AG2805 Life-cycle approaches for Sustainable Urban Development: Lab exercise

1. Introduction

In this assignment you will use an excel tool to compare different design alternatives for a multifamily residential building in terms of global warming potential (GWP) on a life-cycle basis. It is an example that is based on calculations that were recently performed in the early stages of a multifamily housing development in Greater Stockholm.

* 1. The assessment method

The assessment uses a simplified life-cycle approach that considers only the operational energy in the use stage (including user electricity and heating energy) and the product stage.

The alternatives are will be assessed in terms of GWP only.

* 1. The building

The building has a number of set properties and functional requirements that are constant for all alternatives as follows:

**Number of residents:** 12

**Location:** Greater Stockholm (Swedish climate)

**Passive house standard building elements:** ‘best available technology’ insulation thickness for outer walls, windows, roof and foundation insulation, and high efficiency exhaust air heat recovery ventilation system.

**Number of floors:** 3

**Assumed building lifetime:** 50 years

The design choices available in the tool are as follows:

**Frame material:** Concrete or timber

**Shape of floor plan:** Square or Rectangular

**Heating technology:** District heating (Stockholm network) or Heat pump

**Inhabitant density:** Swedish average density (42 m2 per person), Swedish average +25% or Swedish average -25%

**Window size:** 10 % of floor area (Miljöbyggnad Bronze), 15 % of floor area (Miljöbyggnad Gold and Silver), 20 % of floor area (larger)

1. The Task

Work in pairs.

Using the excel tool:

1. A. Find and record which combination of choices gives the lowest *GWP per year (GWP-low) and* which combination of choices gives *the highest GWP per year (GWP-high).* You can copy-paste the tool results for GWP-low and GWP-high as follows*:*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Alternative 1** | |  | **Alternative 2** | |
|  |  |  |
| **Construction material** |  | Concrete | |  | Concrete | |
| **Building shape** |  | Rectangular | |  | Rectangular | |
| **Heating method** |  | District Heating | |  | District Heating | |
| **Window area / Floor surface area** |  | 20% (Miljöbyggnad Gold) | |  | 20% (Miljöbyggnad Gold) | |
| **Inhabitant density** |  | High Density (Swedish average - 25%) | |  | Aver Density (Swedish average) | |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  | **per m2,year** | **per year** |  | **per m2,year** | **per year** |
| **GWP from material kg CO2-eq** |  | 4.77 | 1802 |  | 4.35 | 2193 |
|  |  |  |  |  |  |  |
| **Energy for Heating kWh** |  | 46 | 17350 |  | 41 | 20725 |
| **GWP for Heating kg CO2-eq** |  | 4.63 | 1749 |  | 4.14 | 2089 |
|  |  |  |  |  |  |  |
| **User and property electricity kWh** |  | 35 | 13242 |  | 35 | 17656 |
| **GWP for user electricity kg CO2-eq** |  | 3.50 | 1325 |  | 3.50 | 1766 |
|  |  |  |  |  |  |  |
| **GWP TOTAL kg CO2-eq** |  | 12.90 | 4876 |  | 12.00 | 6048 |
| **ENERGY TOTAL, kWh** |  | 80.93 | 30591.67 |  | 76.15 | 38380.84 |

B. Calculate the GWP per year for GWP-low as a percentage of the GWP per year for GWP-high.

C. Note also the GWP per m2, year for GWP-low and GWP-high.

D. Calculate the GWP per m2 year for GWP-low as a percentage of the GWP per m2 year for GWP-high.

E. Discuss the design-associated reasons for why the percentages calculated in parts B. and D. differ.

1. A. Compare how each alternative for each variable affects GWP for heating, energy for heating, user and property electricity, GWP for material and total GWP. To do this you could do a parametric analysis, where one variable is changed and all others are held constant. Record the results in tables, e.g.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Rectangular** | |  | **Square** | |
|  |  |  |
| **Construction material** |  | Concrete | |  | Concrete | |
| **Building shape** |  | Rectangular | |  | Square | |
| **Heating method** |  | Heat Pump | |  | Heat Pump | |
| **Window area / Floor surface area** |  | 10% (Miljöbyggnad Bronze) | |  | 20% (Miljöbyggnad Gold) | |
| **Inhabitant density** |  | High Density (Swedish average - 25%) | |  | High Density (Swedish average - 25%) | |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  | **per m2,year** | **per year** |  | **per m2,year** | **per year** |
| **GWP from material kg CO2-eq** |  | 4.96 | 1875 |  | 4.29 | 1621 |
|  |  |  |  |  |  |  |
| **Energy for Heating kWh** |  | 13 | 5051 |  | 41 | 15571 |
| **GWP for Heating kg CO2-eq** |  | 1.35 | 509 |  | 4.15 | 1570 |
|  |  |  |  |  |  |  |
| **User and property electricity kWh** |  | 35 | 13242 |  | 35 | 13242 |
| **GWP for user and property elec. kg CO2-eq** |  | 3.50 | 1325 |  | 3.50 | 1325 |
|  |  |  |  |  |  |  |
| **GWP TOTAL kg CO2-eq** |  | 9.81 | 3709 |  | 11.94 | 4515 |
| **ENERGY TOTAL, kWh** |  | 48.40 | 18293.58 |  | 76.22 | 28812.61 |

B. Write down an argument for why the changes in each variable affect the parameters noted above in the way that they do.

*A fictitious example answer:* The increase in insulation thickness in walls causes the GWP due to material to increase by only about 0.8 %, but it causes the energy for heating to decrease by 10%. Therefore there is an overall decrease in GWP, though only by about 4 %. The decrease is because the measure affects the GWP for heating by a greater proportion than it increases GWP for material. However, the measure only has a small effect on heating energy demand because the building loses energy through roof, windows and foundation as well which are unchanged. Furthermore, the user and property electricity demand is not affected by the measure. The change in GWP due to material suggests that the roof insulation is also only responsible for a very small part of the total GWP for building material.

C. From your earlier results identify also which of the variables have the greatest effect on the total GWP and the total energy demand, and which have a lesser effect. With reference to each variable, discuss why some have greater effect, and some have lesser.

1. Write a reflection on what other functions and properties of the building may actually be changed by changing each variable from the perspective of different stakeholders –

* Indoor environmental quality (thermal comfort, lighting, air quality, noise)
* Other potential environmental impacts
* Financial value of the building
* Potential limitations of the modelling approach used

1. The Lab Report

Your lab shall be in the same format as other lab reports. You must hand in your lab report ***the same day no later than 18:00***.