

A cross-platform modular framework for building Life Cycle Assessment

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MOMENTUM OF INNOVATION

Introduction

Current practice

Modular framework

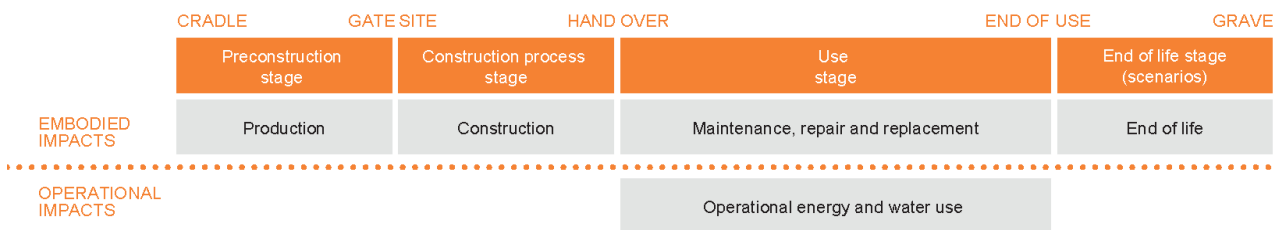
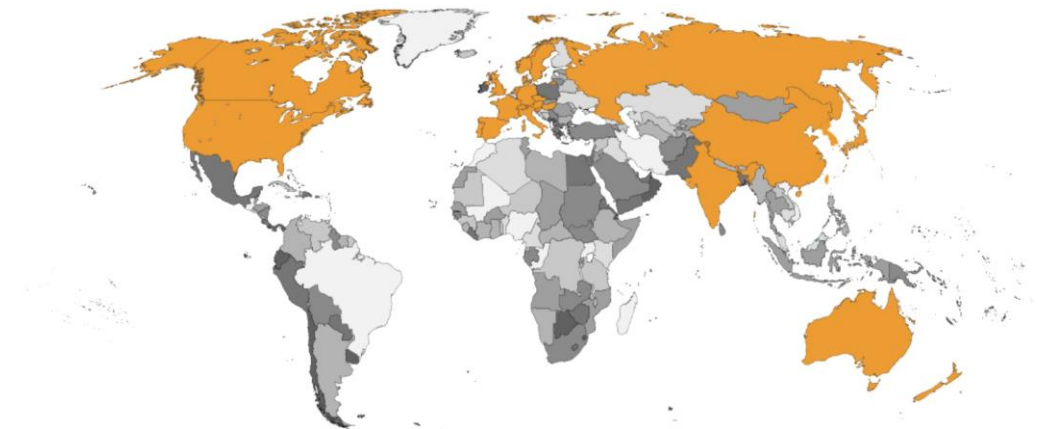
Example application

Conclusions

IEA EBC Annex 72

Assessing Life Cycle Related Environmental Impacts Caused by Buildings

- Subtask 1: Harmonized methodology
- Subtask 2: Assessment workflows and tools
- Subtask 3: Case studies
- Subtask 4: Building sector LCA databases
- Subtask 5: Dissemination



State of play

- Wide design integration of LCA is need to support sustainable construction within environmental limits
- Difficulties in building LCA calculation (data intensive, time consuming) hinder wide application

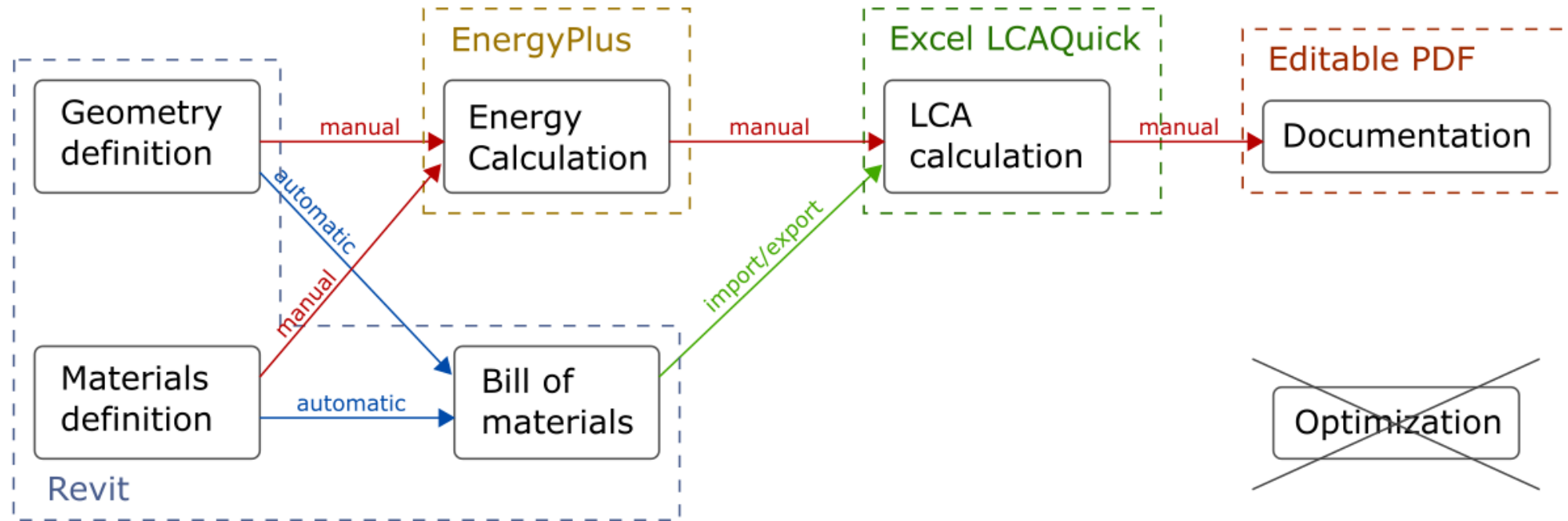
Based on review of literature and existing tools, expert workshop (IEA EBC Annex 72)

- Workflows used in LCA research are highly capable and customizable, but often complex and hardly user friendly
- Commercial tools, while more simple and user friendly in application, often lack transparency and quality assurance

Why a modular approach?

