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Energy performance simulation of districts applied to typical districts

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- Efficacity is an R&D Center, launched in 2014, dedicated to energy transition in urban territories. It aims in orienting and organising research in this scope with its 28 partners from the public and private sector

- Efficacity develops innovative and scientifically robust solutions enabling urban actors to be more effective at every stage of a sustainable urban development project:

  - ✓ Diagnostic and monitoring of territory performances
  - ✓ Design of sustainable urban projects
  - ✓ Design and optimization of integrated energy systems
  - ✓ Deployment of innovative economic models

- Objective:
  - Develop a methodology to determine typical districts
  - Enrich data of these districts using databases of different sources
  - Simulate these typical districts in order to give recommendations for urban planners (new and existing districts)

- Contents of the presentation:
  - Summary description of the developed methodology
  - Presentation of two of the typical districts
  - Example of parametric study on these typical districts

Methodology

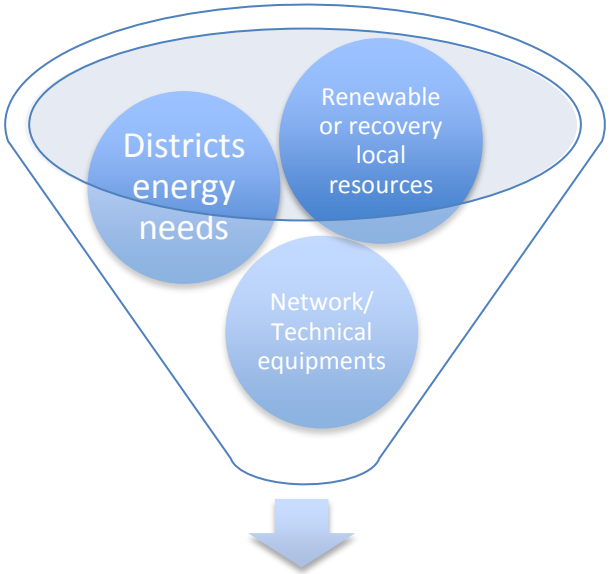
Functional Districts Typology with Differentiated Energy Needs?

Assumption

- A district energy consumption is strongly correlated with its main functions (residential, tertiary, commerce, industry, amenities, etc.).

Objective

- Obtain typical districts classes
- Simulate (sub-)hourly, daily and annual energy profiles, differentiated between classes.



A limited range of energy solutions for each typical district

Main Steps of The Functionnal Districts Typology

- District Definition: IRIS (City blocks grouped for statistical information – 50800 in France)
- Selection of useful data bases to calculate variables describing these districts.

- Construction of the dataset using INSEE data bases (Lodging File, Permanent Base of Equipments, Base Enumeration of companies and institutions) and the IGN's BD Topo.

- Development of a classification method for IRIS from several departments (Method based on Principal Component Analysis and Hierarchical Clusturing)
- Transposition of the classification to the entire metropolitan France (method based on Linear discriminant analysis)

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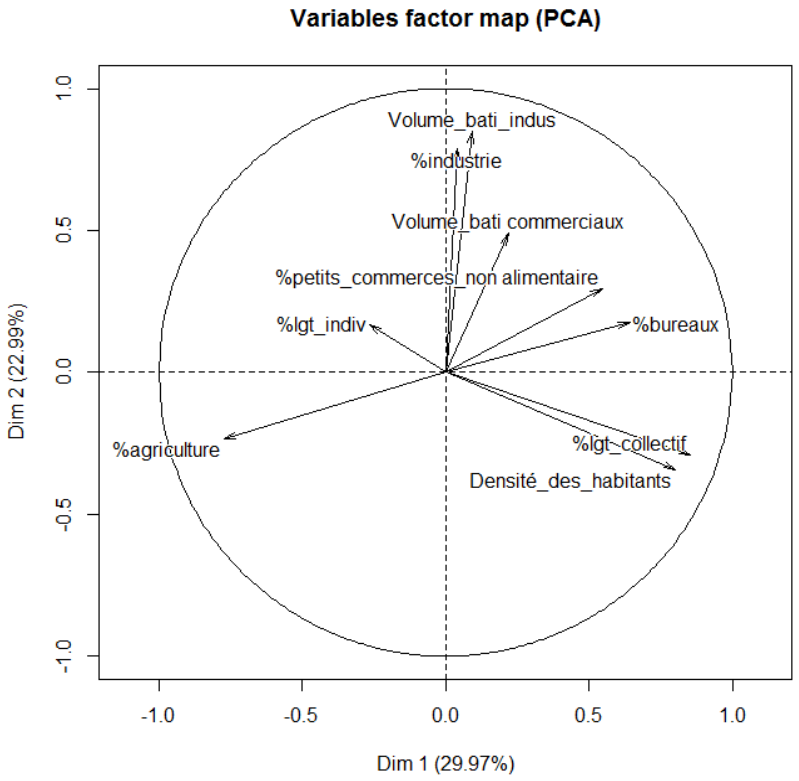
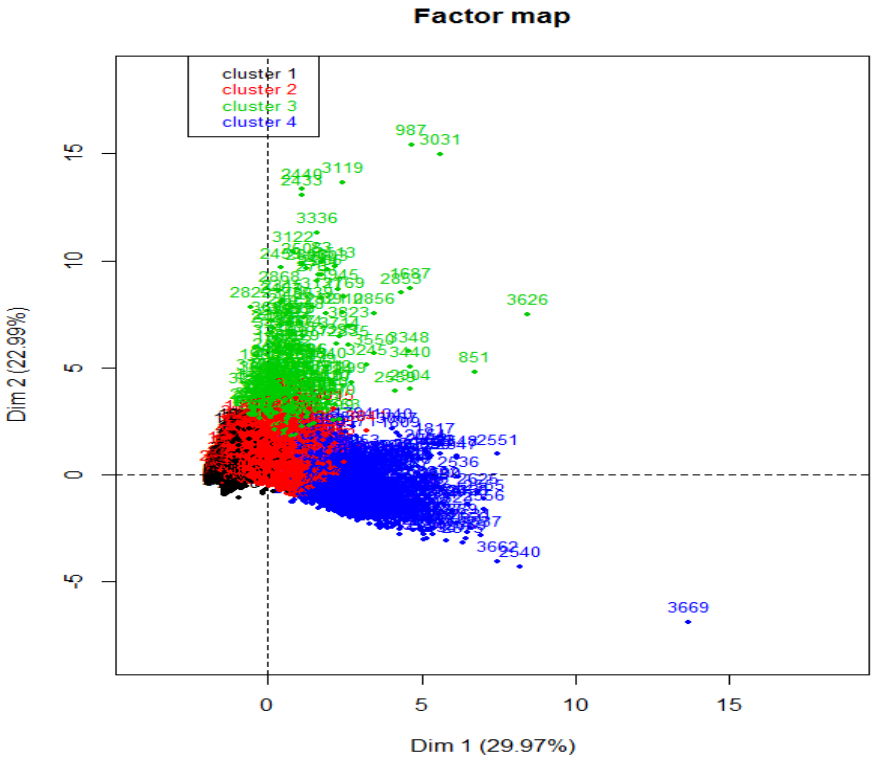
CLASSIFICATION PROCEDURE

