A Refined Approach to Coal

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2007


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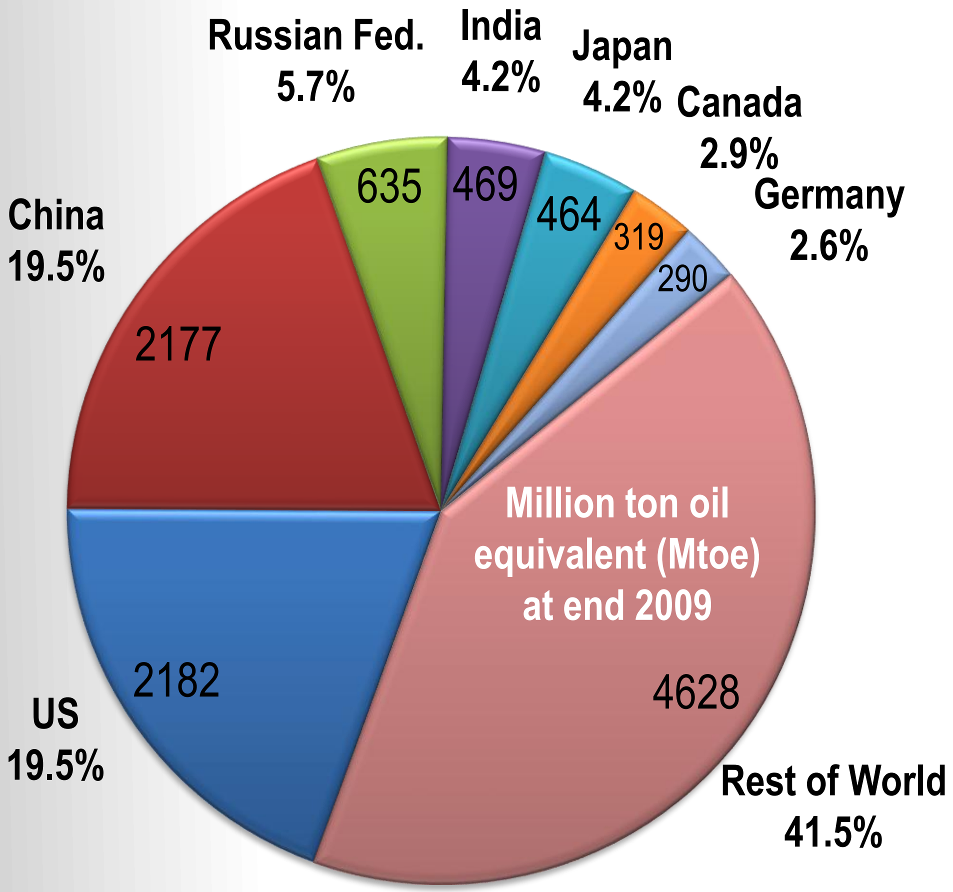
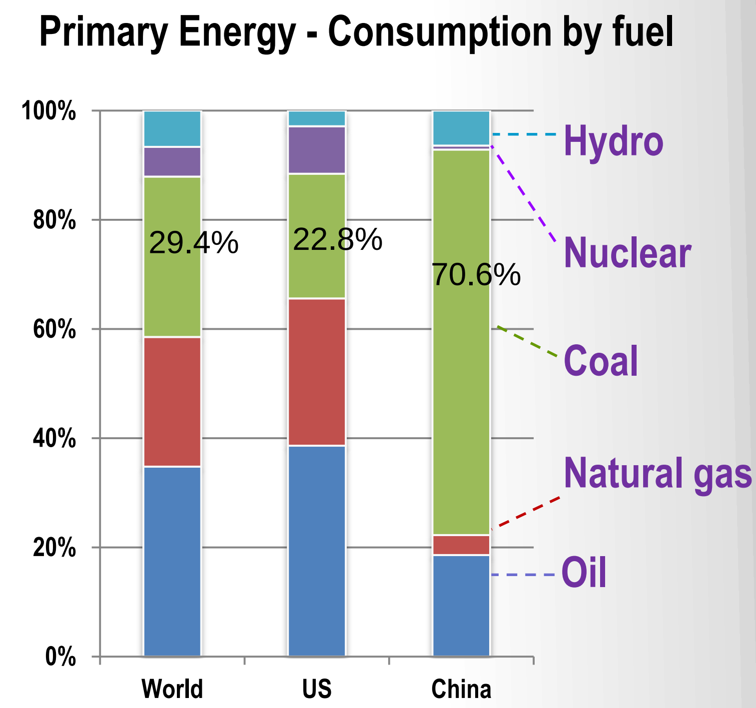
2030


XINHUANET

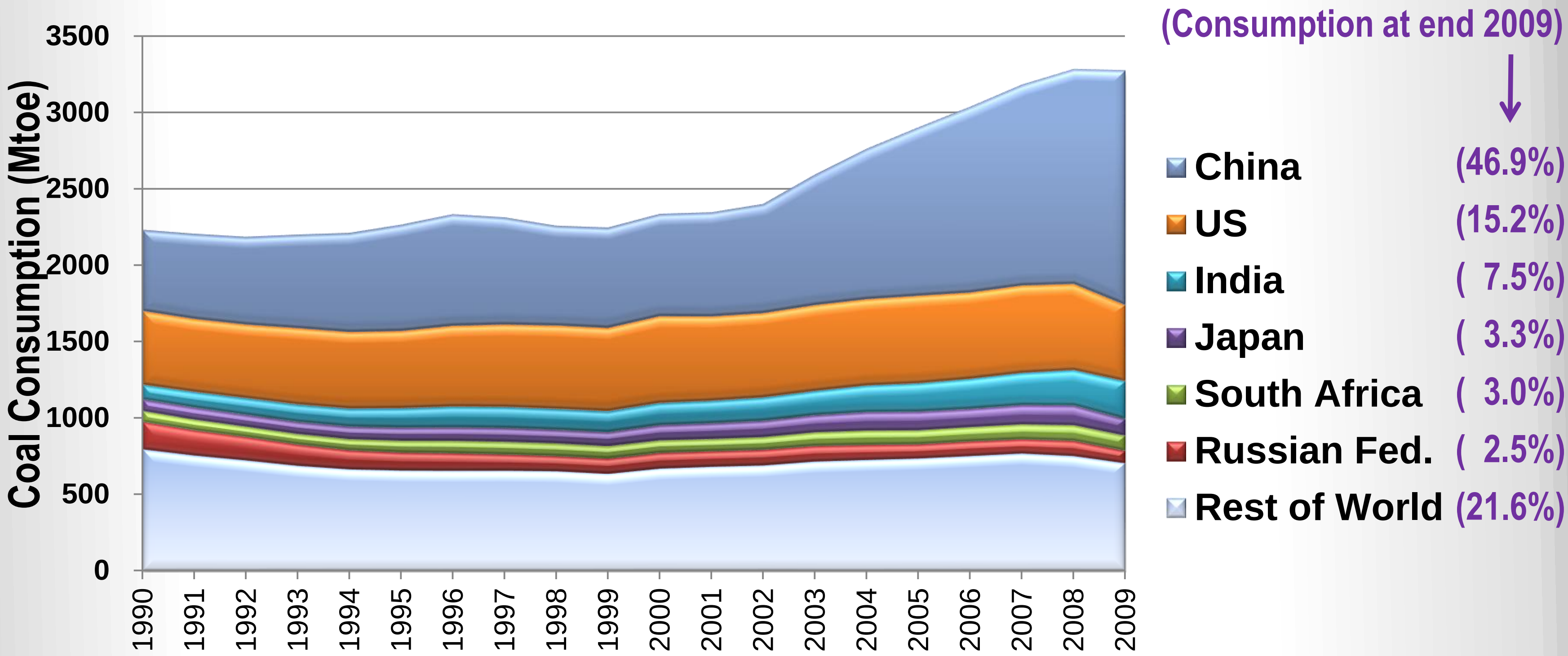
World Energy Consumption (June, 2010)





Data source: BP Statistical Review of World Energy, 2010

World Coal Consumption (1990-2009)



