Gasification and CO2 in the context of power generation

Biswajit Kar
Head, Clean Coal Energy, India
Shell India Pvt Ltd

International Workshop on Carbon Capture and Storage in the Power Sector: R&D Priorities for India
22-23 JANUARY 2008, ASHOK HOTEL, NEW DELHI

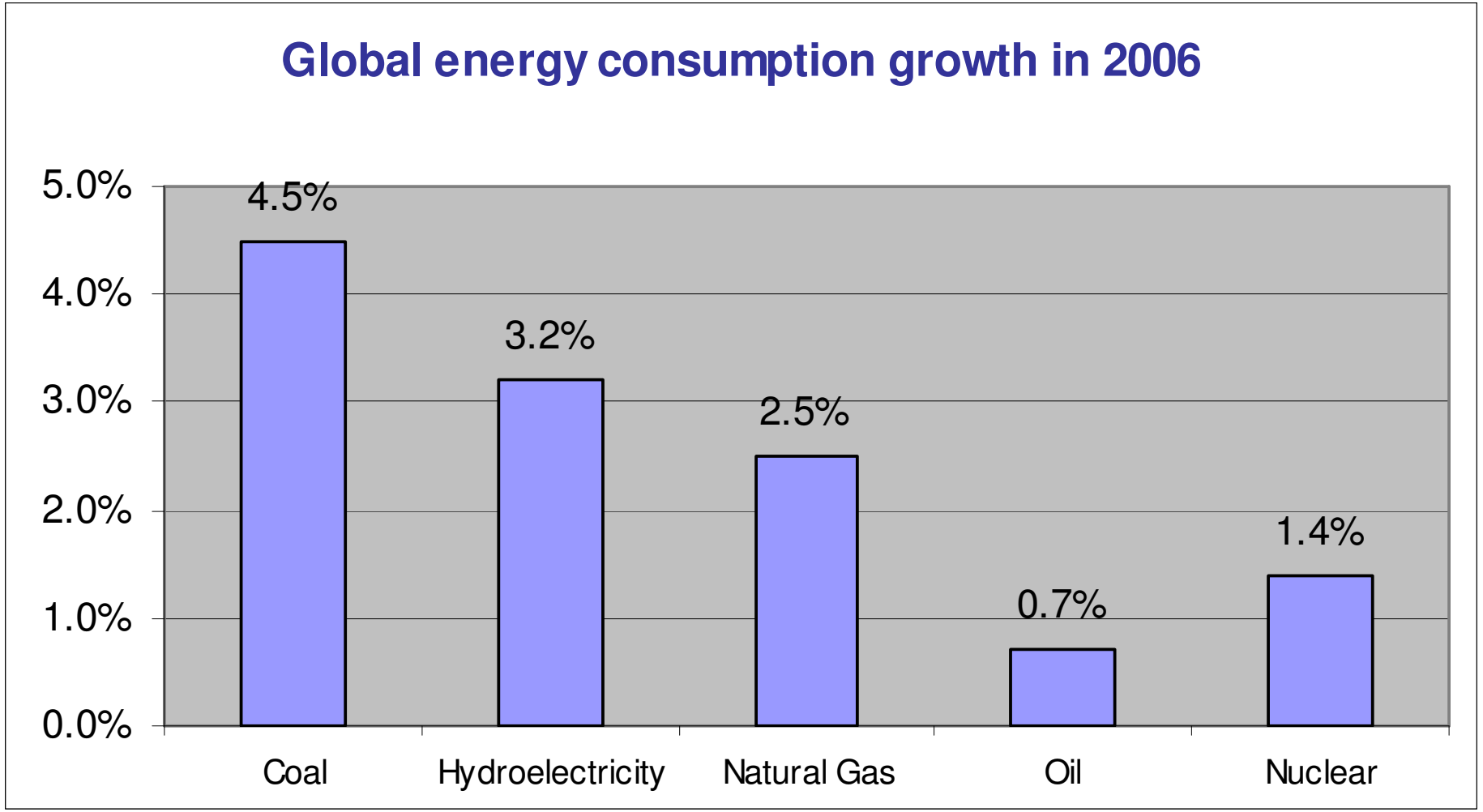
Disclaimer Statement

This presentation contains forward-looking statements concerning the financial condition, results of operations and businesses of Royal Dutch Shell. All statements other than statements of historical fact are, or may be deemed to be, forward-looking statements. Forward-looking statements are statements of future expectations that are based on management's current expectations and assumptions and involve known and unknown risks and uncertainties that could cause actual results, performance or events to differ materially from those expressed or implied in these statements. Forward-looking statements include, among other things, statements concerning the potential exposure of Royal Dutch Shell to market risks and statements expressing management's expectations, beliefs, estimates, forecasts, projections and assumptions. These forward-looking statements are identified by their use of terms and phrases such as ''anticipate'', ''believe'', ''could'', ''estimate'', ''expect'', ''intend'', ''may'', ''plan'', ''objectives'', ''outlook'', ''probably'', ''project'', ''will'', ''seek'', ''target'', ''risks'', ''goals'', ''should'' and similar terms and phrases. There are a number of factors that could affect the future operations of Royal Dutch Shell and could cause those results to differ materially from those expressed in the forward-looking statements included in this Report, including (without limitation): (a) price fluctuations in crude oil and natural gas; (b) changes in demand for the Group's products; (c) currency fluctuations; (d) drilling and production results; (e) reserve estimates; (f) loss of market and industry competition; (g) environmental and physical risks; (h) risks associated with the identification of suitable potential acquisition properties and targets, and successful negotiation and completion of such transactions; (i) the risk of doing business in developing countries and countries subject to international sanctions; (j) legislative, fiscal and regulatory developments including potential litigation and regulatory effects arising from recategorisation of reserves; (k) economic and financial market conditions in various countries and regions; (l) political risks, project delay or advancement, approvals and cost estimates; and (m) changes in trading conditions. All forward-looking statements contained in this presentation are expressly qualified in their entirety by the cautionary statements contained or referred to in this section. Readers should not place undue reliance on forward-looking statements. Each forward-looking statement speaks only as of the date of this presentation. Neither Royal Dutch Shell nor any of its subsidiaries undertake any obligation to publicly update or revise any forward-looking statement as a result of new information, future events or other information. In light of these risks, results could differ materially from those stated, implied or inferred from the forward-looking statements contained in this presentation.

IMPORTANT NOTE: Although this slide pack may contain references to projects located in countries that are subject to comprehensive United States economic sanctions, no "US Person" has been involved in the development of any of those projects.

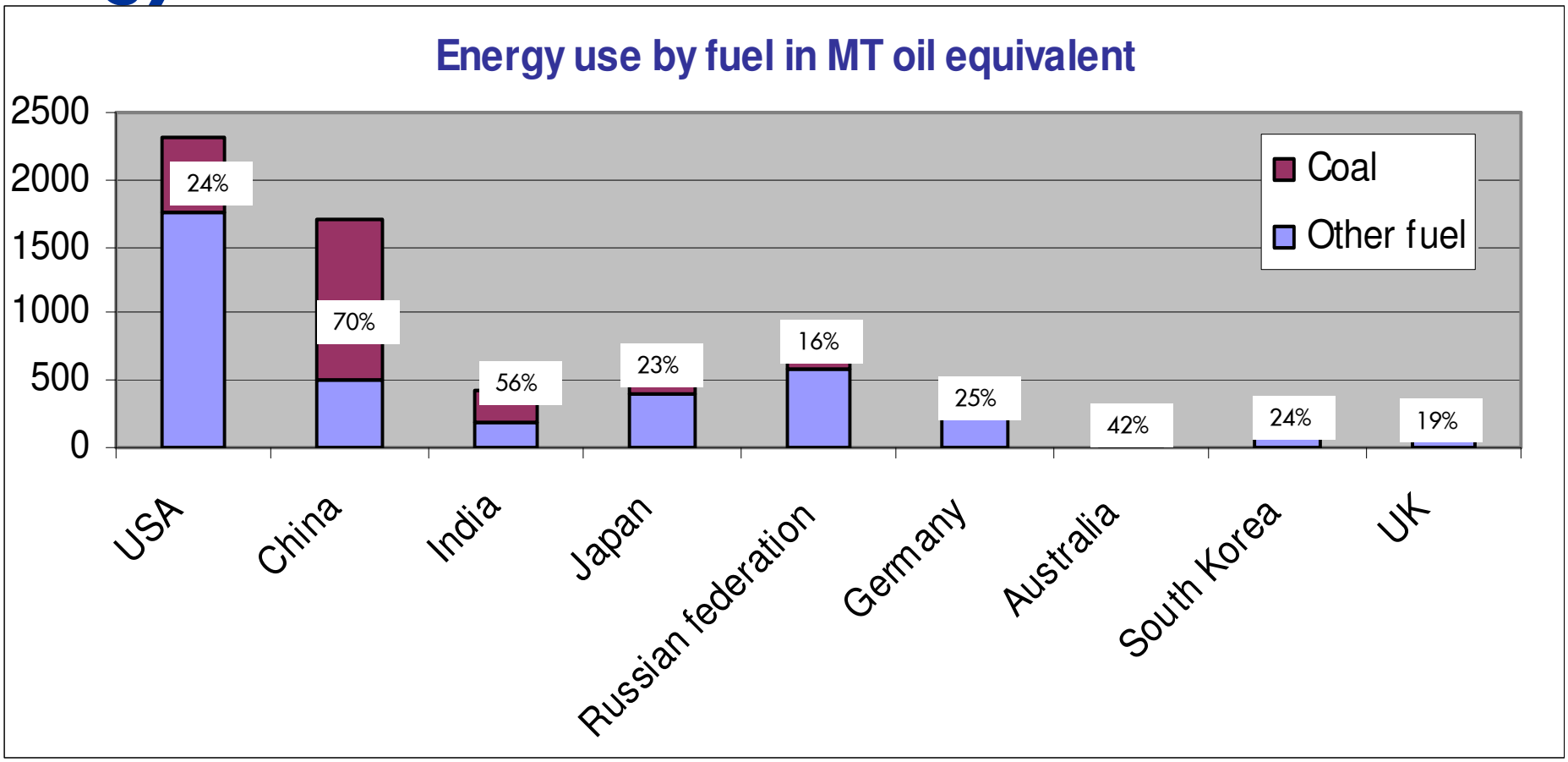
The United States Securities and Exchange Commission (SEC) permits oil and gas companies, in their filings with the SEC, to disclose only proved reserves that a company has demonstrated by actual production or conclusive formation tests to be economically and legally producible under existing economic and operating conditions. We use certain terms in this presentation, such as "resources" that the SEC's guidelines strictly prohibit us from including in filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 20-F, File No 1-32575 and disclosure in our Forms 6-K file No, 1-32575, available on the SEC website www.sec.gov. You can also obtain these forms from the SEC by calling 1-800-SEC-0330.

