Life cycle greenhouse gas emissions for algal biofuels: Effect of different CO_2 supply options

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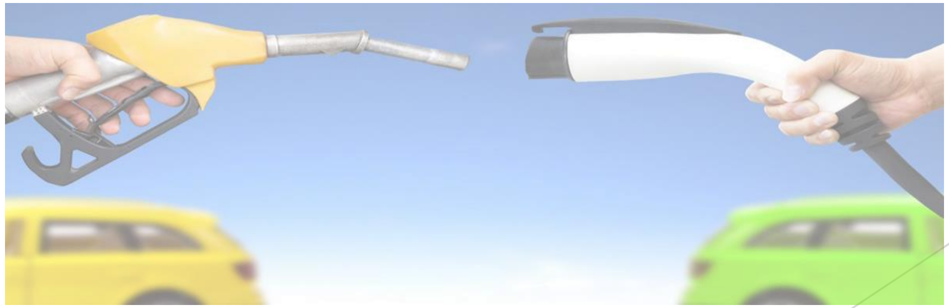
Research at IIT Roorkee

Vehicular emission inventory modeling, Evaluation of co-benefits in transportation sector, Estimation of exhaust and non exhaust emissions from transport sector, Enhancing Production of Biodiesel from Microalgae for Environment Friendly Transport, Sustainable Transportation Systems (**Prof. Bhola Gurjar)**

Artificial Intelligence and Machine Learning for Environmental Data, Data Mining and Big Data Analysis (**Prof. Durga Toshniwal)**

Mapping of Dynamic Air Pollution Information to the Choices of Travelers, Transport negative externalities, Air Pollution Exposure, Transport Modelling and Simulation (**Prof. Amit Agarwal)**

Life cycle assessment of electric vehicles and biofuels, process simulation and optimization of biofuels, Integrated Assessment Modelling (IAM) of EVs and Biofuels. (**Prof. Pratham Arora)**



Introduction

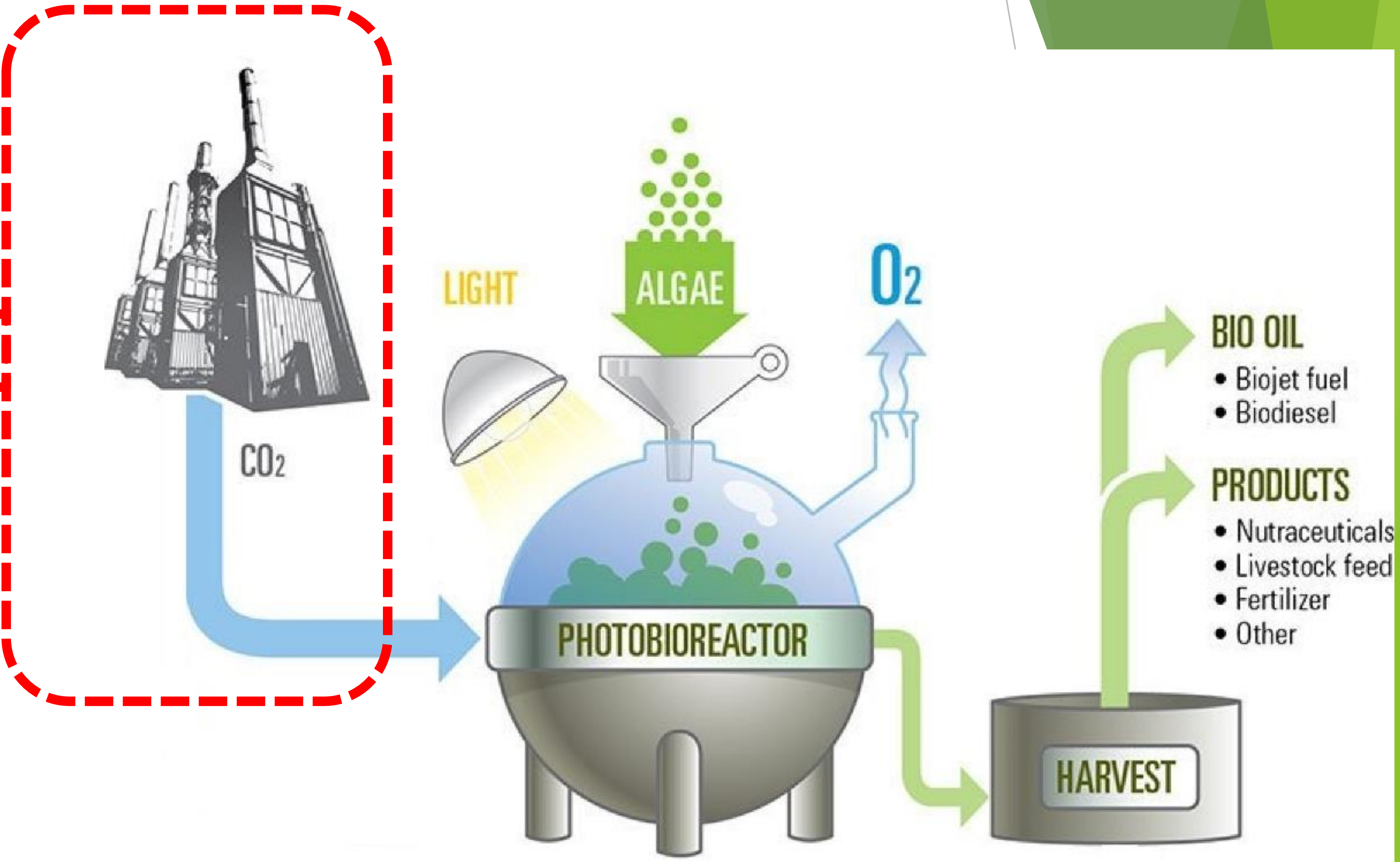
Why make fuels from algae?

