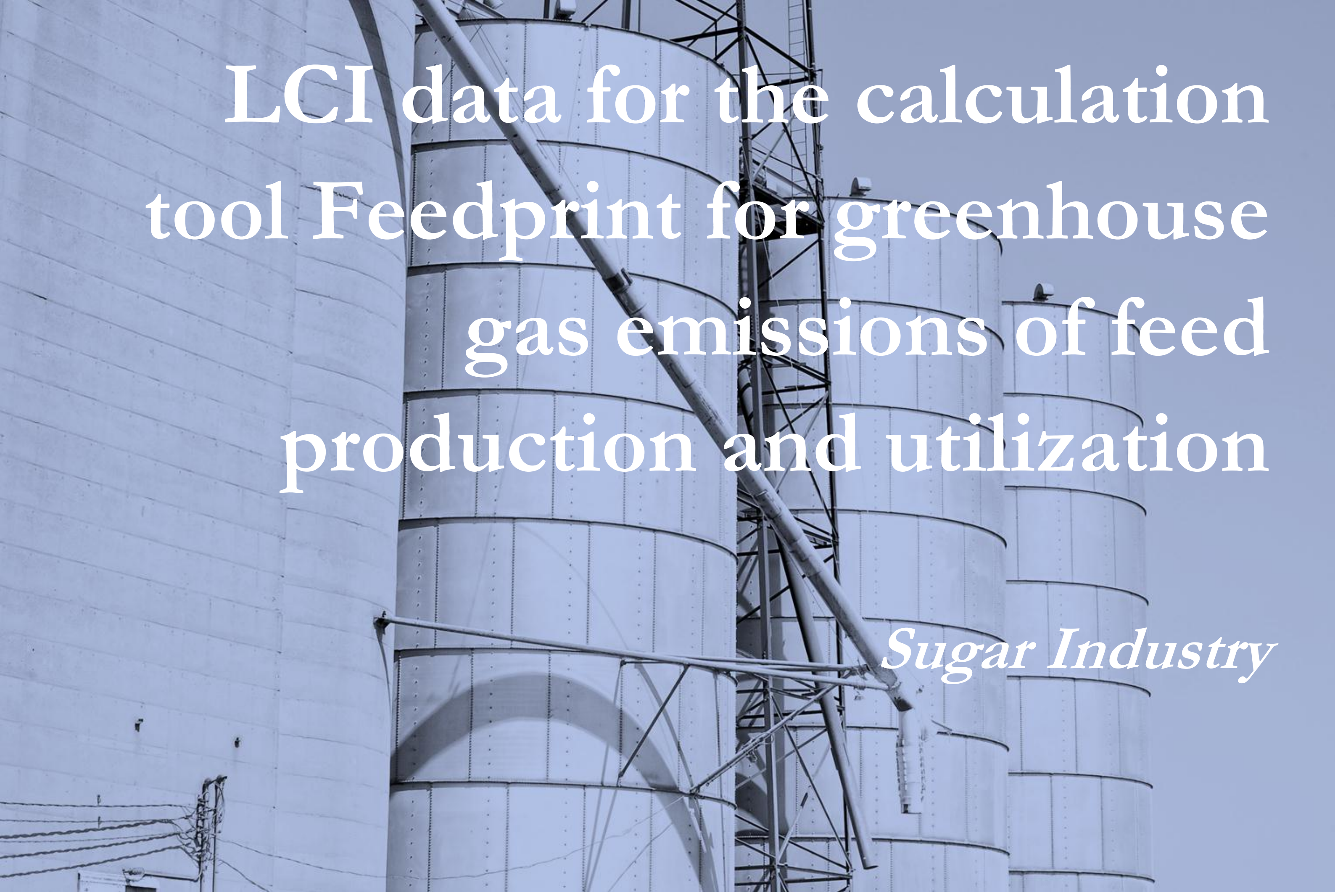

LCI data for the calculation tool Feedprint for greenhouse gas emissions of feed production and utilization

Sugar Industry

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November, 2012

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Table of contents

5.1 Introduction

5.1.1 Context of this document & reading guide

This document is part of the background documentation for the FeedPrint program and database. Background information of this project, underlying methodology and justification thereof, can be found in the 'FeedPrint methodology' document. These chapters focus only on the processing step of crops into the feed materials. Information on origin of crops is given, but details on cultivation and transportation (to and from the processing facility) are described in separate documents: the cultivation of each crop is described in the cultivation background reports similar to this one (Marinussen et al, 2012), whereas transportation is described in the Feedprint methodology report (Vellinga et al, 2012).