Coal remains the fastest growing fuel in the world



Source BP Statistical review of world energy 2007

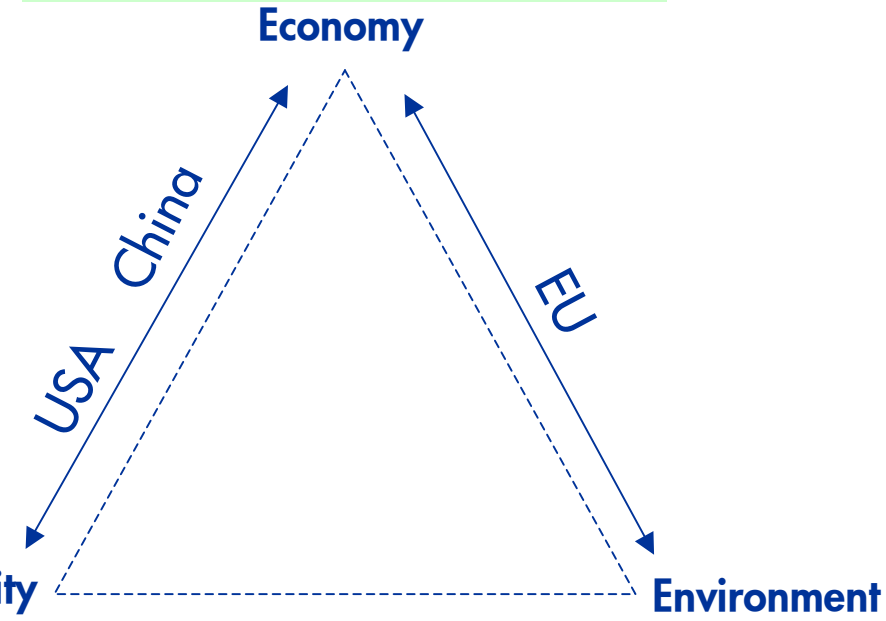
Coal is an abundant and important source of energy



Source BP Statistical review of world energy 2007

Clean Coal Energy – the drivers for a new growth business

Coal prices are relatively low and fairly stable, even as demand is growing

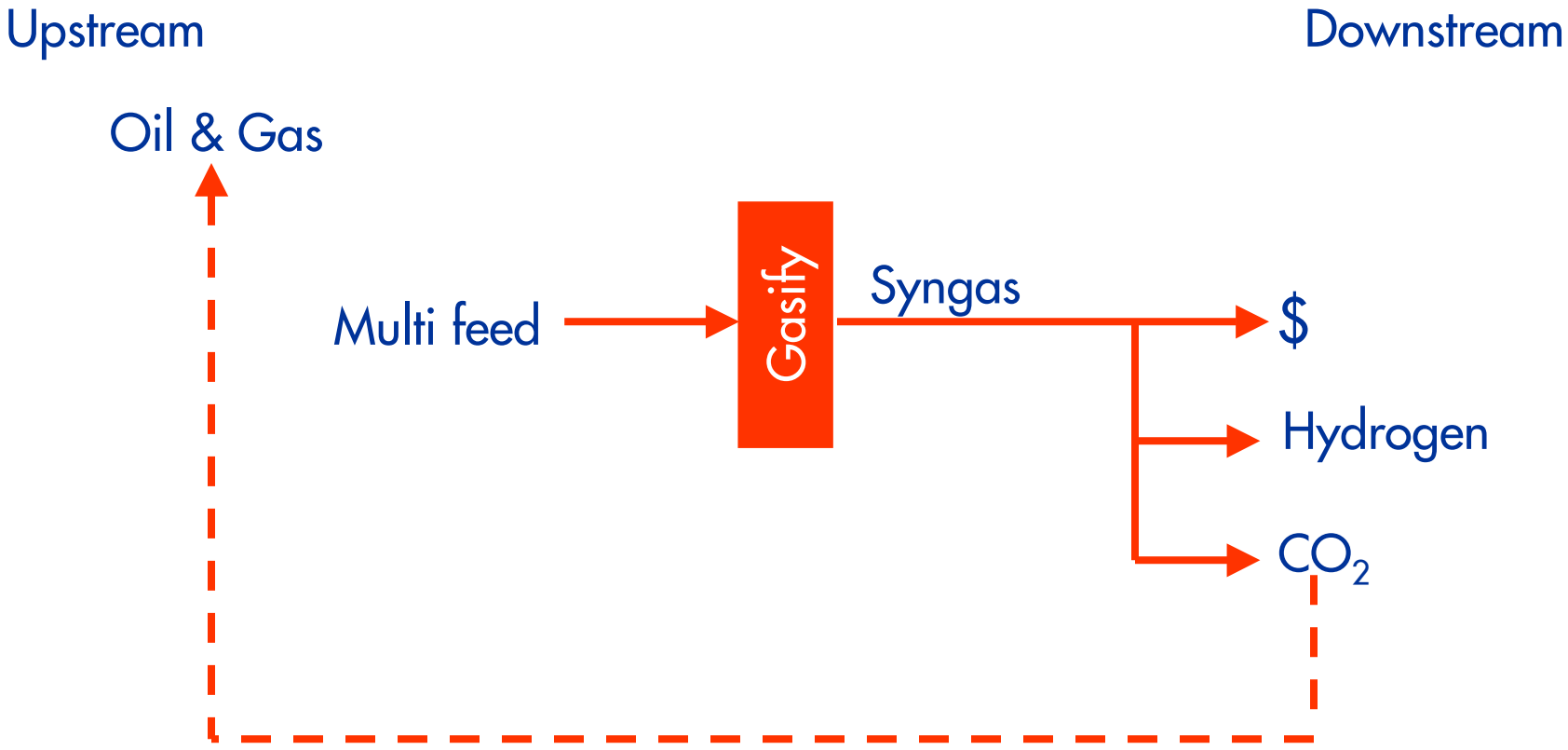


Coal is abundant and available in major industrial countries

Coal gasification provides similar environmental performance to natural gas, allows potential CO_2 capture with excellent ash treatment

