



THE UNIVERSITY OF BRITISH COLUMBIA



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# Life Cycle Assessment

Theory and Practice

 Springer



# Characteristics of LCA

## Learning Objectives

- Explain the relevance of Life Cycle Assessment (LCA) as a tool for environmental management.
- Explain four main characteristics of LCA.
- Demonstrate an understanding of **strengths** and **limitations** of LCA by providing examples of environment-related questions that LCA can answer and questions that LCA cannot answer.
- Explain how LCA emerged and what characterised the early years of development.

# 1. Importance of LCA

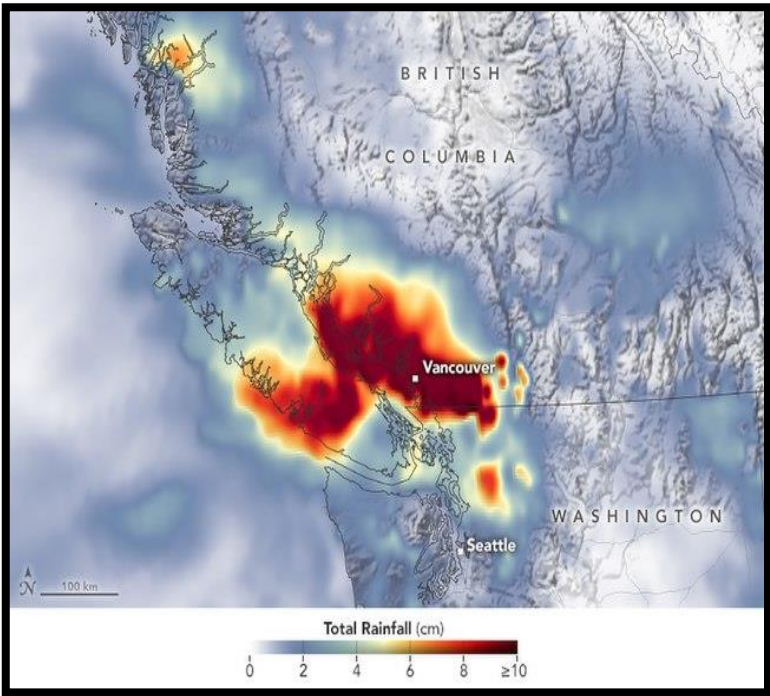
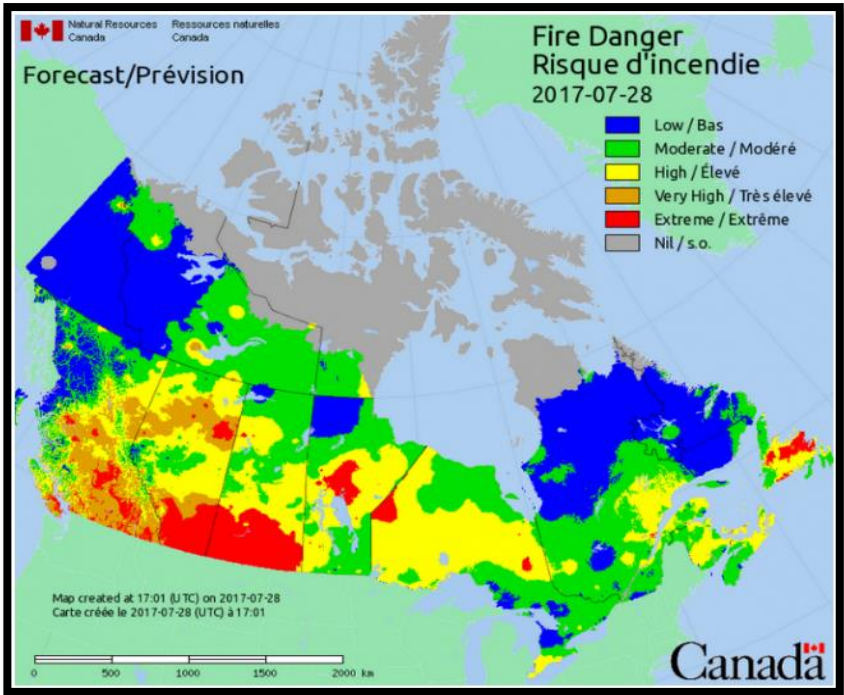
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# Why Is LCA Important?





