Recent Energy Overview

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Recent Energy Overview

Introduction to

Improving Electric Power & CO_2 Carbon Capture Storage (CCS)

(Chris Wedig – Shaw Senior Technology Specialist)

- Linked related energy improvements
  - Ultra super critical (USC) steam generation
  - Integrated Gasified Combined Cycle (IGCC)
  - Nuclear Additions (Power Generation; Future Heating)
  - Renewable expansions (Wind, Solar, Geothermal, Hydro)
- Current political position for power industry
- Latest energy plans

Energy Anticipations

- Global Energy – Past/Present/Future

	1950	2010	2050
World Population (Billion)	2.5	6.5	9.5
World Energy Quads (10^{15} btu)	~ 170	490	~1500
Energy Ratios	1/3	1	3/1
Global Carbon Emissions		7	~26
(Billion 10^9 ton C)			
USA Global Population		-5%	<4%
USA Global Energy Consumption		~22%	~10%

Predicted future global energy (Refer AIChE national sessions: 2006, 2009)

2008 Energy Consumption (Global, USA) (million tons crude oil equivalent)

	Global	USA	USA Global %
Crude Oil	3930	885	22%
Natural Gas	2730	601	22%
Coal	3300	565	17%
Nuclear	620	192	30%
Hydro-Elect	720	57	8%
Total	11300	2300	20%

[Convenient BP Statistical Review 2009]

Imports

Crude oil	~12.5 million barrels / day	(~63% consumption)
Natural gas	~68 million tons oil equivalent / year	(~13% consumption)

Planned USA Future Sources

Crude oil @ Montana, Bakken, under Rocky Mountains

Natural gas @ Slate Rock Injections, at various N.E. states

Basic Electricity Capacities/Energy Links

- Power generators are specified in a variety of items:
  - Electricity per hour (e.g. MWe/hr)
  - Electricity per year (e.g. MWe/yr)
  - Total heat generation (e.g. MW/yr)

  (subscript “e” implies electricity production)
- Capacity items
  - KW kilowatts(10^3)
  - MW megawatts (10^6)
  - GW gigawatts (10^9)
  - TW terawatts (10^{12})
  - PW petawatts (10^{15})

Cleco Rodemacher

Power Generation Efficiency

- Sub-critical ± 33%
- Super-critical
- Ultra super-critical ±45%

Super-critical

- There are multiple super-critical power plants operating and on order in the world:
  - China 70, Europe 31, Japan 19, South Korea 15, USA & Canada 14, others countries 23 (including Australia and India)