- Algae **require CO_2** for growth, therefore fuel is **potentially low carbon.**
- Possible integration to achieve **low-cost CO_2 sequestration** and nutrient remediation.
- Uses all nutrients, **minimizing eutrophication.**
- **Biodegradable**, so minimal issues with accidental spills /leaks.
- Uses **underutilized land**, e.g. deserts.
- **Yields >10x** those for land plants, so much less land is needed.
- Certain species can grow in salty or brackish water.

CO2 supply to algal biorefinery

- A **major challenge** faced by algal biorefinery is the **sustainable supply of carbon dioxide.**
- **CO_2 requirements** are responsible for **10-30% of biorefinery raw material cost.**
- It is very **important to quantify the CO_2 emissions** for production and **transport of CO_2**.
- The present study compares the **global warming potential (GWP) of different CO_2 supply scenarios**, utilizing a functional unit of **1 MJ of refined bio-crude**.

CO_2 supply to algal biorefinery



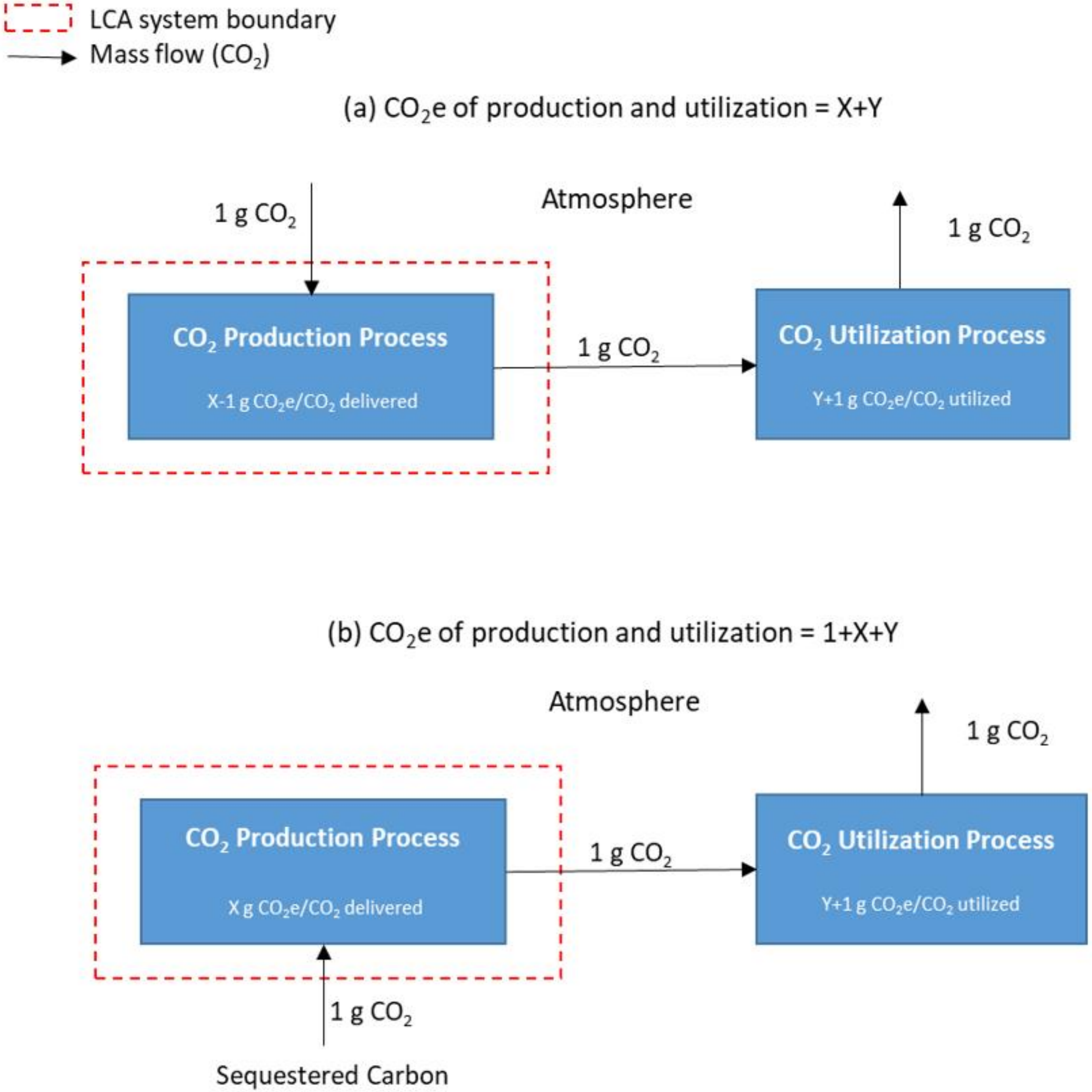
Methodology

- Different CO_2 supply scenarios have been **modelled** in a steady state process simulation software **ASPEN Plus®**.
- The study considers **separate day and night operations** for the CO_2 supply cases, because algae growth only takes place during the daytime.
- A **cradle-to-gate LCA study** was carried out with the help of MS Excel worksheets for different process variants.

