# Supplementary Materials

## LCI Data and Assumptions

### Infrastructure

Infrastructure used in the hydroponic system included the steel structures, plastic trays, heater, pumps, control units and various tubing and other plastics for various processes.

Each steel structure has 4 levels for growing with an employed floor space of 17m$^2$ (69m$^2$ growing space in total). Each of these steel structures (7 in total) were assumed to weigh 35 kg. The plastic trays were assumed to weigh 0.5 kg each.

Water is pumped from a reservoir below each steel structure to the trays above. The fertilizer is added to this water bath in order to reach all plants and recirculated. Water and fertilizer are also added when needed due to evaporation and uptake by the plants. In total, roughly 1450 000 liters per year are used for the hydroponic system. Seedlings are grown in roughly 38 trays (which contain roughly 4 liters of water) and transferred to over 100 trays for cultivation (containing 38 liters of water).

In the current system, 2 pumps are used to circulate the water between the levels (employing roughly 2200 kwh per year). For heating the area, 1 space heater (750 W) is used. Other electronic controllers are used for temperature control and timers for the water circulation and LED lights; in total 4 electronic devices. In total roughly 8 200 individual LEDs are used in the system.

Tubing for the water circulation system, in addition to various trays, tables and other material are also used; which are assumed to weigh roughly 10 kg.

The plants are cultivated manually by removing the plants in their pots for manual packaging, thus no infrastructure for their cultivation is included.

### Growing Medium

The growing medium in the baseline case (as currently employed) is gardening soil. This was modeled based on data from Martin [1] from gardening soil from a Swedish producer. This contains a mixture of peat, sand, clay, fertilizers, fiber mulch and other inputs; see the aforementioned reference for further details.

In the scenarios reviewing the different growing media, combinations of shredded paper, compost and brewers spent grains (BSG) were used. In the baseline scenario, 12 350 kg of gardening soil [1] are used, in order to fill the pots, with the same density, and assuming no compaction, the volume was employed for assessing the amount of each replacement medium; see Table S1 and Table S2 for a review of the densities and amounts in each scenario. While Table 1 provides the dry weight of BSG (roughly 10 dry matter), the BSG must be dried before it is used (from roughly 60%); modeled as drying of sewage sludge [2], see also Table S3.

In Circular A and Circular C scenarios, it is assumed that  20% of the volume is made up of compost, while the other 80% is from shredded paper. In Circular B and Circular D, the contribution of shredded paper and compost are only 10% each, while the BSG accounts for 80% of the volume; see Table S2.

**Table S1: Density for different growing media employed**

| | Density (kg/m³) |
|---|---|
| **Gardening Soil** | 600 |
| **Compost** | 600 |
| **Paper (Shredded)** | 279 |
| **Brewing Dried Spent Grains** | 135 |

**Table S2: Amount of growing media used in each scenario (measured in kg).**

| | Baseline | Circular A | Circular B | Circular C | Circular D |
|---|---|---|---|---|---|
| **Conventional Gardening Soil** | 12 350 | | | | |
| **Shredded Paper** | | 4 593 | 574 | 4 593 | 574 |
| **Compost** | | 2 470 | 1 235 | 2 470 | 1 235 |
| **BSG** | | | 2 223 | | 2 223 |

## Fertilizer

The composition of conventional fertilizers was assumed to be 20 % major nutrients, NPK, and the resisting 80 % is minor nutrients and fillers. The annual use of fertilizers was 180 kg; thus a total of 36 kg NPK, annually (0,20*180 =36 kg). The distribution between the major nutrients are 15, 17, and 20%, NPK respectively. As such, the fertilizers used were modeled only as the major nutrients, accounting for an annual use of 10 kg N, 12 kg P and 14 kg K.