# Natural Disasters



# How to Address Climate Change?

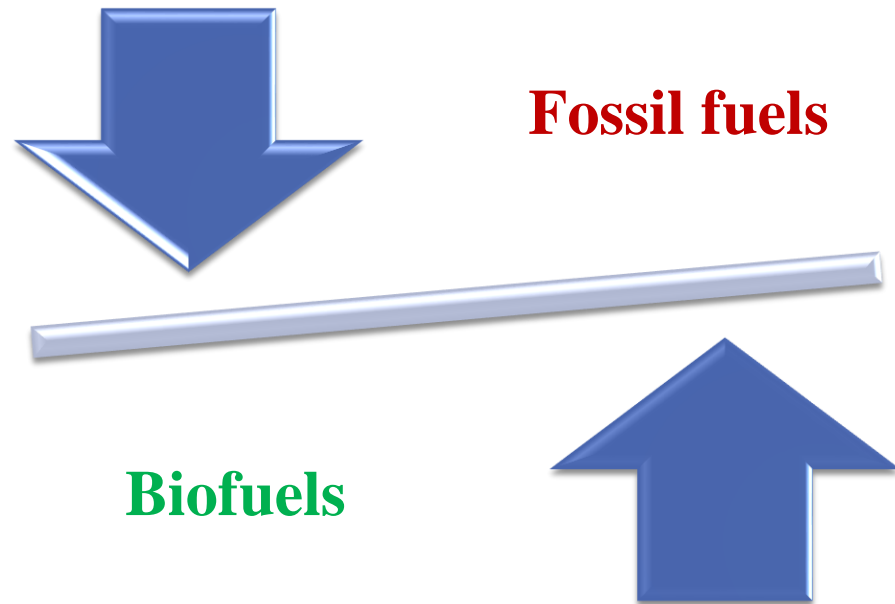
- ❑ Life Cycle Assessment (LCA) involves evaluating the **environmental impacts** associated with all the stages of a product's life—from **raw material extraction**, **manufacturing**, **distribution**, and **recycling** or **disposal**.



- ❑ LCA helps in identifying opportunities to **improve the environmental performance** of products and processes.

# Why Is LCA Important? (Biofuel Case)

- ❑ The use of **biofuels** is not a new trend. They were used in the form of wood and peat before the industrialisation as the only source of fuels.
- ❑ This changed with the emergence of cheap **fossil fuels**, first in the form of coal, later followed by oil and natural gas.



Which one is more

- “**green**”,
- “**sustainable**” or
- “**carbon neutral**”?





# Why Is LCA Important? (Biofuel Case)

❑ In the early 2000s, a renewed interest in using **biofuels** in the transportation sector spurred because of the following reasons:

- Increasing oil prices,
- The question of **energy security**,
- Concerns over **climate change**.



❑ Biofuels were seen as potentially **cost competitive** with **gasoline** and **diesel**.