Data source: BP Statistical Review of World Energy, 2010

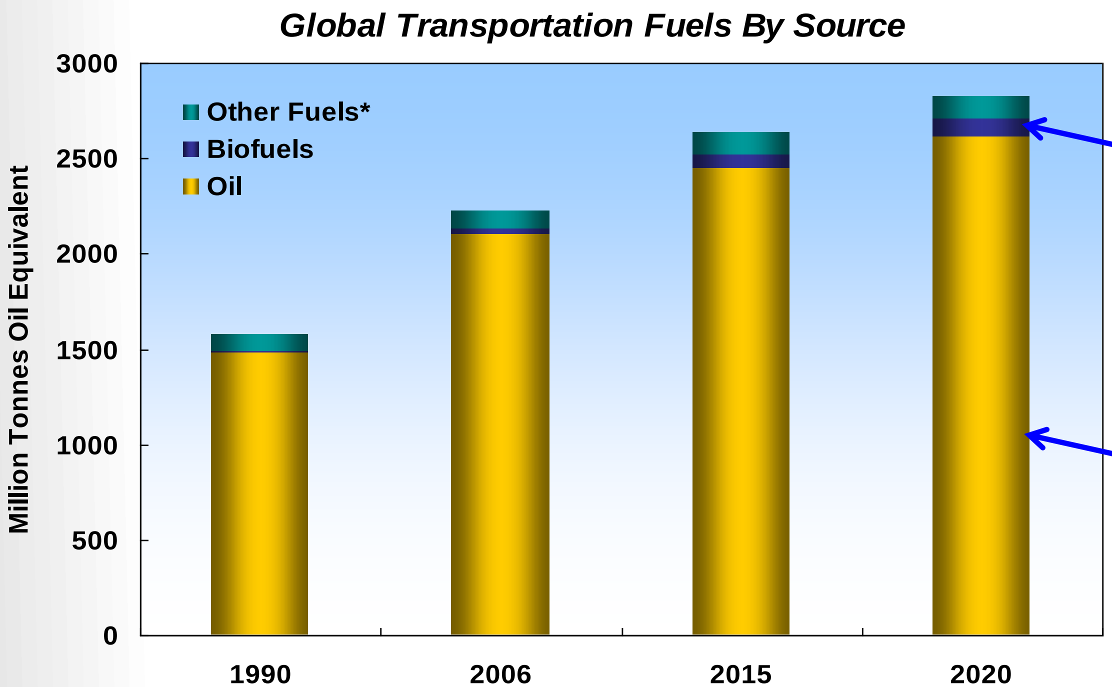
Top 5 CO_2 Emitters: IEA Ref. Case

	2005		2015		2030	
	Gt	*rank*	*Gt*	*rank*	*Gt*	*rank*
US	5.8	1	6.4	2	6.9	2
China	5.1	2	8.6	1	11.4	1
Russia	1.5	3	1.8	4	2.0	4
Japan	1.2	4	1.3	5	1.2	5
India	1.1	5	1.8	3	3.3	3
Sub-Total	**14.7**		**19.9**		**24.8**	

Everybody has a problem……who owns it?

SOx, NOx, Hg and particulates are more urgent

Transport Sector Poses Major Challenge for Renewable Fuels

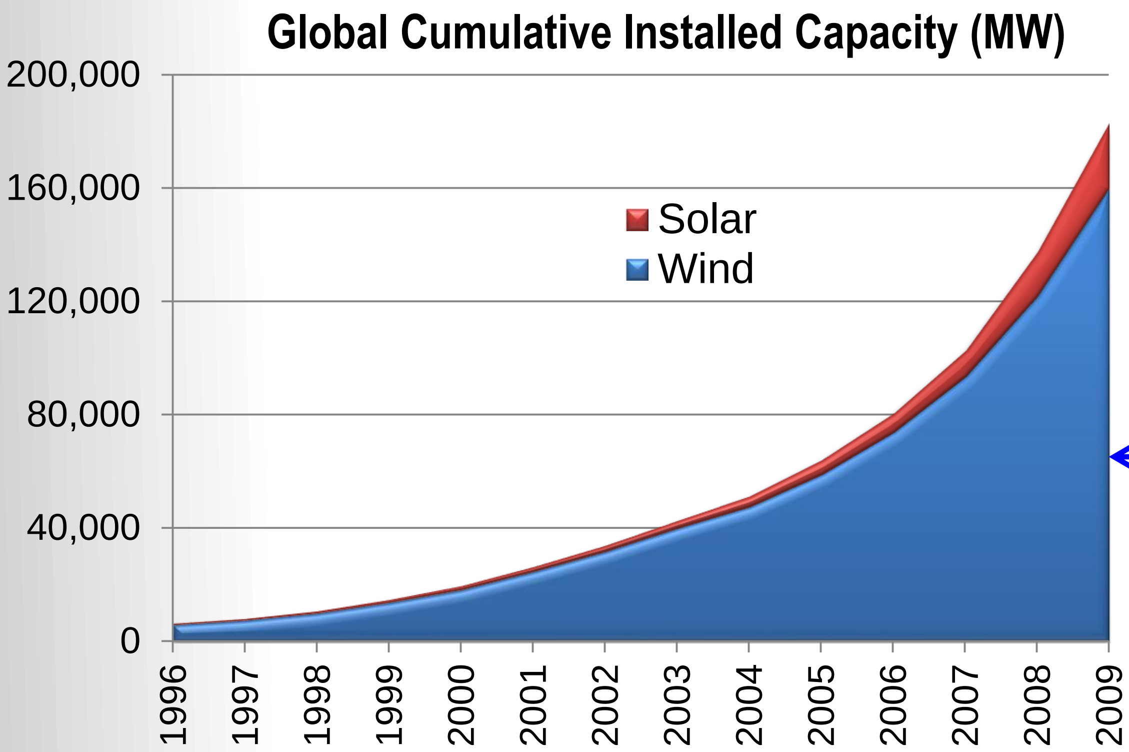


Source: IEA WEO 2008 * CNG, CTL, GTL

Biofuels: expected to grow at 13% annually to > 2.2 MBPD

Crude Oil: continues to be dominant source

Renewable Energy: Solar and Wind



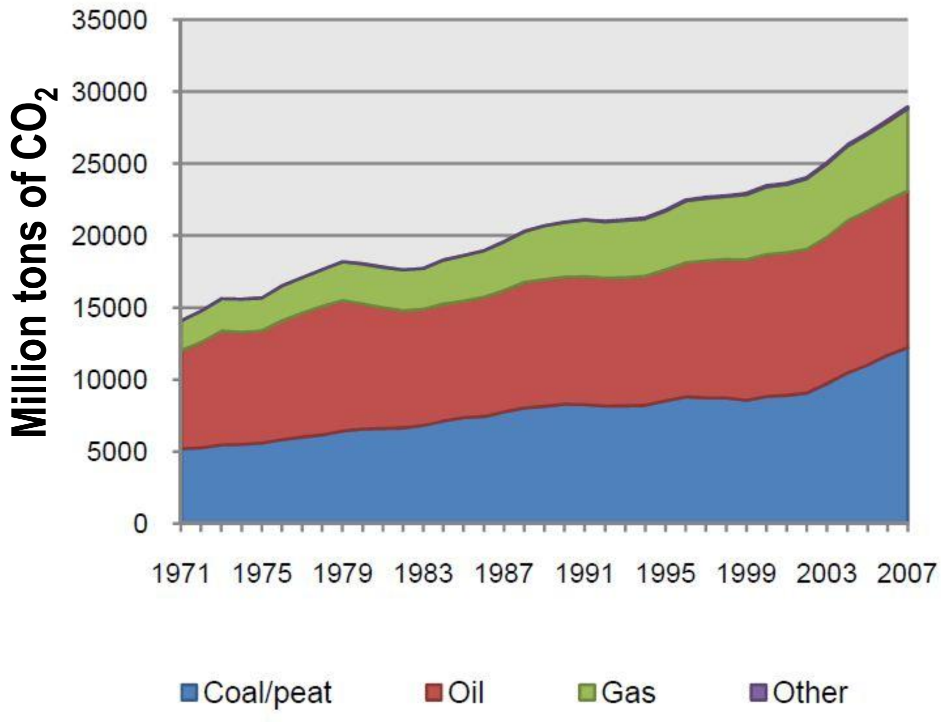
Net capacity grows at 29% annually since 1996

