EULF Workshop, 12-14 September 2016
« Methodologies for energy performance assessment based on location data »

Energy simulation of buildings and urban projects
Spatial data input, use of measurements, « big data »

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MINES ParisTech – CES

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  - Interoperability and new spatial data sources
  - Exchange on modelling issues regarding the building stock
  - Use of measurements, « Big data »

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Presentation of the research group + software editor

- **Presentation of the research group**
  - Development of energy simulation models since 1980
  - Chair Eco-design of buildings and infrastructure, 2008-2018, supported by VINCI
  - Life cycle assessment, urban projects
- **Presentation of the software editor IZUBA Energies**
  - Startup created in 2000
  - Users interface, distribution, training, consultancy
  - Architects and urban designers,engineers, construction industry, teachers

Presentation of the methodology (bottom-up) and tools

- **3D Model of a project (one or several buildings)**
  - Geometry (walls, windows, roofs, rooms, zones…)
  - Semantical attibutes (technologies, use scenarios)
- **Energy simulation**
  - Multizone, heat transfer, air flows, lighting
  - HVAC systems, renewable energies (PV, thermal)
  - Most widely used in France: 2,500 users
- **Thermal regulation, energy certificates**
- **Link with life cycle assessment (CO_2, other impacts)**

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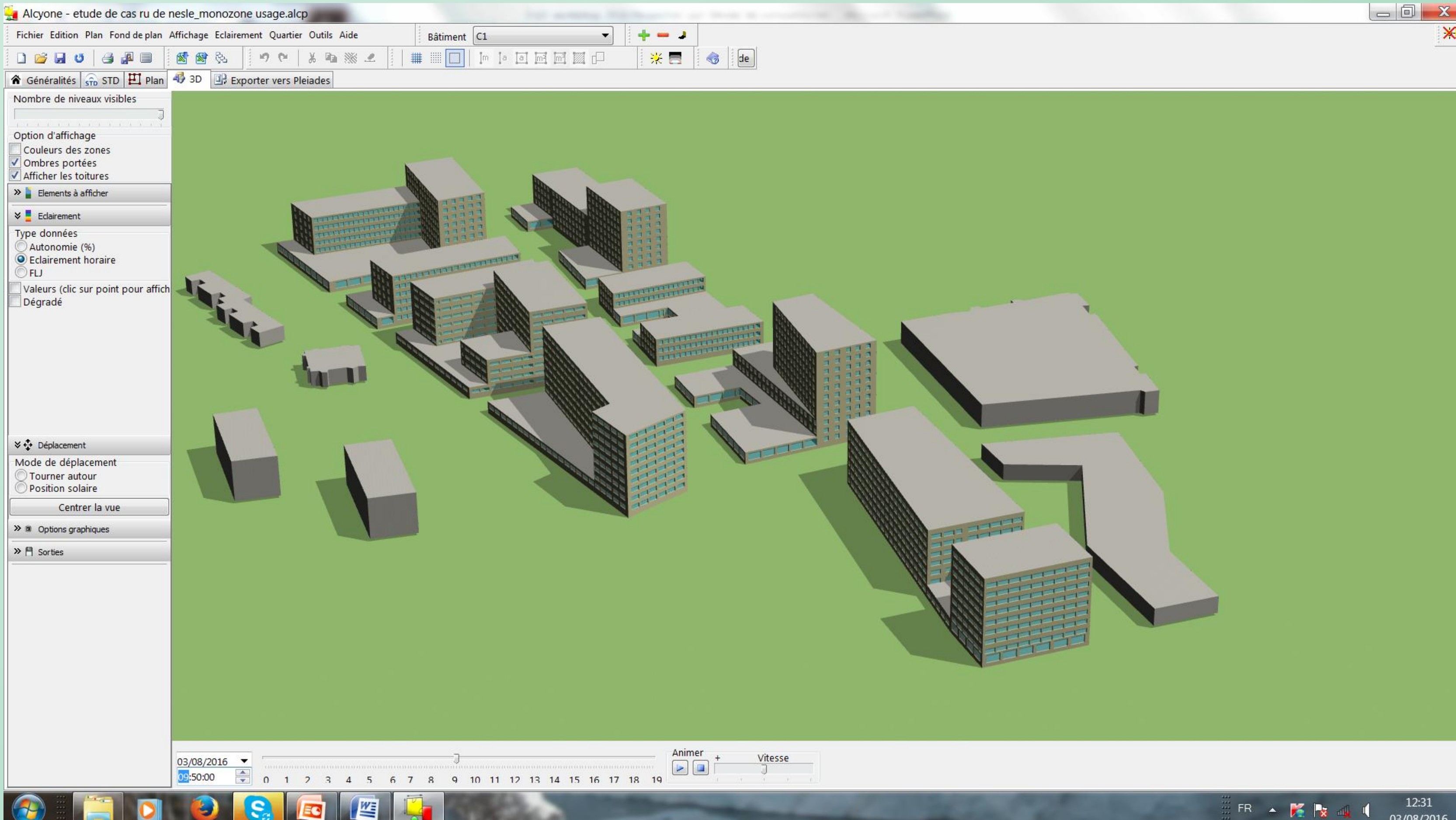
3D modeler ALCYONE

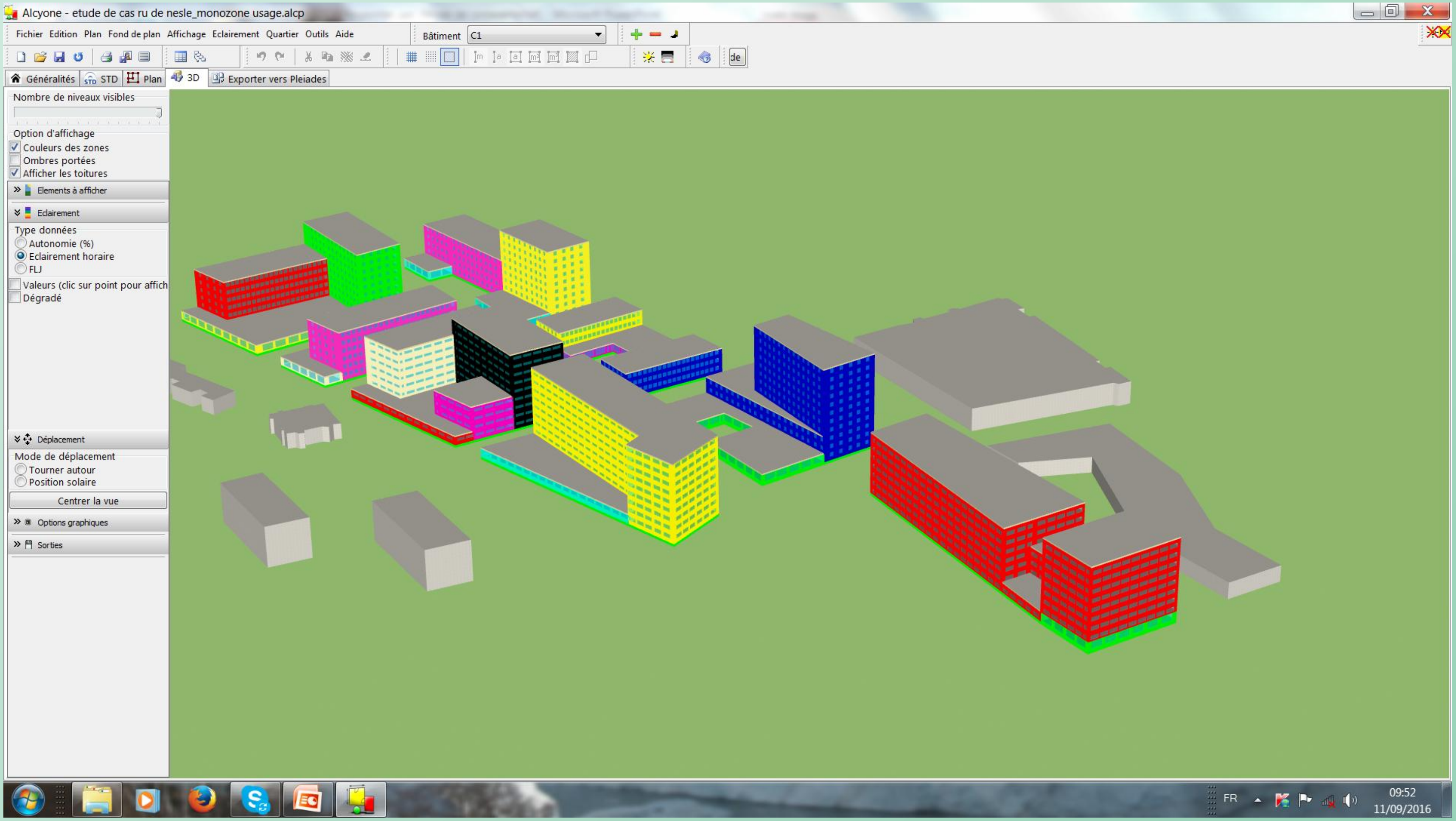


Example urban project, offices, apartments and shops

3D modeller ALCYONE, semantical attributes

- **Several building types, e.g. offices, residential**
- **Performance level/technologies associated with each type (e.g. Passive -> insulation thickness)**
- **Several zones in each building (e.g. Shops on ground floor, apartments above)**
- **Use scenario in each zone (52 weeks, 7 days, 24h: heating/cooling thermostat, ventilation, appliances, solar protection)**
- **Choice of climatic data, shading**