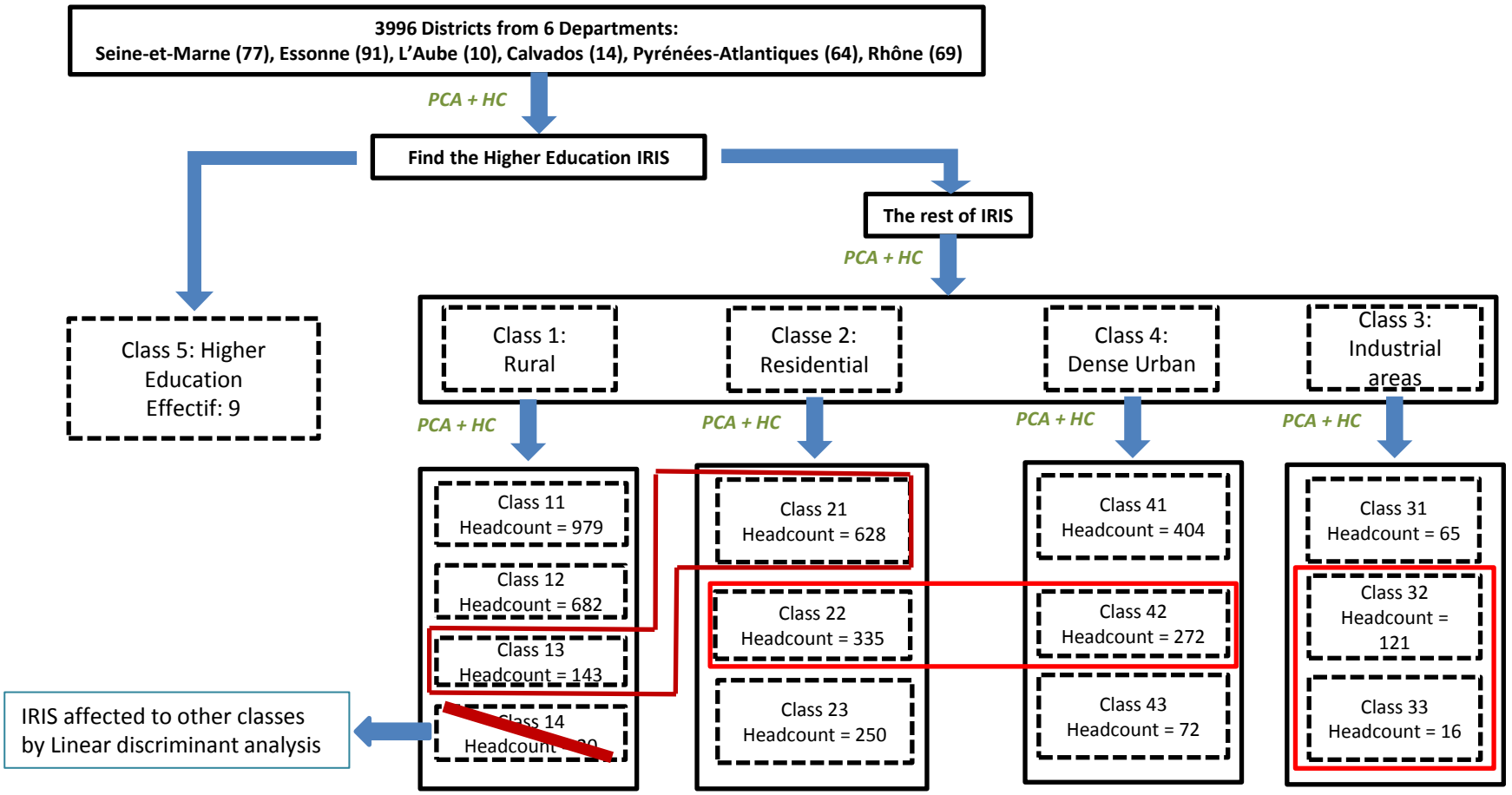
Principal Component Analysis (5 dimensions)



