Excellent Environmental performance of beet sugar production in the Netherlands

Life Cycle Assessment (LCA) study on beet sugar, cane sugar and glucose syrup

Bertram de Crom[1] (bertram.de.crom@suikerunie.com)
Janjoris van Diepen[2] (janjoris@blonkconsultants.nl)
Jasper Scholten[3] (jasper@blonkconsultants.nl)

[1] Bertram de Crom, Suiker Unie, Noordzeedijk 113, Dinteloord, The Netherlands
[2] Janjoris van Diepen (MSc), Blonk Consultants, Gravin Beatrixstraat 34, Gouda, The Netherlands
[3] Jasper Scholten (MSc), Blonk Consultants, Gravin Beatrixstraat 34, Gouda, The Netherlands

Abstract

To get more insight in the environmental performance of the Suiker Unie beet sugar, Blonk Consultants performed a comparative Life Cycle Assessment (LCA) study on beet sugar, cane sugar and glucose syrup. The system boundaries of the sugar life cycle are set from cradle to regional storage at the Dutch market. For this study 8 different scenarios were evaluated. The first scenario is the actual sugar production at Suiker Unie. Scenario 2 until 7 are different cane sugar scenarios (different countries of origin, surplus electricity production and pre-harvest burning of leaves are considered). Scenario 8 concerns the glucose syrup scenario. An important factor in the environmental impact of 1 kg of sugar is the sugar production per ha. Total sugar production per ha differs from 9 tonne of sugar per ha for sugarcane to 15 tonne sugar per ha for sugar beet (in 2017). Main conclusion is that the production of beet sugar at Suiker Unie has in general a lower impact on climate change, fine particulate matter, land use and water consumption, compared to cane sugar production (in Brazil and India) and glucose syrup. The impact of sugarcane production on climate change and water consumption is highly dependent on the country of origin, especially when land use change is taken into account. The environmental impact of sugar production is highly dependent on the co-production of bioenergy, both for beet and cane sugar.

1. Introduction

There is a lot of discussion about the difference in environmental impact between sugar from sugar beet and sugar from sugarcane. To get more insight in the environmental performance of Dutch beet sugar produced by Suiker Unie, Blonk Consultants performed a comparative Life Cycle Assessment (LCA) study on granulated beet sugar, granulated cane sugar and glucose syrup. LCA is a framework that allows the quantitative analysis of the environmental burdens of a product or system throughout all the stages of its life cycle. From the extraction of raw materials, production, processing, use and end of life management. This LCA study has been conducted according to the requirements of ISO 14044 [1], [2] and was externally reviewed by a panel of three experts. The review team declared that the methods used to carry out the LCA are consistent with ISO 14044 and are scientifically and technically valid.

2. Goal, scope & methodology

The goal of this study is to investigate the environmental impact of Suiker Unie beet sugar, compared to cane sugar and glucose syrup from corn starch on the Dutch market. Different kind of sugars (glucose, fructose, sucrose) have different kind of sweetness [3]. As the definition of sweetness is arguable and to prevent a more favourable result for sugar beet and sugar cane compared to glucose syrup, sweetness was not corrected for in the functional unit. The chosen functional unit is 1 kg of dry sugar at regional storage on the Dutch market.

The system boundaries of the sugar life cycle are set from cradle to regional storage at the Dutch market. Therefore, the LCA includes life cycle stages cultivation, transport and processing. The production of sugar packaging and the use phase of the product are not included.

In a multifunctional process, the environmental impact of the whole process should be allocated to its different products. At the production of sugar, allocation is needed for the following products: sugar, molasses, pulp. Economic allocation was applied as default allocation approach for production of co-products according to the Product Environmental Footprint Category Rules (PEFCR) for feed products [4] from the European Commission. For surplus energy production, *substitution* was used according to allocation rules in ISO 14040/14044 [1], [2].

The ReCiPe 2016 method [5] was chosen as impact assessment method. Based on relevant impact categories for agri-food products according to the PEFCR [6], expert judgment and robustness, the following (midpoints) impact categories are selected: climate change with and without land use change (CO_2-eq), fine particulate matter formation (PM2.5 eq), agricultural land use ($m^2 \cdot$year), water consumption (m^3), freshwater eutrophication (kg P-eq), marine eutrophication (kg N-eq), terrestrial acidification (kg SO_2-eq) and fossil resource scarcity (kg oil-eq). Other impact categories like toxicity are not taken into account because of low data availability, low data quality and low robustness. This article focus on the most relevant impact categories climate change, land use, water consumption and fine particulate matter.

