HIDALGO2
CENTRE OF EXCELLENCE

Urban Building Energy Model Pilot

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Context

Building sector in the EU [1]:

- **36%** of GHG emission
- **40%** of final energy consumption

Horizon 2050 objectives:

- Double annual energy renovation rates in the next 10 years [2]
- E.g. 700 000 renovation/year in France

➔ Building Energy simulation:

- Accurately assess energy performance of existing buildings
- Identify sources of energy savings (anomalies and areas for improvement)
- Compare and evaluate renovation and/or energy management strategies
- Ensure the optimal management of buildings

[1]: https://ec.europa.eu/info/news/focus-energy-efficiency-buildings-2020-lut-17_en
[2]: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en

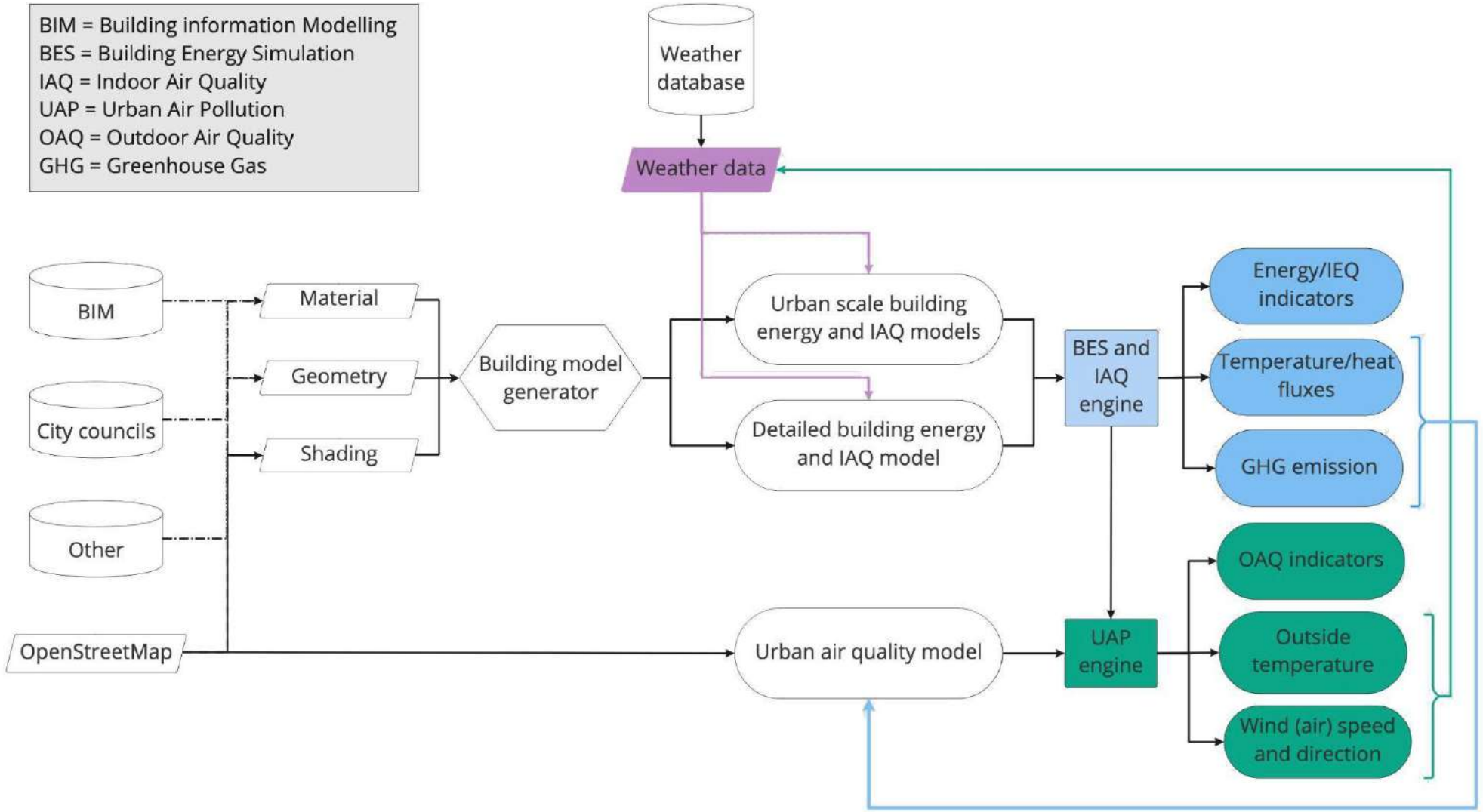
Objectives

- Predict energy consumption, thermal comfort and indoor air quality at both
  - Building scale, and
  - Urban scale
- Integrate the building stock in its environment:
  - Couple with Urban Air Pollution (UAP) model

    ➜ contribution of the building stock (heat and GHG, NOx) to the outdoor air quality model (UAP)

    ➜ improved boundary conditions of the building model (wind speed, outdoor temperature)
  - Improved radiative heat transfer on buildings' envelope, through a better estimation of solar shading

