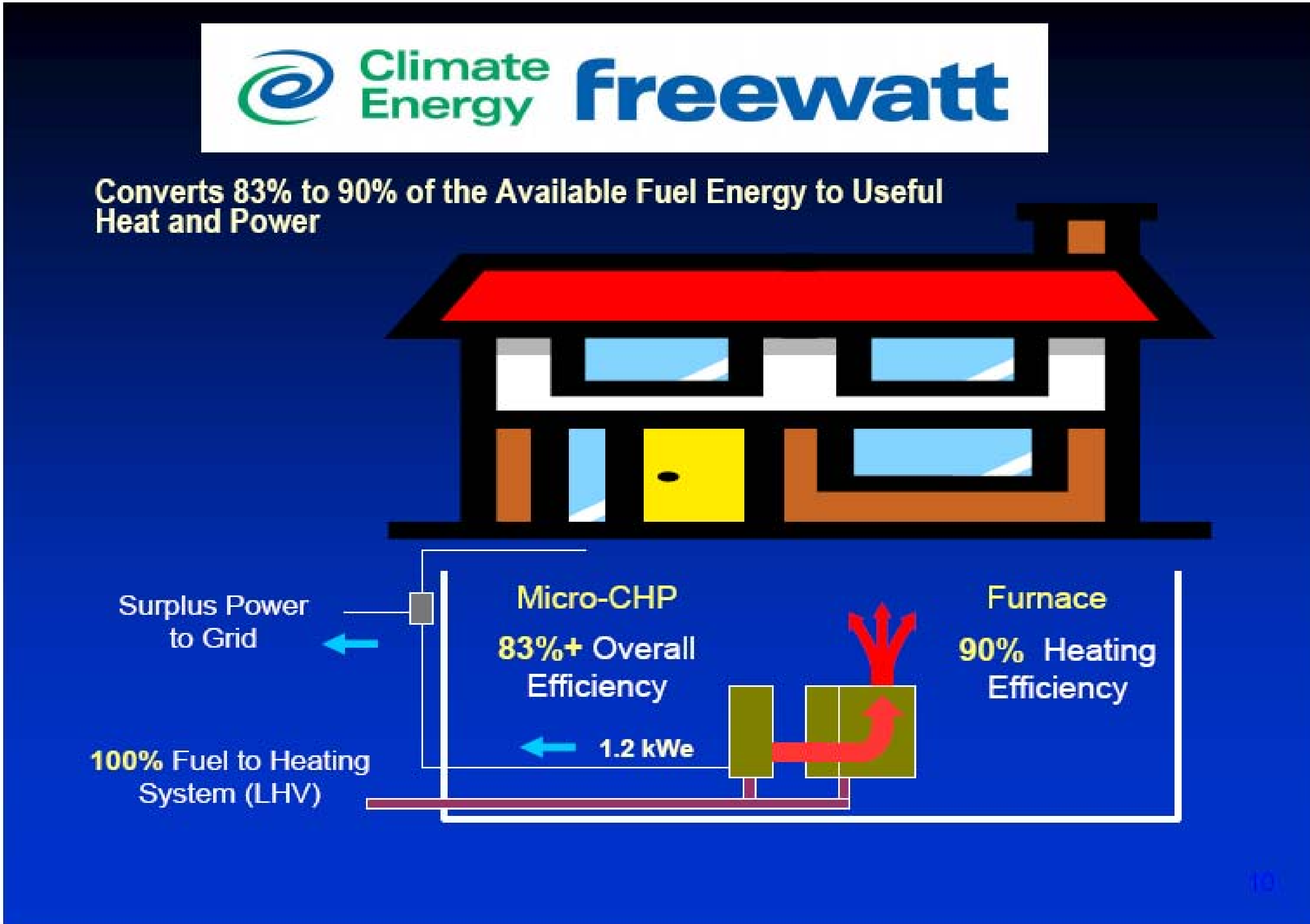


Fig. 3 internal structure


Climate Energy
freewatt
Converts 83% to 90% of the Available Fuel Energy to Useful Heat and Power
Surplus Power to Grid
Micro-CHP
83%+ Overall Efficiency
1.2 kWe
Furnace
90% Heating Efficiency
100% Fuel to Heating System (LHV)

Over the last 10 years the US space heating appliance industry produced about 1,000,000 Megawatts of Thermal Capacity