Annual Power Generation:
~ 23 Mtoe (1500hs/year)
~ 0.2% of global energy consumption in 2009

Data source: IEA PVPS, EPIA, EurObserv'ER and SolarBuzz; BTM Consult ApS

Despite Rapid Growth Impact on World Scale is Negligible

CO_2 Emissions by Fuel (1971-2007)

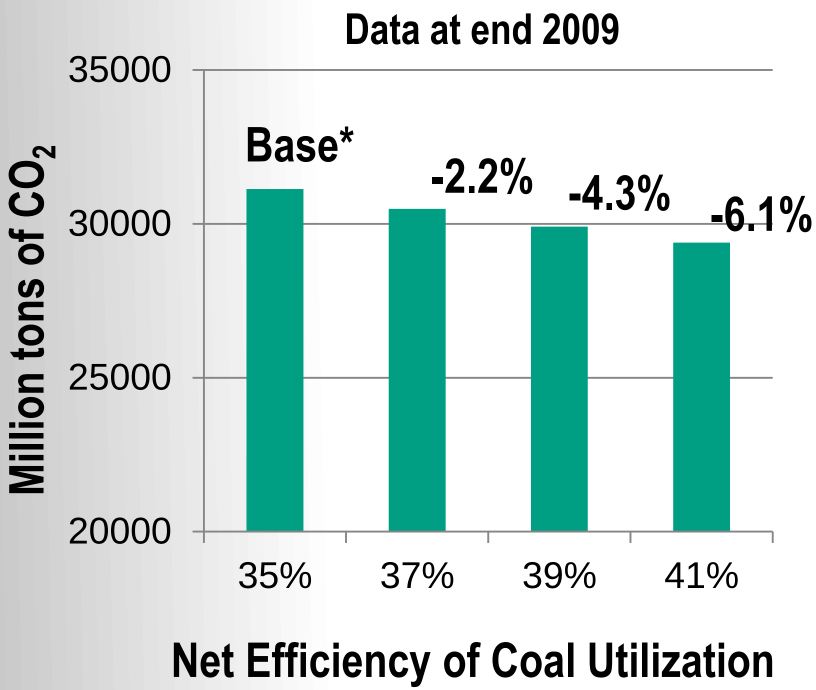


In 2007 Coal accounted for 42% of global CO_2 emissions *and* 26% of global energy consumption

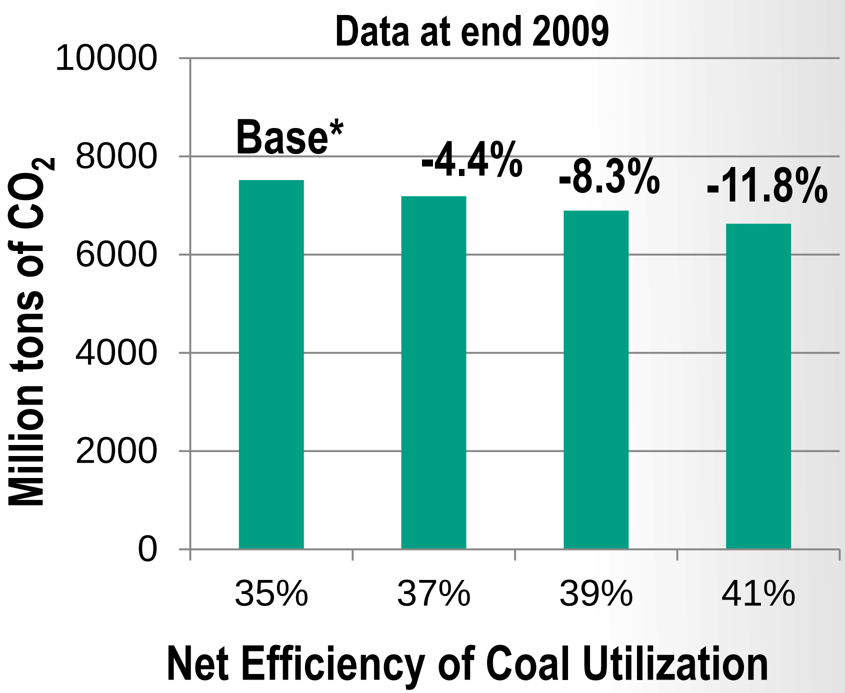
Source: IEA CO_2 Emissions from Fuel Combustion Highlights (2009 Edition)

Coal; CO_2 Emissions

Global



China



Increasing efficiency of coal utilization –a rational and effective approach to reduce CO_2 emissions

* data from BP Statistical Review of World Energy, 2010, the net efficiency estimated as 35%

CO_2 Emission Reduction

CO_2 Emission Reduction (Million tons)	5% Efficiency Improvement of Coal Utilization [a)]	Solar & Wind Displacing Coal (or Oil, Natural Gas) [b)]
Global	1623	91 (77, 54)
US	246	18 (15, 11)
China	761	13 (11, 8)

a) The calculations are based on 2009 data, the current efficiency estimated as 35%;
b) CO_2 emission factors are 3.96, 3.07 and 2.35 ton-CO_2/toe for Coal, Oil and Natural Gas, respectively, from BP Statistical Review of World Energy, 2010.

- **Increasing efficiency of coal utilization -- a very effective way to reduce CO_2 emissions.**
- **Co-processing & utilization of biomass with coal s further reduces CO2.**

*

Challenges for China

Total Primary Energy Consumption by 1000 $ GDP

TOE/1000$ GDP	2005	2006	2007	2008	2009
Japan	0.114	0.119	0.118	0.104	0.092
US	0.189	0.177	0.172	0.163	0.153
China	0.702	0.648	0.552	0.464	0.443

China: 37% improvement in last 5 years,

Data source: GDP data from World Bank; TPES data from BP Statistical Review of World Energy, 2010

National Institute of Clean & Low-Carbon Energy (NICE)

To meet growing demand on energy, and yet reduce the emissions, NICE was established in Dec., 2009.

NICE is a national research institute focused on energy which is funded by the Shenhua Group, an integrated energy conglomerate.

Corporate Profile of Shenhua Group

- **One of the SOEs, established in 1995**
- **The largest coal company in China and the largest coal supplier in the world**

- An integrated energy conglomerate with its businesses extending from coal to power, railway, port and CTL & coal chemical, featuring its cross-regional, multi-industrial and diversified operations
- No 6 and No 3 respectively in terms of its coal-fired installed capacity and wind power installed capacity
- 29 subsidiaries (Branches), 159,000 employees and RMB 411.1 billion total assets