## Biofertilizer

The biofertilizer was assumed to come from a concentrated slurry from biogas digestate. The nutrient content for biogas digestate from co-digestion plants containing a large share of urban household food waste was obtained from [3] with roughly 6 g N, 3 g NH4-N, 1,2 g P, and 1 g K per kg of digestate. As outlined in [4], nitrification will be needed for the digestate. In order to model the total amount of biofertilizer required, the ammonium level was used as a reference. The biofertilizer slurry is mixed with water for the nutrient solution in the hydroponic system similar to the conventional fertilizer. However, as the digestate had lower levels of P and K, additional sources of P and K were added to make up for the difference and ensure the same level of nutrients; see Table S3 and S4 below. The drying of digestate was included in the impacts for the biofertilizer. It was assumed that the total amount of slurry employed was 348 kg.

**Table S3: Assumed nutrient content in nutrient solution (kg nutrients per m$^3$ water)**

| Fertilizer | NH4-N | P | K |
|---|---|---|---|
| Conv. Fertilizer | 0.0677 | 0.077 | 0.089 |
| Biofertilizer | 0.0677 | 0.027 | 0.023 |

**Table S4: Comparison of the different material flows for the baseline vs. circular scenarios (measured in kg)**

| | | Baseline | Circular A | Circular B | Circular C | Circular D |
|---|---|---|---|---|---|---|
| **Growing Medium** | Conventional Gardening Soil | 12 350 | | | | |
| | Shredded Paper | | 4 593 | 574 | 4 593 | 574 |
| | Compost | | 2 470 | 1 235 | 2 470 | 1 235 |
| | BSG | | | 6 669 | | 6 669 |
| **Fertilizer** | Fertilizer (N) | 10 | 10 | 10 | | |
| | Fertilizer (P) | 12 | 12 | 12 | 7 | 7 |
| | Fertilizer (K) | 14 | 14 | 14 | 10 | 10 |

**Table S5: LCI Data employed in the Study**

| Process/Input | Name | LCI Dataset | Reference |
|---|---|---|---|
| **Infrastructure** | Steel Structure | market for steel, chromium steel 18/8 | [2] |
| | LEDs | market for light emitting diode | [2] |
| | Trays | polyethylene production, high density, granulate | [2] |
| | | injection moulding | [2] |

| | | | |
|---|---|---|---|
| | Tubing/Other Plastics | polyethylene production, high density, granulate | [2] |
| | Pumps | pump production, 40W | [2] |
| | Heater and Other Electronics | electronics production, for control units | [2] |
| **Seeds** | Basil Seeds | market for grass seed, organic, for sowing | [2] |
| **Wrapping paper** | Packaging paper | market for paper, wood containing, lightweight coated | [2] |
| **Fertilizers** | Nitrogen (N) | market for nitrogen fertilizer, as N | [2] |
| | Phosphate (P) | market for phosphate fertilizer, as P2O5 | [2] |
| | Potassium (K) | market for potassium fertilizer, as K2O | [2] |
| | Biofertilizer | drying, sewage sludge | [2] |
| **Paper Pot** | Paper and Peat | corrugated board box production | [2] |
| | | market for peat moss | [2] |
| **Growing Media** | Gardening Soil | consumer gardening soil | [1] |
| | BSG | drying, sewage sludge | [2] |
| | News Paper | market for waste newspape | [2] |
| | Compost | market for compost | [2] |
| **Label** | Laminated Label | market for laminating service, foil, with acrylic binder | [2] |
| **Electricity** | Electricity | electricity, medium voltage, Swedish mix | [2] |
| **Biofertilizer** | Biodigestate | drying, sewage sludge | [2] |
| **Transportation** | Truck | transportation, freight, lorry 16-32 metric ton, EURO6 | [2] |
| | Electric Vehicle | transportation, vehicle electric | [2] |

## Background Info about the Product

Figure S1 below depicts the product as available in retail to the consumers. As illustrated, it is wrapped in a waxed paper wrapping with label. The plant is delivered with the pot and growing medium so that it can stay fresh for several days at the retail and to consumers.