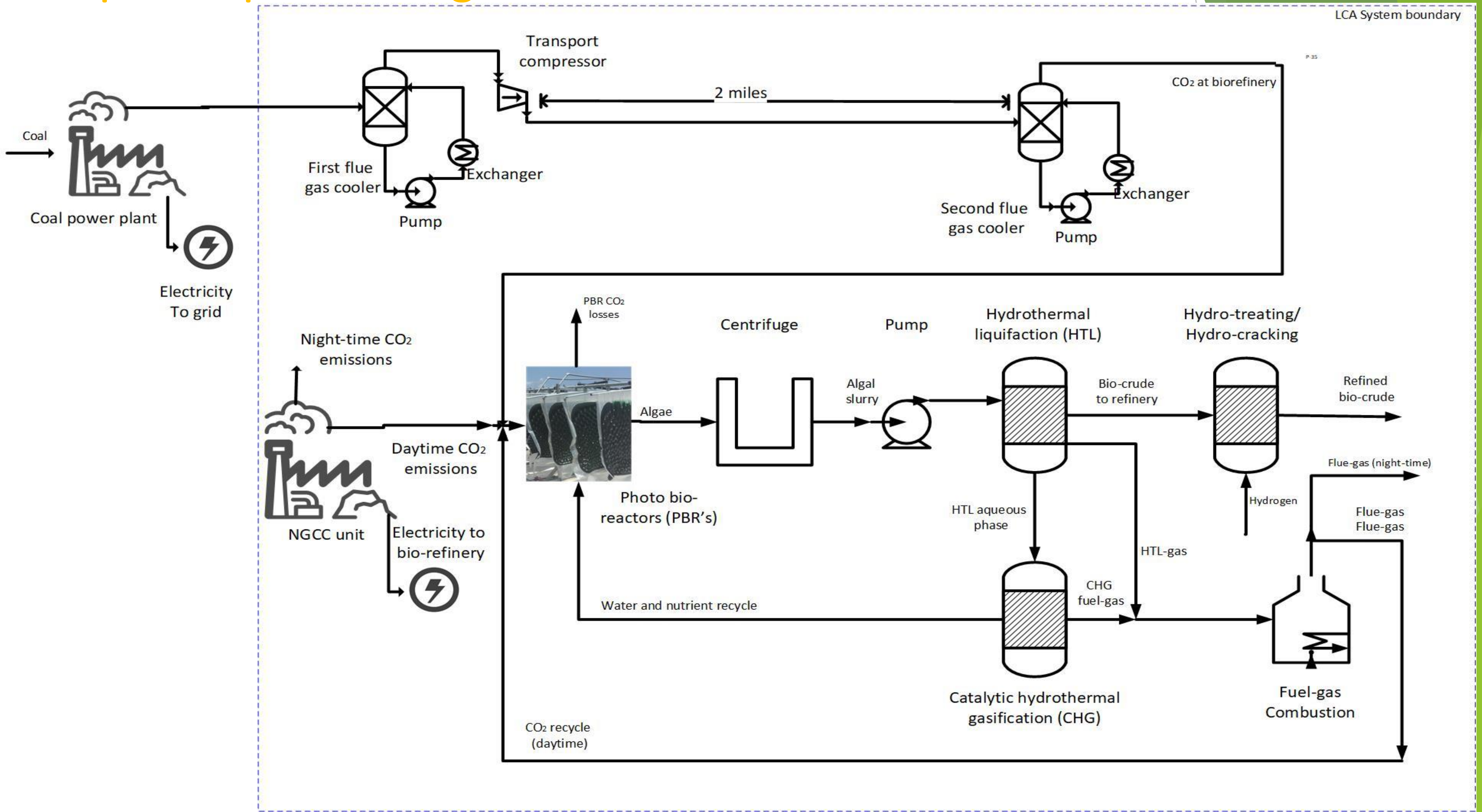
Methodology

- The different **CO_2 supply scenarios** that are considered in the present study utilize the **flue gas from a**
  - Flue gas from a legacy coal-based power plant
  - Flue gas from a legacy natural gas-based power plant
  - Flue gas from a purpose-built natural gas combined cycle (NGCC) plant
  - Flue gas from purpose-built biomass combustion plant.
  - CO_2 supply from a purpose-built direct air capture (DAC) system
- The **power plants** are assumed to located at a distance of **2 miles from the biorefinery.**
- The **standalone NGCC unit and the biomass combustion** units are assumed to be **constructed at the algal biorefinery**.