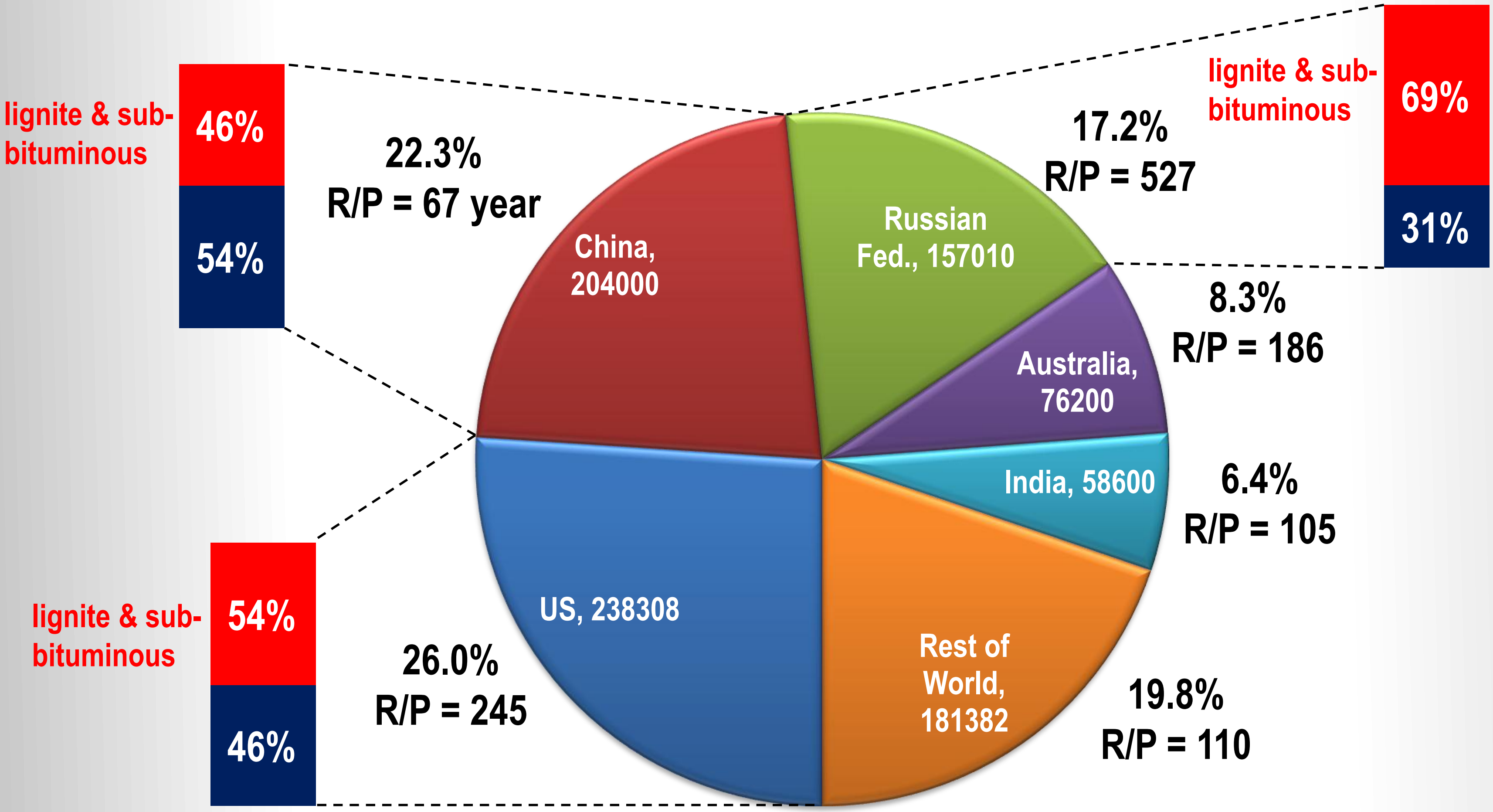



NICE Mission, Areas of Focus

Aims at the cutting-edge sustainable and affordable technology with no adverse impact on climate change and environment and focuses on ......

- Novel Routes for Conversion and Upgrading of Coal & Biomass
- Novel Materials and Systems for Clean and Low Carbon Energy Applications
- Emission Reduction of Coal Power Plants & IGCC
- CCS and CO_2 Utilization including Enhanced Oil Recovery (EOR)
- Renewable Energy and Chemicals
- Modern Coal Power Plants / Energy Storage
- Coal to Natural Gas
- Syngas to Fuels and Chemicals

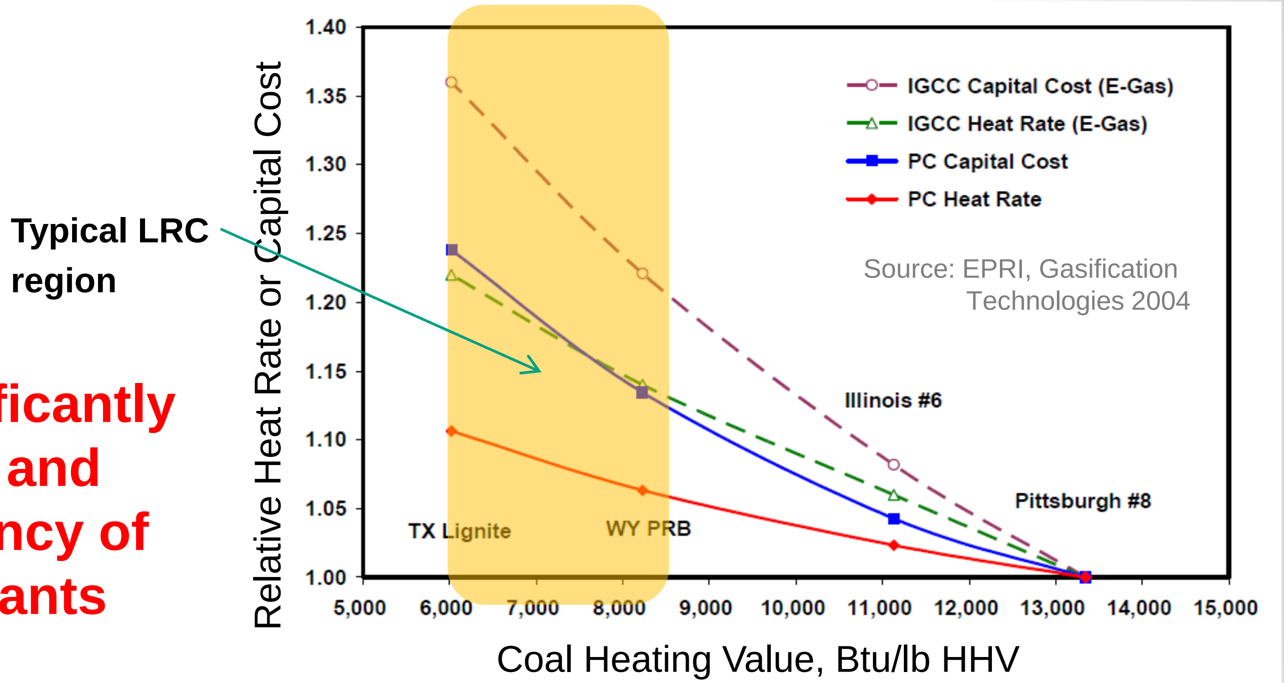
World Coal Reserves: Million tons at end 2009



Data source: BP Statistical Review of World Energy, 2010; Ministry of Land and Resources of PR China

