LIFE CYCLE EMISSIONS FROM FOSSIL FUEL POWER PLANTS WITH CARBON CAPTURE AND STORAGE

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– Consider a 90 % capture plant?

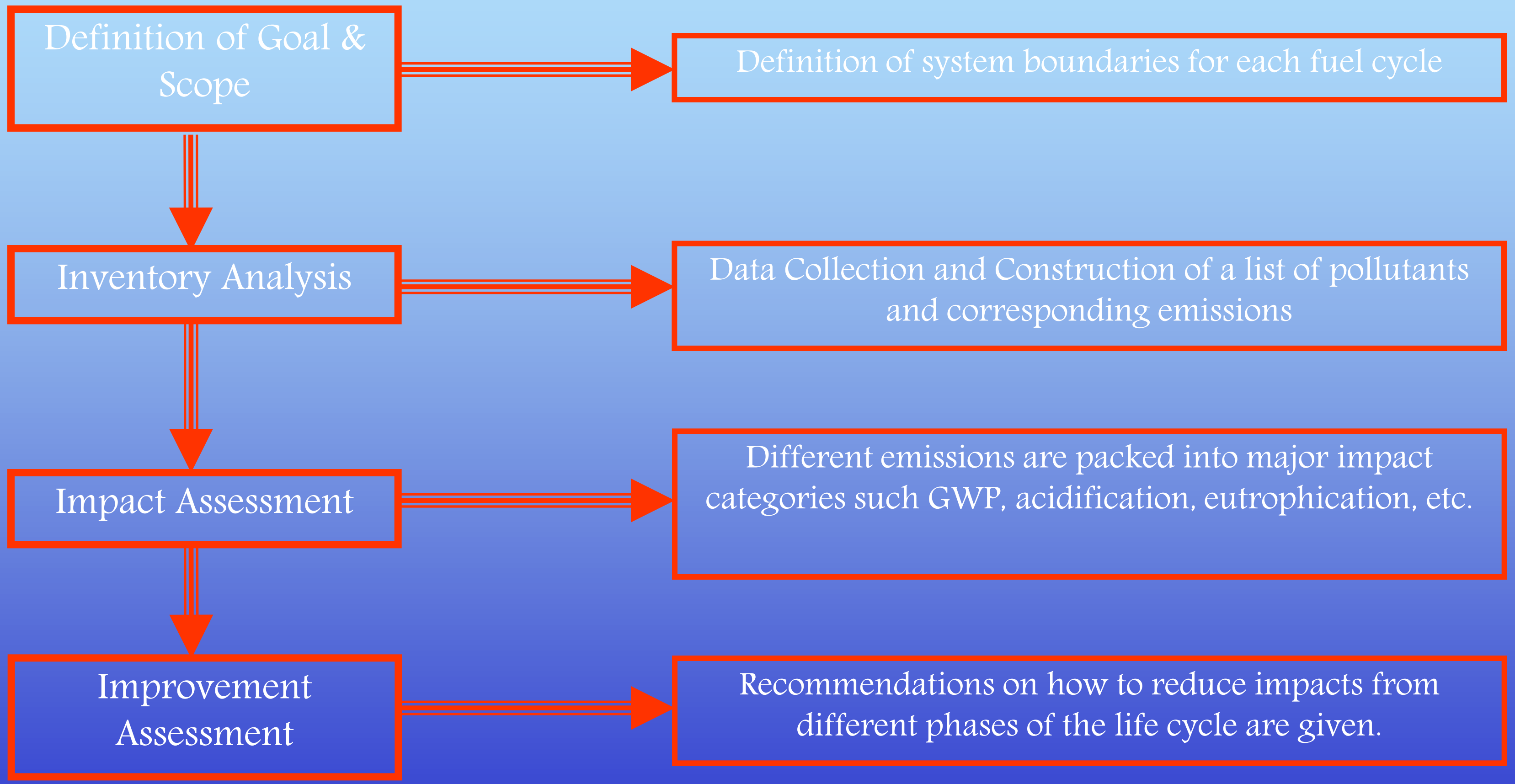
Are CO_2 emissions really reduced by 90 %?

–In the past, extensive research has been undertaken on life cycle GHG emissions from power generation technologies including renewables and nuclear.

–Now similar research is needed for systems with CCS.