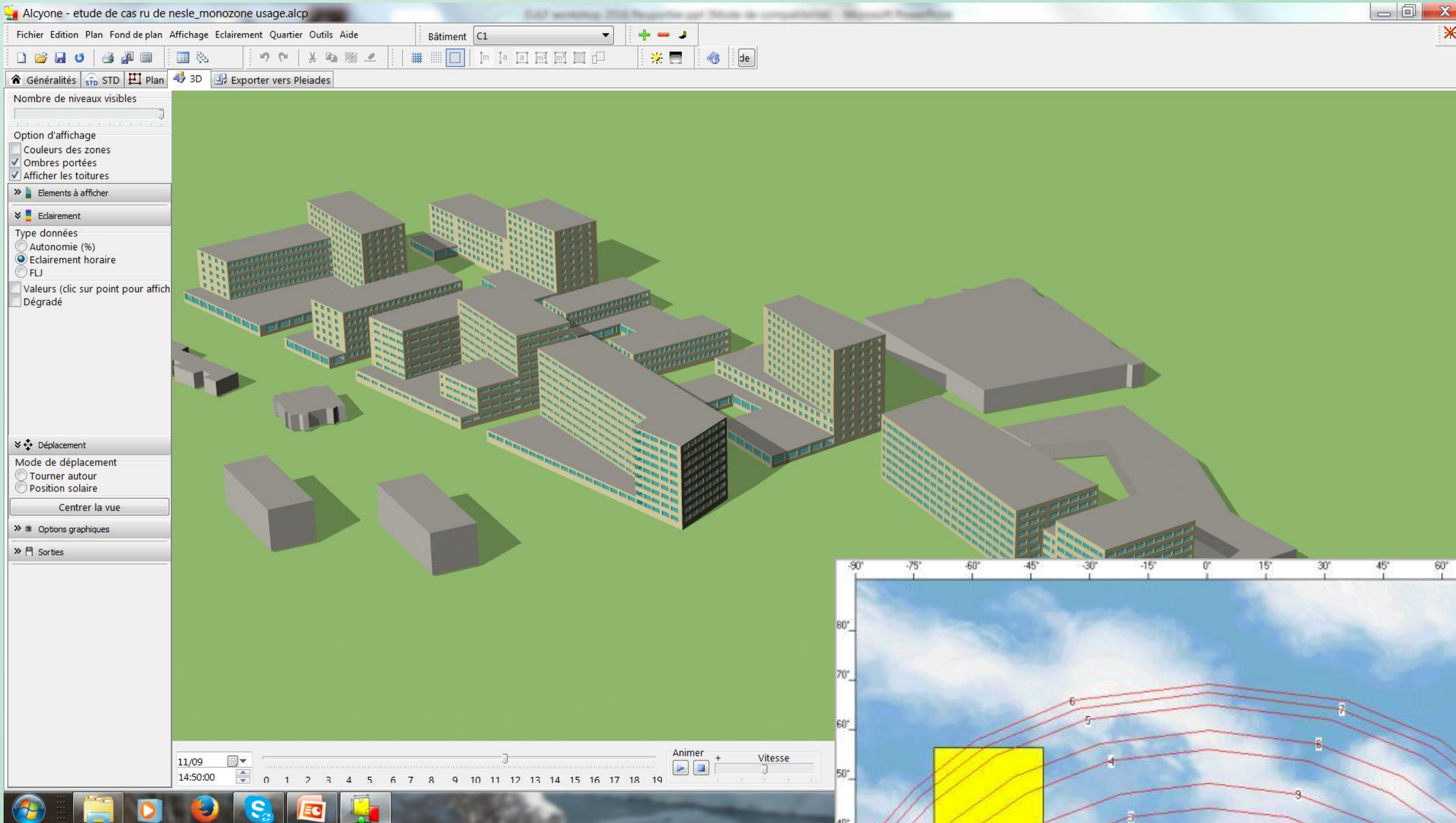
Multizone modelling

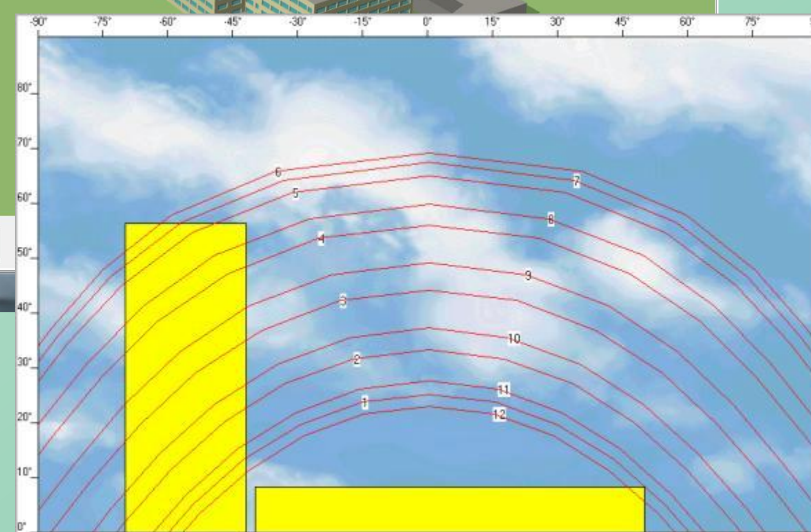


Group residential, offices, shops, school…

-> optimize precision and computation time

Interaction between buildings



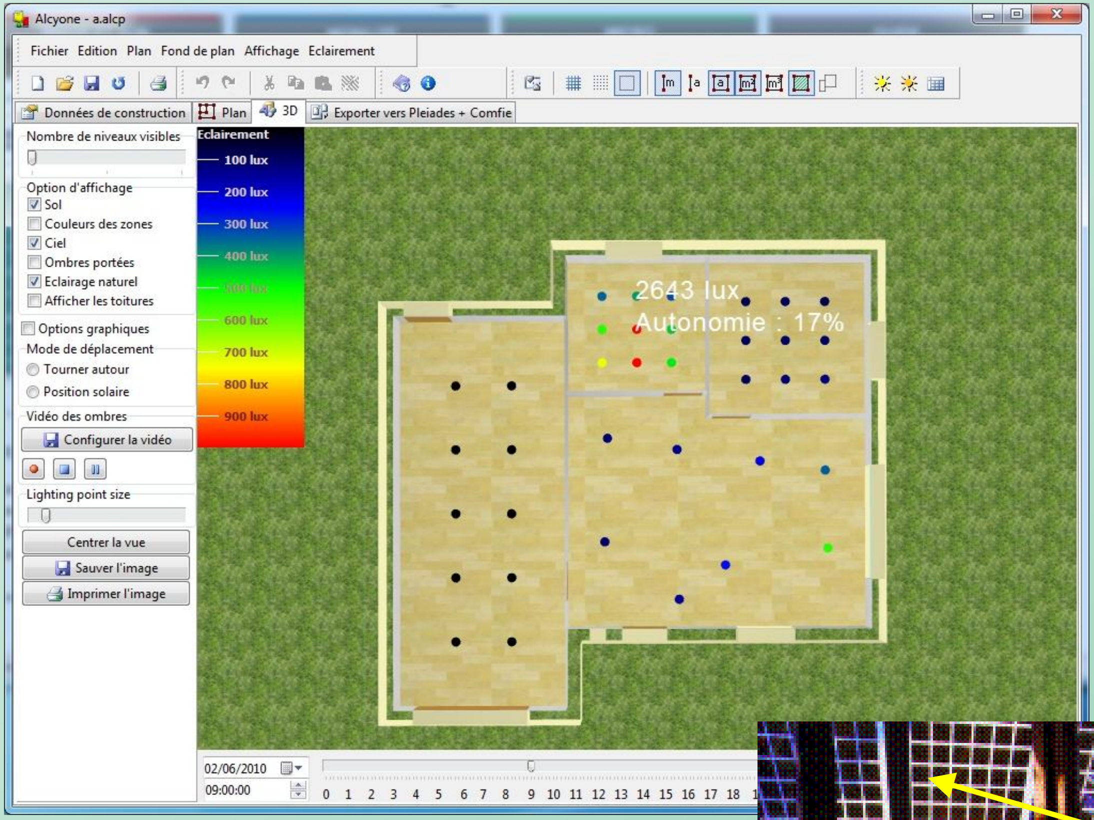


Shading effects,
wind exposure
Link with ENVIMET ?