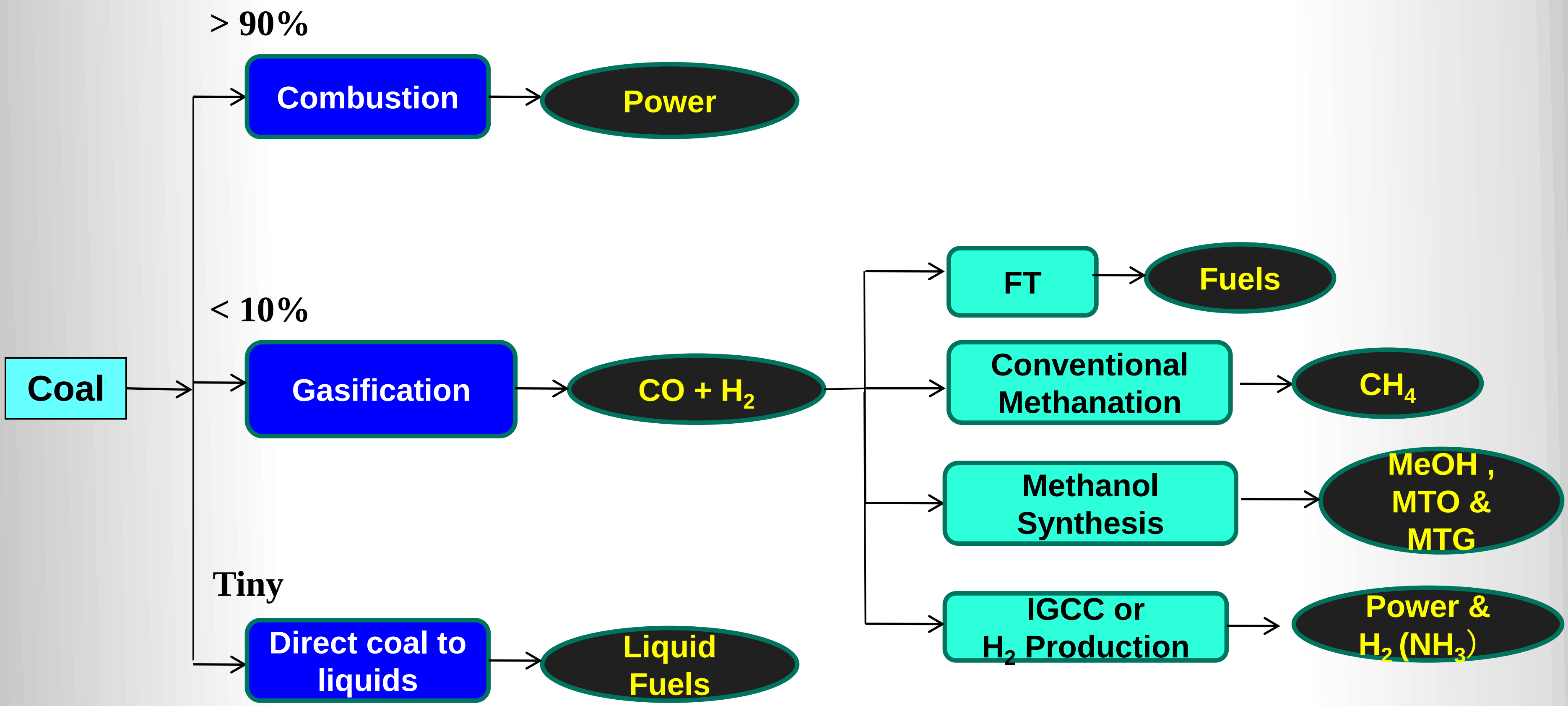
Low Rank Coal (LRC) Challenges

- **Low heating value, high moisture & volatiles**
  - Low price, high transportation costs
  - Higher plant capital, lower efficiency, carbon footprint
  - Limitation as feedstock: poor slurriability
- **Highly active: handling issues, spontaneous ignition hazards**

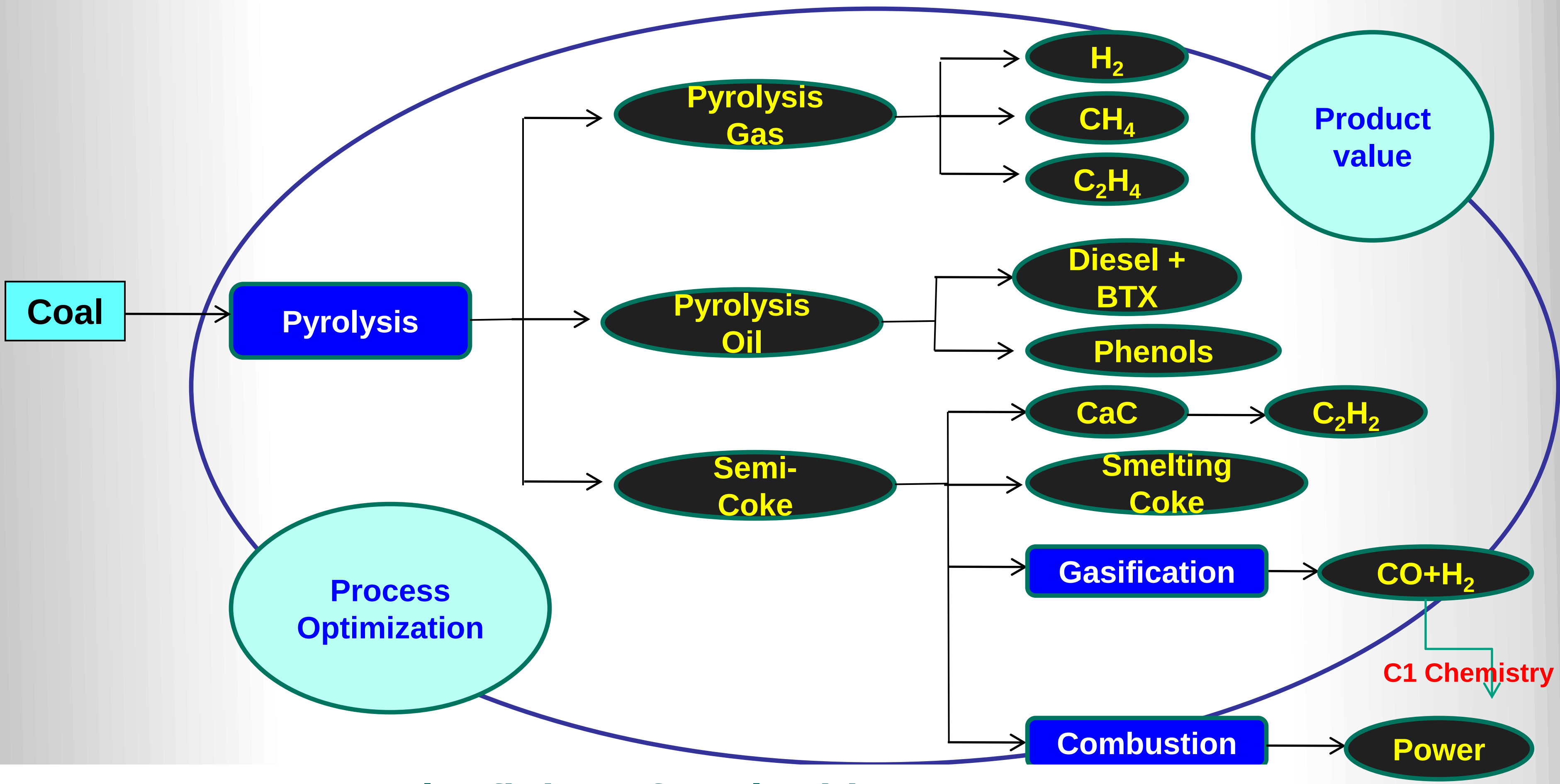


❖ **Use of LRC significantly increases capital and decreases efficiency of existing power plants**

