Nantes | Hamburg | Helsinki

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my SMART Life

Deliverable due date: M36 – November 2019

D2.2 Simulation models of the building stock, energy system, transportation, urban infrastructure

WP2, Task 2.1

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Project Acronym	mySMARTLife	
Project Title	**Transition of EU cities towards a new concept of Smart Life and Economy**	
Project Duration	1st December 2016 – 30th November 2021 (60 Months)	
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Task description	Transversal to all WP2 tasks Modelling, Simulation, and Systems Engineering of the building stock, energy system, mobility and urban infrastructures	

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Abreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
DTS	Dynamic Thermal Simulation
DHN	District Heating Network
PV	Photovoltaic
RES	Renewable Energy Solutions
MPR	MonProjetRenov
HVAC	Heating Ventilation and Air Conditioning (system)
BIM	Building Information Model
BHLS	Buses with High Level of Service

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1. Executive Summary

Urban modelling (or urban simulation) gathers a large diversity of technical fields, tools, and applications. Almost every urban transformation action proposed in mySMARTLife can benefit from the application of such tools, whether it is linked to building energy performance measures, renewable and recovery energy production, smart mobility solutions, impact assessment or key performance indicators.

The context of application can also vary to a large extent, from pre-feasibility studies and dimensioning to real time operation and monitoring.

In the 20th century, prior to the rise of digital modelling, the engineering solutions were mainly designed to fulfil some elementary functions, and then improved afterwards, sometimes through operation and practice in real life. For example, in terms of building construction, producing a hundred-story skyscraper during the 20th century consisted in designing first a stable building, and then adjusting heating and cooling elements later (source: International Building Performance Simulation Association). Digital modelling has made this approach outdated, as now it is possible to study in detail various alternatives during the design to reach an optimal solution (e.g. structural requirements on one hand, energy and environmental objectives on the other hand).

This deliverable provides several elements: a method to choose simulation tools (mainly focused on energy simulation applied to buildings or urab environments), an overview of the models and simulation tools that a French metropolis could harness in the context of smart actions developments, and a presentation of the characterization of energy demand linked to several mySMARTLife actions in Nantes prior to their implementation. It will present both tools well-known in the French context, and tools used world-wide, which are used in Nantes and the rest of France, by engineers, architects, operators, and also research experts.

More than simple references to the commonly used models, this document explains how the choice of the model has to be reasoned depending on several parameters: What are the useful results/outputs? Which stage is considered (decision, design, commissioning, operation, monitoring…)? What is the level of detail of the available inputs? What level of confidence can be granted to the results (uncertainties)? General guidelines are proposed to choose the right model in the right context.

The general methodological framework for the use of modelling tools in an urban transformation context is described in section 3. Different categories of relevant models are then briefly presented in section 4. Finally, the main focus of the deliverables is detailed in section 5 and consists in showing some results applied in the context of mySMARTLife on the actions of Nantes Metropole.

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Please note that the precise analysis of many simulation results linked to Nantes Metropole context is not described here but in other deliverables of the mySMARTLife project: e.g. Work Package 1, deliverables D1.12 and D1.13.

The information gathered in the context of Nantes Metropole results finally in another example (in addition to the ones presented by Hamburg and Helsinki) of the potential use of models for urban transformation issues, which can be applied to different cities in Europe and beyond the EU perimeter.

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2. Introduction

2.1 Purpose and Target

WP2 details a large number of smart actions developed in Nantes in the fields of energy efficient buildings, energy production and distribution, mobility, or urban infrastructures. For the development of these actions, digital modelling simulation tools usually play a crucial part, from the earlier decision making stages, through the design and development process, up to the delivery and exploitation of the solutions.

The objective of this deliverable is to show the application of models on the actions developed in mySMARTLife in the context of Nantes Metropole. Tto understand how the models used are positioned in the general framework of simulation tools for the development of urban project, two sections first describe a general methodology which can support any decision about using simulation tools. These sections also provide a quick overview of the very large variety of existing modelling tools. The models presented here are identified from the perspective of a city developing smart actions, but these tools can also sometimes be used by any stakeholder involved in the development, delivery and exploitation of the action, depending on the perimeter of application of each tool.

The tools presented here are distributed in several categories depending on the technical field (e.g. building, mobility), the scale of application (building, district, city), and the indicators of interest (energy, environment, economy parameters, social parameters), and also the stage of application of the tool (decision support, design, development, delivery, exploitation).

The next parts of section 2 describe the roles of the contributing partners and the link with other tasks of the project.

Section 3 presents a general method to support the decision of the appropriate model for any action linked to urban transformation at any scale, and any type of project.

Section 4 provides a brief overview of the existing modelling tools, for building (or building stock) models, energy systems models, and transportation models.

Section 5 is the main result of the deliverable and describes results of energy characterization prior to the implementation of mySMARTLife's actions, in the case of Nantes Metropole.

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2.2 Contributions of partners

The following Table 1 depicts the main contributions from participant partners in the development of this deliverable.

Table 1: Contribution of partners

Participant short name	Contributions
NBK	Overall content production and deliverable leading
NAN	Overall content reviewing. Documentation on simulation results.
CER	Content production for transportation models, Overall content reviewing

2.3 Relation to other activities in the project

WP2 is divided in several tasks related to the different technical fields of the smart actions developed in Nantes. For any type of smart action developed modelling and simulation tools are generally available. Thus the work presented here is transversal to all WP2 tasks as it describes results from several tools, and provides details about how to use these tools in an optimal way.

The results from this task can also inspire the replication to any other city (lighthouse, follower, or other), as a large part of these tools are not specific to the French context and sometimes well known internationally.

The other lighthouse cities (Hamburg and Helsinki) also propose their own approach in terms of modelling and simulation, described in several deliverables (e.g. D3.2, D4.3).

Energy simulation results for Nantes are presented in D1.12 (related to 3D city modelling) and D1.13 (energy analysis on the long term, 10-20 years).

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3. General method for choosing a model or a simulation tool

3.1 General guidelines for a model decision process

In this section we propose some methodological guidelines to help any engineer or decision maker to decide which is the most appropriate modelling and simulation tool for a given problem.

In the context of urban transformation actions the purpose of models and simulation tools is generally to provide new information based on available inputs, in order to facilitate one or several of the following activities: decision, design, implementation, monitoring/performance check, control.

There is no universal model and every "useful" model corresponds to a specific perimeter of application and specific objectives of use. The most important (and difficult) issue for a model user is to choose the most appropriate model for a given problem. By "most appropriate" model we can understand various criteria: precision of the results, difficulty to parametrize and operate the model, adequation between the level of details of the required input and the level of details of the outputs, usefulness of the results for the context of application (e.g. decision or design). Depending on the situation, the "most appropriate" model is not necessarily the most sophisticated or the most expensive one.

Nobatek/INEF4 has developed between 2016 and 2019 a general framework of decision support to choose the best type of model, in the context of any project related to building or urban development. This is one result of the INEF4 COSYBA project, which will be completed by 2019. This tool, represented in the format of a mind map, simply proposes a short list of questions (3 to 5) to a building/urban developer, and based on the answers the main functionalities of the needed model can be established. The user only has then to choose one of the models/ simulation tools available on the market and that includes these functionalities. During the COSYBA project, the content framework has been detailed mainly for building and energy applications, whereas the technical perimeter of mySMARTLife is broader (mobility, urban infrastructures, district…).

We present in this section some examples of the main questions and types of models proposed by this framework, in relation with the smart actions developed in mySMARTLife. The following sections will then detail briefly the different categories of models and their differences, and finally show applications in the context of Nantes Metropole and MySMARTLife actions.

We limit here the perimeter to energy and/or environmental and/or mobility modelling (including also in several cases economic indicators).

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3.2 Example of a model decision process

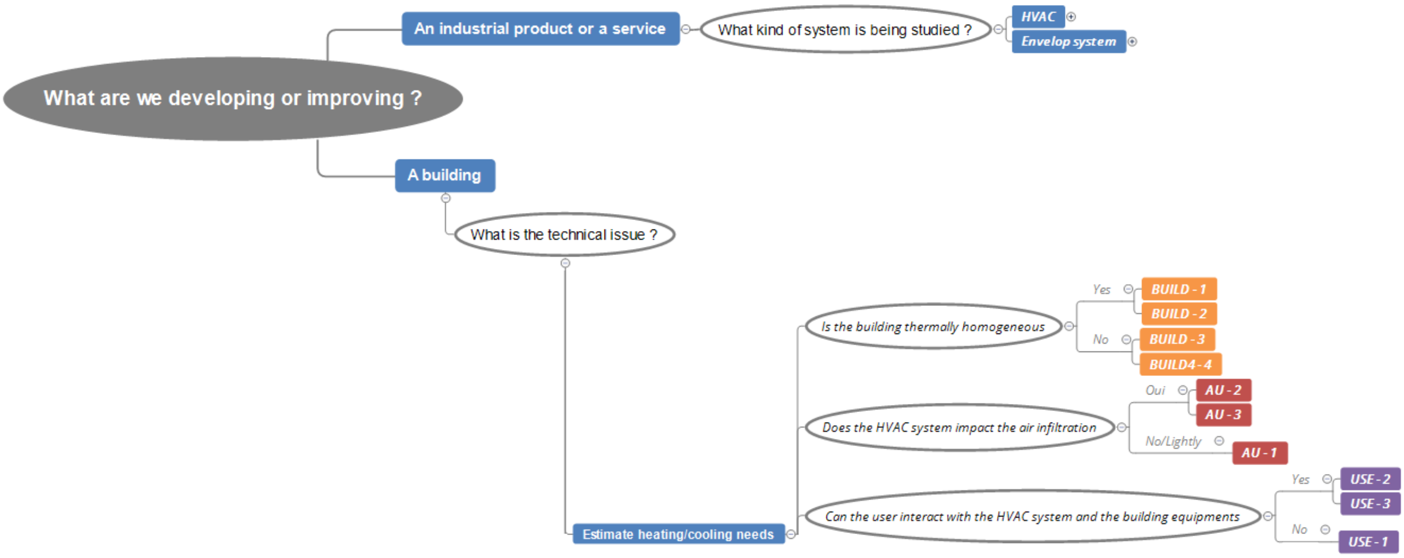

Figure 1: Illustration of the mind map helping to identifiy the required model functionalities for a given development problem (source: INEF4 COSYBA project)

The first question to ask for someone who intends to use a model is: "What do I want to develop or improve?"

In our context we identifiy mainly 4 potential answers:

- A building.
- A district.
- An industrial product or service.
- A network (district scale).

As an example, in the case of a "building" action, the next question will be to identify which is the technical issue to solve:

- Estimate of heating/cooling needs only.
- Estimate of the energy consumption (efficiency and HVAC system behaviour included).
- Estimate of comfort level.
- Bioclimatic design.
- Selection/Dimensioning of a HVAC system.

As a further **example**, for a **building**, for which we would want to **estimate the building heating / cooling needs**, the next step will be to ask a sequence of questions, each one allowing to determine the level of detail required on a specific functionality or technical aspect of the model. For this example, the list of question is:

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- Is the building thermally homogeneous?
- Does the HVAC system impact the air infiltration?
- Can the user interact with the HVAC system and the building equipments?
- Is the lighting system controlled automatically?
- Which type of model outputs (results) are needed/prioritized? (consumption estimates, design, Energy Peformance Guarantee, validation/operation)

Still on this example, based on the answers to the previous questions, a **list of required functionalities** can be established. For each type of functionality, one choice is made among several alternatives. It will correspond to the level of details of the model on several different technical aspects. As an illustration, a selection of required functionalities could be:

- General type of model: Dynamic Thermal Simulation (DTS) model for one building.
- HVAC modelling: hypothesis of an ideal system to obtain the energy needs.
- Building envelope modelling: Single zone nodal thermal model.
- Aeraulics modelling: ideal air exchanges with the exterior (mechanical + infiltrations).
- Occupancy/users modelling: stochastic model (instead of hourly preset scenarios).
- Mathematical method: manual parameter setting (instead of optimization or sensitivity analysis algorithm for example).

Knowing such a list of required functionalities allow to choose the adequate modelling tool for any defined problem or project. Answering the sequence of questions until reaching these functionalities require extended expertise in terms of modelling, but it is the only way to ensure that the right model is finally chosen. Choosing arbitrarily a model, or applying a well-known model in a new application context, without checking the needs in terms of functionalities, could lead to the following risks:

- Wrong results leading to design/implementation/operation errors (e.g. due to a lack of precision of the model or to the parameterization).
- Over-expenses during the use of the model: this the case for example when one parameter is too detailed compared with others, resulting in unecesary efforts in parameter setting.
- Disagreement between stakeholders: this is the case for example when the project developer and the contractor do not agree on the expected results of a solution, because they do not reach the same results with their respective simulations. This can be due to a non standard use of the model, or to an excess of confidence in detailed results due to a misunderstanding about uncertainty considerations or the level of significance of the results.