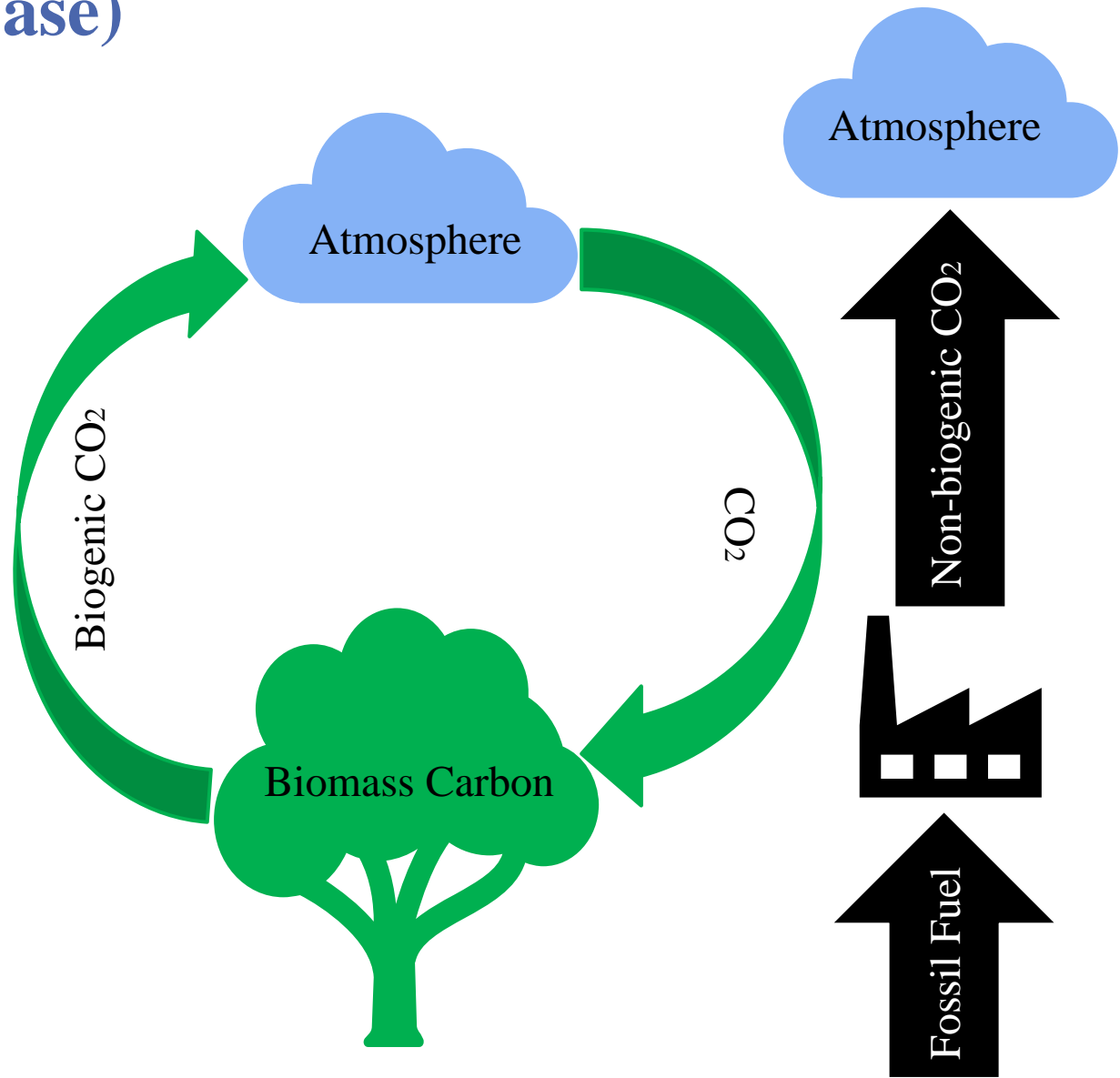
❑ Biofuels were considered means to **reduce dependencies** on large exporters of oil, located in politically unstable regions of the world.

❑ In the transportation sector, biofuels were also generally considered **much better** for the climate than fossil fuels. The reasoning was that

❑ The CO<sub>2</sub> emitted from the combustion of biofuels has a “**neutral**” effect on climate change since it belongs to the **biogenic carbon cycle**.

# Why Is LCA Important? (Biofuel Case)

- ❑ Plants are one of the main sources of the biofuel.
- ❑ The CO<sub>2</sub> emitted from the combustion of biofuels has a **“neutral” effect** on climate change, because it belongs to the biogenic carbon cycle, meaning that it used to be in the atmosphere before being taken up, via **photosynthesis**, by the plants that were the sources of the biofuel and that it will **be taken up by new plants again**.