Main features of energy simulation model COMFIE

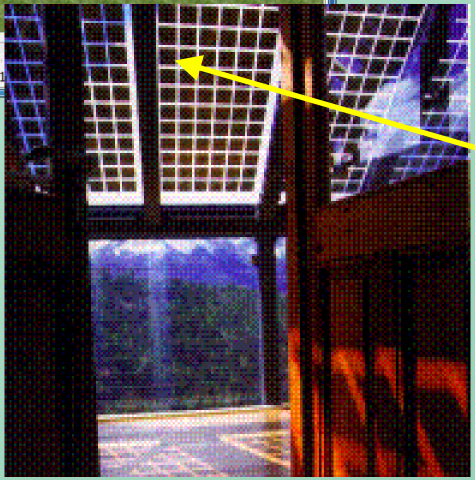
- **Multizone model, use scenarios, orientation etc.**
- **Detailed finite volumes model**
- **Model reduction using modal analysis :10 time constants model in each zone**
- **Air flows calculated like CONTAM/COMIS, no CFD**
- **Daylighting calculations using radiance**
- **-> precision comparable with EnergyPlus or TRNSYS but lower computation time**
- **-> possible to launch thousands simulations in 2h (optimization, uncertainty, large scale projects)**

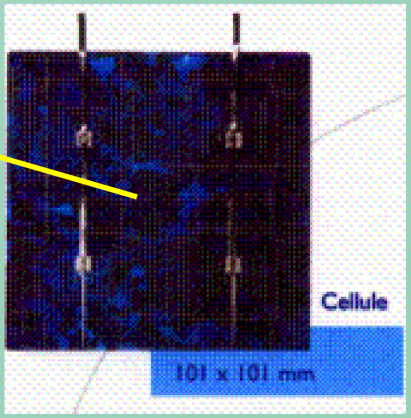
Combining models, examples



Link with a day-lighting model (RADIANCE)

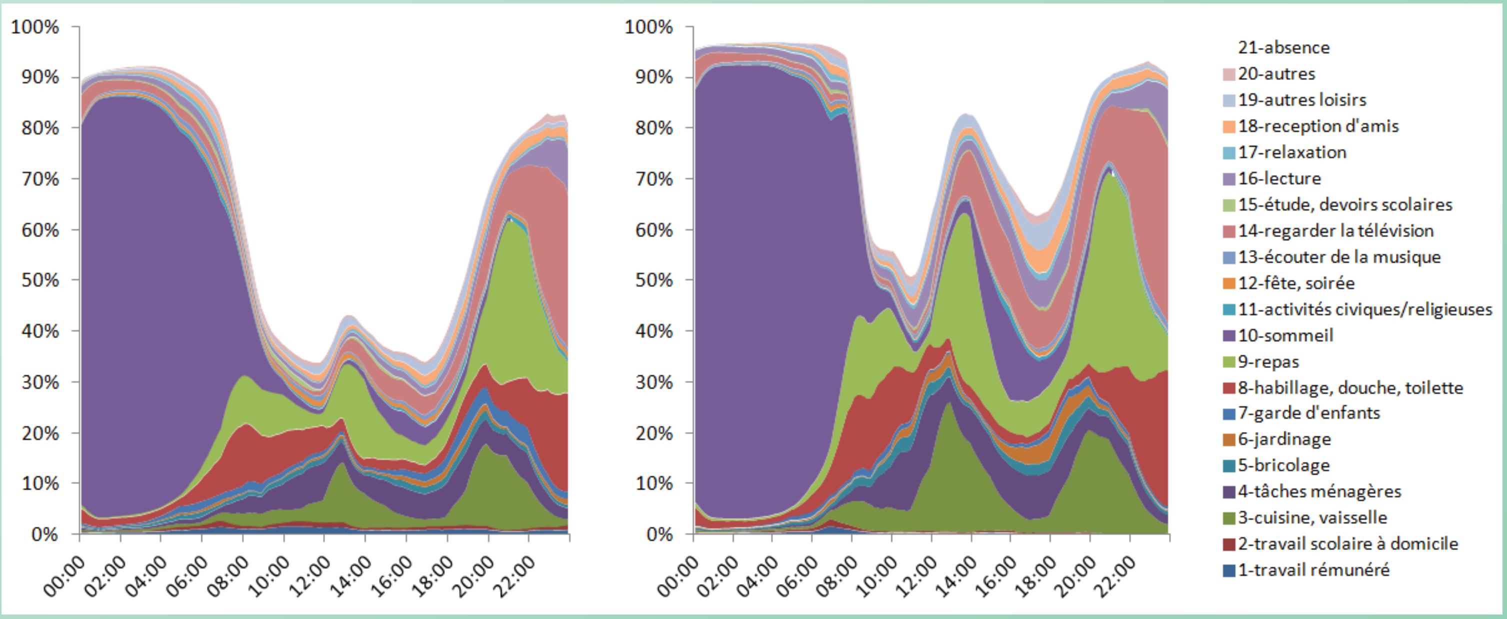
Building integrated Photovoltaic systems





Stochastic model of users behaviour

- **Data from National Statistics Institute (INSEE)**
- **Living area -> number of occupants (probability density function)**
- **PDF for domestic appliances according to revenue**
- **Use of appliances according to activities**



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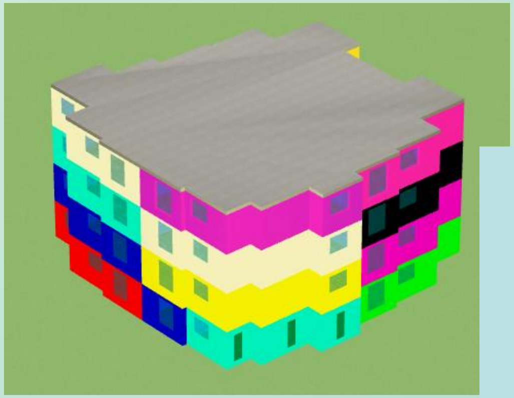
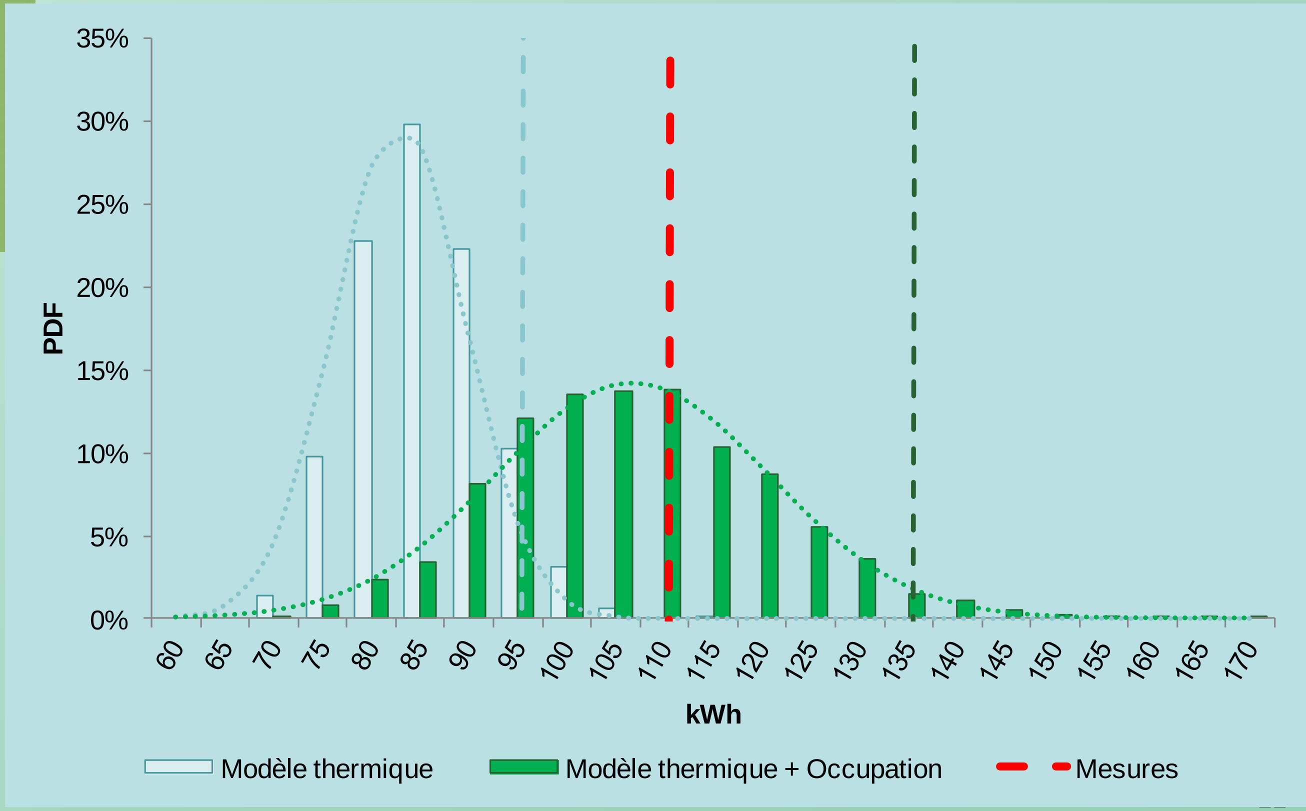
Uncertainty propagation, example