Power Generation Efficiency

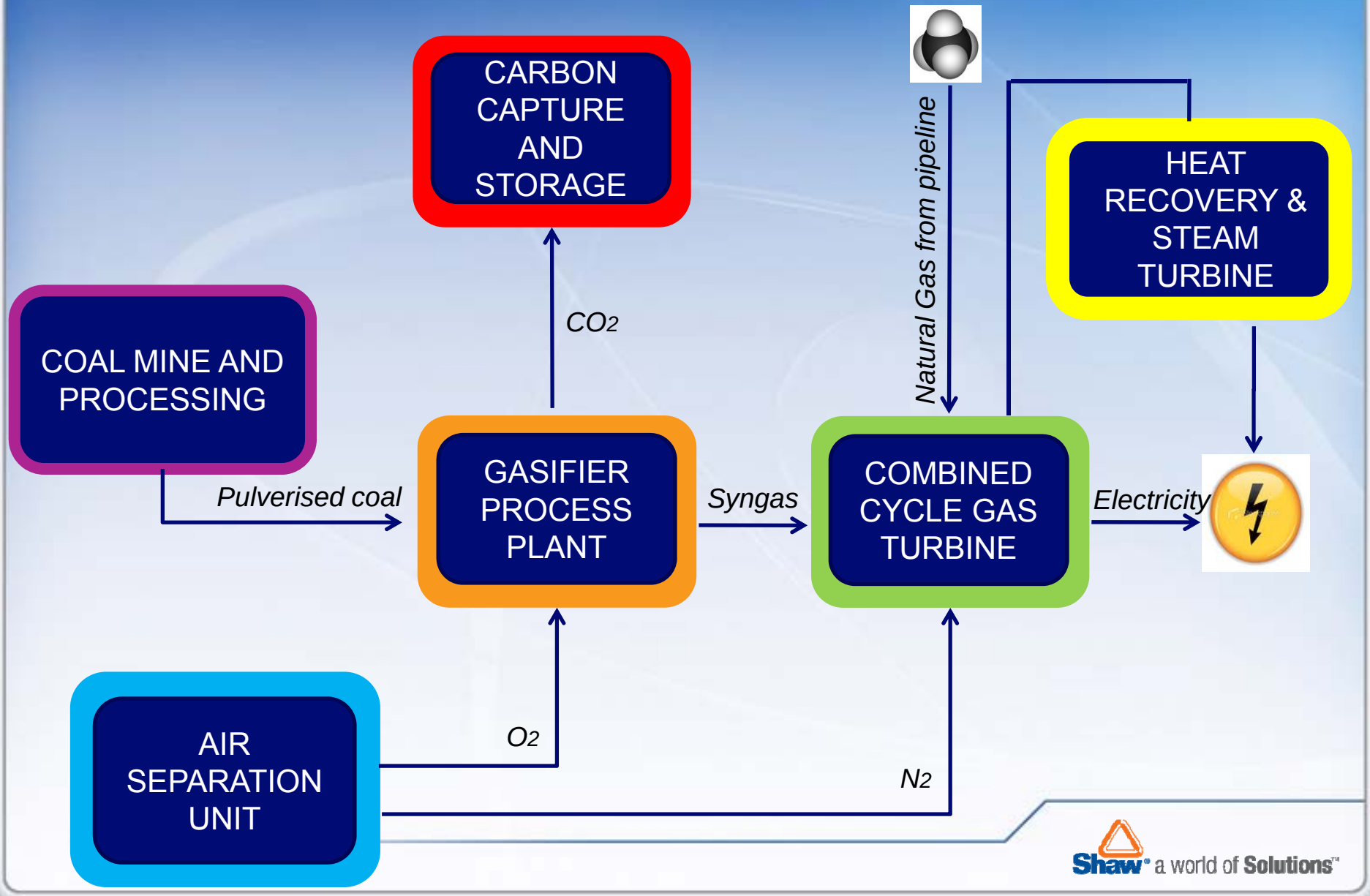
Typical ultra supercritical efficiency (280 barg, 600°C) ~45%

- Increased flue gas heat recovery ~120°F/40°C
- Lower condensation pressure (1.5 mg Hg vs. 4.0 mg)
- 4-stage turbines; alternative designs
- 1st stage turbine extraction re-superheat ~300°C to 600°C
- Associated CO_2 flue gas removal
- Super-critical and ultra super-critical technologies are vital to increasing fuel efficiency and reducing CO_2 emissions
- Super-critical production emits 20% less CO_2 compared to sub-critical plant

Integrated Gasified Combine Cycle (IGCC)

- Improved coal – powered efficiency scheme with CCS potential
- Key technology elements
  - Coal cleaned & O_2 gasified to H_2 + CO (syngas)
  - Air separation unit produces O_2 for coal combustion
  - Air separation unit produces N_2 for gas turbine
  - CO then converted/removed as CO_2
  - H_2S then absorbed and converted/removed as sulphur
  - Cleaned syngas and air generates gas turbine as H_2+N_2
  - Recovered heat from gasifier and gas turbine generates steam
  - High pressure/high temp steam generates steam turbine
  - CO_2 conveniently extracted and sequestered
  - CCS inclusion is only ~15% energy demand (other units ~ 30%)
  - Other contaminants (SO_2, Hg, NOx) conveniently removed

Integrated Gasified Combined Cycle (IGCC)



