LCA Summary Report

- Methyl Ester
- Glycerin
- Fatty Alcohol

Global Green Chemical Public Company Limited
Date March 2025

Full Life Cycle Assessment (LCA) Approach

Global Green Chemicals Public Company Limited (GGC), as a leading producer of environmentally friendly chemical products, is committed to creating sustainable value through transparent business practices. In line with this commitment, GGC has collaborated with life cycle assessment (LCA) experts from the Department of Chemical Engineering, Faculty of Engineering, Kasetsart University, to conduct life cycle assessments of the company's products.

The aim is to evaluate the environmental impacts throughout the entire life cycle of GGC's products. This assessment covers Methyl Ester, Glycerin and Fatty alcohol produced at the GGC1, GGC2, and TEX plants, using the ReCiPe method. Specifically, the environmental impacts were assessed at the midpoint level using ReCiPe 2016 Midpoint (H) v1.09 / World (2010) H, and at the endpoint level using ReCiPe 2016 Endpoint (H) v1.09 / World (2010) H/H. All assessments were carried out using the SimaPro software version 9.5.0.2.

KASETSART UNIVERSITY

Introduction

Project Background

The Thailand Board of Investment (BOI) funded GGC with the condition of minimizing environmental impact. GGC must use certified or renewable raw materials, implement sustainable green chemistry, produce biodegradable products, and align with international standards for environmental impact reduction, such as the Environmental Management Life Cycle Assessment - Principle and Performance outlined in ISO14040.

Therefore, the Company has collaborated with life cycle assessment specialists from the Department of Chemical Engineering, Faculty of Engineering at Kasetsart University to **evaluate the life cycle of Methyl Ester, Glycerin, Fatty Alcohol and Fatty Alcohol Ethoxylate production at GGC1, GGC2 and TEX**. The aim is to provide an overall environmental impact assessment for glycerin products, which are classified as environmentally friendly in the Chemical category as per the Board of Investment (BOI) requirements.

Goal of Project

1) To evaluate and examine the environmental effects associated with refined Methyl Ester, Fatty Alcohol, Glycerin production across its life cycle;
2) To seek investment support from the Board of Investment for producing eco-friendly chemicals.

Methodology: Scope of Project

Product System

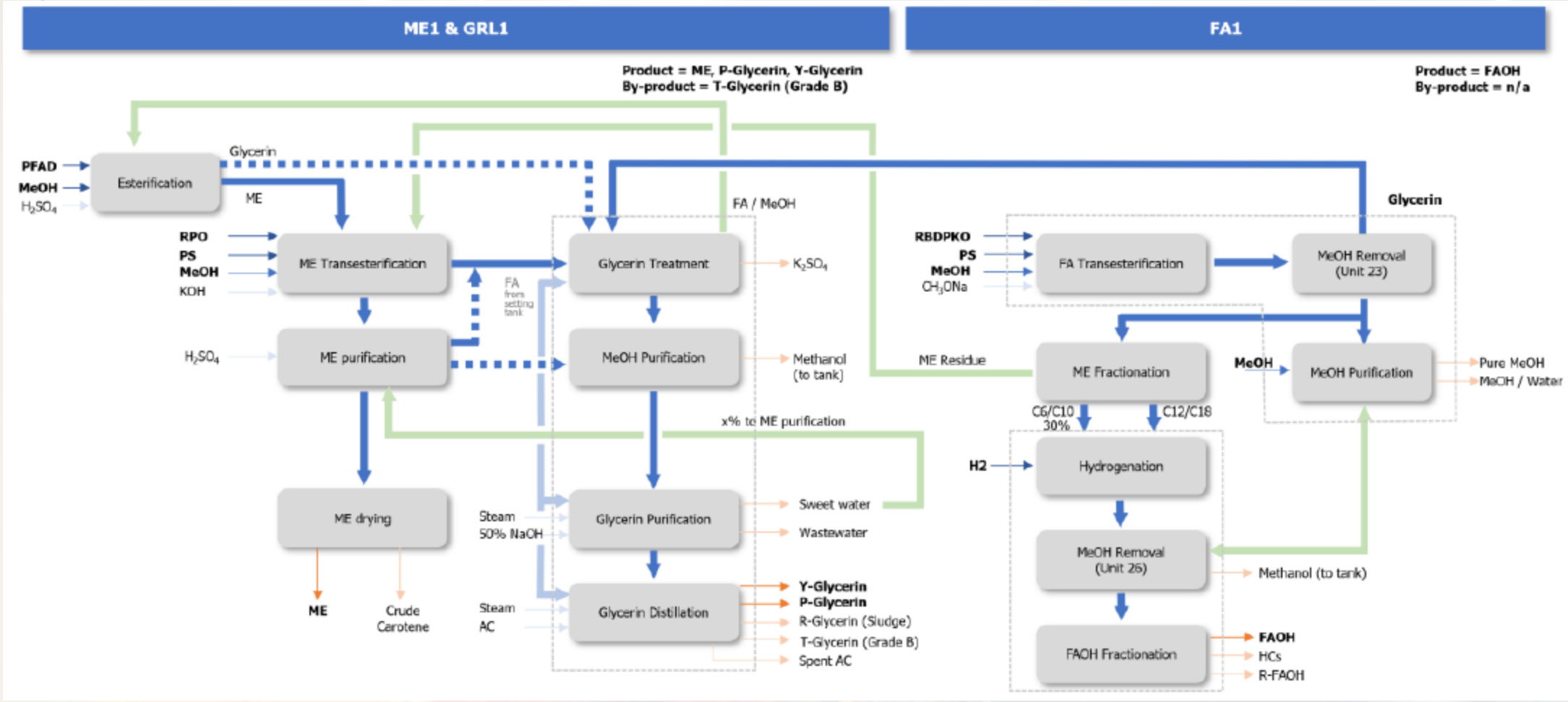

Figure 1: Methyl Ester, Glycerin and Fatty Alcohol production process within Cradle-to-Gate scope at GGC1