–The current work investigates life cycle emissions from power generation technologies with and without CC

Life Cycle Assessment – Methodology

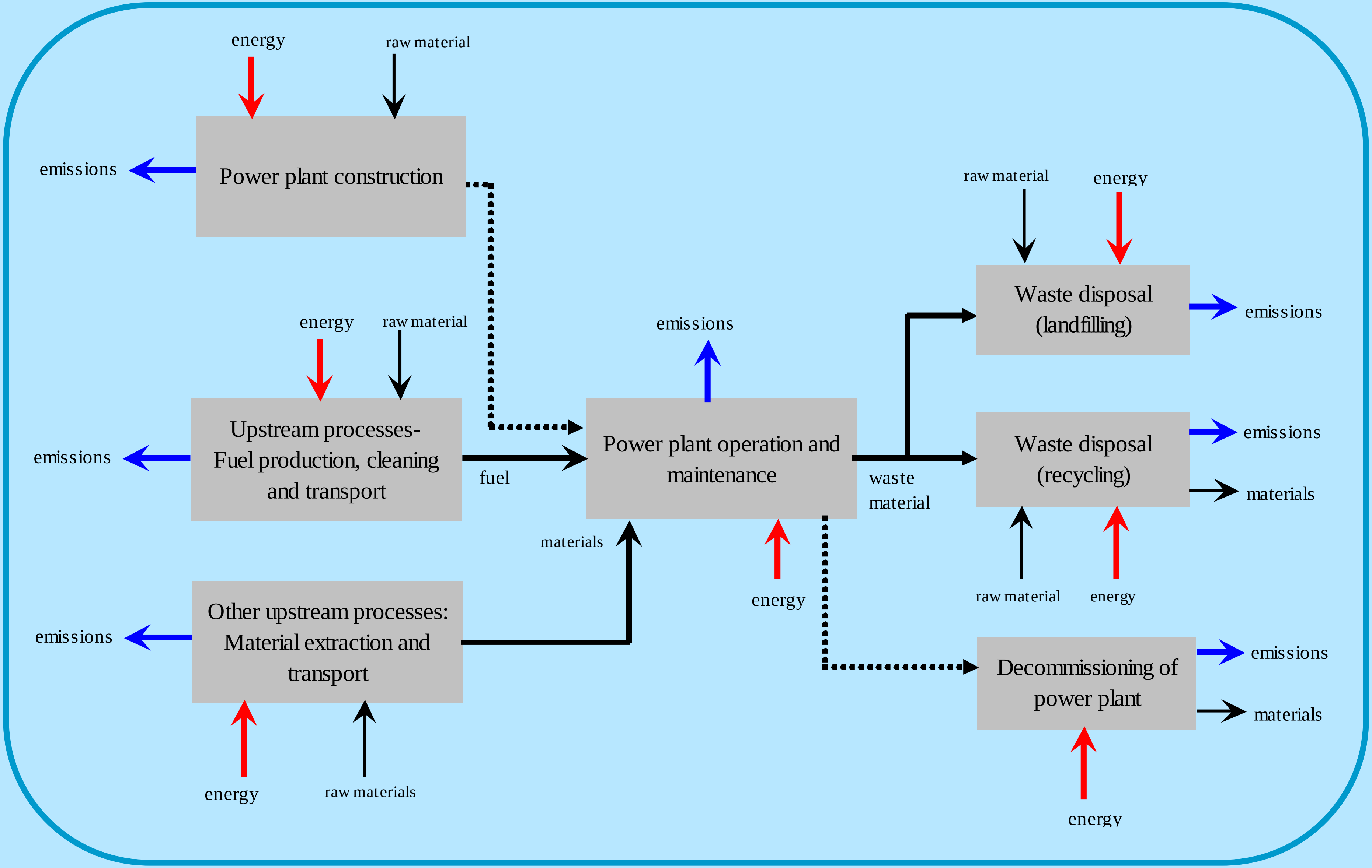


Technologies considered for Analysis

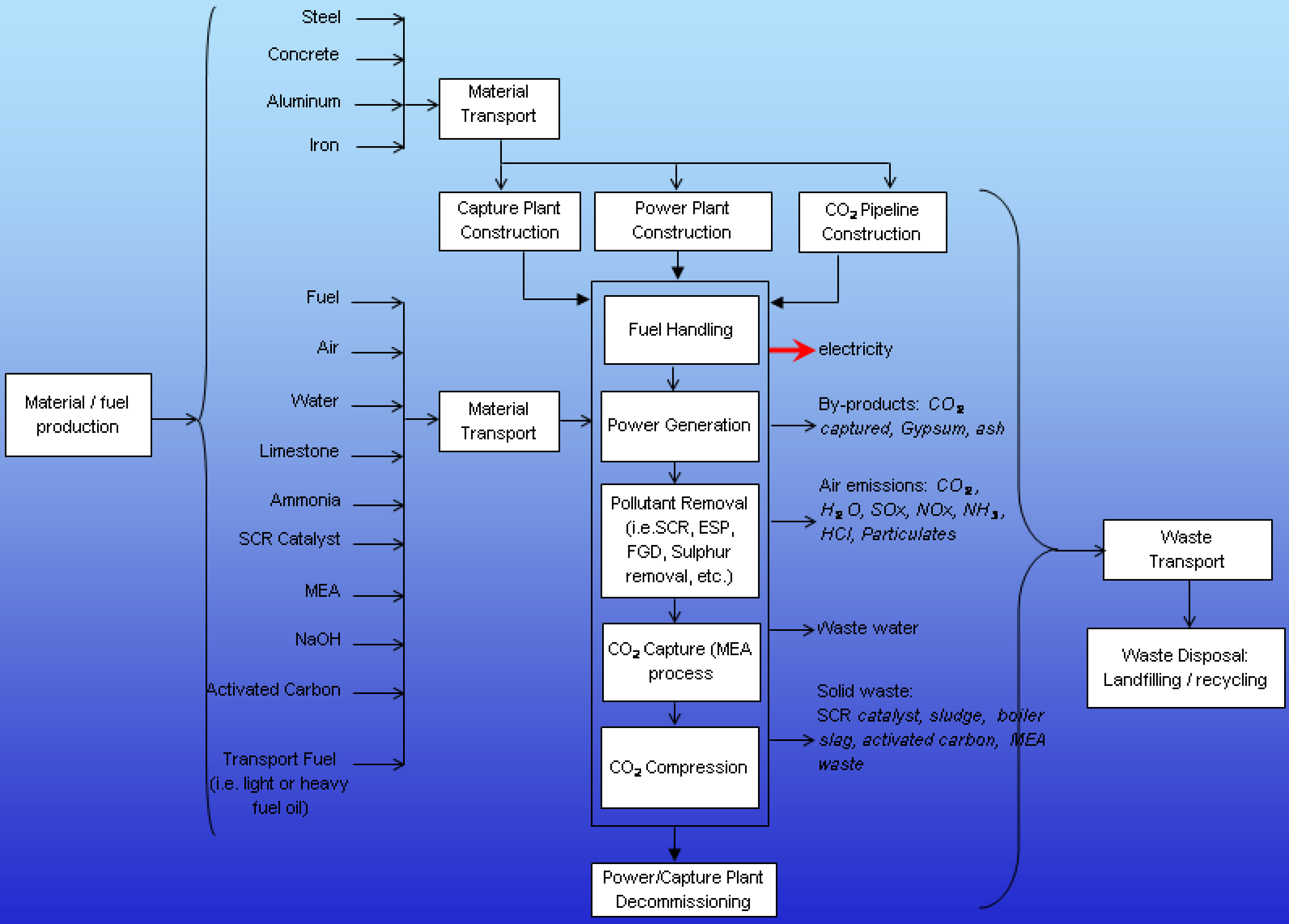
- The following technologies are analysed in detail
  - Supercritical PC with SCR, ESP & FGD (No CCS)
  - Supercritical PC with SCR, ESP, FGD and CCS
  - Natural Gas Combined Cycle (NGCC) without CCS
  - Natural Gas Combined Cycle (NGCC) with CCS
  - Integrated Gasification Combined Cycle (IGCC) without CCS
  - Integrated Gasification Combined Cycle (IGCC) with CCS

- Compared to reference
  - Subcritical PC with SCR, ESP & FGD (No CCS)

Life Cycle Boundaries – General



Example: Life Cycle Boundaries for PC with MEA capture



Techno-economic and LCA model

The University of Reading

NERC

UK CSC

POWER PLANT TECHNO-ECONOMICS AND LIFE CYCLE ASSESSMENT MODEL

Single technology Analysis

- Select Technology
- Performance
- Economic Analysis
- Environmental Analysis
  - Emissions
  - LCA GHG Analysis
  - LCA Energy Analysis
  - Environmental Impacts
- Sensitivity Analysis
- Financial Analysis

Special Functions

- Compare CCS to Non-CCS
- Compare Technologies
- Future Scenario Analysis
- Independent LCA
- Help and Support

Version 1

GHG Emissions: PC vs. NGCC

Supercritical PC

Total GHG emissions (g CO_2-e / kWh): **868**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation & Transport	Waste Disposal
0.2 %	90.7 %	5.5 %	0.2 %	3 %	0.4 %