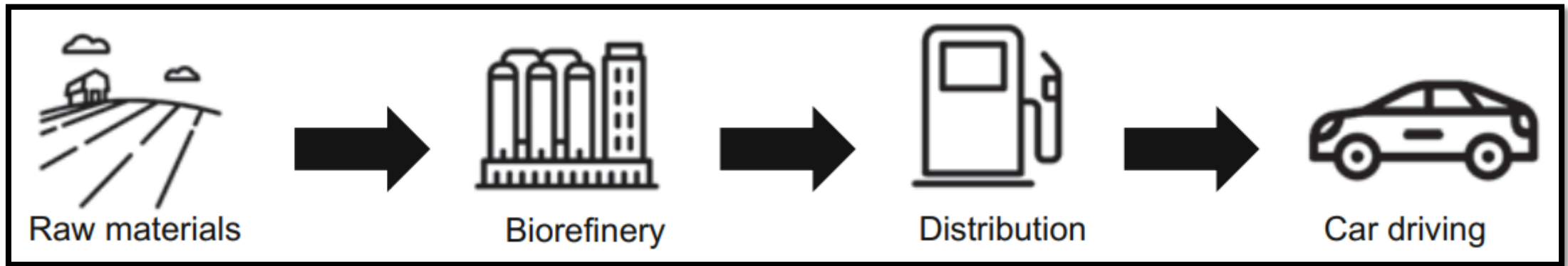
# Why Is LCA Important? (Biofuel Case)



□ While the **distinction** between **biogenic** and **fossil CO<sub>2</sub>** is important, LCA studies have shown that it was a mistake to:

- (1) consider the use of biofuels in the transport sector inherently “**climate neutral**”.
- (2) disregard potential increases in environmental problems other than climate change from a transition from fossil fuels to biofuels.

## Biofuels





# Why Is LCA Important? (Biofuel Case)

## Regarding first point

- ❑ When taking a life cycle perspective it is clear that **no biofuel** is “**climate neutral**”:
- ❑ The inputs of fossil fuels needed in industrial processes prior to the use stage.
- ❑ A consequence of the **increased demand for biofuel crops** may be the conversion of **natural land** (such as forest) to **cultivated land**.
- ❑ The conversion of natural land happens as an indirect consequence, i.e. **forest is being cleared** to make room for the **biofuel crops**.
- ❑ Increases in the production of biofuel crops may **indirectly contribute to a loss of natural land** (e.g. forest).



# Why Is LCA Important? (Biofuel Case)

## Regarding second point

- ❑ LCA considers multiple environmental issues and social issues when evaluating a product or a system.
- ❑ In the case of biofuels, the release of **nutrients** from **fertilizer** use and **synthetic chemicals** from **pesticide use**, lead to **eutrophication** and **toxic effects** on freshwater ecosystems.
- ❑ Cultivation requires large amounts of land and water for irrigation, which can lead to **biodiversity loss** and **water scarcity**.
- ❑ **Social impacts** from an increased production of biofuels have also been reported in the form of **increasing food prices**.





## Advantages and Disadvantages of Biofuels

- ❖ We **are not arguing** that the transportation sector should **abandon biofuels** as a strategy to reduce its use of fossil fuels and climate impacts.
- ❖ The world is not **black** and **white** and a more holistic perspective is required when evaluating technological changes.



# Class Participation 1

1. Explore additional scenarios (e.g., Electric Vehicles (EVs) vs. Internal Combustion Engine (ICE) Vehicles) and analyze them through a **life cycle lens**. You may consider the *environmental impact, resource usage, emissions*.
2. Write down your findings in a paragraph comparing the two cases, **highlighting** their **strengths** and **limitations** from a life cycle perspective.
3. Upload your findings to Canvas.
4. Engage in a class discussion to share your perspectives.