Methodology: Scope of Project

Product System

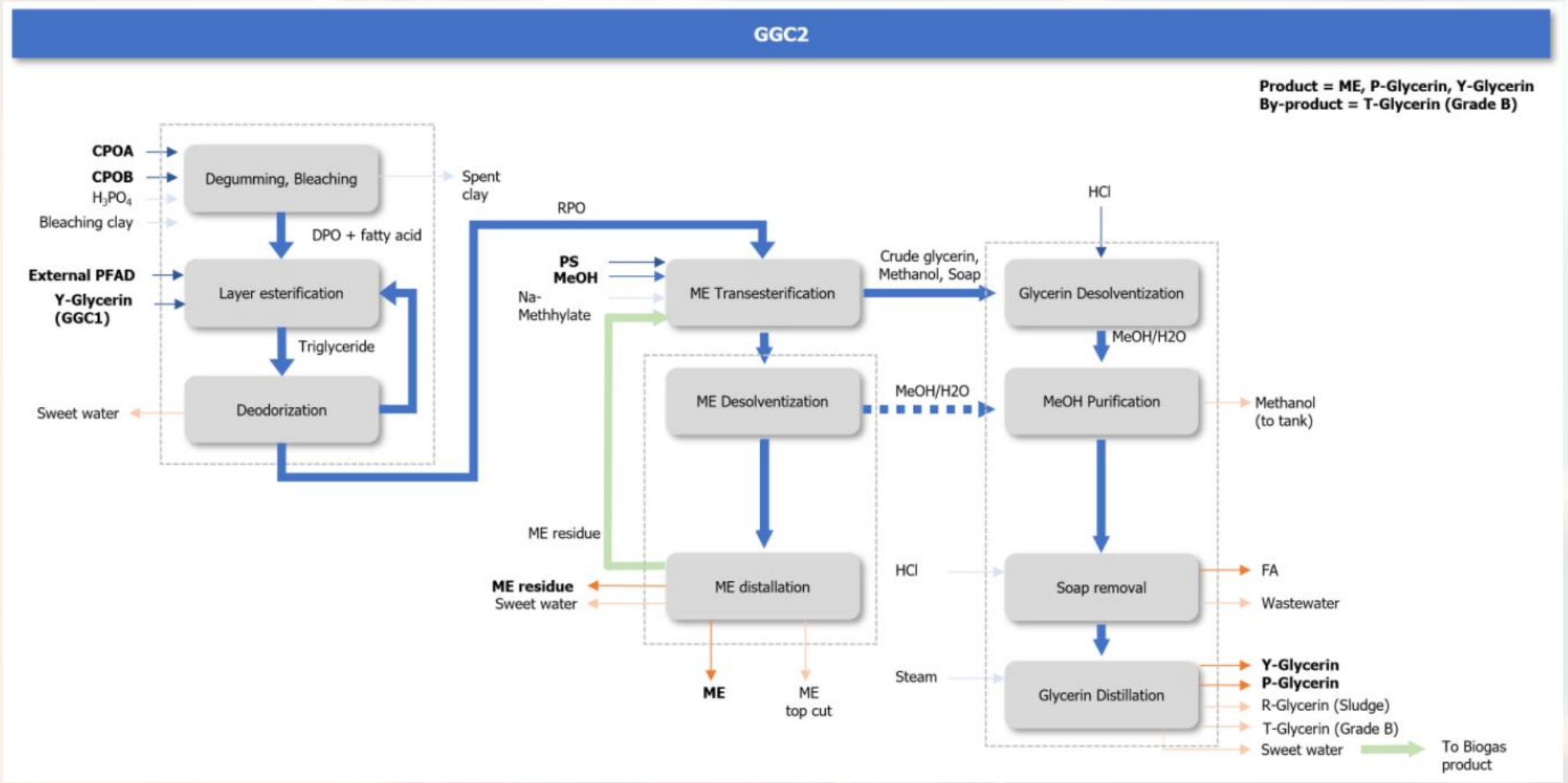

Figure 2: Methyl Ester and Glycerin production process within Cradle-to-Gate scope at GGC2

