FOODPRINT: A NOVEL TOOL FOR MEASURING AND MONITORING CARBON FOOTPRINT IN FOOD INDUSTRIES

Konstantzos Georgios, NTUA
Life FoodPrint, was a project with main goal to develop an integrated strategy for reducing the carbon footprint in the food industry sector.

The project was recently concluded with great success, and its main findings and deliverables, are available at: www.foodprint.gr
One of the main objectives of the Life project FOODPRINT was the development of a robust software tool that can:

- **Calculate** the CF of food products along the supply chain.
- **Quantify** the contribution of each activity to the overall CF of each product.
- **Identify** Carbon and Energy hotspots.
- **Propose** and **prioritize** GHG emissions reduction measures through multi-criteria analysis (MCA) to promote energy and resource efficiency, as well as reduced waste &
At this point, the tool focuses on *pastry and flour products*. However, database can be expended to cover all food products.

Includes **all stages of the supply chain of products** *(Farming, Ingredients Production, Main Product Manufacture, Storage and Transportation)*.

Takes into account **direct** and **indirect** activities *(fuel combustion, energy consumption, waste and wastewater management, packaging production)*.
The software tool was modeled based on excessive literature review, real data collection from partners and actors associated with JOTIS’ supply chain (suppliers etc), as well as energy audits performed at various food industries in Greece and Italy.

Development of energy indicators for various product lines/processes, from real data collected during energy audits.

Development of a methodology to calculate case-specific energy indicators with minimum input.
Methodology (2/3)

Development of case-specific procedures/methods for data collection
✓ Establishment of a list of alternative energy and GHG emissions reduction measures
   Measures were determined based on scientific studies conducted by the project team, and finalized through discussion with various stakeholders.

✓ Evaluation of alternative measures
   Evaluation against various criteria, was based on real case examples, food processing equipment specifications and literature research.

✓ MCA Ranking method: Weighted Sum Model (one of best known & simplest methods)
1. Data input (general, production, transportation etc)

2. GHG Emissions Results & Hot Spots

3. GHG minimization Strategies formation

4. Multi-criteria Analysis

5. Recommendations
User inputs various general data, such as the total electric energy consumption of the factory, fuel consumption, waste and wastewater treatment methods etc.
User should check that all the ingredients of the product under examination, exist in the database of the tool. It contains a fairly broad database; however, if there is no data for a specific ingredient, the user can import very easily new data.
User enters basic data regarding the product (name, type etc) and information about the quantities of each ingredient (recipe) and packaging materials.
Transportation Data

Here, user should insert the average distance per mean or transportation, that each ingredient or packaging material was transported, from the supplier to the factory.

In case of multiply suppliers, please insert average values, while in case of only one mean of transportation, please insert 0 in other choises.

User enters data regarding the transport of all ingredients used for the manufacturing and packaging of the final product (average distance per mean of transportation etc).
User enters data regarding all the processes involved in the manufacturing stage. Processes are divided into three main categories, namely i) electrical, ii) thermal & cooling, and finally iii) cleaning & maintenance.
# Main Production Data

## Step 1: Preheating/Heating
- **Type of Power**: Electrical & Thermal
- **Electrical Power (kw)**: 10

## Step 2: Drying
- **Type of Power**: Electrical & Thermal
- **Electrical Power (kw)**: 8

## Step 3: Boiling
- **Type of Power**: Electrical & Thermal
- **Electrical Power (kw)**: 8

## Step 4: Baking
- **Type of Power**: Electrical & Thermal
- **Electrical Power (kw)**: 8

## Main Production Data Table

<table>
<thead>
<tr>
<th>Step</th>
<th>Process</th>
<th>Type of Power</th>
<th>Electrical Power (kw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Preheating/Heating</td>
<td>Electrical &amp; Thermal</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Drying</td>
<td>Electrical &amp; Thermal</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Boiling</td>
<td>Electrical &amp; Thermal</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Baking</td>
<td>Electrical &amp; Thermal</td>
<td>8</td>
</tr>
</tbody>
</table>

## Thermal Source

<table>
<thead>
<tr>
<th>Thermal Source</th>
<th>Electrical Consumption (kWh/kg of product)</th>
<th>Fuel</th>
<th>Thermal Medium</th>
<th>Energy (fuel) Consumption (kWh/kg of product)</th>
<th>Energy (fuel) Consumption (kWh/kg of product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database</td>
<td></td>
<td></td>
<td></td>
<td>Database</td>
<td>User</td>
</tr>
<tr>
<td>1</td>
<td>0.131</td>
<td>LPG</td>
<td>Steam</td>
<td>0.232</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.052</td>
<td>LPG</td>
<td>Flue Gas</td>
<td>3.523</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.105</td>
<td>Biomass</td>
<td>Hot water</td>
<td>1.136</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.105</td>
<td>Biomass</td>
<td>Superheated Steam</td>
<td>0.828</td>
<td></td>
</tr>
</tbody>
</table>