Each chapter can be read and interpreted as a standalone set of LCI data, which covers the country of crop cultivation, the country of processing, mass balances, energy inputs (and outputs, if applicable), as well as data needed for the allocation of the by-products. In some cases, multiple processes can follow one another with multiple allocation steps. In these cases, the data is entered into the database by following these specific processing steps consecutively. Usually (but not restrictively) the data entered are relative to an input of 1000 kg of crop product.

5.1.2 Overview of products and allocation principles

The two chapters in this document describe the production of sugar from sugar beets and sugar can, whcih produce animal feed by-products. The processes described in this document are treated as a single unit process with multiple valuable output products, where allocation methodology 1 is applied (see also chapter 5 of the methodology document: Vellinga et al, 2012) in which all products are treated as valuable by-products to which upstream emissions will be allocated according to economic, energy, or mass allocation. Only for wet beet pulp, which is an important animal feed material, no upstream emissions are allocated to the wet pulp, as it is considered a very low value residue stream.

5.1.3 Structure of data

This document contains tables that reflect those data applied in the FeedPrint program. Additionally, tables with background data are supplied, which are often inventories of encountered literature. Only the tables that are used as data for the FeedPrint database and calculations are given a table number (see for an example Table 5.1.1). Other tables that are not used in the FeedPrint database are not numbered and have a simpler layout, see the example below.

Table 5.1.1 Example default inputs table for FeedPrint database.

Output	Values		Unit
	Best estimate	Error (σ_g^2)	
Electricity	88	1.4	MJ/ton
Natural gas	245	1.4	MJ/ton

Example of background data not directly used in FeedPrint database

Source	**Data found**	**Remarks**
Reference 1	80 MJ/ton	Older data from 1 processing facility.
Reference 2	90 MJ/ton	Newer data from multiple facilities.

There are a number of recurring types of tables, usually in the following order:

1) Definition of feed materials related to the process;
2) Estimation of countries of origin of the crop and countries of processing;

3) Mass balances for the process;
4) Energy or material inputs needed for the process;
5) Allocation factors for the outputs from the process.

Unless explained otherwise in a specific chapter, these five tables are present for each process. Additional sections or figures can give information on, for example, the definition of the process represented with a flowchart. Each section also contains the references for cited sources. The usual structure of a section is that first the default inputs for the FeedPrint database are presented, with the rest of the section explaining in detail which data sources were used and why.

There are a number of different types of error ranges that can be given for each data point, and these are applied for the energy and auxiliary inputs. More background information can be found in the overall methodology document (Vellinga et al. 2012), which also explains the decision process followed to arrive at the error ranges.

5.1.4 Glossary of terms

Below is a list of terms with definitions as applied in this document.

DMC	Dry matter content in g/kg.
GE	Gross Energy content in MJ/kg.

5.1.5 References

CVB-table: see appendix 1 in Vellinga et al. (2012)

European Commission. (2011). COMMISSION REGULATION (EU) No 575 / 2011 of 16 June 2011 on the Catalogue of feed materials. Official Journal of the European Union, (L 159), 25–65.

Marinussen et al (2012) Background data documents on cultivation. Blonk Consultants. Gouda, the Netherlands

Vellinga, T.V., Blonk, H., Marinussen, M., van Zeist, W.J., de Boer, I.J.M. (2012) Methodology used in feedprint: a tool quantifying greenhouse gas emissions of feed production and utilization Wageningen UR Livestock Research and Blonk Consultants. Lelystad/Gouda, the Netherlands.

5.2 Sugar beet

5.2.1 By-products from sugar beet

Sugar beet products used in the Dutch feed industry are mainly sourced from the Netherlands and Germany. In the Netherlands, Suiker Unie is the main producer. In Germany, Suedsucker is the largest producer. We have gathered data from the public domain for both companies. As data related directly to these companies is either limited or old, it was decided to construct a single LCI inventory for sugar beet processing applicable to the Netherlands and Germany.