As a conclusion of this section, currently, due to the variety of contexts of application of the simulation tools (design, implementation, operation/monitoring) and due to the lack of comprehensive and complete models, it is needed to adopt a method (such as the one proposed here) in the selection of the appropriate models. Neglecting the choice of the required functionalities could lead to mistakes or unnecessary overcosts. Adopting this type of method is currently a strong challenge for the engineers working on smart and innovative actions in the fields of urban transformation of cities.

In the future, it is expected that some models will be able to make the link between the early decision making stages of the developments of an action, up to its daily operation once implemented (e.g. digital twin concept), but for the moment this type of solutions are generally not mature enough for an application in practical and operational context. Therefore, it is still needed to apply models specific to each issue or stage.

3.3 Models for different stages of a project

MySMARTLife deals with a large variety of smart actions (buildings, renewable energy production, mobility, digital services platforms). A large variety of modelling tools can then be involved in the development of theses actions.

One common aspect to all these smart actions is that they are usually implemented with different stages. They can vary slightly from one type of action to another or bear different names, but they often can be described as follows (see next figure):

- **Initial idea**: this corresponds to the initial ambition of the smart action and its positioning compared with the general plan for the city (e.g. energy and climate action plan, or energy master plan).
- **First fesibility studies**: once expressed the first ambiitons for a smart action, then comes the time for the first technical feasibility studies. At this stage, we have limited information available, and we work on the base of approximated expected results, costs and benefits.
- **Decision**: at this stage some models have already been applied in the first feasibility studies, and several solutions alternatives are considered. Some models can offer help at this moment by providing decision support elements to the decision makers, in order to select one alternative.
- **Detailed design**: once the “best” solution is selected, the design teams work on the detailed design of the solution, where detailed models are proposed. The assessment of the costs and expected results is getting more and more precise.
- **Implementation**: this is the realisation of the action. At this moment, what is done “in real life” can present some changes compared to what was modelled during the desing stage. The detailed design simulations are then updated with “in situ” information.
- **Delivery/Commissioning**: the operation of the solution is starting. Some settings are needed to ensure the solution is working correctly, in agreement with the requirements of the product owner. Some specific “dynamic” models, taking into consideration the control parameters can be involved at this stage.

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- **Exploitation/operation/monitoring**: during the life of the solution, models are sometimes used to facilitate the operation of the solution. These models integrate the control parameters and are sometimes embedded into the solution (e.g. Building Energy Management Systems).

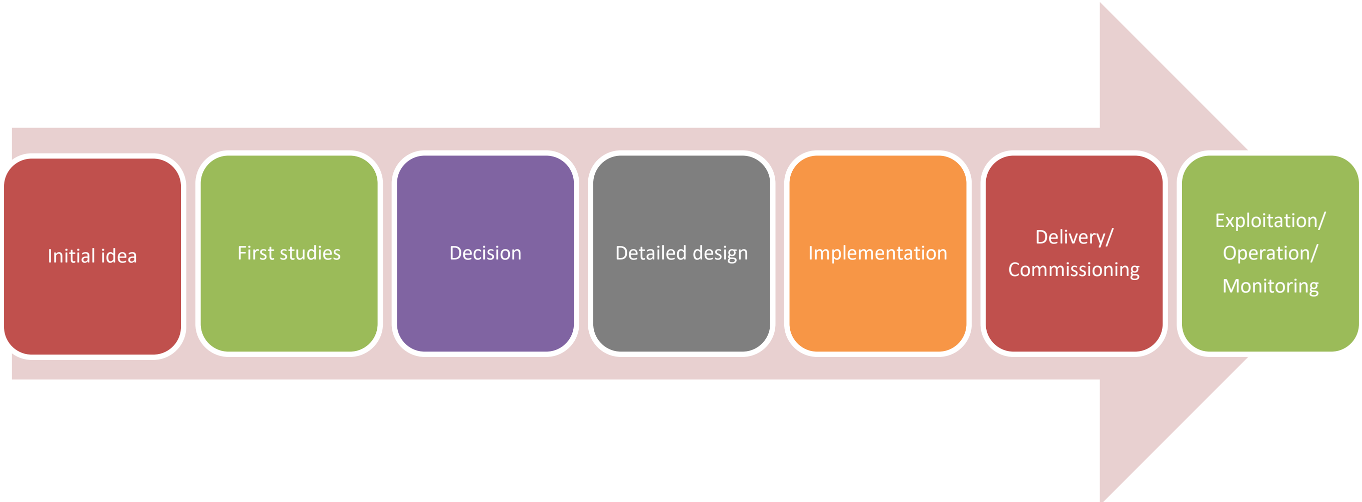

Figure 2: **The different stages for the development of a smart action**

3.4 Models for different scales

The models used in urban contexts are often linked to the concept of spatial scale. Depending on the stage of the action or its dimension, models can be used at different spatial scales:

- one system in one room of a building,
- a building,
- a small group of buildings (e.g. typical size < 100 m),
- a small district (< 300 m),
- a larger district (< 1000 m),
- the city,
- the urban area,
- the region,
- etc.

The different scales for modelling can sometimes be linked to the different stages of the process to develop an action. For example, for the development of district heating networks (DHN), a model at city scale can help in the definition of a district heating master plan for the city. Based on this master plan, district heating modelling at a large district scale can be initiated. Then it can be decided if every small groups of buildings can be connected or not to the nearest district heating network. From the previous

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information, the thermal energy system can be modelled/decided for every building project in the district (supplied by the DHN, or an individual solution). At each scale, each stage, can correspond different models, with different levels of details. This can be one way to sort the different types of models for each category of smart action.

Models at different scales can sometimes depend on each other (e.g. model coupling), especially as concerns their boundary conditions or inputs/outputs proposed.

In the context of urban transformation actions, the most relevant models scales are usually the ones consistent with the decision making scales or jurisdiction of the local authority. For example, models at the metropolitan area scale are relevant a priori to help in determining the metropolitan area's master plans, thermal energy models at district scale are relevant for district developers or the development of district heating networks, etc…

In the following section, the different types of models are briefly presented for each of the following smart actions categories:

- Building and building stock models.
- Energy systems models.
- Transportation models

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4. General simulation tools

4.1 Building stock simulation tools

4.1.1 Building scale models

4.1.1.1 Models used for preliminary and detailed energy design of the building

We present here some examples of building scale models used for the design stage.

4.1.1.1.1 Energy Plus:

website: https://energyplus.net/

Energyplus is an opensource software developed by the US Department Of Energy. It simulates transient heat exchanges in a multizone building model. It includes detailed radiation calculation (solar and thermal). It also embeds several HVAC system models such as heat pumps, boilers, fans, emmiters, etc. Several software as DesignBuilder propose a graphical interface to configure EnergyPlus input files (see next figure).

Input: Building detailed plans, envelope specification, HVAC system specifications, weather file

Output: Heating/cooling needs, temperature inside the building, HVAC system consumption, occupant thermal comfort, etc.

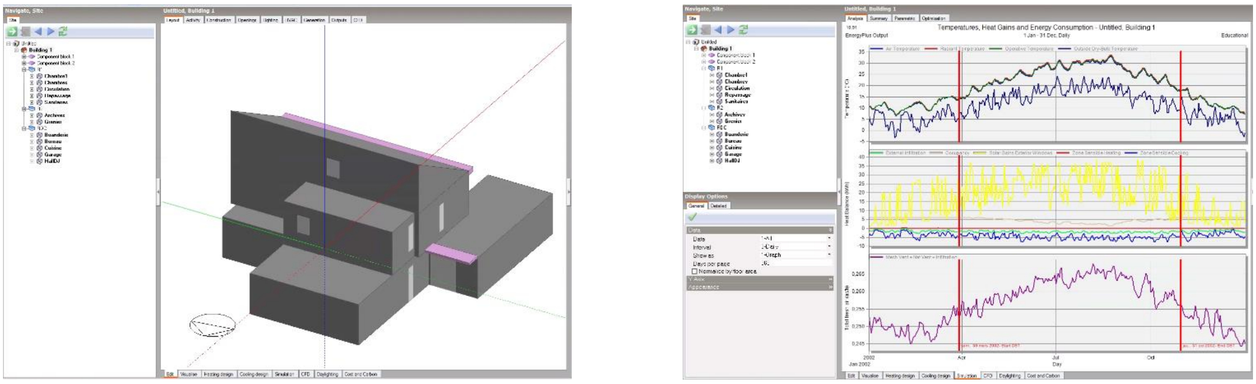

Figure 3**:** Design Builder interface screenshot, building detailed plans (left), simulation outputs (right)

4.1.1.1.2 PLEIADES+COMFIE

Website: http://www.izuba.fr/logiciels/

Pleiades comfie is a french simulation software developed by IZUBA in collaboration with Les MinesParisTech (see next figure). It simulates multizone building model, integrate several HVAC

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components, proposes advances mathematical tools (sensisivity analisys, uncertainty analisys, optimisation). It can perform the mandatory french energy computation (RT-2012). It also performs lighting analysis.

Input: Building detailed plans, envelope specification, HVAC system specifications, weather file

Output: Heating/cooling needs, temperature inside the building, HVAC system consumption, occupant thermal comfort, etc.


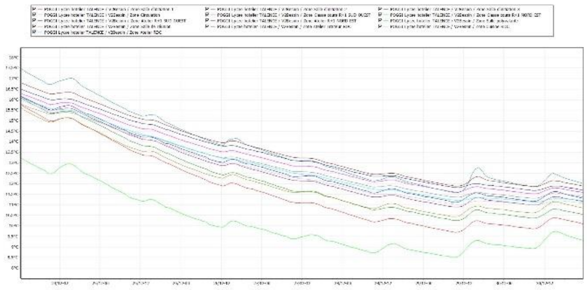

Figure 4: Pleiades Comfie interface screenshot, building detailed plans (left), simulation outputs (right)

4.1.1.1.3 IESVE

Website: https://www.iesve.com/VE2018)

Virtual Environement is a simulation software developed by IES (Irland). The software performs multizone building thermal calculation. Enhanced graphical interface is proposed to simulate detailed HVAC installation (see next figure). Detailed lighting calculation can be performed through using Radiance (https://www.radiance-online.org).

Input: Building detailed plans, envelope specification, HVAC system specifications, weather file

Output: Heating cooling needs, temperature inside the building, HVAC system consumption, occupant thermal comfort, etc.

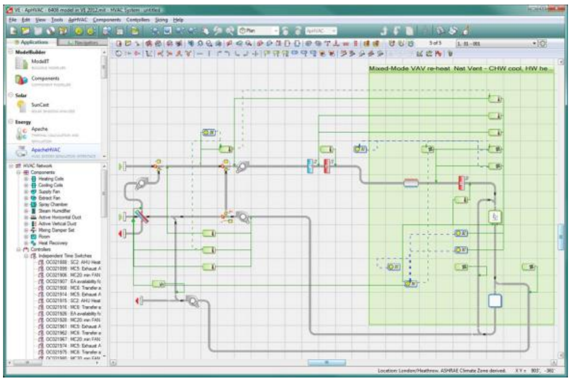
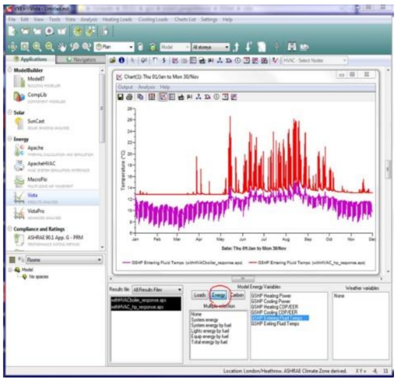

Figure 5: IES VEinterface screenshot, building components model (left), simulation outputs (right)

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4.1.1.1.4 PHPP

Website: https://passipedia.org/planning/calculating_energy_efficiency/phpp_-_the_passive_house_planning_package)

PHPP (Passive House Planning Package) is a simulation tools developed by the Passivhaus institut (Germany). It is an excel sheet that performs single zone building thermal calculation. It integrates simple models to evaluate the performance of a building envelop and its HVAC systems (see next figure).