Methodology: Scope of Project

Product System

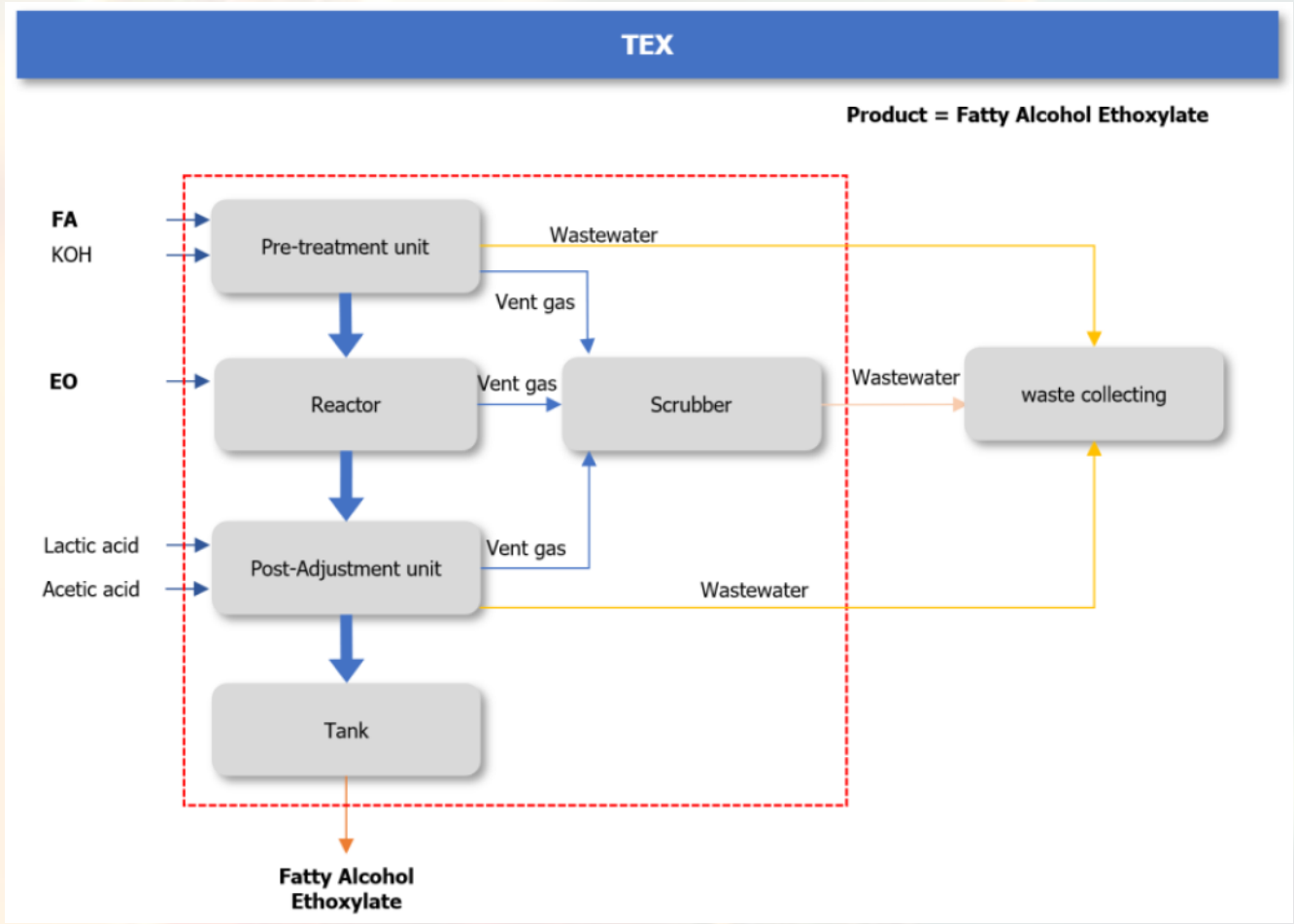

Figure 2: Fatty Alcohol production process within Cradle-to-Gate scope at TEX

Methodology: Scope of Project

Functional unit:

1 kg of Product

Product System:

Cradle-to-Gate

System boundary:

Input and output data raw material, chemical, utility consumption, production and waste disposal at GGC1, GGC2 and TEX plant in Rayong

Allocation:

Mass Allocation

Data quality:

- Input and Output data is based on primary data from companies on Jan – Dec 2023
- Material acquisition is referred secondary data from international database

Database:

International database is Ecoinvent3 in SimaPro Programme

Methodology: Scope of Project

System boundary:

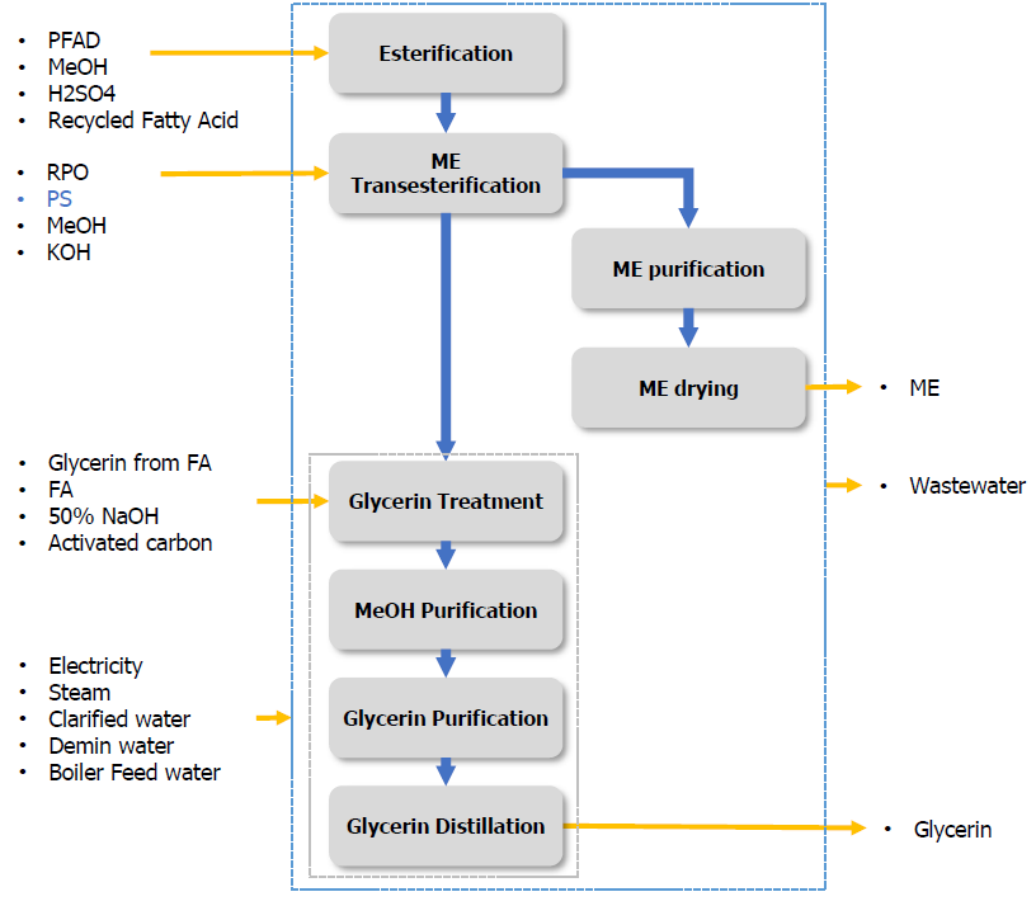

Figure 4: System boundary of Methyl Ester and Glycerin production at GGC1

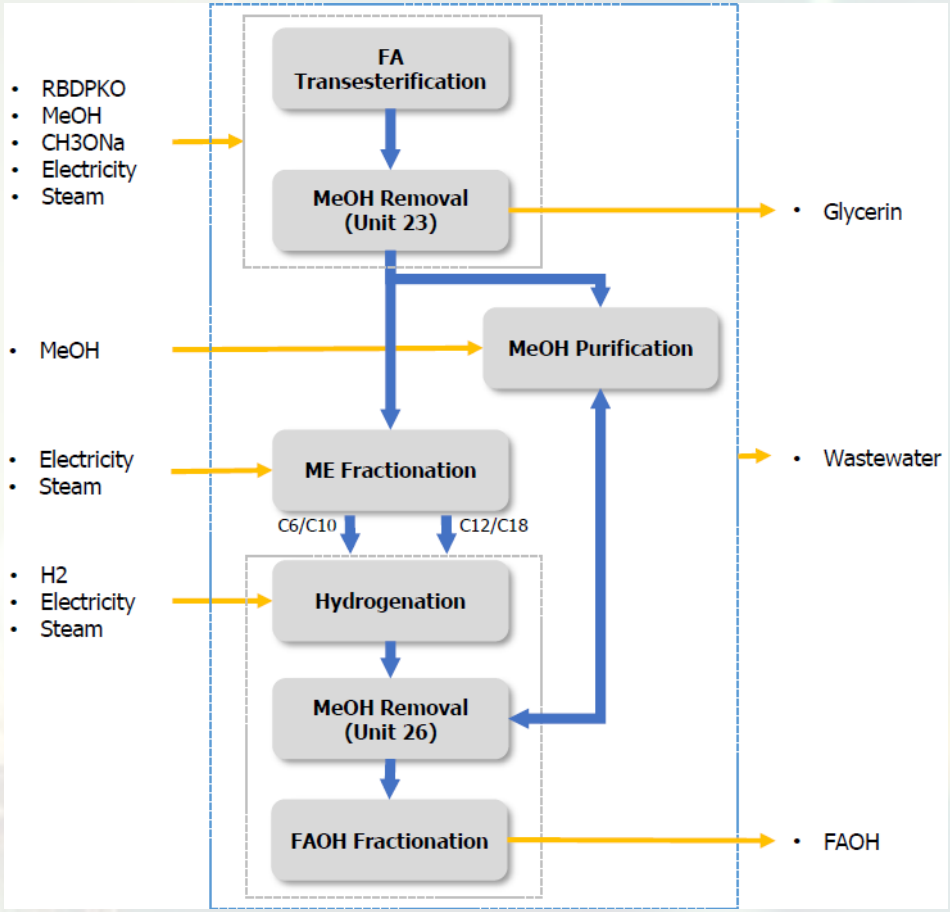

Figure 5: System boundary of Fatty Alcohol production at GGC1

Methodology: Scope of Project

System boundary:

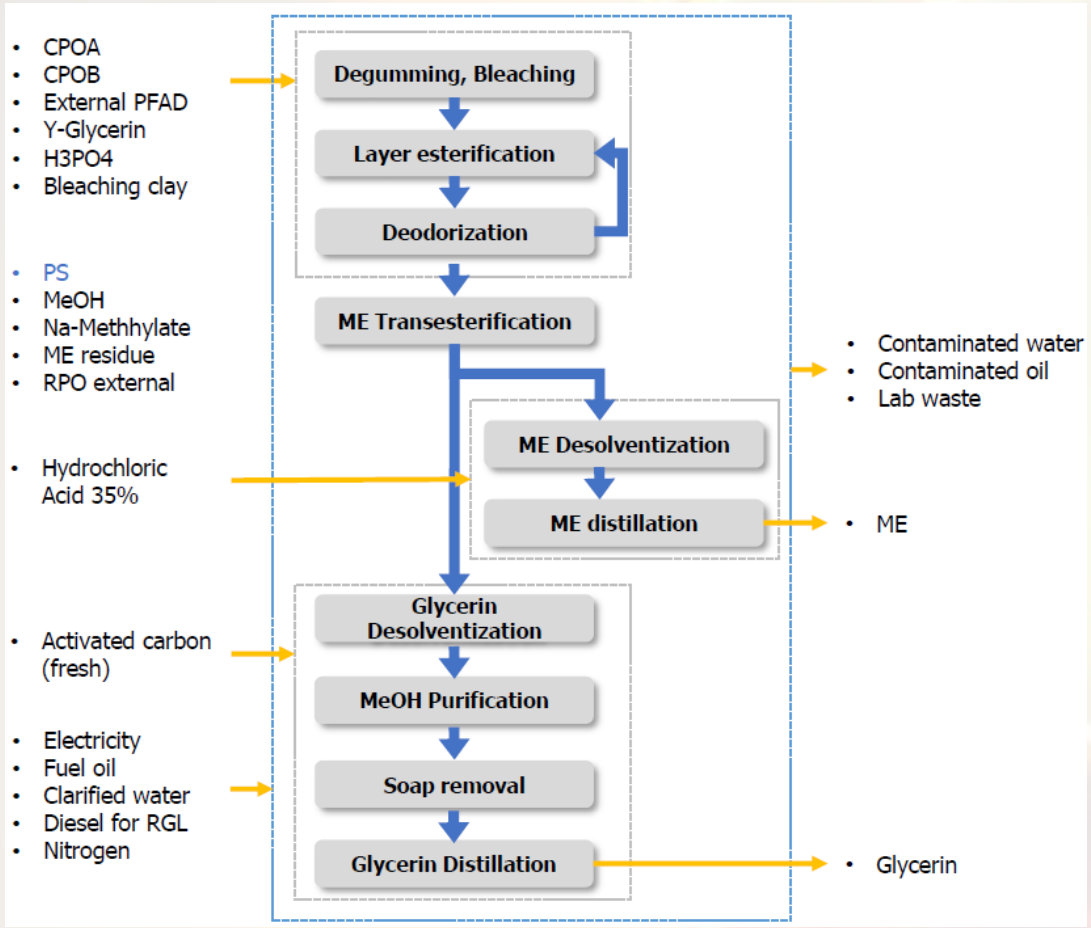

Figure 6: System boundary of Methyl Ester and Glycerin production at GGC2

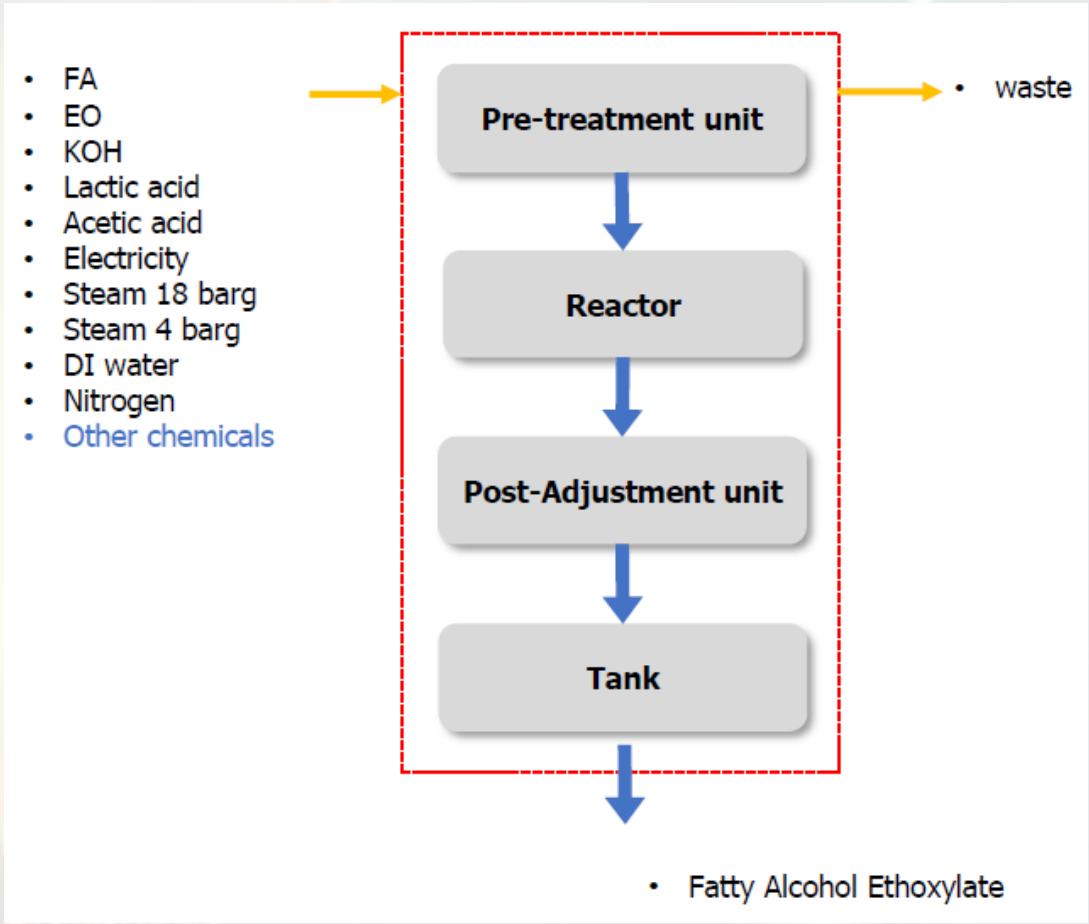

Figure 7: System boundary of Fatty Alcohol Ethoxylate production at TEX

Methodology: Inventory Analysis

1. **Material acquisition** is based on Ecoinvent 3.3, as shown in Figure 8-11.

2. **Process** is considered types and quantities of input and output chemicals, as shown in Figure 4-6.

3. **Transport** is determined by calculating the average transport from raw materials acquisition.

4. **End of life** focuses on the waste generated during production rather than the disposal of the product itself. This waste includes Pitch or Glycerin residue, which consists of sodium salt (Ash), Glycerol residue, other non-glycerol organic matter (Matter organics non-glycerol, mong), Crude Carotene, Spent Activated carbon and sludge. This waste can be repurposed as an alternative fuel for cement factories and a feedstock or sent to discompose.

Methodology: Inventory Analysis

Background Data

- Fatty acid {RoW}| fatty acid production, from palm oil | Cut-off, U
- Methanol {RoW}| market for methanol | Cut-off, U
- Sulfuric acid {RoW}| market for sulfuric acid | Cut-off, U

- Palm oil, refined {GLO}| market for palm oil, refined | Cut-off, U
- Palm oil, refined {GLO}| market for palm oil, refined | Cut-off, U*
- Methanol {RoW}| market for methanol | Cut-off, U
- Potassium hydroxide {RoW}| potassium hydroxide production | Cut-off, U

- Sodium hydroxide, without water, in 50% solution state {RoW}| chlor-alkali electrolysis, membrane cell | Cut-off, U
- Activated carbon, granular {RoW}| activated carbon production, granular from hard coal | Cut-off, U

- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heat, district or industrial, natural gas {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Water, completely softened {RoW}| market for water, completely softened | Cut-off, U
- Water, deionised {RoW}| market for water, deionised | Cut-off, U