### Additional Options
- **Fuel**: Biodiesel, Biomass, Diesel, Ethanol, Kerosene, LPG, Methane
- **Thermal Medium**: Steam, Superheated Steam, Superheated water, Thermic oil

---

This table provides detailed information on the energy consumption for different processes and thermal sources used in the production process.
### Summary Results

<table>
<thead>
<tr>
<th>Stage</th>
<th>GHG emissions (kg GHGe / kg of product)</th>
<th>GHG emissions (kg GHGe / piece)</th>
<th>Allocation (%)</th>
<th>Energy Consumption (kwh / kg of product)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients Production</td>
<td>0.671</td>
<td>0.161</td>
<td>6.8%</td>
<td></td>
</tr>
<tr>
<td>Ingredients Transportation</td>
<td>0.027</td>
<td>0.006</td>
<td>0.3%</td>
<td></td>
</tr>
<tr>
<td>Packaging (inc. transportation)</td>
<td>0.006</td>
<td>0.002</td>
<td>0.1%</td>
<td></td>
</tr>
<tr>
<td>Product Manufacturing</td>
<td>5.798</td>
<td>1.392</td>
<td>58.7%</td>
<td></td>
</tr>
<tr>
<td>General Facilities</td>
<td>3.369</td>
<td>0.809</td>
<td>34.1%</td>
<td></td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td><strong>9.87</strong></td>
<td><strong>2.37</strong></td>
<td><strong>100%</strong></td>
<td><strong>1.20</strong></td>
</tr>
</tbody>
</table>

### GHG emissions per Year

| From production of | 1.194.058 | 11% |
| From the whole factory | 10.605.200 |     |

### GHG emissions Allocation

<table>
<thead>
<tr>
<th>GHG emissions (kg GHGe / year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Fuels</td>
</tr>
</tbody>
</table>

Allocation of GHG emissions per 1 kg of product

- Product Manufacturing: 89%
- Ingredients Production: 10%
- Ingredients Transportation: 1%
- Packaging (incl. transportation): 0%
<table>
<thead>
<tr>
<th>Ingredients Production &amp; Transportation</th>
<th>Production</th>
<th>Transportation</th>
<th>Total</th>
<th>Allocation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUGAR</td>
<td>0.579</td>
<td>0.019</td>
<td>0.5979</td>
<td>85.7%</td>
</tr>
<tr>
<td>FLOUR</td>
<td>0.015</td>
<td>0.001</td>
<td>0.0163</td>
<td>2.3%</td>
</tr>
<tr>
<td>SALT</td>
<td>0.000</td>
<td>0.000</td>
<td>0.0002</td>
<td>0.0%</td>
</tr>
<tr>
<td>WATER</td>
<td>0.007</td>
<td>0.003</td>
<td>0.0099</td>
<td>1.4%</td>
</tr>
<tr>
<td>COCOA</td>
<td>0.063</td>
<td>0.004</td>
<td>0.0732</td>
<td>10.5%</td>
</tr>
</tbody>
</table>

**Summary**

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>kg GHGe/kg of product from Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>COCOA</td>
<td>SUGAR</td>
</tr>
<tr>
<td>WATER</td>
<td>FLOUR</td>
</tr>
<tr>
<td>SALT</td>
<td>TOTAL</td>
</tr>
</tbody>
</table>

**kg GHGeq/kg of product**

---

**GHG Emissions & Hot Spots**

(3/5)
GHG Emissions & Hot Spots

(4/5)

<table>
<thead>
<tr>
<th>Process</th>
<th>Production kg GHG eq/kg of product</th>
<th>Allocation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheating / Heating</td>
<td>0.17</td>
<td>2.9%</td>
</tr>
<tr>
<td>Drying</td>
<td>0.83</td>
<td>14.3%</td>
</tr>
<tr>
<td>Boiling</td>
<td>0.55</td>
<td>9.6%</td>
</tr>
<tr>
<td>Baking</td>
<td>0.43</td>
<td>7.5%</td>
</tr>
<tr>
<td>Freezing</td>
<td>2.74</td>
<td>47.2%</td>
</tr>
<tr>
<td>Storage (cool)</td>
<td>0.27</td>
<td>4.7%</td>
</tr>
<tr>
<td>Clean-in-place (CIP)</td>
<td>0.79</td>
<td>13.7%</td>
</tr>
<tr>
<td>Washing</td>
<td>0.01</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td><strong>5.7981</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

Regarding product manufacturing, Freezing is the biggest contributor of GHG eq, and a possible Hot Spot.