Input: Building exterior envelop, envelope specification, HVAC system specifications, simplified weather file

Output: Overall building energy consulption, required output for the Passivhaus label

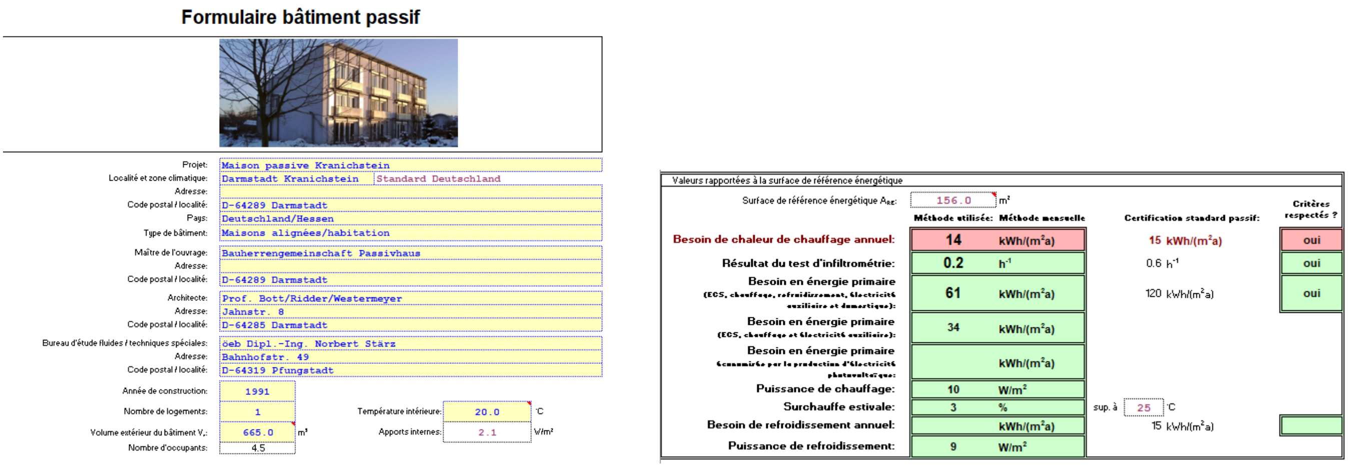

Figure 6: PHPP interface screenshot

4.1.1.1.5 CLIMABIM

Website: https://climabim.fr/

Clima BIM is a plugin developed by BBS logiciels (France). It connects to Revit or Archicad, and allows the architect to perform rapid energy calculation. It uses a single zone building model based on the mandatory french calculation. It can be used for quick assessment of the building envelop and the HVAC system energy performances (see next figure).

Input: Building exterior envelop, envelope specification, HVAC system specifications, simplified weather file

Output: Overall building energy consulption, mandatory energy usage

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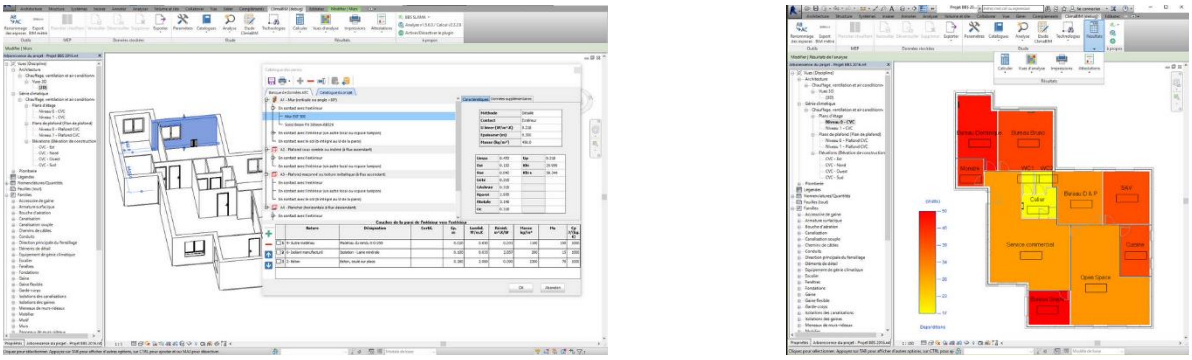

Figure 7: ClimaBIM interface screenshot

4.1.1.1.6 BIM4REN (starting H2020 project)

BIM4REN, a 2018-2022 H2020 project will aim to build a digital ready renovation workflow based on stakeholders' elicitations, and a novel, state of the art, open, decentralized environment (see next figure). Based upon those requirements, innovative tools for data collection, data management, and data driven design will be developed to make the most of the potential of BIM, all integrated into a One Stop Access Platform. Demonstration will be made on pilots as living labs and a new generation of workers will be trained.

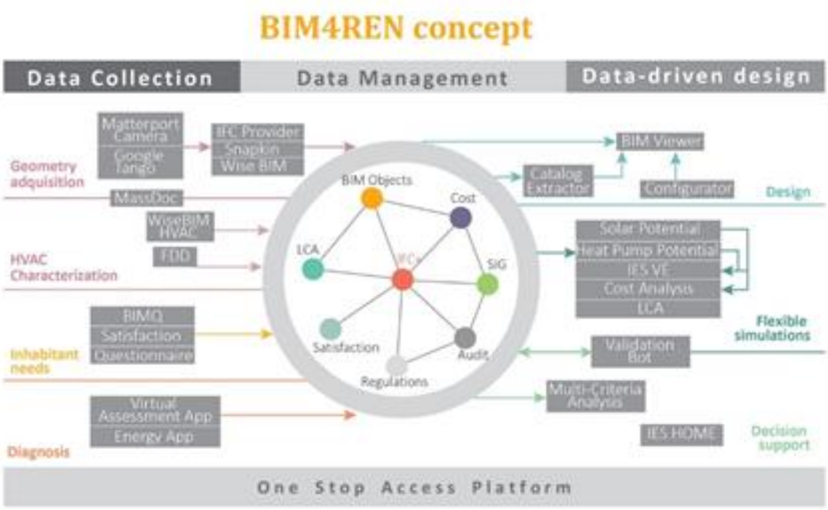

Figure 8: BIM4REN concept around 4 steps

4.1.1.2 Models used as regulatoy tools

These models are generally used to check if a new or retrofitting project fits the regulation context in terms of performance and/or means to achieve a better level of performance. These tools should mainly be used in the context of the verification of scenarios or the diagnosis of existing buildings or systems. They are generally not supposed to be used as main design tools as the assumptions included are

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generally simplified, and aim at considering the main characteristics of the building rather than all the environmental parameters which could affect its real performance (e.g. user behaviour or BEMS scenarios).

In the context of mySMARTLife and Nantes Metropole, several tools have been applied in the case of the action 2, to assess the performance of buildings (e.g. to compare the existing state prior to action with the expected state after implementation of the action). U48Win, Clima-Win, WinPTZ are examples of tools compatible with the Th-C-Ex, which is the calculation method included in the French thermal regulation for buildings.

4.1.1.3 Smart buildings data platforms

Examples:

4.1.1.3.1 HIT2GAP platform (H2020 project)

Website: http://www.hit2gap.eu/

H2G is a H2020 project that aims at developing and testing a novel architecture for commercial buildings monitoring and energy management: while traditional BMSs are black boxes on which analytics tools developments is a complex task, the Hit2Gap platform relies on standard web technologies to offer a modular and open solutions on which analytics and data sources can be easily plugged (see next figure).

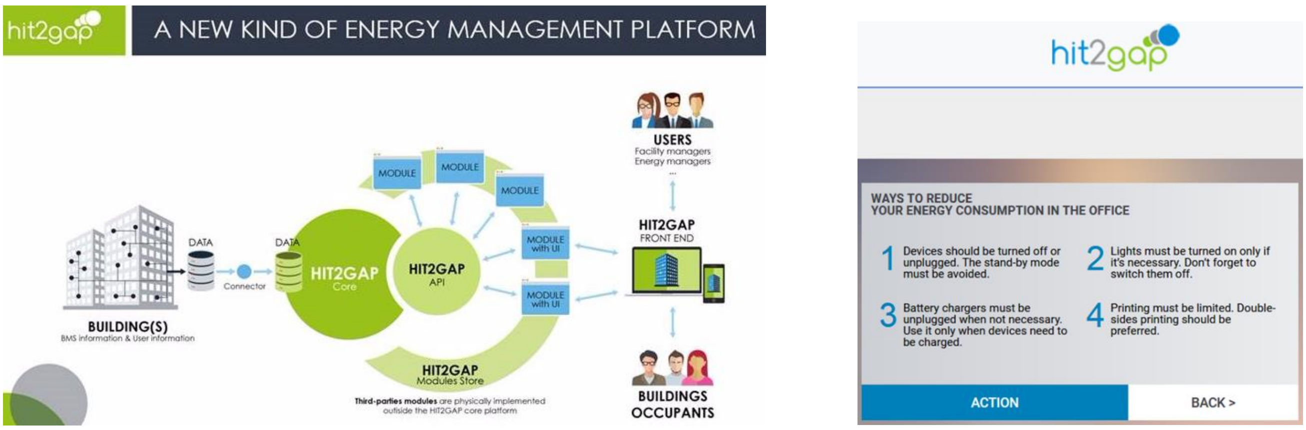

Figure 9: Hit2Gap concept and interface

4.1.1.4 Non-expert tools for retrofitting decision support

Examples:

4.1.1.4.1 ODMIR4

Website: http://www.cstb.fr/archives/webzines/editions/edition-de-septembre-2009/odmir-4-pour-la-rehabilitation-energetique-des-maisons-individuelles.html

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ODMIR4 is a French collaboration between the french building technical center (CSTB), Armines, EDF (main french electricity operator), and phénix evolution (building retrofit expert). This 3-year collaboration gave birth to the ODMIR 4 software. Made for non-expert, it allows any house owner to rapidly assess the the energy performance of its building, and to evaluate the impact of several reatrofitting scenario. The usage of the software does not require any training (see next figure).

Figure 10: ODMIR4 concept and interface

4.1.1.5 Mon Projet Renov

Website: https://metropole.nantes.fr/renover-logement

Mon Proiet Renov is a solution developed by Nantes Metropole in the scope of mySMARTLife. Deliverable D2.5 is dedicated to presenting its features, strengths and opportunities for replication. Please refer to it for more details.

4.1.2 District scale models

4.1.2.1 Energy models for groups of buildings (same district)

Here are some examples of district scale models.

4.1.2.1.1 DIMOSIM

Website: http://www.cstb.fr/fr/actualites/detail/dimosim/

DIMOSIM is a collaborative project between the French building technical center (CSTB) and the association Pays du SUD. It aims at studying the south west French territory energy strategy. The objective was to define a new economy dynamic using the energy transition. The software was used to identifiy and visualize building performance, local ressources, and distribution networks (see next figure).

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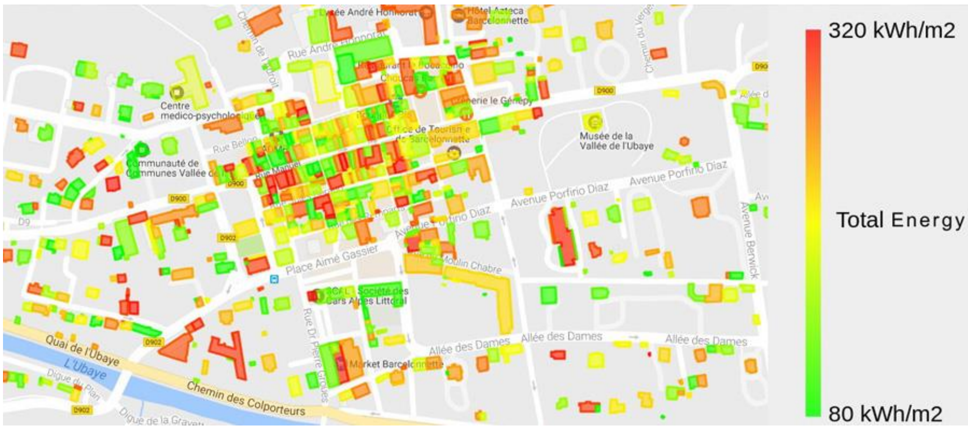


Figure 11: DIMOSIM's interfcae, representation of energy needs for the buildings of a district

4.1.2.2 Energy models for buildings portfolio

Examples:

4.1.2.2.1 PROLEPS

Website (in France): https://www.nobatek.inef4.com/wp-content/uploads/2017/10/Nobatek_Focus2015.pdf)

Proleps is a building estate management software focused mainly on energy efficiency (see next figure). It provides key performance indicators about the buildings at different scales: building, site and entire estate, including historical data. It assists the managers in identifying buildings with high energy consumptions and improvement opportunities, therefore to define priorities. Proleps also provides assistance in setting up and driving energy master plans.