Foreground Data

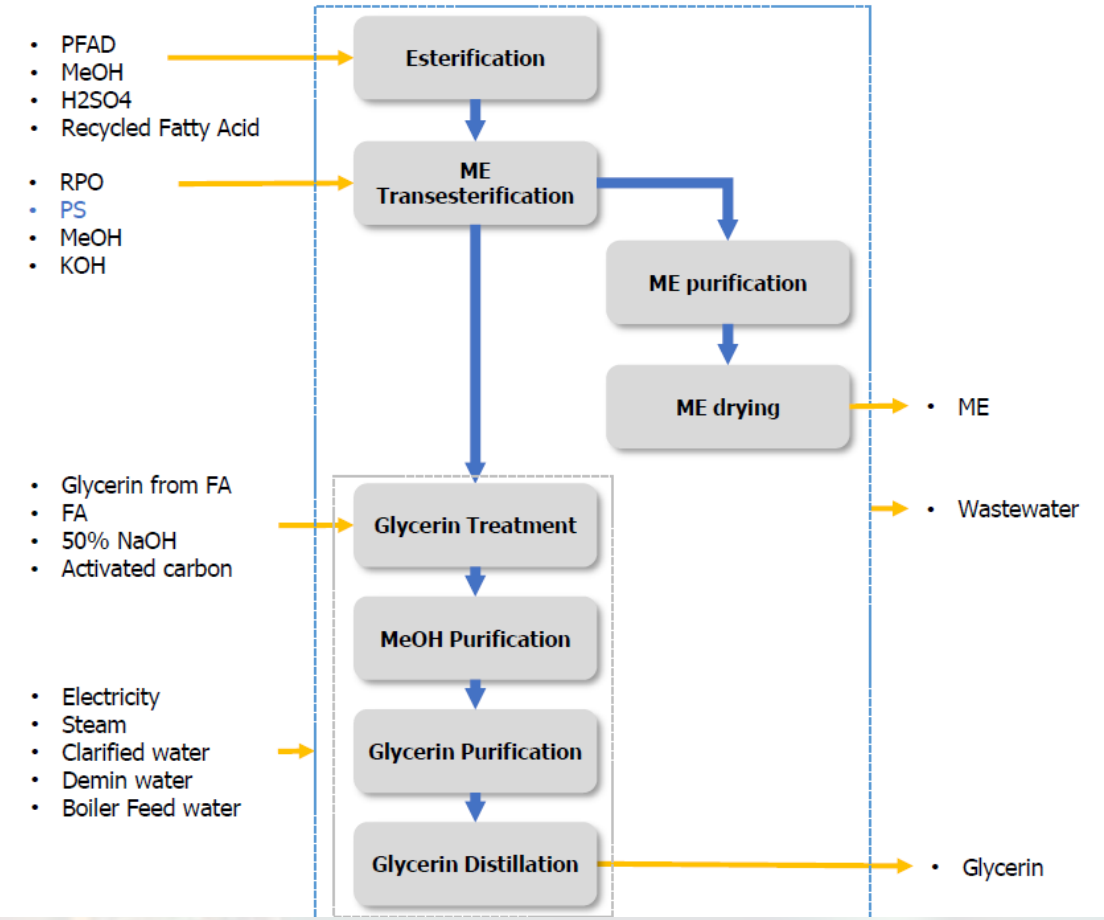

Figure 8: Reference of raw material for Methyl Ester and Glycerin production at GGC1

Methodology: Inventory Analysis

Background Data

- Palm kernel oil, crude {RoW}| palm oil mill operation | Cut-off, U
- Methanol {RoW}| market for methanol | Cut-off, U
- Sodium methoxide {GLO}| sodium methoxide production | Cut-off, U
- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heat, district or industrial, natural gas {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U

- Methanol {RoW}| market for methanol | Cut-off, U

- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heat, district or industrial, natural gas {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U

- Hydrogen, gaseous, low pressure {RoW}| market for hydrogen, gaseous, low pressure | Cut-off, U
- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heat, district or industrial, natural gas {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U

Foreground Data

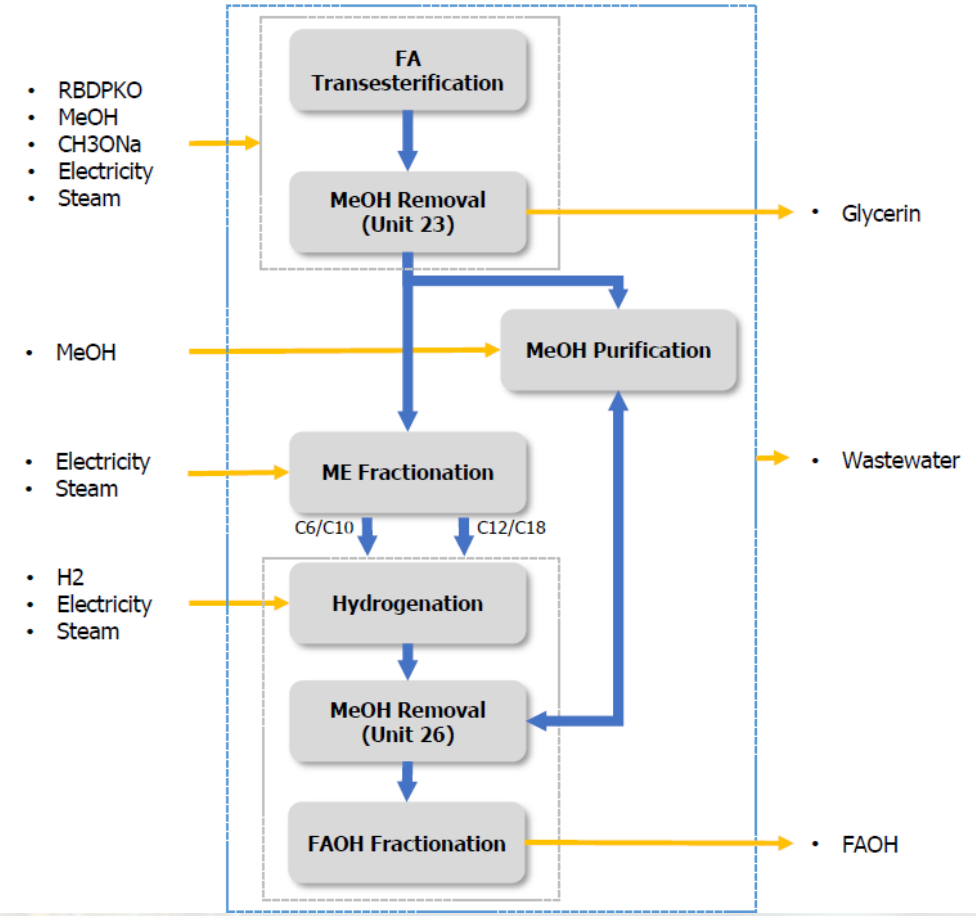

Figure 9: Reference of raw material for Fatty Alcohol production at GGC1

Methodology: Inventory Analysis

Background Data

- Palm oil, crude {RoW}| palm oil mill operation | Cut-off, U
- Fatty acid {RoW}| fatty acid production, from palm oil | Cut-off, U
- Glycerin from GGC1
- Phosphoric acid, industrial grade, without water, in 85% solution state {RoW}| purification of wet-process phosphoric acid to industrial grade, product in 85% solution state | Cut-off, U
- Clay {RoW}| market for clay | Cut-off, U