Hierarchical Clustering

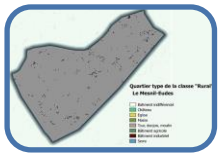


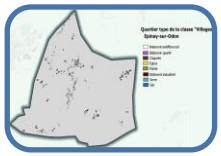
CLASSIFICATION PROCEDURE



REPRESENTATIVE TYPICAL DISTRICTS

- Determine the most representative district for each class.
- Energy modeling of the 10 typical districts

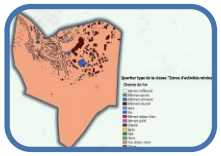

Rural


Villages

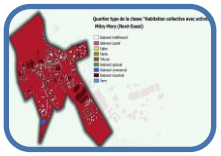

Individual residential areas


Individual residential areas with activities


Areas of intense activities


Mixed activities areas

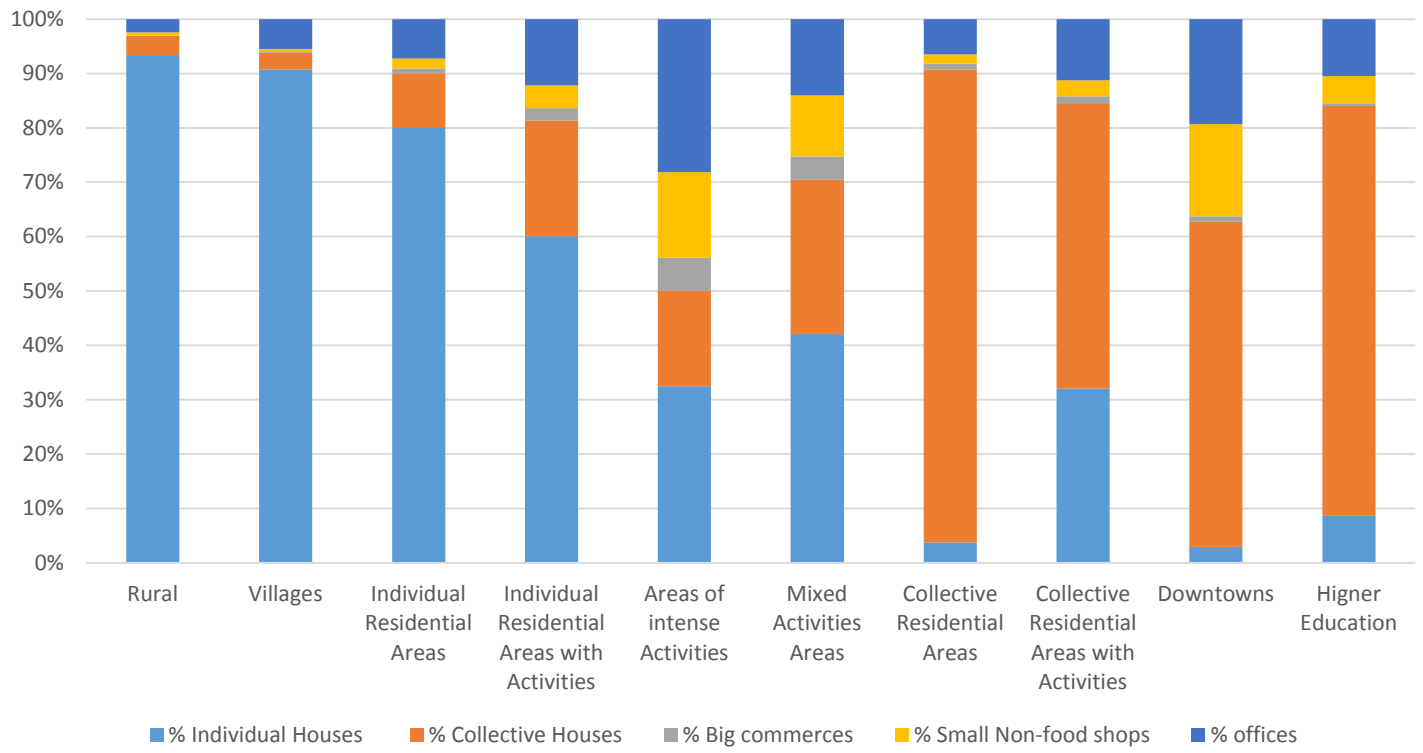

Collective residential areas


Collective residential areas with activities

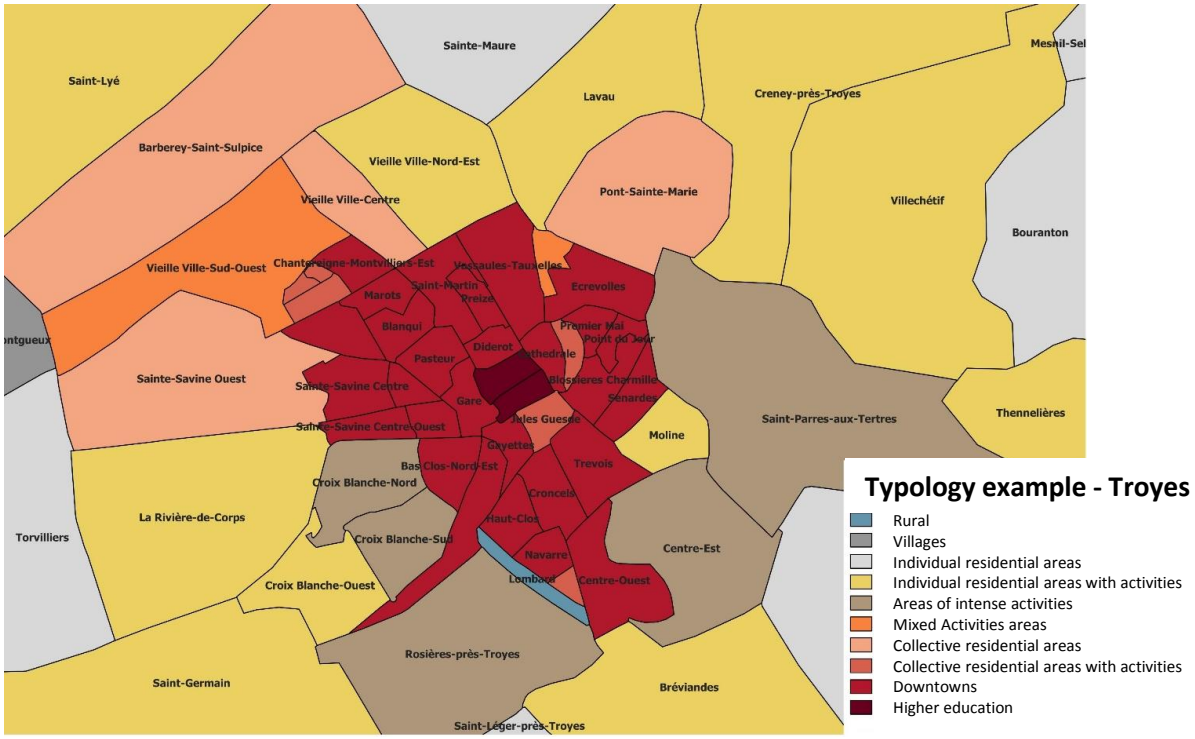

Downtowns


Higher education

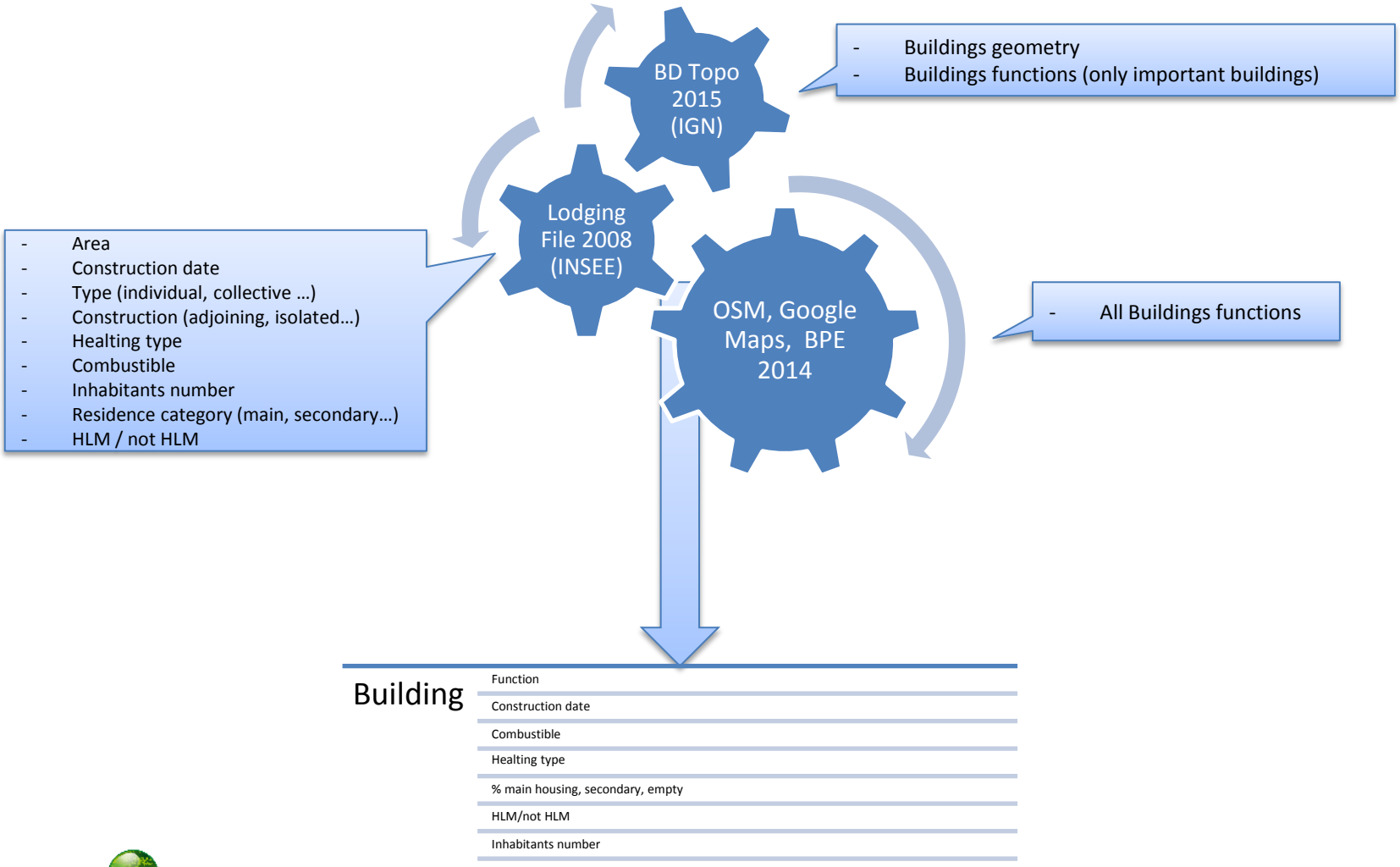
General Comparison Between Districts Types