Methodology



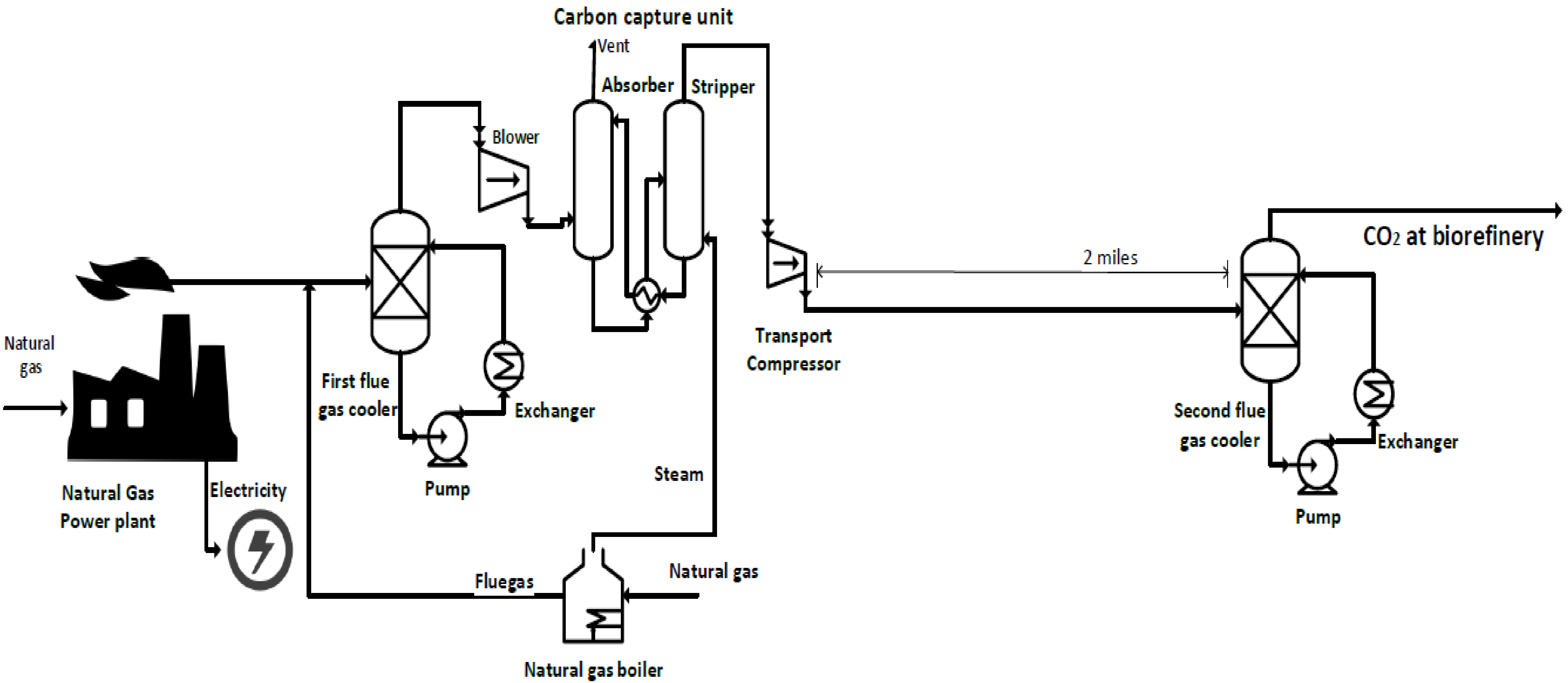
Coal power plant flue gas