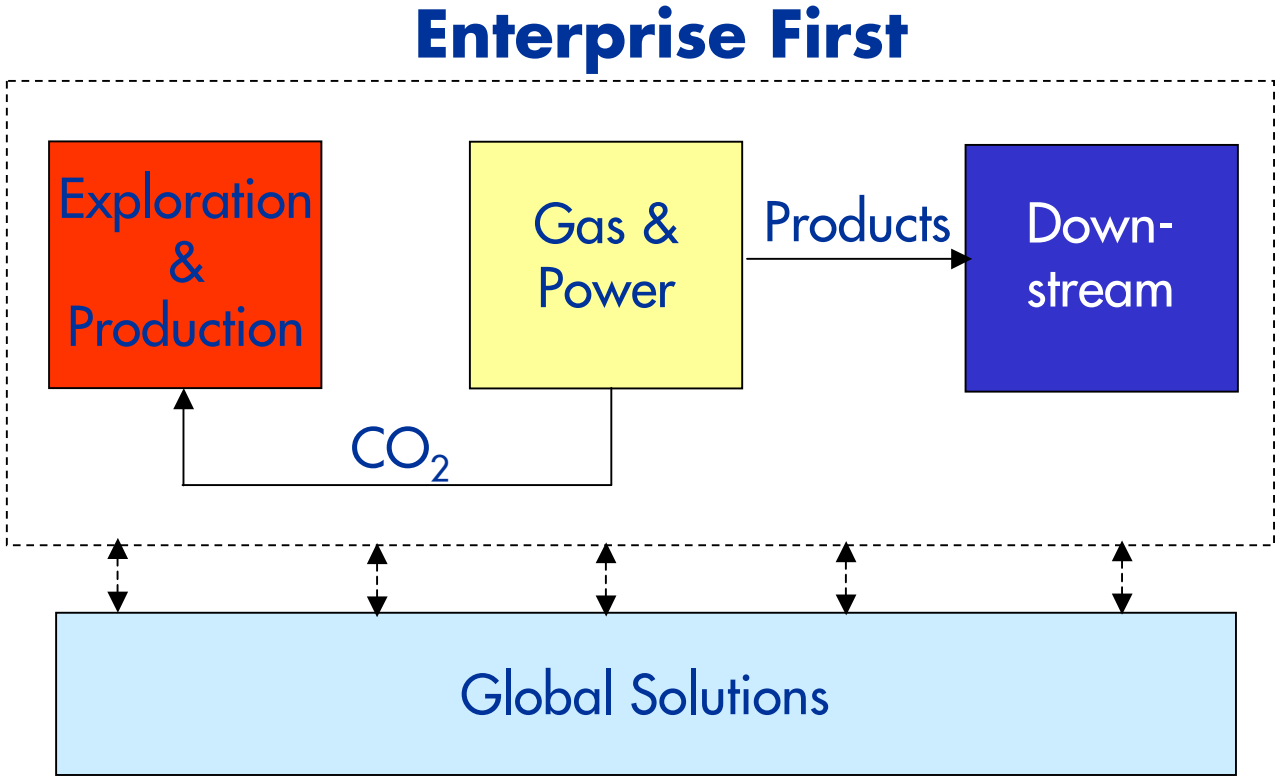
The Coal Gasification Strategy is consistent with Group strategy

More upstream, profitable downstream



Source: Shell-CCE analysis

The Clean Coal Energy Strategy requires cross business effort



Gas & Power taking an integrator role

"Clean Coal" myths

- Technology unproven
  - –All components widely proven; many successful Gasifiers in manufacturing, chemicals, H2 manufacture. Several successful IGCC applications.

- High cost
  - –Investment cost ~20% higher than conventional coal; gap could potentially close due to deployment and tightening emissions regulations

- Suitable only for bituminous coal and petroleum coke
  - –Shell's dry feed system is equally suitable for lower rank coals (sub bituminous coal and lignite)

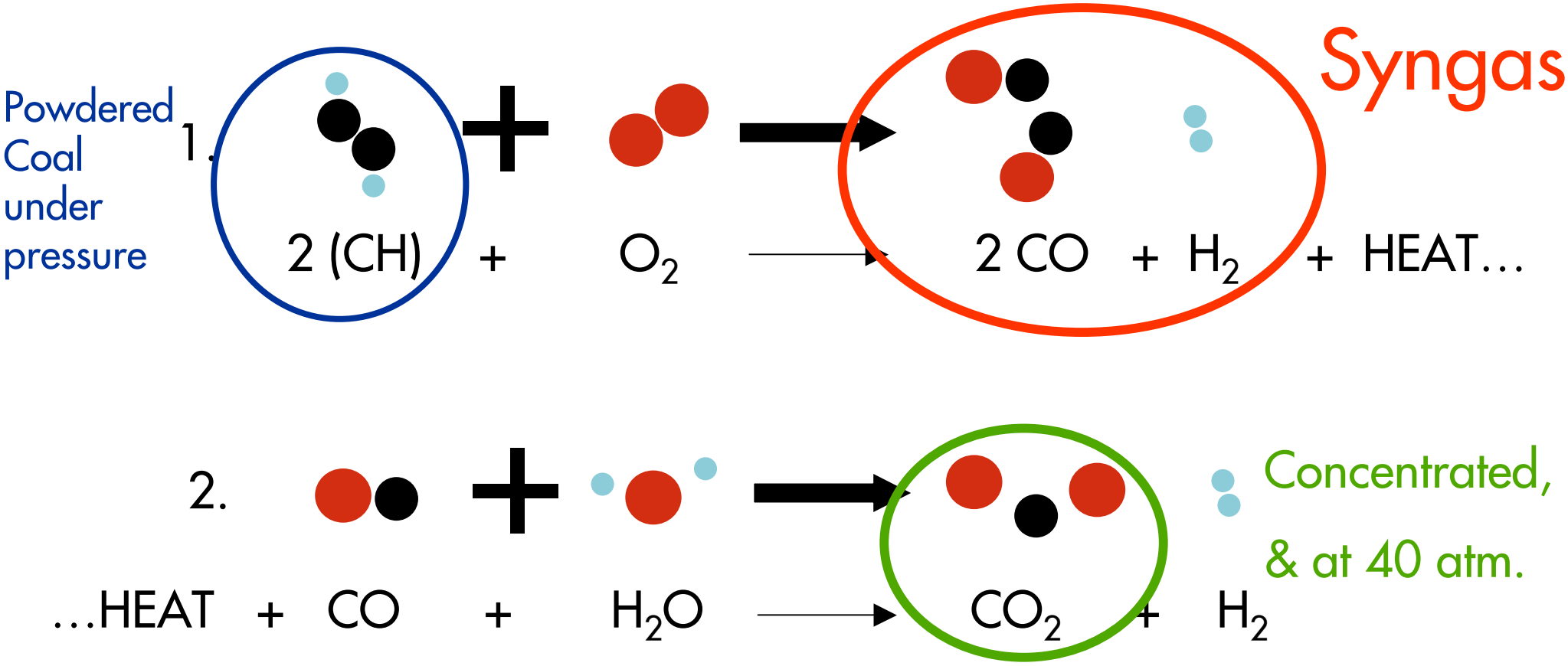
Coal Gasification and sustainable development

Gasification offers the cleanest, most efficient method available to produce synthesis gas from low or negative-value carbon-based feedstocks such as coal, petroleum coke, or materials that would otherwise be disposed as waste.

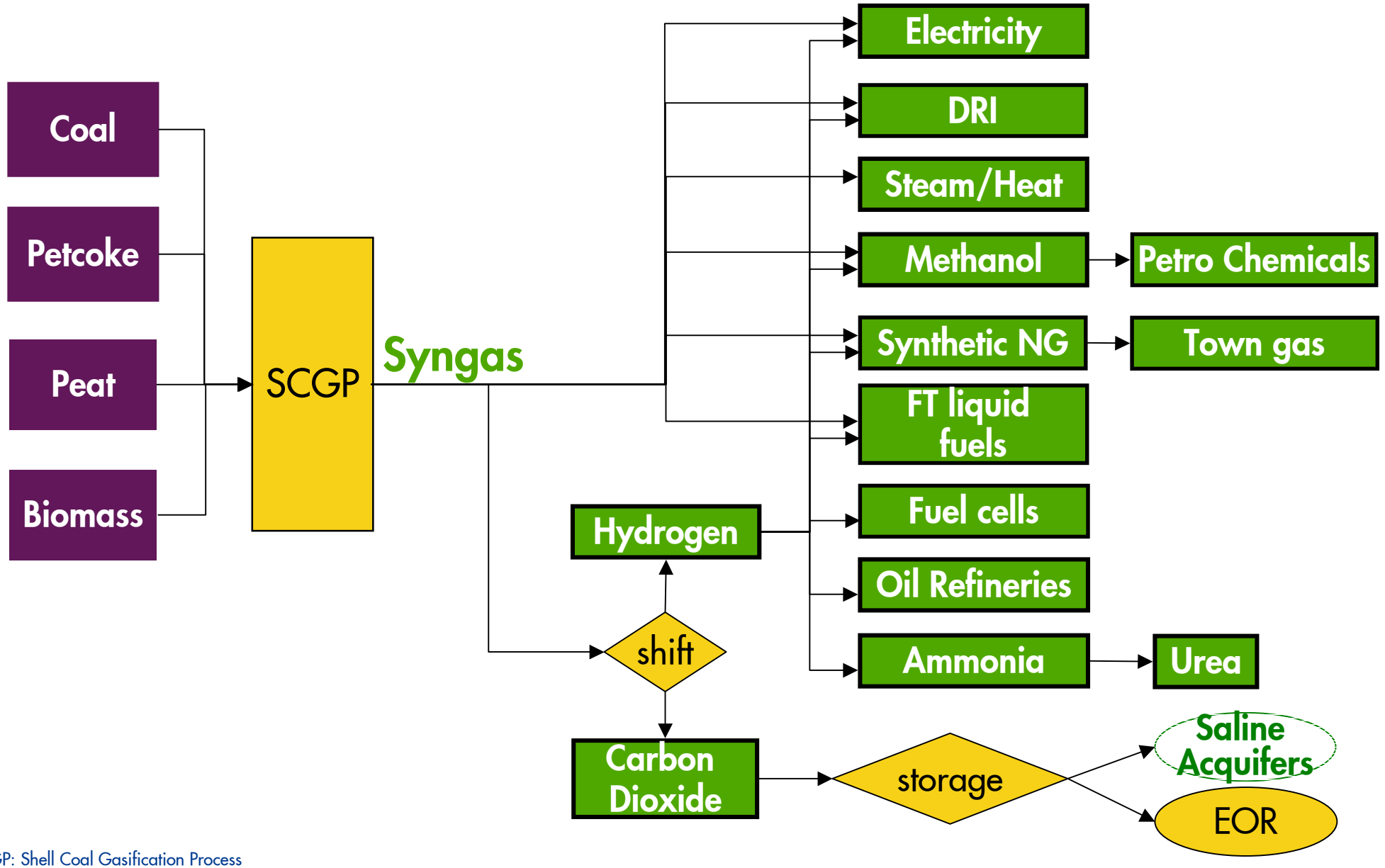
- The containment of CO_2 in coal gasification allows for potential CO_2 sequestration ("zero emissions") potentially delivering CO_2 reduction in coal-based economies
- Coal gasification could deliver near complete mercury removal (versus around 60% with advanced boiler technology)
- Coal gasification provides a production option for hydrogen