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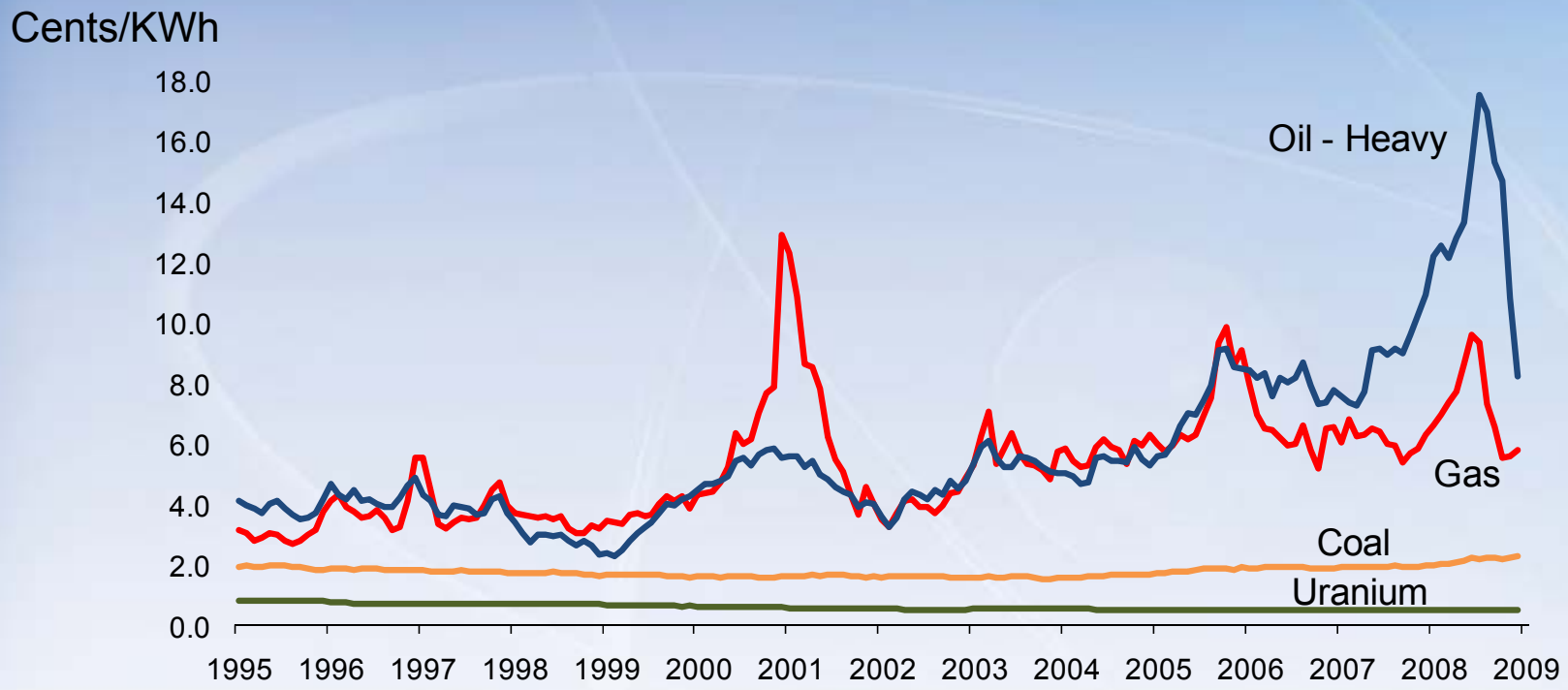
Fuel Cost to U.S. Electric Utilities
1995 – 2008



- Anticipated future energy source costs will extend related further differences
- Anticipated future CO_2 emission cost will vary these feedstock types financially

Source: Ventyx Velocity Suite

Updated: 5/09

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Nuclear Plans & Advantages

- Current global situation
  - 436 existing units
  - 30 operating countries
  - 2600 billion KWh (or 370 GWe/hr)
  - equivalent operating hrs/yr ~ 7000
  - 15% total electricity

