

IEooc_Application3_Exercise1a

Transport vs. Cooling of Apples

by Stefan Pauliuk, Version 1.0, May 2020

Objective: *To quantify the energy requirements for transport and storage/cooling. Calculate greenhouse gas emissions from these processes. Comparative calculation of the CO₂ footprints of different value chains (simple comparative life cycle assessment)*

Method: *Quantitative systems analysis*

"Consumers always want crisp and fresh fruit. Anytime. Also in April or May, when there are actually no ripe apples in Germany. The fact that we still find crunchy apples from Lake Constance or from South Tyrol in the supermarket in spring is due to energy-intensive cooling and storage over the winter.

In contrast, far away, in New Zealand or Chile, the harvest season just started. The fruits are harvested from huge apple orchards and brought to Europe by container ship." [1]

This situation raises the question of the environmental impact: Which of the two supply chains for apples - local harvest with subsequent cooling and import of seasonal goods from the southern hemisphere - have the lower environmental impact?

The following tasks will address this question.

Task 1. System definition

Draft a system definition for each of the two products "1 kg of apples from local harvest (fall) with subsequent cooling and consumption in May" and "Import of 1 kg of apples, seasonal goods from the southern hemisphere and consumption in May" in such a way that a comparative assessment of the environmental impact of both product systems is possible! Which processes are relevant for this?

<http://www.teaching.industrialecology.uni-freiburg.de/>

Task 2. Energy requirements for cultivation, transport and cooling

Calculate the energy flows and GHG emissions of the three process steps: cultivation, transport, and cooling, with the following data for both products:

a) Cultivation (data: see ref. [2]):

Cultivation in Germany: 2.8 MJ / kg, cultivation in New Zealand: 2.1 MJ / kg.

Assumption: This energy comes from natural gas (0.07 kg CO₂ / MJ, ref. [3])

b) Ocean transport and cooling:

Assumption: land transport is the same for both (if not OK, e.g. for regional apples, please get the relevant data yourself!) and is therefore not considered.

Sea refrigerated transport: Distance NZ-DE/NL (Rotterdam): 23000 km, energy requirement: 0.11 MJ / (t * km) (ref. [4]). This energy comes from heavy oil (proxy: diesel, 0.07 kg CO₂ / MJ, ref. [3])

c) Domestic storage / cooling:

Cooling large enterprise: 100 kWh / t (ref. [5])

Cooling small business: 500 kWh / t (ref. [5])

Generic cooling: 45 kWh / m³ / yr (ref. [6]), (with 1 ton of apples on 2 m³ and 0.5 years of storage, the value per ton is: 45 kWh / t.)

Also, electricity mix DE: 474 g CO₂-eq / kWh (ref. [7]) or 'green' electricity with 50 g CO₂-eq / kWh.

Task 3. Energy and GHG account

Determine the total energy demand and GHG emissions of the system (cumulative energy demand and CO₂ footprint) for the option "cooling large enterprise" and the electricity mix DE

Task 4. Sensitivity analysis

Vary transport distance ocean (e.g. South Africa: 12000 km) as well as the energy intensity of cooling and the electricity mix.

Task 5. Interpretation, application and further research needs

How realistic are modeling and calculation? Which recommendations for consumers and tips for further research follow from the above analysis?

References

- [1] <https://www.br.de/radio/bayern1/inhalt/experten-tipps/umweltkommissar/umwelt-afel-regional-neuseeland-100.html>
- [2] <https://doreenbrumme.de/2015/06/oekobilanz-eines-afels-einheimisch-und-regional-vs-importiert/>
- [3] https://en.wikipedia.org/wiki/Energy_content_of_biofuel
- [4] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Tech_Brief_RE_for-Shipping_2015.pdf
(Fig. 1, with 39 MJ/kg energy density, ref. [3])
- [5] <https://www.spiegel.de/wissenschaft/mensch/oekobilanz-regionale-aepfel-sind-nicht-automatisch-klimafreundlich-a-560751.html>
- [6] <https://www.tis-gdv.de/tis/tagungen/svt/svt10/weilhart/inhalt-htm/>
- [7] <https://de.statista.com/statistik/daten/studie/38897/umfrage/co2-emissionsfaktor-fuer-den-strommix-in-deutschland-seit-1990/>