Current Paths of Coal Utilization

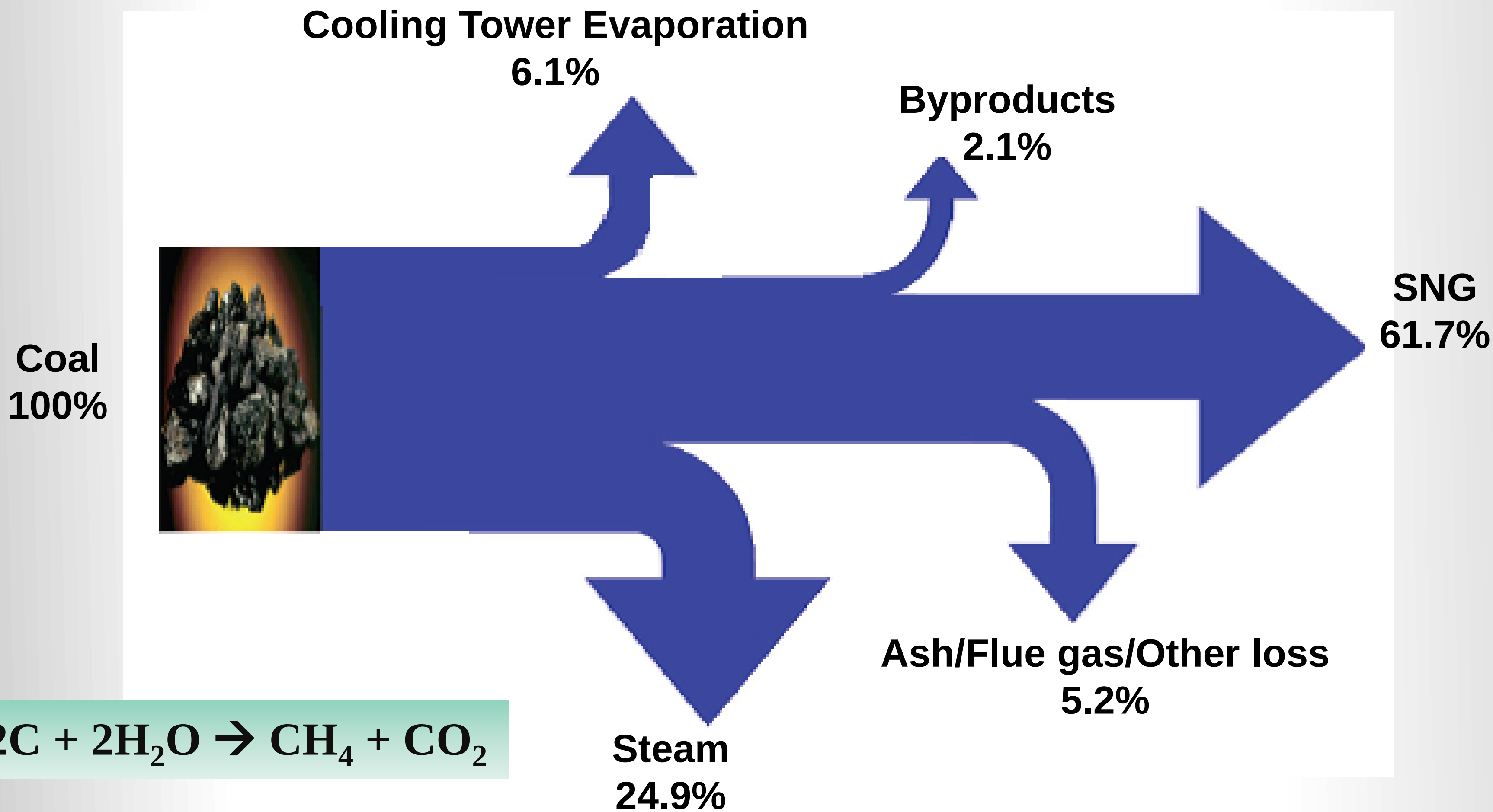


New Look at Old Coal Utilization – Coal Refining



NICE Strategy: Novel refining of coal & biomass
Modern coal power generation technologies

Coal to Natural Gas Model – Energy Flow



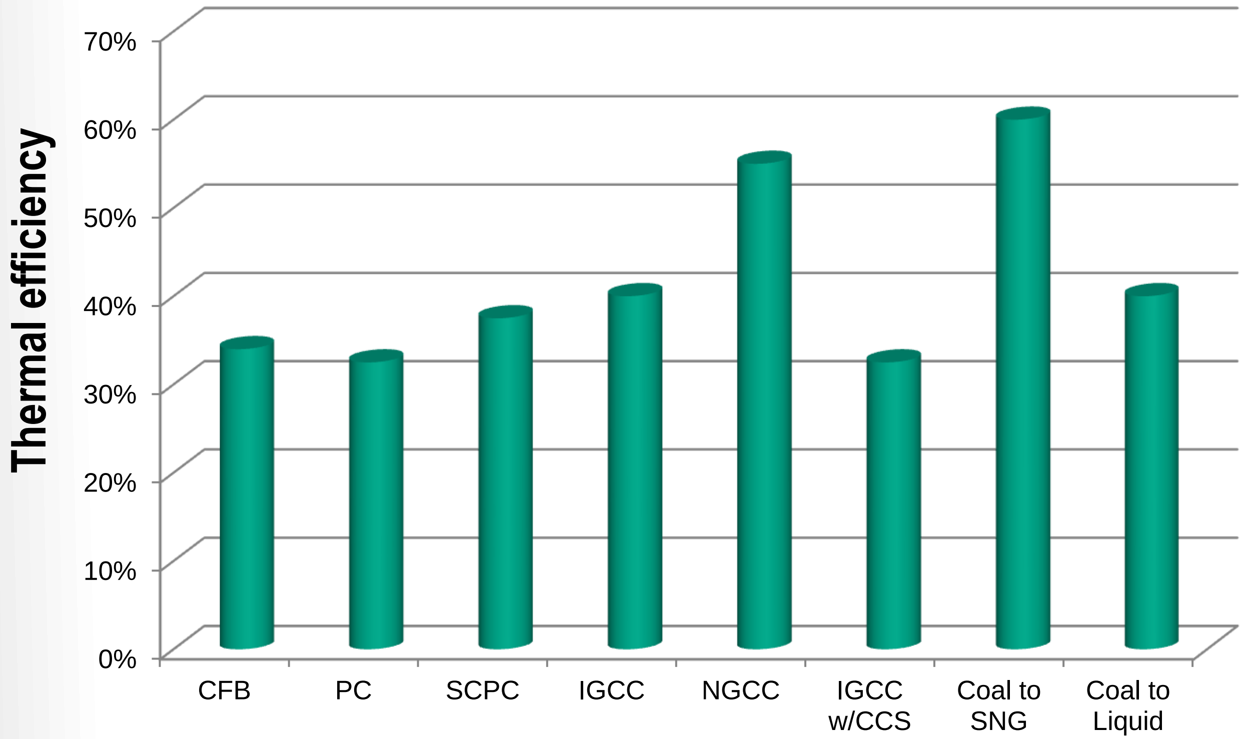
$$2C + 2H_2O \rightarrow CH_4 + CO_2$$

Coal & Biomass to Pyrolysis Liquids and Natural Gas

- Coal to Natural Gas efficiency: 60~65%
- Single step, CAPEX much lower than Coal and Biomass to Liquids via F-T
- Infrastructure ready
- Pipe line transport Natural Gas & Oil: lower cost than transporting coal
- Ash and water stay in coal mine
- Inherent CO_2 separation. Both CO_2 and ash may be captured in the mine
- Natural Gas – Gasoline hybrid vehicles ?
- Natural Gas emits less CO_2 (~30%) per mile than gasoline or diesel (CH_4 vs. CH_2)
- Modern digester technology to convert biomass to Natural Gas ?

Natural Gas: an affordable, lower carbon, flexible alternative fuel

Thermal Efficiency from Different Coal Chains



CO_2: Regulations & Policy

- Enhance energy conservation, efficiency
  - Industry, buildings, transport
  - Mandatory fuel efficiency standards
- Enhance energy security, particularly fossil hydrocarbons
- Emissions reduction
  - CO_2 emissions - technology break through
  - More stringent vehicle emissions standards
  - SO_x emissions: Possible bunker fuel sulfur reduction
- Environmental legislation
  - CO_2, Climate Active Gas Emissions
  - Let the markets work, learn from Natural Gas experience

CO_2 emissions; US policy……Nuclear energy ?

Summary

- Coal is and will be one of the most important energy resources in the world.
- Renewable energy will show most growth, but remain small percentage of total supply.
- More attention should be paid on low rank coal utilization.
- Fossil Energy research should focus on SOx, NOx, Hg, particulates reduction and more efficient conversion routes for coal and cost effective conversion of CO_2.
- Coal refining is an attractive new way to improve utilization of coal.
- Storing CO_2 with EOR is one of the most attractive approaches for CCUS.
- Coal and biomass to produce NG and pyrolisis liquids -- a higher efficiency solution.
- Solutions best left for the Market to choose.

Acknowledgments

➢Dr. Ke Liu, Vice President & CTO of NICE

➢Dr. Changning Wu, Engineer

➢ Dr. Xiaofen Guo, Senior engineer

Back up

Estimated Incremental Costs for a Pulverized Coal Unit

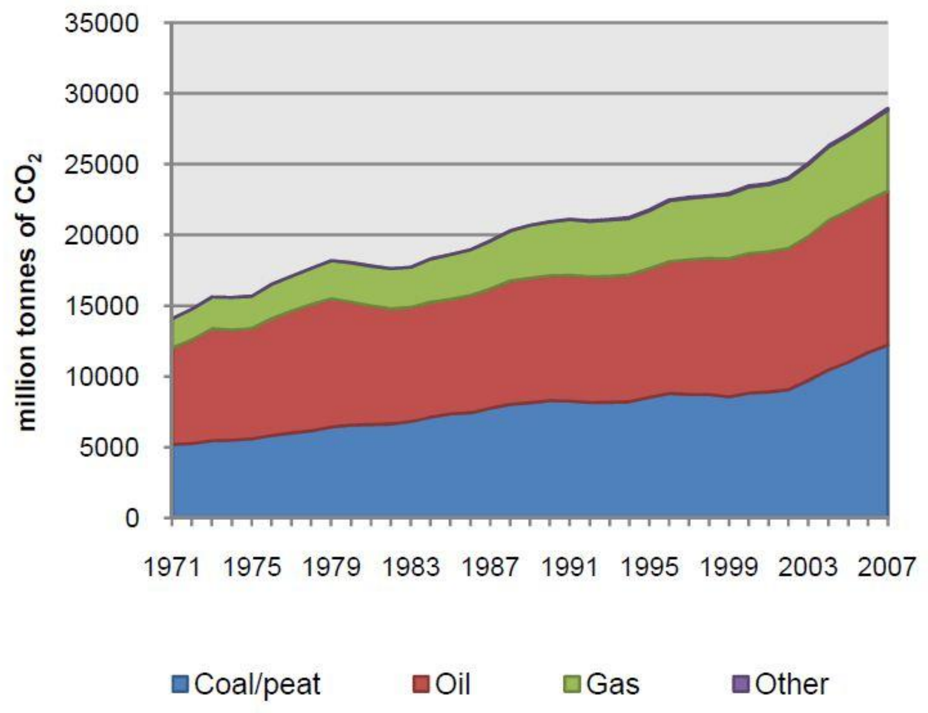
to meet today's best demonstrated criteria emissions control performance vs. no control