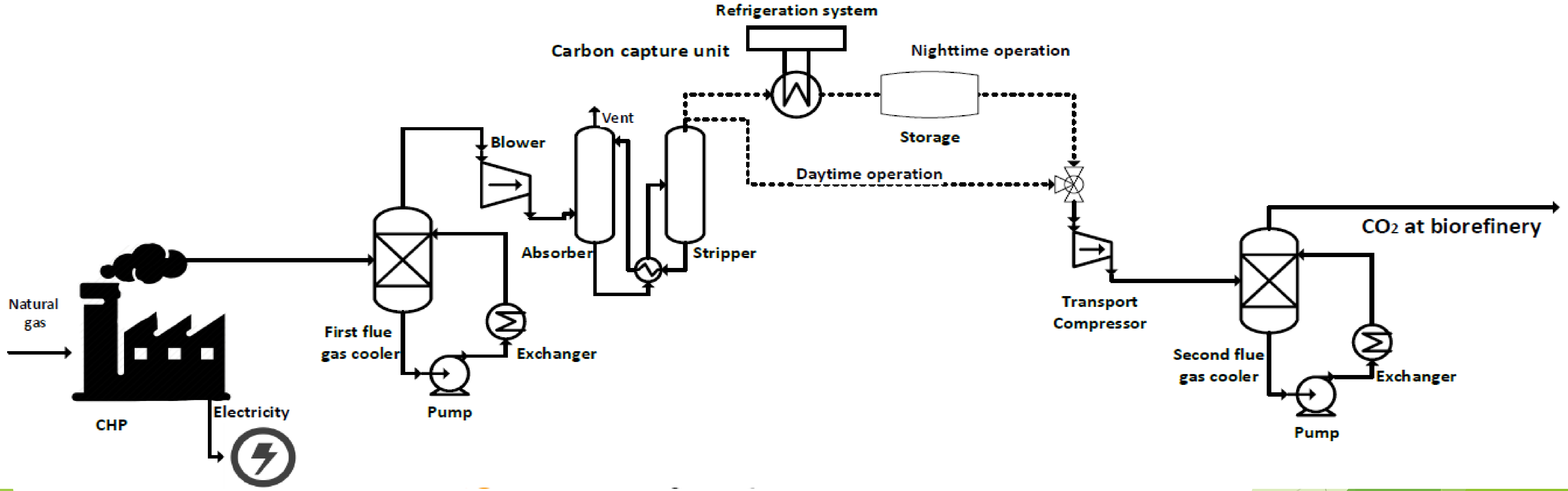
Natural gas power plant flue gas with carbon capture