- Broad range of available solutions, but lack of transparency, interconnectivity and interfaces for automation
- Several LCA background databases exist, for detailed modelling of buildings (time consuming)
- Building element catalogues - which could save time for LCA - are mostly embeded in specific tools, difficult to assess
- Enable inteconnectivity of modules with digital building models, data and tools through common framework

Expert workshop



Workflow example from Annex 72 expert workshop

Aim of this study:

Provide a conceptual, software-independent framework, that is:

- Transparent to externals
- Modular (components are interchangeable)
- Supports automation

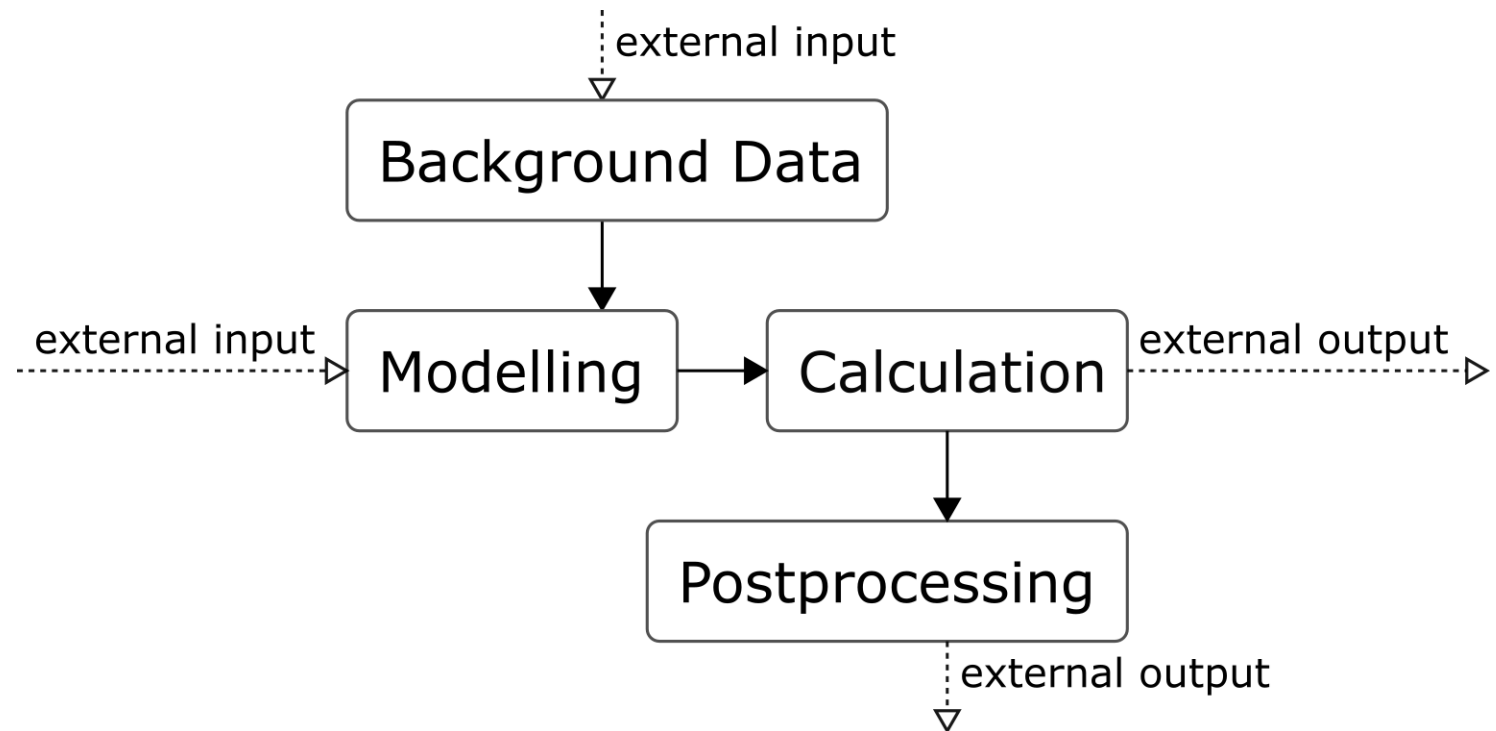
Goal:

Use existing software solutions for the implementation of the components

Main structure:

4 Modules:

- Background Data
- Modelling
- Calculation
- Postprocessing



External exchange:

Inputs

- Collection of data (e.g. EPDs, building component database)
- Parameters of the model (input ranges from few parameters to a detailed BIM model)