3. Sugar production scenarios

For this study 8 different scenarios were evaluated. The first scenario is the actual sugar production in the Netherlands. Scenario 2 – 7 are different cane sugar scenarios, while scenario 8 is the glucose syrup scenario.

The *beet* sugar scenario is based on cultivation and processing of sugar beets at Suiker Unie. Both Suiker Unie sugar factories are equipped with a combined heat and power plant (CHP). This technology allows to produce heat and electricity, the surplus electricity is delivered to the public grid. Suiker Unie started some years ago with fermentation of beet pulp and tails to produce biogas which is partly used as fuel in the CHP. Most of the biogas is upgraded to natural gas quality en supplied to the national grid.

The country of origin has a great impact on the environmental impact of *cane sugar*. The top world producers of cane sugar are Brazil and India and are included in this study. Like sugar production from beet, co-production of bioenergy influences also the environmental impact of cane sugar. Bagasse from the sugarcane is used as a biofuel for the sugar mill. Surplus electricity production from bagasse has become more common and the efficiency of the electricity production has increased [7]. Although forbidden in most countries, pre-harvest burning is still practiced easing the harvesting process (about 60% in Brazil). Emissions of pre-harvest burning of the sugarcane field is an important parameter in the environmental impact of sugarcane. Especially as pre-harvest burning causes local health problems due to fine particulate matter emissions [8].

Corn starch is commonly used as the source of *glucose syrup*. A scenario was calculated with a Dutch market mix of corn from several countries of origin and corn refinery in The Netherlands.

The following scenarios for sugar production were calculated in this study:

1) Beet sugar, at Suiker Unie plant
2) Cane sugar with no electricity delivered to the grid and no pre-harvest burning (Brazil)
3) Cane sugar with no electricity delivered to the grid and no pre-harvest burning (India)
4) Cane sugar with electricity (from bagasse) delivered to the grid and no pre-harvest burning (Brazil)
5) Cane sugar with electricity (from bagasse) delivered to the grid and no pre-harvest burning (India)
6) Cane sugar with no electricity delivered to the grid and pre-harvest burning (Brazil)
7) Cane sugar with no electricity delivered to the grid and pre-harvest burning (India)
8) Glucose syrup from corn starch

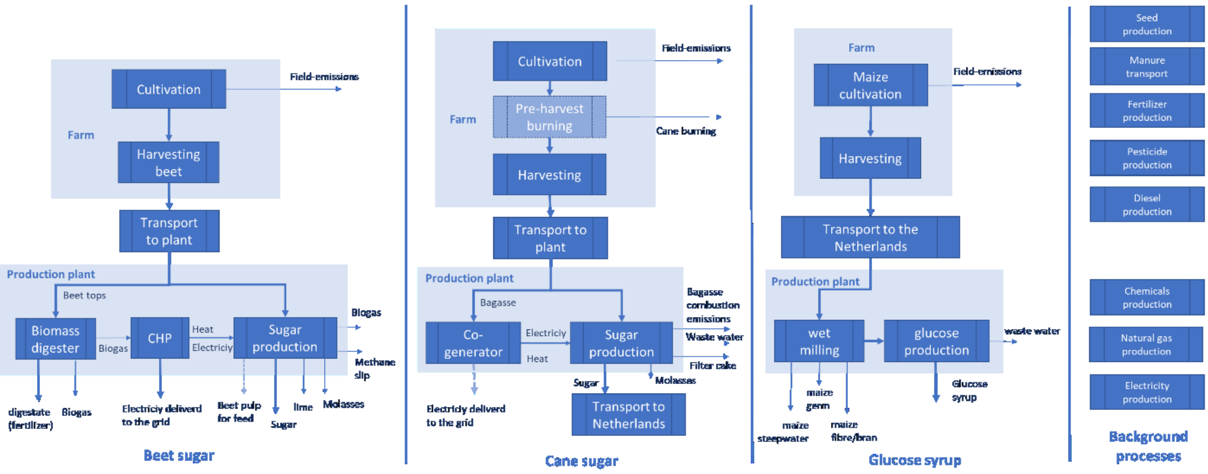

Figure 1 Simplified process flows of the different sugar production scenarios

4. Software and data

SimaPro LCA software (version 8.5) was used as a tool for calculating the environmental impact. Agri-footprint version 4.0 [9], [10] was used as main source for secondary data. Agri-footprint is a high quality and comprehensive LCA database, focused on the agriculture and food sector. The Ecoinvent database version 3.4 was used as a source for secondary data of some specific chemicals when data was not available in Agri-footprint.

