14th Annual Southern African Coal Conference 2019

Is CO_2 from Coal Power Generation the Environmental Disaster the Ideologists Claim?

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DISCLAIMER

- *The information presented here is work in progress towards a post grad study in CCU*
- *Consider all data and concepts in the presentation as "not verified"*
- *All views expressed are the views of the presenter*
- *The use of any information from the presentation is at your own risk*

PRESENTATION OUTLINE

1. Background Information and Introduction to Cleaner Coal Technology
2. The Role of Coal - South African Context
3. Basic GHG Definitions and Global Emissions
4. LNG vs Coal
5. Improving the image of Coal

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GLOBAL TREND

- Extract from International Energy Agency - Global Energy and CO_2 Status Report, 2017

  *"**Global energy demand rose by 2.1% in 2017**, more than twice the previous year's rate, boosted by strong global economic growth, **with oil, gas and coal meeting most of the increase in demand for energy**, and renewables seeing impressive gains.*

  ***Over 70% of global energy growth was met by oil, natural gas and coal**, while renewables accounted for almost all of the rest. Improvements in energy efficiency slowed down last year. As a result of these trends, global energy-related **carbon dioxide emissions increased by 1.4% in 2017,** after three years of remaining flat.*

  ***Fossil fuels accounted for 81% of total energy demand in 2017**, a level that has remained stable for more than three decades. "*

- CO_2 emissions grew by 1.6% in 2017 to 36.2 Giga tons and grew a further 2.7% in 2018

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GLOBAL TREND

- Global energy demand is expected to grow by more than 25% through to 2040.
- Most energy scenarios predict an increase in the share of the renewables, but in absolute numbers the fossil fuels will continue to provide most of the energy need for the foreseeable future
- The deployment of Cleaner Coal Technologies and Carbon Capture & Utilisation technologies will be necessary in maintaining a low carbon development path.
- The focus of Cleaner Coal Technologies is on addressing emissions instead of trying to get rid of a fuel

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CLEANER COAL TECHNOLOGIES

Some available CCT technologies include:

- **Cleaner Coal Technology in Coal Mining**
  - Coal Washing
  - Methane Gas Capture
  - Underground Coal Gasification (UCG)
  - Ultra-clean coal (UCC)

- **Cleaner Coal Technologies used During Combustion**
  - HELE technology
  - Fluidised-Bed Combustion (FBC)
  - Integrated Gasification Combined Cycle (IGCC)
  - Pulverised Coal Supercritical and Ultra- Supercritical Boilers
  - Oxy-fuel combustion
  - Chemical Looping Combustion

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CLEANER COAL TECHNOLOGIES

- **Cleaner Coal Technologies used During Combustion – continued………**
  - Carbonate Looping Technology
  - Low NOx Burners
  - Advanced Controls
  - Supercritical CO_2 based power generation

- **Cleaner Coal Technologies for Flue Gas Streams**
  - Particulate emissions control technologies
  - Flue gas desulfurization
  - NOx Reduction (SNCR, SCR)
  - Mercury Removal
  - Multi-pollutant flue gas treatment with Activated Carbon

- **Cleaner Coal Technologies used post Combustion**
  - Carbon Capture and Storage
  - Carbon Capture and Utilisation
  - Combined Heat and Power (CHP)

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THE ROLE OF COAL

- This indigenous resource is a significant contributor towards the economy.

- Despite coal's importance, the role of coal in the economy is being disrupted by policy and regulatory changes, such as:
  - policy shifts to reduce the contribution of coal in South Africa's energy mix
  - climate change commitments to reduce greenhouse gas emissions under the Paris Agreement

- Although there is "immense opportunity" for renewable-energy exploitation in South Africa, other forms of baseload power are still essential in the energy mix of the country.

- CCS is being considered as part of South Africa's energy and climate change future.

- Some realities of CCS for South Africa:
  - The general geology of South Africa is not suitable for onshore CO2 storage.
  - CCS Value chains will be complex and has no economic contribution. ie Capture and storage will be a cost burden

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BASIC GHG DEFINITIONS

There are lots of terms which get used interchangeably, such as "**greenhouse gas**", "**CO_2**", "**CO_{2eq}**", and "**Carbon**"

Greenhouse gas is a generic name for any gas in the atmosphere which absorbs and re-emits heat. The main GHG gases of concern are; Water Vapour, Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Ozone and Flourinated Gases

Carbon dioxide: is the by-product of the combustion of fossil fuels and living cellular respiration.

Carbon dioxide equivalent "CO_{2eq}" is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For any type of greenhouse gas, CO_{2eq} signifies the amount of CO_2 which would have the equivalent global warming impact.

Carbon is a chemical element which is present in many gases and compounds.

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GLOBAL WARMING POTENTIAL

Kyoto Protocol defined GHGs
100-year Global Warming Potential (GWP) values as defined in IPCC Assessment Reports

Greenhouse gas	Average lifetime in the atmosphere	100-year Global Warming Potential
Carbon dioxide	thousands of years	1
Methane	12.4 years	25
Nitrous oxide	121 years	265–298
Fluorinated gases Hydro-Fluoro-Carbons (HFCs) Per-Fluoro-Carbons (PFCs) Sulfur Hexafluoride (SF_6) Nitrogen Trifluoride (NF_3)	A few weeks to thousands of years	 124 – 14,800 7,390 – 12,200 22,800 17,200

The 20 yr Greenhouse Gas Global Warming Potential of Methane is 85.

This implies that one ton of methane emission is equivalent to emissions of 85 tons of carbon dioxide in the short term. (ie. 1 t CH_4 = 85 t CO_{2eq})

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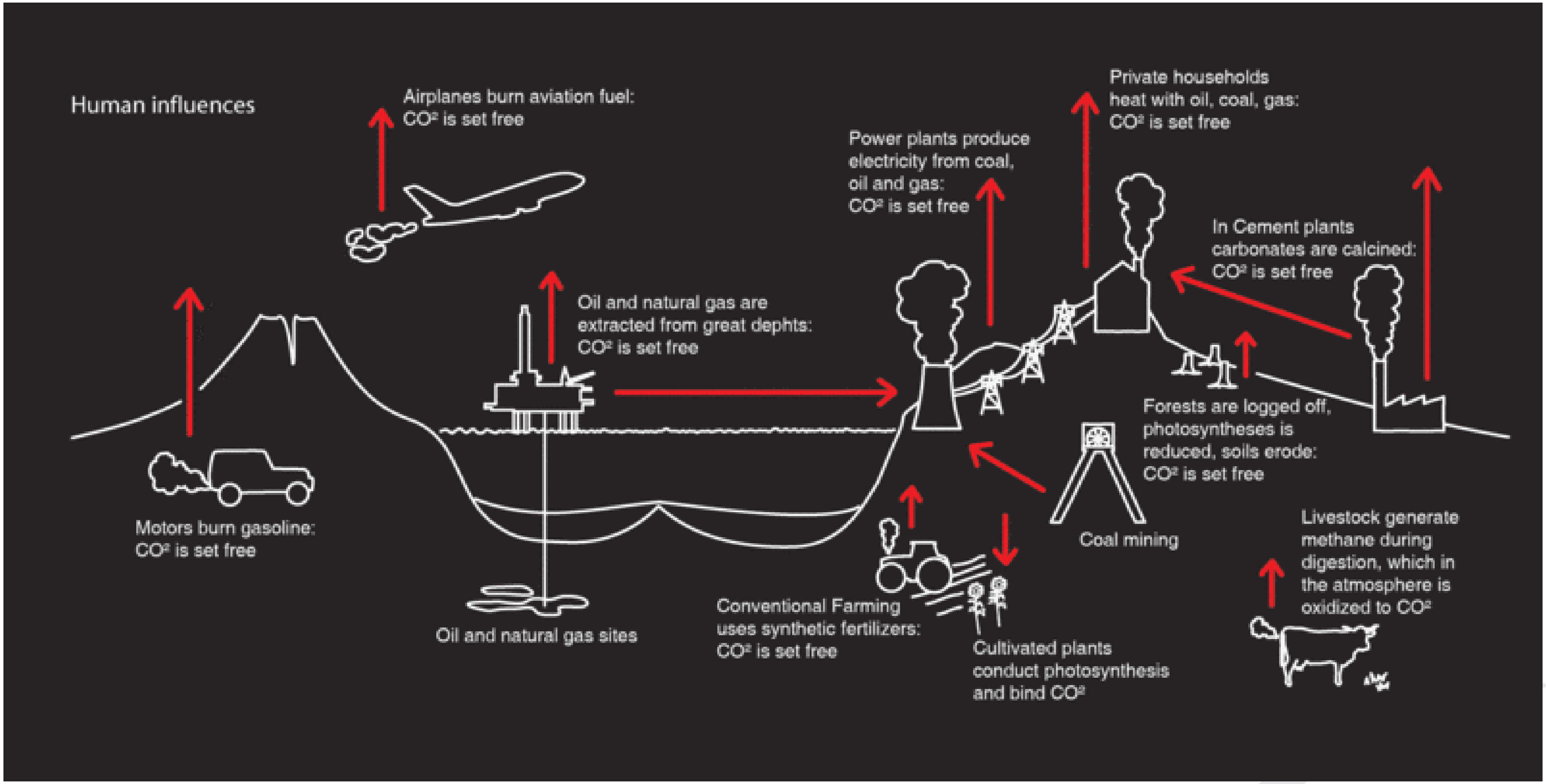
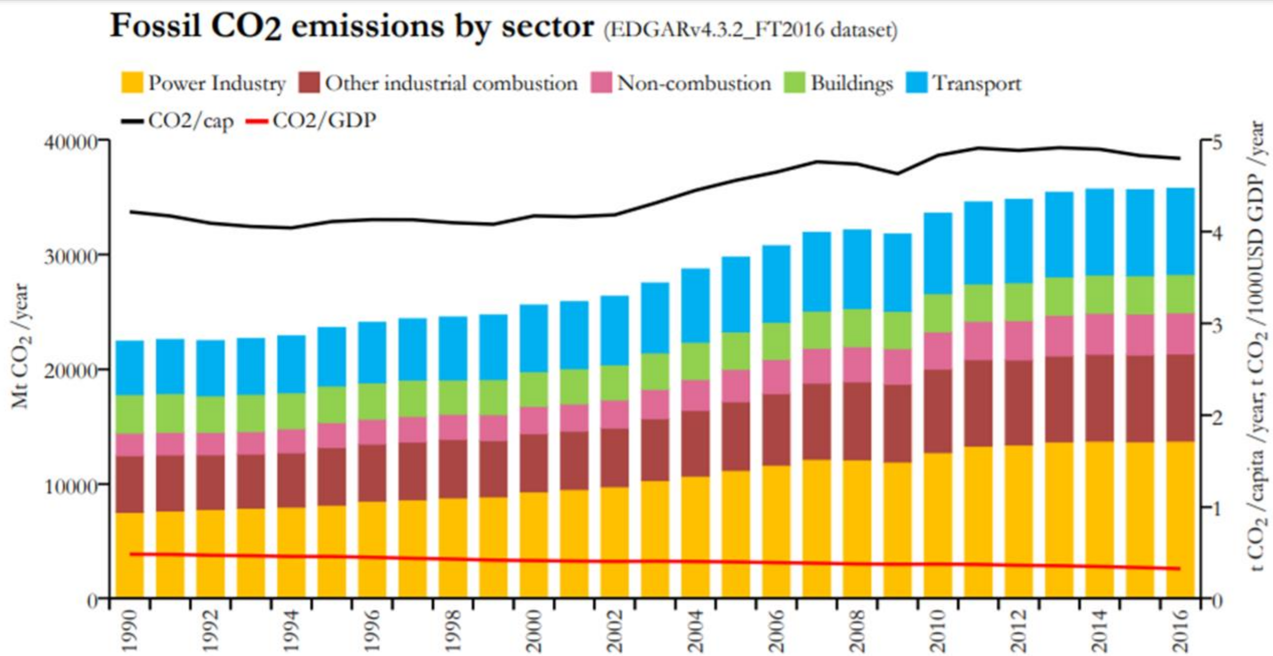
CARBON SOURCES

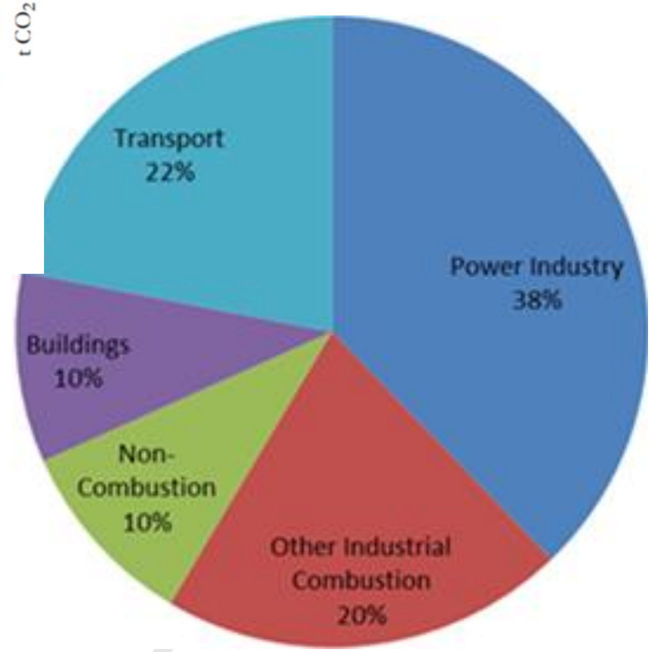


Source: University of Augsburg, Environmental Science Center (WZU)