Figure 12: PROLEPS interface screenshot

4.1.2.3 Multi-criteria energy and environment models

Examples:

4.1.2.3.1 District Energy Concept Advisor

Website: http://www.district-eca.de/index.php?lang=en

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Fraunhofer Institute for Building Physics IBP has developed a computer software to support actors in the field of urban planning during the first stages of planning energy-efficient district concepts (see next figure). This software was developed in collaboration with international partners from IEA ECBCS Annex 51 "Energy Efficient Communities ". The very heart of the software is a tool for the energy assessment of districts, which uses archetypes and other pre-set configurations to allow for a simple and quick data input mapping all the buildings in the district. Thus it takes the user just a few steps to identify the energy saving potential of various strategies in the areas of building construction, technical building systems, and centralized supply systems.

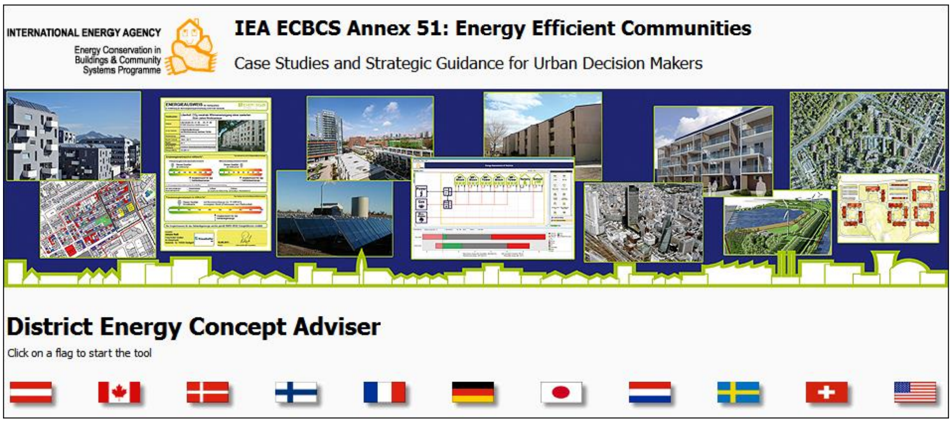


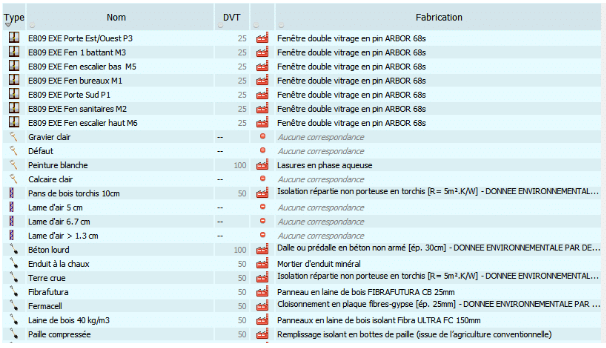
Figure 13: Annex 51 District Energy Concept Adviser front page

4.1.2.3.2 NovaEquer

Website: http://www.izuba.fr/logiciel/novaequer

NovaEquer is a software developed by the French company Izuba, in collaboration with the academic research center Mines ParisTech (see next figure). It allows life cycle analysis at building and district scale, providing 12 environmental indicators such as hidden CO_2 and contribution to global warming. It can be used in collaboration with the software Pleiades Comfie (described above) to perform the future french mandatory calculation ragarding energy and carbon emission (mentioned as E+C- in the French national context).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.



Type	Nom	DVT		Fabrication
	E809 EXE Porte Est/Ouest P3	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Fen 1 battant M3	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Fen escalier bas M5	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Fen bureaux M1	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Porte Sud P1	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Fen sanitaires M2	25		Fenêtre double vitrage en pin ARBOR 68s
	E809 EXE Fen escalier haut M6	25		Fenêtre double vitrage en pin ARBOR 68s
	Gravier clair	--		*Aucune correspondance*
	Défaut	--		*Aucune correspondance*
	Peinture blanche	100		Lasures en phase aqueuse
	Calcaire clair	--		*Aucune correspondance*
	Pans de bois torchis 10cm	50		Isolation répartie non porteuse en torchis [R= 5m².K/W] - DONNEE ENVIRONNEMENTAL...
	Lame d'air 5 cm	--		*Aucune correspondance*
	Lame d'air 6.7 cm	--		*Aucune correspondance*
	Lame d'air > 1.3 cm	--		*Aucune correspondance*
	Béton lourd	100		Dalle ou prédalle en béton non armé [ép. 30cm] - DONNEE ENVIRONNEMENTALE PAR DE...
	Enduit à la chaux	50		Mortier d'enduit minéral
	Terre crue	50		Isolation répartie non porteuse en torchis [R= 5m².K/W] - DONNEE ENVIRONNEMENTAL...
	Fibrafutura	50		Panneau en laine de bois FIBRAFUTURA CB 25mm
	Fermacell	50		Cloisonnement en plaque fibres-gypse [ép. 25mm] - DONNEE ENVIRONNEMENTALE PAR ...
	Laine de bois 40 kg/m3	50		Panneaux en laine de bois isolant Fibra ULTRA FC 150mm
	Paille compressée	50		Remplissage isolant en bottes de paille (issue de l'agriculture conventionnelle)

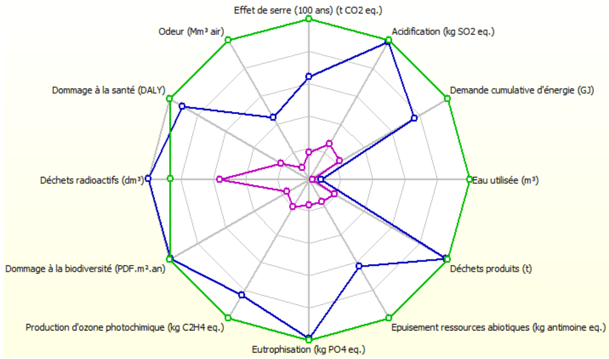


Figure 14: NOVA EQUER interface screenshot

4.1.2.3.3 ELODIE

Website: https://logiciels.cstb.fr/batiments-et-villes-durables/performances-environnementales/elodie/

Developped by the French building technical center (CSTB), the software ELODIE is a collaborative tool that quantifiy the environmental impacts of a building over its life cycle (see next figure). It applies both to commercial and residential buildings. It complies with the new French mendatory energy carbon calculation (E+C-). It is BIM ready.

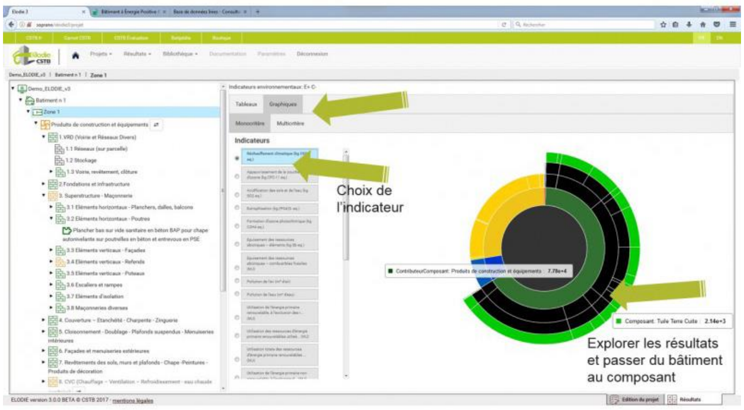


Figure 15: ELODIE interface screenshot

4.1.2.3.4 NEST

Website: https://www.nobatek.inef4.com/produits/nest/

Nest is a tool for the quantitative assessment of the environmental impacts of urban projects. NEST, NEIGHBOURHOOD EVALUATION FOR SUSTAINBALE TERRITORIES®, has been designed taken into account the operational practice of urban design and can be used from the sketch stage of a project. Based on a 3D model of an urban project, NEST calculates a set of indicators reflecting major environmental issues urban planners are currently facing (see next figure). NEST has already been applied on several urban planning operations in France and Spain. It was developed through a PhD thesis

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

(Yepez-Salmon, 2011) focused on "Environmental assessment of eco-neighbourhoods" in Nobatek and the GRECAU laboratory (ENSAPBx). NEST is an application for the collaborative data management EEGLE platform (https://www.eegle.io/). NEST indicators, which have been developed associating a scientific approach as well as operational urban planning objectives, are the following:

- Environmental indicators deal with primary energy, climate change, waste production, water consumption, wastewater production and air quality
- Socio-economic indicators address the diversity and density of public amenities within the district/city.

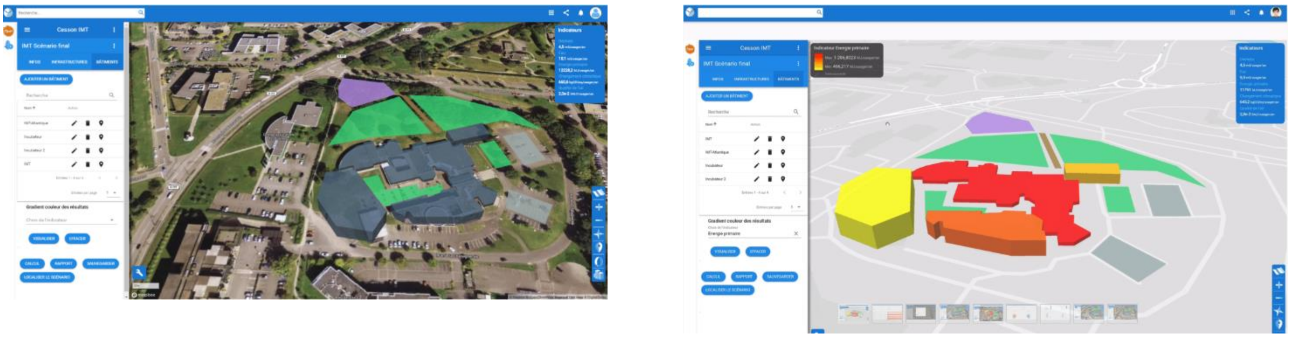


Figure 16: NEST interface screenshot

4.1.3 City scale models

4.1.3.1 Energy modelling at city scale, top-down and bottom-up approaches

4.1.3.1.1 CitySIM

CitySim: https://leso.epfl.ch/transfer/software/citysim/

The software CitySim is aiming to provide a decision support for urban energy planners and stakeholders to minimize the net use of non-renewable energy sources as well as the associated emissions of greenhouse gases (see next figure). A commercial version of an interface developed by kaemco is available (http://www.kaemco.ch/download.php).

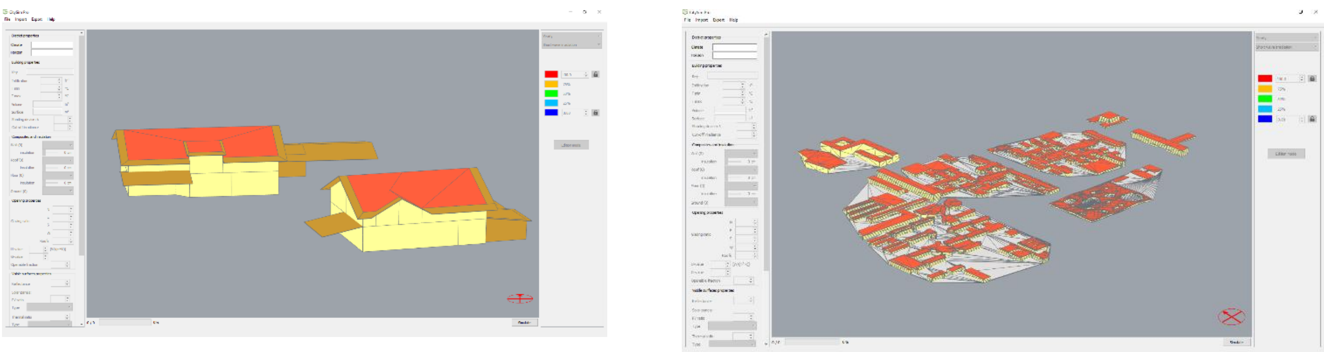


Figure 17: CitySim Pro interface screenshot

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

4.2 Energy system models and simulation tools

4.2.1 Energy systems at building scale

4.2.1.1 Conventional energy dimensioning tools

4.2.1.1.1 BAO Promodul

Website: http://www.logiciels-bao.fr/

The toolbox BAO is developed and marketed by INEF4 cercle Promudul. It allows simplified energy modelling of buildings to guide the retrofitting approach (see next figure). The simulation kernel is based on the mandatory French energy calculation. The software allows quick comparison between several retrofitting scenarios, and helps the calculation of energy saving, global costs and return on investment. Though it integrates calculation rules compatible with the French regulation (cf section 4.1.1), it also aims at providing support for the dimensioning of the systems.