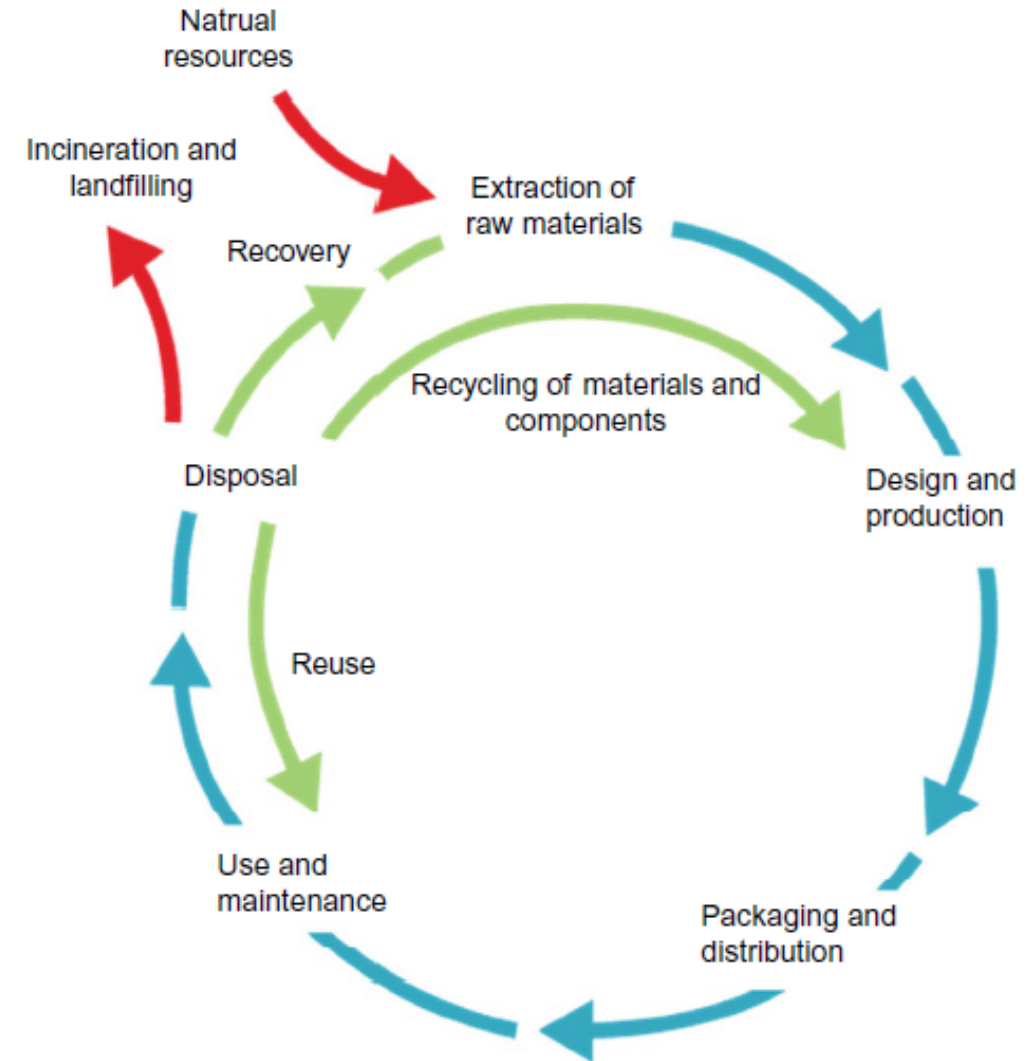
## 2. Main Characteristics

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# Main Characteristics of LCA

- ❑ A man-made object starts its **lifecycle** by
  - The harvesting and extraction of resources, followed by
  - Design and production,
  - Packaging and distribution
  - Use and maintenance
  - Management of the object as waste, which marks the end of the life cycle.

