BSESC—Life-Cycle Analysis

# Proficiency Level 4. Analyze

## Learning Objective 4

Calculate the life-cycle impact from the life-cycle inventory for a simple system.

### Lecture Notes

**Step 1. System overview.**

To test out the life-cycle analysis (LCA) impact calculations, we consider a simplified example. We will use an oil furnace that produces heat for a home from fuel. Careful research indicates that the furnace produces carbon dioxide and sulfur in the production of heat. The functional unit for the study is 1000 kWh of heat energy production. We plan to determine the life-cycle production of carbon dioxide and sulfur. This is a simplified example that ignores combustion efficiency, but it is intended to help describe the process.

**Step 2. Perform the inventory analysis for the LCA.**

In the inventory analysis section of the LCA, we gather up data on all the processes shown in the system diagram on the basis of the functional unit. Essentially, we take each unit process in the system and determine how it contributes to the functional unit, while also including the outputs from the process. The furnace uses 2 liters of fuel oil to produce 10 kWh of heat, as shown in Table 1. The fuel production also produces emissions, so we track that process as well. In this way, we are accounting for the fuel oil needed for the production of heat.

Table . Example of the inventory analysis technology matrix [A], for the furnace

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Units** | **Heat Production** | **Fuel Production** |
| Fuel | Liters fuel | -2 | 100 |
| Heat produced | kWh | 10 | 0 |

The next level of information in the inventory phase is collecting the intervention matrix [B] shown in Table 2. This matrix will capture all the information about the consequences we are trying to understand.

Table 2. Example of intervention matrix [B], for the furnace.

|  | **Units** | **Heat Production** | **Fuel Production** |
| --- | --- | --- | --- |
| Carbon dioxide | kg | 1 | 10 |
| Sulfur | kg | 0.1 | 2 |
| Crude Oil | liters | 0 | -50 |

The inventory gives us $\left[A\right]=\left[\begin{matrix}-2&100\\10&0\end{matrix}\right]$ from Table 1 and $\left[B\right]=\left[\begin{matrix}1&10\\0.1&2\\0&-50\end{matrix}\right]$ from Table 2.

**Step 3. Calculate the impact assessment for the LCA.**

After the inventory is complete, we need to set up one additional matrix for our calculations, the demand vector based on the reference flow [f]. This matrix is defined based on our original functional unit for the problem. Traditionally all the elements of the vector are zero except the functional unit reference. We use the functional unit to define the [f] matrix, based on 1000 kWh of heat we wish to produce. Notice that for this matrix, you need the units to line up with the same rows in [A].

$$\left[f\right]= \left[\begin{matrix}0\\1000\end{matrix}\right]$$

The first step in the calculation is determining the scaling matrix [s]. The scaling matrix may also be referenced as the characterization step in some LCA literature. Details of the characterization are provided formally by Heijungs and Suh (2002). For this step, we first calculate the inverse of the [A] matrix, and then multiply it by [f]. If you are not familiar with the details of [matrix inversion](https://en.wikipedia.org/wiki/Invertible_matrix#:~:text=Matrix%20inversion%20is%20the%20process,for%20matrices%20over%20any%20ring.) and [multiplication](https://en.wikipedia.org/wiki/Matrix_multiplication), you may want to review the calculation. Many software packages can perform this calculation for you. The process is essentially the solution of a set of simultaneous equations.

$$\left[s\right]=[A]^{-1}\left[f\right]=\left[\begin{matrix}0&0.1\\0.01&0.002\end{matrix}\right]\left[\begin{matrix}0\\1000\end{matrix}\right]=\left[\begin{matrix}100\\2\end{matrix}\right]$$

The scaling matrix gives us the correct multiplication factor for determination of the final environmental impacts or costs. The impact matrix is called [g], and it is determined by matrix multiplication of [B] and [s].

$$\left[g\right]=\left[B\right]\left[s\right]=\left[\begin{matrix}1&10\\0.1&2\\0&-50\end{matrix}\right]\left[\begin{matrix}100\\2\end{matrix}\right]=\left[\begin{matrix}120\\14\\-100\end{matrix}\right]$$

**Step 4. Interpret and review results.**

The final impact matrix [g] indicates that to produce 1000 kWh of heat, we can expect to generate 120 kg of carbon dioxide and 14 kg of sulfur, and consume 100 liters of crude oil over the full life cycle we considered.

Table 3. Example of impact matrix [g], for the furnace

|  |  |  |
| --- | --- | --- |
|  | **Units** | **Impact** |
| Carbon dioxide | kg | 120 |
| Sulphur | kg | 14 |
| Crude Oil | liters | -100 |

This simple example illustrates the full calculation sequence for the LCA. To test out sensitivity analysis, the problem set should also be completed.

### References

Heijungs R and S Suh. 2002. *The Computational Structure of Life Cycle Assessment*. <https://doi.org/10.1007/978-94-015-9900-9>.