**Figure S1: Depiction of the Grönska packaging for basil (www.gronska.se)**

**Figure S2: Depiction of the paper pots (picture from Amazon.com)**

# Results

**Table S6: Annual GHG emissions for Baseline and Circular scenarios (measured in $CO_2$-eq annually)**

| | Baseline | Circular A | Circular B | Circular C | Circular D |
|---|---|---|---|---|---|
| **Seeds** | 7 | 7 | 7 | 7 | 7 |
| **Growing medium** | 3 087 | 22 | 112 | 22 | 112 |
| **Nutrients** | 135 | 135 | 135 | 46 | 46 |

| | | | | | |
|---|---|---|---|---|---|
| **Lighting** | 1 052 | 1 052 | 1 052 | 1 052 | 1 052 |
| **Ventilation** | 19 | 19 | 19 | 19 | 19 |
| **Pumps** | 87 | 87 | 87 | 87 | 87 |
| **Heat** | 131 | 131 | 131 | 131 | 131 |
| **Water** | 43 | 43 | 43 | 43 | 43 |
| **Paper Pot** | 1 | 1 | 1 | 1 | 1 |
| **Wrapping paper** | 63 | 63 | 63 | 63 | 63 |
| **Label** | 46 | 46 | 46 | 46 | 46 |
| **Transportation** | 110 | 23 | 23 | 23 | 23 |
| **Distribution** | 335 | 335 | 335 | 335 | 335 |
| **Infrastructure** | 125 | 125 | 125 | 125 | 125 |
| ***Total*** | ***5 241*** | ***2 089*** | ***2 179*** | ***2 000*** | ***2 090*** |

**Table S7: Annual acidification impacts for Baseline and Circular scenarios (measured in $SO_2$-eq annually)**

| | **Baseline** | **Circular A** | **Circular B** | **Circular C** | **Circular D** |
|---|---|---|---|---|---|
| **Seeds** | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| **Growing medium** | 1.30 | 0.11 | 0.72 | 0.11 | 0.72 |
| **Nutrients** | 0.72 | 0.72 | 0.72 | 0.25 | 0.25 |
| **Lighting** | 4.14 | 4.14 | 4.14 | 4.14 | 4.14 |
| **Ventilation** | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| **Pumps** | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| **Heat** | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 |
| **Water** | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| **Paper Pot** | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 |
| **Wrapping paper** | 3.85 | 3.85 | 3.85 | 3.85 | 3.85 |
| **Label** | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| **Transportation** | 0.26 | 0.05 | 0.05 | 0.05 | 0.05 |
| **Distribution** | 2.10 | 2.10 | 2.10 | 2.10 | 2.10 |
| **Infrastructure** | 0.67 | 0.67 | 0.67 | 0.67 | 0.67 |
| ***Total*** | ***15.2*** | ***13.8*** | ***14.4*** | ***13.3*** | ***13.9*** |

**Table S8: Annual eutrophication impacts for Baseline and Circular scenarios (measured in $PO_4$-eq annually)**

| | **Baseline** | **Circular A** | **Circular B** | **Circular C** | **Circular D** |
|---|---|---|---|---|---|
| **Seeds** | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 |
| **Growing medium** | 0.44 | 0.03 | 0.38 | 0.03 | 0.38 |

| | | | | | |
|---|---|---|---|---|---|
| **Nutrients** | 0.29 | 0.29 | 0.29 | 0.12 | 0.12 |
| **Lighting** | 2.44 | 2.44 | 2.44 | 2.44 | 2.44 |
| **Ventilation** | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| **Pumps** | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| **Heat** | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| **Water** | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |
| **Paper Pot** | 95.19 | 95.19 | 95.19 | 95.19 | 95.19 |
| **Wrapping paper** | 1.70 | 1.70 | 1.70 | 1.70 | 1.70 |
| **Label** | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| **Transportation** | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 |
| **Distribution** | 102.43 | 102.43 | 102.43 | 102.43 | 102.43 |
| **Infrastructure** | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| ***Total*** | ***204.8*** | ***204.4*** | ***204.7*** | ***204.2*** | ***204.6*** |