Source: www.gasification.org

Chemical Essentials of Gasification

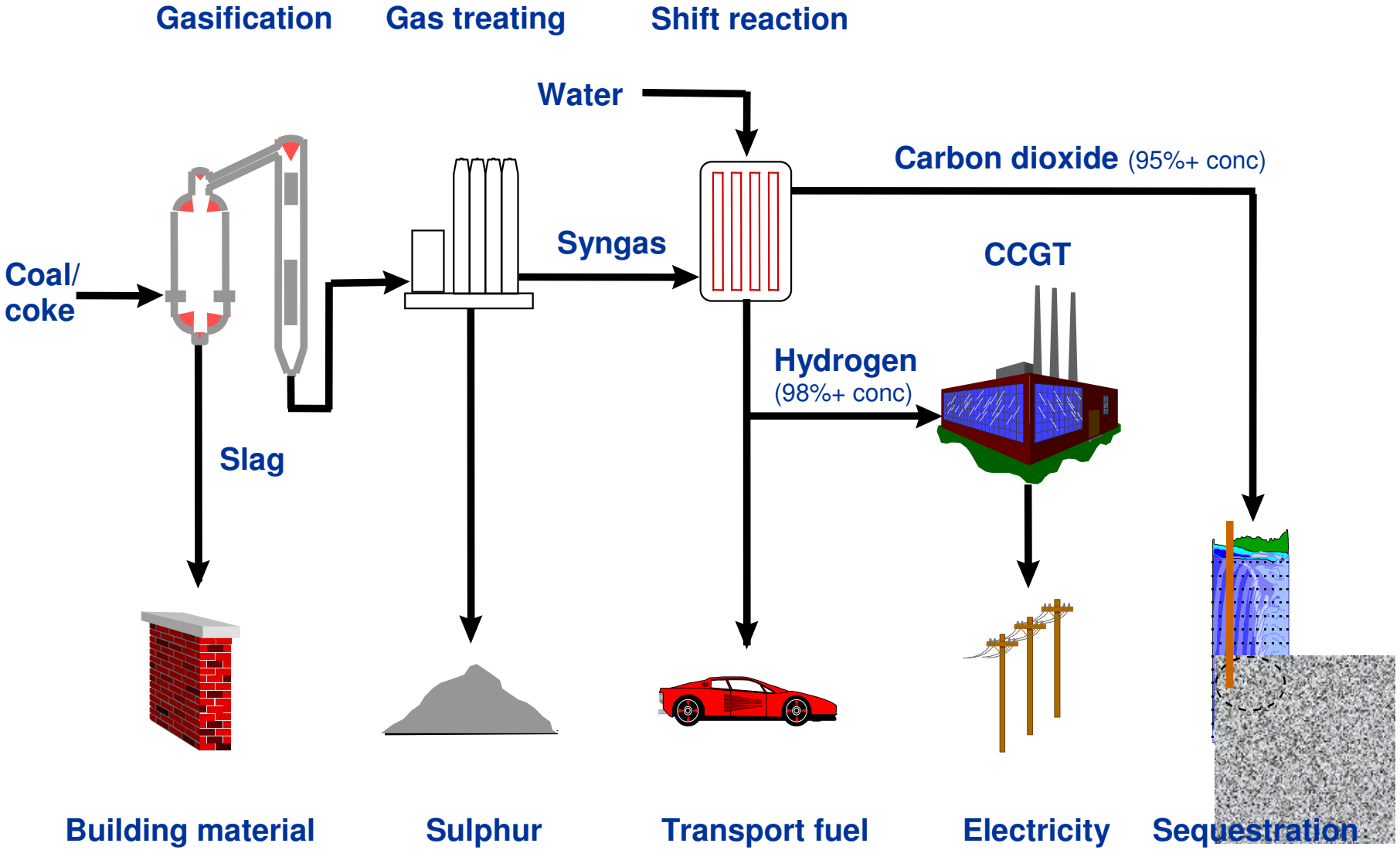


Potential Value Chains



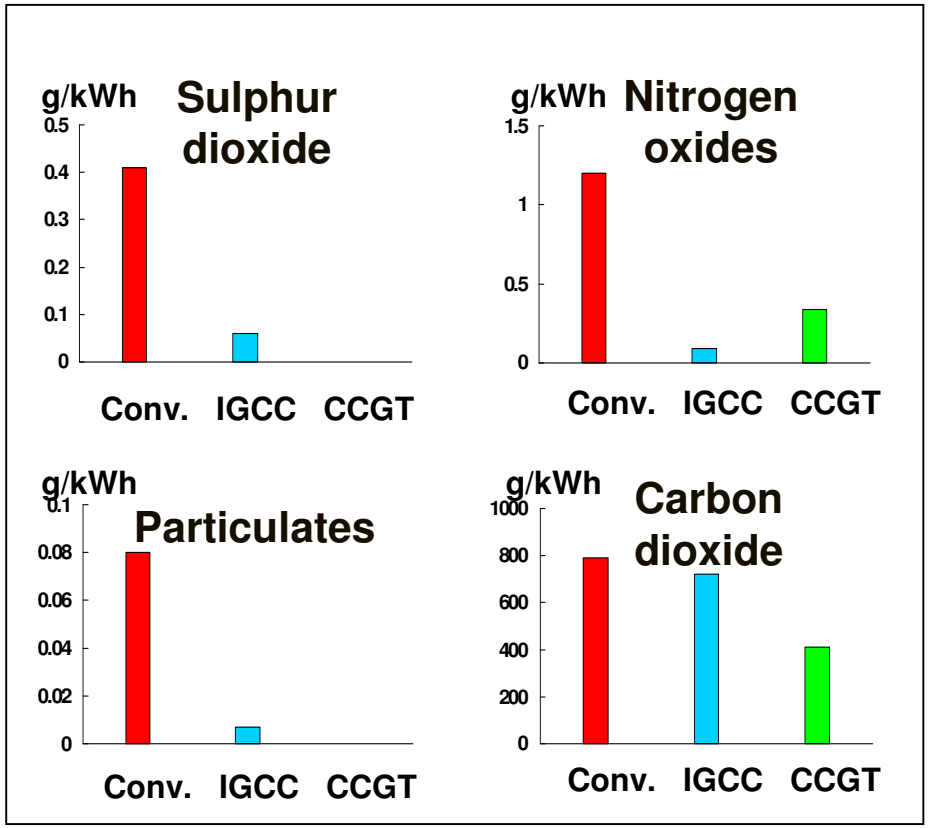
SCGP: Shell Coal Gasification Process

Integrated Ecology Cycle



Source: CERA, integrated ecology cycle

Emission comparison



Above comparisons are for power production

- Coal gasification is providing a more sustainable emissions footprint compared to conventional coal fired power.
- The potential of CO2 sequestration could lower the emission footprint even further

Source: www.gasification.org

Power Generating Technologies Comparison

Pulverized Coal

- Dominate coal generation technology
- Three types: sub critical, supercritical, ultra critical.
- Advancements in materials, controls and temperature mixing led to improved performance and reliability.

Fluidized Bed Combustion

- Greater fuel flexibility – (waste coals, pet coke, fuels,..).
- Lower heat rate efficiency vs. pulverized coal
- Inherent low Nox rates from lower combustion temperatures (0.37→0.07#Nox / MMBtu).

Combined Cycle Gas Turbine

- The combined cycle gas turbine (CCGT) is a combination of two different technologies: the gas turbine and the steam turbine.
- The CCGT technology provides several advantages over conventional oil and coal generation. E.g. lower Capex, high efficiency, flexibility in plant size.

Integrated Gasification Combined Cycle

- Operating on a wide range of fuels and offers the ability to produce a range of products including power, heat, hydrogen and other valuable chemicals
- Future applications of IGCC could be configured to remove carbon components with minimal efficiency losses when compared to today's technologies.