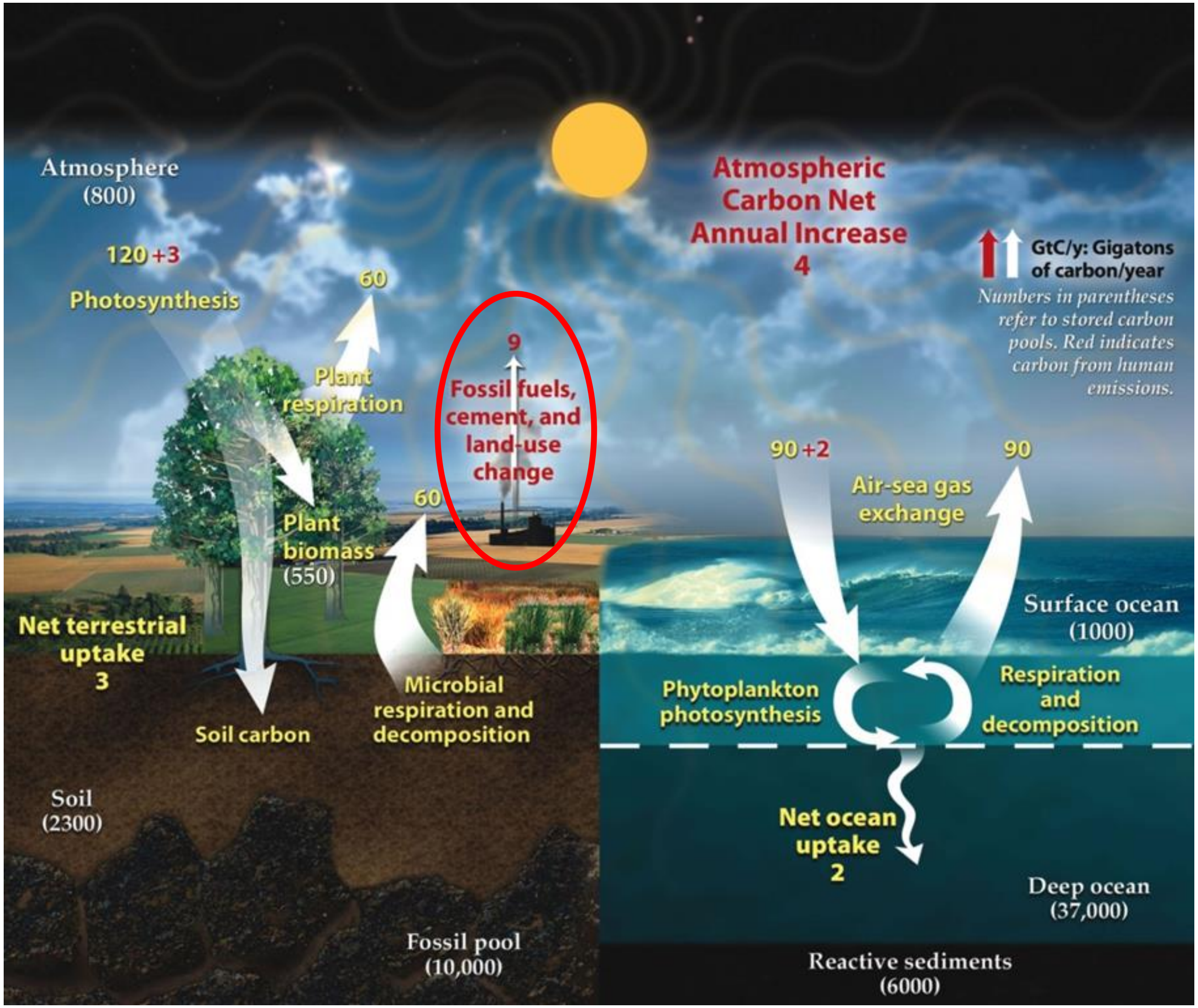
GLOBAL CO_2 EMISSIONS BY SECTOR



Year	Mt CO_2/yr	t CO_2/cap/yr	t CO_2/kUSD/yr	population
2016	35753.306	4.796	0.321	7461900000
1990	22450.442	4.215	0.479	5328680000



SIMPLIFIED GLOBAL CARBON CYCLE



Source: US Department of Energy

Movement of **Carbon** between land, atmosphere, and ocean in giga tons per year.

Yellow numbers are natural fluxes,

Red numbers are human contributions,

White arrows indicate natural cycle.

The effects of volcanic and tectonic activity are not included.

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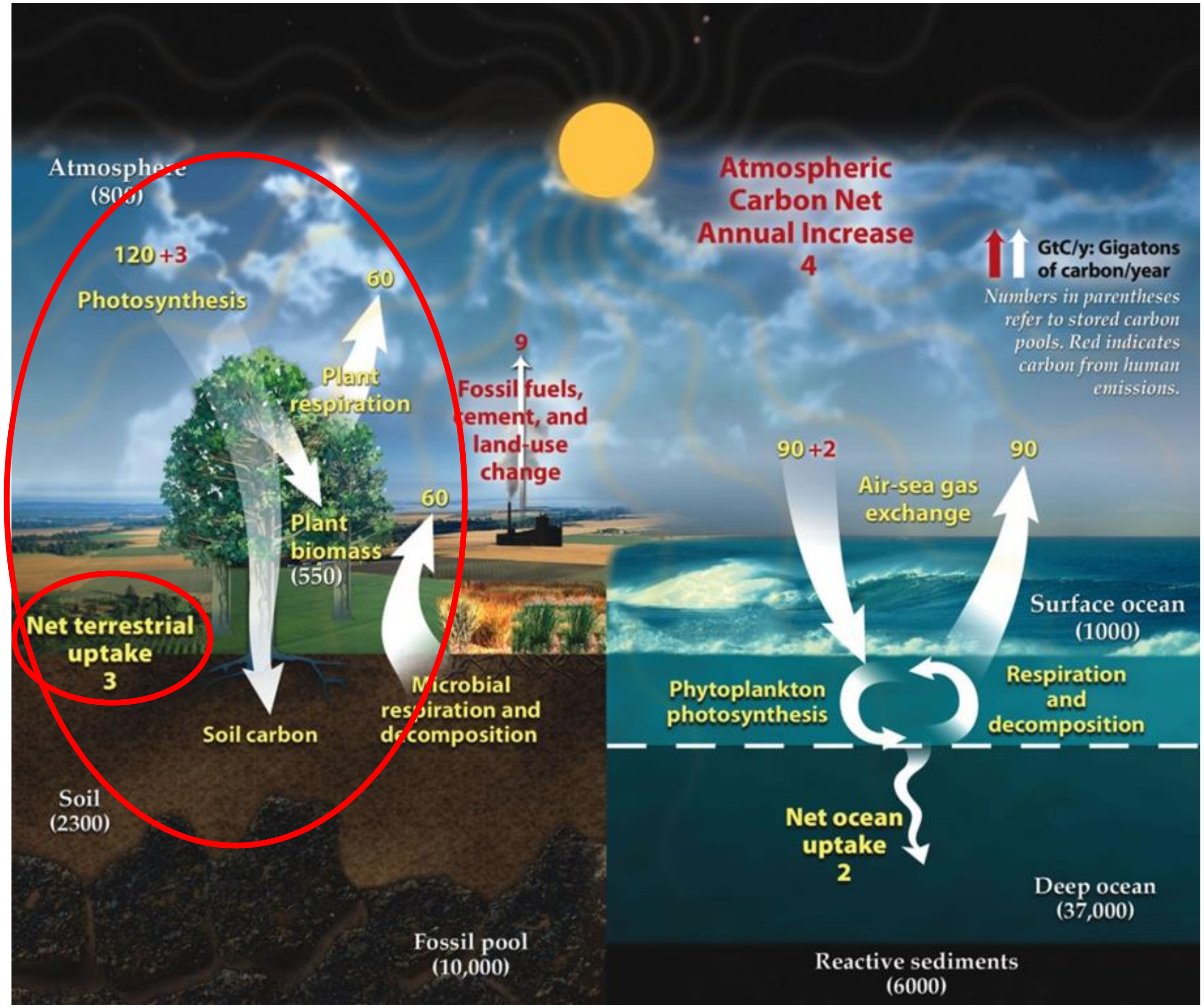

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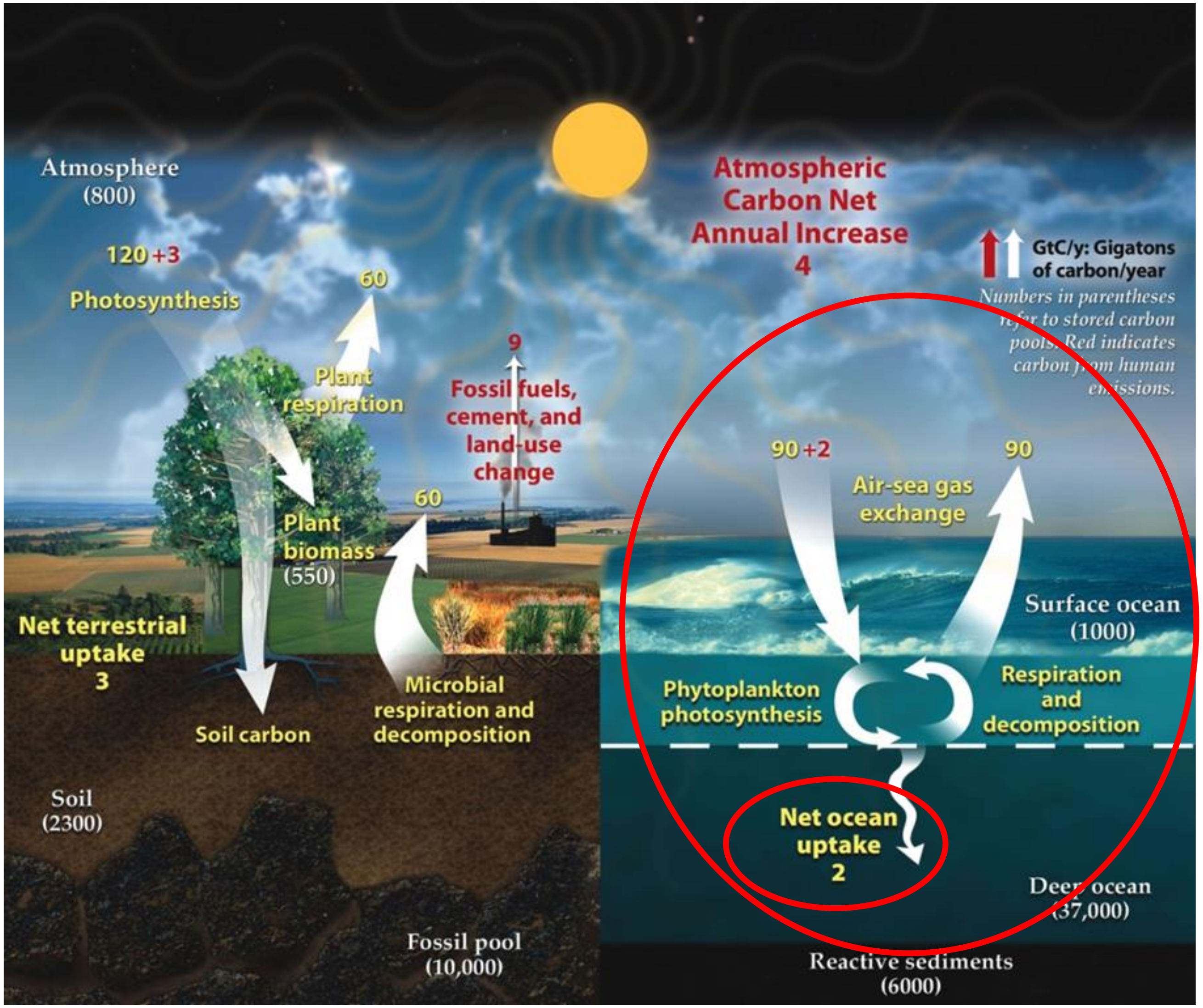

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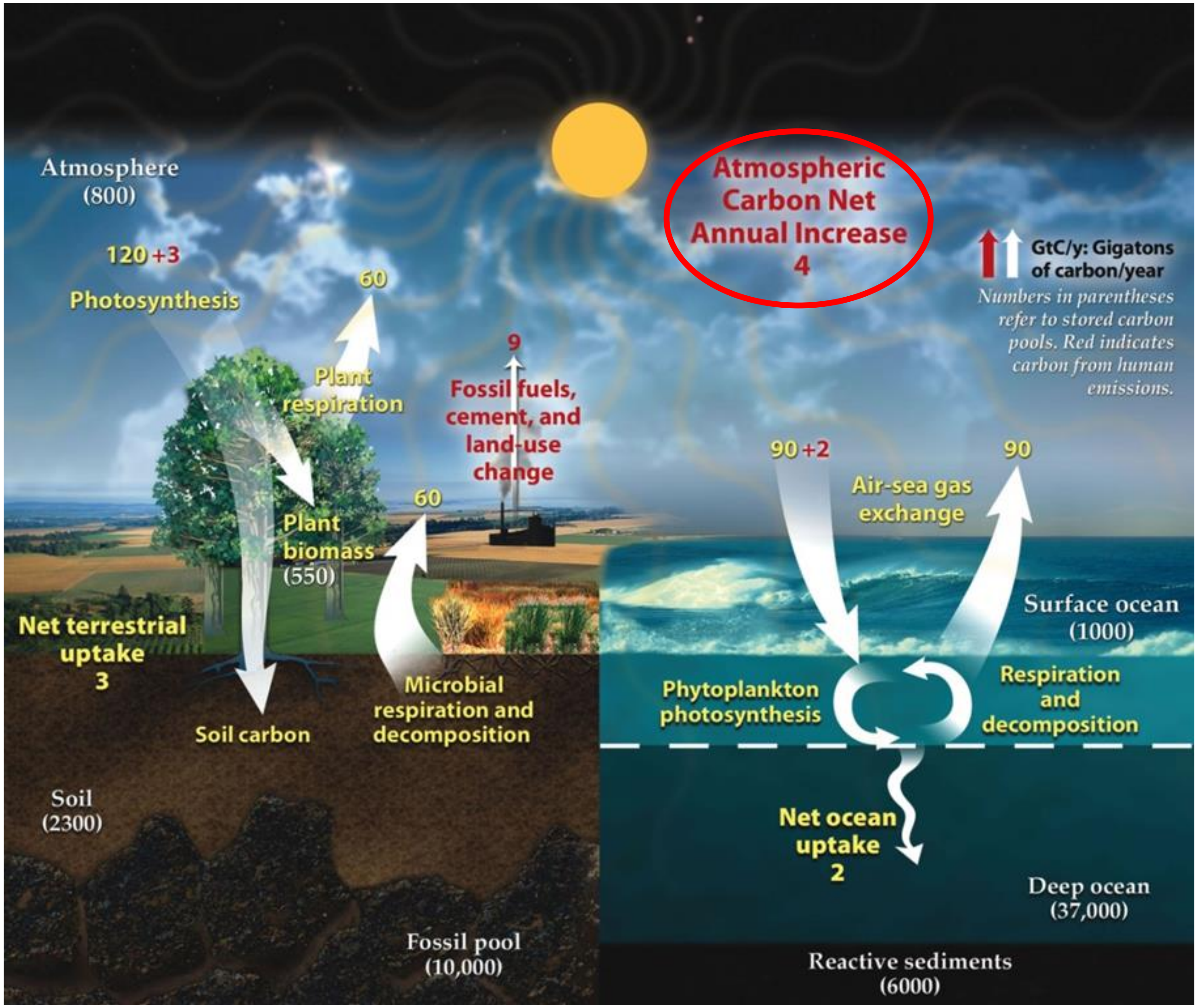