Objectives


BIM = Building information Modelling
BES = Building Energy Simulation
IAQ = Indoor Air Quality
UAP = Urban Air Pollution
OAQ = Outdoor Air Quality
GHG = Greenhouse Gas
Weather database
Weather data
BIM
City councils
Other
OpenStreetMap
Material
Geometry
Shading
Building model generator
Urban scale building energy and IAQ models
Detailed building energy and IAQ model
Urban air quality model
BES and IAQ engine
UAP engine
Energy/IEQ indicators
Temperature/heat fluxes
GHG emission
OAQ indicators
Outside temperature
Wind (air) speed and direction


Status

Advanced Modelling at Building Scale

Continuous monitoring (**IoT**), processing and analysis (**AI**): comfort and consumption alerts, anomalies detection, …

Reliable models

Geometric model + physical model + Sensor data

Simplify and speed up geometry definition

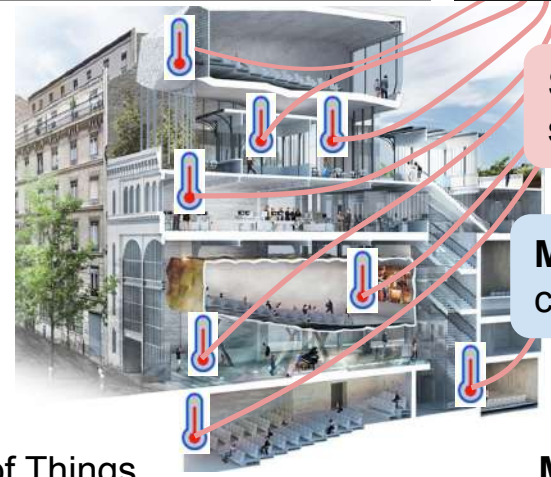
WEB

Numerical model with data assimilation

3D scan

BIM: 3D reconstruction

Monitored building



Speed up simulation

Computer cluster

MOR + on cloud **HPC**

Real time simulation

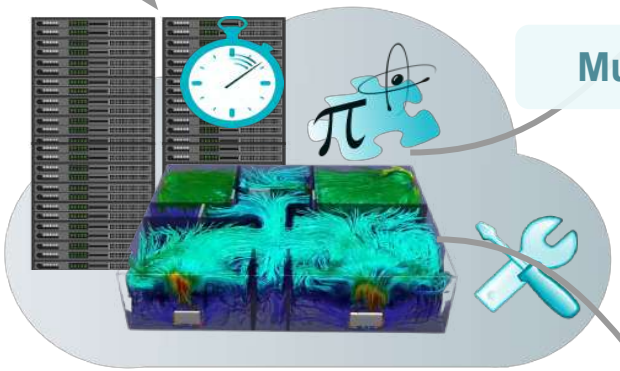
Predict thermal comfort and energy consumption, optimal control

Acronyms:
IoT: Internet of Things
AI: Artificial Intelligence
BIM: Building Information Modelling