GLOBAL VIEW OF THE DISTRICTS TYPOLOGY



ESTIMATING BUILDINGS PARAMETERS ALLOWING DISTRICT ENERGY MEDIALIZATION



PowerDis
Numerical tool for district energy simulation

SIMULATION TOOL "POWERDIS" – OBJECTIVES AND DEVELOPMENT

- Objective: compare different energy concepts on a district level in order to:
  - Assist in investment choices (district heating/cooling, local solutions, mix of both)
  - Improve the conception and operation of district energy concepts
  - Study in detail the impact of an increased share of REN&R etc.
- Potential users:
  - Members of the Efficacity institute for research and consultancy issues
  - Consultants, network operators etc. (licences)
- Specific phenomena considered:
  - Building electrical consumptions are most of all stochastic
  - Very random knowledge of district characteristics
  - Urban phenomena (solar masks, adjacencies, micro-climate etc.)
- Chosen approach:

  → Simulation kernel calling models/components from other tools ("co-simulation")
- Integration/coupling of simulators of the Efficacity members:
  - Build-Sys-Pro/DYMOLA (EDF)
  - DIMOSIM (CSTB)
  - Pleiades Comfie (ARMINES)
  - DYMOLA (ENGIE)

POWERDIS – CURRENT STATE

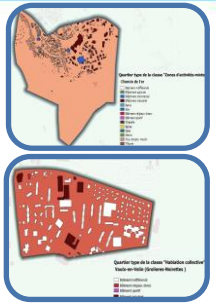
- Calculation kernel (co-simulation)
  - V0 has been developed (proof of concept)
  - V1 in progress (first real prototype)

- Implemented components in V0 (from the project partners):
  - Central energy production: Boiler, CHP
  - District heating network
  - Buildings with emitters and controllers (3 tools in parallel)
  - GUI: for the moment, use of the Dimosim GUI that will be replaced by an Efficacity GUI

- In this study:
  - Use of the Dimosim tool for the calculations due to a wider range of systems covered (heating, cooling, DHW and electricity) for demonstration issues
  - Most of the used Dimosim modules will be included in V1 of PowerDis