The cultivation of sugar beets was based on primary data of 9000 Suiker Unie farmers for yield, energy use, manure and fertilizer use. As cultivation data varies year by year, a yearly average was taken for the years 2013 through 2017. When no primary data was available, secondary data from Agri-footprint 4.0 [9], [10] was used. The processing data for the beet sugar were based on primary data of Suiker Unie from both production plants in the Netherlands. As production data varies year by year, a yearly average was taken for the years 2013 through 2017.

The dataset for cultivation of sugarcane in Brazil and India was taken from Agri-footprint 4.0 [9], [10]. Modelling of (emissions of) crop residues of sugarcane cultivation has been improved since the release of Agri-footprint 4.0. As this change has a significant positive impact on the results, the sugarcane cultivation dataset was adapted accordingly. The dataset for processing of sugarcane in Brazil and India were also taken from Agri-footprint 4.0. These Agri-footprint processes are based on Australian sugar mills, derived through industry consultation. No recent good-quality processing data and/or specific data for Brazilian and Indian sugar mills could be found in literature. The data for sugarcane processing was adapted by some latest insights.

The cultivation, transport and milling datasets of corn were taken from Agri-footprint 4.0 [9] and is based on secondary datasets. The country of cultivation was based on the Dutch market mix based on FAO trade statistics. The corn refinery process to produce glycose syrup from corn starch was modelled based on US data from a corn refinery of >400.000 tons corn per year [11]. Wheat is an alternative source for glucose syrup instead of corn and was considered in a sensitivity analysis.

5. Results

An important parameter for the environmental impact of 1 kg of sugar is the sugar production per ha. Yields of sugarcane in Brazil and India don't vary a lot and range from 70 – 75 tonne per ha in the last three years 2015 - 2017 (FAO). Sugar beet has a yield of around 85 tons per ha in The Netherlands. The total sugar production per ha differs from 9 tonne of sugar per ha for sugarcane to 15 tonne sugar per ha for sugar beet (2017).

Land use

This difference in land use for beet sugar, cane sugar and glucose syrup (see Figure 2) is mainly due to the differences in yields and process efficiencies as described above. Pre-harvest burning and surplus electricity production have no effect on land use.

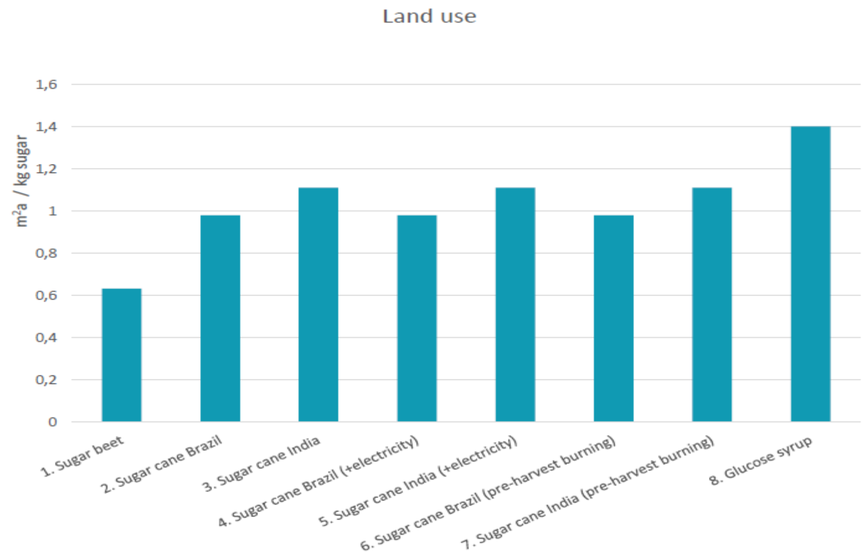

Figure 2 Agricultural land occupation of sugar for different sugar production scenarios

According to the ISO/TS 14067 [12] and the latest PEFCR guidance of the European Commission [6] the carbon emissions due to land use change (LUC) should be reported separately. Climate change caused by LUC differs per country. Sugar cane cultivation takes place in developing countries where deforestation is an environmental issue. Sugar cane cultivation in India is almost not associated with LUC. Climate change caused by LUC is less relevant for maize cultivation as most of the maize on the Dutch market is cultivated in Europe. Sugar beet cultivation in the Netherlands is not associated with LUC.