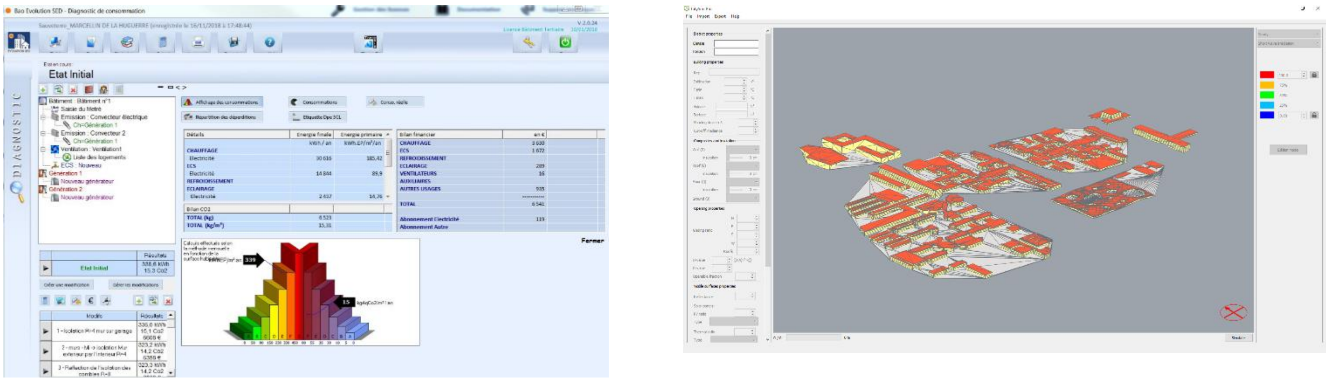


Figure 18: BAO Promodul interface screenshot

4.2.1.1.2 PVsyst

Some tools are used for the dimensioning of specific energy systems to be integrated to the buildings. PVsyst is an example; it is a software used for the dimensioning of photovoltaic systems. It can represent in the format of graphs the different values of sizing of the various components of a PV system (see next figure). It has been used in the context of Nantes Metropole in mySMARTLife for several PV installations, presented in section 5.

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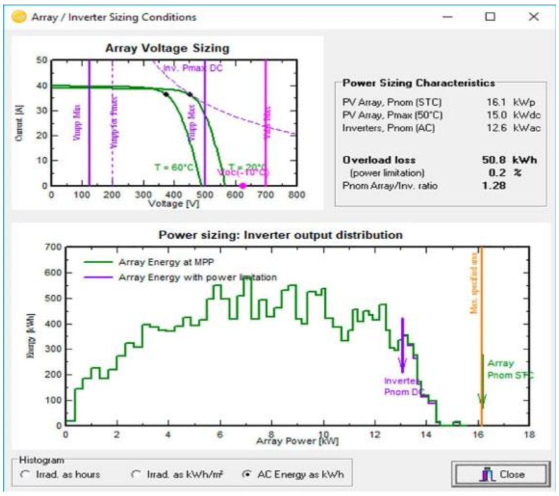

Figure 19: Dimensioning PV components with PVsyst

4.2.1.2 Advanced co-simulation tools

Examples of environments used for co-simulation or interaction between the building envelop and its systems:

4.2.1.2.1 Modelica

Website: https://www.modelica.org/

Modelica® is a non-proprietary, object-oriented, equation-based language to conveniently model complex physical systems. The Annex 60, an international collaboration allowed the development of several building-oriented libraries such as “Buildings” from the Lawrence Berkley National Laboratory (LBNL), BuildsysPro developed by EDF (France), or IDEAS developed by the university of Louvain (Belgium). Several graphical interfaces such as Open Modelica (Open source), or Dymola (Dassault System) simplifies and accelerates the modelling process. Also the language is easy tu use with Fuctional Mockup Interface stabdard (FMI) and allows co simulation between softwares (see next figure).

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research and innovation programme under grant agreement No 731297.

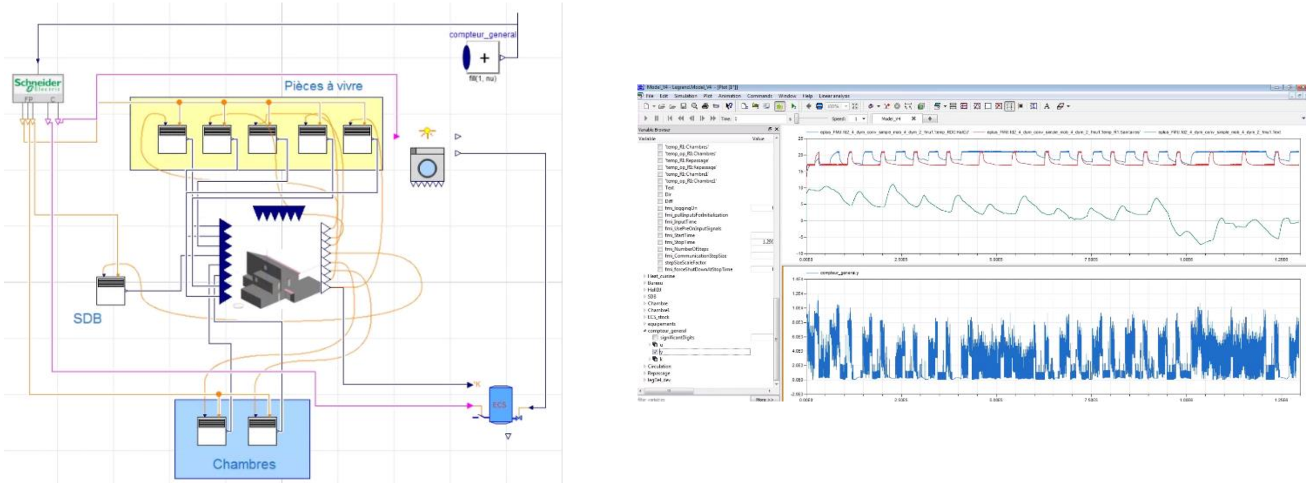

Figure 20: Dymola interface screenshot

4.2.1.2.2 TRNSYS

Website: http://www.trnsys.com/

TRNSYS is a graphically based software environment used to simulate the behavior of transient systems (see next figure). The vast majority of simulations are focused on assessing the performance of thermal and electrical energy systems. Models adapted to the building and its systems are available both in the standard library and in the commercial library TESS. Custom models can be written in Fortran 70. Co-simulation with matlab is possible.

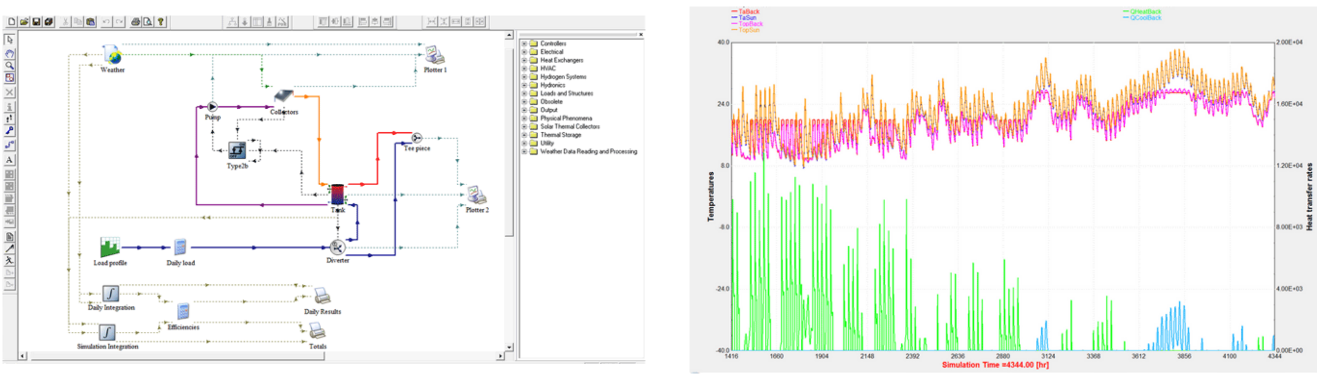

Figure 21: TRNSYS interface screenshot

4.2.1.3 BEMS tools

The BEMS tools are often “black-box” embedded models proposed in industrial products (e.g. SCHNEIDER, DELTADORE, HAGER, LEGRAND).

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4.2.2 District heating and cooling energy models

4.2.2.1 Decision support and early stage design models (optimization)

Here are some examples of models used for District Heating and/or Cooling (DHC) design.

4.2.2.1.1 IMT Atlantique decision support tool

Website: https://www.imt-atlantique.fr/sites/default/files/

In this regards the tool developed by IMT Atlantique aims to optimise the different production units connected to the district heating. This optimisation is based on the minimization of an objective function which represents a composite cost (economic, environmental, energy).

This non commercial tool has been developed previously to mySMARTLife. Within the project, a methodology has been proposed by IMT Atlantique which makes use of it, though other tools could have been used.

4.2.2.1.2 ODHEAN

Website: http://www.journees-rdi-transition

ODHEAN is a tool developed by Nobatek in collaboration with the ADEME (French Environmental Agency) during the project SIGOPTI. The objective is to help the designers to optimize a district heating. It simulates the heating demand response behaviour, the heat loss and pressure loss in pipes. It has several optimization algorithms to guide the overall network design, and the elements sizing.

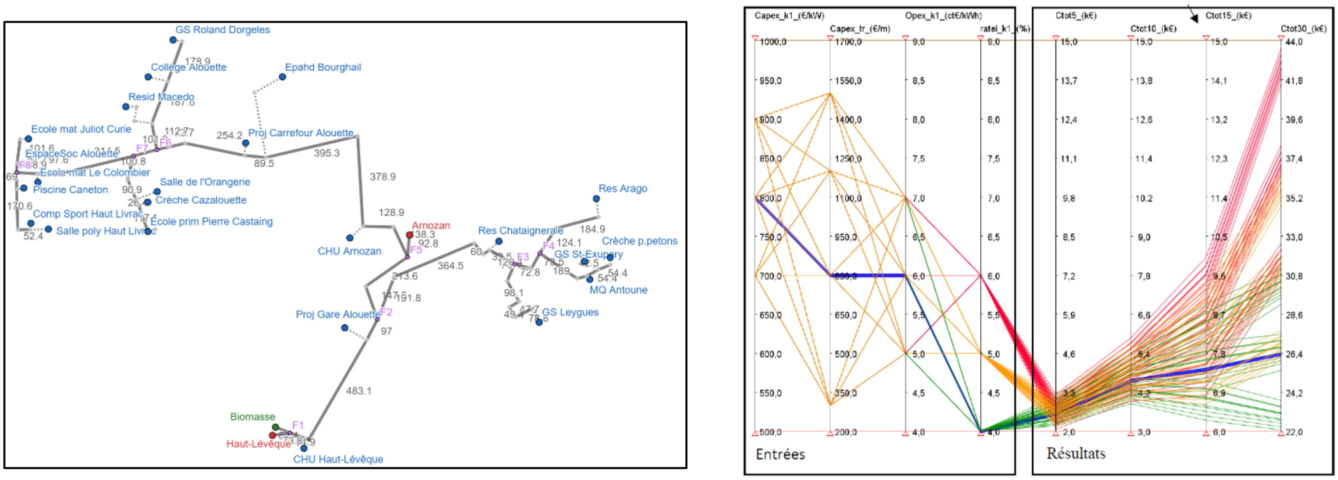

Figure 22: ODHEAN screenshot

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

4.2.2.2 Detailed design models (incl. optimization)

4.2.2.2.1 TERMIS

Website: https://www.schneider-electric.africa/fr/product-range-presentation/61613-termis-engineering/

Termis is developed by Schneider electric, it is an extensive district energy network simulation platform for improving system design and operation. It can be used for pipeline design, hydraulic and thermal analyses, operation planning, and creation and analysis of alternative scenarios. It propose a friendly graphical user interface for modelling and analysing simulation results.

4.2.2.3 Models used for optimal operation and/or control

4.2.2.3.1 IMT optimization tool

Website: https://www.imt-atlantique.fr/fr/l-ecole/actualites/ameliorer-la-performance-des-reseaux-de-chaleur-grace-la-modelisation

The model used here optimises the physical variables used for control purpose (temperatures, mass flows…). The optimization can be a static optimization, a pseudo dynamic or dynamic depending on the objectifs and the configuration of the system.