MOR: Model Order Reduction
HPC: High Performance Computing

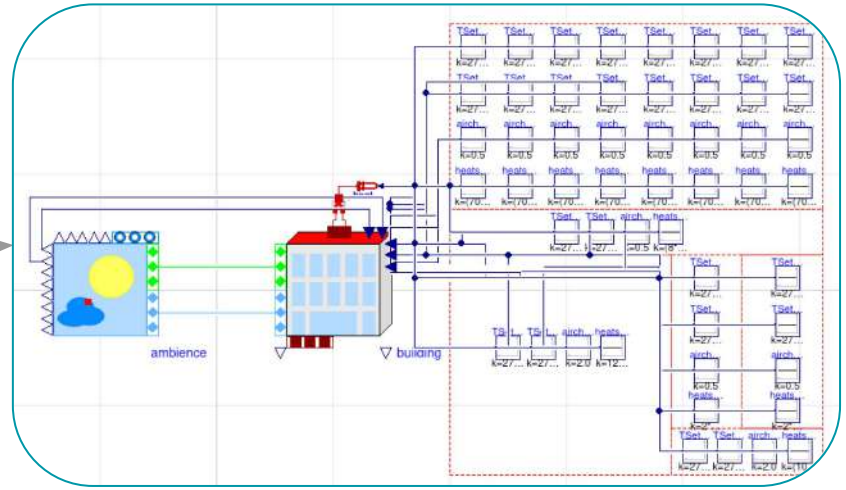
Building Energy Modelling

IFC file

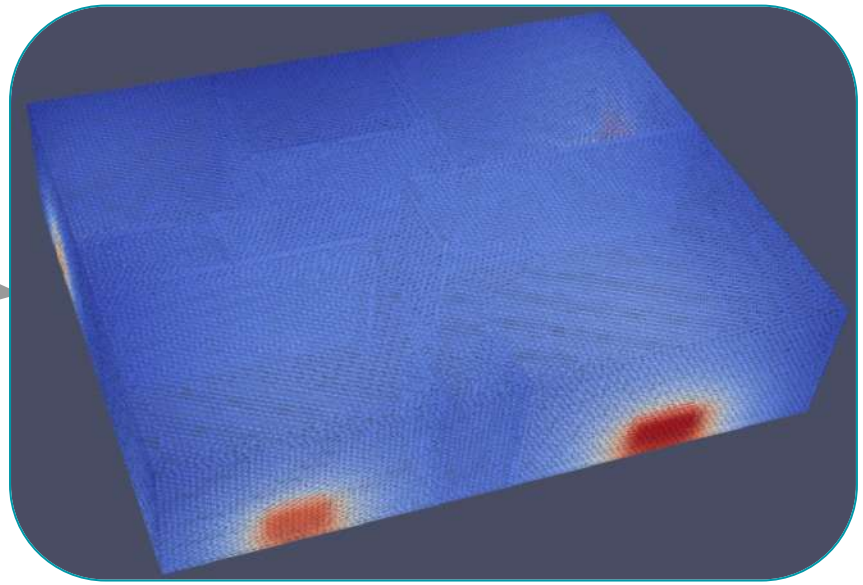


Automated generation of building energy models

Multizone

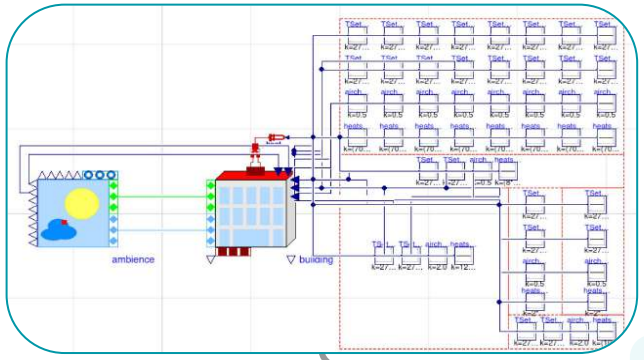


3D



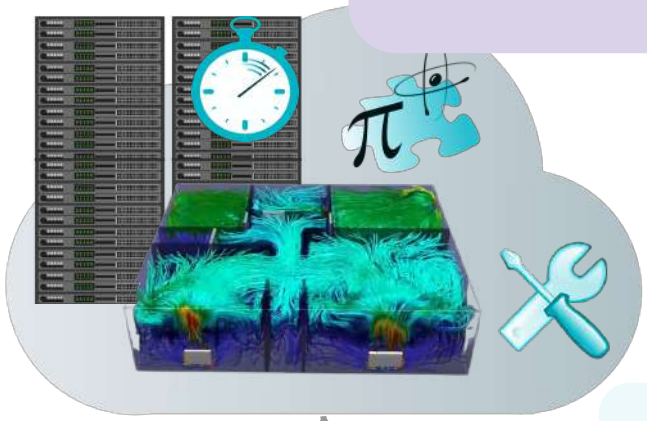
Data Driven Model Order Reduction

Data



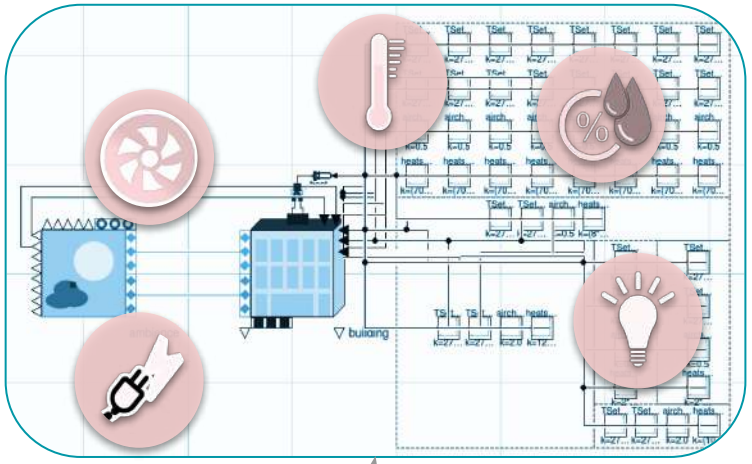
Complex models

MOR + Data assimilation