Total USA Installed Electric Capacity ~ 800,000 Megawatts

Electric Power from your heating system

- Small-Scale Cogeneration
- Combined Heat and Power
- Micro-CHP (1 to 5 kW)

Fuel → Heat +Electricity

Honda IC Engine Technology

The Best Fit Today Because …

Size: 1.2 kWe, 12,000 Btu/hr

Total Efficiency: Over 85%

Emissions: Low NOx, CO

Quiet Operation: < 46 dBA

Cost: Most competitive

Quality: It's a Honda

History: 30,000 Sold to Date in Japan

Micro-CHP Potential Benefits to the Homeowner

- Significantly reduced electric bills, about 50%
- Reduced Gas Rate?
- Backup power supply in event of grid outage
- Reduced impact on the environment with no lifestyle change

Climate Energy freewatt

Micro-CHP Benefits to the Pennsylvania Electric Utility System

- **Reduced Need for Generation and Distribution of Power**
- **New low-cost peak demand management resource**

Micro-CHP Implementation Plan for Pennsylvania

- **Phase 1: Pilot-Transition Program ~ 1,000 homes**

  Total installed Capacity 1 to 2 Megawatts

  2 years duration

  Temporary Rules

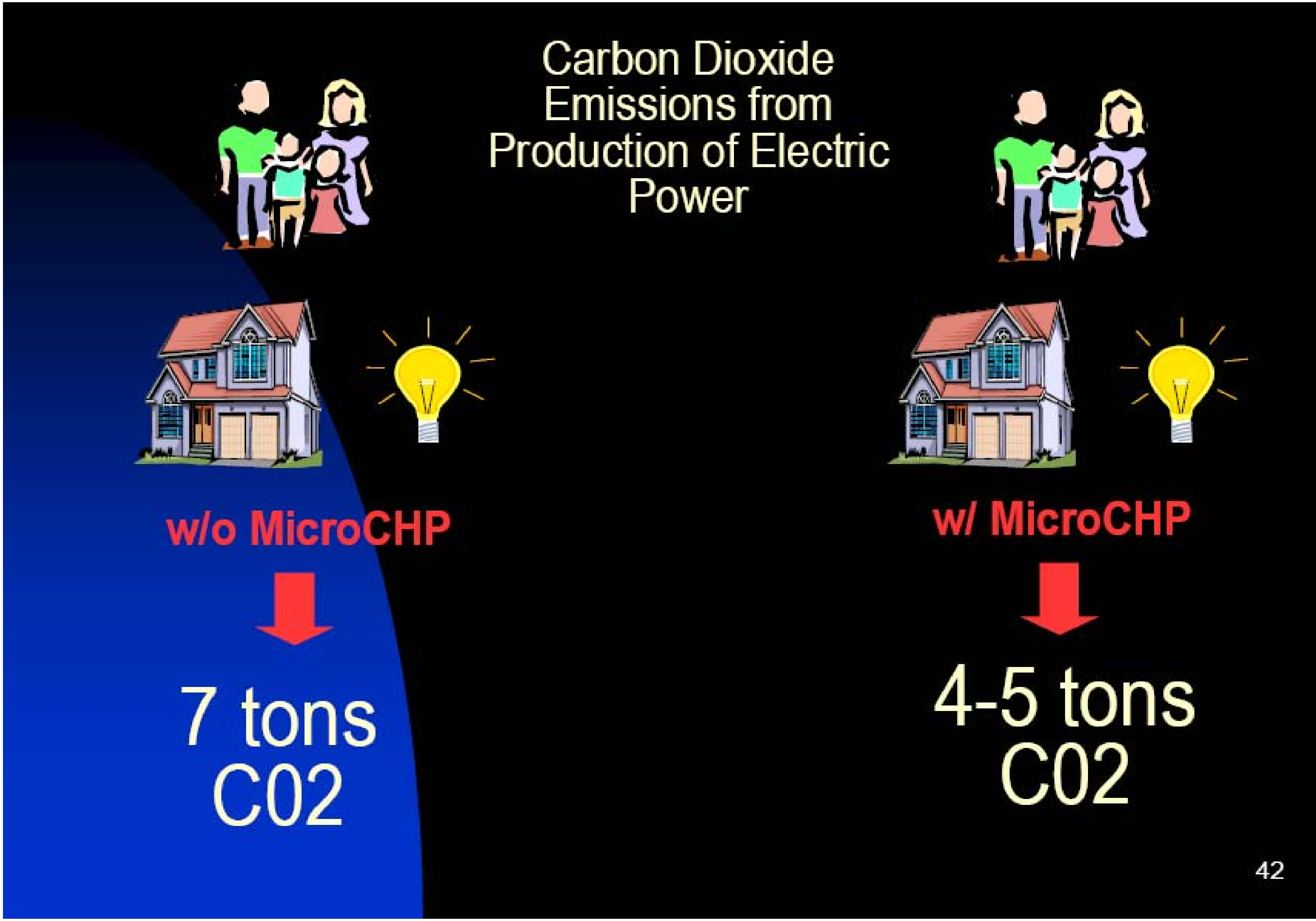
- **Phase 2: Fully Developed Long-Term Program**

