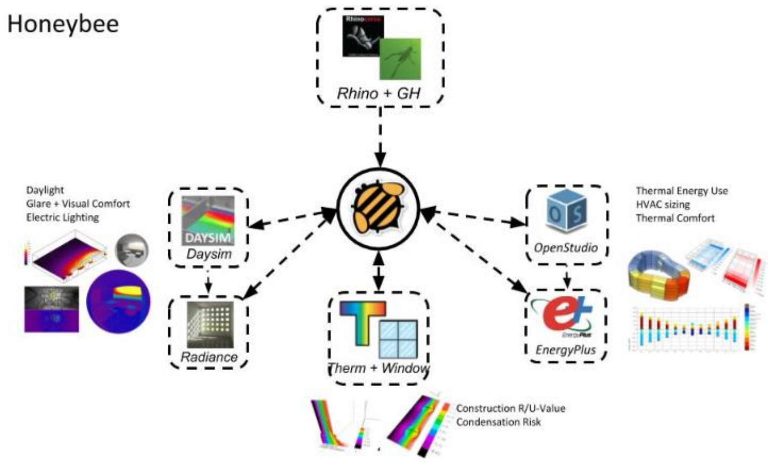
Technical assumptions:

Simulation tool

Rhino and grasshopper was used to model the buildings geometry. Energy simulations were run in a grasshopper script using open-source Pollination plugins. Honeybee plugin uses EnergyPlus simulation engine and hence energy models made in Honeybee rely upon methods of calculation available in EnergyPlus. The script incorporates diverse build-on tools and engines for energy modelling:

- Radiance for point-in-time lighting
- Daysim (which uses Radiance) for lighting over time
- EnergyPlus for heat, electrical and fuel resource modeling
- OpenStudio for integration of Radiance and EnergyPlus
- Therm for conduction through construction models and condensation risk

Honeybee relation with other simulation engines:



000 honeybee relation to other engines

For more info about the simulation tool: https://docs.ladybug.tools/honeybee-wiki

Constructions and materials

A built-on constructions library in Honeybee based on ASHRAE 90.1 2019 and IECC 2021 was used to set the materials, layers and constructions for walls, roofs, floors and windows. This library considers two variables: construction type and climate zone.

The library generates the constructions that are most suitable for each combination of construction type and climate zone category. This approach may not closely resemble typical construction practices in some European countries, but it was the only practical, standardized method to ensure the simulations could be run consistently across multiple countries.

About ASHRAE 90.1

Standard 90.1 has been a benchmark for commercial building energy codes in the United States, and a key basis for codes and standards around the world, for almost half a century. This standard provides the minimum requirements for energy-efficient design of most sites and buildings, except low-rise residential buildings. It offers, in detail, the minimum energy efficiency requirements for design and construction of new sites and buildings and their systems, new portions of buildings and their systems, and new systems and equipment in existing buildings, as well as criteria for determining compliance with these requirements.[1]

Construction type

Depending on the traditional construction systems, each country/city was categorized in two load bearing systems:

- Mass (concrete frame)
- Wood (wooden frame)

For example, Murcia was categorized as Mass (concrete frame) and Stockholm as Wood (wooden frame).

Climate zone

Each city was categorized in the 8 ASHRAE climate zones:

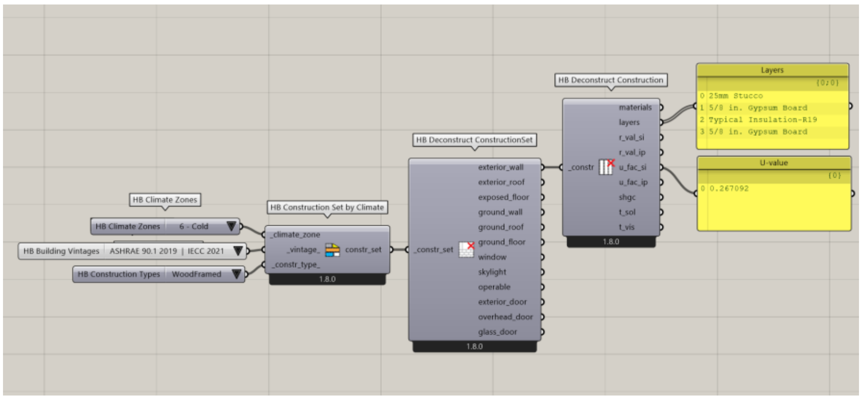
- 1 Very hot
- 2 Hot
- 3 Warm
- 4 Mixed
- 5 Cool
- 6 Cold
- 7 Very cold
- 8 Subarctic

For more information about the ASHRAE climatic data for building design standards and to see the Europe Climate zoning map: https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/169_2020_a_20211029.pdf

Example of constructions and materials selection

Each city has its own set of constructions and u-values from the library. This is an example for Stockholm:

[1] Taken (8. April) from: https://www.ashrae.org/technical-resources/bookstore/standard-90-1



Stockholm was categorized as most typically wooden frame construction system and climate zone 6. The library generated the following constructions:

- External walls U-value 0,267 W/m²K.:
  - 25mm Stucco
  - 5/8 in. Gypsum Board
  - Typical Insulation-R19
  - 5/8 in. Gypsum Board