- **Launch 1000s simulation (Monte Carlo)**
- **Useful for e.g. energy performance guarantee**



example : 16 dwelling units



Software validation, intercode comparison

« Bestest » Procedure , International Energy Agency

Comparison with 8 codes (TRNSYS, DOE, SUNREL, ESP,…)

35 cases (window size and orientation, intermittent heating, thermal mass, ventilation, internal gains…)

Experimental validation, IEA task 34, EMPA test cell

Figure 1a Outdoor test facility with removable façade element.

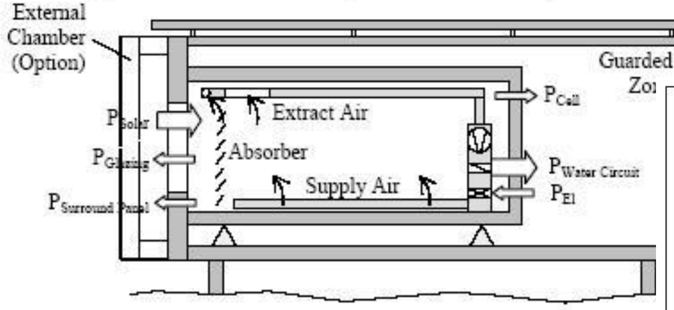
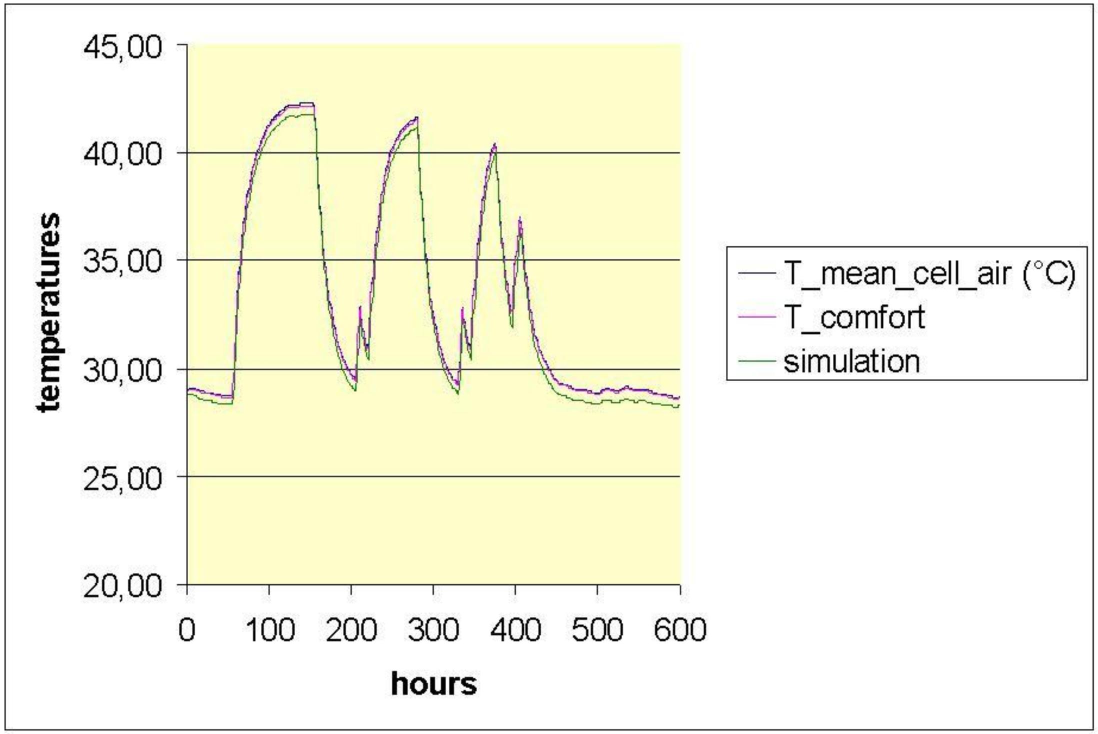


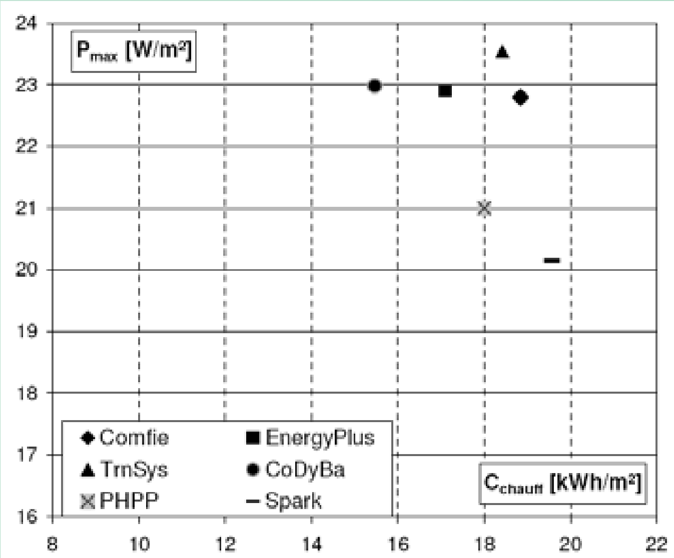
Figure 1b Diagram of test toom with an optional external chan

Less than 1°C discrepancy



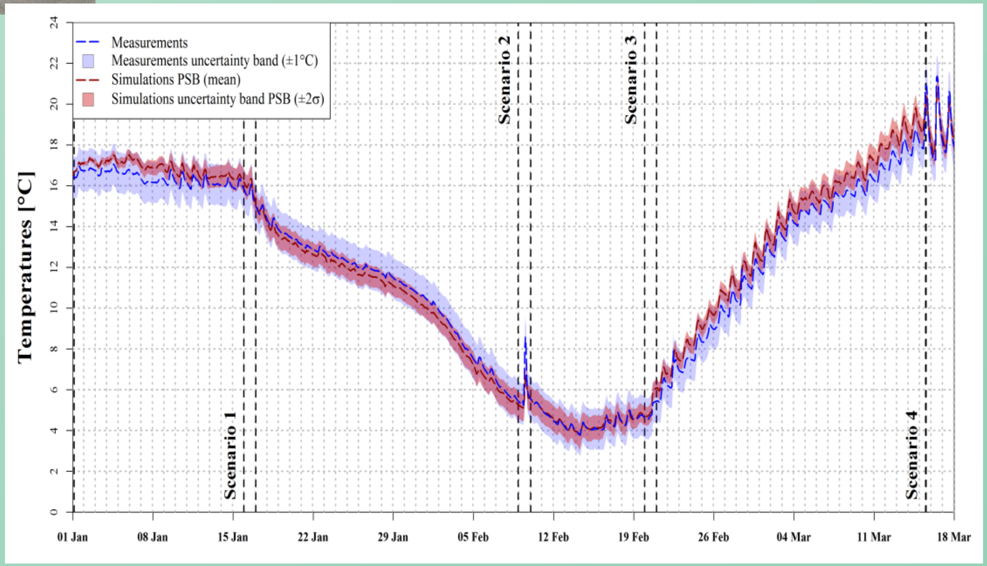
Comparison for passive houses

Maximum heat demand

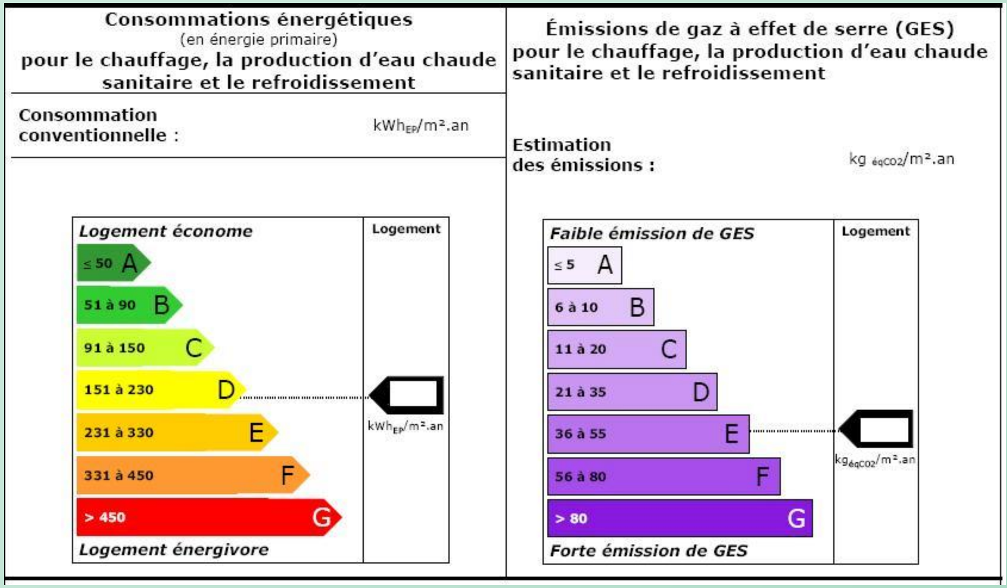


Heating load

Plate forme INCAS, INES (Chambéry)