  Size and Limits to be determined as appropriate - Suggested Goal (20% of annual gas air furnace and boiler sales be promoted for Micro-CHP, I.e. approximately 30,000 based upon 2005 sales in PA.

  Long-term Rules

What's Next for Climate Energy in Pennsylvania?

- Warm Air Micro-CHP Retail Sales – Beginning Second Quarter of 2007
- Hydronic Micro-CHP System – Beginning Fourth Quarter of 2007


Carbon Dioxide Emissions from Production of Electric Power
w/o MicroCHP
7 tons C02
w/ MicroCHP
4-5 tons C02
42

ISSUES

- Micro-CHP fits into the reality of today's changing electric utility industry
- Electric utilities will view CHP both as an opportunity and a challenge
  - Micro-CHP – more opportunity/less challenge
- Key Issues
  - Interconnection
  - Permitting
  - Fees
  - Net metering
  - Tax credits

Key Issues – "Fees"

- Utility imposed "fees" (exit/entrance, stand-by/access) ADD to the costs of CHP!!!!
- Exit fees – means to recover future stranded costs associated with loss of customer
- States "all over the place" on fees
  - Six states with no fees
  - Five states with conditional fees
  - Two states with broad fees on all self generation
  - Two states with conflicting legislative and administrative positions

Key Issues – "Fees" (cont'd)

- Other "fee" issues that are not standardized
  - Grid connected vs. independent
  - Reduction in consumption from grid vs. complete avoidance
  - "Hidden" exit fees
    - e.g. stand-by rates (MIT case in MA)
- "Bottom Line"
  - Regulatory treatment of "fees" driven by local regulators/legislators/utilities/perception of CHP
  - Smaller sizes likely to receive better treatment

Key Issues – Net Metering

- Net-metering

  Net total monthly electrical consumption or the difference between electricity "taken " from the grid and the amount generated by the CHP appliance

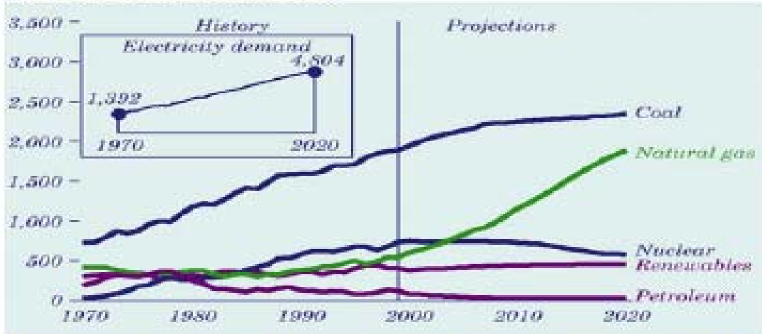
- *Already in the "books" in many states (40+) as well as in several bills*
  - *S 1766 "mandates" net metering for systems <250 kW*
- Small systems favored
- Most do not have "cash-back" provisions
  - Carry-over credits
  - Year-end round-up
  - Net-negative flows to utility

Bottom line…

- Legislative and regulatory issues are important to the eventual success of Micro-CHP
- Micro-CHP and intended market sector likely to yield more favorable treatment than some other technologies (size/application)

Potential Impacts at the National Level
(10 Million units)

Figure 4. Electricity generation by fuel, 1970-2020 (billion kilowatthours)



History: Energy Information Administration (EIA), Form EIA-860B, "Annual Electric Generator Report - Nonutility;" EIA, *Annual Energy Review 1999*, DOE/EIA-0384(99) (Washington, DC, July 2000); and Edison Electric Institute. **Projections:** Table A8.