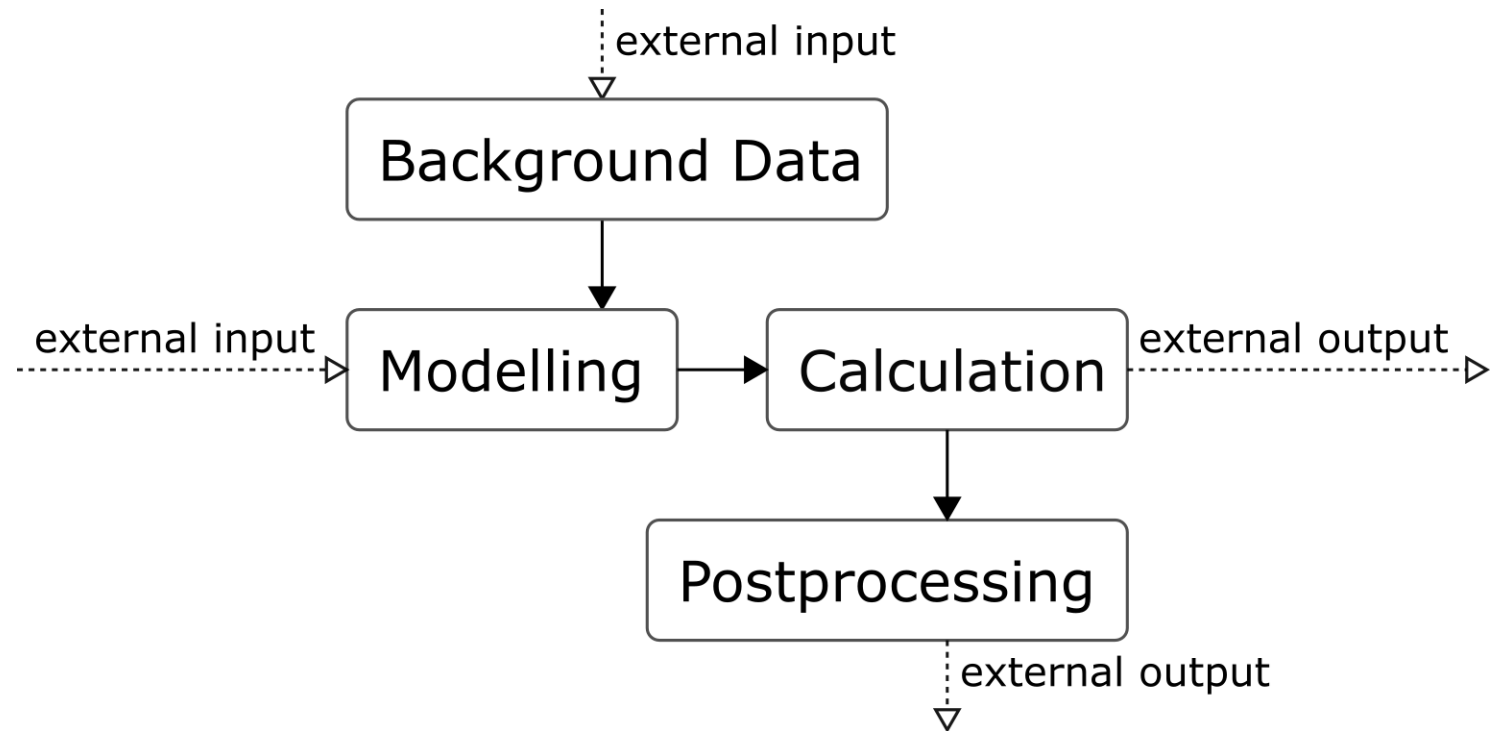
Outputs

- Raw results (for further use)
- Processed results (e.g. optimized building, diagrams)

Main structure:

4 Modules:

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Background Data Module:

Collection of data that is established **before** modelling (independent of the building or the calculation)

Typically Databases

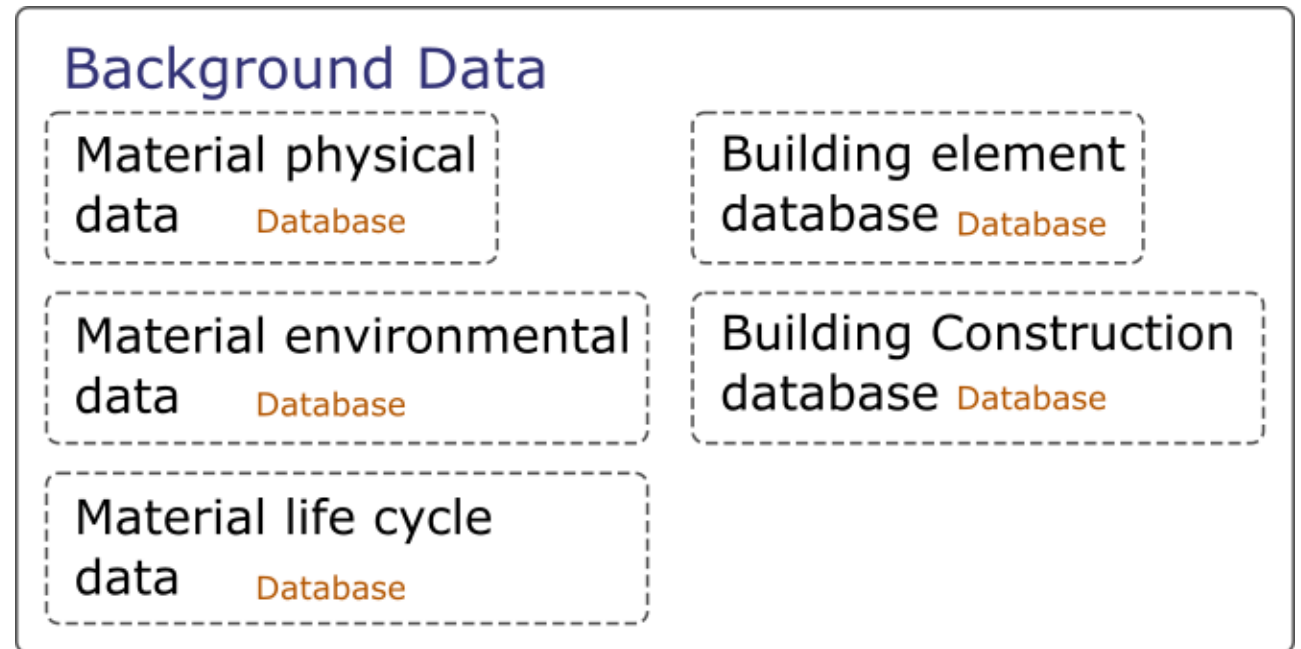
Options:

Material level:

- Physical data (thermal conductivity, density, etc.)
- Environmental data (e.g. LCIA database, EPD database – impact per mass/volume)
- Life cycle data (e.g. expected lifetime)

Component / Construction level:

- Building constructions (assembly of materials)
- Building elements (e.g. for early design stages)



Modelling module:

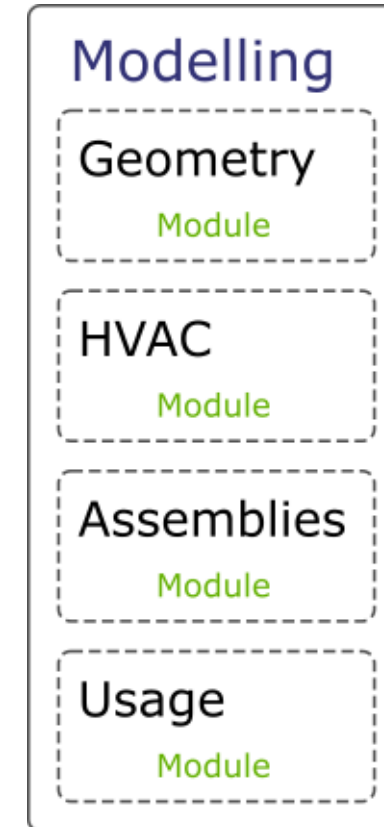
To establish the complete building model (object of assessment) to further use in the calculations

Options:

- Parametric / manual modelling
- Granularity: from simple (e.g. surface areas without explicit geometry) to detailed (including geometry, assemblies, HVAC)

Components:

- *Geometry* (3D modelling ,e.g. building zones, surfaces)
- *HVAC* (simple systems for energy demand calculation or detailed model for simulation)
- *Assemblies* (e.g. composite materials, consturctions, joints)
- *Usage* (user-dependent values, schedules – e.g. setpoints, occupancy)



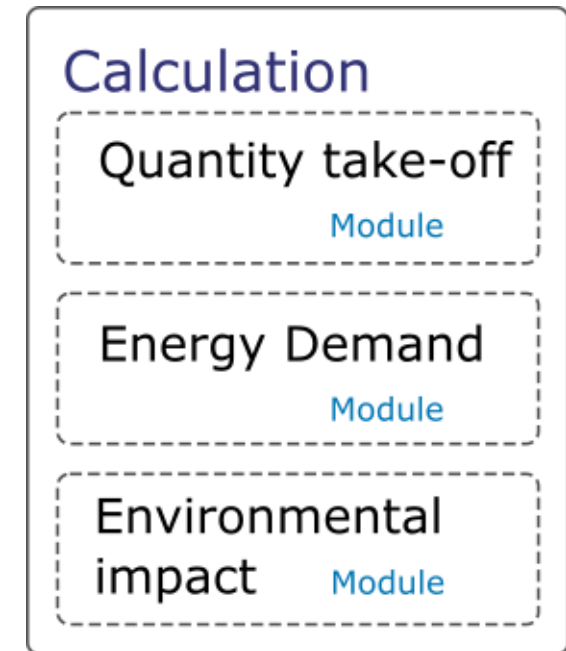
Calculation module:

To perform all the calculations needed to provide the information that is not incorporated in the building model (e.g. future scenarios)

Options depend on the used methodology and the granularity of the model

Components:

- *Quantity take-off* (e.g. to provide the bill of materials, depending on the detailness of the calculation)
- *Energy calculation* (energy used for the operation of the building – options range from steady state seasonal methods to detailed energy simulations)
- *Environmental impact calculation* (Allocation of the environmental impact, calculation of replacements – options from static to dynamic time-dependent calculations)



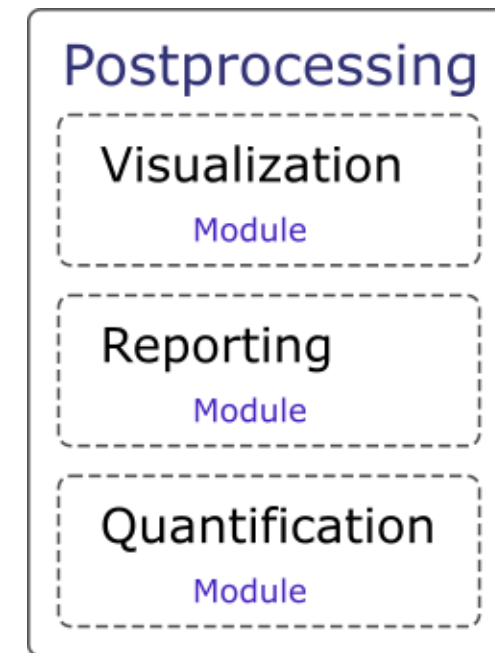
Postprocessing module:

To evaluate and manipulate all the raw results from the calculation, and provide different options to **communicate** the results

Options from single numbers to detailed 3D building model visualizations

Components:

- *Visualization* (diagrams, 3D building models, interactive options)
- *Reporting* (for certification purposes)
- *Quantification* (to provide a selection of results to further use e.g. in the optimization as objectives)



