**PRODUCT INFORMATION**

Sugar for use in food corresponds mainly to crystalized white sugar (composed of sucrose, a disaccharide of glucose and fructose). It is extracted from the stem of sugar cane or the root of sugar beet through a refining process (Fig. 1). Processes also exist to produce sugar from corn and wheat starches, however they represent a very small part of sugar consumed in the EU. The European Union is the world’s biggest producer of beet sugar and the largest importer of raw cane sugar for refining. Sugar cane typically contains 12-13% sugar of which 30 to 100% can be extracted, while sugar beet contains about 16% sugar of which 40 to 80% can be extracted [2].

**EU production:**
109 million tons of sugar beet, equivalent to 17.5 million tons of sugar (2013) [3].

**Co-products:**
- Sugar cane: bagasse (mainly cellulose, hemicellulose and lignin) and molasses (64.1% sugars and 5.5% protein) [4].
- Sugar beet: pulp (mainly cellulose, hemicellulose and pectin) and molasses (sugar 63.2%, and 14.3% protein [5]), calcium carbonate and stones (from beet washing) [6].

Pulp and molasses are often used as animal feed.

**Figure 1:** sugar production chain and system boundary (* the study by [1] did not incorporate the emissions associated with the generation of the farming, transport and refinery infrastructure, it only account for the emissions resulting from their use).
sugar cane). New varieties of tropical sugar beet are now becoming available and could possibly compete with sugar cane in dryer tropical areas. Since 2006, the EU sugar market is regulated by production quotas, a minimum beet price and trade mechanisms. However, out-of-quota industrial white sugar does not have a fixed buy price. The total EU production quota is 13.5 million tons of sugar (2013) [3]. Sugar imports (3.3 million tons) are mainly in the form of raw cane sugar for refining (64%) and white sugar (26%), from the African, Caribbean and Pacific states and Least Developed Countries (LDC) which benefit from quota-free, duty-free access to the EU market. Imports from other countries are subject to high import duties (€339 per ton on raw cane sugar for refining and €419 per ton on white sugar). Apart from food applications sugar and sugar molasses are also used in the production of bio-based products (such as, biopolymers, organic acids and amino acids) and bioethanol, through fermentation processes. For this applications research is also targeting new feedstocks for the production of sugars, such as lignocellulosic materials.

**Technology Readiness Levels**

![Technology readiness levels for sugar production systems.](image)

**SWOT analysis (Strengths-Weaknesses-Opportunities-Threats)**

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1. Sugar is produced in many countries, and both the production of the sugar crops and the process of sugar refining are well known. S2. The sugar cane and sugar beet industries benefit from strong research and development and a wide range of crop varieties is available.</td>
<td>W1. Sugar production can be strongly affected by seasonal variations in climatic conditions such as drought (particularly sugar cane). W2. Sugar is the main source material for the production of ethanol and a possible competition (post 2017) between use for food or fuel could lead to increased price variability.</td>
<td>O1. The EU production quota will end in 2017, possibly allowing an increase in production. O2. Future increases in atmospheric CO₂ have potential to increase sugar beet yields (experiments showed increases of sugar beet yield by up to 26%).</td>
<td>T1. Increases in temperature associated with climate change could lead to lower biomass production in sugar beets. T2. The cultivation of sugar cane is often associated with the destruction of natural habitat and environmental degradation which could lead to a negative response from consumers.</td>
</tr>
</tbody>
</table>
ENVIRONMENTAL DATA AND INFORMATION

System boundaries of the environmental assessment (Fig. 1)
- **Cradle to farm gate** includes the processes of cultivation of the sugar crops, pre-harvest burning (for sugar cane) as well as harvesting. None of the cradle to farm gate studies investigated incorporated emissions associated with the making of the production infrastructure.
- **Cradle to sugar mill**: includes the same elements as cradle to farm gate as well as transport of the crop to the refinery, the process of extraction and concentration of sugar to raw form and then to white sugar, by separation of the molasses from the sucrose. Most studies ([1] excepted) incorporated emissions associated with the making of the production infrastructure. The majority of sugar cane brought into Europe as raw sugar undergoes extra transport and refining into white sugar. The emissions associated with these extra steps were incorporated by [7] only.