[The principles of Life Cycle Assessment \(LCA\) - YouTube](#)



Source: [Life Cycle Thinking](#)



# Broad Range of Environmental Issues

- ❑ LCA covers a broad range of environmental issues. The **core reason** for considering multiple environmental issues is **to avoid burden shifting** between life cycle stages and processes.
  - In some cases, efforts for lowering one type of environmental impact **unintentionally increase other types of environmental impacts**.
  - For example, decreasing impacts on climate change by **substituting fossil fuels** with **biofuels** has the potential to cause an increase in other environmental issues such as **water scarcity**, **eutrophication**, and **land occupation**.
- ❑ LCA coverage:
  - Climate change,
  - Freshwater use,
  - Land occupation and transformation,
  - Toxic impacts on human health,
  - Depletion of non-renewable resources and eco-toxic effects from metals and synthetic organic chemicals.

# Quantitative Nature of LCA

❑ LCA results answer the following question:

- “How much does a **product system** potentially impact the environment?”
- “The impact on climate change is **87 kg** of CO<sub>2</sub> equivalents”

❑ LCA results are calculated by

- (1) **Mapping** all emissions and resource uses,
- (2) Use factors derived from mathematical cause/effect models to calculate potential impacts on the environment from these emissions and resource uses.

❑ **Example:**

- (1) The **first** step often involves thousands of emissions and resource uses, e.g. “0.187 kg CO<sub>2</sub>, 0.897 kg nitrogen to freshwater, 0.000000859 kg dioxin to air, 0.331 m<sup>3</sup> freshwater...”.
- (2) The **second** step simplifies the complexity by classifying these flows into a manageable number of environmental issues (e.g., climate change and freshwater use).