Sources: GE Energy Gas Turbine and combined cycle products AEP, EPRI and US DOE, Supercritical Plant Overview Ron Ott, Black & Veatch 2/04, IEA Clean Coal Centre; IGCC data is Shell internal

Pulverized coal technology

Sub-critical

35% efficiency

23% with CO_2 capture

Status: Decline

Super-critical

42% efficiency

28% with CO_2 capture

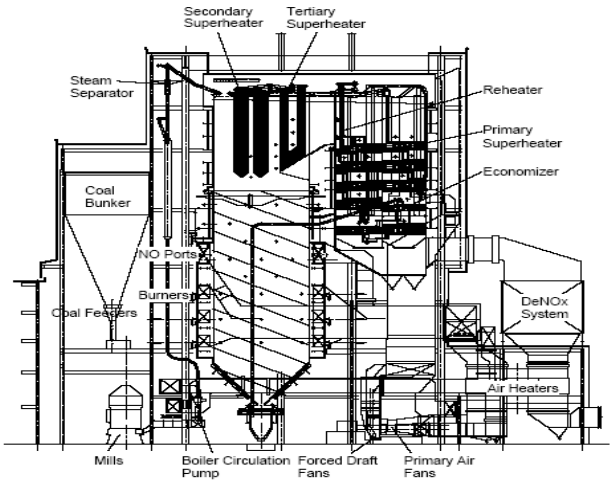
Status: Mature

Ultra-critical

44% efficiency

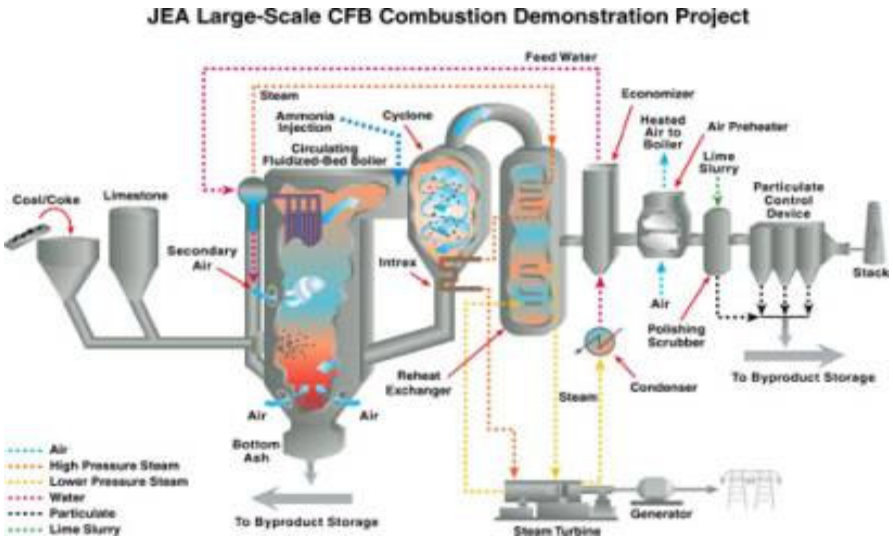
29% with CO_2 capture

Status: Growth



Source: Supercritical Plant Overview Ron Ott, Black & Veatch 2/04

Fluidized Bed Combustion



Non pressurized

30%-40% efficiency

20%-27% with CO_2 capture

Status: mature

Pressurized

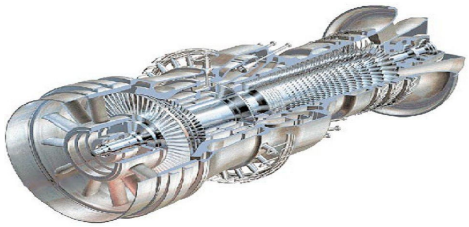
>40% efficiency

30% with CO_2 capture

Status: Growth

Source: IEA Clean Coal Centre

CCGT

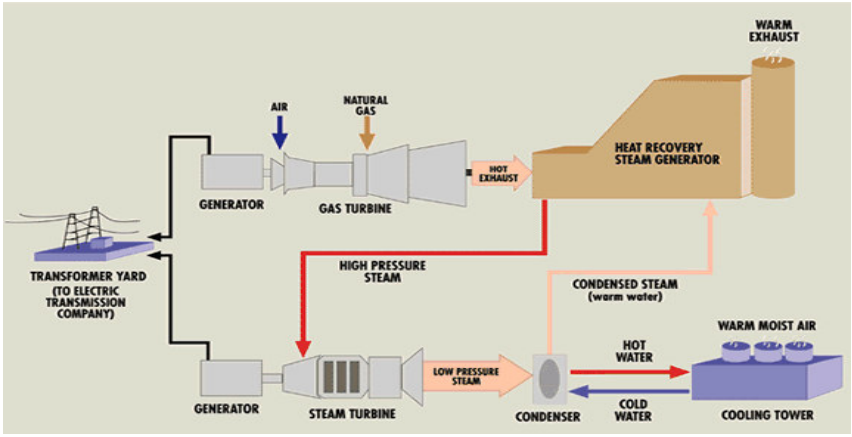


GE M Class

52% efficiency

40% with CO_2 capture

Status: Decline



GE F Class

55%-58% efficiency

43%-45% with CO_2 capture

Status: Mature / Growth

GE H Class

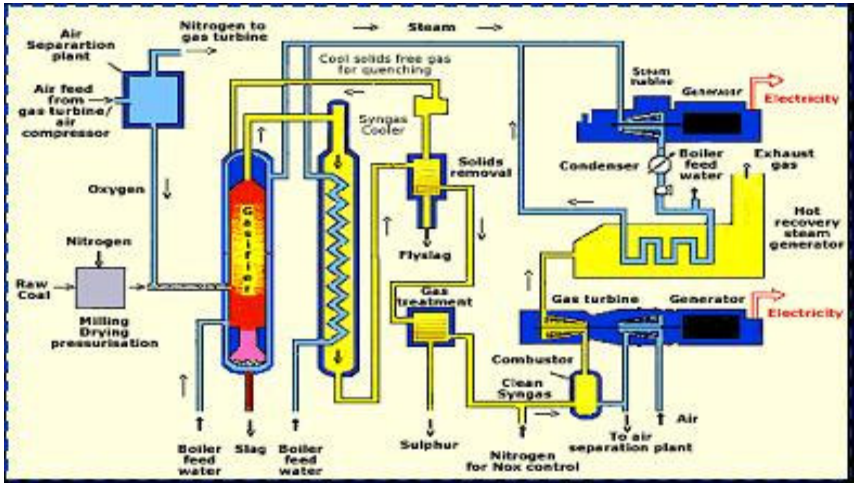
60% efficiency

47% with CO_2 capture

Status: Introduction

Source: GE Energy Gas Turbine and combined cycle products
AEP, EPRI and US DOE

Shell IGCC



First generation

43% efficiency

34% with CO_2 capture

Nuon Willem Alexnader power plant
Buggenum, Netherlands.
Photograph courtesy of NUON