Structure

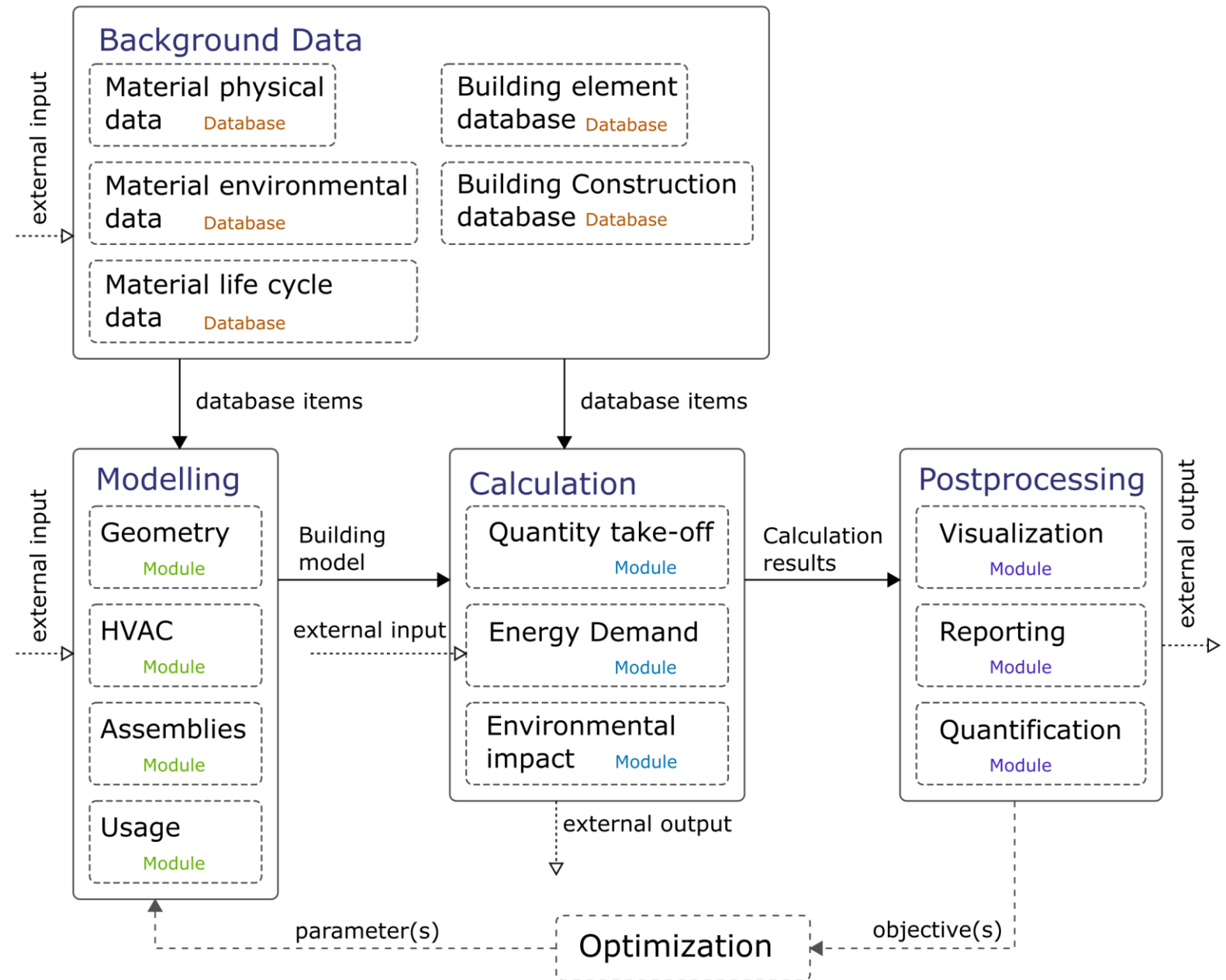
Complex interchangeable system

Optimization

The structure supports the option for optimization

Objectives are provided from the postprocessing module

Parameters are fed into the Modelling module where the model can be generated automatically



Optimization-enabled workflow:

Goal of this implementation is to support the **automatic model generation** for optimization

Many **existing software** are used for the implementation of components

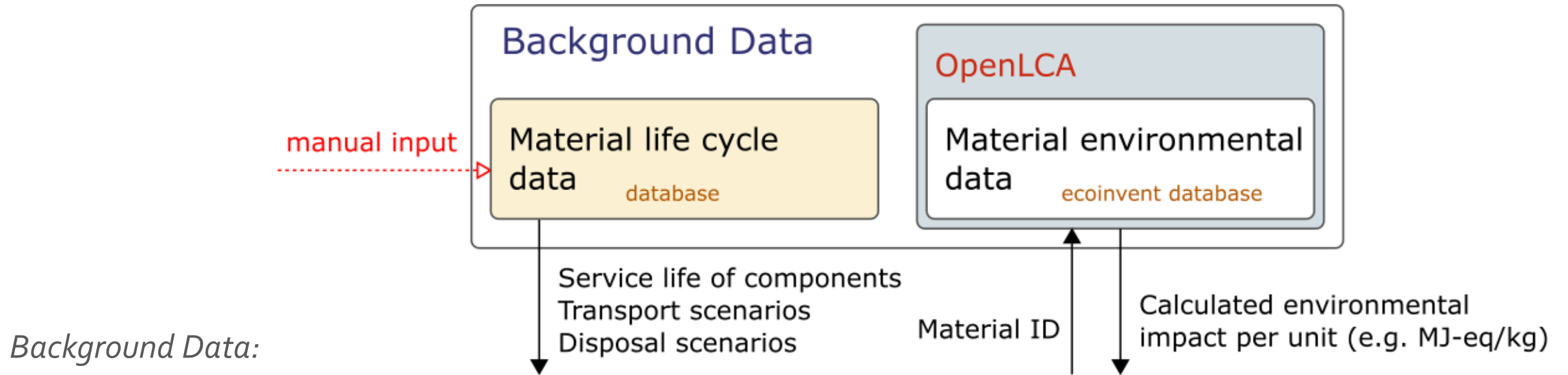
Extra components are developed using **Python** language