Feed materials derived from sugar beets present in the CVB database are shown in the table below:

Table 5.2.1 Animal feed products from sugar beet processing and characteristics (source: CVB)

Name CVB	DMC	Sugar content
	g/kg	g/kg
Sugarb pulp SUG<100	898	73
Sugarb p SUG100-150	903	118
Sugarb p SUG150-200	912	186
Sugarb pulp SUG>200	915	223
Sugarbeet molasses	723	430
Sugar	1000	1000
Beetp pressed fresh+sillage	218	188

In the Annual Environmental Report of 2003 (Suiker Unie, 2003), Suiker Unie has published data on energy use and the production mass balance, but these have not been updated since at the necessary detail for LCI data. Suedsucker has some information on their website and they supplied additional information on request. The European Commission (2006) report on food, drink and milk industries contains some data on sugar beet processing and beet pulp drying. There was only one relevant research paper with data on sugar beet processing. However, it is about Slovenian industry, which may not be comparable with the sugar industry in the Netherlands and Germany. More recently, a paper (Klenk et. al, 2012) on the European sugar industry was published, and this data will likely be incorporate in a future update of the database.

5.2.2 Sourcing

The Dutch feed industry source sugar products mainly from the countries listed in Table 5.2.2. The beet cultivation generally takes place in the same country of processing.

Table 5.2.2 Estimated countries of origin of the feed materials.

Phase	the Netherlands	Germany
Processing	90%	10%
Crop cultivation in the Netherlands	100%	0%
Crop cultivation in Germany	0%	100%

5.2.3 Flowchart

In Figure 5.2.1, a flowchart of sugar beet processing is shown.

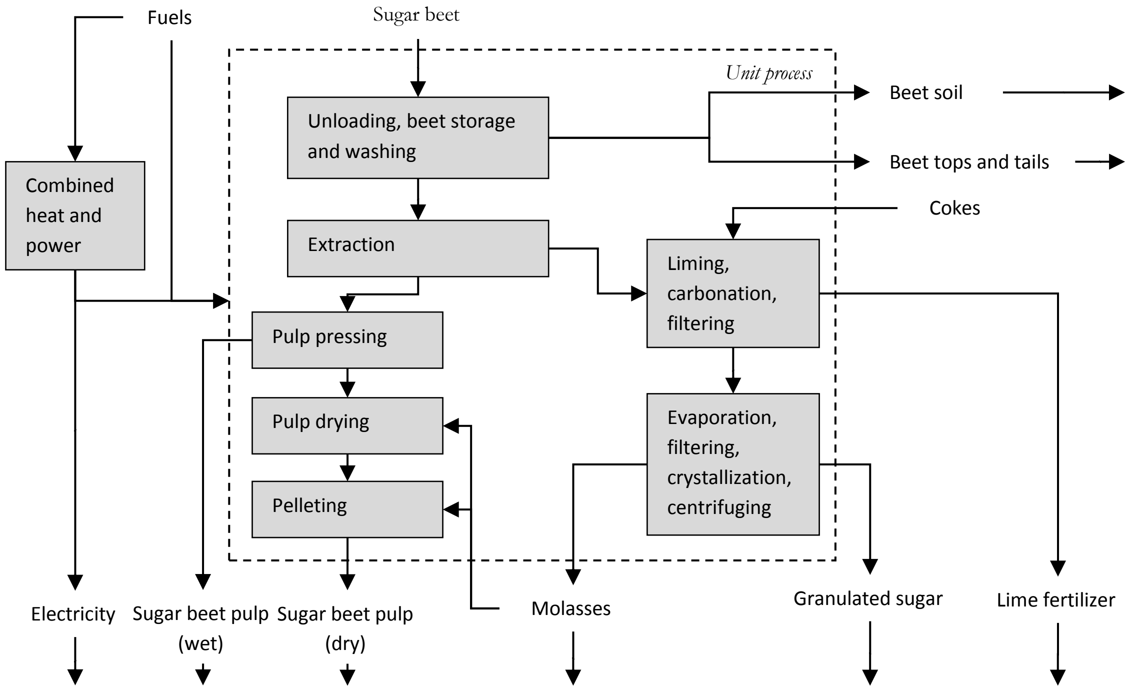

Figure 5.2.1 Flowchart of sugar beet processing.
(based on: http://www.suedzucker.de/en/Zucker/Zuckergewinnung/production-diagram.pdf)

The molasses are mixed in, partially with the beet pulp products, and it is not straightforward to identify exactly the amounts of wet beet pulp before mixing with molasses to various degrees. It also depends on the processing site whether the molasses are further dried with the pulp, or added later in the pelleting process. Because of these considerations, it was decided to group all the dried beet pulp By-products listed in the CVB list as one beet pulp product.