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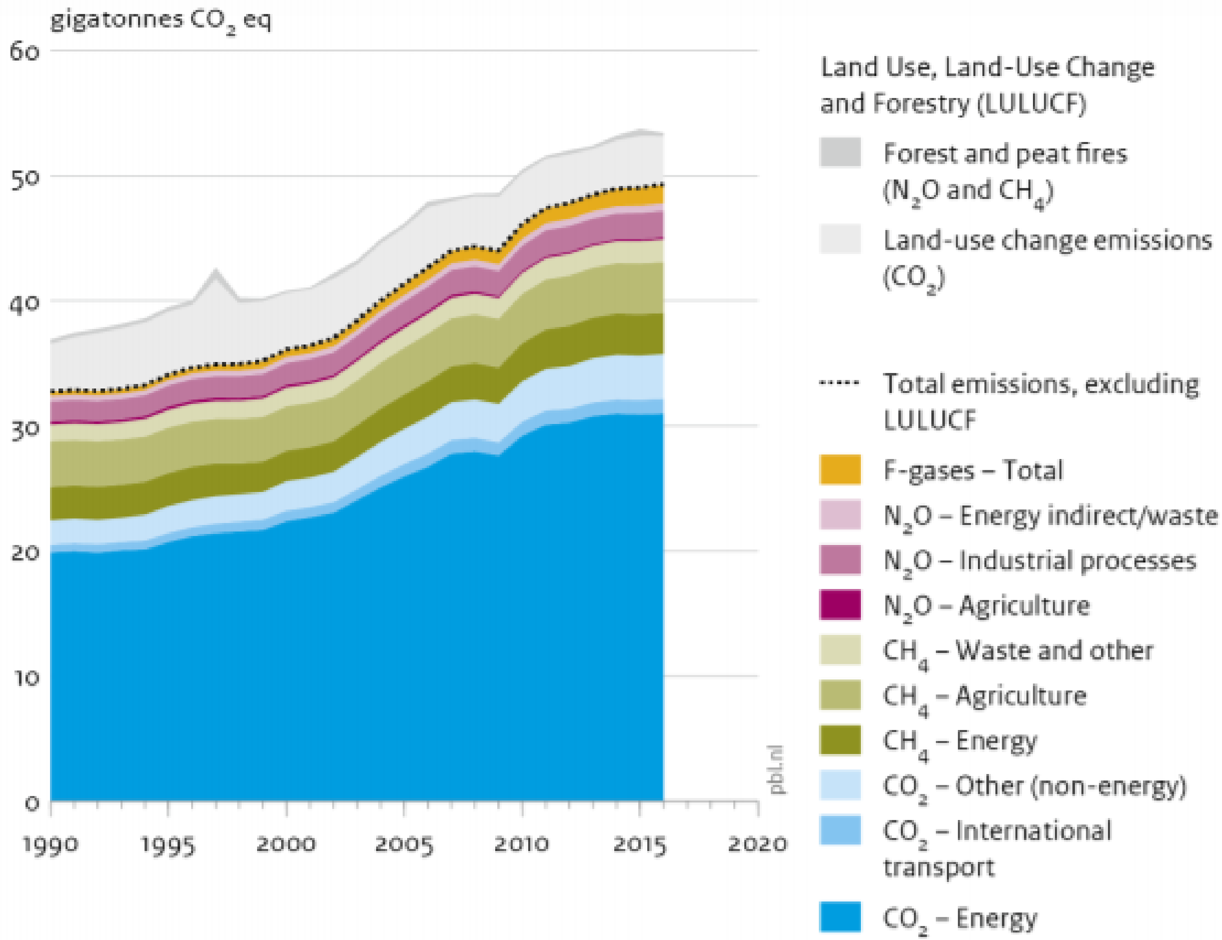
GLOBAL GHG EMISSIONS as CO_{2eq}

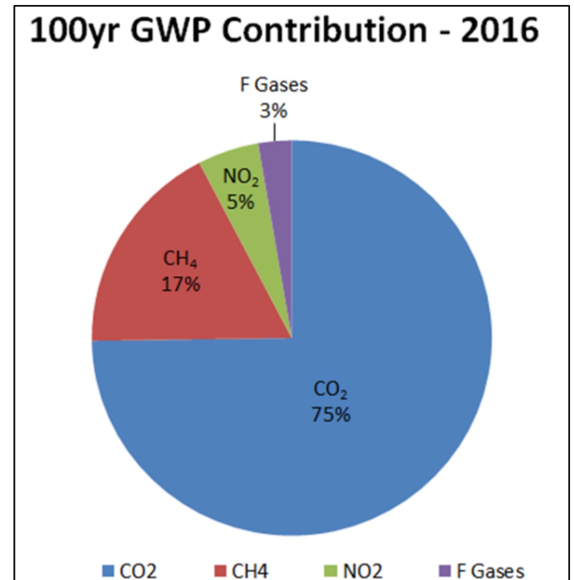
Global greenhouse gas emissions, per type of gas and source, including LULUCF



Source: EDGAR v4.3.2 (EC-JRC/PBL 2017); Houghton and Nassikas (2017); GFED 4.1s (2017)

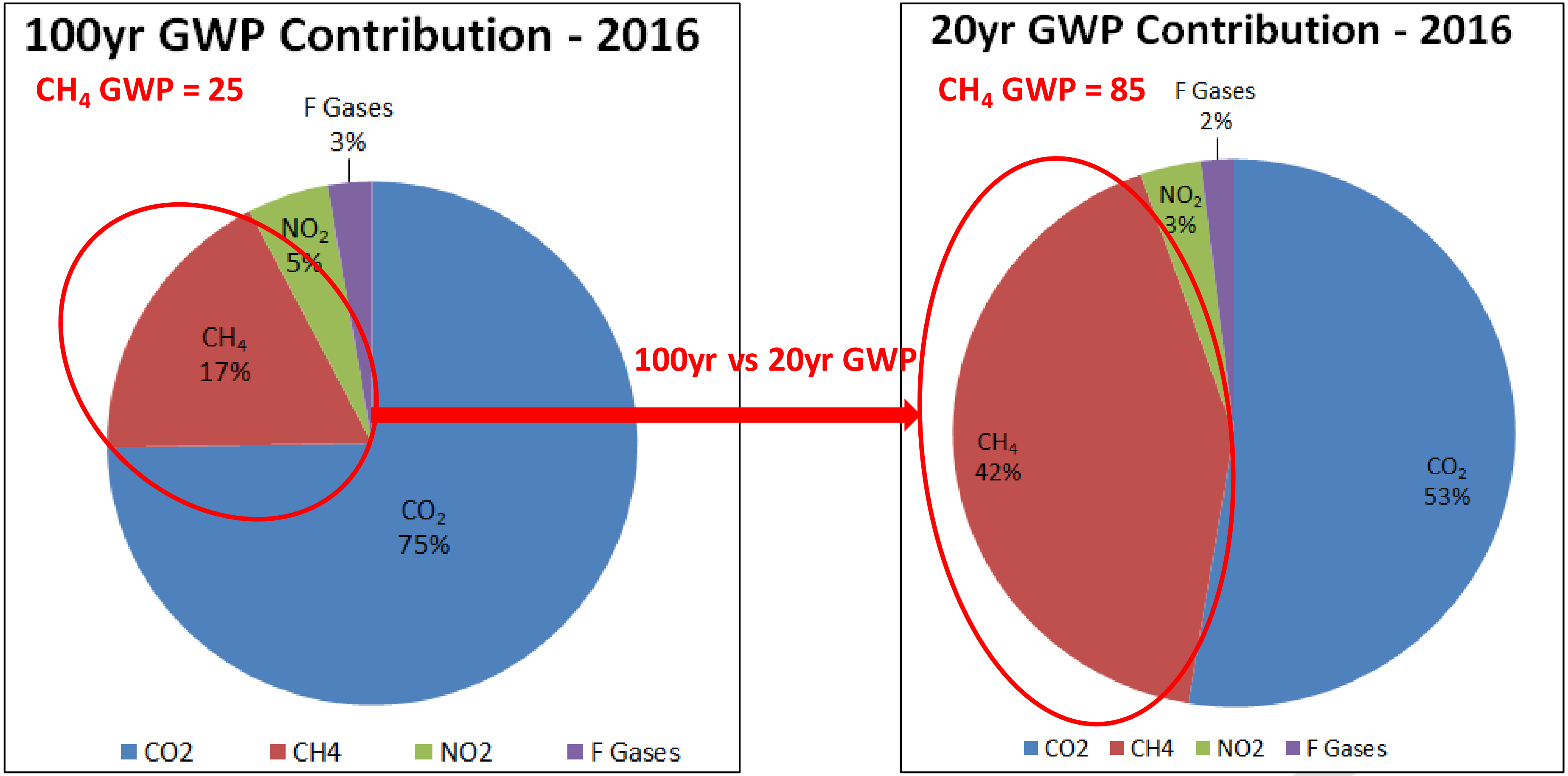
<u>GHG Contribution</u>

CO_2	~ 75%
Non CO_2	~ 25%



(EDGAR: = The **E**missions Inventory **D**ata for **G**lobal **A**tmospheric **R**esearch)

IMPACT of NON-CO_2 GAS LIFE



Super-pollutant greenhouse gases such as methane, nitrous oxide and fluorinated compounds have an outsize negative impact and collectively contribute contribute ~47% (@ CH_4 GWP of 85) to the current the global warming trend.

4. LNG vs Coal

HOW CLEAN is LNG

- **A FACT:** Smokestack emissions from gas combustion are significantly lower than from coal combustion.

- Emissions from smokestacks, however, do not tell the full story

- Each fossil fuel has a different life cycle and each fuel contributes greenhouse gases at different stages of its life cycle.