Climate change

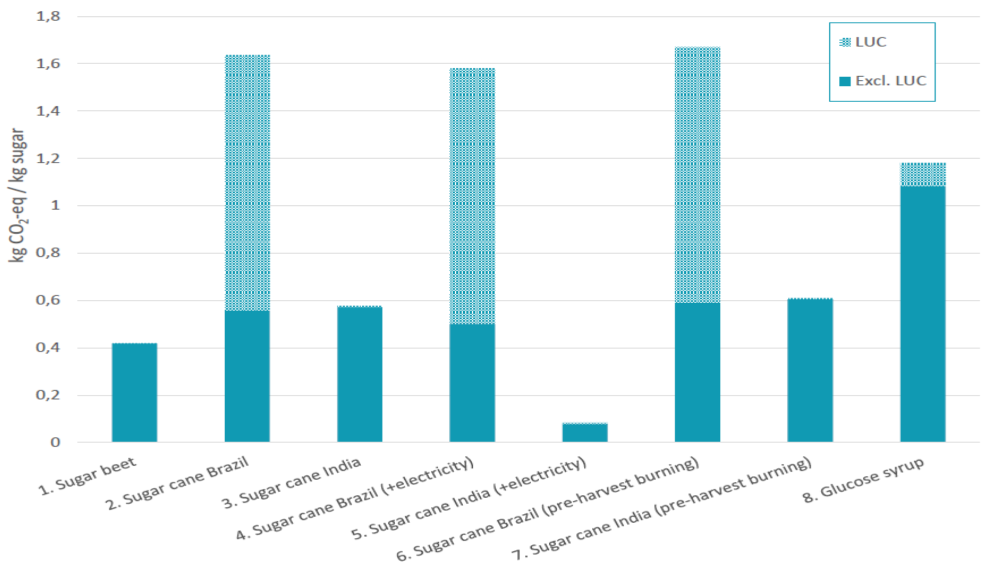

Figure 3 Climate change impact of sugar for different sugar production scenarios

The impact on climate change of sugar production differs highly (see Figure 3 and Figure 4), depending on the surplus energy production, both for cane sugar as for beet sugar. For cane sugar, the substitution effect of surplus energy production on climate change differs depending on the country of origin. Electricity production in Brazil is mainly hydropower so the positive impact of green electricity delivered to the grid by the sugar production is not as high as in India, where fossil fuel is mainly used for electricity production.

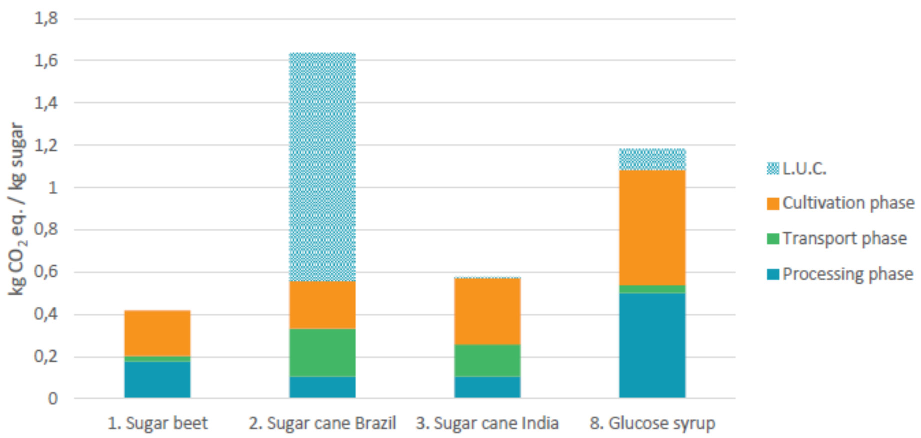

Figure 4 Contribution analysis of different life cycles to climate change for different sugar production scenarios

Fine particulate matter

Cane sugar production has a higher particulate matter production then sugar beet production (see Figure 5). Pre-harvest burning has a negative impact on fine particulate matter. The scenario of cane sugar production with surplus electricity in India has the lowest fine particulate matter production, it's even negative. The avoided production of conventional electricity has a high impact on the result.