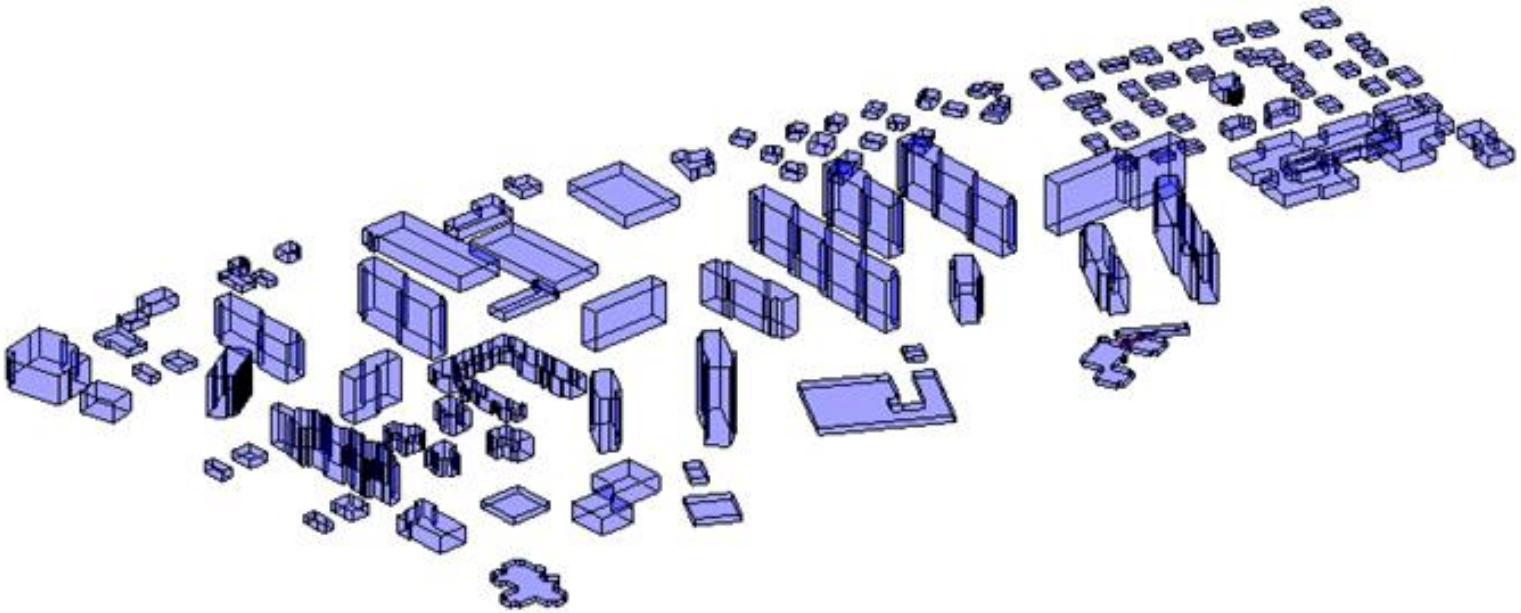
Case study for illustration

DEFINITION OF TWO CASE STUDIES

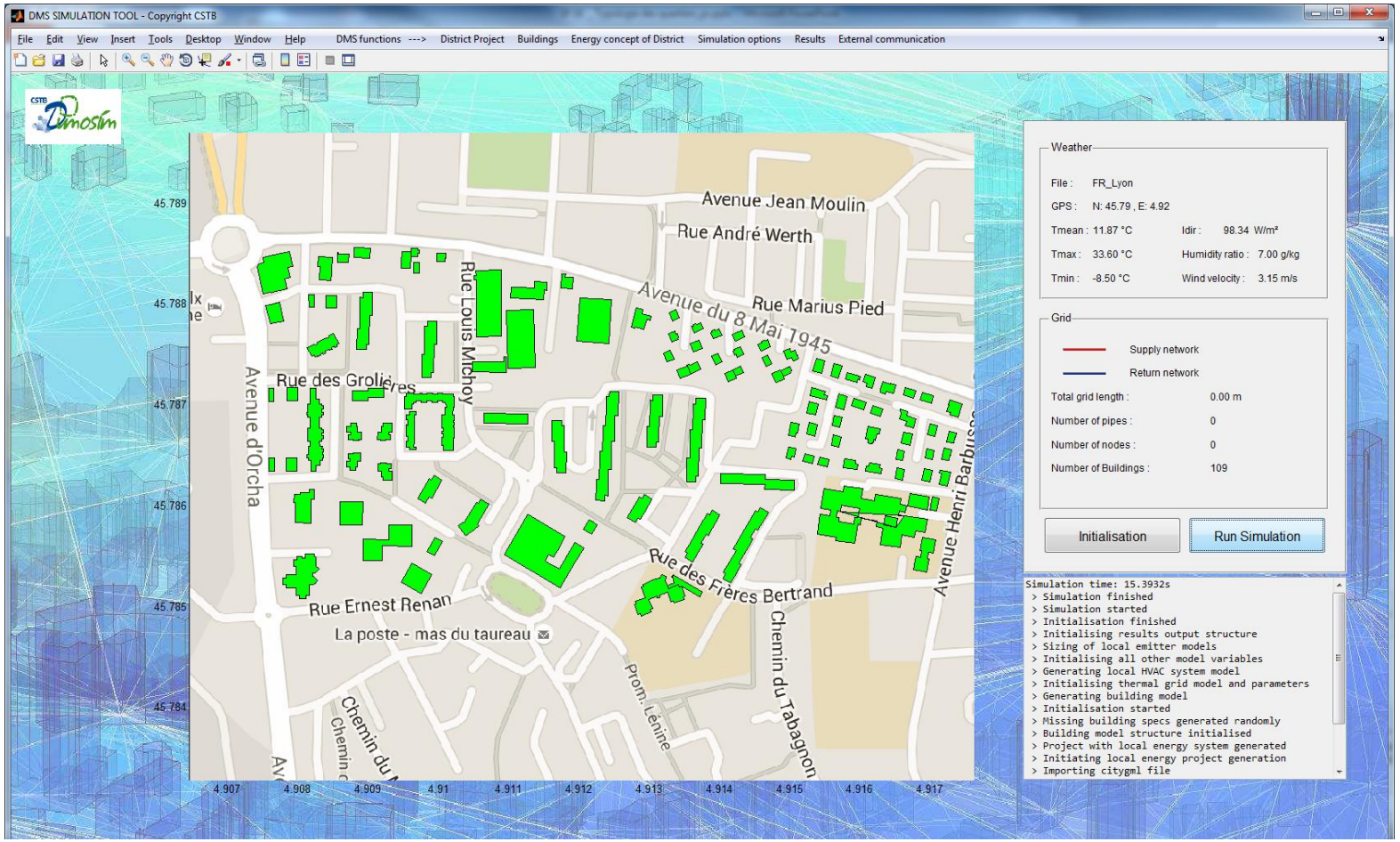


- Two “typical” districts:
  - Typical “Collective Residential area” district – about 100 buildings
  - Typical “Mixed activities area” district – about 500 buildings
- Hypotheses:
  - Hourly time step yearly calculation
  - Monovalent systems, no backuplaws e
  - Constant building setpoint temperatures, typical heating tc.
  - Investment costs: National sources (ADEME, AFPG etc.)
  - Maintenance costs: 0-2 % of investment, depending on component
  - Constant energy prices and CO2 emissions no night tariffs etc.
  - Simplified global costs analysis (= no refurbishment of components)
  - No other fundings considered (tax reductions etc.)
  - Annual escalation 3-5%, discount rate 4%
- Analysis:
  - Global costs (20 years) – using estimated national cost data
  - CO2 emissions – using national emission data (constant)
  - Primary energy consumption (European average values for primary energy factors)