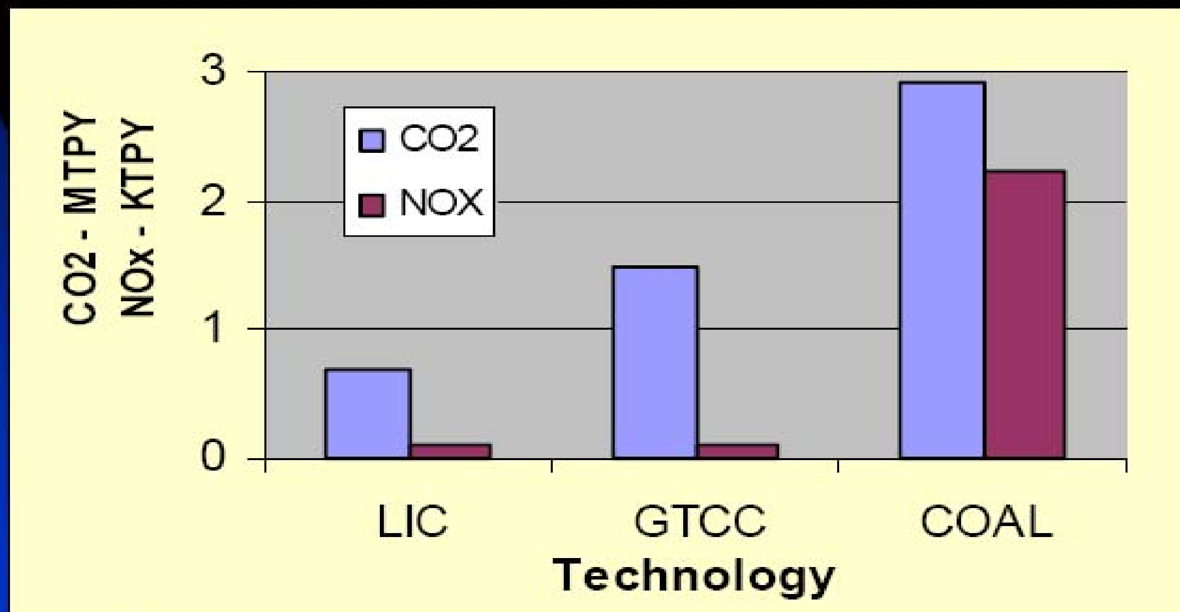
Electric generation in the US -2000

- Coal - ~1900x10^9 kwhr
  - ~600x10^9 kwhr for residential sector
- Gas - ~500x10^9 kwhr
- Oil - ~100-110x10^9 kwhr

LIC Electrical Energy Contribution

- 30x10^9 kwhr/year
  - ~5% of coal generation for residential sector
  - ~30% of total fuel oil-based electrical generation!!!
- Equivalent to:
  - ~30% of total Demand-Side Management (DSM) programs

Annual Emissions Comparison
(Per Million LIC Units)



GTCC and Coal are Based on Equivalent kWhr Production

40

LIC = Liquid Injected CoGen

Liquid-Injected Cogen

- Evolutionary hydronic heating technology
- Synthesizes new technology with old
- Compare to “hybrid” automobile