- Palm oil, refined {GLO}| market for palm oil, refined | Cut-off, U*
- Methanol {RoW}| market for methanol | Cut-off, U
- Sodium methoxide {GLO}| sodium methoxide production | Cut-off, U
- Palm oil, refined {GLO}| market for palm oil, refined | Cut-off, U

- Hydrochloric acid, without water, in 30% solution state {RoW}| hydrochloric acid production, from the reaction of hydrogen with chlorine | Cut-off, U

- Activated carbon, granular {RoW}| activated carbon production, granular from hard coal | Cut-off, U

- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heavy fuel oil {RoW}| market for heavy fuel oil | Cut-off, U
- Water, completely softened {RoW}| market for water, completely softened | Cut-off, U
- Diesel {GLO}| market group for diesel | Cut-off, U
- Nitrogen, liquid {RoW}| industrial gases production, cryogenic air separation | Cut-off, U
- Refinery sludge {RoW}| treatment of refinery sludge, hazardous waste incineration | Cut-off, U

Foreground Data

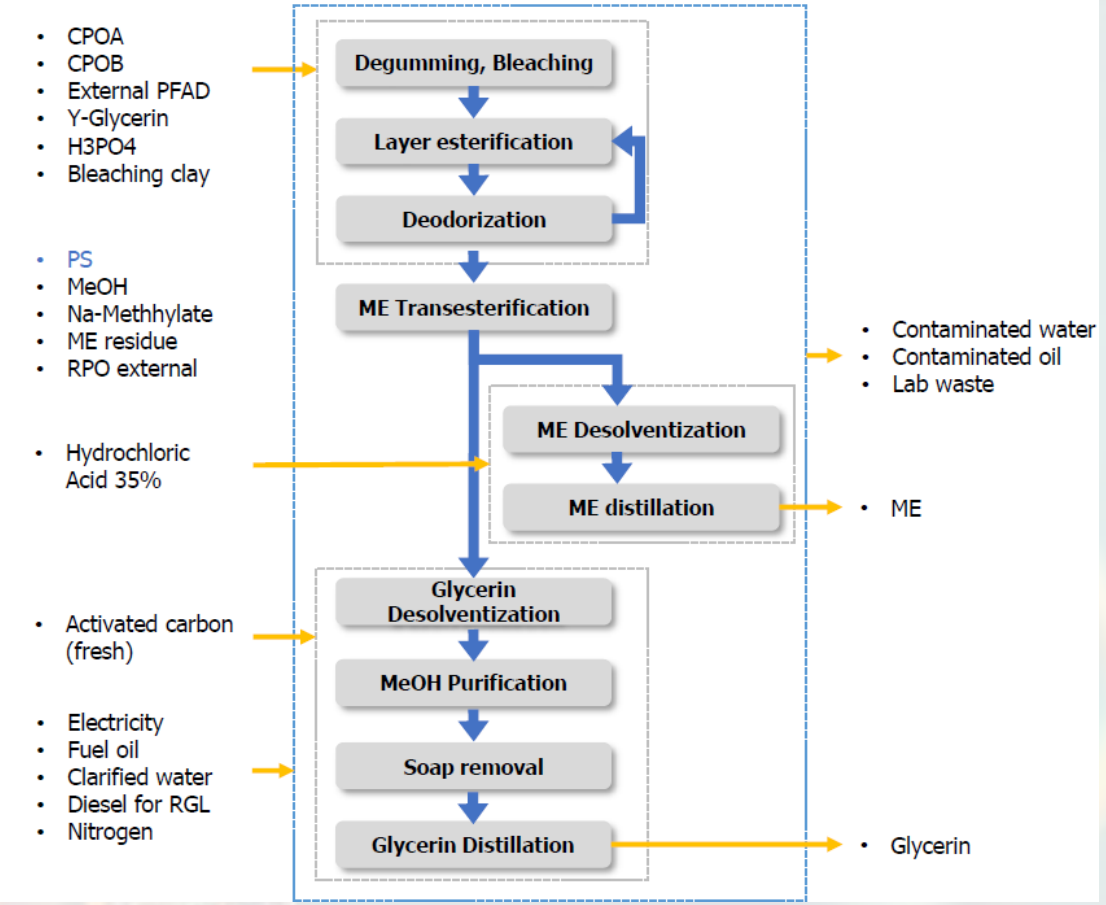

Figure 10: Reference of raw material for Methyl Ester and Glycerin production at GGC2

Methodology: Inventory Analysis

Background Data

- FAOH C12/C10, GGC1
- Ethylene oxide {RoW}| ethylene oxide production, ethylene oxidation | Cut-off, U
- Potassium hydroxide {RoW}| potassium hydroxide production | Cut-off, U
- Lactic acid {RoW}| lactic acid production | Cut-off, U
- Acetic acid, without water, in 98% solution state {RoW}| acetic acid production, butane oxidation | Cut-off, U
- Electricity, high voltage {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Heat, district or industrial, natural gas {RoW}| heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical | Cut-off, U
- Water, deionised {RoW}| market for water, deionised | Cut-off, U
- Nitrogen, liquid {RoW}| industrial gases production, cryogenic air separation | Cut-off, U
- Sulfuric acid {RoW}| sulfuric acid production | Cut-off, U
- Hazardous waste, for incineration {RoW}| treatment of hazardous waste, hazardous waste incineration | Cut-off, S