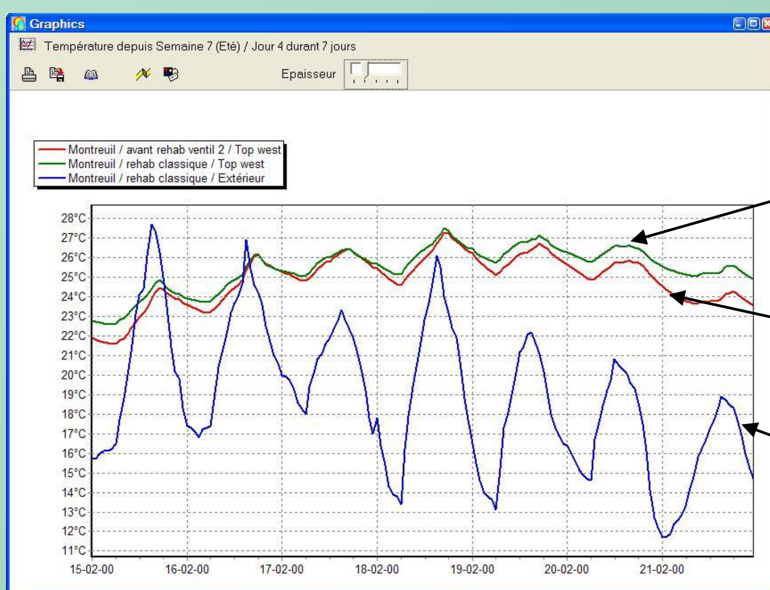


User interface, PLEIADES, link with regulation



Energy certificate
Primary energy,
kWh/m^2/a
and kg CO_2/m^2/a

Graph editor,
e.g. temperature profiles

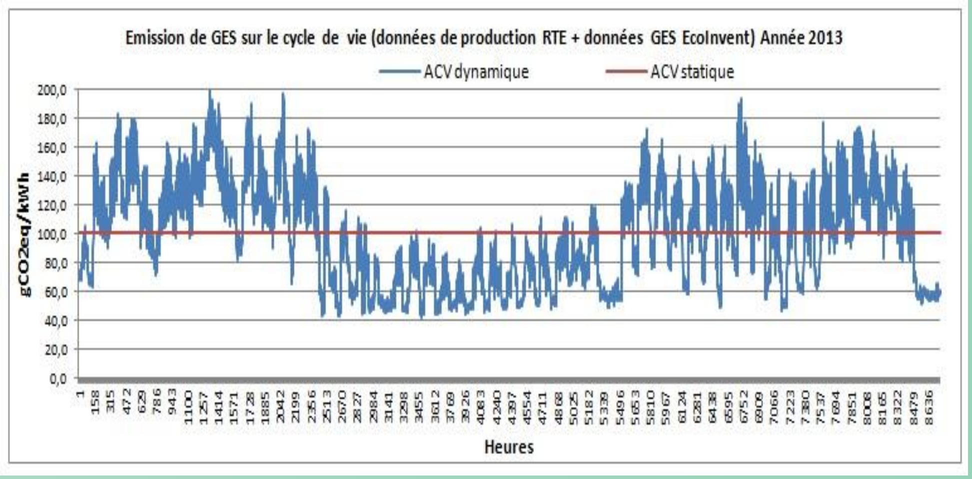


after renovation
before renovation

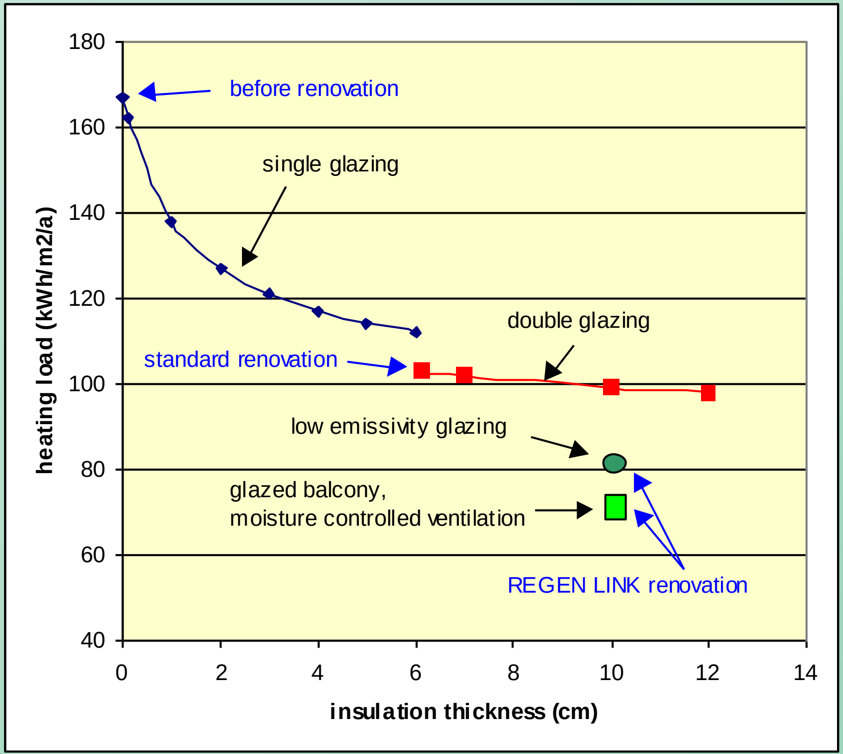
external

Link with Life Cycle Assessment tool novaEquer

- **Evaluation of environmental impacts : resources (primary energy, water, raw materials), climate, health, biodiversity, waste…**
- **Whole life cycle (embodied energy)**
- **Buildings, transport, waste (e.g. incineration)**
- **Example : CO2 emissions, temporal variation**



Renovation of a social housing block near Paris



Construction 1969, not insulated, single glazing

Heating load : 160 kWh/m2/an

Research in progress : optimization of social housing stock using genetic algorithm

Example application : Lyon Confluence

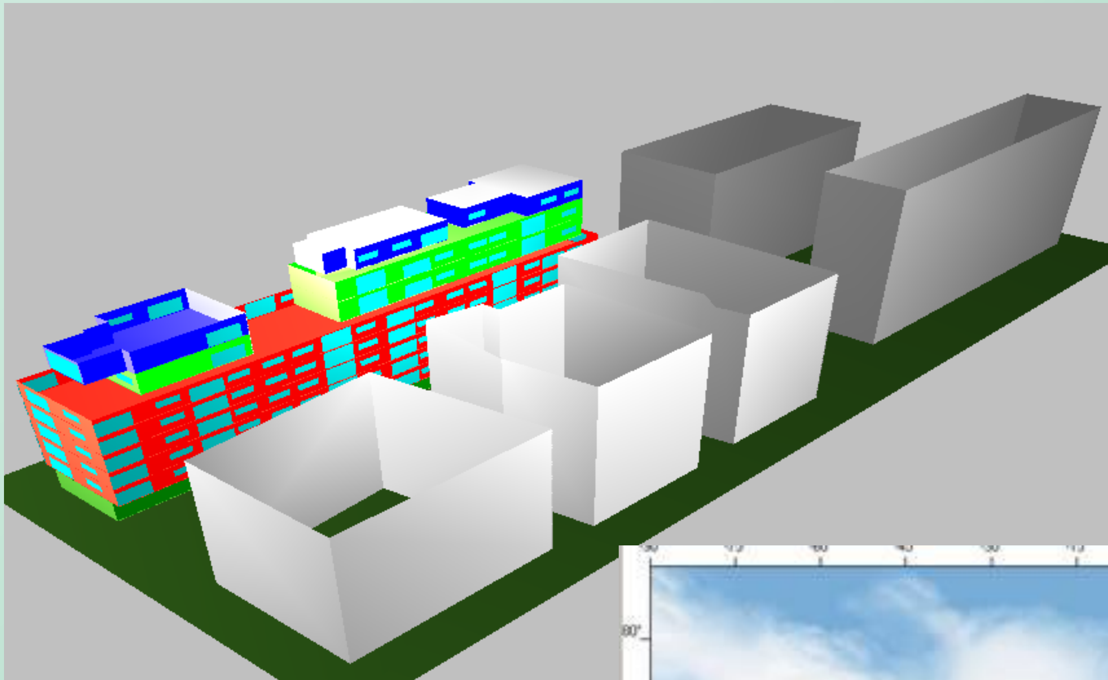
blocks A, B C, around 60,000 m² dwelling, 15,000 m² offices, 70,000 m² green spaces, streets, banks…

Performance of this project ?
Can it be improved ?