The drying of beet pulp is treated as a separate process in the LCI data, and the preceding wet beet pulp is considered a residue to which no economic allocation is attributed.

5.2.4 Mass balance

The default mass balance, shown in the table below, is constructed from the various sources listed in the remainder of the section. The mass balance (Table 5.2.3) shows product outputs (as is) per 1 tonne of processed sugar beet (which has a dry matter content of approximately 25%).

Table 5.2.3 Default mass balance sugar beet processing, excluding drying beet pulp.

	Dry matter content (g/kg)	Mass (kg product/tonne sugar beet)
Granulated sugar	1000	167
Lime fertilizer ($CaCO_3$)	500	60
Molasses	723	36
Sugar beet pulp	218	230

In this case the beet pulp dry matter content as in the CVB database is used as reference.

Table 5.2.4 Default mass balance sugar beet processing, excluding drying beet pulp.

	Dry matter content (g/kg)	Mass (kg product/tonne sugar beet)
Input:		
Sugar beet pulp	218	230
Output		
Sugar beet pulp (dried)	900	56

Background data sources on sugar beet processing are found below.

Mass balance from Suikerunie

Product	Mass output (kg product/tonne sugar beet)
Granulated sugar	167
Lime fertilizer	31
Molasses	39
Sugar beet pulp (dry)	26
Sugar beet pulp (wet)	118
Beet tops and tails	9
Beet soil	4

Suiker Unie Milieujaarverslag 2003.

Although Suiker Unie (2003) does not mention dry matter contents, when CVB data is applied, the total dry matter of beet pulp is 49.5 kgs/tonne beets. This is quite similar to the other sources.

Bietenstatistiek.nl notes a range in sugar content of beets in the past five years from 16.3 to 17.7 %, as shown in the table below.

Variation in beet sugar content according to bietenstatistiek.nl

year	2006	2007	2008	2009	2010	Average
Sugar content	16.3%	17.4%	17.2%	17.7%	16.8%	17.1%

Mass balance from Suedsucker

Product	Mass output (kg product/tonne sugar beet)	Dry matter (g/kg)	Protein content (g/kg)
Granulated sugar	160	1000	-
Lime fertilizer	8	720	-
Molasses	30	720	100
Sugar beet pulp (dry)	60	912	101
Beet tops and tails	10	163	151
Beet soil	40		-

Suedsucker (Dr. Frieder Lorenz) notes that the sugar beet pulp contains 18% sugar, which lies in the middle oft he range of beet pulp products on the CVB list.

Mass balance according to Krajnc, 2007

Product	Mass output (kg product/tonne sugar beet)
Granulated sugar	137
Lime fertilizer	51
Molasses	29
Sugar beet pulp (dry)	45
Beet tops and tails	11
Beet soil	98

As Dutch and German sources clearly indicate higher sugar yields compared to the mass balance from Krajnc (2007), which focuses on Slovenian industry. The data is considered to be less relevant compared to the other sources mentioned earlier. The difference in yields might be explained when taken into account the relatively high amount of soil in the incoming beets. When adjusted for this, the figures are close to those by Suiker Unie and Suedsucker. However, giving the uncertainty and low geographical relevance of the source, this data will not be incorporated in the default mass balance.

5.2.5 Inputs

In this section, generic inventory data will be gathered for inputs and outputs in sugar beet processing. In the two sections that follow, the default inputs are listed for Dutch and German sugar beet processing, specifically. For the general processing industry, there is data for both Dutch and German processing. For the beet pulp drying process, specific data reported here is from EC (2006), and described below.

The table below (Table 5.2.5) shows the overall energy inputs for sugar beet processing, but with the energy use for beet pulp drying specifically subtracted. The two separate data sources underlying are discussed in the remainder of this section.

*Table 5.2.5: Inputs for sugar production (per 1 tonne sugar beet, excluding beet pulp drying)**

Parameter	Unit	Best estimate	Min	Max
Natural gas	MJ/tonne	580	520	720
Heavy oil	MJ/tonne	18	0	36
lime	Kg/tonne	40	30	50
Electricity	MJ/tonne	4	0	18

* These figures are derived from the sugar production inventory data and the drying beet pulp data. See also the text in the remainder of this section.

Table 5.2.6: Inputs for beet pulp drying (per 1 tonne sugar beet, or 230 kg wet beet pulp).