This non commercial tool has been developed previously to mySMARTLife. Within the project, a methodology has been proposed by IMT Atlantique which makes use of it, though other tools could have been used.

4.3 Transportation models and simulation tools

In order to avoid any misunderstanding, this section starts with a definition of “transport modelling”. While sections **4.1 and 4.2 presented simulation tools**, **we consider here mathematical models** for the case of the transportation technical field. Models (in transportation but also in other domains) aim at representing a complex real-world system into a simpler way. They generally provide a mathematical representation of relationships between the different components of the system and are able to mimic its overall functioning. Hence, they allow for estimating certain quantities and they could be used for real-time monitoring, for short-term decision support or for long-term planning.

There exists a wide range of models and tools in transportation engineering. One could explain this diversity by:

1. The large variety of modes of transportation;
2. The difference of needs by managers in charge of a transportation system;
3. The difference of objectives pursued by practitioners when using these models;
4. The boom of computing possibilities in recent years.

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Hereafter, we limit ourselves to the road mode. A classification of road transport models can be carried out based on the time and space scales at which they could be used (see Table 2).

Table 2: Overview of models use depending on time-space scales.

		Space scale	
		Local / Urban	Regional / Nationwide
Time scale	Short term (hour / minute)	Dynamic traffic management, decision support system ➔ *Dynamical microscopic / mesoscopic model*	Supervision, network operations, information ➔ *Dynamical mesoscopic / macroscopic model*
	Long term (year /decade)	Planning, land use, long-term forecast, evaluation of projects ➔ *Static model*	

As shown in Table 2, for long-term transportation and land-use planning, one would use a **static approach**. Such approach allows for long time planning of transport infrastructures by enabling an estimation of the transportation demand forecast. It also allows the evaluation of relevance of infrastructure projects, notably in terms of public investments, and in comparison of projects alternatives. Among these models, we can mention:

- LUTI (Land Use and Transport Integrated) models which appear in 1964 in the USA with Metropolis. These models consider the interactions between the urbanism of a city and the development of its transportation system.
  The four-step model that consists in modelling the transport demand by decomposing a trip into four actions:
  - Trip generation. It answers the following question: what are the number of trips generated and attracted by each zone of the considered area?
  - Trip distribution. At this step, the model allows to compute the number of trips from a zone called the origin, to another zone, called the destination. It ends up by providing the Origin-Destination (OD) matrices.
  - Mode choice. Following the computation of the volume of trips between zones, it is necessary to determine the transportation mode that is used to realize the trip. It usually distinguishes modes such as public transport means, cars, bicycles or walk. The choice of the transportation modes mainly relies on the accessibility and the cost associated with the travel time.
  - Route assignment is the final step of the model. It identifies what are the routes used for realizing the trips.

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In general, these static models need data about the demographics of the territories, the localization of working and living zones, as well as data about the transport offer and also some macro-economic parameters such as the prices of energy.

Such models can be used for instance for providing some insights about the investment of a public authority in the development of a major public transportation line such as a tramway.

For short-term applications, as soon as the temporal horizon is shorter than a day, **dynamical models** should be used. In comparison to static models, "dynamical" means that these models consider variables that depend on time. Indeed, the time is an important feature at this scale. This kind of models is often considered as an additional step following the use of a static model (in particular, it could be seen as a fifth step for the four-step model) which can be referred to as "dynamic network loading" models. These models need data about the transportation demand and its time dependency (that could be provided by OD matrices by time slice of the studied period), the network characteristics and parameters about drivers' behaviour such as the desired maximal speed.

Among the dynamical models, one can distinguish:

- Microscopic models that are classically used in order to assess local crossroad planning or to perform local traffic management. These models consider individual variables, that is to say, variables that can describe the behaviour of each vehicle, such as the position, the speed, the acceleration or the steering angle. Micro modelling can represent the vehicles longitudinal behaviour (one talks about car-following models), lateral behaviour (with lane changing models for instance) or insertions (through gap acceptance models). As they have to compute many individual variables (depending on the number of vehicles, on the network size and on the time horizon), they usually require a lot of computational effort.
- Macroscopic models that rely on a hydrodynamics analogy between the flowing of vehicles and a fluid. They assume that a vehicle stream could be approximated by a continuum of particles. Hence, they use aggregated variables such as density, flow or mean speed. Macro models are useful for traffic supervision, decision support system, short-term prediction or for area-wide traffic management. They are usually simpler than microscopic models to calibrate since they introduce less parameters and they are also faster in terms of computational time. However, they are not as precise as micro simulations.
- Mesoscopic models. The term "mesoscopic" may recover different kind of models such as kinetic models (that integrate a probability function into a macroscopic model to add uncertainties) or deterministic models with a disaggregated view of macroscopic flow. The idea is to adopt an intermediary point of view, between micro and macro scales. Variables could be the passing time of vehicles at fixed positions for instance. Mesoscopic models have almost the same use cases than

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macro ones, say near-real-time monitoring, decision support system, short-term prediction or area-wide traffic management. They are a good compromise between precision and computational cost.

- Hybrid methods that couple different models: for instance, micro/meso or micro/macro coupling. It allows using each model on its most pertinent domain. A particular attention should be put on the interfaces between each model.

It is noteworthy that dynamical models could be coupled with energy consumption models, noise or greenhouse-gases emission models to allow additional estimations on the environmental impacts of traffic.

Also, come into the picture the agent-based (and multi-agents) models. The aim of these models is to reproduce the human decision-making and behaviour of different agents that interact. These models usually consider interactions between different layers, including a communication layer. Even if they are close to microscopic dynamic models in terms of final outputs, say the description of individual behaviours, they differ from them by the consideration of the decision-making process.

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5. Tools used for Nantes demonstration in mySMARTLife

Several tools have been used in the context of Nantes Metropole's mySMARTLife actions, generally to get knowledge about the energy situation (of a building or a busline for example) prior to the more detailed feasibility analysis of an action and its impact (e.g. retrofitting, renewable energy production, change of energy source, etc.). This section presents an overview of the results from simulations and in some cases measurements, obtained generally before the implementation of mySMARTLife actions.

As we focus here on the results dealing with the characterization of energy consumption prior to the development of mySMARTlife actions, some other simulation based results, though part of some mySMARTLife activities, are not detailed in the following sections, more specially:

- Mon Projet Renov platform to support the citizens in their individual retrofitting projects. The platform is fully described in deliverable D2.5 of mySMARTLife project. Not included here as the corresponding mySMARTLife's action is about the service provided by this tool, not the related retrofitting projects themselves.
- Building integrated RES including photovoltaics. Feasibility studies have been carried out in the scope of the implementation of task 2.3. The development of these actions is detailed in D2.7 (Smart Energy supply and demand). Not included here as the tools (e.g. PVSyst) have been used for feasibility analysis purposes, not the energy characterization of the state prior to the action.
- Decision support tool for district heating optimization. This part is developed in subtask 2.5.3. Detailed information is available in D2.8 and D2.10. Not included here as this tool is used in mySMARTLife to apply a methodology (for decision support and optimization) and not specifically for the energy characterization of a district heating network.

The results presented in this section are complementary to the results of the baseline context in Nantes (presented in deliverable D2.1) and the activities on monitoring and evaluation (WP5), which include a full framework of comparison of the performance before and after implementation of the actions, in agreement with the definition of Key Performance Indicators (KPIs).

5.1 Retrofitting of multi-owner buildings

This work is linked to subtask 2.2.1, dealing with the retrofitting of 6 multi owner buildings by the end of 2019, led by Nantes Metropole, and representing about 22,000 square meters and 270 dwellings.

For the retrofitting of multi-owner buildings, the main question raised before the implementation of the retrofitting work is to check if the project fits the regulation context in terms of performance and/or means to achieve a better level of performance. According to the method proposed in section 2 and to the tools presented in section 3, the most appropriate simulation tools are the ones that can be used in the context of the verification of scenarios. Indeed we aim here at considering the main characteristics of the building rather than all the environmental parameters which could affect its real performance. U48Win, Clima-Win, WinPTZ are all tools that can be used in the French context.

Prior to the action of retrofitting of multi-owner buildings, as part of mySMARTLife's actions developed for Nantes in WP2, several thermal studies have been carried out. Hereafter various results are shown. Most of them have been adapted to the format of BEST tables (Building Energy Specification Tables). Five different buildings contexts are considered for this action, mentioned later as follows: Benoni Goullin, Massillon, Nantes-Paris, Le Strogoff, Val de Loire.

For more details about the retrofitting actions implemented in mySMARTLife in the context of Nantes please refer to deliverable D2.3.

5.1.1 Benoni Goullin building [Action 2, BEST 1C]

The energy renovation works consisted in insulating the facades and the low floor, replacing the windows and installing a new ventilation system. Since both boilers are relatively new, there has been no replacement or connection to the heating network.

Calculations have been carried out with the ThCEx model, proposed by the CSTB (French Scientific and Technical Center for Buildings), in agreement with the French national regulation. It considers the consumption for heating, DHW, lighting, and auxiliary devices.

Next figure shows how the simulation tool allows to estimate that the primary energy consumption need can be reduced from 232 to 80 kWhEP/m².year and the CO2 emission from 42 to 7 kgeqCO2.m².year.

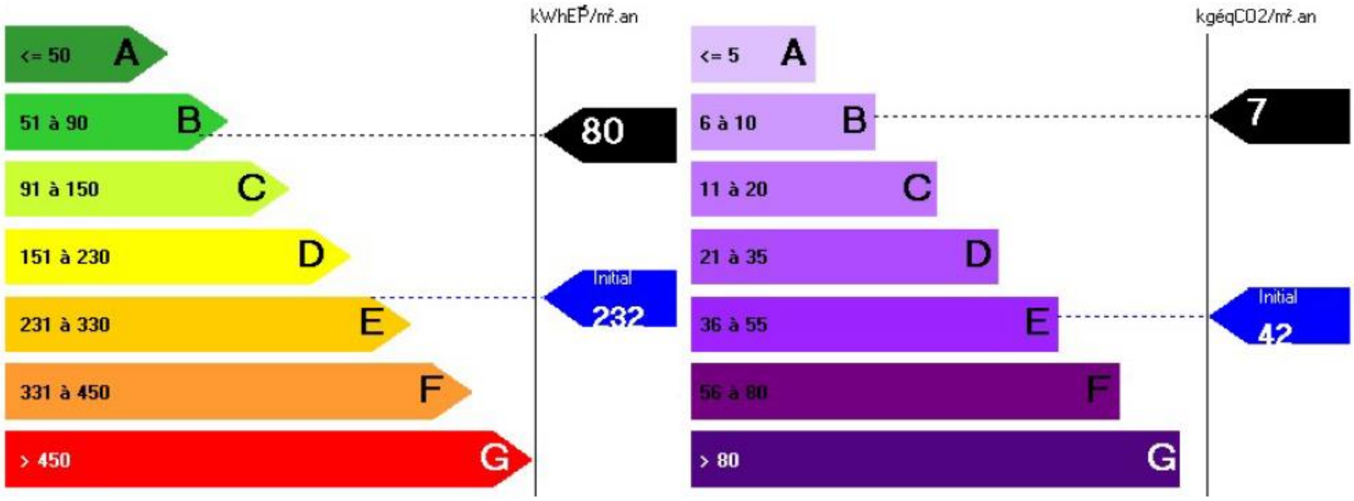

Figure 23: Comparison of initial state (in blue) and potential performance after retrofitting (in black) Primary energy consumption (left side, in kWhEP/m².year) and CO2 emission (right side, in kgeqCO2.m².year)

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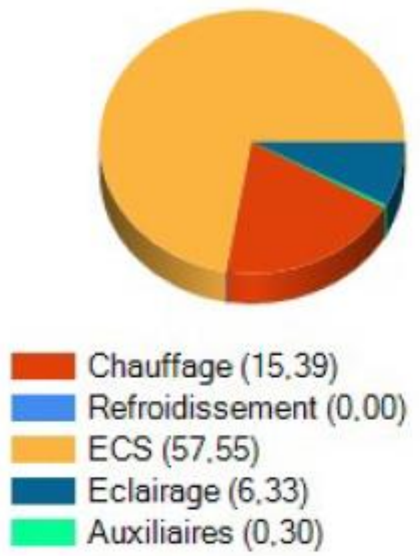

Figure 24: Extract from the French national thermal regulation calculation about the potential consumption in primary energy (kWhPE/m²) after retrofitting;
DHW (57.55, in yellow), heating (15.39, in red), lighting (6.33, in blue).