Method

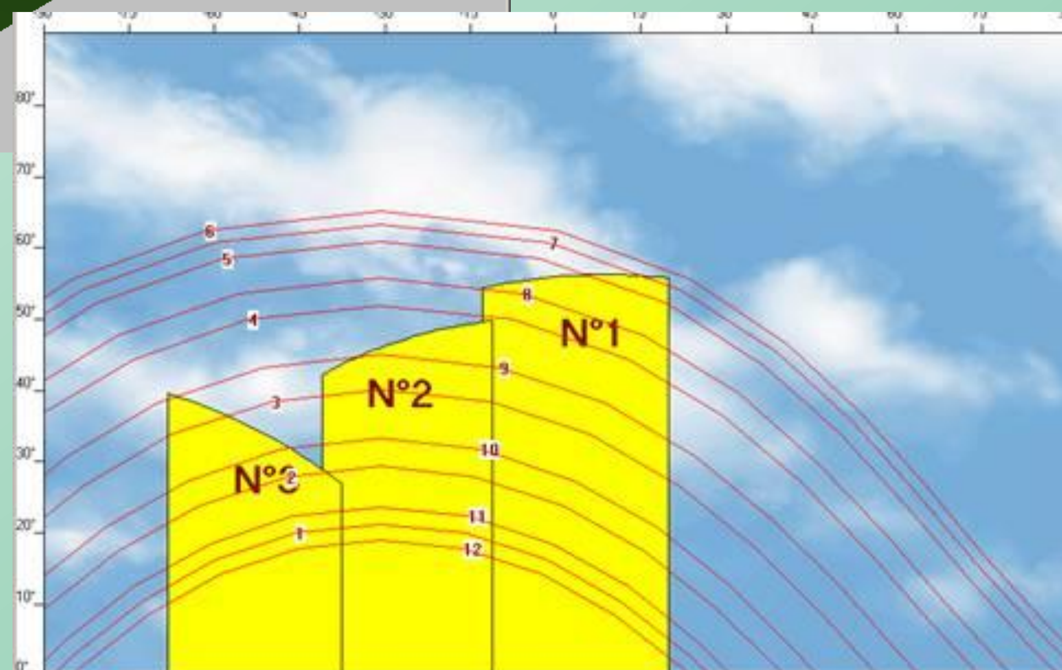
- **Definition of a standard : usual materials and techniques, thermal regulation level**
- **Definition of best practice, passive house : high insulation, triple glazing, reduced thermal bridges, heat recovery on ventilation**
- **Project, according to the objectives of the European programme CONCERTO : Regulation – 40%, 80% heat and 50% electricity provided by renewables**

Modeling of buildings: 3 blocks, 20 buildings

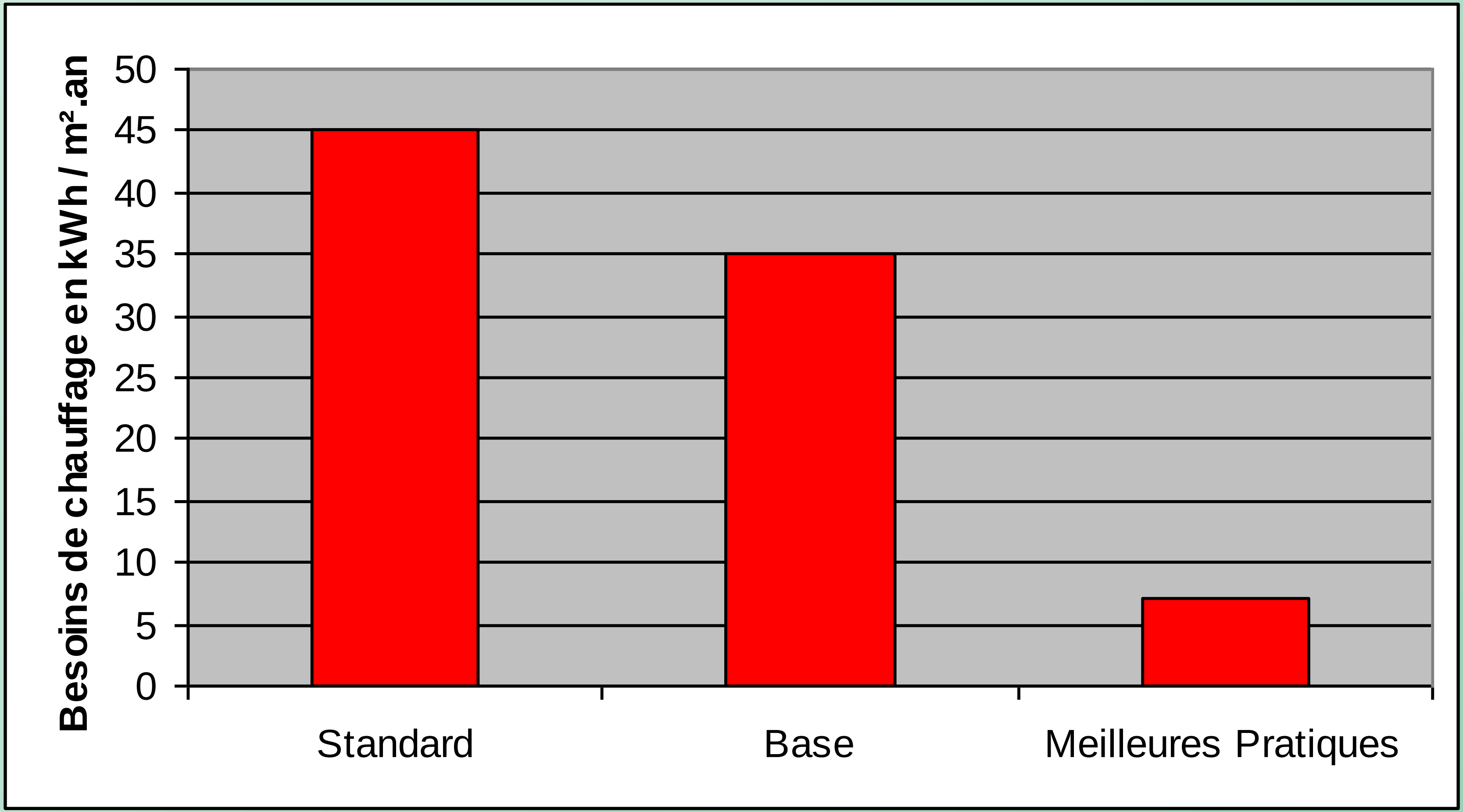


Plans of each floor -> 3D view ALCYONE, see www.izuba.fr

Shading by other buildings are accounted for

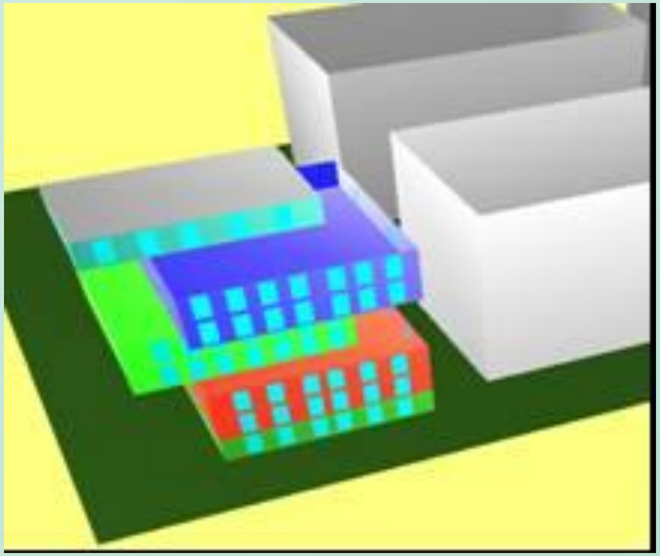


Results of energy simulation using COMFIE



Average values for all buildings
Variation from 1 to 3 according to the architecture
(buildings 1 and 10 of block B, same technologies)

