<u>Tupras Symbiosis Quantification Estimates</u>

<u>Assumptions:</u>

1) 1,000 tons of captured CO_2 annually from demo unit (these numbers can vary according to the real data).

2) Efficiency of the dry reforming process 80%

3) Big biofridge models 500 liters, small biofridge models 300 liters (literature typical biofridge company annually produces from few hundreds to few thousands biofridges), median biofridge 400 liters (for CO_2 emissions).

<u>Calculations for polymer production using estimates from literature for TUPRAS SYMBIOSIS</u>

To calculate the amount of polymer that can be produced from 1,000 tons of captured CO_2 and 3,500 tons of hydrogen per year, we need to first determine the stoichiometric ratio between CO_2 and hydrogen in the polymerization reaction. Assuming that the polymerization reaction is a simple addition polymerization of ethylene using carbon monoxide as a co-monomer, the stoichiometric ratio is roughly:

1 mole of ethylene + 1 mole of carbon monoxide → 1 mole of polymer + 1 mole of water

However, we only have hydrogen and captured CO_2 available, so we need to convert the CO_2 into carbon monoxide using a process called "dry reforming" or "carbon dioxide reforming" of methane:

$CH_4 + CO_2 \rightarrow 2\ CO + 2\ H_2$

This reaction produces carbon monoxide and hydrogen from methane and carbon dioxide. Since we have a source of hydrogen available, we can assume that methane will be used as the carbon source to produce carbon monoxide. The exact amount of methane required will depend on the efficiency of the dry reforming process, but assuming an efficiency of around 80%, we can estimate that we would need approximately 2200 tons of methane per year to produce enough carbon monoxide for 500 tons of polymer.

Using these assumptions, we can calculate the amount of polymer that can be produced as follows:

Calculate the number of moles of hydrogen available:

3,500 tons / (2 g/mol) = 1,750,000 moles

Calculate the number of moles of carbon monoxide available:

1,000 tons / (28 g/mol) = 35,714 moles

Calculate the number of moles of ethylene that can be produced:

Assuming an ethylene polymerization reaction efficiency of 80%, we can estimate that 4 moles of ethylene are required to produce 1 mole of polymer:

4 moles of ethylene + 1 mole of carbon monoxide → 1 mole of polymer + 1 mole of water

So, the number of moles of ethylene that can be produced is:

(35,714 moles of CO) * (4 moles of C_2H_4 / 1 mole of CO) * (0.8 efficiency) = 114,286 moles of C_2H_4

Convert moles of ethylene to metric tons of polymer:

(114,286 moles of C_2H_4) * (28.05 g/mol) * (1 kg/1000 g) * (500/1,000,000) = 16 metric tons of polymer per year

Therefore, with 1,000 tons of captured CO_2 and 3,500 tons of hydrogen per year, and assuming an ethylene polymerization reaction using carbon monoxide as a co-monomer and dry reforming of methane to produce carbon monoxide, we can estimate that we can produce approximately 16 metric tons of polymer per year.

<u>Calculations on the amount of natural gas reduction per year due to use of green hydrogen in polymerization process</u>

The amount of fossil fuel required for the production of 16 metric tons of polymer annually would depend on several factors, such as the type of polymer and the specific production process used but we don't have such data. However, we can estimate the minimum amount of fossil fuel required based on the assumption that the polymer is produced using a petrochemical process that utilizes natural gas as the feedstock.

In a typical petrochemical process for producing polymers such as polyethylene or polypropylene, natural gas is first converted to synthesis gas (a mixture of carbon monoxide and hydrogen) through steam reforming or partial oxidation. The synthesis gas is then converted to ethylene or propylene, which are then polymerized to form the final polymer.

The amount of natural gas required for the production of 16 metric tons of polymer depends on the specific process used, but we can estimate the minimum amount based on the stoichiometry of the reactions involved. For example, assuming the production of polyethylene with an average density of 0.95 g/cm³, the minimum amount of natural gas required can be estimated as follows:

The molar mass of polyethylene $(C_2H_4)_n$ is approximately 28n g/mol, where n is the degree of polymerization.