Parameter	Unit	Best estimate	Max	Min
Electricity	MJ/tonne	15	7	10
Natural gas	MJ/tonne	325	385	55

A: EC (2006). Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Food, Drink and Milk Industries August 2006.

Energy consumption for drying beet pulp is described in the EC (2006) report (BREF, reference document for best available techniques). High temperature drying (HTD) is considered by the EC report to be the most prevalent method in Europa for beet pulp drying, and below we list all three drying options described. Figures in the Table below were derived from fuel energy and electricity demand for drying presented in the EC (2006) report (Page 553, Table 4.110). EC (2006) also gives a baseline energy use (without drying) and the median energy use level for total processing will be seen to be quite comparable to the overall processing energy use by other sources. The drying option with the lowest energy usage is actually an integrated plant in which surplus heat from sugar processing is used in the drying installation.

The drying figures from EC (2006) are based on a facility where 160 kg pressed pulp (at 31% dry matter content; 49.6 kg total dry mater) is produced from 1 tonne of beat. The drying energy below represents the subsequent drying step from 31% DMC to 90% DMC. The figures derived from this should be quite representative for the By-products on the CVB list.

*Drying beet pulp, inventory from EC (2006).**

Input	Unit per tonne sugar beet	HTD	Evaporation dryer	LTD	Rel	Com	TRC	GSp	TeC	Ref
Electricity	kWh	1.9	2.8	4.1	3	2	2	2	1	A
Natural gas	MJ	385	55	325	3	2	2	2	1	A

A: EC (2006). Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Food, Drink and Milk Industries August 2006.

* Table includes scores for the Pedigree reliability scoring method.

*Inventory data for sugar production (including beet pulp drying)**

Input	Unit per ton sugar beet	Mean	Min	Max	Rel	Com	TRC	GSp	TeC	Ref
Natural gas	MJ	920			4	4	3	1	1	A
Heavy oil	MJ	12	12	12	4	4	3	1	1	A
Electricity Bought	kWh	6.9	6.9	6.9	4	4	1	1	1	A
Electricity sold	kWh	0.3	0.3	0.3	4	4	1	1	1	A
Energy (total)	MJ	1105	835	1320	3	2	2	2	1	C
Natural gas	MJ	905	635	965	3	2	2	2	1	D
Electricity Bought	kWh	1.1	0	0	3	2	2	2	1	D
Electricity sold	kWh	0	0.9	0.11	3	2	2	2	1	D
Energy (total)	MJ	900								E
Energy (total)	MJ	995								F
cokes	kg	3	3	3	4	4	3	3	1	B
lime	kg	40	40	40	4	4	3	3	1	B

a. Suiker Unie Milieujaarverslag 2003. b. Krajnc et al (2007) c. EC (2006), Danish data, total energy only. d. EC (2006), Three German plants. e: Suedsucker website, Suedsucker (Dr. Frieder Lorenz) f: Kranjc, 2007. Slovenian industry data.

* Table includes scores for the Pedigree reliability scoring method.

The data from EC (2006) distinguish drying and processing (see also the Table E on beet pulp drying). The baseline energy use without drying is 580 MJ per tonne beet processed. As the mean value of overall energy inputs from EC (2006) is close to the figures from both Suedsucker and Suiker unie, this data is used as a best estimate for overall processing. The Danish data are rather high compared to those from other sources, and even the overall mean value is considerably higher. Thus, this mean value is used as a maximum for the default energy inputs.

5.2.6 Allocation

The intermediate product of wet beet pulp is considered here as a residue to which according to the allocation methodology no economic value is attributed. As specific energy is attributed for the drying of beet pulp (without allocation), in the allocation (Table 5.2.7) the price for dry beet pulp is also set to zero. This is approach 3 as described in the methodology document (see §5.3, Vellinga et al, 2012).

Table 5.2.7 Allocation data for Dutch sugar production (excludingo beet pulp drying)

Product	Name CVB	DMC (g/kg)	Mass (kg/tonne sugar beet)	Price (euro/kg product)	Caloric value (MJ/kg)
Granulated sugar	Sugar (37200)	1000	167	0.83	16.19
Lime fertilizer	NA	500	60	0.1[b]	-
Molasses	Sugarbeet molasses (37100)	723	36	0.18[a]	11.3
Sugar beet pulp	Sugarb pulp SUG<100* (37010) Sugarb p SUG100-150* (37020) Sugarb p SUG150-200* (37030) Sugarb pulp SUG>200* (37040) Beetp pressed fresh+sillage* (58500)	218	230	0	-

a: Dutch export data from FAO (average 2005-2009). SD for molasses: 0.039.

b: Estimate based on http://www.indexmundi.com/en/commodities/minerals/lime/lime_t5.html

* These by-products are considered residues (in the wet form prior to drying) for allocation purposes.