- 50 new nuclear units under construction and potentially many more
- Latest nuclear unit production rates
  ~1000-1700 MWe/hr
- Essentially zero CO_2 emissions

(Reference recent presentation at Power-Gen International, Dec. 2008,

Jim Bernhard, Chairman, President and CEO, The Shaw Group)

Global Nuclear Expansions (2030 Future)

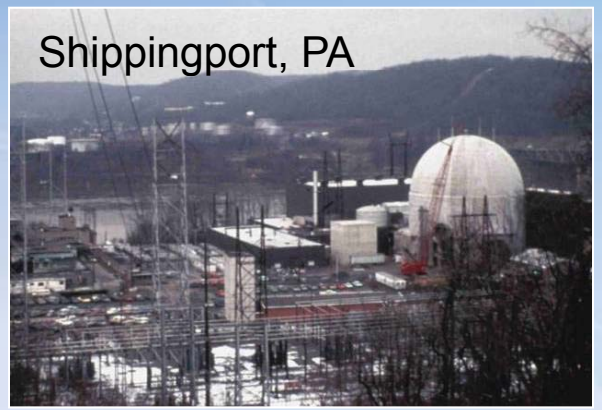
- Current global nuclear production (2010) ~2600 billion KWe/yr
- Anticipated total energy expansion (2030) ~+60%
- Nuclear expansion (2030) predictions vary:
  - Energy Information Administration (EIA) +46%
  - International Atomic Energy Agency (IAEA) +53% → 108%

Individual medium expansions (2030) by IAEA

	billions KWe/yr	
N America	250	
EU	150	
Mid East, Africa, SE Asia	310	
Far East	660	
Total	1370	(53%)

U.S. Nuclear Decisions – Past & Present

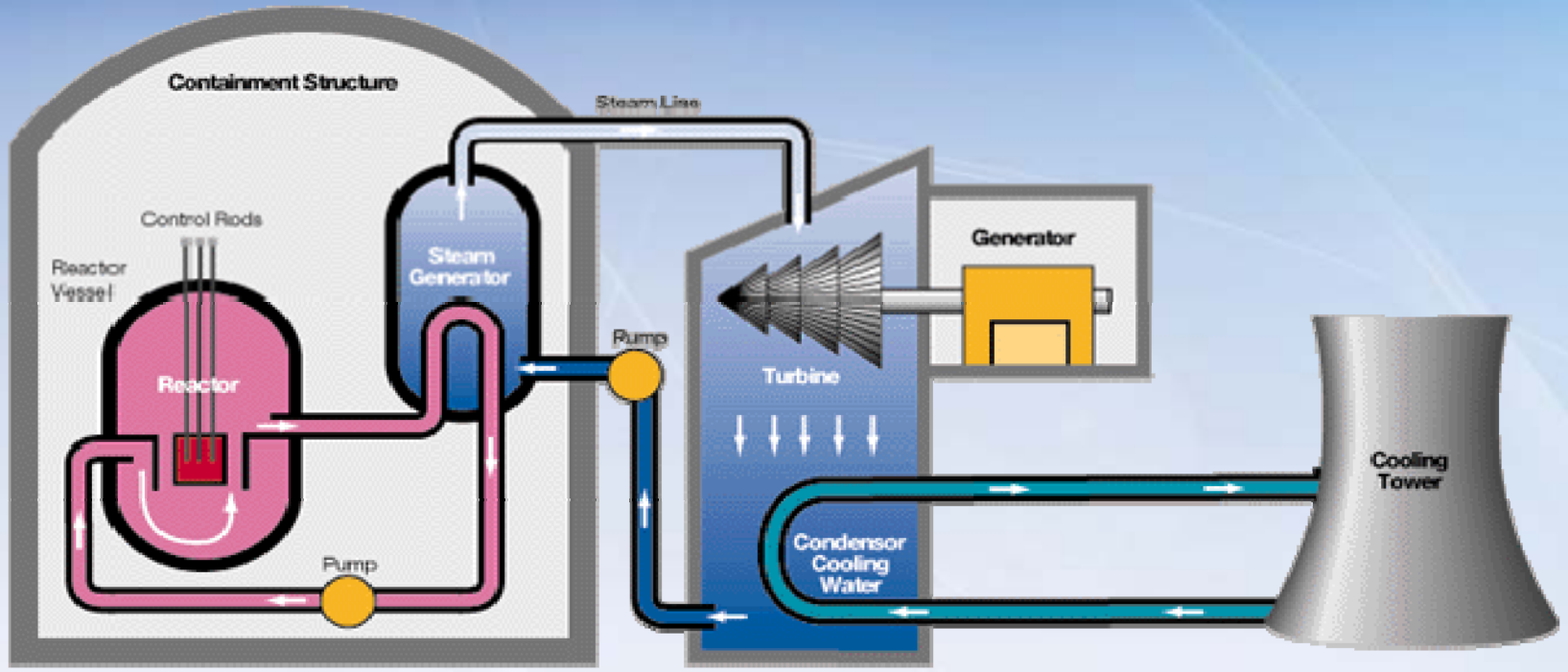
- First unit built in 1957 in Shippingport, PA (Westinghouse/S&W)
- 1979 – Since the Three Mile Island incident, virtually no new units were considered until early 2000s
- 1986 – Chernobyl nuclear failure and emissions extended negative decision
- Total current units - 104
- Extended lifetime - 60 years
- Nuclear energy ~8% total US energy
  ~20% US electricity
- 4 new units at 2 sites (S. Carolina & Georgia) are now proceeding; others anticipated