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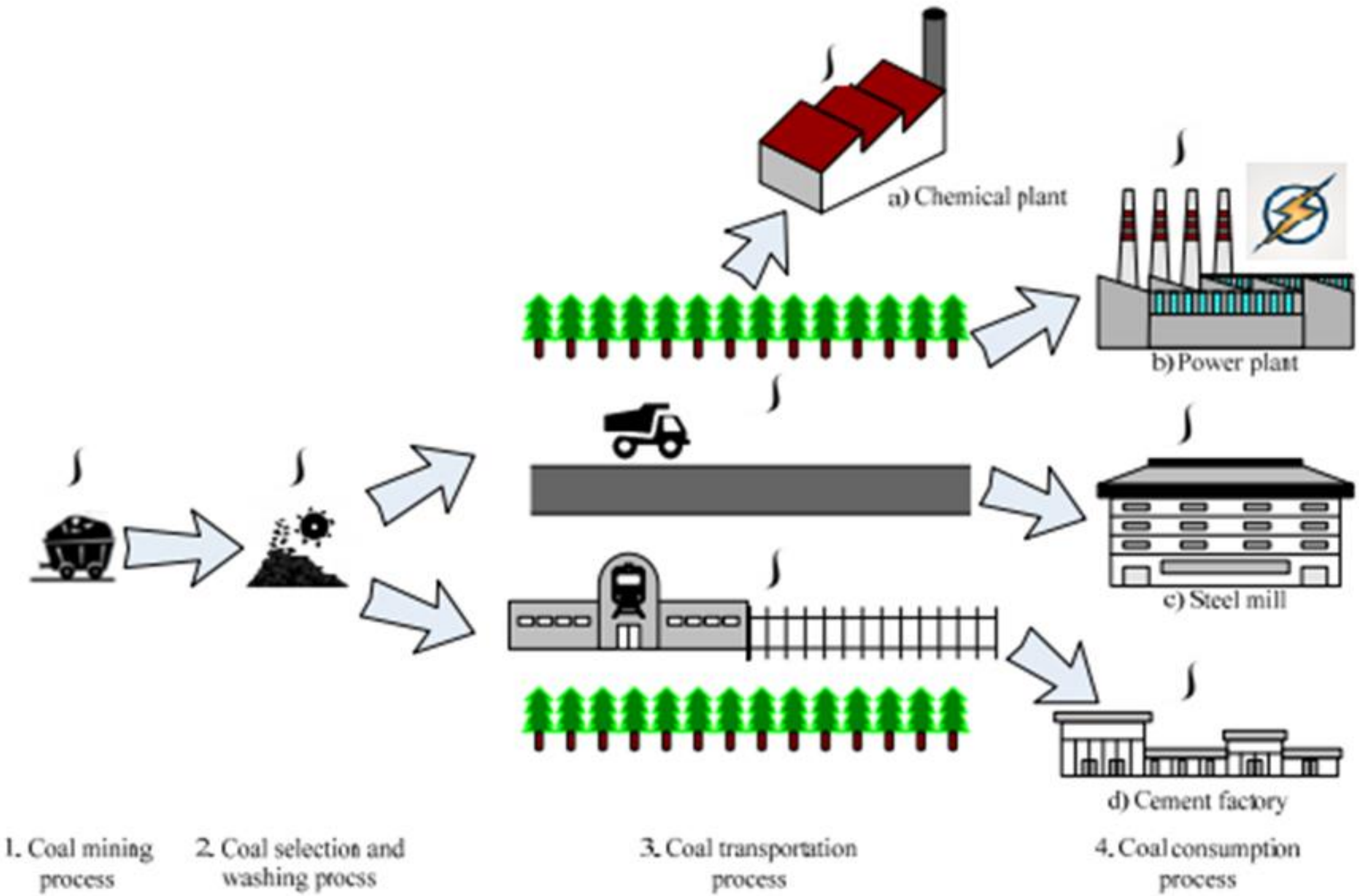
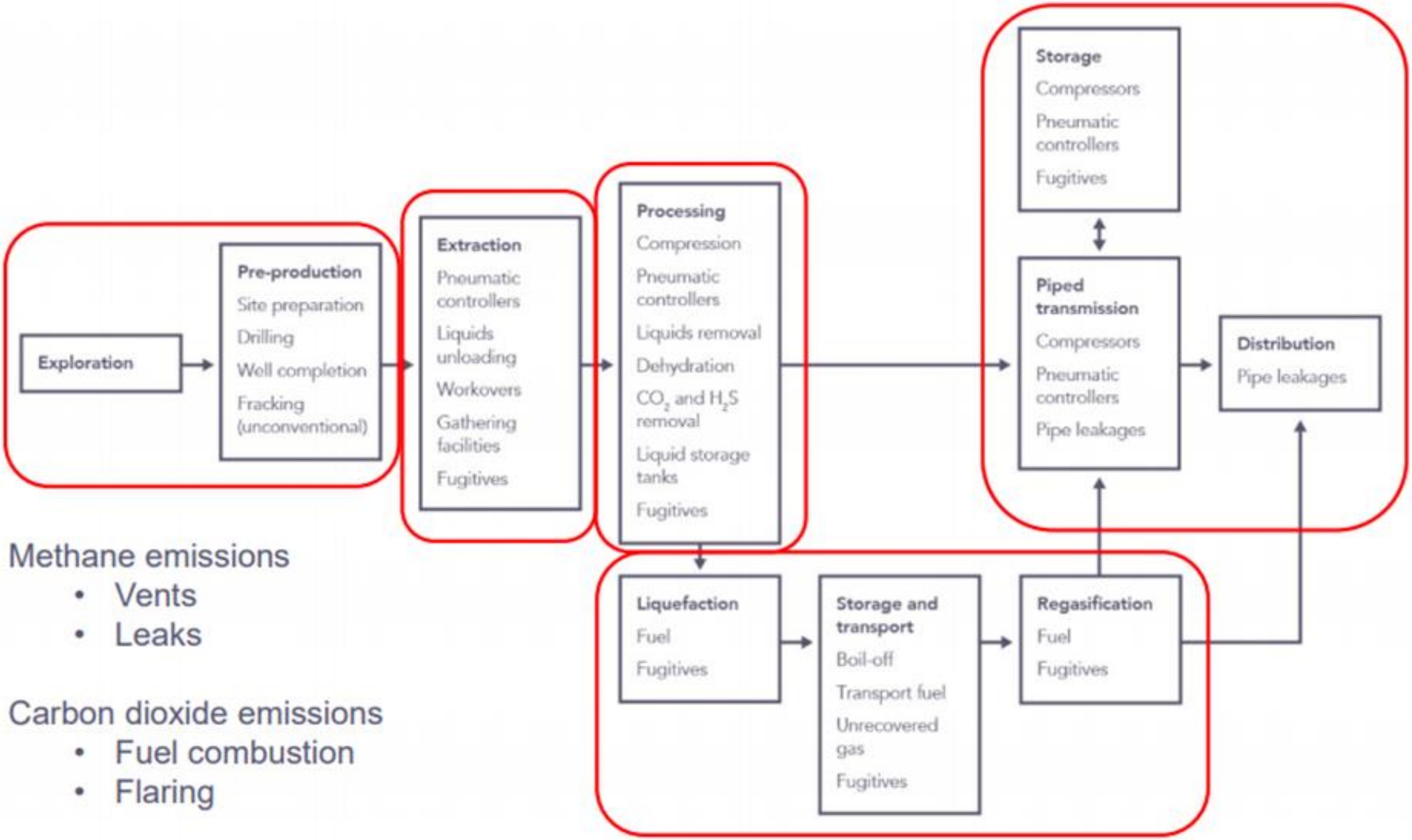


LNG VALUE CHAIN



Methane emissions

- Vents
- Leaks

Carbon dioxide emissions

- Fuel combustion
- Flaring

GAS COMBUSTION

- Banked Systems (ie.systems kept warm for scheduled or emergency use) and intermittently used plants often lead to poor system efficiencies
- Operating at Altitude and prevailing Ambient conditions have a negative impact on efficiency.
- The operating mode
- The impact of emissions in the value chain

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EMISSIONS STUDY - AUSTRALIA

- 2011 Australian Study to test LNG's advantage in emissions, particularly when displacing coal. Coal exported and burned in Chinese power plants

- The emissions intensity at the smoke-stack (t/MWhr)
  - LNG burned in a combined-cycle gas turbine plant was 0.44 tons
  - 0.72 tons with an ultra-super critical boiler,
  - 1.02 tons for a sub-critical plant

- Annual Production : 20 million tons of LNG and 500 million tons of black coal and a smaller portion of brown coal.

- Total emissions from the nation's LNG production total about 8 million tons versus about 27 million tons for the entire coal mining industry.

- For the year ending June 2010, Rio Tinto Coal Australia reported total emissions of 3.44 million tons based on coal production of 47.5 million tons.

  By Comparison; Inpex and Total's Ichthys project will produce its 7 million tonnes of emissions from an 8.4 million tonne per year LNG project

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- Total emissions from the nation's LNG production total about 8 million tons versus about 27 million tons for the entire coal mining industry.

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- Power plant efficiencies and methane leakage rates explain most of the variance in greenhouse gas emissions by natural gas and coal power plants

- Upward pressure on prices is likely to result from increases in demand for natural gas for electricity and other competing uses. Such price volatility and supply insecurity can harm consumers and the economy.

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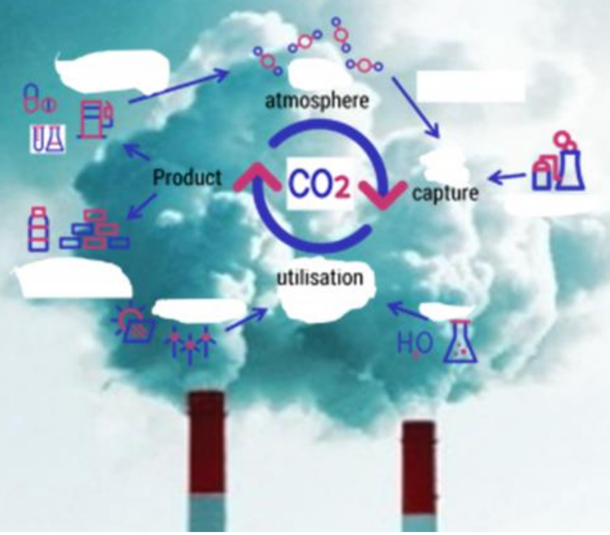

Vinesh Rajcoomar
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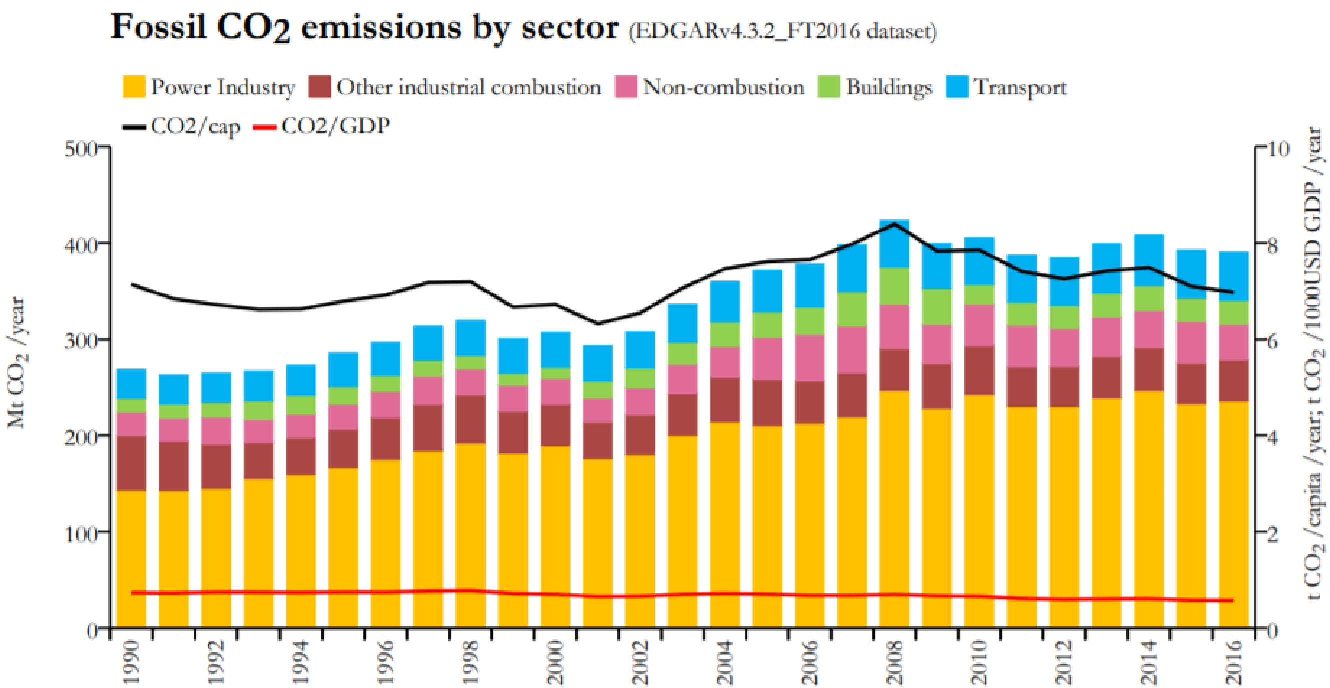
5. Improving the Image of Coal

EMISSIONS BY SECTOR – SOUTH AFRICA

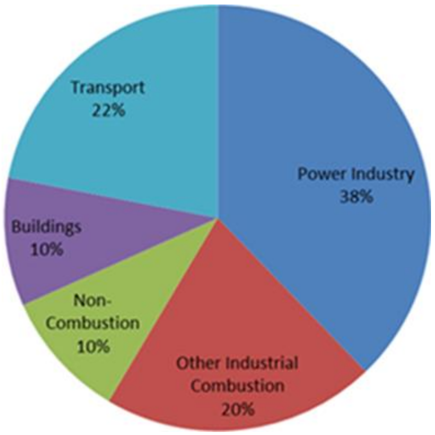


Year	Mt CO_2/yr	t CO_2/cap/yr	t CO_2/kUSD/yr	population
2016	390.558	6.974	0.570	56015473
1990	268.333	7.137	0.735	37560525

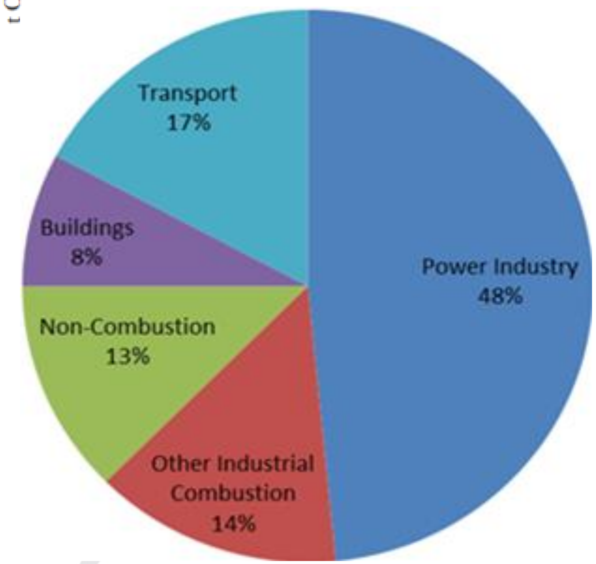
62% of emissions are from point sources which are more concentrated and preferred for capture

38% is from ambient air and are dilute and considered more challenging to capture