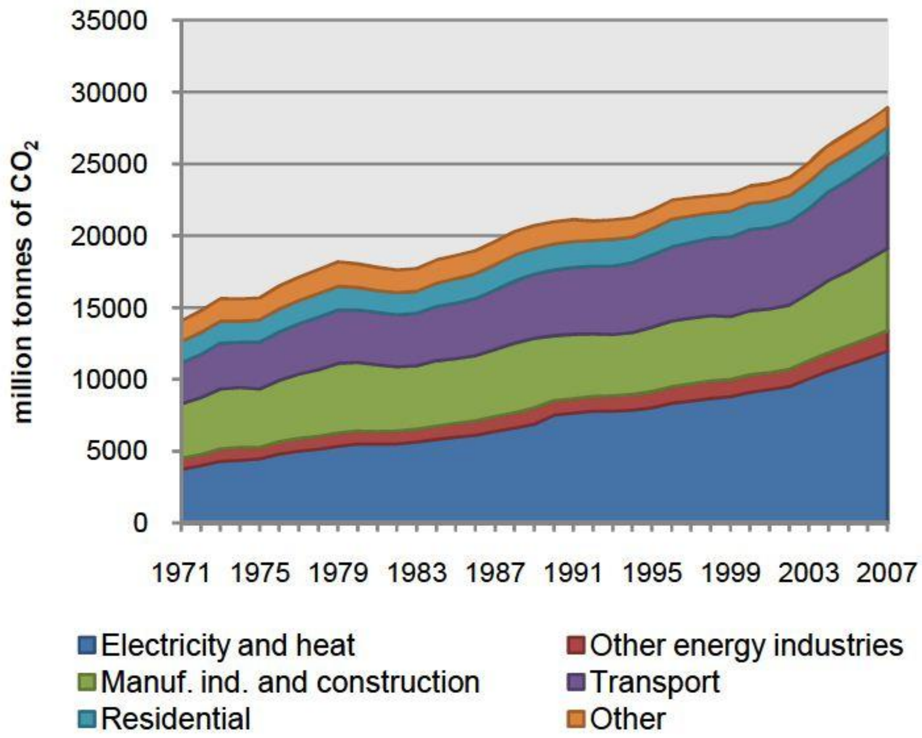
	Capital Cost ($/kW$_e$)	Operation & Maintenance Cost (₵/kW$_e$h)	Cost of Electricity [a)] (₵/kW$_e$h)
Particulate Control [b)]	40	0.18	0.26
NO_x	25 (50-90)	0.10 (0.05-0.15)	0.15 (0.15-0.33)
SO_2	150 (100-200)	0.22 (0.20-0.25)	0.52 (0.40-0.65)
Incremental control cost	215	0.50	0.93 [c)]

a). Incremental COE impact, bituminous coal
b). Particulate control by ESP or fabric filter included in the base unit costs
c). When added to the "no-control" COE for SC PC, the total COE is 4.78₵/kW$_e$h

Data source: MIT Study on the Future of Coal, 2007

CO_2 emissions by fuel & sector





Data source: IEA CO_2 Emissions from Fuel Combustion Highlights (2009 Edition)

LRC Refining Opportunities

LRC
- Low Hv,~4000Kcal/Kg
- High moisture: ~30%
- Sulfur: 0.6%(DAF)
- Highly unstable

Poor quality
Low selling value
Transportation costs
Handling difficulties

LRC Refining Technology

Commercially available!

Refined coal
- Improved Hv,~6000Kcal/Kg
- Reduced moisture: ~8%
- Sulfur: 0.44%(DAF)
- Stable, similar as sub-bituminous

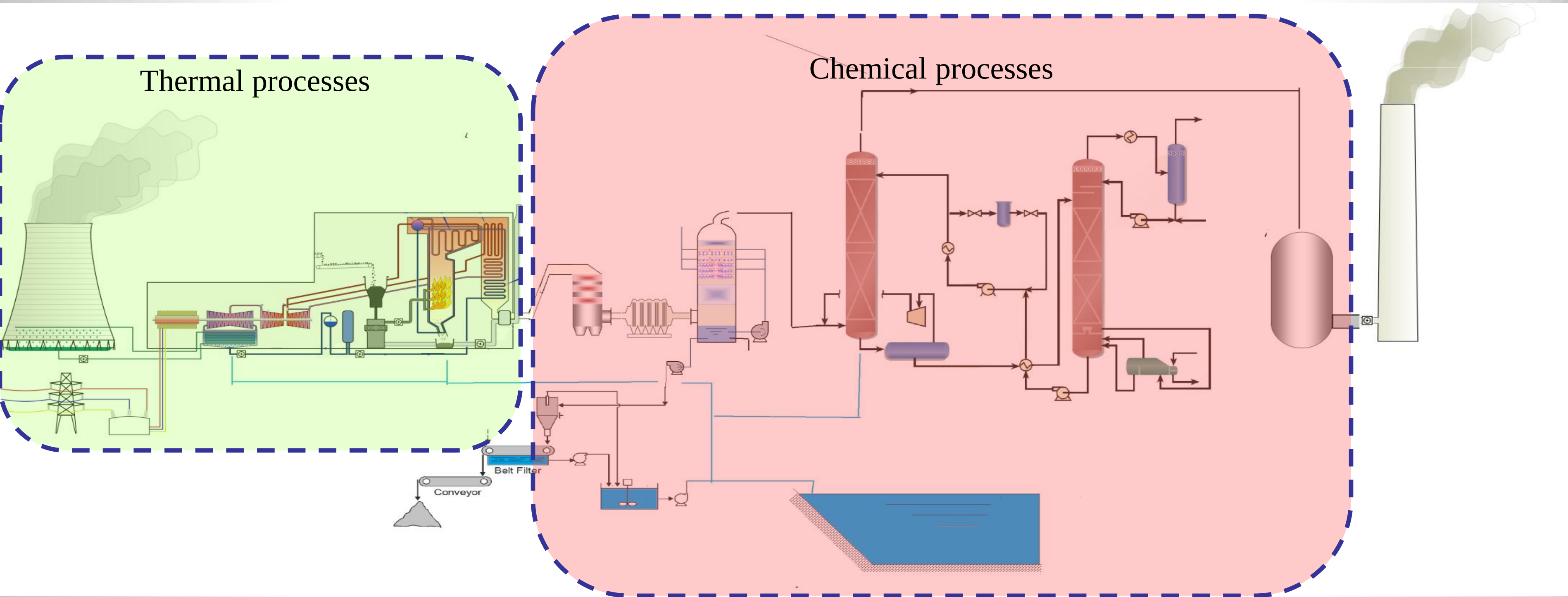
High value liquid products (Pyrolysis Oil)

Significantly Improved quality
High value-adding oil products
Suitable for Transportation
Stable and safe

Huge market potentials:
- Large LRC market: ~50% coal reserves in China, ~50% coal reserves in US
- With the high value products, market is not limited to LRC. In fact, the economics is much better for the Shenhua's oil-rich coal in Northern Shaanxi & Inner Mongolia