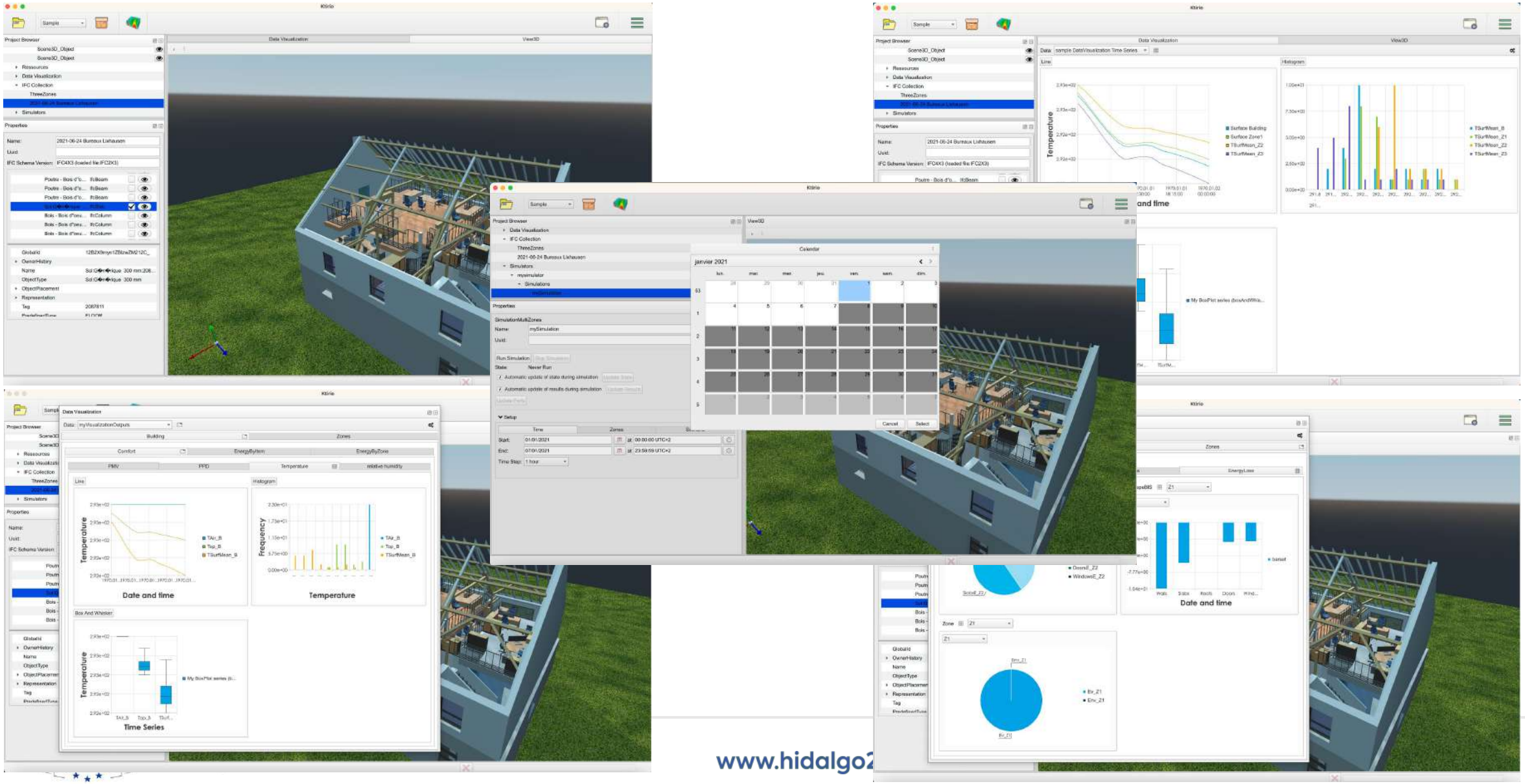


Reduced and enhanced models

+ Improved accuracy
+ Faster



Advanced Modelling at Building Scale



Urban scale model

Energy simulation (heat exhaust)

- BuildingSystems library
  - ➢ Low order multizone model
    - \+ Detailed energy analyses of city districts.
    - − Huge data sets of building parameters (geometries, material properties, …)
      - ■ Can be generated using QGIS in combination with the Open eQuarter plug-in for example