Second generation

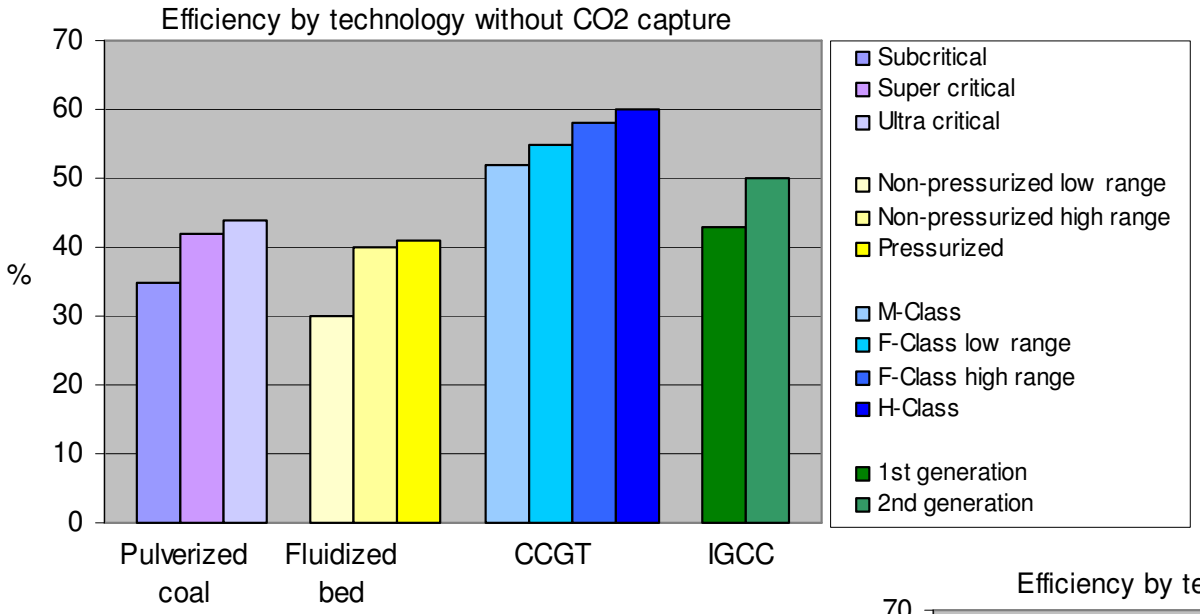
48%-50% efficiency

39%-40% with CO_2 capture

Third generation

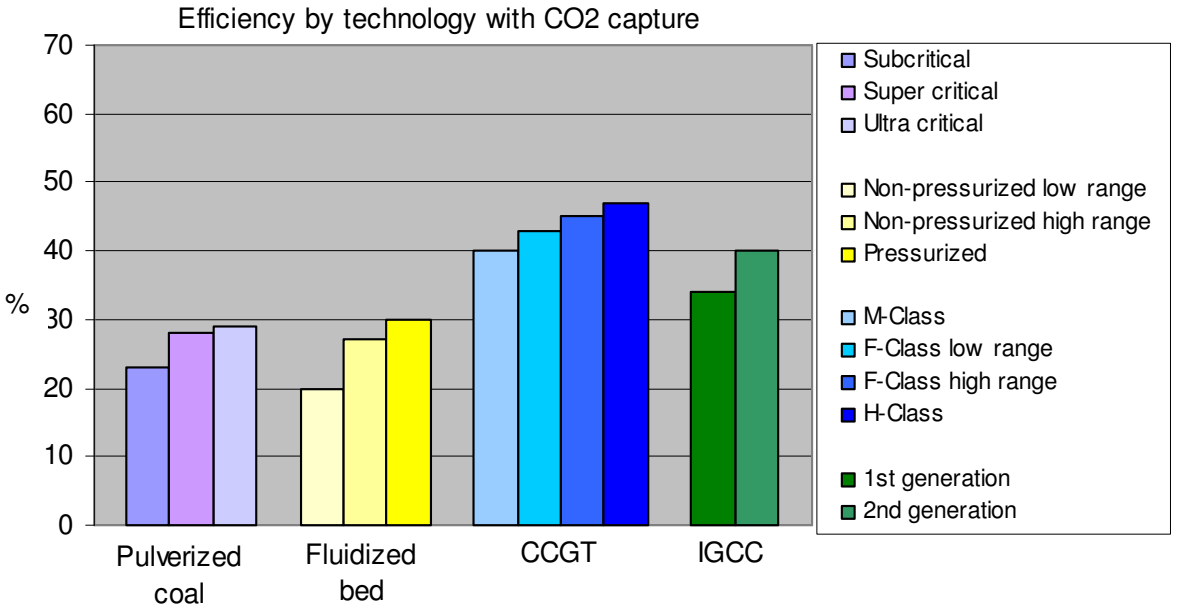
Source: Shell Global Solutions

Efficiencies by Technology



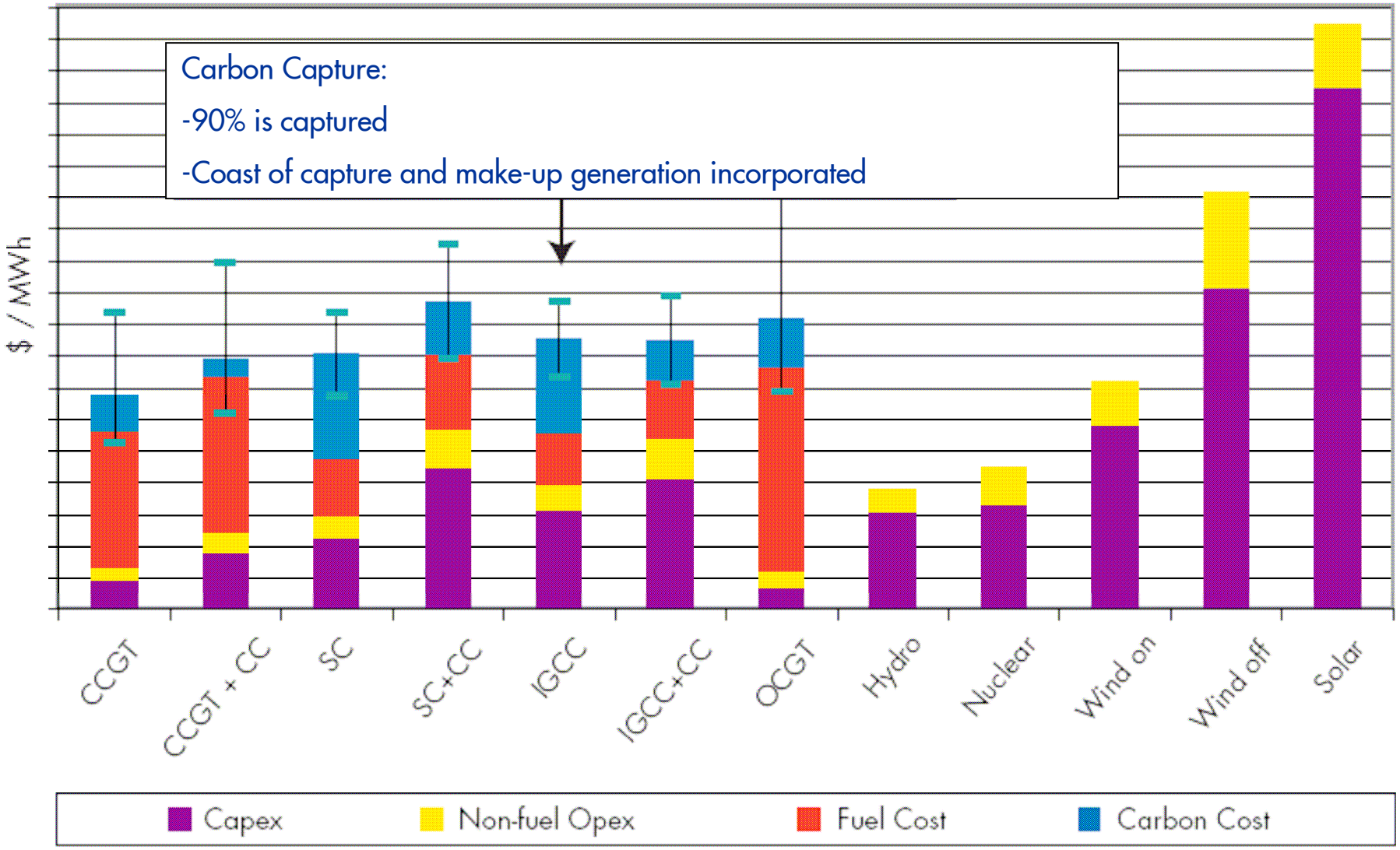
- CCGT is efficiency leader, IGCC is winning ground on PC due to efficiency increase by technology improvement.

- IGCC is showing the lowest impact on efficiency from CO_2 capturing and thus increasing the gap with PC, and closing in on CCGT efficiency



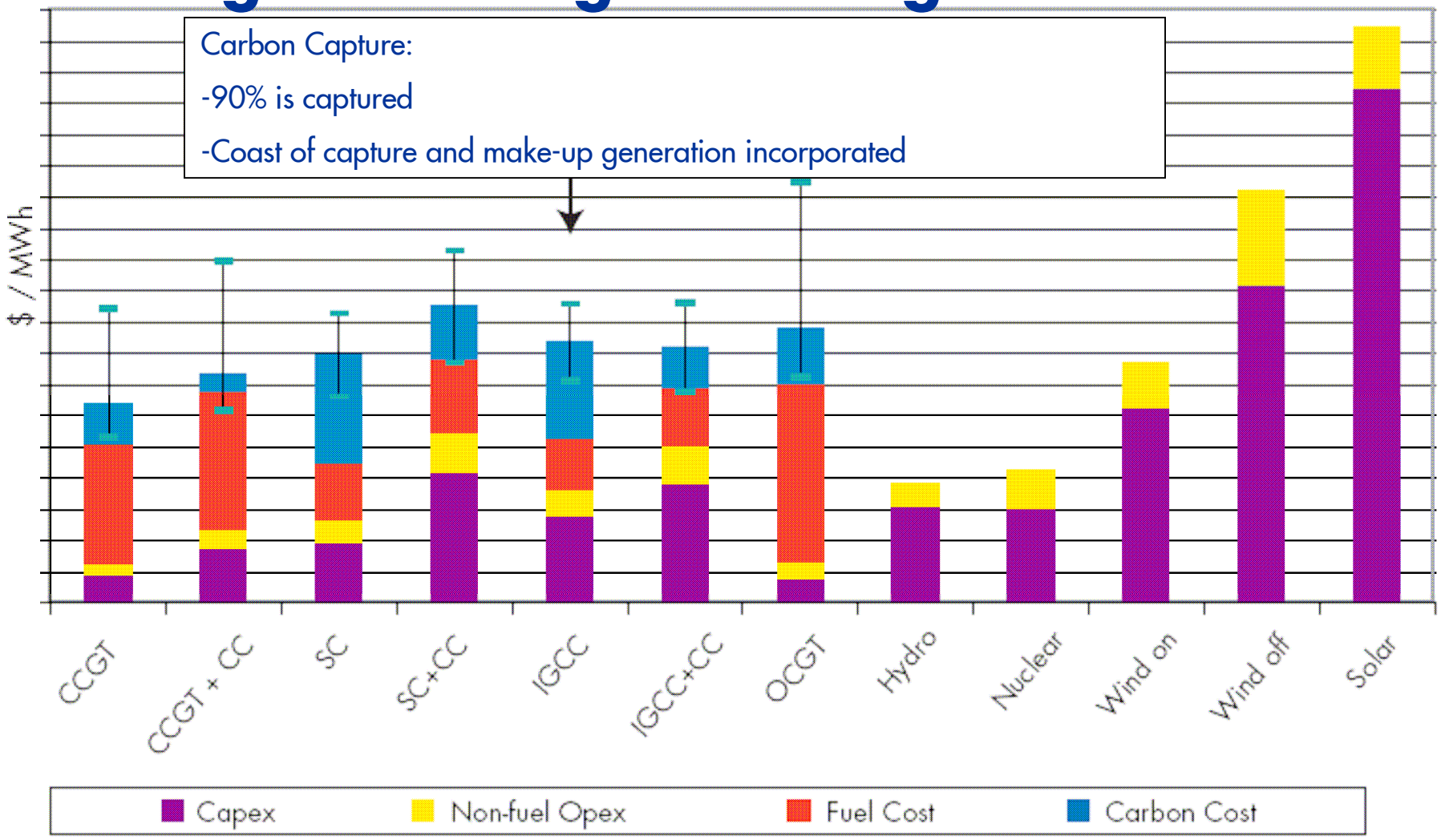
Sources: GE Energy Gas Turbine and combined cycle products AEP, EPRI and US DOE, Supercritical Plant Overview Ron Ott, Black & Veatch 2/04, IEA Clean Coal Centre; IGCC data is from Shell.