5.2.7 References

CVB-table (2012): see appendix 1 in Vellinga et al. (2012)

European Commission (2006). Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Food, Drink and Milk Industries August 2006

Ingo Klenk, Birgit Landquist and Oscar Ruiz de Imaña, Sugar Industry, 137 (62) March-April 2012, p 169–177.

Krajnc, D., M. Mele, P. Glavic (2007). Improving the economic and environmental performances of the beet sugar industry in Slovenia: increasing fuel efficiency and using by-products for ethanol. Journal of Cleaner Production 15 (2007) 1240-1252.

Suedsucker (Dr. Frieder Lorenz)

Suiker Unie (2003). Suiker Unie Milieujaarverslag 2003

Vellinga, T.V., Blonk, H., Marinussen, M., van Zeist, W.J., de Boer, I.J.M. (2012) Methodology used in feedprint: a tool quantifying greenhouse gas emissions of feed production and utilization Wageningen UR Livestock Research and Blonk Consultants. Lelystad/Gouda, the Netherlands.

5.3 Sugar cane

5.3.1 By-products from sugar cane

The main animal feed by-product from sugar production from sugar can is sugarcane molasses.

Table 5.3.1 Feed materials derived from sugar cane

name CVB	DMC*
Sugarc mol SUG<475	734 g/kg
Sugarc mol SUG>475	730 g/kg
Sugar	1000 g/kg

*Reference: CVB Veevoedertabel

5.3.2 Sourcing

The Dutch feed industry obtains molasses and sugar in the countries that are listed in Table 5.3.2. Information was obtained from the CBI Market Survey: The sugars market in The Netherlands, 2009. There are no sugar cane processing facilities in the Netherlands itself. Refined sugar is processed on a large scale in many countries and traded all over the world. It is thus very difficult to assess the exact origin of sugar from sugar cane. As Brazil and India are the largest sugar cane producers and sugar exporterts, in the case of sugar it is assumed that sugar is produced in these two countries with the sugar canes from the same region.

Table 5.3.2: Estimated countries of origin of molasses from sugar cane.

Country	Contribution range
Sugar molasses	
India	25%
USA	15%
Pakistan	25%
Sudan	15%
Tanzania	5%
Mauritius	5%
Senegal	5%

* Suger cane for molasses is assumed to originate from the country of processing.

Table 5.3.3 Estimated countries of origin of sugar from sugar cane.

Country	Contribution range
Sugar	
India	40%
Brazil	60%

* Suger cane for molasses is assumed to originate from the country of processing

5.3.3 Flowchart

The production process of the milling and refining of sugar can be found in Figure 5.3.1. First of all sugar cane is milled to raw sugar. Several by-products arise during this process: bagasse, filter cake and molasses. During the second stage raw sugar is further refined, more filter cake arises and the final product: refined sugar. As these processes take place in the same factory, we will only gather LCI data for the overall production process.