# Strengths and Limitations of LCA

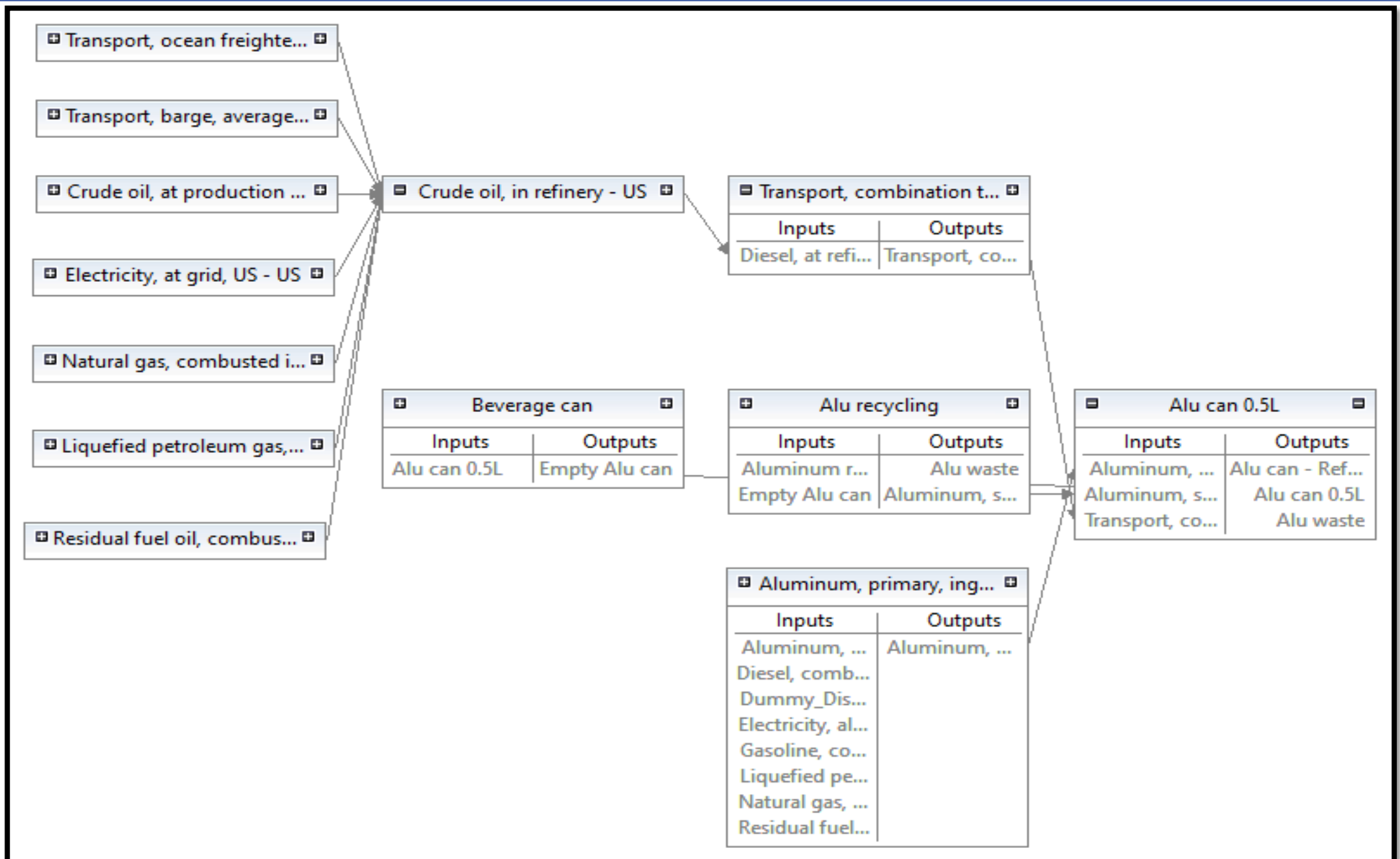
## ☐ Strength 1

- A main strength of LCA is its **comprehensiveness**. This allows the comparison of environmental impacts of **production systems** that are made up of **hundreds of processes**, accounting for thousands of resource uses and emissions.

## ☐ Limitation 1

- The **comprehensiveness** is also a **limitation**, as it requires **simplifications** in the modelling of the production systems, which prevents LCA from calculating actual environmental impacts.
- For example, considering the uncertainties in mapping of resource uses and emissions over time. The estimated impacts are **aggregated over time** (e.g. in 20 years). Therefore, it is more accurate to say that LCA calculates **potential impacts**.





# Strengths and Limitations of LCA

## ❑ Strength 2

- LCA follows the “**best estimate**” principle in the context of comparative assessments. This allows for **unbiased comparisons** because the **same level of precaution** is applied throughout the impact assessment modelling.

## ❑ Limitation 2

- LCA models are based on the average performance of the processes and do **not support** the **consideration of risks** of rare (e.g., marine oil spills or accidents at industrial sites).
- For example, **nuclear power** appears **quite environmentally friendly** in LCA because the small risk of a devastating disaster is not considered, like the ones that happened in **Chernobyl** (Ukraine) and **Fukushima** (Japan).

[The Chernobyl Disaster: How It Happened \(youtube.com\)](https://www.youtube.com/watch?v=9U3W333333)

# Strengths and Limitations of LCA

## ❑ Limitation 3

- LCA can tell you what (production system) is **better** for the environment, it **cannot** tell you if better is “**good enough**”.
- Therefore, it is **wrong** to conclude that a product is environmentally sustainable, in absolute terms, with reference to an LCA showing that the product has a lower environmental impact than another product.

# What LCA Can and Cannot Answer?

## ❑ LCA can answer

- Is paper, **plastic** or **textile bags** the **most environmentally friendly option** for carrying groceries back from the supermarket?
- What is the most environmentally friendly way to package and transport food?
- From an environmental perspective, **should plastics be incinerated or recycled?**
- Are **electric cars** more **environmentally friendly** than conventional **internal combustion engine cars**?



# What LCA Can and Cannot Answer?

❑ LCA **cannot** answer

- Should **taxes** on old diesel cars be **increased to reduce emissions** of particles and thereby reduce hospital spending on treating lung diseases?

**Explanation:** LCA cannot be used to compare the **societal disadvantages of higher taxes** with advantages of less pollution.

- Do total global emissions of endocrine disruptors cause polar bears to become hermaphrodites?

**Explanation:** LCA is not designed to assess a specific effect on a specific organism from a specific group of chemicals.