Global CO_2 Emissions



SA CO_2 Emissions



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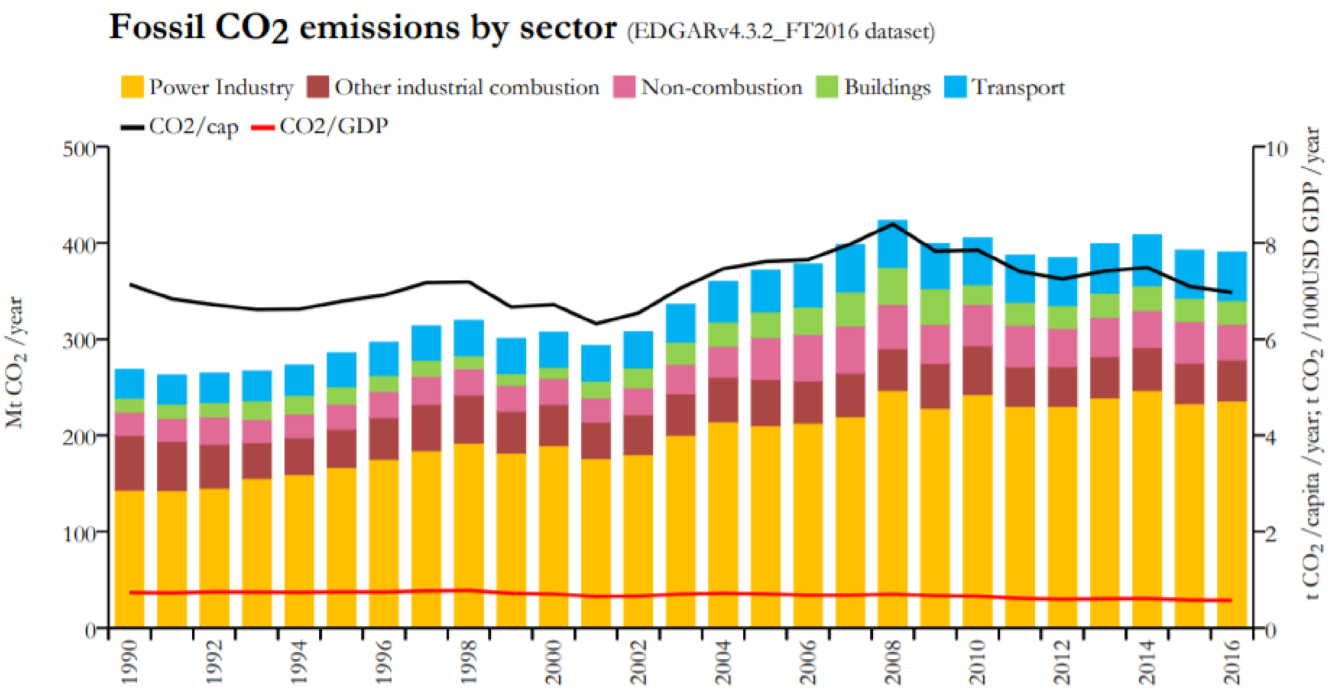

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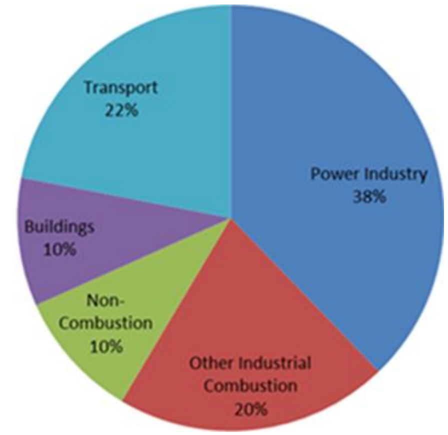

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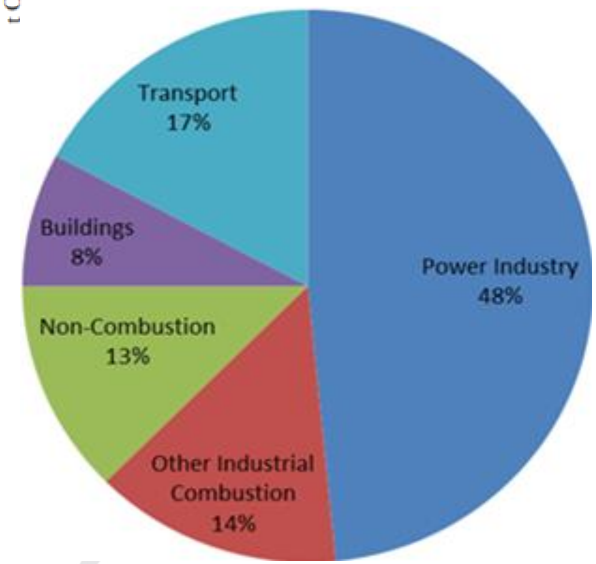

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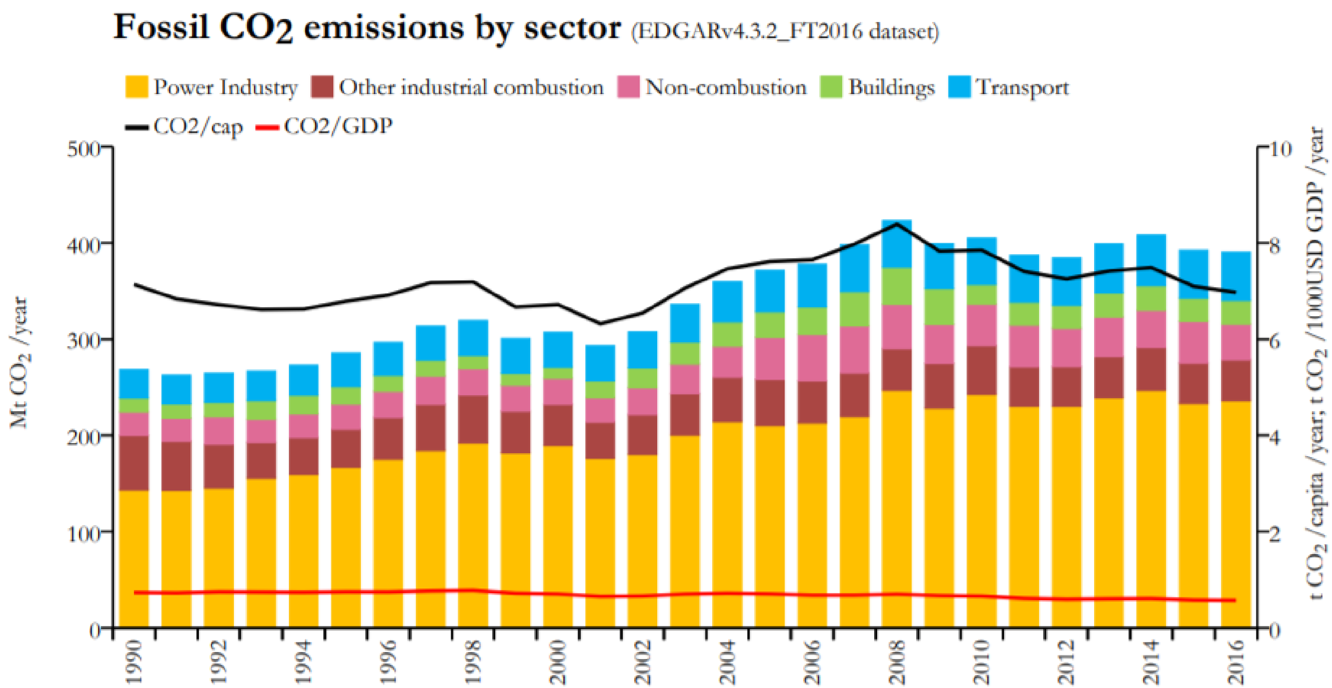
cleaning up CO_2 COAL



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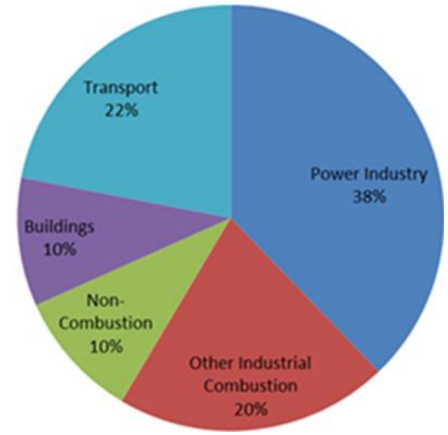

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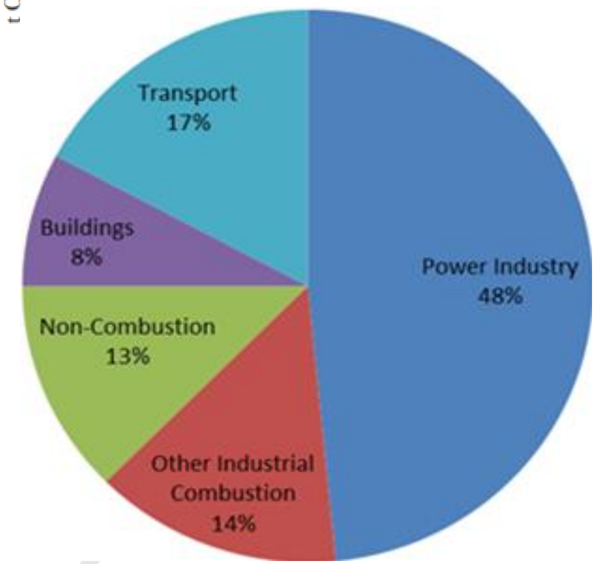

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CCT – CHP CONCEPT

- Increased efficiency by optimising the energy utilisation and the efficiency of the energy-generating process is the quickest, most effective and most cost-effective way to tackle CO_2 and GHG emissions.

- Water, energy and climate change are intrinsically interconnected.

- To maximise the many benefits that arise from combined heat and power solutions HELE Power generation can be combined with a Desalination Plant incorporating multiple power cogeneration opportunities.

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  - the type of cooling system used,
  - the operation cycles and load factor,
  - industrial symbiosis and industrial clustering

- Thermal power generation at coastal regions utilizing wet cooling technology will provide electricity more efficiently (between 3 – 5%) when compared to plants at higher altitudes utilizing dry cooling technology for identical power generating technology producing the same net power output.

- Additionally generating power close to the load centres would reduce transmission losses and assist with balancing the power grid.

- The combined effect of a better generating efficiency, lower transmission losses and generation close to the point of consumption will conservatively reduce the net carbon emissions footprint between 120 – 150 kg CO_2 / MWhr for the coastal plant.

- HELE thermal power generation technologies will provide electricity with a comparatively lower emissions profile. The average CO_2 at the point of generation for the ESKOM fleet is 1030 kg / MWhr compared to ~700 kg / MWhr for HELE technology.

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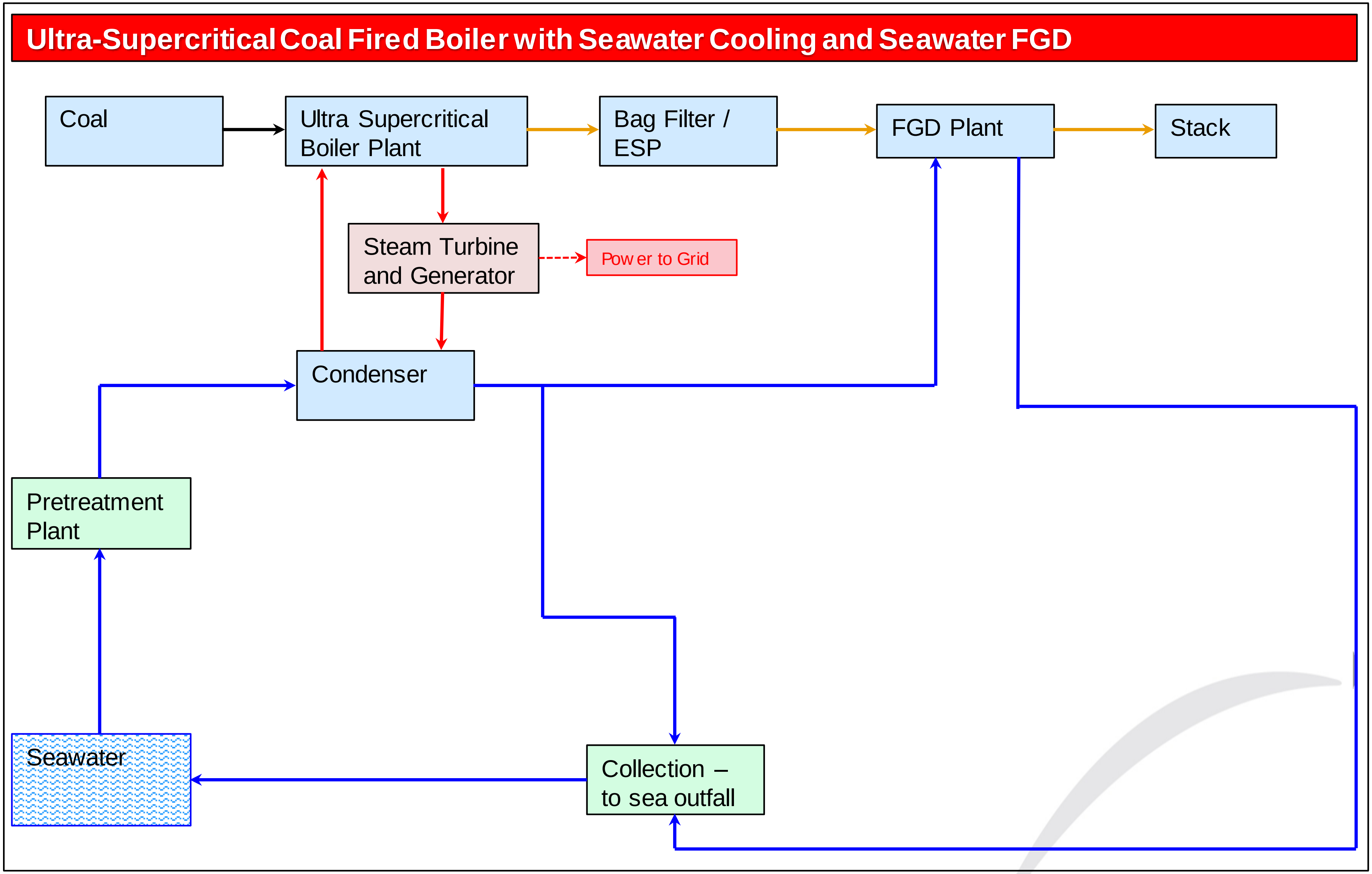