	Natural gas-based power plant	Coal- based power plant
N_2	75.6	65.4
O_2	11.6	4.1
H_2O	8.5	18.6
CO_2	4.3	11.9
Temperature (°C)	82	60

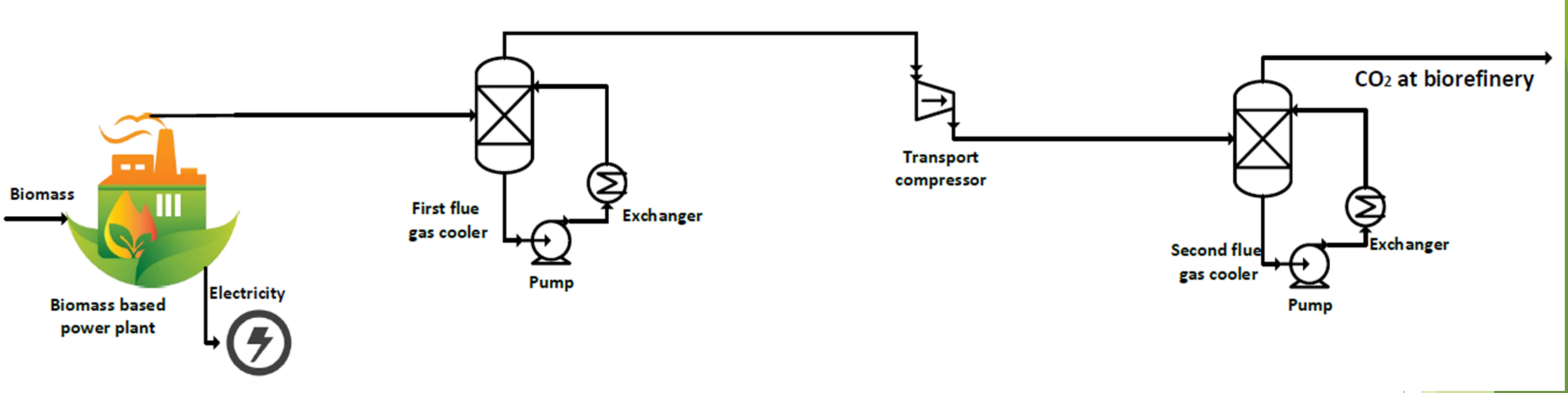
Natural gas power plant flue gas



Standalone NGCC flue gas with carbon capture and refrigeration