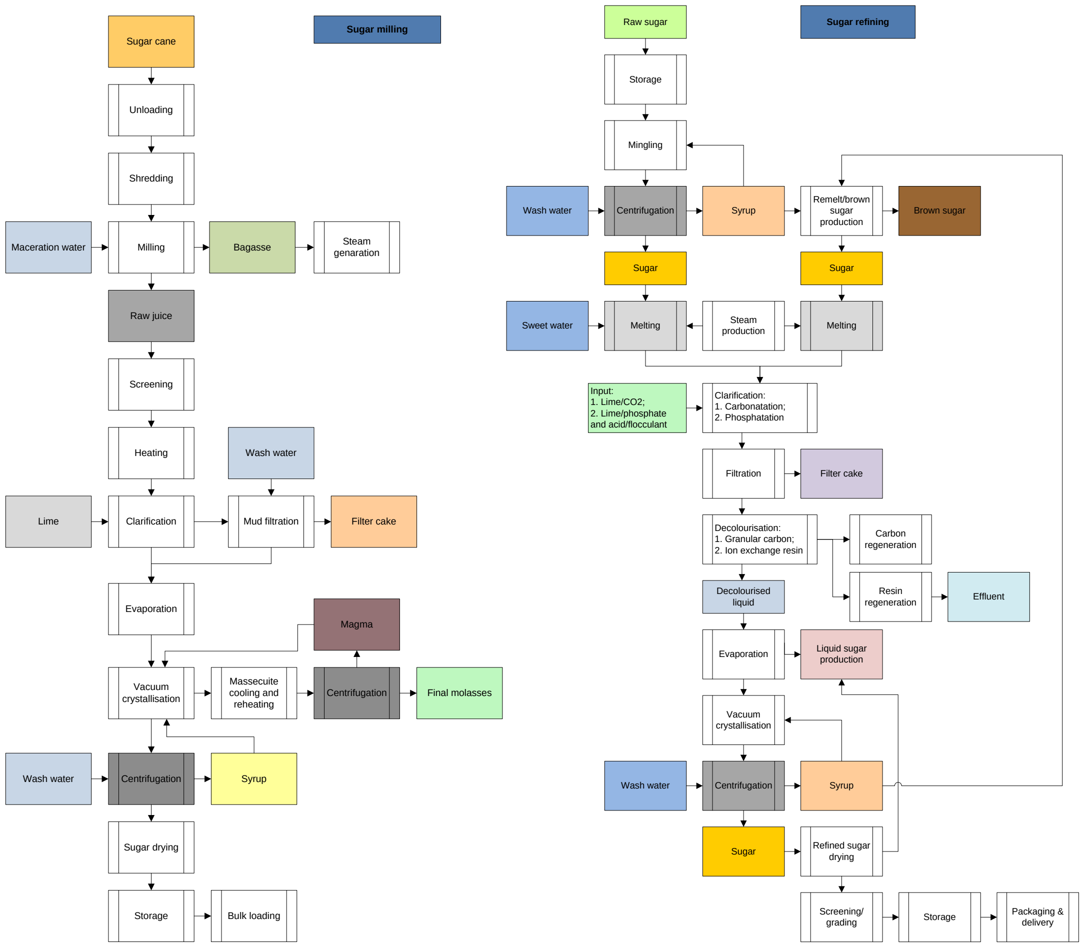

Figure 5.3.1 Flowchart of sugar can processing. Source: NPI, 1999

5.3.4 Mass balance

The default mass balance for sugar can processing into sugar and molasses can be found in the tables below. The values will be underpinned in the remainder of the text.

Table 5.3.4 Mass balance

Input:	**DMC (g/kg)**	**Mass (kg)**
Sugar cane	300	1000
Output:		
Sugar	990	132
Bagasse*	500	280
Filter cake*	260	30
Molasses	730	31

* Both bagasse and filter cake are considered low-value wet by-products and no upstream emissions are allocated towards these by-products. Furthermore, it is assumed that bagasse is used as a fuel at the sugar can processing facility.

We have found a number of mass balances describing the production process of sugar, which are shown in the table below including the dry matter contents.

Table 5.3.5 Mass balance inventory

Product	DMC (g/kg)	Renouf[G]	ETPi[H]	BMA[I]
Input:				
Sugarcane	300[A]	1000	1000	1000
Output:				
Sugar	990[B]	143	87.6	120
Bagasse	500[C]	280	300	330
Filter cake	260[H]	-	30	30
Molasses	800[B]	28	-	30

References: (A) FAO, 986; (B) FAO, 1997; (C) ETPi, BMA, see (H) and (I); (G) Renoef et al, 2011; (H) ETPi, 2011. (I) Blonk Milieu Advies, 2001.

All the mass balances differ slightly from each other. The first column states the dry matter content (DMC) of each product. This is used to check each of the mass balances. The second columns is a mass balance from Renouf et. al, 2011. This mass balance appears to be correct, but filter cake seems to be missing. The second mass balance from ETPi includes filter cake but does not include molasses. The amount of sugar is also very low, but this could be due to the fact that these numbers come from the Pakistan industry from 1996-1997 and is slightly outdated. The third mass balance comes from Blonk Milieu Advies, 2001, but includes plant residues, which is usually indicated by bagasse. The default mass balance is a combination of the first three mass balances which will be used in this report. The amount of sugar is an average of Renouf et all and Blonk Milieu Advies. Bagasse has always a similar share of around 50%, here we have chosen for the most up to date number of Renouf et al.