City district model with 144 building models

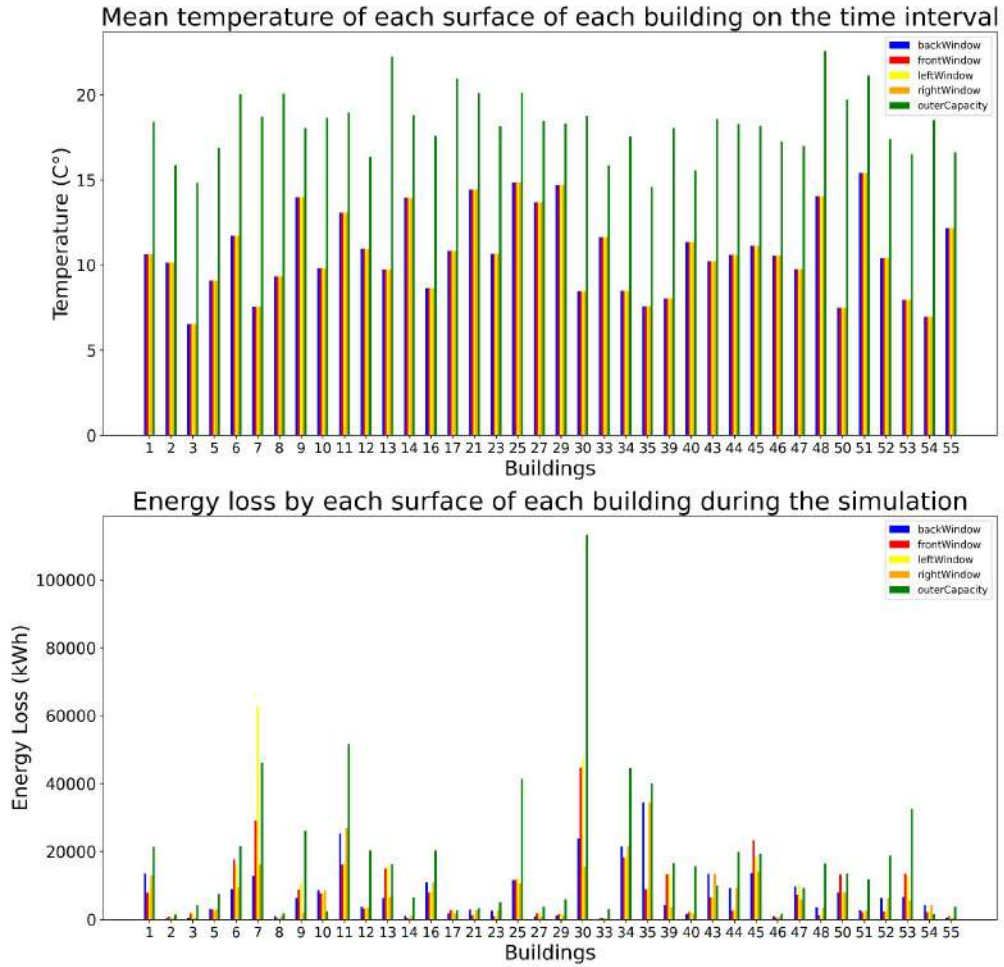
Urban scale model

Energy simulation (heat exhaust)

- Solar mask computation
- Build and simulate basic model for each building making various simple assumptions, different levels of fidelity
- More advanced models can be used if IFC files are available for specific buildings.
- To be coupled with the Urban Air Pollution Model including Temperature, heat fluxes and CO2 and possibly other pollutants.

City district model with 144 building models

Urban scale model



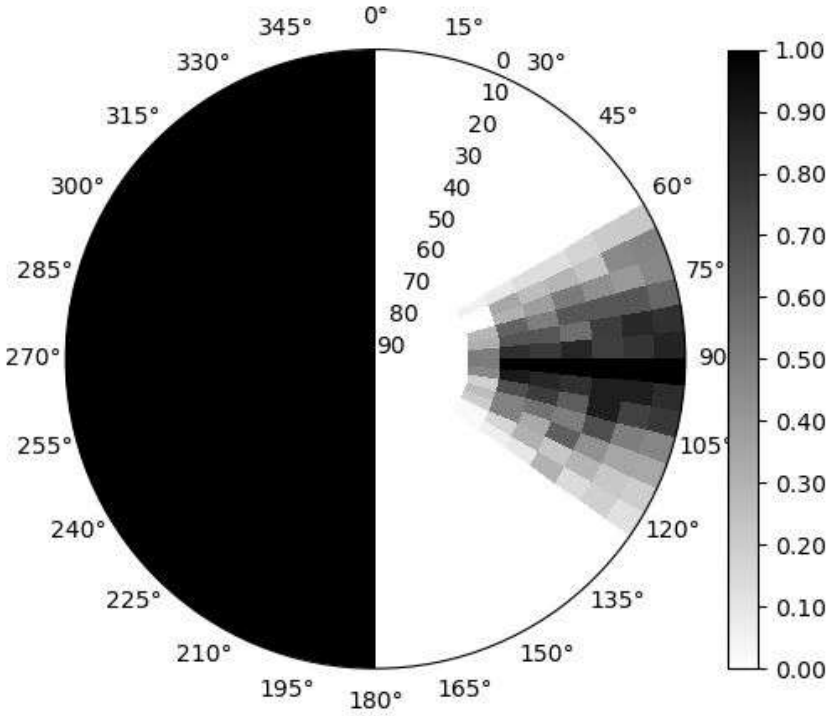
City district model with 144 building models

Solar Masks computations are critical

Radiative heat transfer

- Weather data transformation:
  - Each weather data source may have its own format
  - ➜ Format to meet simulation tools requirements
- Automatically collect envelope surface properties:
  - Geometry : area, orientation,
  - Surface properties: emissivity, absorption, …
- Compute view factors
- Compute solar shading masks
  - Needs to consider the building in its environment
- Test and validation

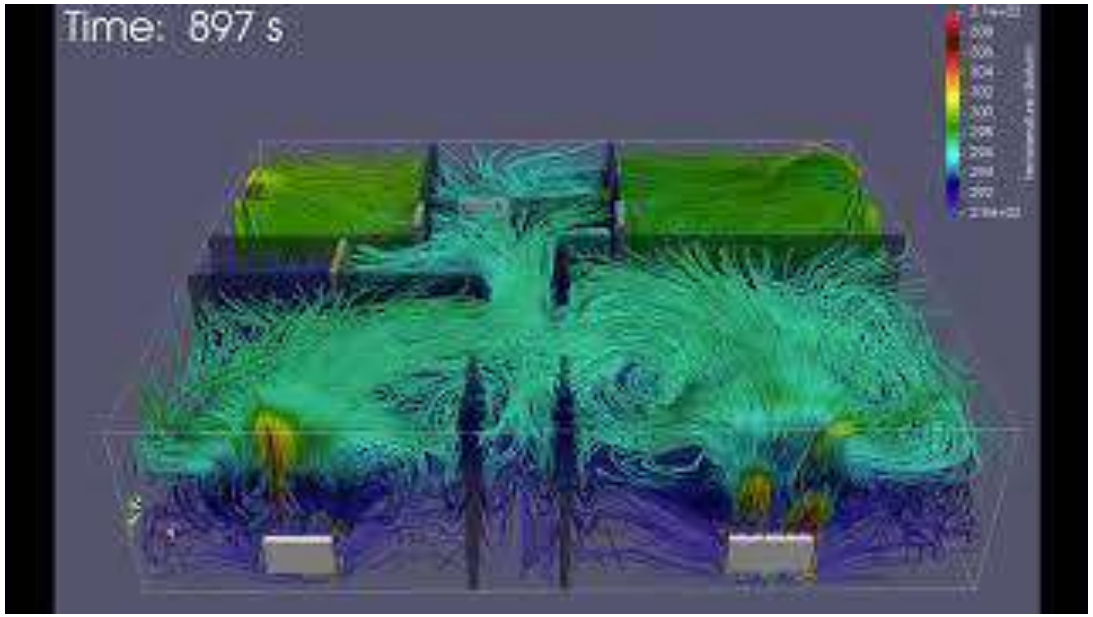
On the right, an example of a shading mask computed for a building face that is totally masked or partially masked by another structure.