The previous figure shows how the main part of energy needs after retrofitting will be due to the DHW consumption, as the needs for heating will represent around ¼ of it.

After the French national regulation calculation, other studies have been carried out according to the BEST tables framework. The next table presents the results of this calculation, by considering the consumption of the existing state, the potential consumption of the retrofitted building, in comparison with the consumption of a reference "normal practice" state. As the surface used for this calculation is different from the one used in the French regulation, the results are slightly different, but the general conclusion and ambition remain completely aligned. In the BEST Table, the surface used is the living area whereas for the French regulation calculation, the gross floor area is used.

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energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas	gas	kWh/m²yr	insulation of walls, roof, ground floor, windows, sensitiv thermostatically controlled valve	189,57		60,00	17,70	71%
Cooling + ventilation								
		kWh/m²yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m²yr	hybrid mechanical ventilation	1,51		0,63	0,14	79%
Lighting								
	electricity	kWh/m²yr	none	5,60		10,00	5,00	50%
Domestic Hot Water (DHW)								
	electricity/gas	kWh/m²yr	none : existing individual water heater	34,94		50,00	34,94	30%
Other energy demand								
		kWh/m²yr						0%
		kWh/m²yr	Subtotal sum of energy demand	231,62	0,00	120,63	57,77	52%

Figure 25: BEST table calculation results

The ambition of the retrofitting project could aim at a 52% energy consumption reduction compared with a “normal practice” state.

5.1.2 Massillon building [Action 2, BEST 1F]

The energy retrofitting includes on one hand, actions related to the building itself: insulation of the roof, the low floor and the facades and the replacement of windows.

On the other hand, the actions related to the equipment of the building are the following: replacement of the ventilation system for a better controlled one, renovation of the insulation of the heating pipe network and installation of thermostatic valves.

In a similar way, calculations are done according to the French national thermal regulation rules, and then according to the BEST table framework. Thus, the differences between the results are still due to the fact that the surface used in the two simulations are not the same.

The results from the French regulation calculation tool are represented in a different mode (next figure); this is due to the fact there are different calculation tools, even though they include the same framework of calculation rules (from the French thermal regulation).

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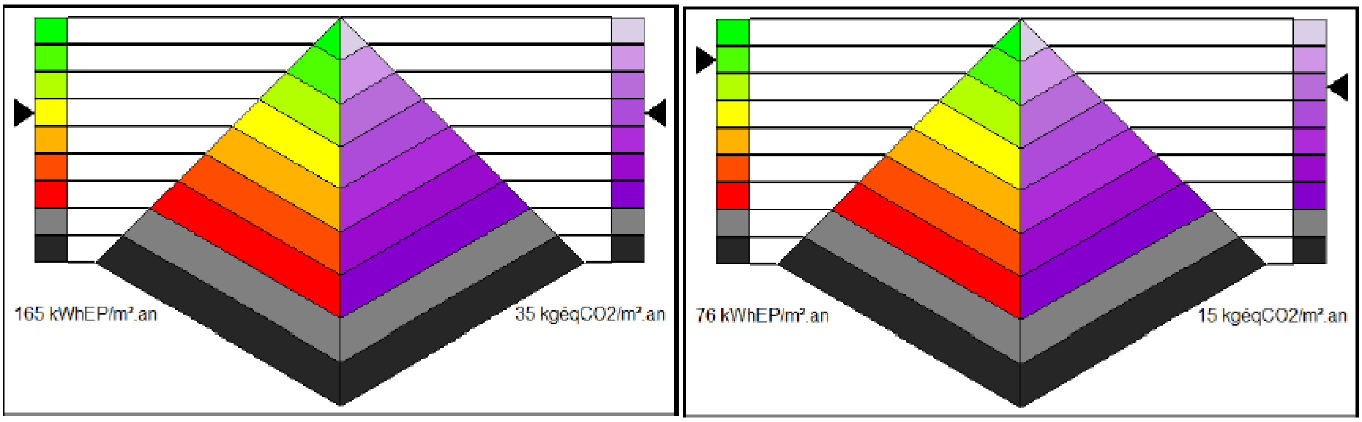

Figure 26: Comparison of initial state (figure on the left) and potential performance after retrofitting (figure on the righ): primary energy consumption (on the left of each figure, in kWhEP/m².year) and CO2 emission (on the right of each figure, in kgeqCO2.m².year)

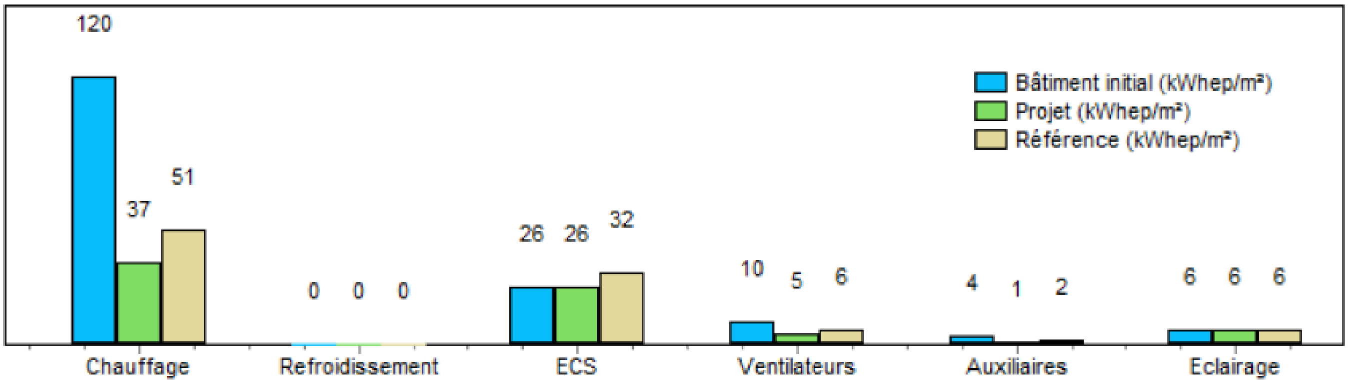

Figure 27: consumption in primary energy (kWhPE/m²), for the initial state (blue), a reference typical state (yellow), and a potential state after retrofitting (green); Extract from the French national thermal regulation calculation

The results in the previous figure represent from left to right estimates for heating, DHW (ECS), ventilation, auxiliary devices and lighting. Whike the need in DHW is not reduced by the retrofitting, the main improvement is due to the reduction on the heating demand (120 to 27 kWhPE/m²). This is obtained as a large part thanks to works on the building envelope.

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energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas	gas	kWh/m²yr	insulation of walls, roof, ground floor, windows, sensitiv thermostatically controlled valve	138,68		60,00	43,09	28%
Cooling + ventilation								
		kWh/m²yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m²yr	low consumption hygrometric ventilation	4,38		3,00	2,11	30%
Lighting								
	electricity	kWh/m²yr	none	4,98		10,00	5,00	50%
Domestic Hot Water (DHW)								
gas	gas	kWh/m²yr	none : initial condensing gas boiler for heating a	30,44		50,00	30,44	39%
Other energy demand								
		kWh/m²yr						0%
		kWh/m²yr	Subtotal sum of energy demand	178,48	0,00	123,00	80,64	34%

Figure 28: BEST table calculation results

In the previous figure, we can note that the ambition of the retrofitting project could aim at a 34% primary energy consumption reduction compared with a “normal practice” state.

5.1.3 **Nantes-Paris buildings** [2 buildings supplied by District Heating Network - Action 2, BEST 1A and 1B]

For the two buildings of Nantes Paris, the facades were insulated as well as the roofs and the low floors and the windows were replaced. As for the technical equipment of the buildings, they were connected to the district heating for the building heating; thermostatic valves were installed, as well as a new ventilation system.

For these buildings, the application of the national regulation tool leads to the following results: 263 kWhPE/(m².year) consumption for the state prior to retrofitting, and 77 kWhPE/(m².year) for a potential state after retrofitting.

The application of the BEST tables framework leads to estimates of 54% and 50% primary energy savings (respectively for each building) compared with a reference typical state (cf next figure).

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2,1	Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses							
energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas +electricity	district heating +electricity	kWh/m²yr	insulation of walls, ground floor, windows	74,14		60,00	20,64	66%
Cooling + ventilation								
		kWh/m²yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m²yr	hybrid mechanical ventilation	0,55		5,01	1,50	70%
Lighting								
	electricity	kWh/m²yr	none	5,13		10,00	5,00	50%
Domestic Hot Water (DHW)								
	electricity/gas	kWh/m²yr	none : existing individual water heater	30,30		50,00	30,30	39%
Other energy demand								
		kWh/m²yr						0%
		kWh/m²yr	Subtotal sum of energy demand	110,11	0,00	125,01	57,43	54%

energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas+electricity	district heating +electricity	kWh/m²yr	insulation of walls, ground floor, windows	119,63		60,00	21,28	65%
Cooling + ventilation								
		kWh/m²yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m²yr	hybrid mechanical ventilation	0,08		4,38	1,31	70%
Lighting								
	electricity	kWh/m²yr	none	5,84		10,00	5,80	42%
Domestic Hot Water (DHW)								
	electricity/gas	kWh/m²yr	none : existing individual water heater	33,25		50,00	33,25	33%
Other energy demand								
		kWh/m²yr						0%
		kWh/m²yr	Subtotal sum of energy demand	158,81	0,00	124,38	61,64	50%

Figure 29: BEST table calculation results

The figures above show that the ambition of the retrofitting project could aim at a 54% primary energy consumption reduction compared with a “normal practice” state for the first building (top table), and 50% for the second (lower table).

5.1.4 Le Strogoff building, thermal solar panel for domestic hot water production [Action 2, BEST 1D]

On Le Strogoff building, a partial insulation of facades was undertaken. The low floor facing the outside and the roof were insulated. The windows were replaced. The boiler room has been completely

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renovated: the boilers were replaced, and a new installation of solar thermal panels was set up for the production of DHW. Finally, the ventilation system was replaced for a better controlled one.

In a similar way, calculations are done according to the French national thermal regulation rules, and then according to the BEST table framework. Thus, the differences between the results are still due to the fact that the surface used in the two simulations are not the same.

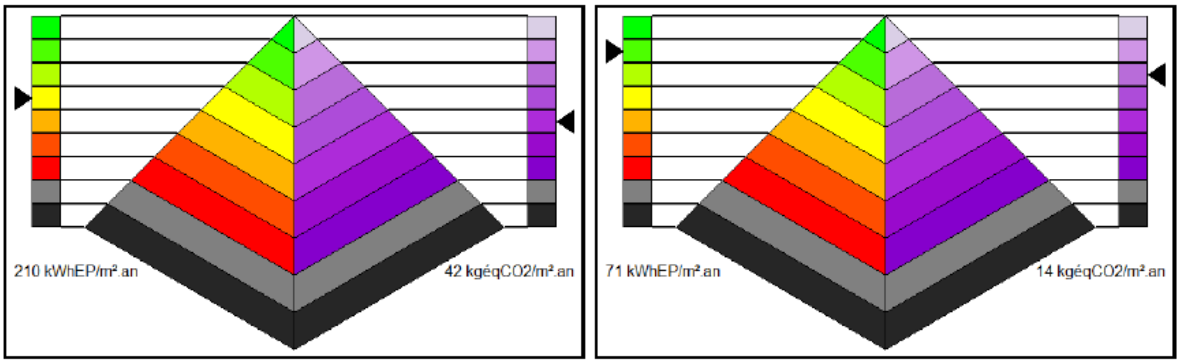

Figure 30: Comparison of initial state (figure on the left) and potential performance after retrofitting (figure on the right); for primary energy consumption (on the left of each figure, in kWhEP/m².year) and CO2 emission (on the right of each figure, in kgeqCO2.m².year).