The results presented in Table 1 illustrate the environmental indicators associated with the production of sugar from sugar cane, sugar beet and other crops. The most widely reported impact categories are climate change, acidification, eutrophication, and energy (water consumption, not presented here, is also reported in some studies). Few or no results were found for the remaining impact categories. The studies used a variety of functional units (kg of monosaccharide in juice form, kg extractable sugar, raw sugar, tones of harvested canes or beets and kg crystallized white sugar) and we performed an harmonization into kg extractable sugar.

**Environmental assessment: settings & impacts**

Table 1: LCA result for different sugar production systems and system boundaries. Functional unit in kg of extractable sugar.

<table>
<thead>
<tr>
<th>Sugar crop type</th>
<th>Sugar cane</th>
<th>Sugar beet</th>
<th>Corn / wheat</th>
<th>Sugar cane</th>
<th>Sugar beet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>References</strong></td>
<td>[1, 6-9]</td>
<td>[6, 7]</td>
<td>[6, 7]</td>
<td>[9, 10]</td>
<td>[11]</td>
</tr>
<tr>
<td><strong>Study boundary</strong></td>
<td>Cradle to sugar mill gate</td>
<td>Cradle to sugar mill gate</td>
<td>Cradle to sugar mill gate</td>
<td>Cradle to farm gate</td>
<td>Cradle to farm gate</td>
</tr>
<tr>
<td><strong>Geographical coverage</strong></td>
<td>Australia, Mauritius, Brazil</td>
<td>UK, EU</td>
<td>USA</td>
<td>Australia, USA</td>
<td>Germany</td>
</tr>
</tbody>
</table>

Impact categories from Environmental Sustainability Assessment methodology

<table>
<thead>
<tr>
<th>Climate change (kgCO₂eq)</th>
<th>-0.05 – 0.76</th>
<th>0.242 – 1.3</th>
<th>0.64 – 1.16</th>
<th>0.042 – 0.251</th>
<th>0.196 – 0.234</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Additional impact categories</strong></td>
<td>Acidification (kg SO₂ eq)</td>
<td>-4.7E⁻² – 1.33E⁻³</td>
<td>2.96E⁻² – 4.84E⁻³</td>
<td>7.83E⁻² – 0.01</td>
<td>-4.70E⁻² – 8.56E⁻³</td>
</tr>
<tr>
<td>Eutrophication – aquatic (kgPO₄ eq)</td>
<td>1.38E⁻⁴ – 4.20E⁻³</td>
<td>6.40E⁻⁴ – 1.20E⁻³</td>
<td>2.3E⁻³ – 3.36E⁻³</td>
<td>1.38E⁻⁴ – 4.23E⁻³</td>
<td>2.57E⁻³ – 3.64E⁻³</td>
</tr>
<tr>
<td>Energy use MJ/kg</td>
<td>-10.05 – 3.59</td>
<td>4.35 – 6.3</td>
<td>5.9 – 7</td>
<td>8.65E⁻³ – 1.96</td>
<td>N.A.</td>
</tr>
</tbody>
</table>

**Note:** N.A. = Not Available

**Comments and interpretation of environmental performance (Table 1 & Fig. 3)**

- On a normalised scale for the EU28, eutrophication and energy use represent the most important environmental impact associated with sugar, mainly because of fertiliser use and heating needs for the refining process.
- The lowest impacts for energy use were reported for sugar cane, principally because of the use of bagasse to generate energy.
- The effects of study boundary are particularly visible for acidification and eutrophication where the inclusion of the sugar milling processes reverse performance of sugar cane from lowest emitter to highest emitter.
The normalisation presented in Fig. 3 is performed using the normalization factors provided in the JRC 2014 methodology [12] and ReCiPe normalization values (see explanatory factsheet).

**Figure 3:** Environmental performance expressed as normalized impact categories. Circles correspond to cane sugar, triangle correspond to sugar beet, diamond for corn or wheat (cradle to sugar mill). Crosses correspond to sugar beet and horizontal bars correspond to sugar cane (cradle to farm gate).

**REFERENCES / FURTHER INFORMATION**