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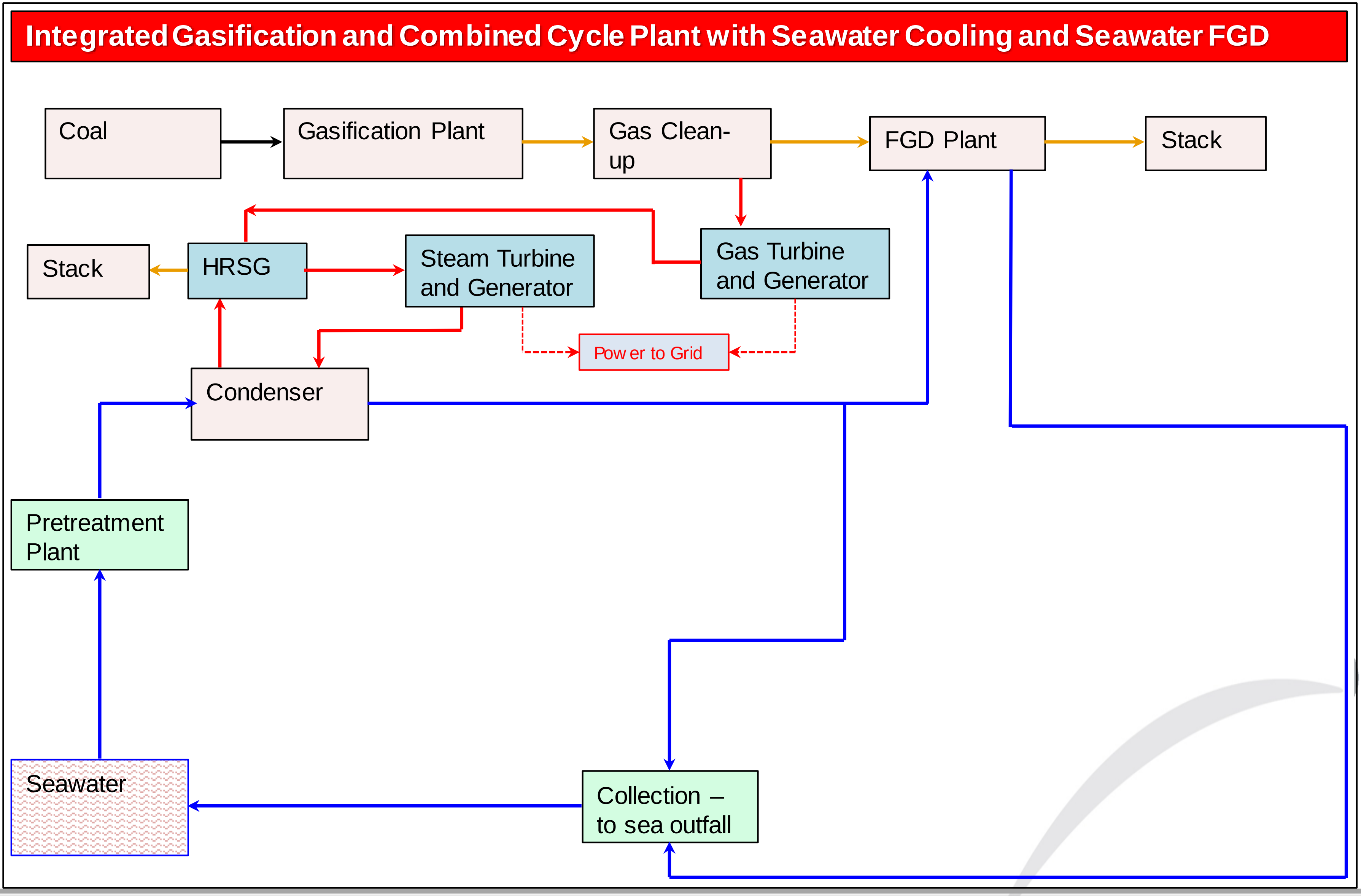

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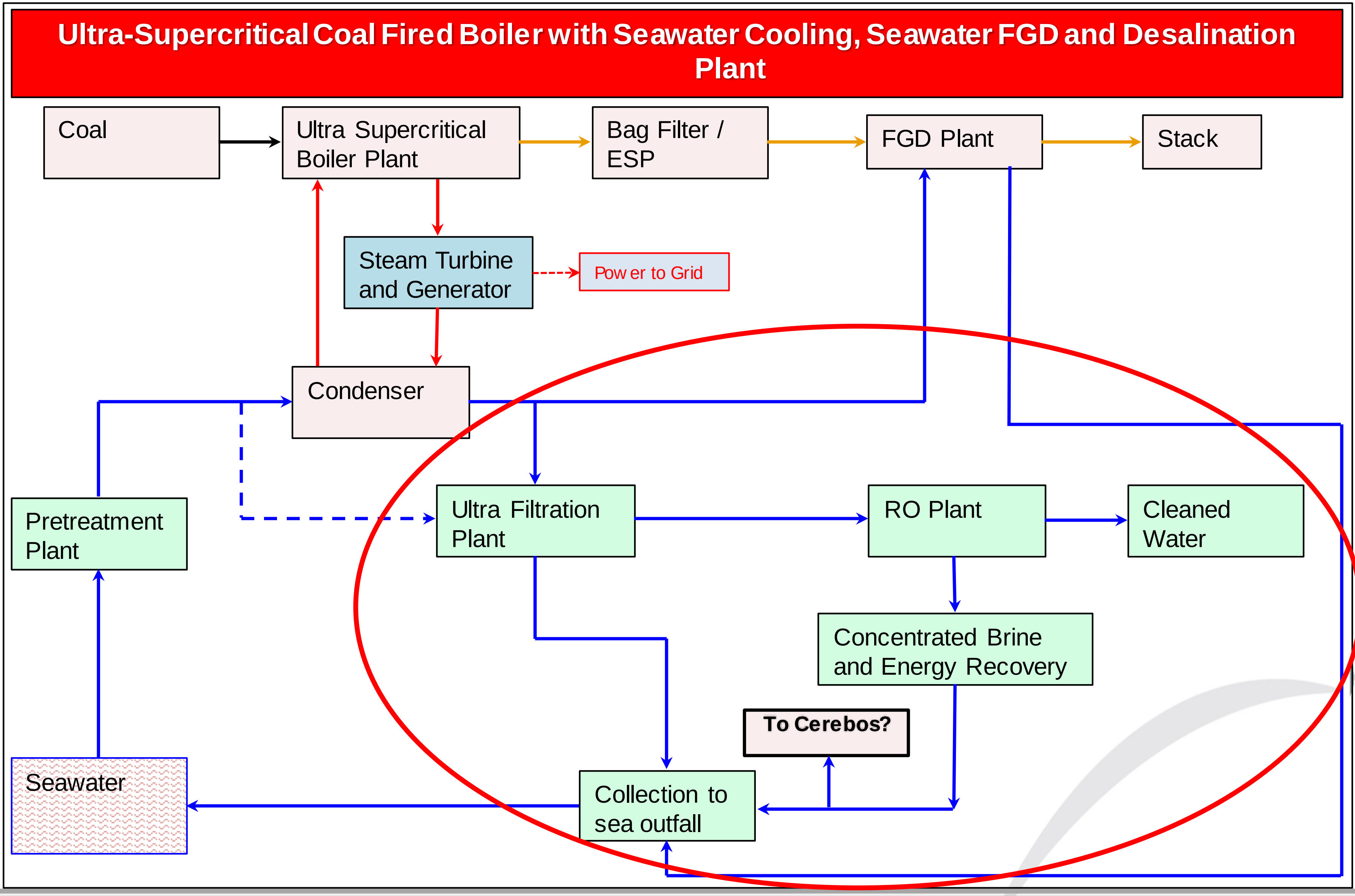

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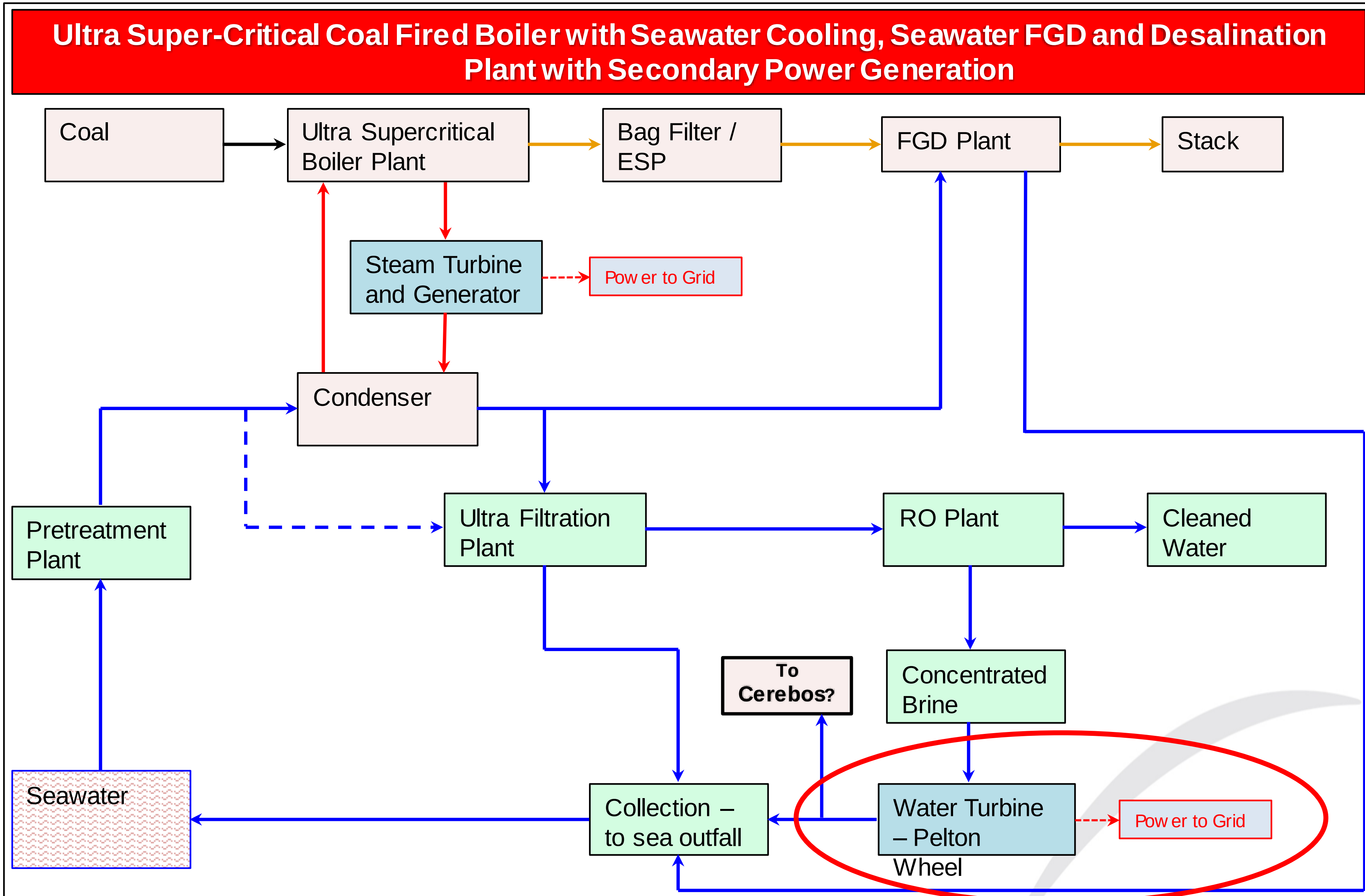

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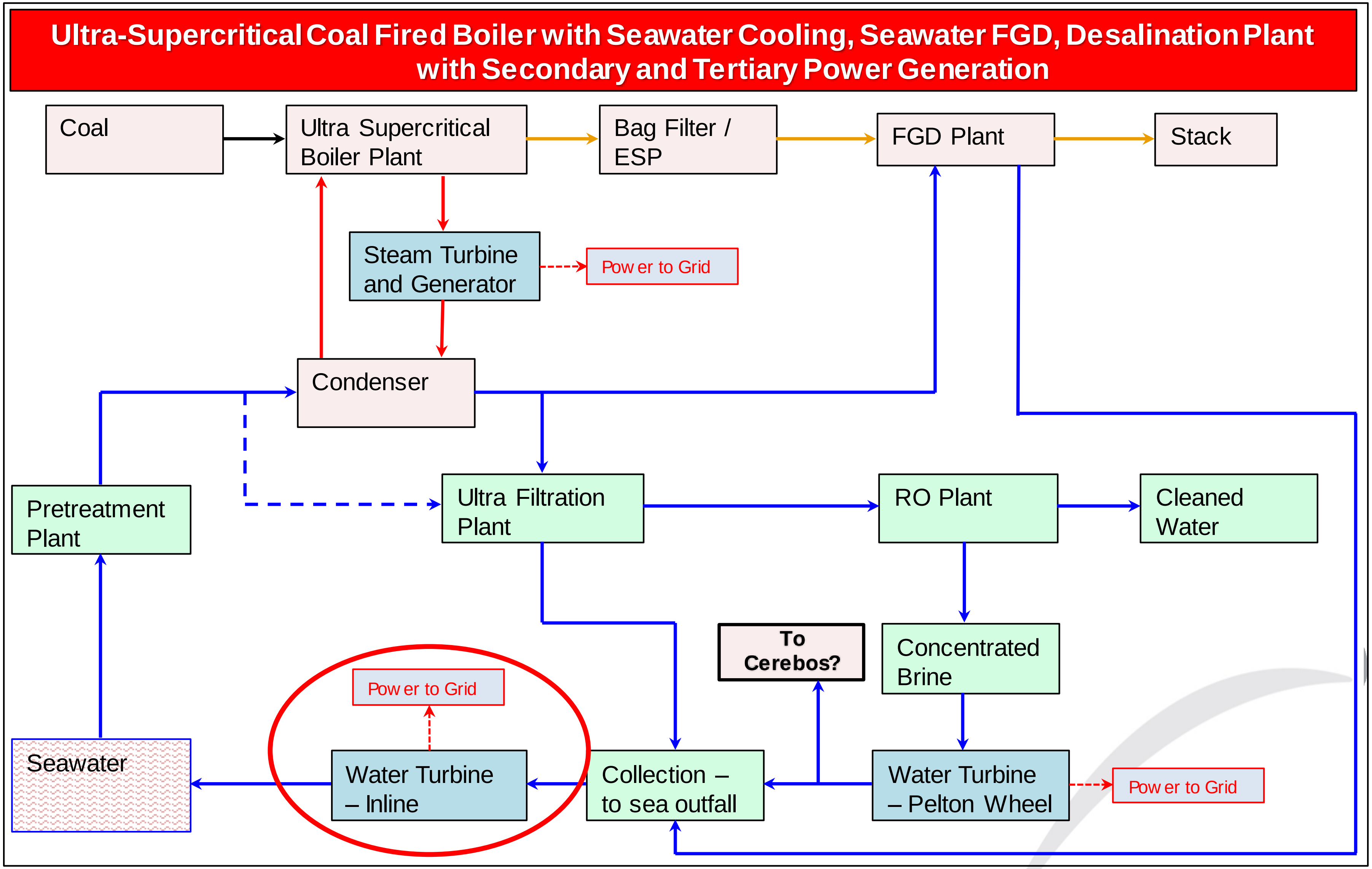