The implementation is based on **Grasshopper¹** platform*

*Except for the background data

¹ <https://www.grasshopper3d.com/>



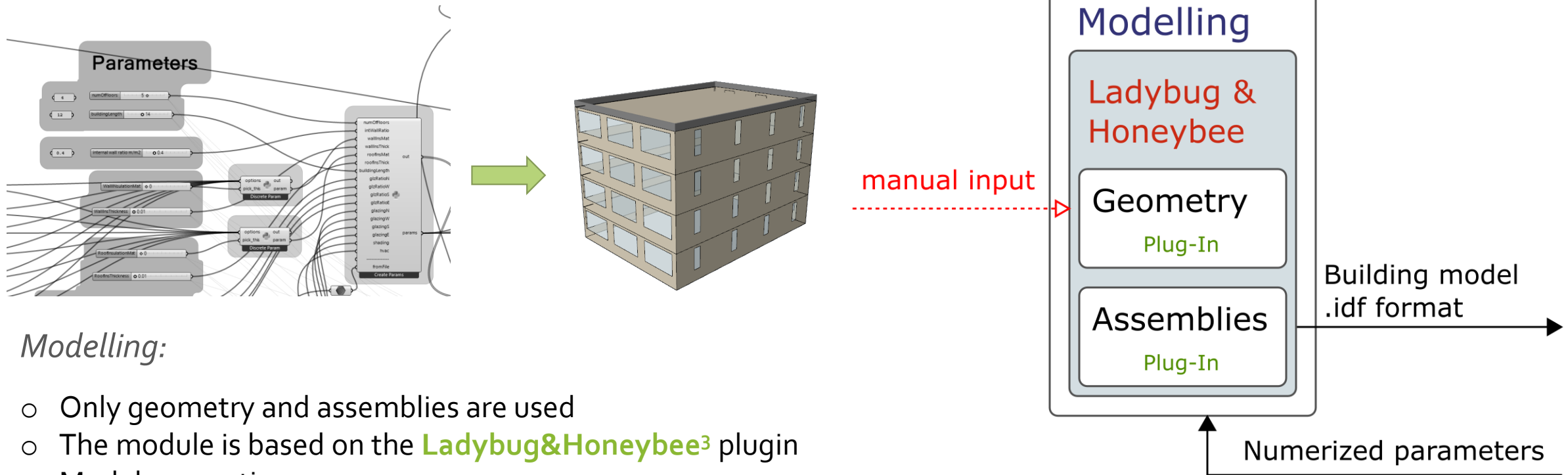


Background Data:

- Combined database consisting
 - material physical data (e.g. thermal conductivity)
 - lifecycle information (e.g. estimated service life)
- Material environmental data is produced in **OpenLCA²** from the ecoinvent database.
 - Unit processes are associated with a Material ID

Databases established prior to modelling and calculation

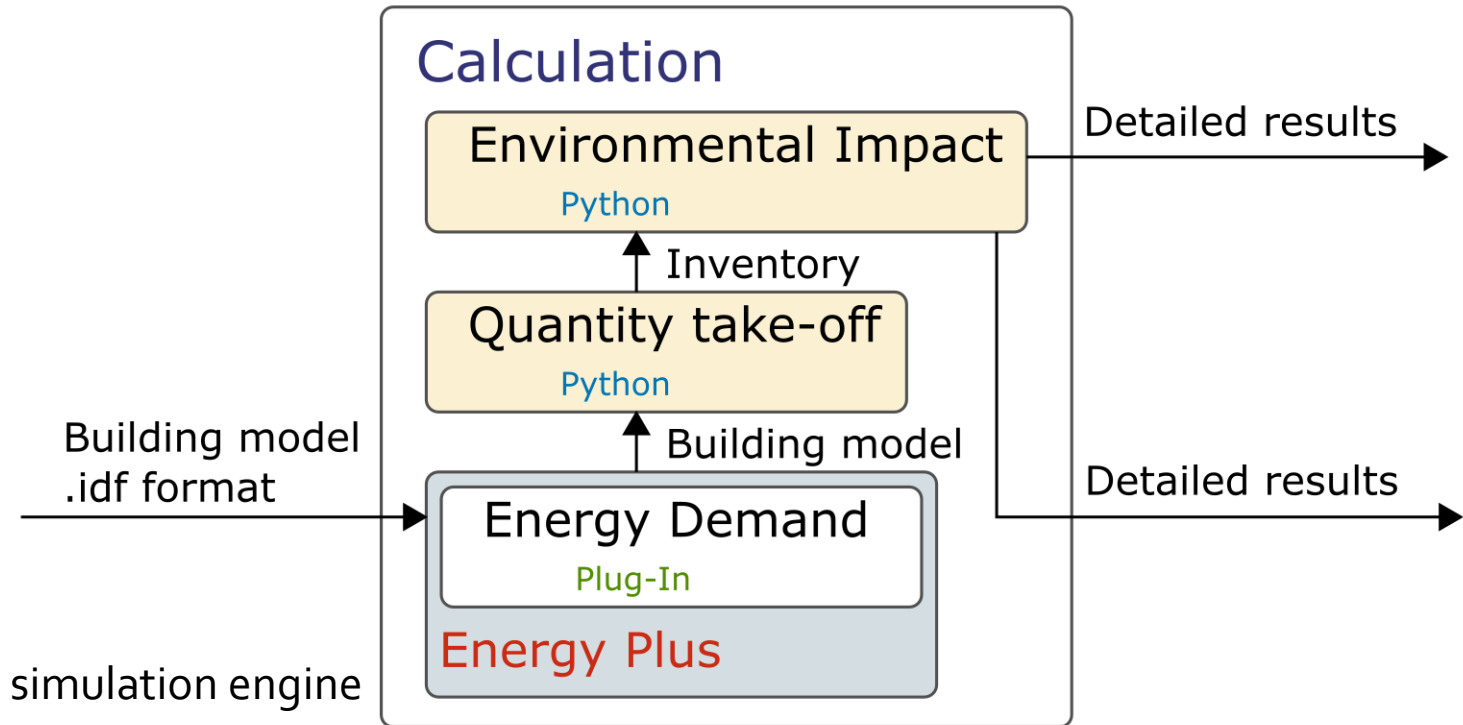
² <http://www.openlca.org/>



Modelling:

- Only geometry and assemblies are used
- The module is based on the **Ladybug&Honeybee³** plugin
- Model generation
 - Initial manual modelling (establishment of the parametrized geometry and assemblies)
 - Automatic modelling based on parameters from the optimization module
- The output is the data structure of the complete building model including an .idf format that is used by EnergyPlus