**Table S9: Annual human toxicity impacts for Baseline and Circular scenarios (measured in kg 1,4-dichlorobenzene eq annually)**

| | **Baseline** | **Circular A** | **Circular B** | **Circular C** | **Circular D** |
|---|---|---|---|---|---|
| **Seeds** | 3 | 3 | 3 | 3 | 3 |
| **Growing medium** | 101 | 9 | 44 | 9 | 44 |
| **Nutrients** | 72 | 72 | 72 | 25 | 25 |
| **Lighting** | 1 634 | 1 634 | 1 634 | 1 634 | 1 634 |
| **Ventilation** | 30 | 30 | 30 | 30 | 30 |
| **Pumps** | 135 | 135 | 135 | 135 | 135 |
| **Heat** | 203 | 203 | 203 | 203 | 203 |
| **Water** | 24 | 24 | 24 | 24 | 24 |
| **Paper Pot** | 2 429 | 2 429 | 2 429 | 2 429 | 2 429 |
| **Wrapping paper** | 284 | 284 | 284 | 284 | 284 |
| **Label** | 22 | 22 | 22 | 22 | 22 |
| **Transportation** | 37 | 8 | 8 | 8 | 8 |
| **Distribution** | 547 | 547 | 547 | 547 | 547 |
| **Infrastructure** | 938 | 938 | 938 | 938 | 938 |
| ***Total*** | ***6 458*** | ***6 338*** | ***6 373*** | ***6 291*** | ***6 326*** |

**Table S10: Annual Abiotic Resource Depletion for Baseline and Circular scenarios (measured in MJ-eq annually)**

| | Baseline | Circular A | Circular B | Circular C | Circular D |
|---|---|---|---|---|---|
| **Seeds** | 40 | 40 | 40 | 40 | 41 |
| **Growing medium** | 2 173 | 322 | 1 167 | 322 | 1 167 |
| **Nutrients** | 1 012 | 1 012 | 1 012 | 567 | 567 |
| **Lighting** | 8 207 | 8 207 | 8 207 | 8 207 | 8 207 |
| **Ventilation** | 152 | 152 | 152 | 152 | 152 |
| **Pumps** | 679 | 679 | 679 | 679 | 679 |
| **Heat** | 1 018 | 1 018 | 1 018 | 1 018 | 1 018 |
| **Water** | 465 | 465 | 465 | 465 | 465 |
| **Paper Pot** | 2 429 | 2 429 | 2 429 | 2 429 | 2 429 |
| **Wrapping paper** | 8 827 | 8 827 | 8 827 | 8 827 | 8 827 |
| **Label** | 566 | 566 | 566 | 566 | 566 |
| **Transportation** | 1 660 | 350 | 350 | 350 | 350 |
| **Distribution** | 3 708 | 3 708 | 3 708 | 3 708 | 3 708 |
| **Infrastructure** | 1 326 | 1 326 | 1 326 | 1 326 | 1 326 |
| ***Total*** | ***32 261*** | ***29 100*** | ***29 945*** | ***28 655*** | ***29 501*** |

# References


1. Martin, M. Evaluating the environmental performance of producing soil and surfaces through industrial symbiosis. *Journal of Industrial Ecology 0*.
2. Ecoinvent. Ecoinvent version 3.4 2017.
3. Martin, M.; Wetterlund, E.; Hackl, R.; Holmgren, K.M.; Peck, P. Assessing the aggregated environmental benefits from by-product and utility synergies in the Swedish biofuel industry. *Biofuels* **2017**, 1-16.
4. Strandmark, E. Biogödsel som kvävekälla i hydroponisk tomatproduktion; SLU, Sveriges lantbruksuniversitet. Fakulteten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap. Institutionen för biosystem och teknologi, 2019.