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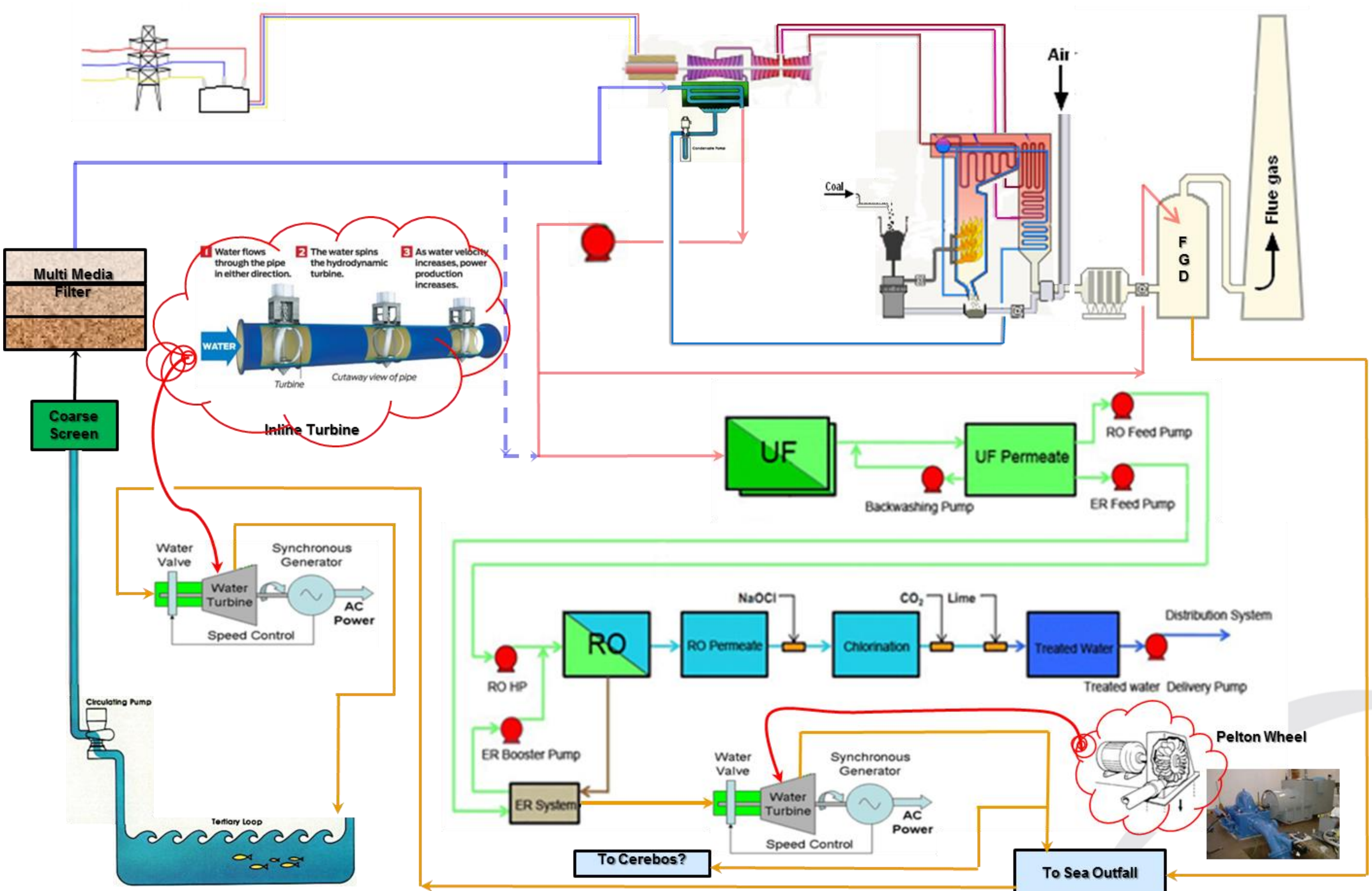
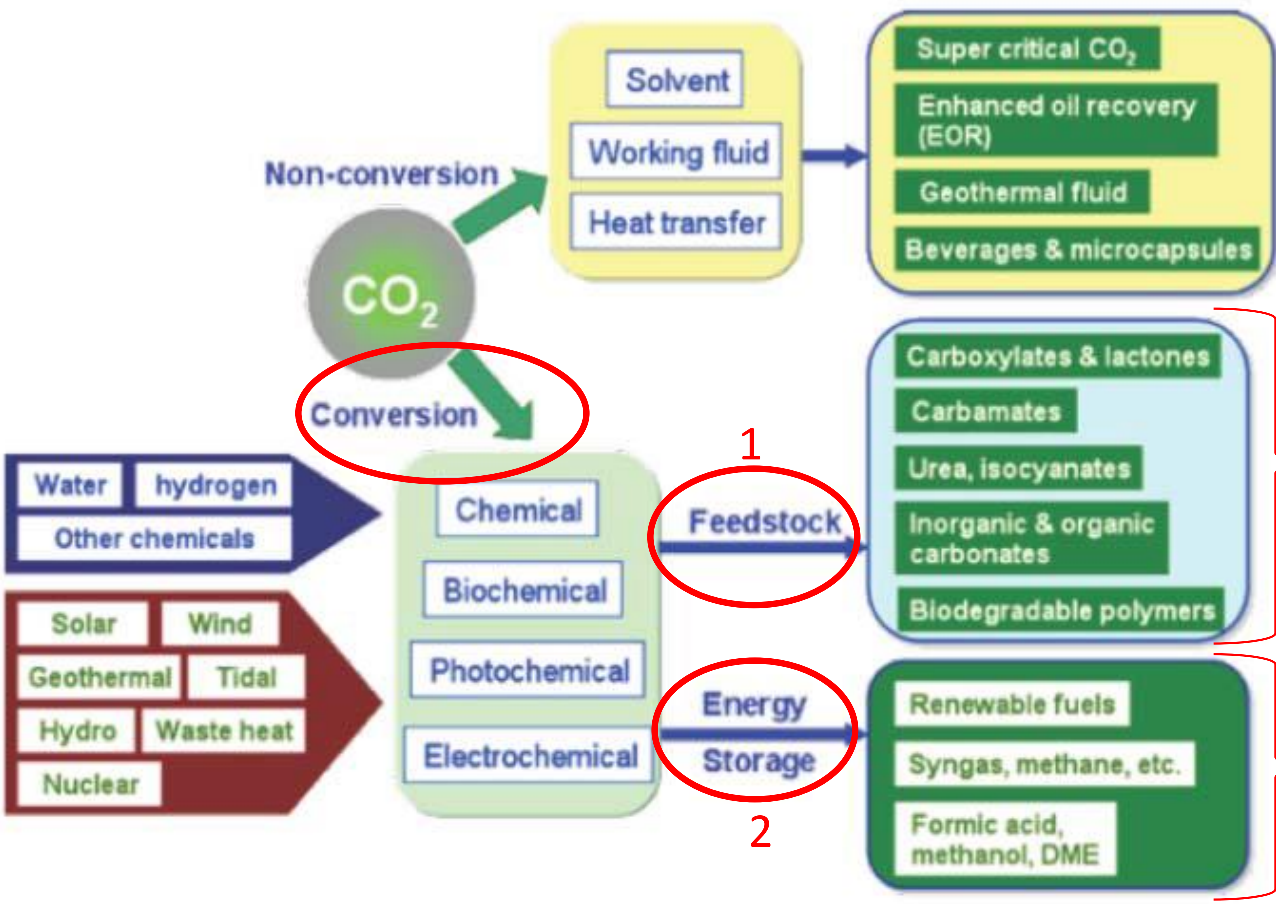


CARBON UTILISATION PATHWAYS



The carbon capture and utilization (CCU) paradigm advances the view that CO_2 is a valuable source of carbon.

The utilisation reactions can be differentiated into two main groups:

- Reaction with other reactants to form fine chemicals.
- Conversion with hydrogen (synthesis gas) to form hydrocarbons or simple alcohols (methanol)

Source: Carbon Dioxide Utilization – Electrochemical Conversion of CO_2 – Opportunities and Challenges, DnV Research and Innovation, Position Paper 07-2011

CCU as a MITIGATION STRATEGY

- Energy efficiency and renewables are often positioned as the only solutions needed to meet climate goals in the energy system, but they are not enough.

- However, without carbon capture and utilisation coal power plants cannot achieve the deep reductions that would be required to avoid substantial contribution to global warming.

- Carbon is an input chemical and basic component for numerous processes and economic activities which is mainly derived from fossil-based raw materials.

- Globally over 90% of organic chemicals are derived from fossil based carbon which constitutes only 7% of the global demand of crude oil.

("The grand challenges in carbon capture, utilization, and storage: Berend Smit; Ah-Hyung Alissa Park and Greeshma Gadikota – Published Nov 2014).

- The fuel pathway that has the potential to provide the most meaningful impact on CO_2 emissions with the production of Methane, methanol and DME

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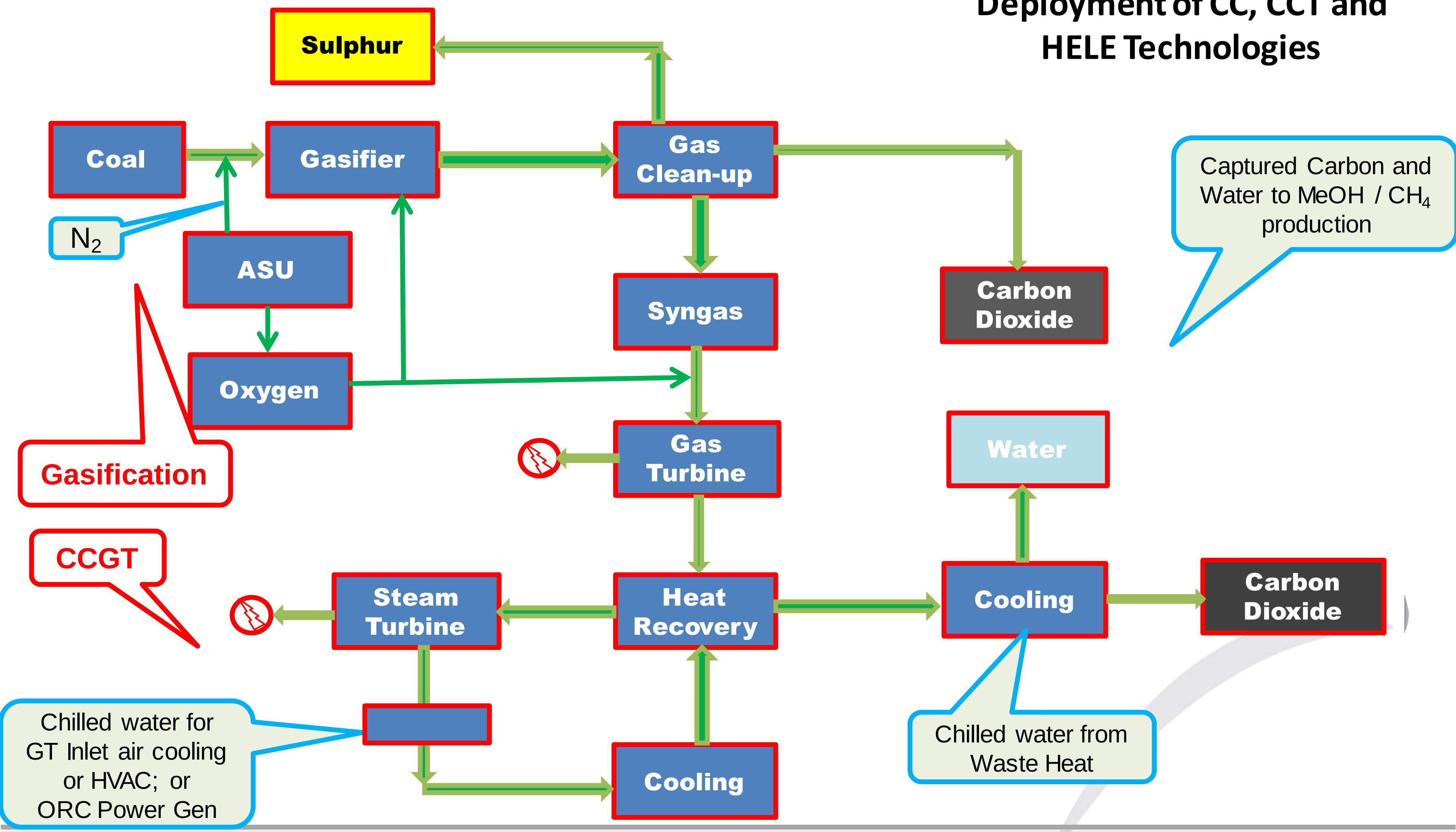
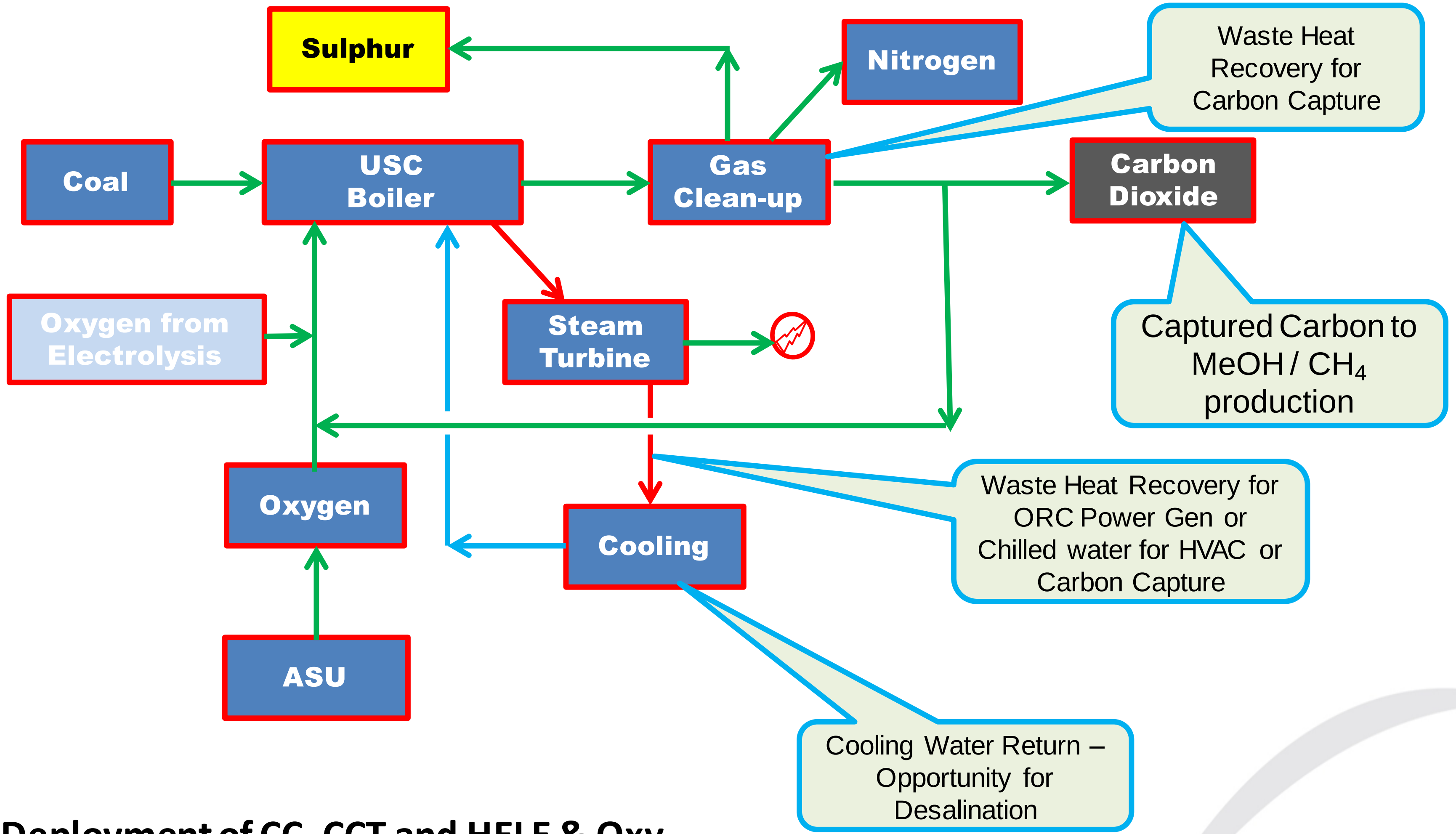
CARBON CAPTURE CONCEPT WITH IGCC