Some source note a higher Molasses yield of 4 to 4.6% (Khatiwada, 2009 and Silalertruksa, 2009), but the dry matter content is not stated, so it is unclear whether this larger yield could be due to lower dry matter content. Also, the sugar yield is relatively low in these references, and this can result increased molasses output (which is approximately 50% sugar)..

5.3.5 Inputs

Below are the default material inputs for sugar cane processing. It is assumed that the sugar cane processing plant is self-sufficient in its energy requirements.

Since there is limited data on the material inputs and the range of countries from which molasses and sugar originate, large error ranges of 50% are assumed for the material inputs.

Table 5.3.6 Default auxiliary material inputs for sugar cane processing.

Input	value	Error	Unit
Lime, calcium hydroxide, milk of lime, $Ca(OH)_2$	0.5	±50%	kg/1000 kg cane
Sulphur	11.54	±50%	kg/1000 kg cane
Acid, phosphoric acid, H_3PO_4	0.04	±50%	kg/1000 kg cane
(Polyacrylamide) flocculant	0.00012	±50%	kg/1000 kg cane
Lubricant	0.005	±50%	kg/1000 kg cane
Sulfurdioxide, SO_2, bleaching powder	15.03	±50%	kg/1000 kg cane

Several inputs are necessary during sugar cane processing. Although the various types of inputs are described in a various amount of articles, like Akbar et al., 2006, and M.A. Renouf et al, 2011, and ETPi 2011, not all articles report the actual amount of inputs. As Renouf has the most transparent references, we decided to use Renouf as our main data provider and the report of ETPi when the required data was not available in the article of Renouf et al.

We assume that the sugar mills are capable of meeting their own energy requirements by using bagasse as fuel, this is mentioned in the articles of Renouf et al., 2011, ETPi, 2011 and Blonk Milieu Advies, 2011. Although it is possible for sugar mills to produce electricity as surplus for the market, there is no data on how common this practice is. Silalertruksa, 2009, gives a figure of 26.5 kWh electricity per tonne of sugar cane processed which could be sold. Considering the uncertainty of this data (also if trying to take into account avoided emissions) it is neglected in the current LCI data inventory.

5.3.6 Allocation

In this section you can find the economic value, gross energy content, protein content and mass of each by-product which arises during the production process of sugar. As bagasse is usually directly burned at the processing plant for electricity and heat production, it is not included as an output product. Filter cake, which is a residue product, is also not included in the final allocation.

Table 5.3.7 Allocation factors of by-products of sugarcane

	CVB Name	Mass	DMC (g/kg)	Price	GE (MJ/kg)
Sugar	Sugar (37200)	132	990	680 euro/ton	16.2
Molasses	Sugarc mol SUG<475 (42210) Sugarc mol SUG>475 (42220)	31	730	140 euro/ton	11.2

Prices

The data in the table below are from the Dutch LEI institute and are considered to be quire reliable and will be applied in the final allocation. Some more background sources are mention below this table.

Table 5.3.8 Prices of by-products.

Year	2007	2008	2009	2010	2011*	Average
Molasses euro/ton	109.4	131.7	148.6	152.8	158.0	140.1

Reference: BInternet, 2011. *Average over January – April.

According to Schothorst, 2011, the average price of molasses from sugarcane <47.5% sugar is 11.75 euro/100 kg, which is slightly lower than the values of WUR, but this could be possible due to the fact that the average of Schothorst taken between 2004 and 2009). The average import prices of sugar in the Netherlands over 2004 – 2009 according to Eurostat are: 0.68 euro/kg.

Khatiwada, 2009 notes prices at the factory gate of a Nepalese sugar cane processing facility, where the price of sugar is between 11 and 13 times more expensive compared to molasses. This is quite a big difference compared to the Dutch data, which can be either due to further processing of molasses, tax differences, or transportation costs.

5.3.7 References

Akbar, N.M., et al, 2006. Study on Effluents from Selected Sugar Mills in Pakistan: Potential Environmental, Health, and Economic Consequences of an Excessive Pollution Load, Sustainable Development Policy Institute (SDPI), Islamabad, Pakistan, June 2006.

BINternet, LEI, 2008, Prijzen volgens Prijs-informatie Desk, http://www.lei.wur.nl/NL/statistieken/Agrarische+prijzen/default.htm, all prices are ex. BTW (taxes), off factory

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