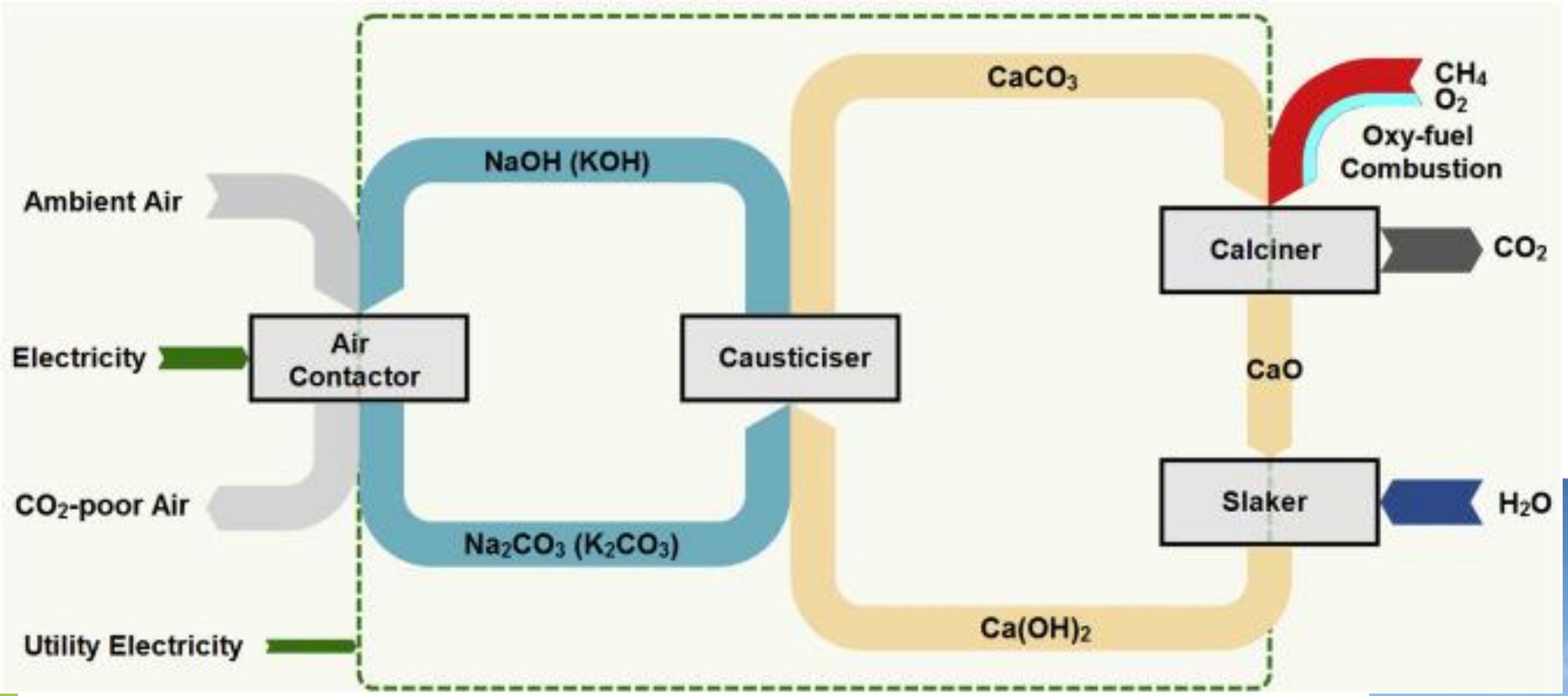


Biomass combustion and gasification flue gas



https://mam.tubitak.gov.tr/en/teknoloji-transfer-ofisi/coal-and-biomass-combustion-gasification-systems-and-plant-installation

