Supplementary materials for LCA

Software: OpenLCA

Database: ProBas+ and ELCD

Impact Assessment Method: ReCiPe Midpont(H) V.1.11 of August 2014 and Cumulative Energy Demand Version 1.0.1

**1. Industrial Symbiosis**

1.1 Gypsum boards without REA from waste incineration plants

The impact assessment was calculated on the basis of the table below. The data on masses and energy formed the product declassification of the company Saint-Gobain Rigips Austria GesmbH [1]. The data sets had a spatial reference to Germany. Electrical energy is supplied via a power plant mix in Germany. The heat required to dry the gypsum boards is supplied by a gas-fired boiler.

|  |  |
| --- | --- |
| **Designation** | **Description** |
| Plasterboard | RIGIPS Bauplatte (RB) |
| Thickness | 12,5 mm |
| Area | 1m2 |
| Density | 750 kg/m3 |
| Components |  |
| Gypsum | 85% |
| Water | 12% |
| Cardboard | 3% |
| Energy |  |
| Electricity | 0.5 kWh |
| Natural gas | 19.24 MJ |
| Diesel | 0.037 MJ |

1.2 Gypsum boards with REA from waste incineration plants

The impact assessment has been calculated on the basis of the following table. The mass and energy data formed the product declassification of Saint-Gobain Rigips Austria GesmbH[1].

The electrical energy is obtained from the waste incineration plant of Industry symbioses. The gypsum from the MIP filter is further used in the gypsum board production. The heat required to dry the gypsum boards is supplied by a gas-fired boiler.

|  |  |
| --- | --- |
| **Designation** | **Description** |
| Plasterboard | RIGIPS Bauplatte (RB) |
| Thickness | 12,5 mm |
| Area | 1m2 |
| Density | 750 kg/m3 |
| Components |  |
| Gypsum | 85% (49% new/ 51% FGD)[2] |
| Water | 12% |
| Cardboard | 3% |
| Energy |  |
| Electricity | 0.5 kWh |
| Biogas | 19.24 MJ |
| Diesel | 0.037 MJ |

1.3 Waste incineration plant

Germany (2016) operates 68 waste incineration plants. The average of all plants is 345,000 t/a, this value is the assumption value of the WIP[3]. On average, an input of one tonne of waste produces 0.00638 tonnes of gypsum from the filtering system. The average energy content of waste is 8 MJ/kg to 12 MJ/kg and assumed in the calculation to be 10 MJ/kg. [4] This results in 2,201 tonnes of FGD gypsum per year. This accounts for 51 % of production. The total quantity of new and FGD gypsum would thus be 4,315 t from which 541,490 m2 could be produced. Ordinary gypsum plasterboard factories reach several million m3 per year[5].

|  |  |
| --- | --- |
| Designation | Description |
| Energy contant waste | 10 MJ/kg (2.7 kWh/kg) |
| Capacity | 345.000 t/a |
| Gypsum | 0.00638 t/t waste |

1.4 Biogas

The energy content per cubic metre of methane is 9.97 kWh/m3[6]. A value of 90 % methane per cubic metre (low gas) [7] is assumed for the production of biomethane, resulting in a value of 8.97 kWh/m3. In 2014, 165 biomethane production plants were operated in Germany, with an average feed-in rate of 630 scm/h, this value represents the assumed value[8].

|  |  |
| --- | --- |
| Designation | Description |
| Energy methane | 9.97 kWh |
| Biomethane |  |
| Methane content | 90 % |
| Energy content | 8.97 kWh |
| Plant production | 630 standard cubic meter/hour |
| Full load hours | 8.760 h/a |

1.5 Office building

The energy requirement in German office buildings is approx. 177 kWh/m2 for heat and approx. 60 kWh/m2 for electricity. The net area for use in the building is approx. 90% of the total area. This 90% forms the basis for the energy demand. [9]

1.6 Aquaponics

The large aquaponics plant is based on a design for the city of Magdeburg. The total area is 2,556 m2, of which 1430 m2 can be used for hydroponics and 300 m3 for aquaculture[10]. The residual materials from the breeding of fish and plants are 10% for the fish and 15% for the plants[11].Production and residual materials result as following:

|  |  |
| --- | --- |
| Designation | Description |
| Area building | 2.556 m2 |
| Hydroponic |  |
| Lettuce | 205.920 kg |
| Aquaculture |  |
| Tilapia | 22.200 kg |
| Energy |  |
| Heat demand | 121,7 MWh |
| Electricity demand | 69,6 MWh |

1.7 Insect breeding

The floor area of the insect breeding is about 850 m². The operating height of the rearing building is approx. 4 m. The produced insect biomass is around 180,000 kg per year. The heat demand is nearly of 78,000 kWh per year. The electrical energize demand is approx. 241,000 kWh. [12]

|  |  |
| --- | --- |
| Designation | Description |
| Area building | 850 m2 |
| Species | *Gryllus assimilis* and *Tenebrio molitor*. |
| Heat demand | 78 MWh |
| Electircity demand | 241 MWw |

1.7 Energy

|  |  |  |
| --- | --- | --- |
| Designation | Description | |
| Energy consumption | Electricity in kWh | Heat in kWh |
| Plasterboard | 270.745 | 2.893.963 |
| Office | 540.000 | 1.593.000 |
| Aquaponics | 69.600 | 121.700 |
| Insect farm | 241.000 | 78.000 |
| total | 1.121.345 | 4.686.663 |
|  |  |  |
| Energy production |  |  |
| WIP | 93.150.000 | 4.191.750.000 |
| Biomethane | 49.503.636 (Energy contant in gas ) | |