USA Ungeared Long Run Marginal Cost



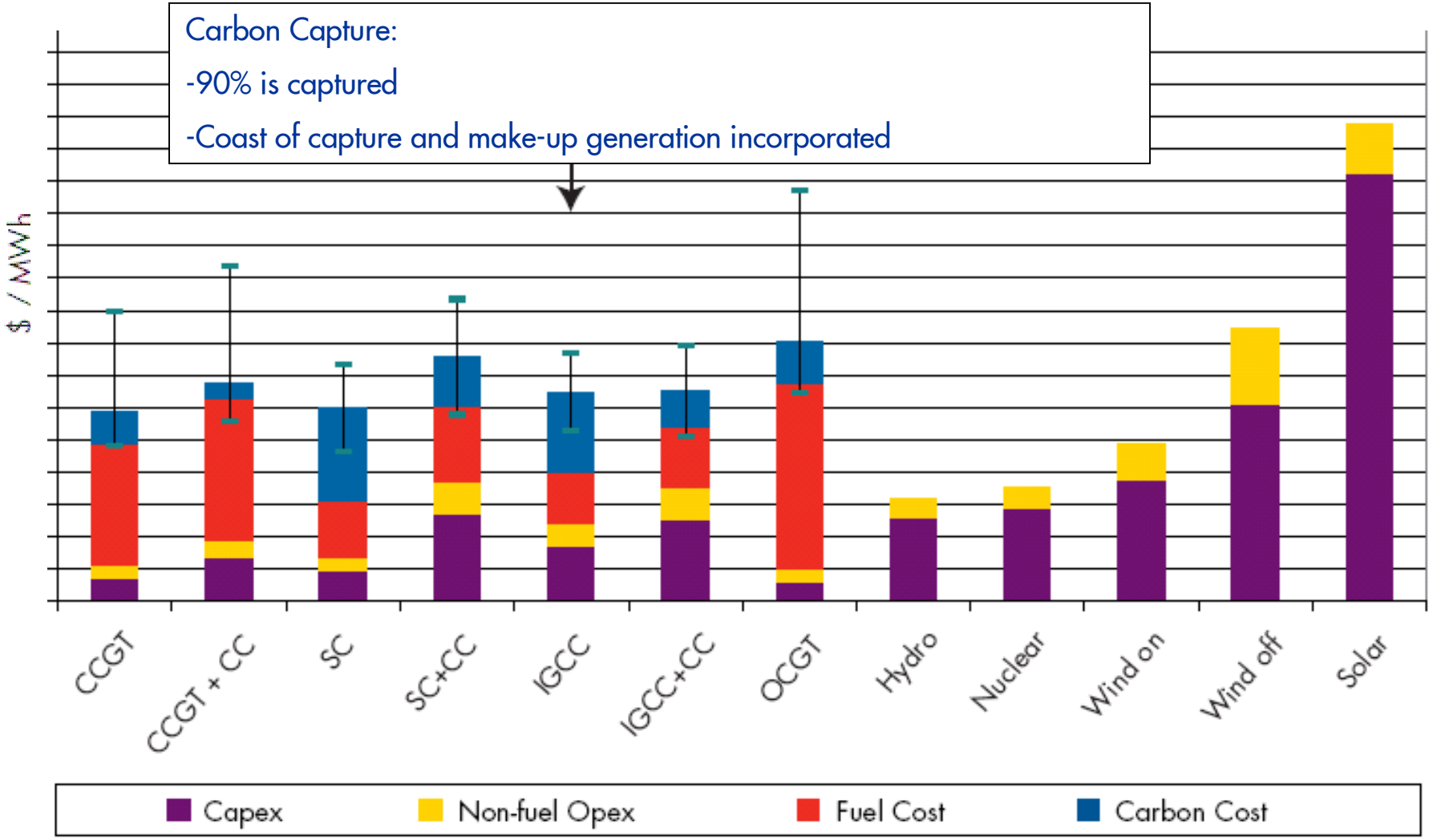
Source: Shell Internal, Power Group, Power generation in a Carbon Constrained World Oct. 2007

EU Ungeared Long Run Marginal Cost



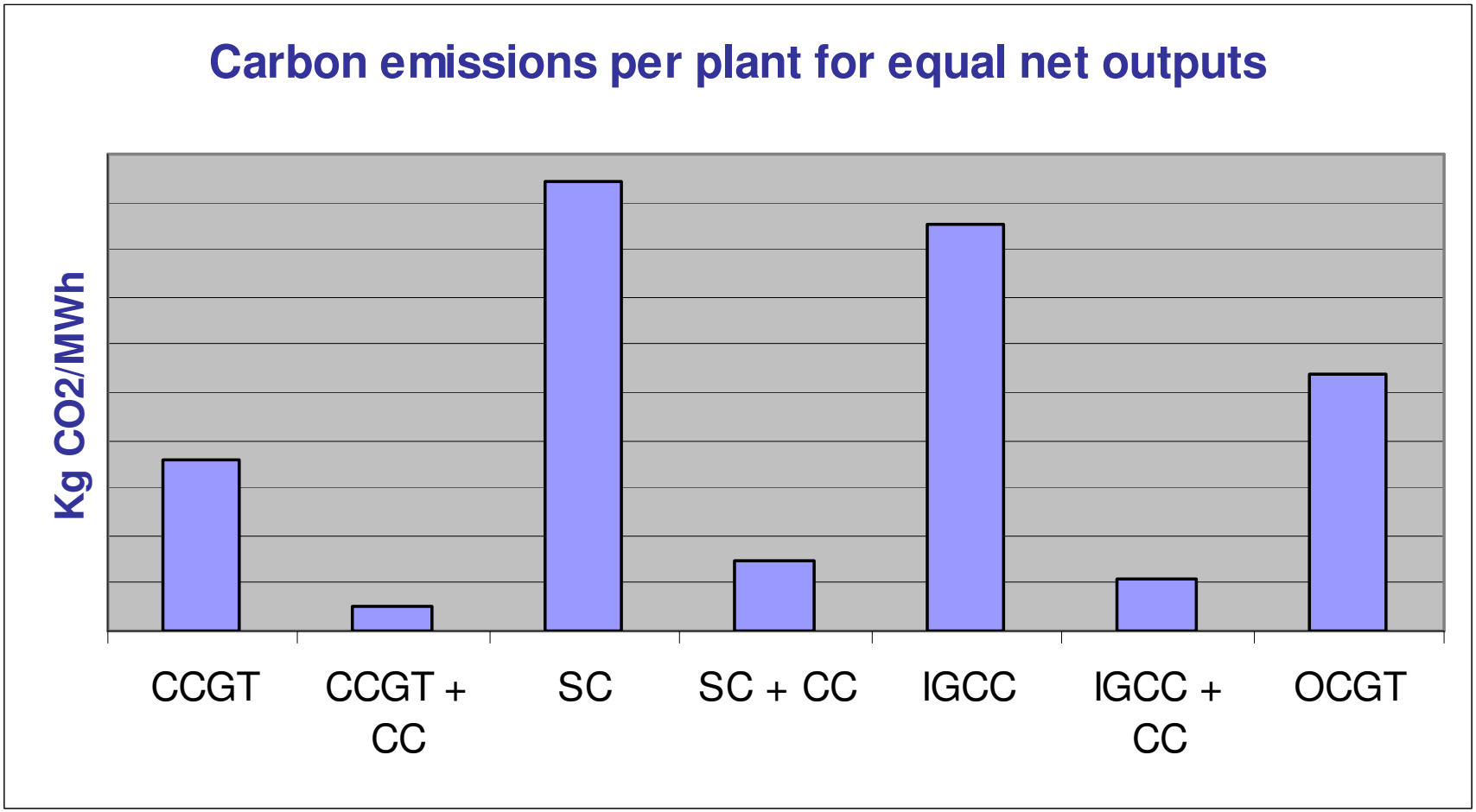
Source: Shell Internal, Power Group, Power generation in a Carbon Constrained World Oct. 2007