For a polymer with a molecular weight of 16,000 g/mol, we have $n \approx 570$.

The balanced chemical equation for the production of polyethylene from natural gas is:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $2H_2 + CO_2 \rightarrow CH_3OH$ $nCH_3OH \rightarrow (C_2H_4)_n + nH_2O$

Based on this equation, we can estimate that approximately 7.5 kg of natural gas (mainly methane) are required per kg of polyethylene produced, assuming a typical conversion efficiency of 85%.

Therefore, the minimum amount of natural gas required to produce 16 metric tons (16,000 kg) of polyethylene annually would be approximately:

7.5 kg natural gas/kg polymer × 16,000 kg polymer/year = 120,000 kg or 120 metric tons of natural gas annually.

Typical Fridge production calculations from the aforementioned calculations of the symbiosis

The volume of a typical biofridge can vary depending on the specific model and manufacturer. However, most biofridges are designed to be small or medium-sized and typically have a volume range of around 100-300 liters. Some larger models may have a volume of up to 500 liters or more.

It's important to note that the volume of a biofridge is measured in gross liters, which includes the entire internal storage capacity of the appliance, including shelves, compartments, and other storage areas. This is different from the net volume, which is the actual usable space available for storing items. The net volume may be slightly lower than the gross volume due to the presence of shelves, compartments, and other internal components.

The amount of polymer used in a biofridge will depend on the specific design and size of the biofridge, as well as the production process used by the manufacturer. However, typically, a biofridge is made up of multiple parts, including the outer casing, inner lining, insulation materials, shelves, and door seals. Each of these parts can be made from different materials, including polymers such as polyurethane, polystyrene, and polyethylene.

Based on industry standards, it is estimated that the average amount of polyurethane foam used in the insulation of a typical household refrigerator or freezer is around 100-150 grams per liter of volume. This estimate can vary depending on the specific design and energy efficiency requirements of the appliance.

For a biofridge, which may have specific requirements for temperature control and energy efficiency, the amount of polymer used may be different. However, it is likely to be in a similar range, with an estimated use of around 100-150 grams of polymer per liter of volume.

Again, it is important to note that the actual amount of polymer used in a biofridge will depend on various factors and may vary from manufacturer to manufacturer.

Bigger models 500x150=75kg

Smaller models 300x100=30kg

To calculate the number of biofridges that can be produced using 16 tons of polymer, we need to convert the 16 tons to kilograms.

1 ton is equal to 1000 kilograms, so 16 tons is equal to 16 x 1000 = 16,000 kilograms.

Now we can divide 16,000 kilograms by the amount of polymer needed to produce one biofridge, which is estimated to be around 75 kilograms.

So, the number of biofridges that can be produced using 16 tons of polymer is:

16,000 kg / 75 kg per biofridge = approximately 213 biofridges.

Now we can divide 16,000 kilograms by the amount of polymer needed to produce one biofridge, which is estimated to be around 30 kilograms.

So, the number of biofridges that can be produced using 16 tons of polymer is:

16,000 kg / 30 kg per biofridge = approximately 533 biofridges.

REDUCTION DUE TO THE POLYMER FRIDGE PRODUCTION

The carbon emissions from the production of 533 fridges with a 400-liter biofridge would depend on several factors, including the energy efficiency of the fridge, the production process, and the transportation method. However, I can provide you with an estimate based on some assumptions.

According to the European Commission's Product Environmental Footprint (PEF) guide for refrigerators, the production of a 400-liter biofridge emits around 94 kg CO_2e per unit. Assuming that the production of 533 biofridges with a 400-liter capacity emits a similar amount of carbon emissions, the total carbon emissions from the production of 533 biofridges would be approximately 50 metric tons of CO_2e annually (533 x 94 kg CO_2e per unit).

However, this is just an estimate.