Mode advanced models

Coupled CFD, heat and transport for detailed building models

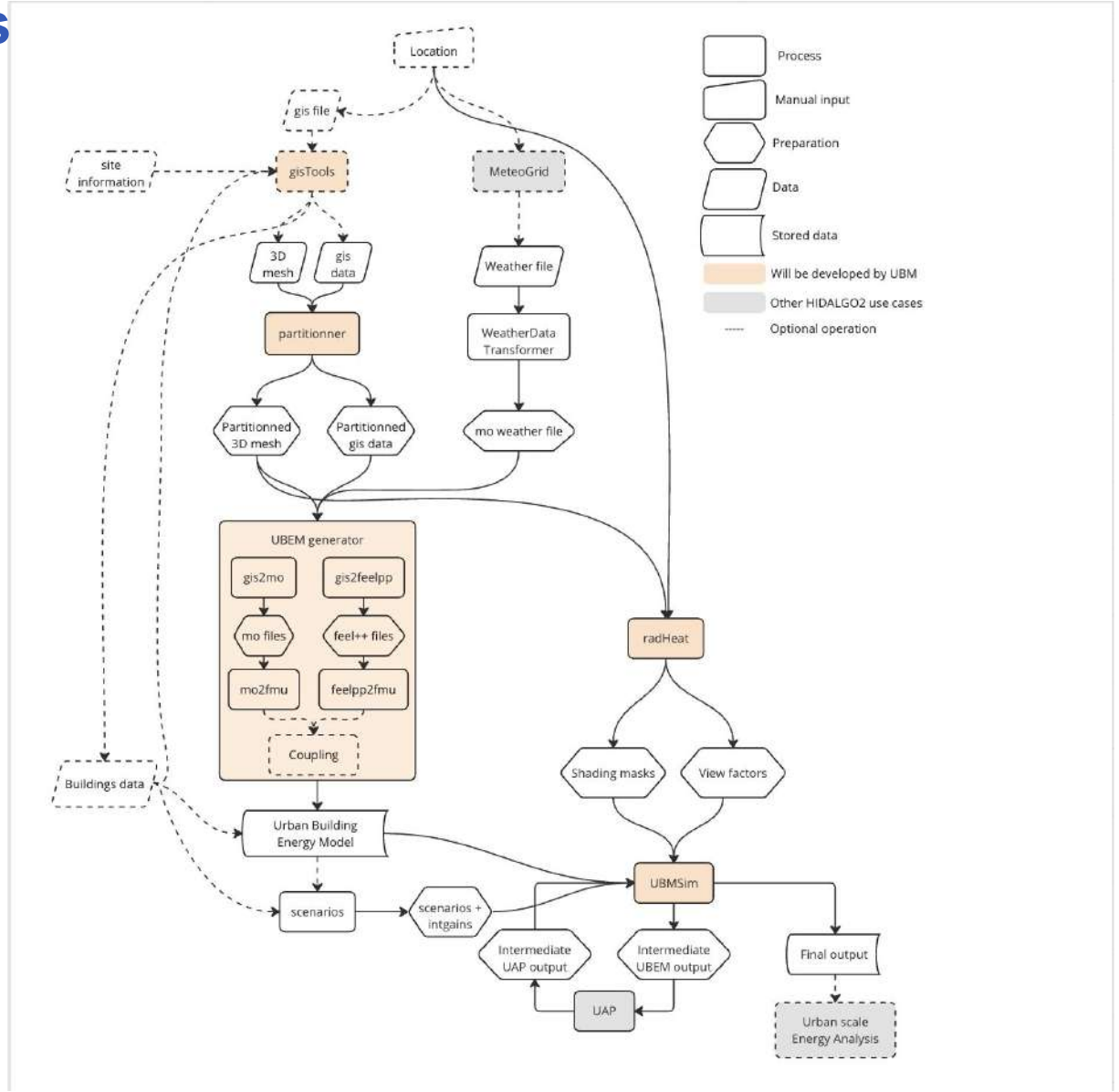
- Using **Feel++**, we can perform:
  - Heat transfer simulations (no air flow) using **heat toolbox**
  - Air flow simulations using CFD toolbox
  - Coupled CFD and heat transfer using **heat-fluid toolbox**
  - Passive transport using **CFPDE toolbox**
    - Air flow is simulated beforehand using **CFD toolbox**
- In the future, we plan to:
  - introduce the temperature field in the transport equation
  - consider more air pollutants (currently CO2)
  - Apply data assimilation and MOR