Foreground Data

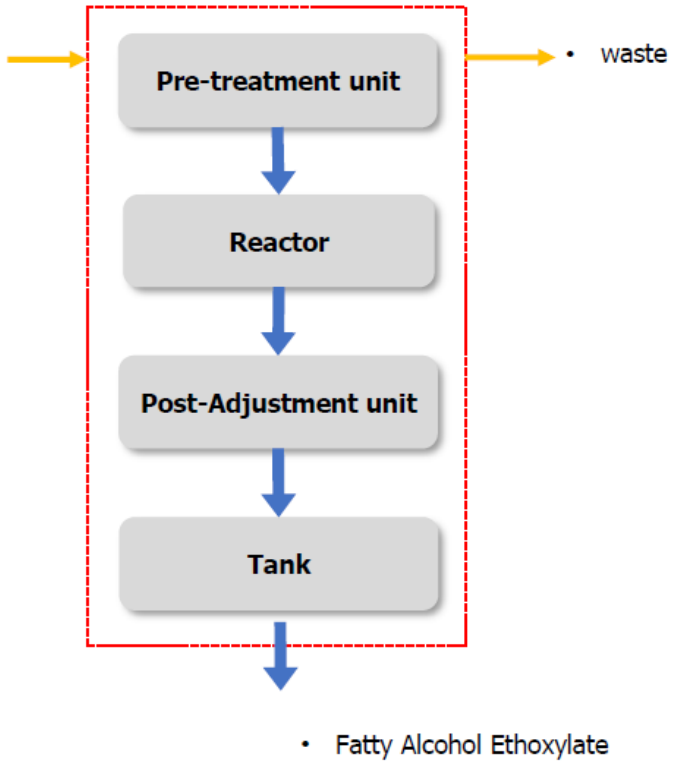

Figure 11: Reference of raw material for Fatty Alcohol Ethoxylate production at TEX

Methodology: Life Cycle Impact Assessment

The life cycle impact assessment is performed by analyzing data from inventory analysis applying ReCiPe methodology and SimaPro 9.5.0.2. calculation software, which can be used to assess 18 Midpoint environmental impacts and 3 Endpoint environmental impacts, which are Human health, Ecosystems, Resources. This evaluation methodology can be assessed individually or as a whole of impacts. Figure 5 displays the evaluation of all impacts in the Point unit (Pt).

18 Midpoint environmental impacts, including:

1. Climate change
2. Stratospheric ozone depletion
3. Ionizing radiation
4. Ozone formation, Human health
5. Fine particulate matter formation
6. Ozone formation, Terrestrial ecosystems
7. Terrestrial acidification
8. Freshwater eutrophication
9. Marine eutrophication
10. Terrestrial ecotoxicity
11. Freshwater ecotoxicity
12. Marine ecotoxicity
13. Human carcinogenic toxicity
14. Human non-carcinogenic toxicity
15. Land use
16. Mineral resource scarcity
17. Fossil resource scarcity
18. Water consumption

3 Endpoint environmental impacts, including:

1. Human health
2. Ecosystem
3. Resources

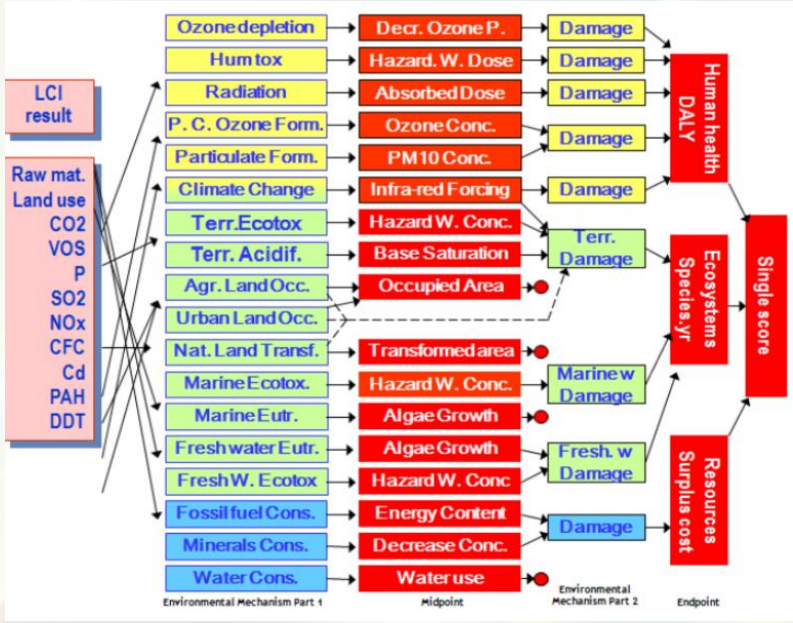

Figure 12. Relationship between Midpoint and Endpoint impacts considered in ReCiPe methodology.

Result and Discussion

The results show that the production of methyl ester, glycerin, and fatty alcohol at GGC1 and GGC2 plants contributes significantly to midpoint impacts such as freshwater eutrophication and human carcinogenic toxicity. These impacts are primarily attributed to wastewater generated during the production of refined palm oil and the use of fertilizers (ammonium sulfate) in oil palm cultivation, which serves as a feedstock for production. At the endpoint level, the highest impact was on human health, largely due to fertilizer use in oil palm cultivation for palm oil production.

For the production of fatty alcohol ethoxylate at the TEX plant, the key midpoint impact was human carcinogenic toxicity, while the main endpoint impact was also on human health. These impacts mainly stem from waste management related to coal combustion used in generating heat for fatty alcohol production and from electricity consumption used in producing liquid oxygen for ethylene oxide production.

Thank you