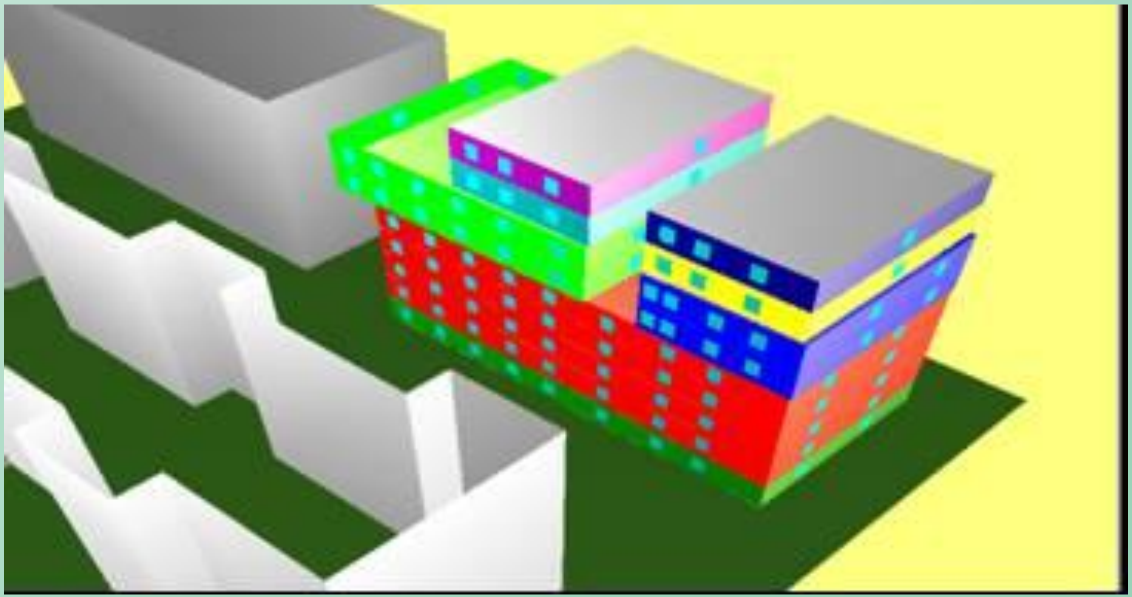
Different architectural design



Building 1, low compactness, North exposure

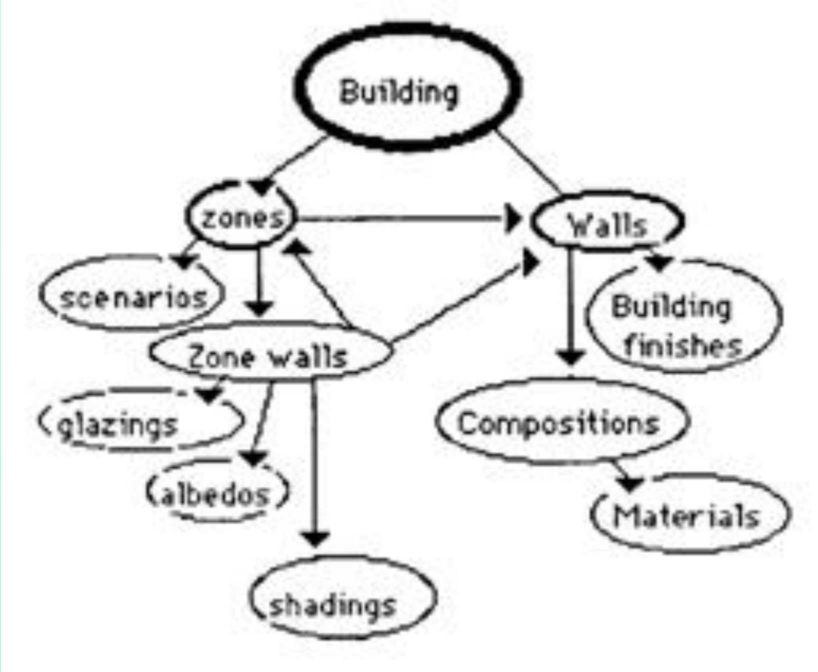
Variation from 1 to 3 according to architecture : buildings 1 and 10 (same technologies)

Building 10, south oriented



Input data, interoperability

- **Import of Sketchup or Autocad files: precision depends on architect's practice, reliability can be low**
- **gbXML ok, IFC4 soon (REVIT)**
- **CityGML + Application Domain Extension Energy ?**



Future possibilities regarding spatial data ?

- **National geographic institute in France (IGN) -> data base providing the ground area and height of each building**
- **Tax administration -> use of the buildings (e.g. number of dwelling units), construction date and information about their renovation (32 Million Bdgs)**
- **Use of this information to elaborate a typology, then simulation of each type (with possible parametric variation) -> evaluate the potential energy saving in a territory**

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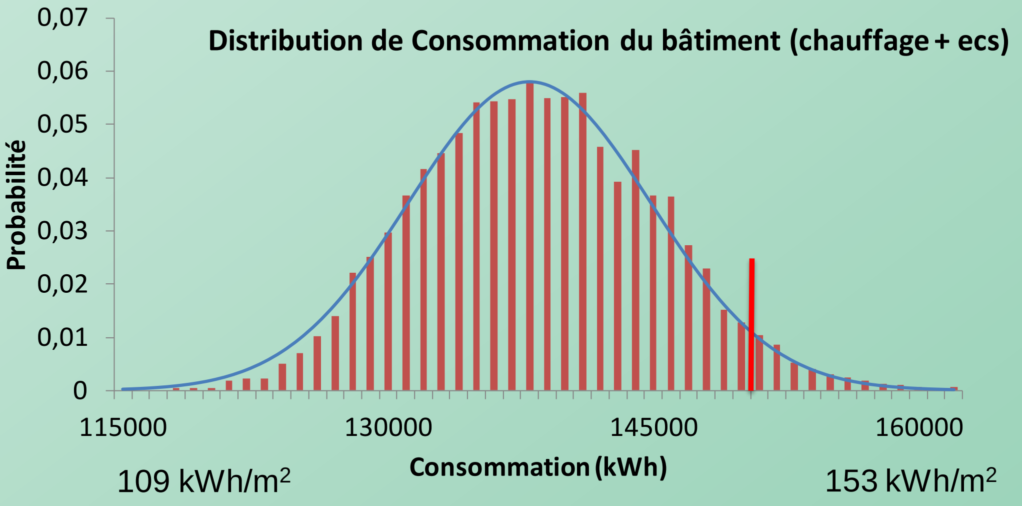
Use of measurements ?

- **Energy bills: energy consumption depends on users' behaviour -> need to relate consumption to use parameters (« big data »)**
- **E.g. guaranteed consumption in terms of set point, climatic data, domestic hot water consumption**

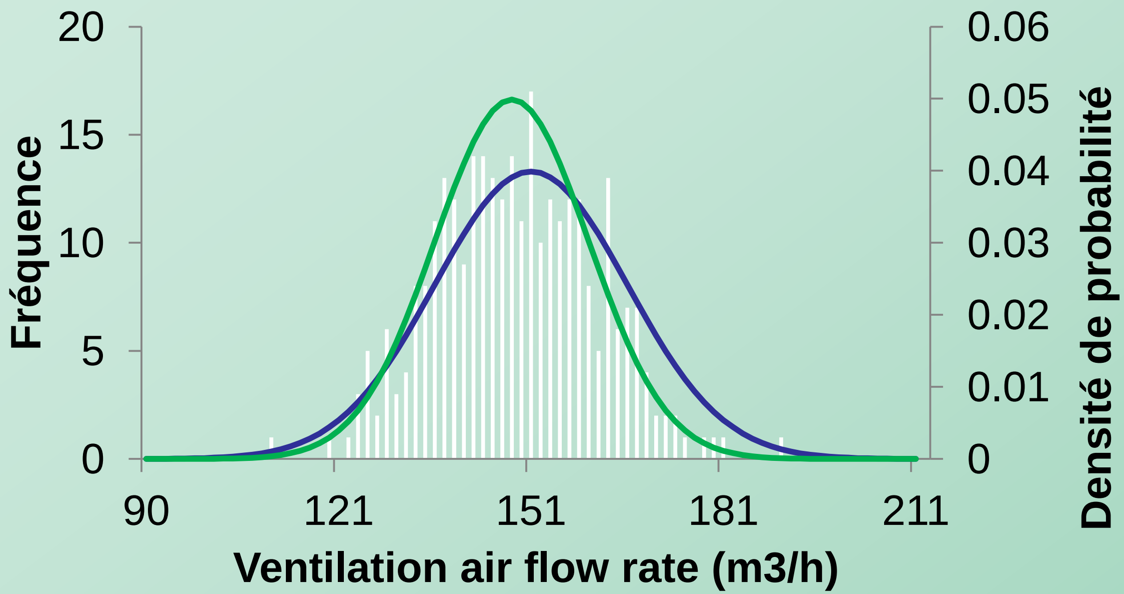


Uncertainty propagation -> guarantee level within 5% risk Verification using IPMVP