NGCC

Total GHG emissions (g CO_2-e / kWh): **485**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation and Transport	Waste Disposal
0.3 %	74.3 %	25.1 %	0.0 %	0.3 %	0.0 %

Methane leakage from transport is included with Fuel production emissions

GHG Emissions: Non-CCS vs. CCS

Supercritical PC without CCS

Total GHG emissions (g CO_2-e / kWh): **868**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation & Transport	Waste Disposal
0.2 %	90.7 %	5.5 %	0.2 %	3 %	0.4 %

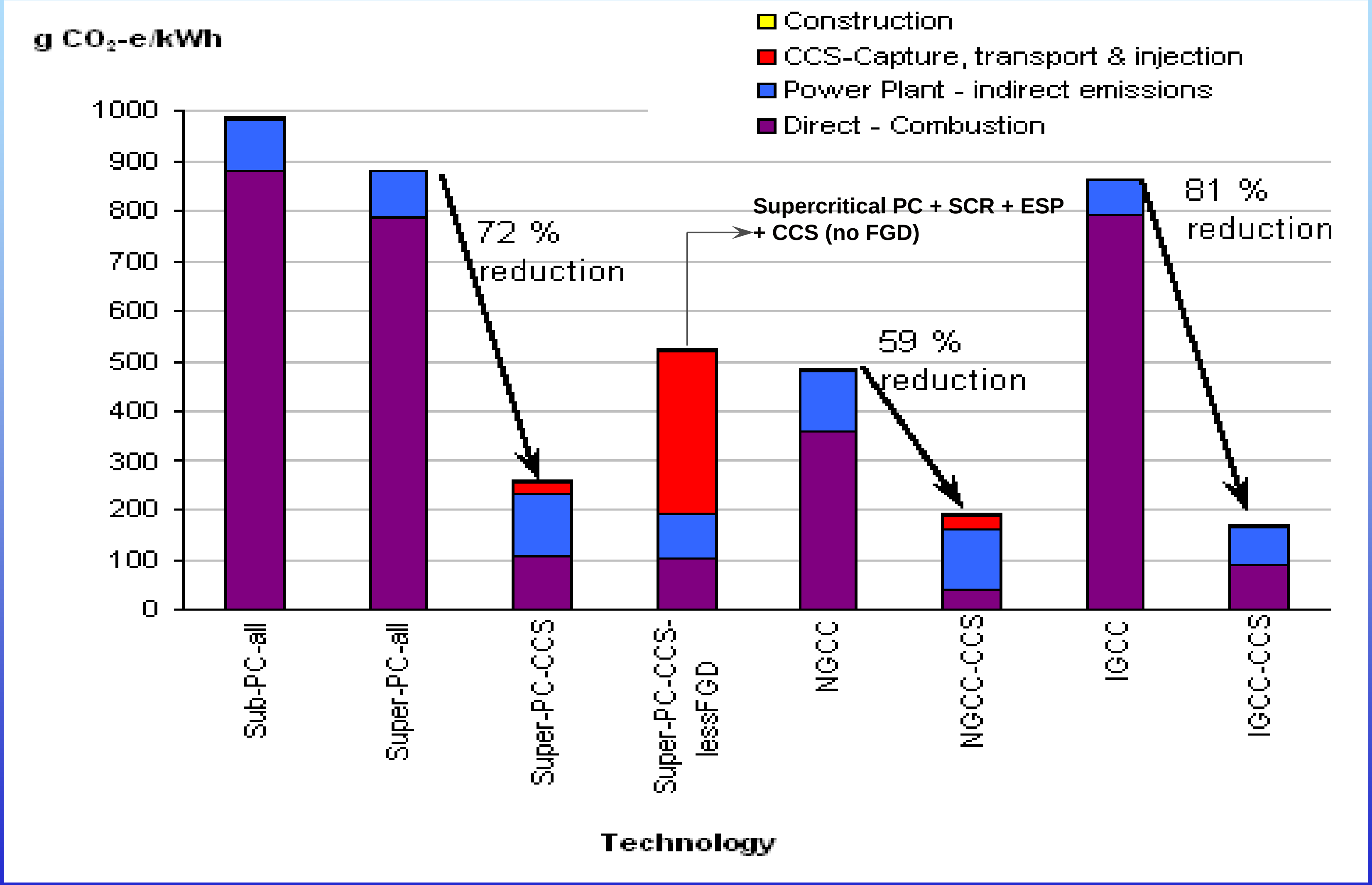
Supercritical PC with CCS (90 % capture)