Allocation of GHG emissions from production per 1 kg of product:

- Preheating / Heating: 3%
- Drying: 14%
- Boiling: 10%
- Baking: 7%
- Freezing: 47%
- Storage (cool): 5%
- Clean-in-place (CIP): 14%
- Washing: 0%
User can easily see the energy/GHG emissions distribution among all production processes, and spot the most energy & carbon-intensive stage(s).
User fills in a specific questionnaire, that is compiled based on the data have been input in the previous steps. These answers, will enable the tool to develop a list of possible measurements, that will be later rank based on MCA.
The 3 basic criteria set by the tool are:

✔ the estimated investment cost of the reduction measure,
✔ the degree of implementation difficulty, and
✔ the expected reduction of greenhouse gas emissions.
User should manually rate each alternative reduction measure in relation to the criteria selected. Alternatively, the user can click the Default Values button and enter the predefined values from the tool's database.
Final ranking based on various criteria weights scenarios
Sensitivity analysis with real time changes (each time the weights are changed, user can directly see the effect on the final ranking of the measures)
Expected reductions based on a final selection.
User can choose the desired measures based on the results.

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Measurement No</th>
<th>Process</th>
<th>Hot Spot</th>
<th>Description</th>
<th>Rating</th>
<th>GHG emissions savings (kgCO₂/h)</th>
<th>GHG emissions savings (kgCO₂/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M10</td>
<td>Drying</td>
<td>Steam boiler house</td>
<td>Implement Automatic control with conductivity sensor and electrovalve</td>
<td>6.76%</td>
<td>0.02</td>
<td>3.014</td>
</tr>
<tr>
<td>2</td>
<td>M30</td>
<td>Cooling and similar</td>
<td>General note</td>
<td>Substitute with Electronic control (EV)</td>
<td>5.70%</td>
<td>0.20</td>
<td>36.413</td>
</tr>
<tr>
<td>3</td>
<td>M16</td>
<td>Baking</td>
<td>Vapor exhaust</td>
<td>Heat exchanger to recover latent &amp; sensible energy</td>
<td>5.64%</td>
<td>0.20</td>
<td>23.623</td>
</tr>
<tr>
<td>4</td>
<td>M7</td>
<td>Drying</td>
<td>Vapor exhaust</td>
<td>Heat exchanger to recover latent &amp; sensible energy</td>
<td>5.60%</td>
<td>0.12</td>
<td>16.970</td>
</tr>
<tr>
<td>5</td>
<td>M3</td>
<td>Boiling</td>
<td>Vapor exhaust</td>
<td>Heat exchanger to recover latent &amp; sensible energy</td>
<td>5.56%</td>
<td>0.08</td>
<td>10.053</td>
</tr>
<tr>
<td>6</td>
<td>M20</td>
<td>Baking</td>
<td>Vapor exhaust</td>
<td>Heat exchanger to recover latent &amp; sensible energy</td>
<td>5.57%</td>
<td>0.07</td>
<td>7.876</td>
</tr>
<tr>
<td>7</td>
<td>M33</td>
<td>General</td>
<td>Wastewater Treatment</td>
<td>Reuse at least 15% of the cleaned wastewater for various purposes</td>
<td>5.48%</td>
<td>0.50</td>
<td>60.060</td>
</tr>
<tr>
<td>8</td>
<td>M26</td>
<td>Cooling and similar</td>
<td>General note</td>
<td>Implement a water cooled heat exchanger in series with condenser to produce free hot water</td>
<td>4.05%</td>
<td>0.60</td>
<td>72.825</td>
</tr>
<tr>
<td>9</td>
<td>M31</td>
<td>General</td>
<td>Ingredients</td>
<td>Source local ingredients in order to avoid GHG emissions from transportation</td>
<td>4.56%</td>
<td>0.01</td>
<td>973</td>
</tr>
<tr>
<td>10</td>
<td>M25</td>
<td>Cooling and similar</td>
<td>General note</td>
<td>Substitute fuel burning heat generator with electrical compression driven Heat Pump</td>
<td>4.32%</td>
<td>0.60</td>
<td>72.825</td>
</tr>
</tbody>
</table>
Then the tool calculates the total expected savings for each production stage, not only per kg of product, but also per year.
Foodprint

Development of an integrated strategy for reducing the carbon footprint in the food industry sector

Project Budget

- Project Budget
- Total project budget: 1,874,864€
- EC Funding: 50% (891,182€)

Duration

- Start date: 01/09/2014
- End date: 31/10/2017
- Duration: 38 months

FOODPRINT MCA TOOL is available [here](#), and the manual is available [here](#).
For any inquiries or questions please send us an email at: lifeprojectfoodprint@gmail.com

The Greek Food & Drink Industry in figures

The Food & Drink Industry is a key sector of the Greek economy, with an annual turnover of 16.5 billion €, employing 360,000 people - direct and indirect employees - covering the 28% of the manufacturing sector and exporting products of 4 billion €.

It is a dynamic, competitive, export-oriented industry, with extensive investments and trade in Greece, Balkans, Europe and all over the world.
Thank you for your attention.

Contact Information:

gkonsta@chemeng.ntua.gr
www.foodprint.gr