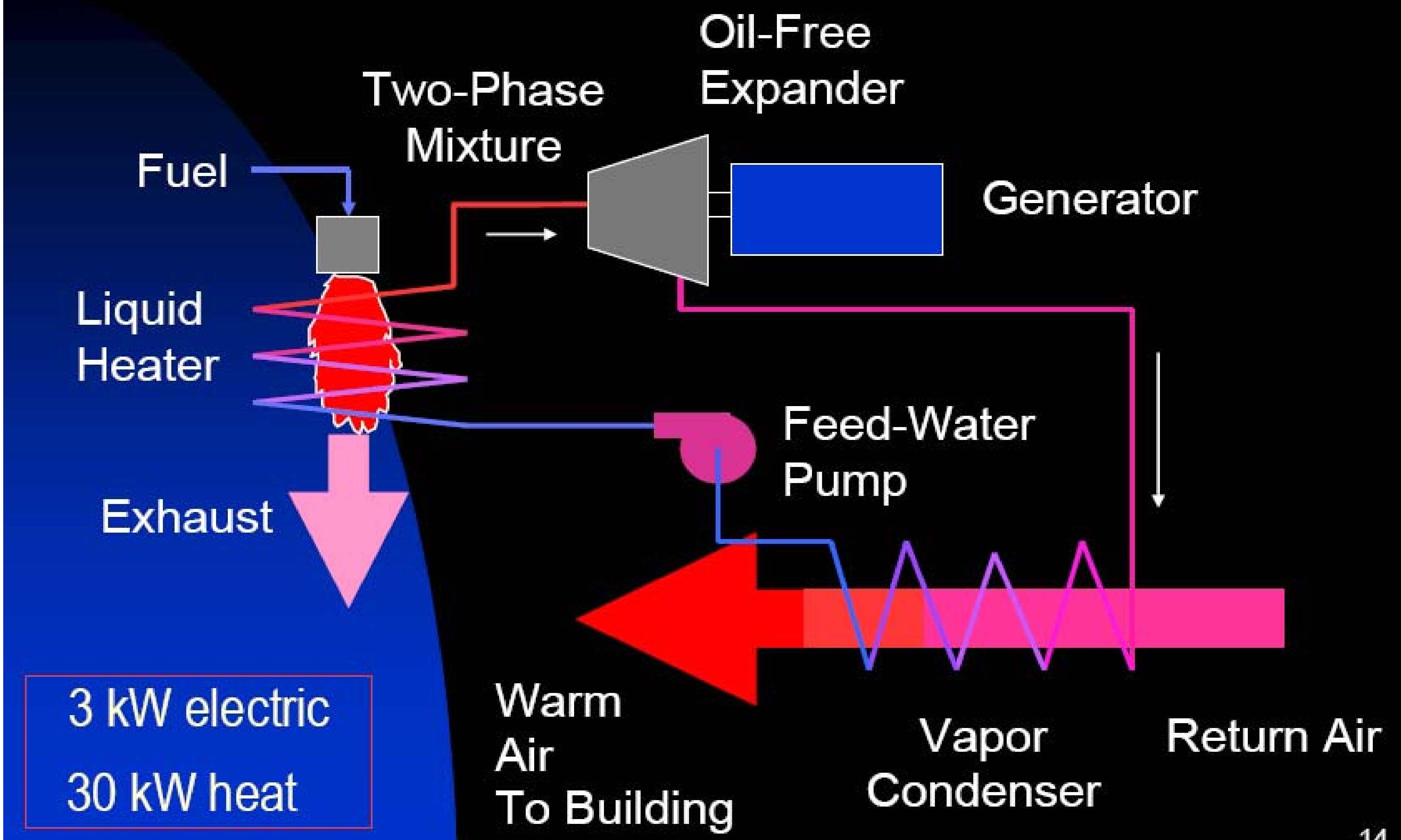
12

LIC = Liquid Injected

Liquid-Injected Cogeneration

- Simplified "Steam" power cycle made possible by modern materials, manufacturing and electro-mechanical technology
- Cycle configured to specific needs of Micro-CHP
  - Instantaneous water heating with only partial vaporization
  - Power from two-phase, oil-free expander

Liquid-Injected Cogen Furnace



Advantages of Liquid-Injected Cogen

- Appropriate heat/power ratio for homes
- Low hot water inventory – intrinsically safe
- Uses compact, lightweight, high performance components
- Expander rotation matches generator speed
- External combustion - low emissions
- Quality heat provided at up to 200 F
- Builds on existing heating industry technology and business base

Concept View of LIC Warm-Air Furnace

LIC = Liquid Injected CoGen

Cogen Heating System Monthly Electric Output*

*10% power to heat ratio, New York example

Conclusions on Micro Co-Generation

- **Reduces overall emissions of CO_2**
- **Reduces fuel consumption because of electrical power generation.**
- **May be opposed by:**

a) Electric utilities (reduces electricity sales)

b) Cities, counties, & states (reduces utility tax receipts)

c) Governmental air pollution control agencies (unregulated air pollutant sources although emissions from small natural gas heating furnaces now unregulated and do not require permits).

d) Heating and air conditioning installation contractors who now have a monopoly on the installation, maintenance, and repair of home heating and air conditioning appliances (electric utilities such as Seattle City Light and some PUDs used to maintain electrical appliances such as home heat pumps, electric water heaters, etc.)

e) Natural gas companies which sell natural gas to natural gas fueled electric generating plants (large increase in natural gas electrical generating plants in the last 10 years)