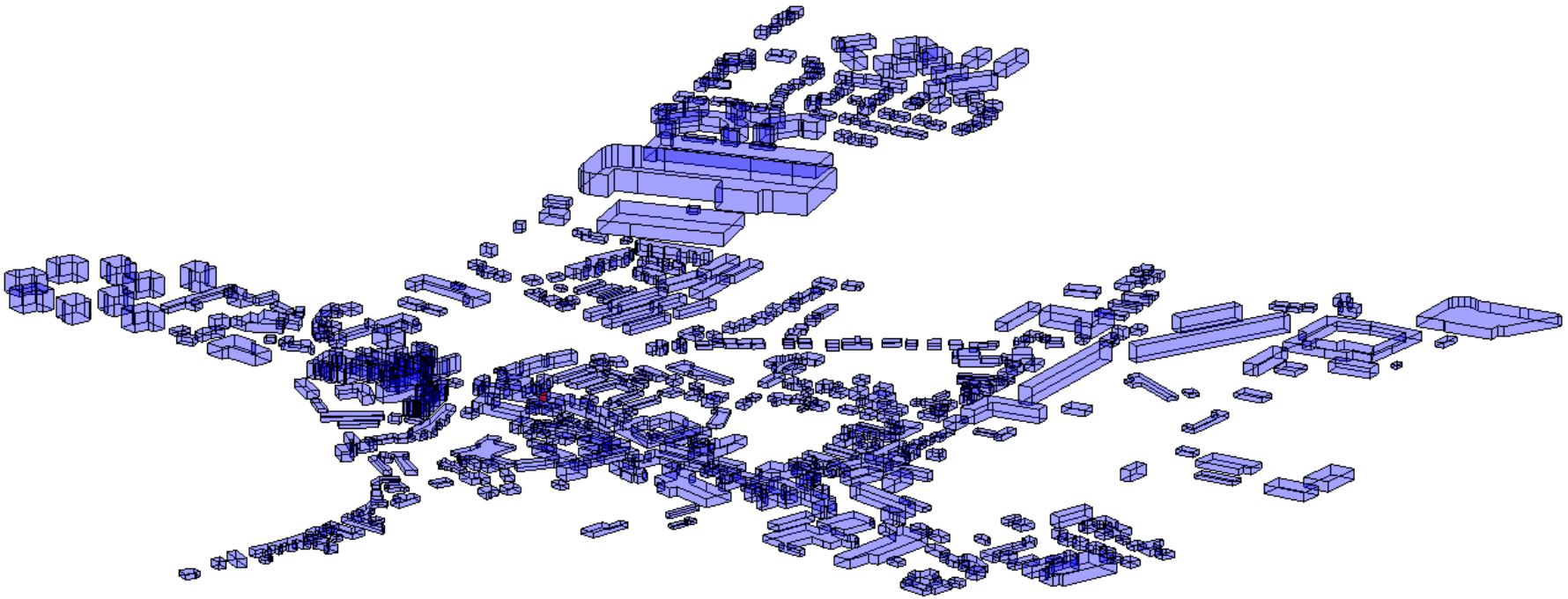
Case study 1 – « residential » district – 2.5D view



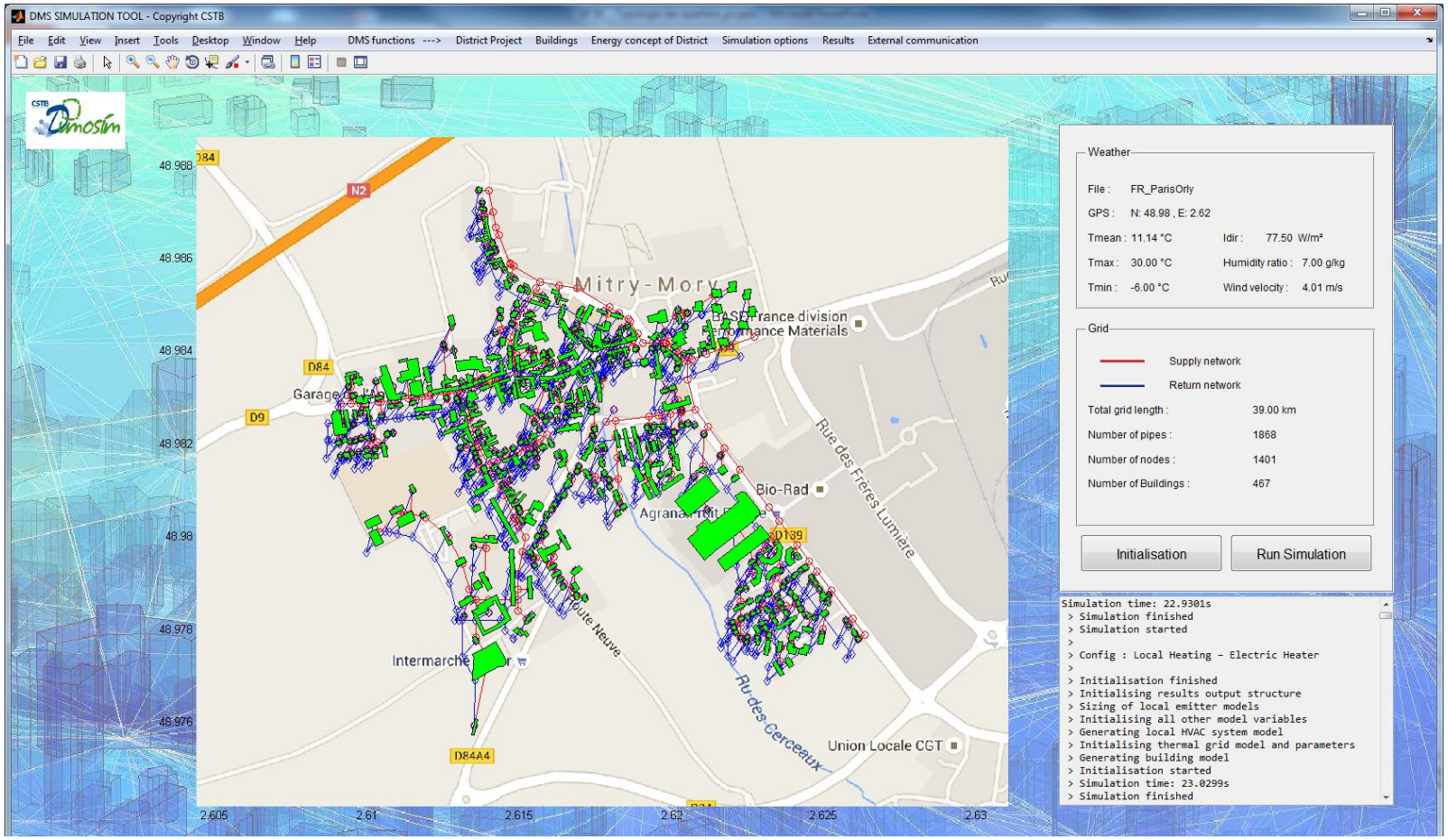
The residential district in the simulation tool case with local energy systems