Deployment of CC, CCT and HELE Technologies

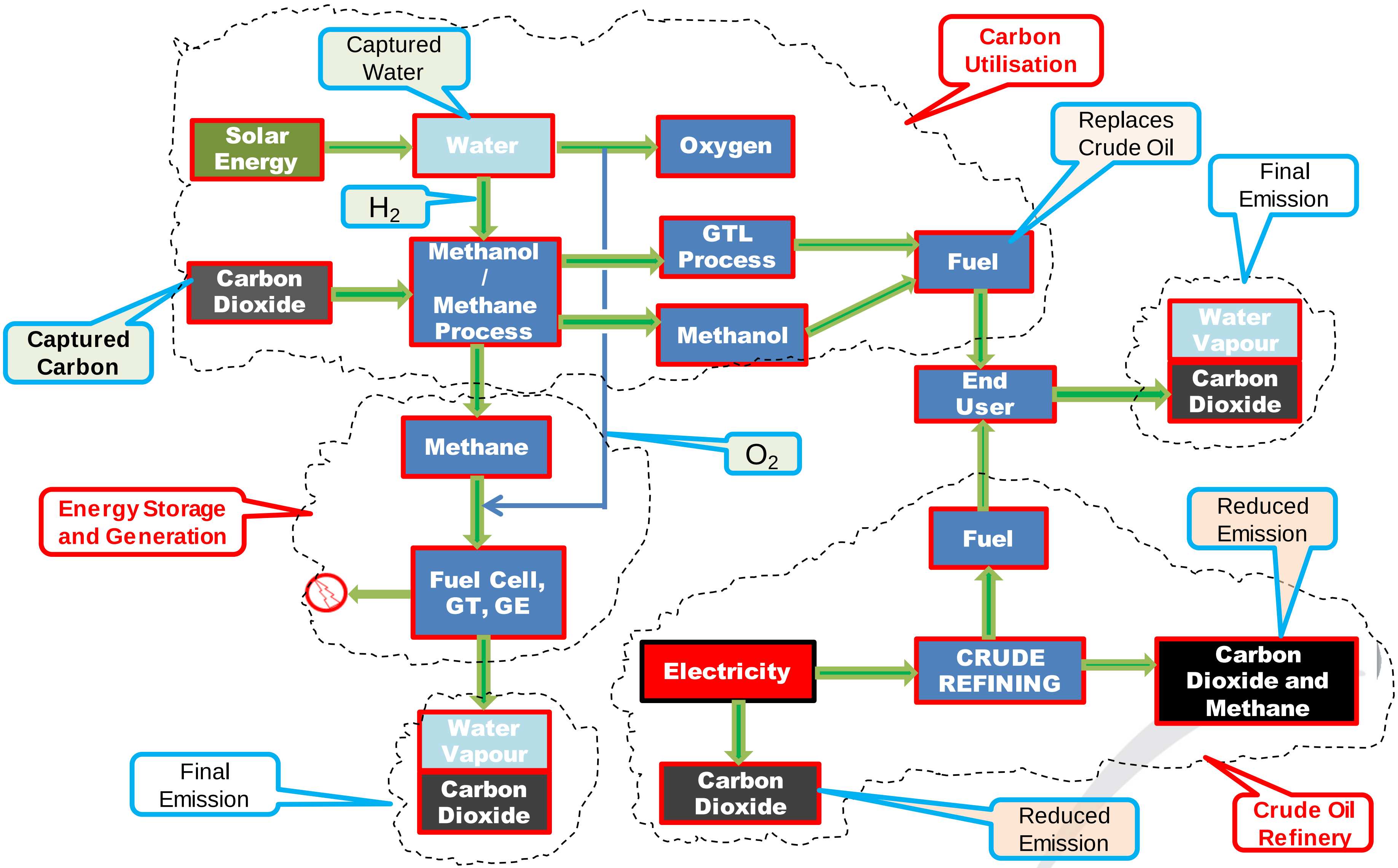


CARBON CAPTURE CONCEPT WITH USC/SC BOILER

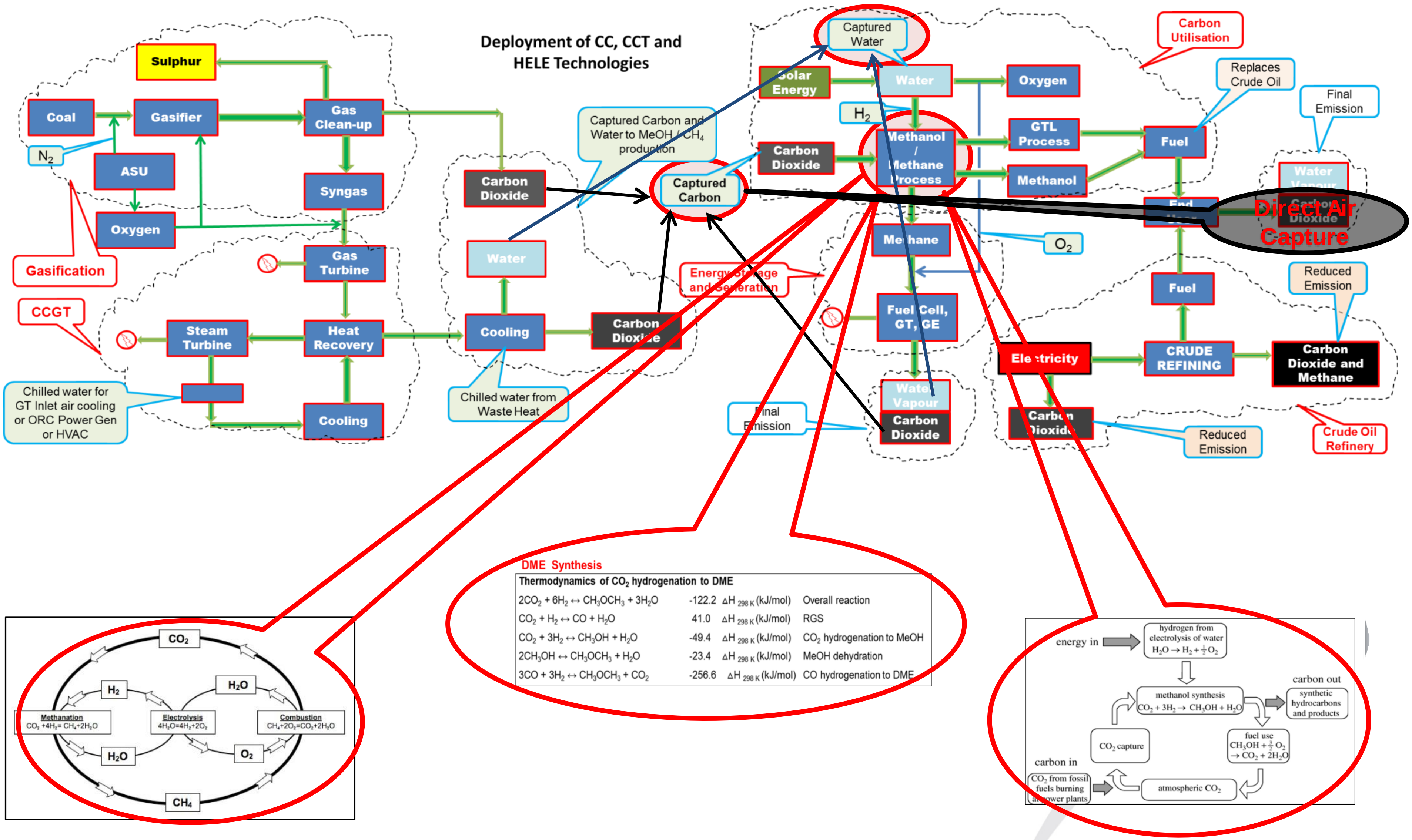


Deployment of CC, CCT and HELE & Oxy-Combustion Technologies

CO_2 UTILISATION – SYNTHETIC FUEL CONCEPT



CCU – CARBON REUSE CONCEPT



Thermodynamics of CO_2 hydrogenation to DME

$2CO_2 + 6H_2 \leftrightarrow CH_3OCH_3 + 3H_2O$	-122.2 $\Delta H_{298\,K}$ (kJ/mol)	Overall reaction
$CO_2 + H_2 \leftrightarrow CO + H_2O$	41.0 $\Delta H_{298\,K}$ (kJ/mol)	RGS
$CO_2 + 3H_2 \leftrightarrow CH_3OH + H_2O$	-49.4 $\Delta H_{298\,K}$ (kJ/mol)	CO_2 hydrogenation to MeOH
$2CH_3OH \leftrightarrow CH_3OCH_3 + H_2O$	-23.4 $\Delta H_{298\,K}$ (kJ/mol)	MeOH dehydration
$3CO + 3H_2 \leftrightarrow CH_3OCH_3 + CO_2$	-256.6 $\Delta H_{298\,K}$ (kJ/mol)	CO hydrogenation to DME

CONCLUDING REMARKS

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- Indigenous supplies will increasingly play a role in maintaining diversity and security of supply, whilst coal plants often seek opportunities to increase their efficiency.

- Waste CO_2 has the potential to become an important resource for conversion into useable products and fuels resulting in significant GHG emissions reductions.

- CCU would be a way to:
  - produce renewable fuels for transport and or power generation
  - store solar and wind energy

- There is a huge OPPORTUNITY for SA to make CO_2 an Energy Source
  - SA is the leading country in GTL and CTL Technologies
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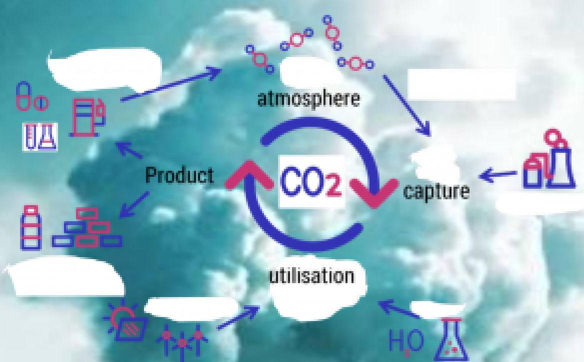
    - Good renewable resources especially Sun and Wind Energy

THANK YOU FOR YOUR ATTENTION



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