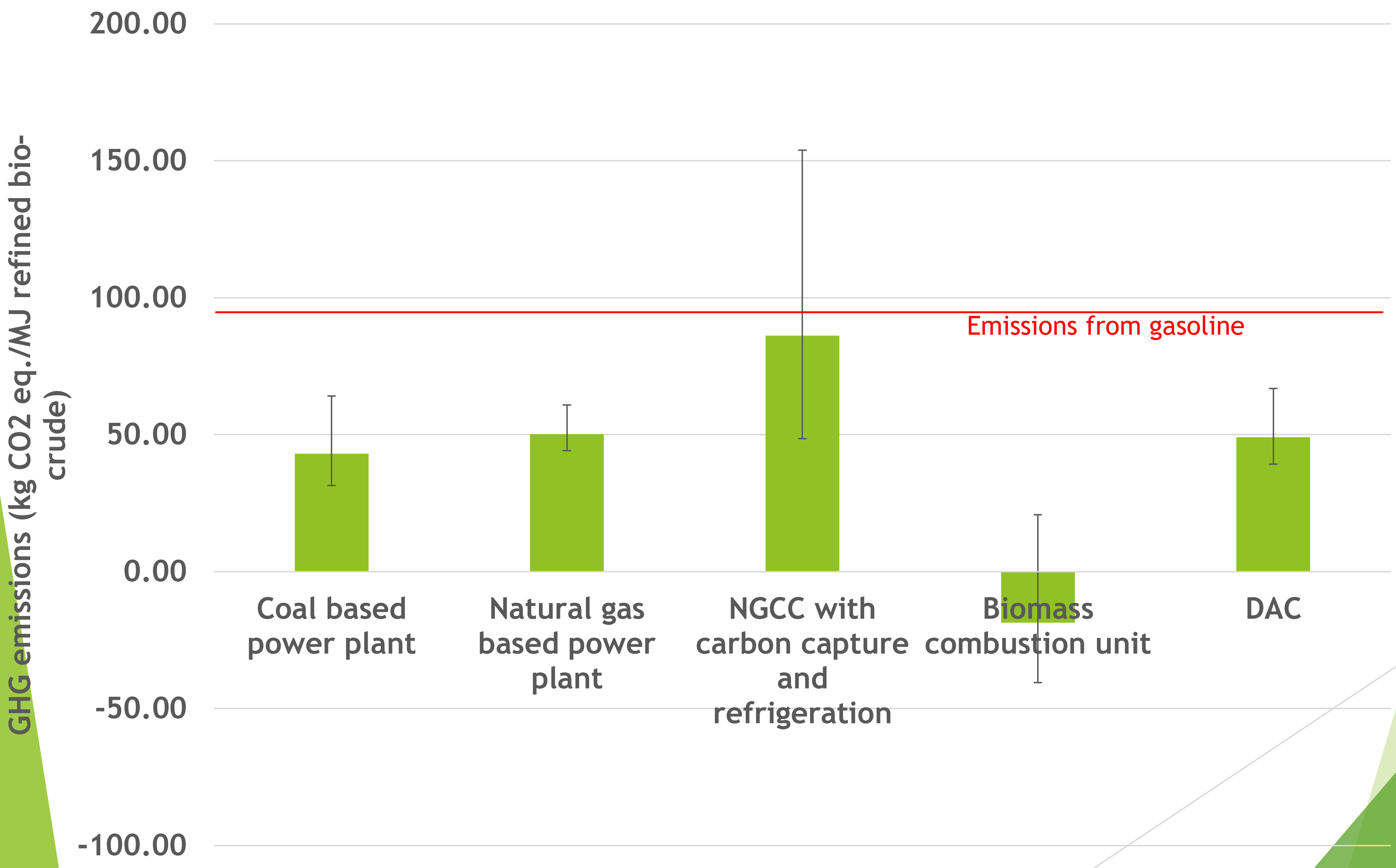
Direct air capture



http://www.texasvox.org/direct-air-capture-co2-climate-solution-limitations/

https://www.sciencedirect.com/science/article/pii/S0959652619307772

Results



200.00
150.00
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50.00
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-50.00
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GHG emissions (kg CO2 eq./MJ refined bio-crude)
Emissions from gasoline
Coal based power plant
Natural gas based power plant
NGCC with carbon capture and refrigeration
Biomass combustion unit
DAC

Conclusions

CO_2 supply from the combustion of **biomass** has the **lowest GHG footprint** for the delivered CO_2.

Construction of a **standalone NGCC unit** near the biorefinery has the **highest GHG footprint**. However, the GHG footprint of such a plant is very **sensitive** to the **grid electricity carbon footprint** as well as emissions from the supply chain of natural gas feedstock.

The fossil fuel power plant CO_2 supply has positive emissions for supplying stack gases and is expected to become **prohibitive** as the **distance** between the power plant and biorefinery **increases.**

The results provide a **benchmark for comparison of different CO_2 supply options** for the establishment of a sustainable algal biorefinery.