- Roof U-value 0,117 W/m²K.:
  - 5/8 in. Gypsum Board
  - Typical Insulation-R47

- Ground floors U-value 0,852 W/m²K.:
  - Typical Insulation-R4
  - 8 in. Normalweight Concrete Floor
  - Typical Carpet Pad

- Windows U-value 1,948 W/m²K.:
  - U 0.34 SHGC 0.38 Simple Glazing

Climate Zones

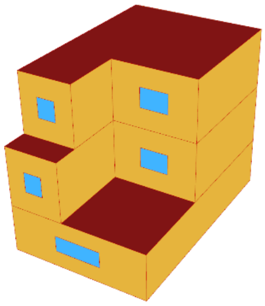
Each city was simulated with its own EPW file. Downloaded from: https://www.ladybug.tools/epwmap/

To simplify the simulations, there were modelled single thermal zones without internal walls. The energy-modelling follows the recommendations of honeybee energy-modelling published in https://docs.ladybug.tools/honeybee-wiki/single-zone-model/modeling-zone-geometry

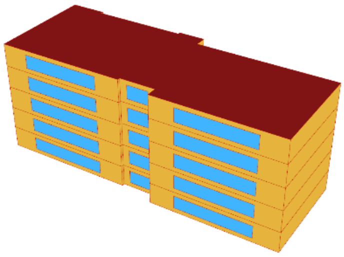
Case studies / typologies

There are three base case studies modelled in the tool. Just the geometry and the typology were used other inputs such as location, years built, technical features, etc., were overwritten.

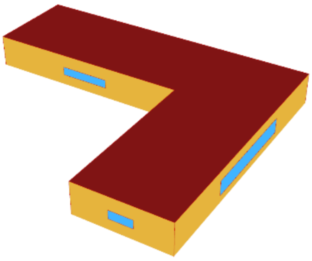
1. Single family house (ca. 196 m2 GFA)



2. Residential building (ca. 2 793 m2 GFA)



3. Educational building (ca. 493 m2 GFA)



Program/schedules

The programs and schedules used in the simulations are from Honeybee libraries. According to each case study it was limited to these three types:

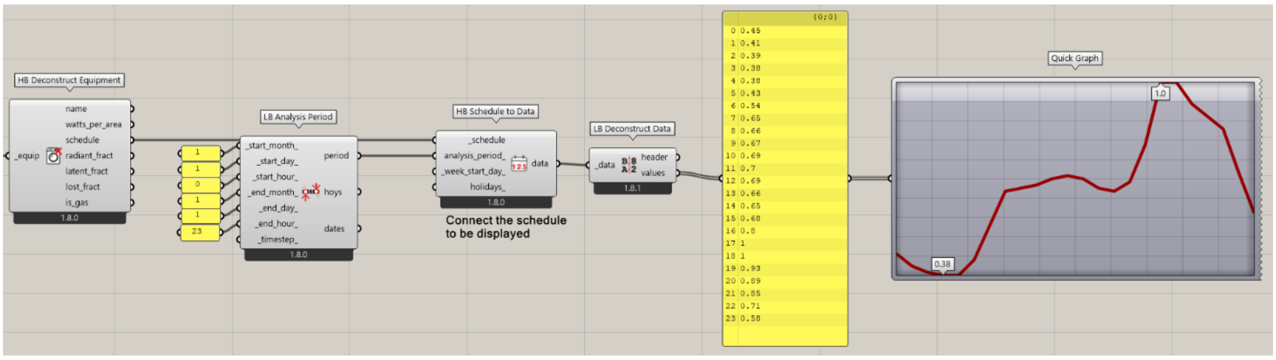
2019::MidriseApartment::Apartment (Single family house case study)

2019::HighriseApartment::Apartment (Residential building case study)

2019::SecondarySchool::Classroom (Educational building case study)

The schedules/programs determine the periods of time daily when the building is in use.

For instance, this is the schedule used in the residential building case study (2019::HighriseApartment::Apartment) for the electric equipment during a typical 24 hours day:



Technical inputs

To calculate the internal loads each simulation has each own set of inputs from the library depending on the typology. As an example, some of the technical inputs for the Residential building typology.

- Users, people per area: 0,02 ppl/m2
- Lighting, watts per area: 9,36 W/m2
- Electric equipment, watts per area: 6,66 W/m2
- Hot water, flow per area: 0,14 L/hm2
- Infiltration, flow per ext area: 0,000569 m3/s
- Ventilation, ach: 0,35
- Set point, heating 21,7 C
- Set point, cooling 24,4 C

The inputs generated by the typology library were used widely in all the regions. This approach may not closely resemble typical technical inputs in some European countries, but it was the only practical, standardized method to ensure the simulations could be run consistently across multiple countries.

Results energy demand

Simulation results for heating and cooling demand show results for room heating and cooling. Hot water and electricity are not included. The results are shown in kWh/year.

Improvements

Cooling and heating systems: The cooling and heating systems were assumed to cover 100% of the heating and cooling demand. In the practice this is not common, especially when it comes to heating since most of the solutions usually don't have the capacity to cover the peak-demand when the temperatures are too low and need and extra strategy to cover this demand. For example, in Norway, usually a ground-source heat pump covers 90% of the heating demand and 50% of the peak demand, then an El-boiler is usually needed to cover the rest. The purpose of the simplification is to offer an overall estimation in energy savings in kWh/year.