China Ungeared Long Run Marginal Cost



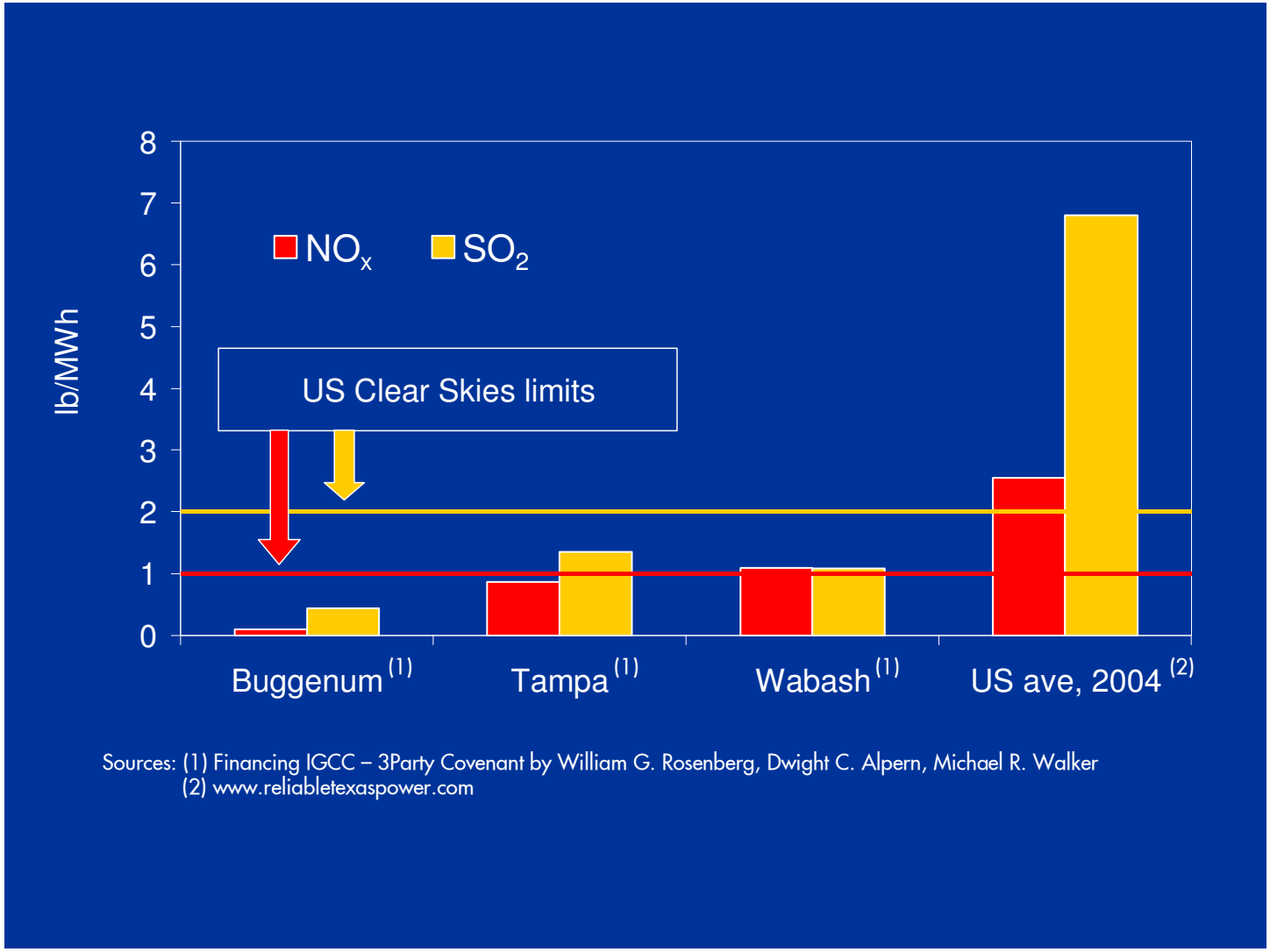
Source: Shell Internal, Power Group, Power generation in a Carbon Constrained World Oct. 2007

CO2 Emissions from Power Generation



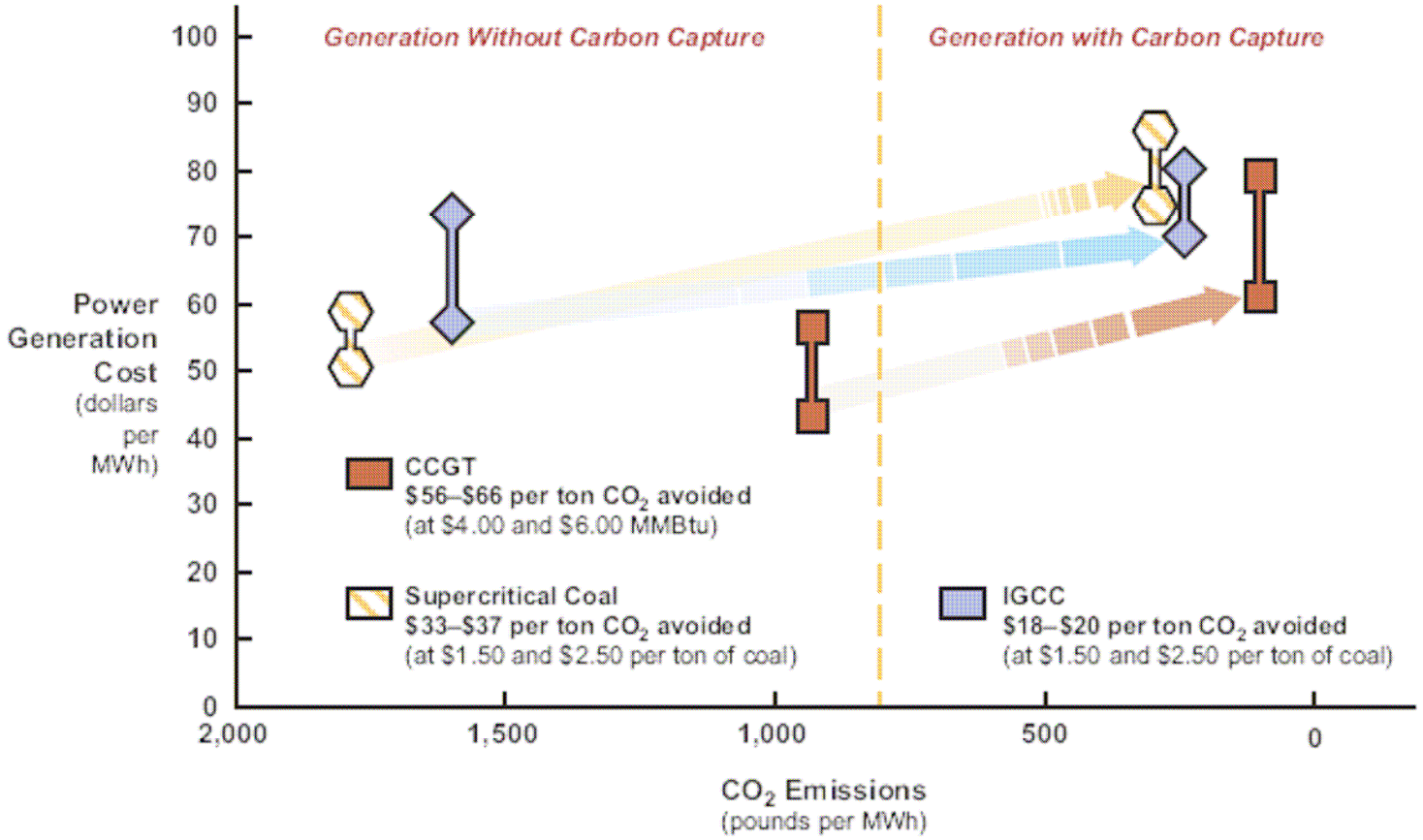
Source: Shell Internal, Power Group, Power generation in a Carbon Constrained World Oct. 2007

Emission rates: three IGCCs vs. Conventional Coal



Sources: (1) Financing IGCC – 3Party Covenant by William G. Rosenberg, Dwight C. Alpern, Michael R. Walker
(2) www.reliabletexaspower.com

Power Generation Costs and CO_2 Capture



Source:Carbon Capture and Geological Storage: Within Our Reach or Beyond Our Grasp? Aug. 2005