1.8 As can be seen from the table in chapter 1.7, the largest energy consumption is heat with a total of 19,896,963 kWh. Based on this value, an input quantity of less than 20,000 t/a would be calculated. For this reason, the throughput of the smallest waste incineration plant in Germany is assumed to be 50,000 t/a [3]. The biomethane plant would also have a value of less than 50,000 m3. Depending on the size of the plant, the value could be reached within a few days. The plant is therefore designed for a production rate of 200 scm/h[13]. The table below shows the assumptions used in the LCA.

|  |  |  |
| --- | --- | --- |
| Designation | Description | |
| **Energy consumption** | **electricity** | **thermic** |
| Office | 540.000 kWh | 1.593.000 kWh |
| Aquaponics | 69.600 kWh | 121.700 kWh |
| Insect farm | 241.000 kWh | 78.000 kWh |
| Plasterboard | 39.247 kWh | 419.512 kWh |
| **Total** | 1.418.847 | 2.544.212 |
|  | | |
| **Energy production** | |  |
| WIP | 13.500.000 kWh | 60.750.000 kWh |
| Biomethane | 15.715.440 kWh (1.752.000 scm) | |
|  |  |  |
| **Resources / products** |  |  |
| Gypsum from FDG | 319 t |  |
| Number of plasterboards | 78.495 pieces |  |
|  |  |  |
| **Energy and heat for the public grid** |  |  |
| WIP | 12.081.153 kWh | 58.625.300 |
| Biomethane | 15.295.928 kWh (1.705.231 scm) | |

**2. Sharing economy**

2.1 Tools

The tool category comprises several items which are considered to be lent as a whole. Included are a folding rule, a hammer and 6 different screwdrivers [14-16].

|  |  |
| --- | --- |
| Designation | Description |
| **Hammer** |  |
| Steel | 300 g |
| Wood | 158 g |
| **Screwdrivers** |  |
| Rubber | 144.33 g |
| Steel | 288.66 g |
| **Folding rule** |  |
| Wood | 126 g |

2.2 Bicycle pump

Commercial bicycle pump [17]

|  |  |
| --- | --- |
| Designation | Description |
| Polypropylene | 1.125 kg |
| Polyamide | 0.375 kg |

2.3 Grill

A simple grill that is often used in this form in the home [18].

|  |  |
| --- | --- |
| Designation | Description |
| Stainless steel | 7.00 kg |

2.4 Ladder

simple ladder with 6 aluminium steps [19].

|  |  |
| --- | --- |
| Designation | Description |
| Aluminium | 5.00 kg |

2.5 Wok

A simple wok as a kitchen appliance [20]

|  |  |
| --- | --- |
| Designation | Description |
| Cast iron | 3.10 kg |
| Wood | 0.2 kg |

2.6 Dinghy

Only the dinghy is considered without accessories [21]

|  |  |
| --- | --- |
| Designation | Description |
| Polyvinylchloride | 6.5 kg |

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[2] Schmederer, J. (2017). *infoBlätter Kreislaufwirtschaft: Gipsplatten und mehr. (infoSheets Recycling economy: Gypsum boards and more).* Augsburg, Germany: Bayerisches Landesamt für Umwelt (Bavarian State Office for the Environment)

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[6] Paschotta, R. (2018). Methan. Retrieved from <https://www.energie-lexikon.info/methan.html>

[7] Klinski, S. (2006). Studie: Einspeisung von Biogas in das Erdgasnetz (Study: Injection of biogas into the natural gas network). Gülzow, Germany: Fachagentur Nachwachsende Rohstoffe e. V.

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*dena analysis of the existing building stock and its energetic situation).* Berlin, Germany: Deutsche Energie-Agentur GmbH (German Energy Agency GmbH).

[10] Meyer, A. (2018). Dezentrale Energieversorgung für das Urban Farming – Energieversorgung und Speicherung für ein Aquaponiksystem am Standort Magdeburg (Decentralized energy supply for urban farming - Power supply and storage for an aquaponics system at the location Magdeburg) (Master Thesis). Magdeburg, Germany: University of Applied Science Magdeburg-Standel

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[14] <http://www.rollen-shop.eu/Handwerkzeug--Schraubendreher-6-tlg--Schraubendreher-Satz--3x-Schlitz-3-x-Kreuz-80-150-mm-PH-1--2--3/a42815746_u5038_z1daa36e4-7898-454a-9156-4bea8d5c3bf5/>

[15] <http://www.rollen-shop.eu/Handwerkzeug--Messen---Wiegen-Zollstock-2-m-Meter-weiss--Werbefrei--Gliedermassstab-200-mm-Meterstab-Metermass/a41988127_u5038_z1daa36e4-7898-454a-9156-4bea8d5c3bf5/>

[16] <http://www.rollen-shop.eu/-Schlosserhammer-Schlosser-Hammer-mit-Stiel-aus-Holz--300-g/a41550726_u5038_z322692e5-defe-48c6-80f8-324568a9cd4e/>

[17] <https://www.amazon.de/Ultrasport-Luftpumpe-Standpumpe-Autoventile-Fahrradventile/dp/B078BMDGHM>

[18] <https://www.thueros.de/shop/gartengrill/thueros-t2/thueros-t2-edelstahl-mit-edelstahlfuss.html>

[19] <https://www.bauhaus.info/stehleitern/krause-corda-stufenstehleiter/p/25696165>

[20] <https://www.kochen-essen-wohnen.de/gusseisen-wok-fuer-induktion.html>

[21] <https://www.amazon.de/Speeron-Boot-4-Kammer-Schlauchboot-Personen-Gummiboot/dp/B010MDL00S/ref=sr_1_1_sspa?ie=UTF8&qid=1542722508&sr=8-1-spons&keywords=schlauchboote&psc=1>