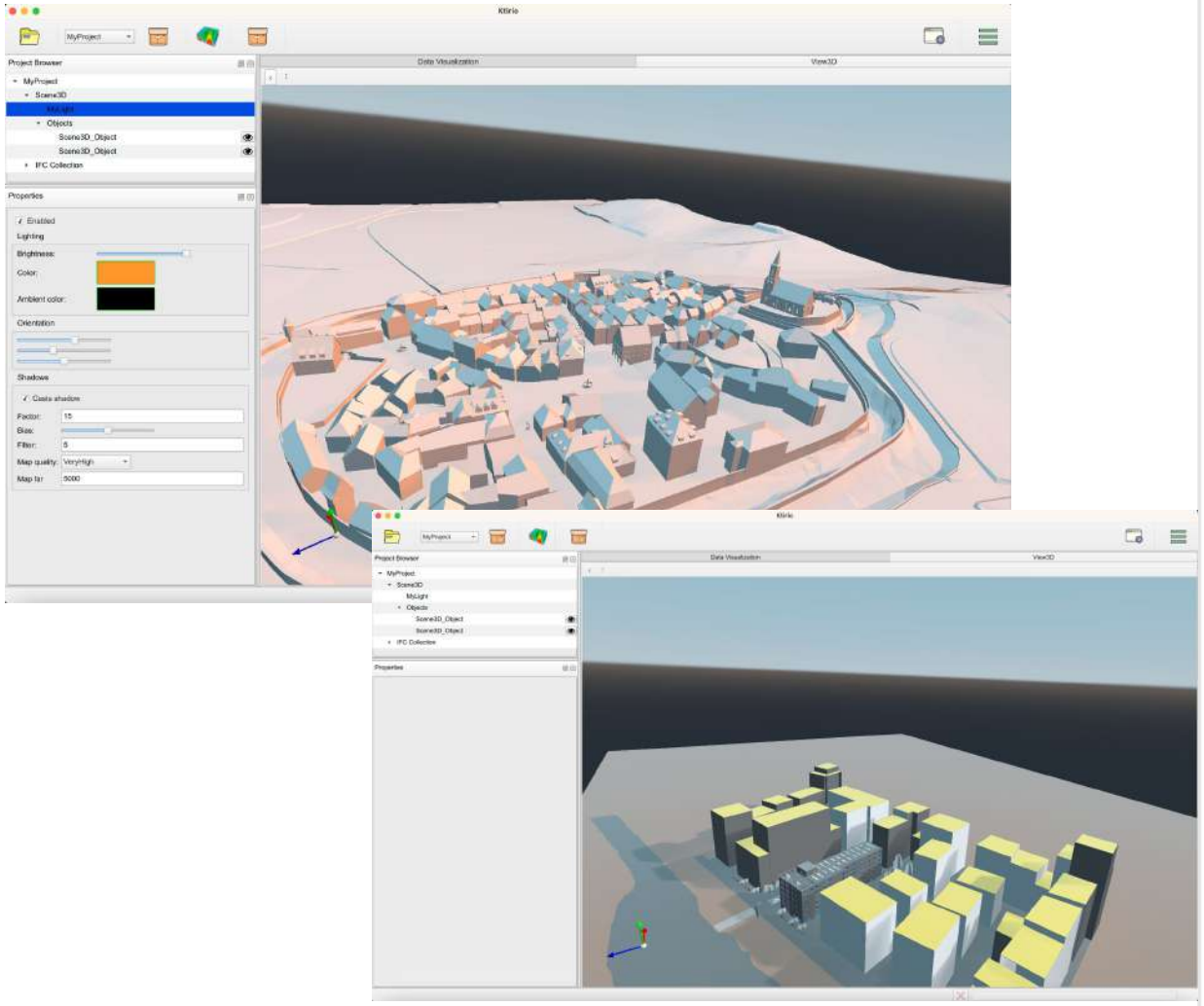
Urban Scale Models

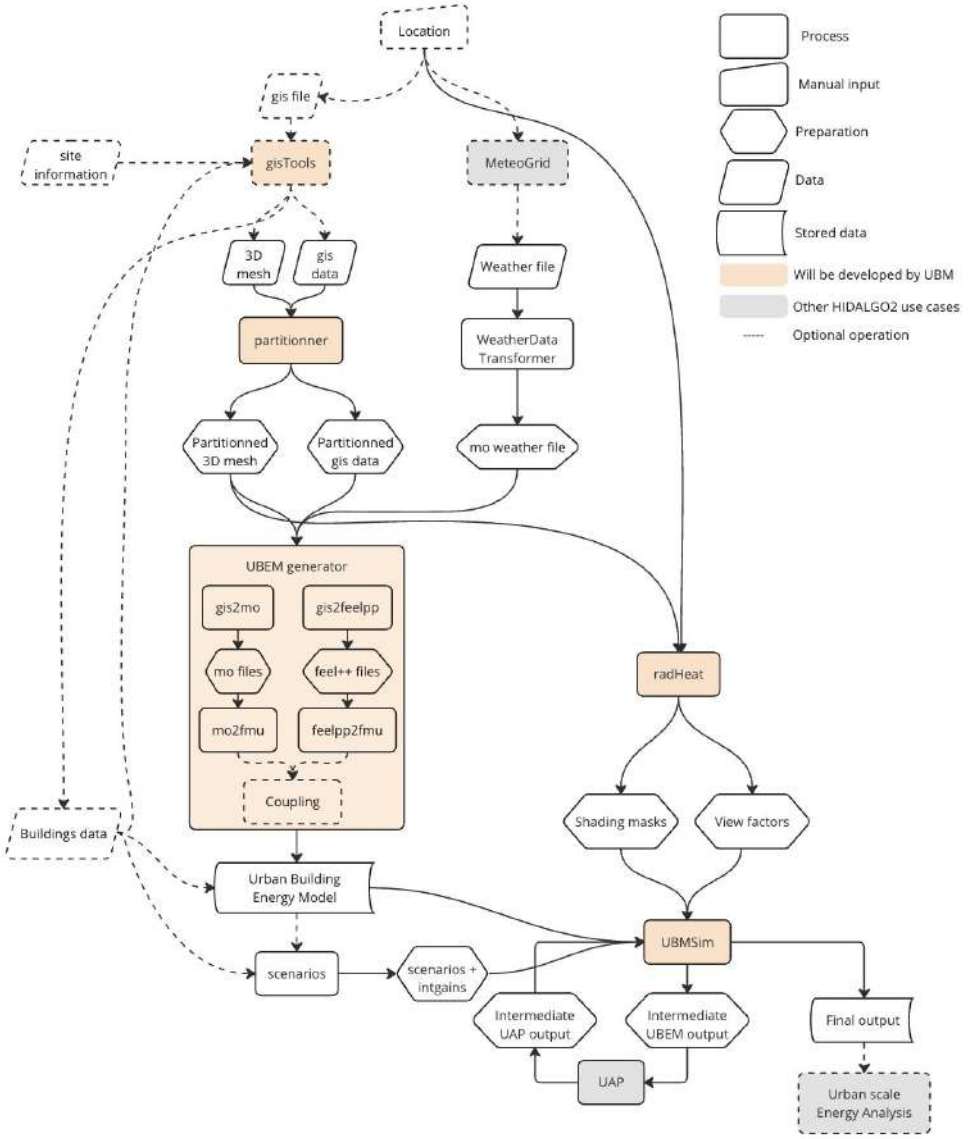
- Automate model generation
  - Data collection procedure
  - Tool chain from GIS to UBEM
- Embed reduced detailed model in the Urban scale model
- **Couple with UAP**
- Benchmarking