Total GHG emissions (g CO_2-e / kWh): **244**

Construction	Direct Combustion	Fuel production	Fuel Transport	Other Operation and Transport	Waste Disposal
1.3 %	43.7 %	25.8 %	0.7 %	25.1 %	3.4 %

Production of MEA in addition to other materials

GHG Emissions in g CO_2-e/kWh



Life Cycle Efficiency

Case	Power plant Efficiency, %	LCA efficiency, %	% reduction in efficiency
Subcritical PC	35.3	32.9	6.8
Supercritical PC	39.6	36.3	8.3
Supercritical PC +CCS	30.0	27.7	7.7
NGCC	50.1	41.0	18.2
NGCC + CCS	42.8	36.5	14.7
IGCC	37.2	35.0	5.9
IGCC +CCS	32.0	30.2	5.6

Resource Consumption

Technology	Coal *	Nat Gas *	Limestone *	NH_3 *	MEA *	Selexol *	Water **
Reference: Sub PC	329.7	-	19.0	0.68	-	-	3.1
Super PC	294.9	-	16.9	0.61	-	-	3.1
Super PC + CCS	390.1	-	27.2	0.80	3.6	-	4.1
Super PC+CCS - FGD	379.2	-	-	0.78	56.3	-	3.9
NGCC	-	130.1	-	0.20	-	-	na
NGCC + CCS	-	151.9	-	0.23	1.33	-	na
IGCC	314.9	-	-	-	-	0.02	0.6
IGCC + CCS	365.9	-	-	-	-	0.03	0.9

* in g/kWh units ** in l/kWh units

Sensitivity Analysis of GHG Emissions

Technology	A	B	C	D	E
Reference: Sub PC	+3.5%	NA	-0.09%	NA	NA
Super PC	+3.5%	NA	-0.09%	NA	NA
Super PC + CCS	+16.9%	NA	-0.50%	+0.05%	+14.8%
NGCC	NA	+10.9%	NA	NA	NA
NGCC + CCS	NA	+33.2%	NA	+0.07%	+11.3%
IGCC	+3.3%	NA	-0.06%	NA	NA
IGCC + CCS	+24.4%	NA	-0.4%	+0.08%	+25.6%

A: All coal imported from Russia instead of locally mined
B: Natural gas losses increase from 1% to 3 %
C: 50 % of waste (Ash and FGD) recovered and used in construction materials
D: CO_2 pipeline length increases by 100 km
E: Capture efficiency decreases by 5 percentage points

Other Air Pollutants

Technology	NOx (as NO) (g/kWh)	SO_2 (g/kWh)	Particulates (g/kWh)	NH_3 (g/kWh)
Super PC	0.410	1.250	0.058	0.005
Super PC + CCS	0.590	0.009	0.030	0.470
NGCC	0.140	-	-	0.005
NGCC + CCS	0.160	-	-	0.150
IGCC	0.120	0.300	0.004	-
IGCC + CCS	0.100	0.330	0.004	-

* Increase in NOx and Ammonia concentration may lead to

- Higher acidification potential (increases by 11% for NGCC)

- Higher Eutrophication potential (increases by a factor of 4 for PC)

Other Environmental Issues with MEA Capture

- MEA Waste

– MEA waste contains many organic compounds, cations (sodium, selenium, etc.) and anions (such as chlorides, nitrates).

- MEA waste is considered hazardous waste

- Emissions of MEA and Ammonia with the flue gas

– Some of the MEA escapes with the flue gas (concentration 1-4 ppm)

- MEA as a gas is irritant but it has a short lifetime and so is not expected to be harmful.

- however, MEA is completely soluble in water and is considered "moderately hazardous" to aquatic life

- Ammonia in flue gas may cause the formation of particulates due to reaction with NOx

- Nitrosamines

– The reaction of MEA with NOx in the atmosphere or in the flue gas leads to the formation of Nitrosamines

- Nitroasamines are carcinogens.

Conclusions

- Life cycle GHG emissions from fossil fuel power stations with CCS (90 % CO_2 capture) can be reduced by 60-81%.

- IGCC is favorable with GHG emissions reducing to less than 160 g/kWh.

- Sensitivity analysis shows that the coal transport distance, the capture efficiency, and methane leakage from gas production and transport can significantly affect LC GHG emissions.

- Like other end-of-pipe pollution control technologies, the amine process should be viewed as a "pollution transfer" rather than "pollution prevention" method. While the GWP reduces, other impacts increase.

- The implementation of CCS changes the environmental assessment and so positive and negative impacts must be evaluated carefully.

QUESTIONS