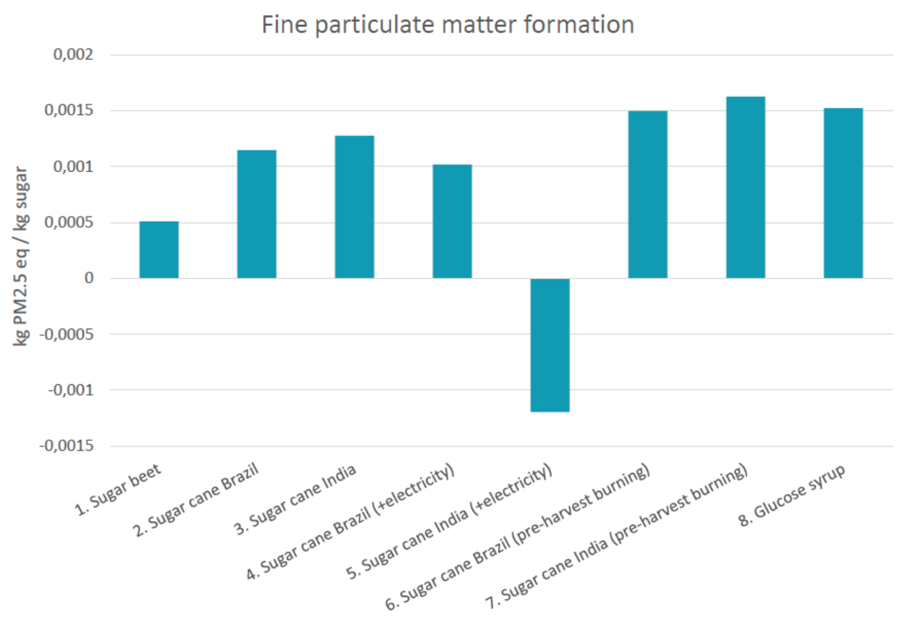

Figure 5 Fine particulate matter formation of sugar for different sugar production scenarios

Water consumption

The water flows of relevance are mostly irrigation water and some water consumption during processing. As most water consumption during processing of sugarcane and beet is water recovered from the evaporation of the cane or beet juice [13], no input of extra water is needed. Sugar beet farms in the Netherlands do only use little irrigation water according to the water footprint data [14]. Water consumption for cane sugar production differs a lot per country. Especially India scores high on water consumption (see Figure 6). The ReCiPe impact assessment only considers water consumption. When looking at water stress, where also the availability of water is considered, the scenarios of sugarcane production in India are even worse. Water consumption for irrigation causes a lot of water stress in the Indus valley where a lot of sugarcane is cultivated [16].

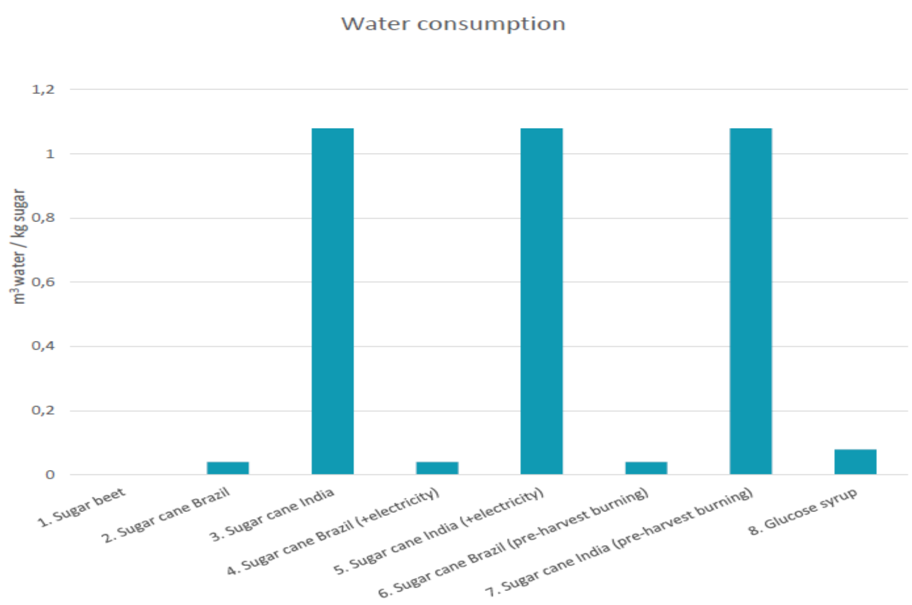

Figure 6 Water consumption of sugar for different sugar production scenarios

6. Conclusions

The results from this LCA lead to the following conclusions regarding this investigation:

- The production of beet sugar at Suiker Unie has in general a lower impact on climate change, fine particulate matter, land use and water consumption, compared to cane sugar production (in Brazil and India) and glucose syrup. Cane sugar from India with surplus electricity production has a lower impact on climate change and fine particulate matter when 'substitution' is used as allocation method for the surplus electricity production.
- The impact of cane sugar on climate change and water consumption is highly dependent on the country of origin, especially when land use change is taken into account.
- The environmental impact of sugar is highly dependent on the co-production of bioenergy, both for beet sugar and cane sugar.
- The relevance of surplus energy production in the sugar industry increases. When economics of production process and business change, it could be arguable to allocate surplus energy as a co-product.

Data for sugarcane processing is somehow outdated. As energy efficiency is increasing and surplus energy production has a major effect on the environmental impact, it is recommended to collect more recent (primary) data.

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