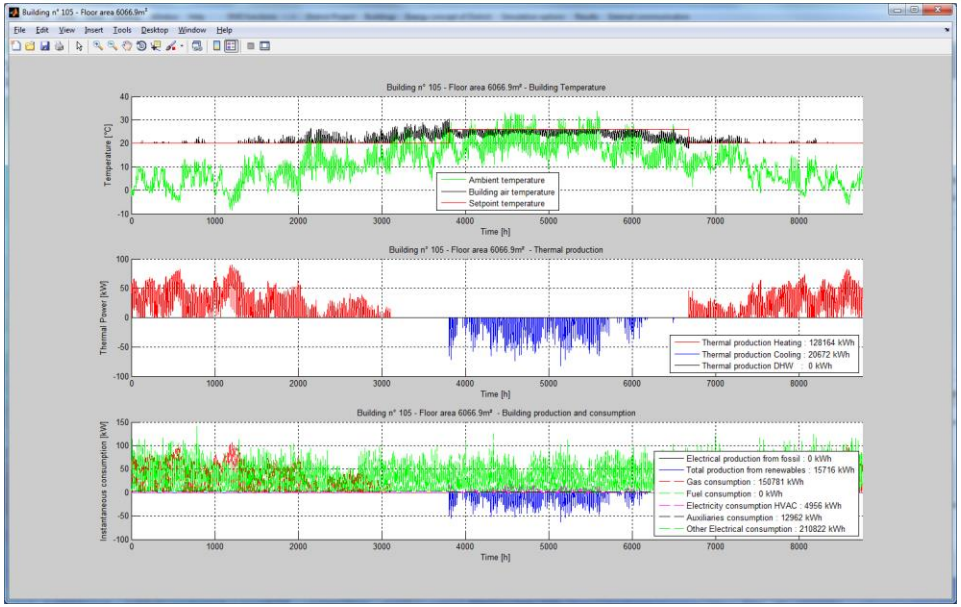
Case study 2 – « mixed » district – 2.5D view



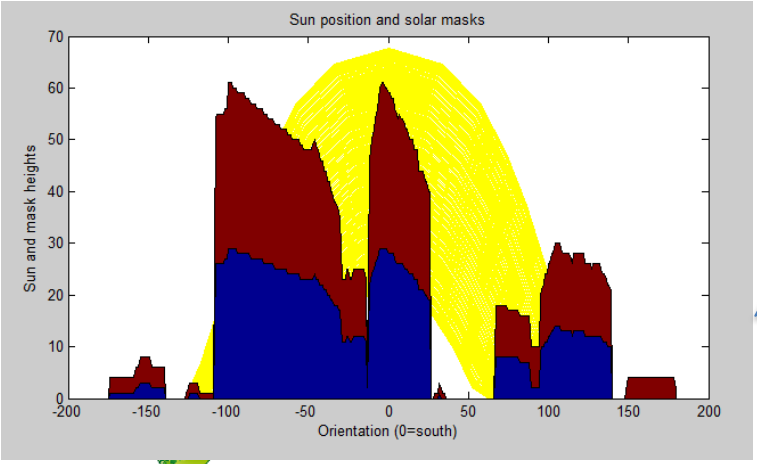
Mixed district in the simulation tool
Case with district heating network



Examples of calculation results



Results on Building level
- Temperatures
- Heating/Cooling/DHW delivered
- Power production/consumption etc.



Solar masks from surrounding buildings and ground
- Mask heights on floor of buildings
- Mask heights on roof of building
- Sun positions (yellow)

→ At each time step, calculation of solar gains on different envelop parts

Example: Performances for the residential District

Parametric study results sorted by energy costs in €/MWh

Energy concept	Primary energy consumption [kWh/m2/y]	CO2 emissions [kgCO2/m2/y]	Global costs of energy [€/MWh]
Local Heating – Turbine	275,20	34,76	63,61
Local Heating – Air Source Heat Pump	217,85	6,75	73,30
Local Heating – Condensing Boiler	216,59	24,56	88,02
Local Heating – CHP ICE	263,93	32,94	97,89
District Heating – Heat Sharing Network - Aquifer	221,72	6,88	97,94
Local Heating – Boiler	232,10	28,19	99,48
District Heating – Central Heat Pump - Aquifer	211,91	6,57	103,42
Local Heating – Fuel Cell	348,47	1,34	110,98
Local Heating – CHP Stirling	245,89	30,01	112,21
District Heating – Heat Sharing Network - Geothermal	233,55	7,24	123,77
Local Heating – Electric Heater	341,52	10,59	131,40
District Heating – Central Heat Pump - Geothermal	224,54	6,96	136,06
District Heating – Condensing Boiler	219,04	21,77	143,96
District Heating – Boiler	231,34	24,64	153,04
District Heating – CHP Turbine	272,72	32,86	161,27
District Heating – CHP Stirling	246,84	27,73	177,82
District Heating – CHP ICE	262,76	30,84	180,65
District Heating – CHP Fuel Cell	337,41	2,10	306,98

SUMMARY

- Methodology for the determination of typical districts
  - Objective: using these typical districts, be able to provide generic recommendations on appropriated energy concepts for other districts)
  - Developed based on 6 French departments, currently being extended to other departments
  - Most of the necessary relevant data available in databases
    → definition of 10 district classes
  - Main problems: energy related data, internal gain profiles for all building types
- Case study
  - Hourly time step yearly calculation for different energy concepts in districts
  - First results to illustrate an analysis based on cost, environment and energy criteria
  - A broader analysis will be carried out on all 10 district typologies
- PowerDis
  - Simulator in development, V0 ready, but next version necessary for complete parametric studies
  - V1 is currently being developed with the input from models of 3 simulation tools (BuildSysPo, Comfie-Pleyades, Dimosim)

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