U.S. Nuclear Decisions – Feedstock & Nuclear Waste

- Currently U.S. imports ~80% uranium
- New uranium production site now installed in Colorado (since ~25 years)
- ~30 new units under consideration
- Nuclear waste disposal ? (Yucca Mountain, NA)
- U.S. nuclear industry has safely used interim storage since 1986
  - Concrete-and-steel storage vaults/containers have endured rigorous testing, including high-speed train collisions and jet fuel-fed fires
  - NRC recently concluded that spent fuel can be safely stored at or near a reactor site for an additional 60 years after a plant is shut down

Pressurized Water Reactor Plant
AP 1000 Type



- Current standard nuclear electricity production reactor, Pressurized Water Reactor (PWR), produces vaporized high pressure steam from 86 barg/300°C to 120 barg/325°C
- Reactor temp is ~350°C; efficiency ~33%
- Joint development and ownership – Westinghouse and Shaw

AP1000 U.S. Projects & Prospects

Westinghouse / Shaw AP1000:

- Conceptual design
- Detailed engineering
- Site-specific engineering
- Project management
- Construction/construction mgmt
- Engineering & design services
- Turnkey modifications
- Startup & commissioning

EPC Contract Signed

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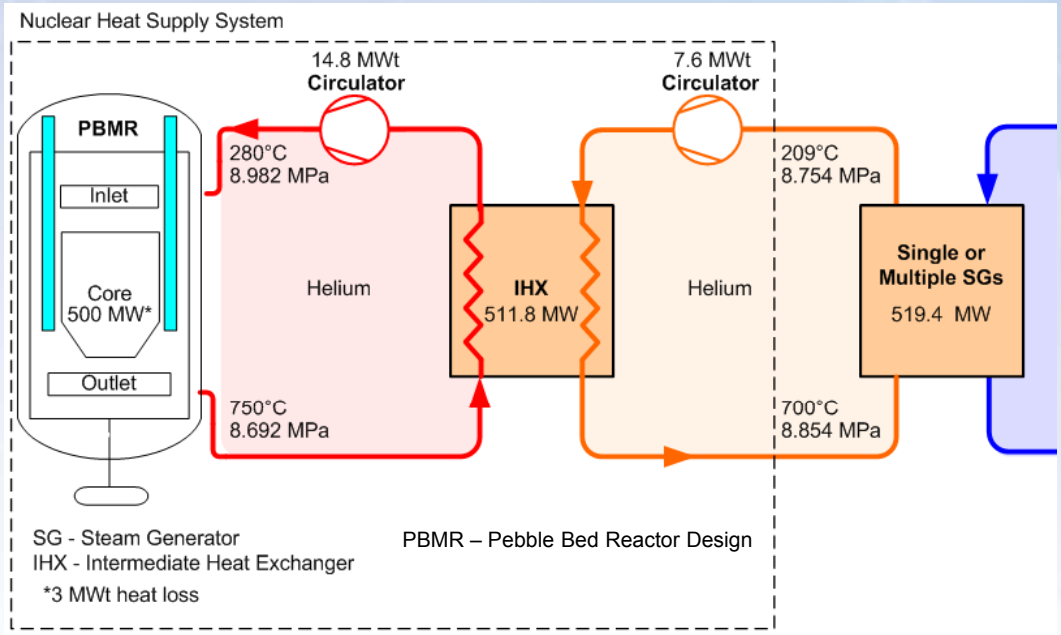
Future Petrochemical – Nuclear Links