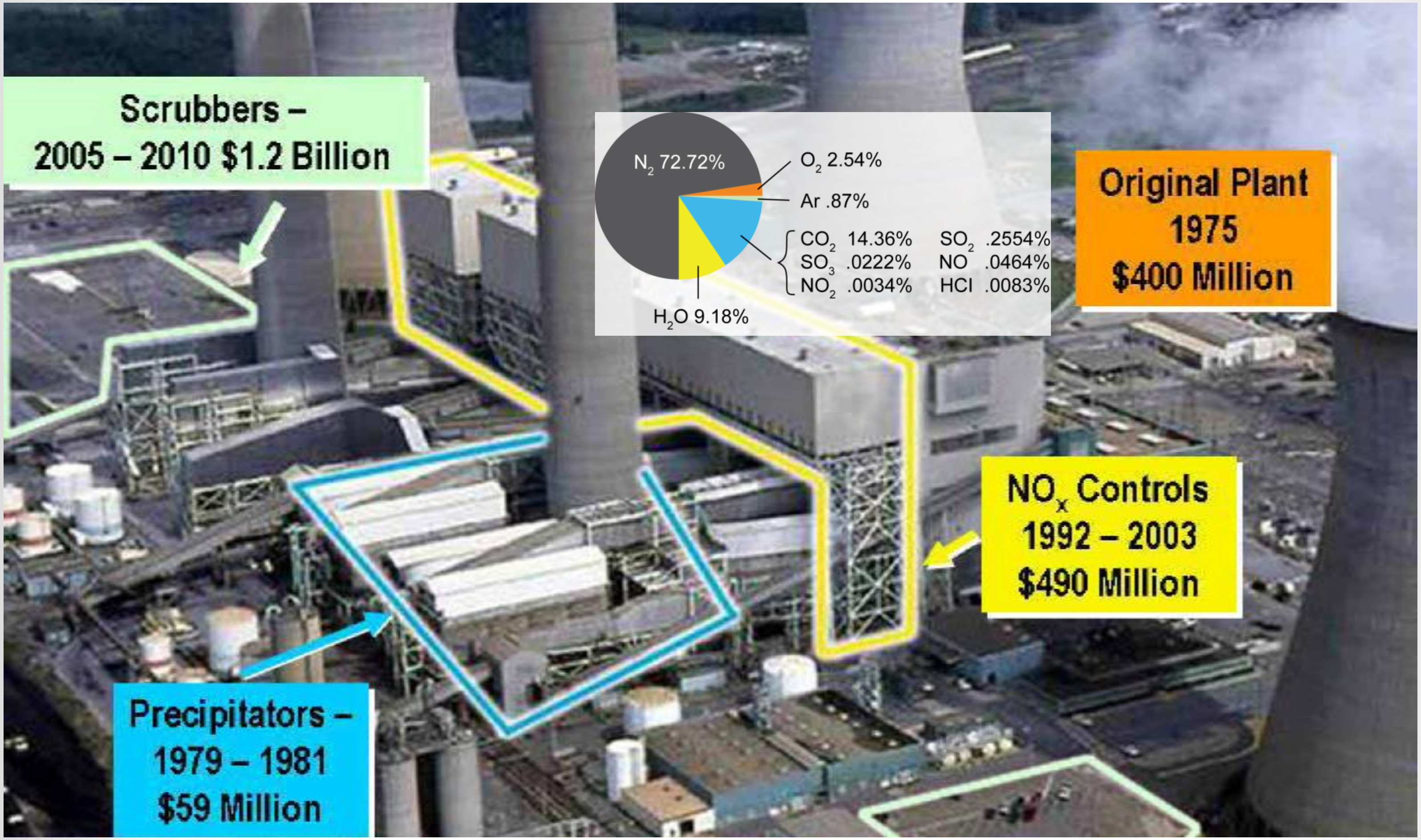
Modern Coal Power Plants Become a Chemical Plant

- Increasing importance of Chemical processes in modern coal-fired power plants
- Traditional power plant designs by thermal engineers, large room to improve/optimize
- System integration between chemical and thermal processes



Cooling tower | Transmission | Boiler System | SCR/Dust removal | FGD | Water Plant | CO2 Capture | Hg/Metal control | Stack

A Look At A Typical Coal Plant Reflects An Historical View Of The Problem- Slide From PNNL



Slides from PNNL
Source: Southern Company

Storing CO_2 with EOR

- **Oil fields get old, requires injection of water & polymers for EOR, CO_2 is better than water for EOR**

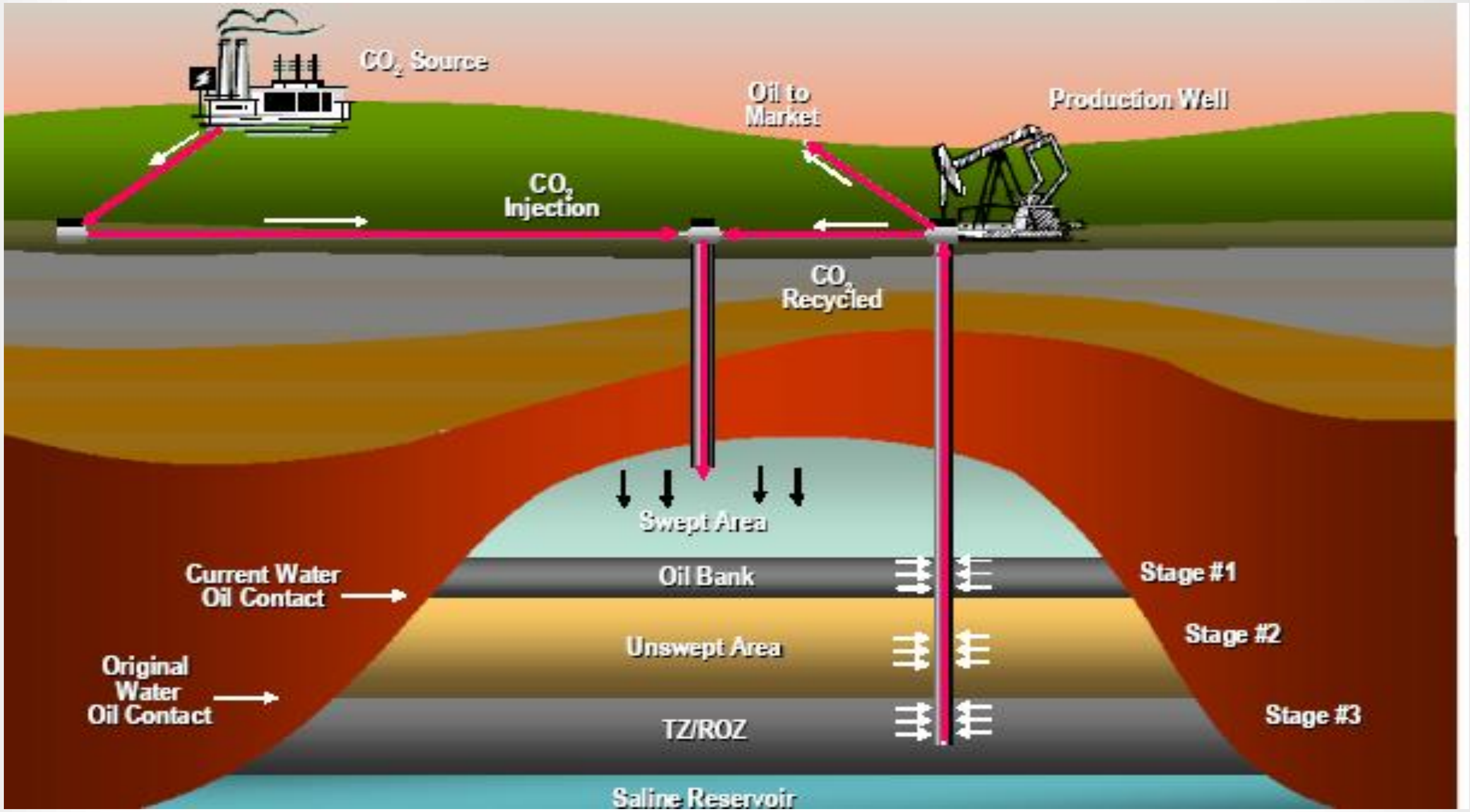


Illustration of "Next Generation" Integration of CO_2 Storage and EOR