- Easy Configuring and Deployments

On the right, the workflow we are currently developing including parallel computing



Urban Scale Models





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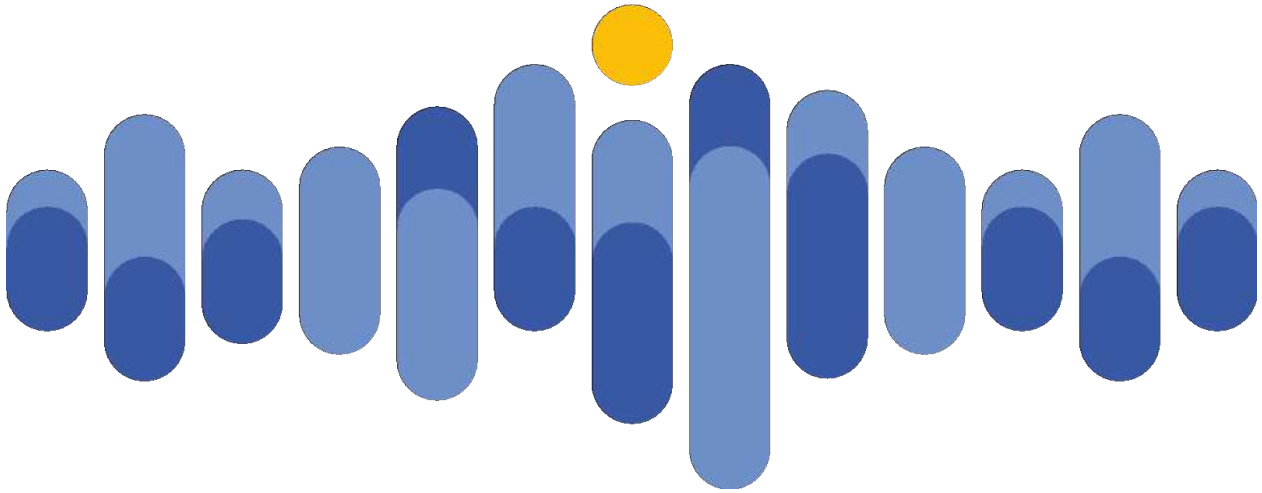
Questions ?



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