³ <https://www.ladybug.tools/honeybee.html>



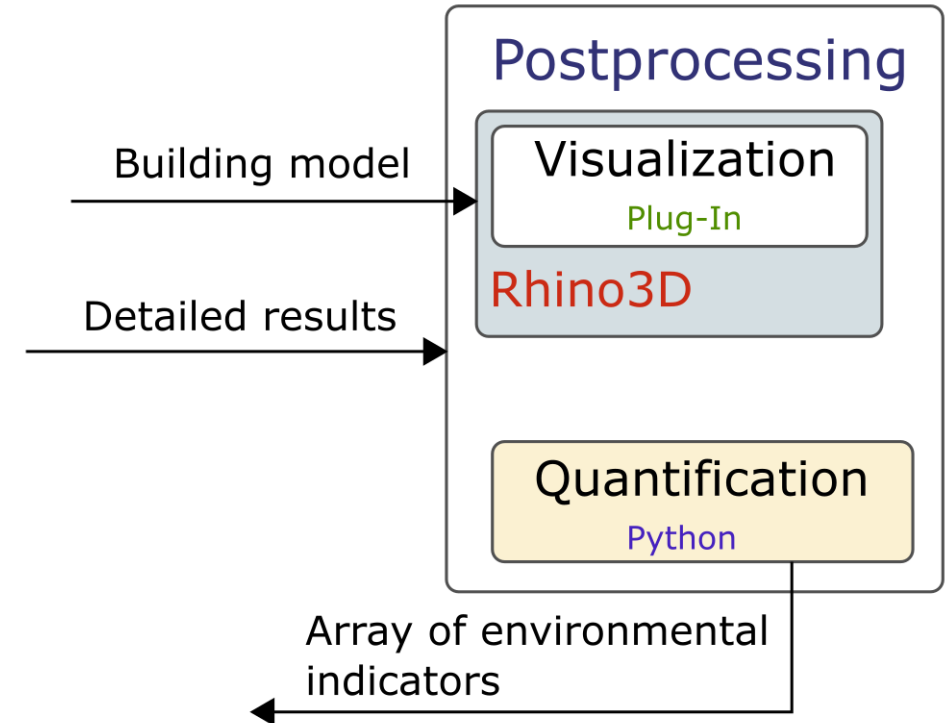
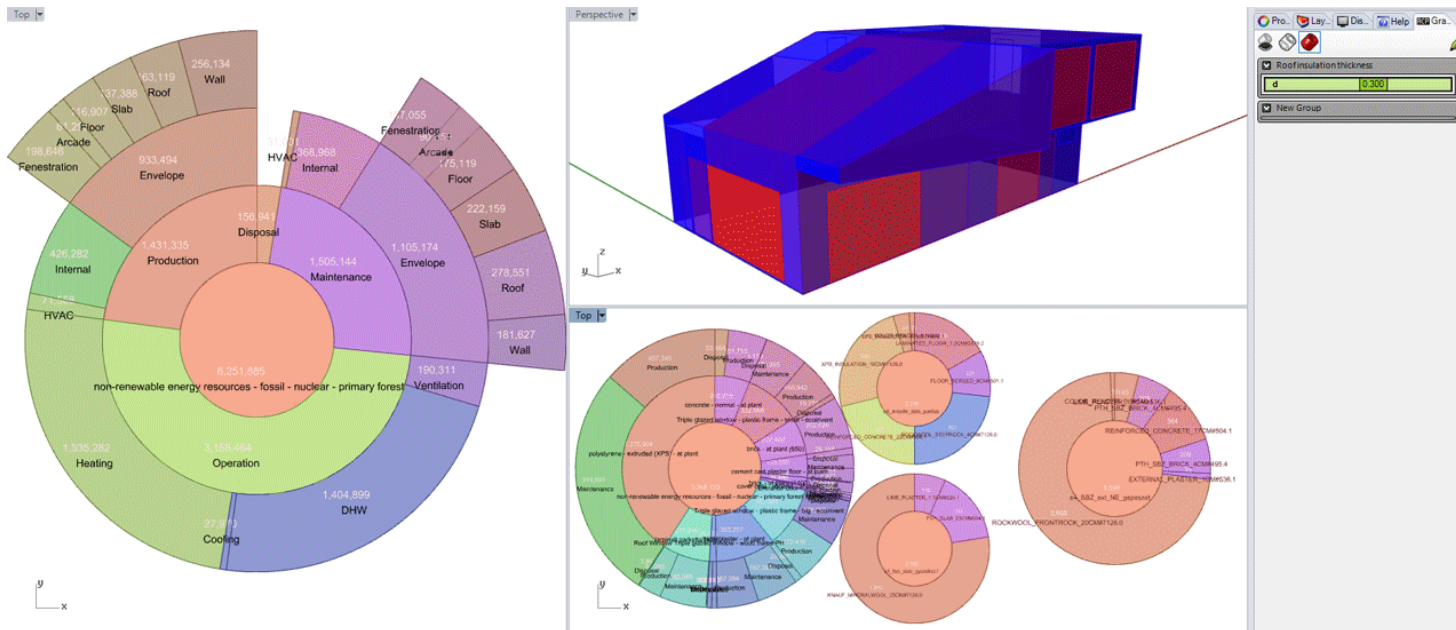
Calculation:

- Energy demand is calculated with **EnergyPlus**⁴ simulation engine
- Building model data is used to extract material quantities
- Environmental impact is calculated considering:
 - Calculated quantities
 - Database entries from the Background Data module
 - Calculated energy demand
 - Additional calculations (e.g. number of replacements)

⁴ <https://energyplus.net/>

Postprocessing:

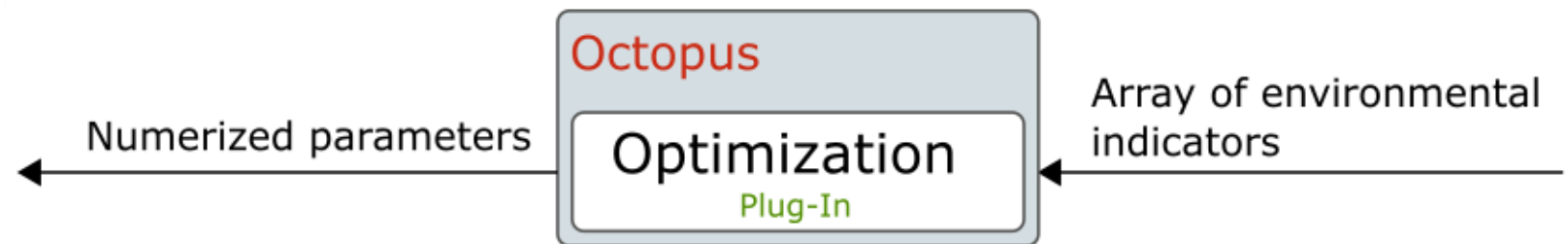
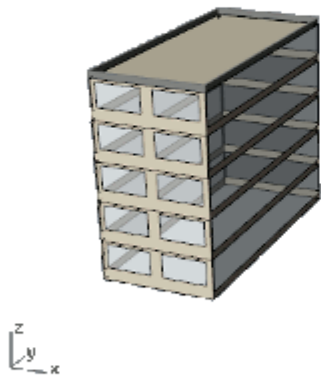
- Visualizations are projected back to Rhino
 - Evaluation of solutions thorough 3D model views and charts
 - Real-time feedback on parameter-change (manual refinement)
- Selected results are aggregated and provided to the optimization module



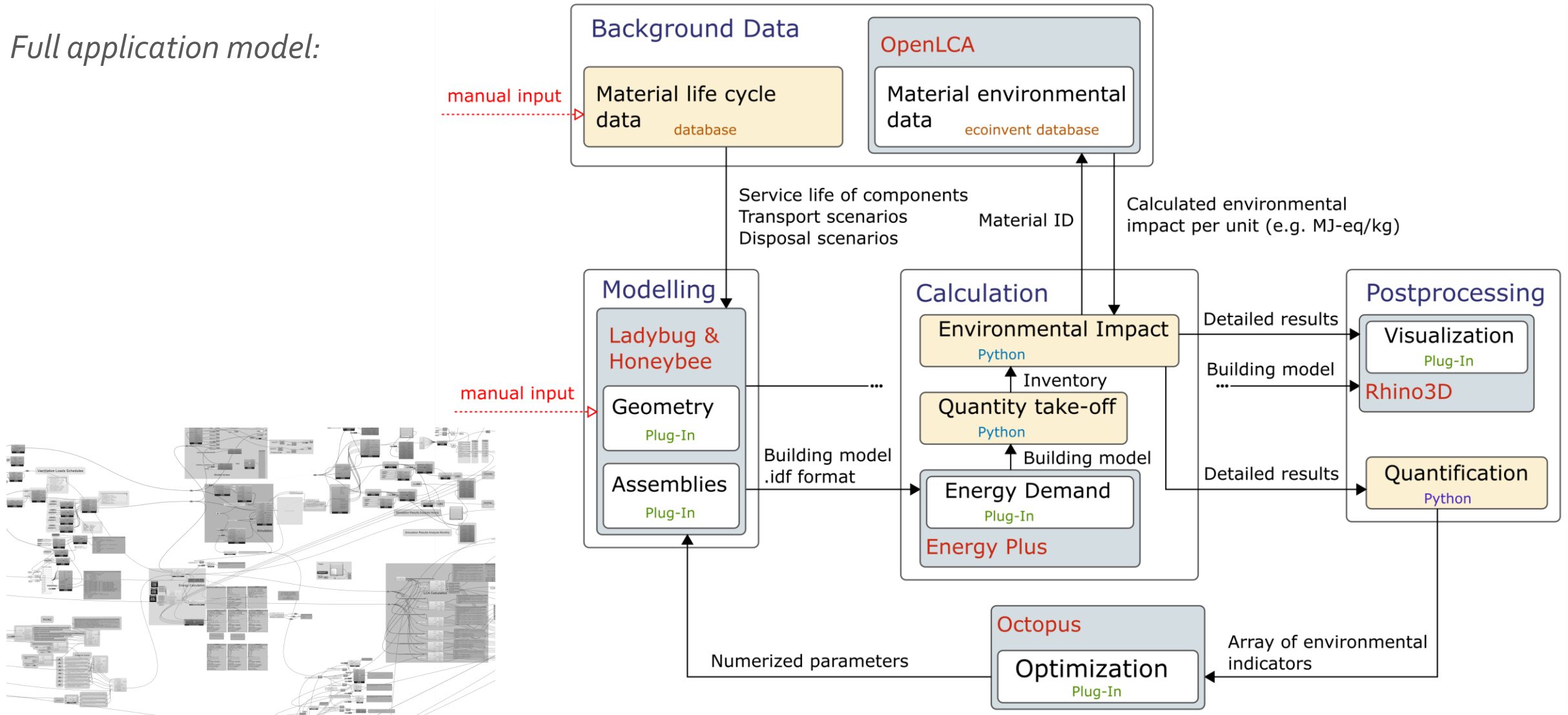
Optimization:

- For the implementation the **Octopus**⁶ component is used
- Multi-objective optimization is possible
- Objective function(s) are provided by the postprocessing module (e.g. total GWP and total CED)
- Parameters are numeric and discrete – translation to building parameters is provided by the modelling module

⁶ <https://www.food4rhino.com/app/octopus>



Full application model:



Conclusions

- General description of a modular framework, input for discussion on harmonized approach
- Aim to provide common framework to enable interconnectivity of LCA data and tools
- Definition common modules for customized workflows to enable wide application in practice

Next steps

- Definition and provision of individual modules for testing and feedback from community
- Development and description of exemplary use cases to show information needs
- Detailed specification of data and exchange requirements between modules
- Common hierarchical data structures to support assessment in different design stages



International
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Thank you for your attention!

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