- Future nuclear units will provide heating for major petrochemical/refining units
  - High Temp Gas Cooled Reactor (HTGR)
  - Circulating helium at ~750-850°C
  - Higher efficiency 47%
- Current designs for
  - NH_3 Unit
  - Olefin Unit



U.S. Political Energy Plans

Recent Crucial Energy Objectives

Future Energy Policies – U.S. Government

- Crude oil consumption reduction
- Double investment in various renewable energies
- Tax concessions for mini financial family energy costs
- Contributory financial assistance for vehicle energy reduction
- Produce 1 million electric hybrid cars by 2015
- Support national oil & national gas production
- Increase biofuels production (60 billion EtOH/year by 2030)
- Approve & increase nuclear energy production
- Carbon emission reductions (reduce to 90% by 2020)
- Electricity from renewable sources (10% by 2012; 25% by 2025)

Wind Power Generation

- Increasing capacity (up to 5MW per latest unit)
- Increasing U.S. capacity (four times facilities in last four years)
- U.S. total capacity: ~30,000 MW/yr (~1% total energy)
- Texas total capacity: ~1600 units; ~7000 MW/yr
- Unit power cost: ~$0.03/kWh
- European wind power generation: ~66,000MW/yr
- Future combined air compression (~100 barg) vs. DC power generation; coordinated power access and industrial integration

Other Potential Alternative Energies

- Lower impact hydro-power systems
- Tidal hydro-power systems
- Geothermal high temperature natural water circulation
  - ~100 – 200°C typical; ~700°C max (HP source)
  - natural H_2O multi-contaminants (NH_3, H_2S, CH_4, CO_2, et al)
- Solar power generation

Solar Energy

Several solar systems have been identified and employed

- Reflected sun heat to steam generation/turbine
- Heat circulating oil to deliver steam generation/turbine (~750°F)
- Heat/melt salt to circulate to steam generation/turbine; heat retained when sunlight stops
- Photovoltaic (PV) panels (semi-conductors with silicon ~10% efficient, but individual direct access) and gallium indium compounds which emit electrons
- Sun heated electrolyzer/catalyst converts H_2O to H_2 + O_2 which generate electricity via a fuel cell and retain H_2/O_2 storage when sunlight stops.

Immediate Solar Plans

Government and state programs, 2010 prediction, is to double national renewable power in next 3 years

Solar power is still a minimal percentage (~0.20%) but future potential units could achieve a much greater percentage (~4%) by 2030; key contribution will be government financial incentive and tax credits

US solar units under construction

- Solana, Arizona, 2012 - 280 megawatts
- 3 square miles solar installation

(Refer to STS February 2009 related presentation)

Conclusion

- Immediate future energy efficiencies briefly described
- We all need to maintain energy opportunity information
- Anticipated increasing vehicle electricity
- Hope we can minimize energy imports and maximize technical exports
- We, and hopefully all others, shall minimize contaminant emissions
- Refer our main presentation by Chris Wedig, Senior Technology Specialist for Shaw