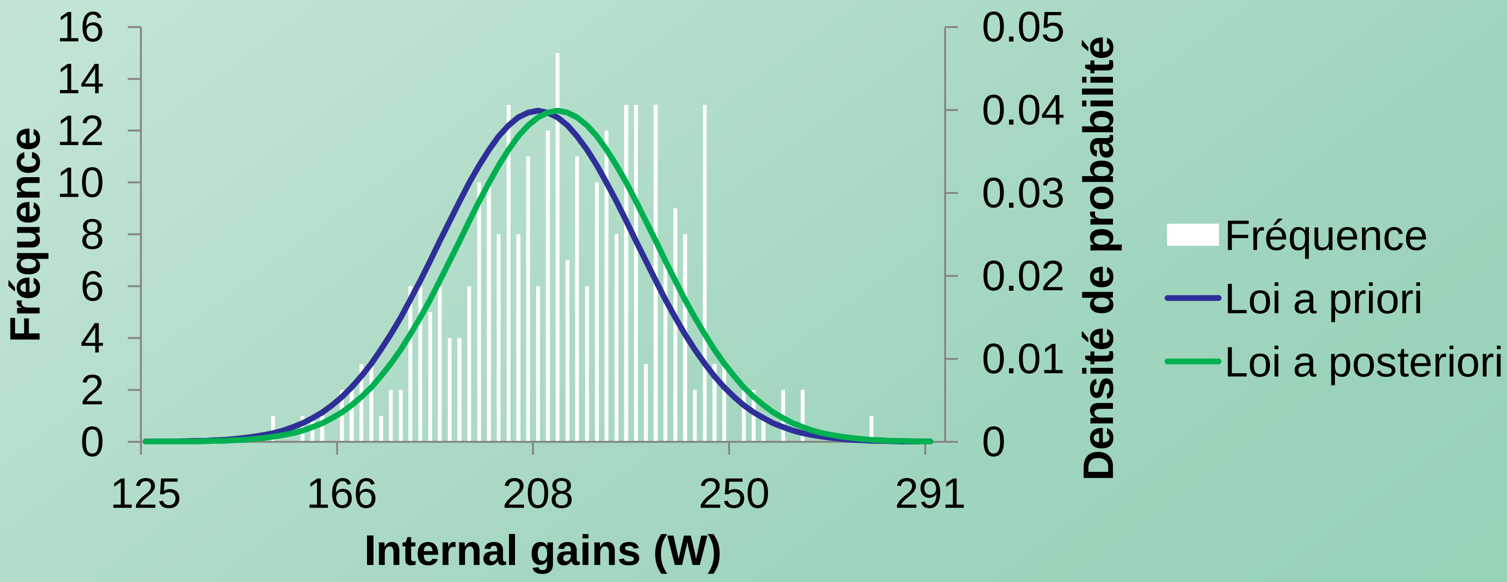
Model identification ?

- **Co-heating or other similar methods**
- **Fit OK but different parameter values (time constant, ande even heat loss coefficient) according to the measurement period (winter, spring…)**
- **Possible reasons : varying climatic data (temperature…), exchange with the ground (e.g. crawl space temperature), multizone and effect of solar radiation, several time constants**
- **Research project in progress, model calibration**

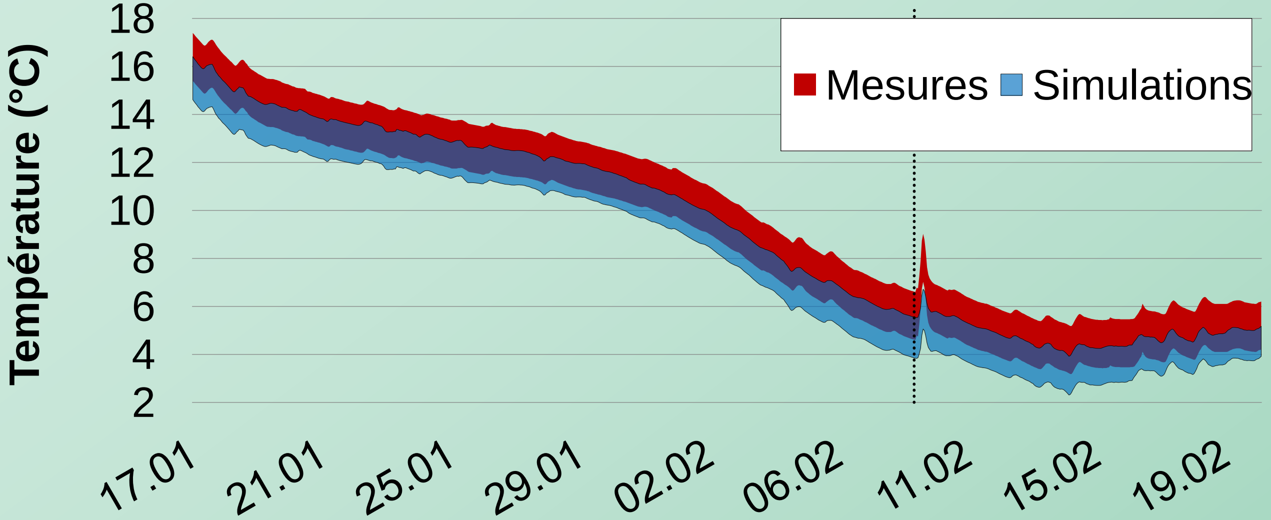
Example, bayesian calibration



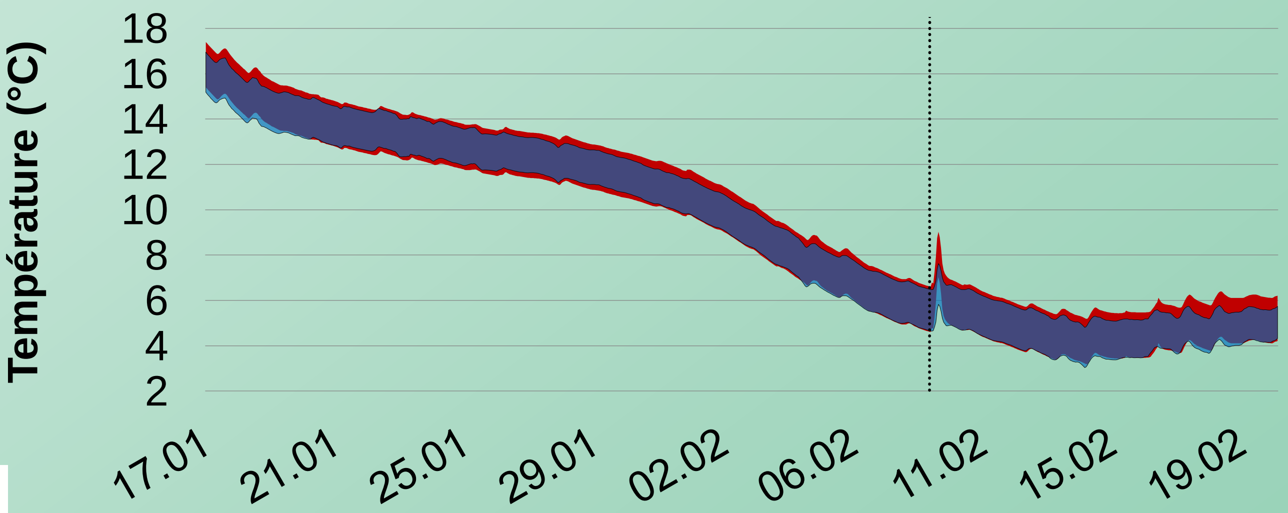
Uncertainty on input parameters



Use of measurements for model calibration



Before calibration



After calibration

Collection of energy performance certificates ?

- **The certificates in France correspond to a theoretical performance**
- **Use scenario is conventional, e.g. 16°C from 8h to 18h during working days, 19°C otherwise**
- **Input data is not always precise because of the limited time to elaborate the certificate (combined with dwelling area, electricity and gas security aspects, asbestos etc.)**
- **Monozone calculation, not realistic in multi-family buildings**

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Conclusions and perspectives

- **Contribute to define a common format for spatial data adapted to energy performance evaluation and follow up -> easier description of a territory**
- **Exchange on building stock models (e.g. multizone aspect, uncertainties, users' behaviour, optimization)**
- **Exchange practice regarding measured performance**
- **Link with software users and construction industry**
- **Help collecting energy certificates and progress towards European harmonization**

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Thank you for your attention