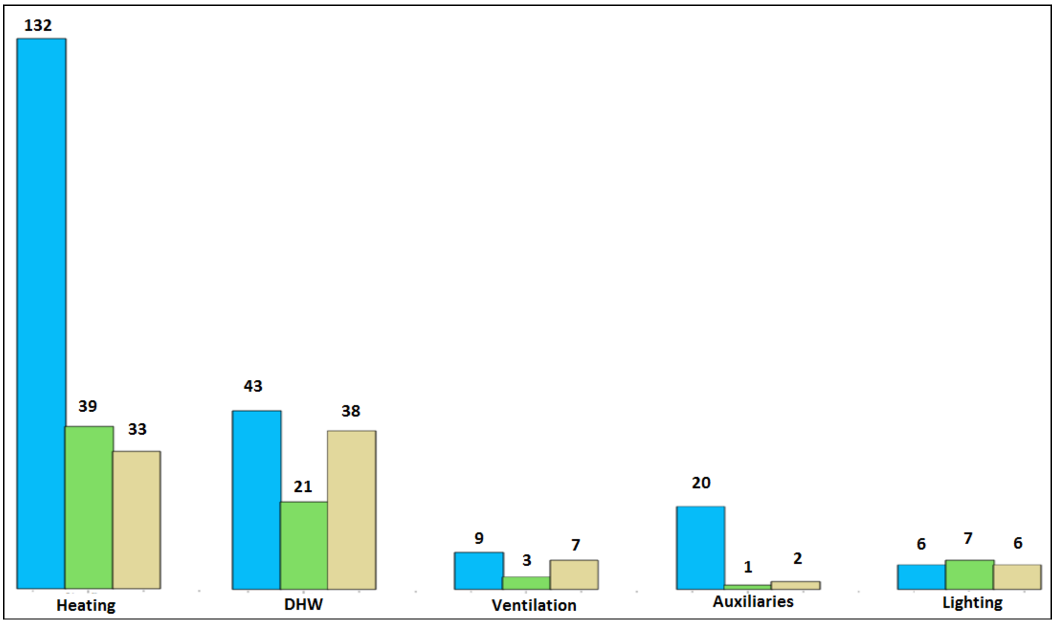

Figure 31: Consumption in primary energy (kWhPE/m²), for the initial state (blue), for a reference typical state (yellow), and a potential state after retrofitting (green); Extract from the French national thermal regulation calculation.

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In the previous figure the results represent estimates, from left to right, for heating, DHW (ECS), ventilation, auxiliary devices and lighting. Here again most of the improvement in energy needs is linked to the reduction of the heating demand.

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas	gas	kWh/m²yr	insulation of roof, ground floor, partial insulation of walls and windows	164,88		60,00	49,21	18%
Cooling + ventilation								
		kWh/m²yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m²yr	renovation of the ventilator	4,38		3,52	1,26	64%
Lighting								
	electricity	kWh/m²yr	none	7,38		10,00	7,00	30%
Domestic Hot Water (DHW)								
	solar	kWh/m²yr	solar collector	53,52		50,00	25,87	48%
Other energy demand								
		kWh/m²yr						0%
		kWh/m²yr	Subtotal sum of energy demand	230,16	0,00	123,52	83,34	33%

Figure 32: BEST table calculation results

According to the previous figure, the ambition of the retrofitting project could aim at a 33% primary energy consumption reduction compared with a "normal practice" state.

5.1.5 Val de Loire building [Action 2, BEST 1E]

The main energy renovation actions on the building itself consisted in insulating the facades, low floor and roof, and in replacing the windows. Regarding the equipment, some of the individual boilers for heating and DHW production were replaced (14 out of 20) ; the newest ones were not replaced. Finally, the ventilation system was replaced.

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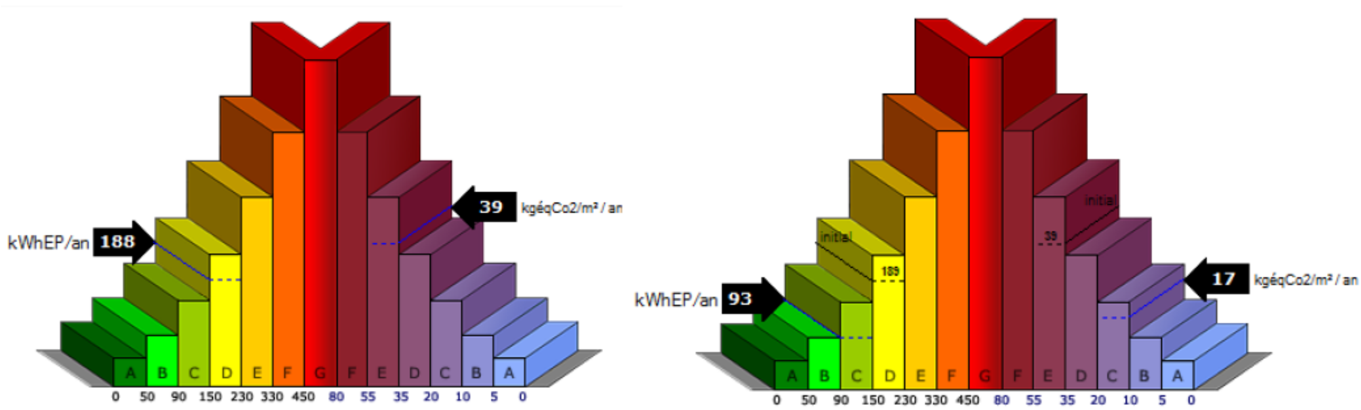

Figure 33: comparison of initial state (left figure) and potential performance after retrofitting (right figure); for primary energy consumption (left side of each figure, in kWhEP/m².year) and CO2 emission (right side of each figure, in kgeqCO2.m².year); Extract from the French national thermal regulation calculation,

2,1 Energy demand per m2 of total used conditioned floor area (kWh / m2yr) incl. system losses

energy carrier existing building	suggested energy carrier		specify energy efficiency measures	New or existing building [5]	National regulation for new built [6]	National regulation for refurbished buildings or normal practice (6a)	suggested specification [7]	Additional energy savings
Heating + ventilation								
gas	gas	kWh/m^2yr	insulation (walls, ground floor),replacement of 2/3 of the individual boiler for heating and hot water.	122,50		60,00	30,43	49%
Cooling + ventilation								
		kWh/m^2yr						0%
Ventilation (if separate from heating/cooling)								
	electricity	kWh/m^2yr	hybrid mechanical ventilation	0,00		4,20	6,71	0%
Lighting								
	electricity	kWh/m^2yr	none	6,17		10,00	2,95	71%
Domestic Hot Water (DHW)								
	electricity/gas	kWh/m^2yr	replacement of 2/3 of the individual boiler for heating and hot water.	36,21		50,00	33,28	33%
Other energy demand								
		kWh/m^2yr						0%
		kWh/m^2yr	Subtotal sum of energy demand	164,87	0,00	124,20	73,36	41%

Figure 34: BEST table calculation results:

The ambition of the retrofitting project could aim at a 41% primary energy consumption reduction compared with a "normal practice" state. The differences between the results are still due to the fact that the surface used in the two simulations are not the same.

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5.2 Retrofitting of individual houses [Action 3, BEST 3]

This work is linked with the activities described in Subtask 2.2.2 about the energy retrofitting in individual houses.

For the retrofitting of individual houses, the main question raised before the implementation of the retrofitting work is to check what the initial state of the building is before proposing a retrofitting project. According to the method proposed in section 2 and to the tools presented in section 3, we need tools very similar to the ones used in section 5.1 (multi-owner retrofitting), but this time more focused on the energy diagnosis study rather than the verification of scenarios.

An energy diagnosis of the buildings involved in action 3 (lead by ENGIE) has been carried out and a study of the retrofitting impact with Bati-Cube (see next figure) has been proposed.

For potentially eligible houses, an appointment was scheduled on site in order to realize a global thermal diagnosis of the housing.

Audits were realised by a technician of Engie Home Service. They were based on the measurement of walls, windows and the collection of their technical characteristics (material, insulation level…). Realization of audits also required collection of information on the heating and hot water production systems (type of equipment, age…), ventilation systems, and on the household habits (living temperature and number of people in the houses…).

Data collected from each house was then filled in the “bati-cube” software (www.bati-cube.fr), in order:

- to establish a first estimation of the energy performance of each house; this first estimation can also be compared with the amount of energy bills of the household (heating, gas, electricity…).
- to identify works to realize to achieve a BBC-renovation performance level (80 kWh_{EP}/m^2/year for dwellings located in the Nantes area)

Next figure and table present the results obtained for an individual house, showing that more than 60% in energy and CO2 emissions annual savings can be expected thanks to the retrofitting project, as well as around 50% of reduction of the bills.

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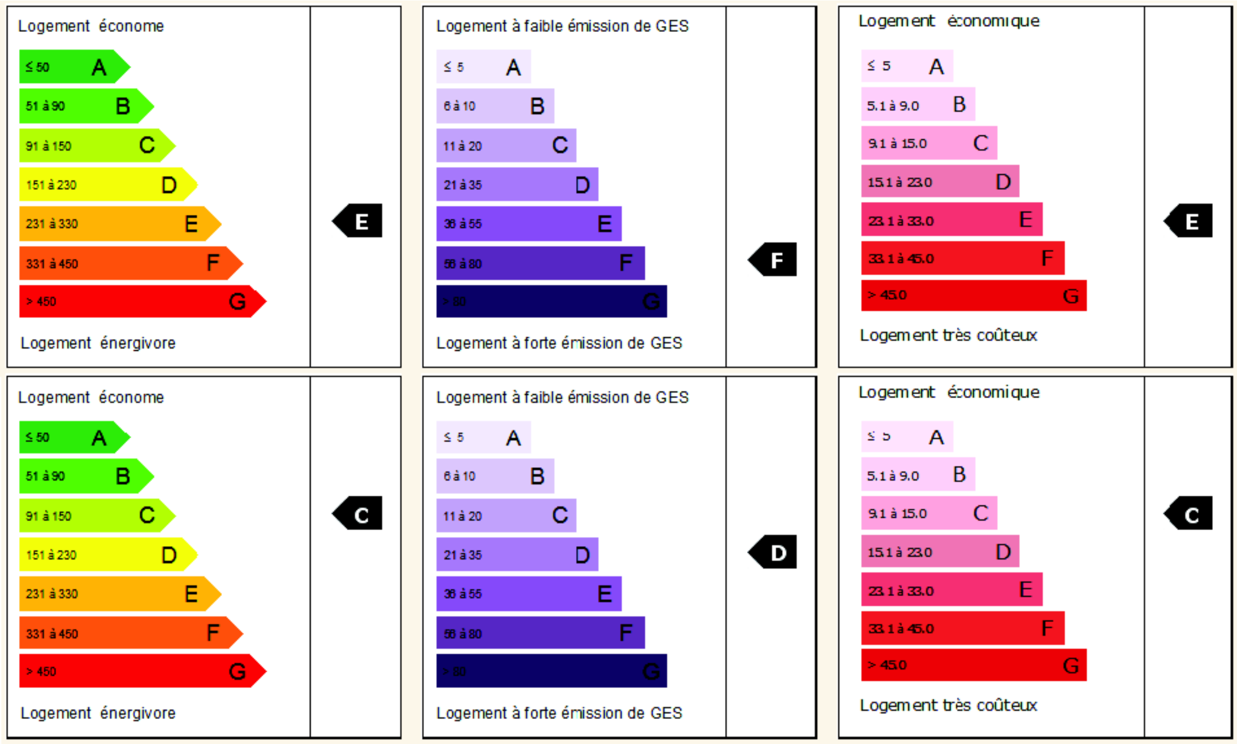

Figure 35: Extract of results from Bati-Cube. On the top the labels represent the existing state, and on the bottom the estimates after retrofitting. From left to right: energy demand (kWhpe/m².year), CO_2 emissions (kgCO_2/m².year), cost index (€/m².year)

Table 3: Example of estimates of energy consumption, CO_2 emision, and bills reduction, comparison between the existing state and the estimates after retrofitting

	Energy need (kWhpe/m².year)	CO2 emissions kgCO2/m².year)	Cost index (€/m².year)
Existing state	305	61	27
Project	116	24	14
Saving	**189**	**37**	**13**
Savings (%)	**62%**	**61%**	**48%**

As outputs of the calculation, the bati-cube software specifies the energy class of each house (classification from A to G, A rating being attributed to the most energy-efficient buildings) before and after energy retrofitting works. Only houses increasing from an energy class E to B were eligible to the project.

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5.3 Sustainable mobility

The action described in subtask 2.7.1 includes the deployment of 24m full electric buses in Nantes Métropole (around 20 buses). Prior to the implementation of this action, one crucial information is the assessment of the energy consumption of the former generation of buses (natural gas based) on the considered Busway line (Buses with a High Level of Service, BHLS). Nantes Métropole worked with data provided by the SEMITAN (operator of the public transport network in Nantes Metropole) in order to provide an estimate of the consumption over the past years. This information is calculated considering the consumptions of the natural gas buses year by year and depends on the cumulated number of kilometres travelled.

Next figure shows how the annual consumption of the gas buses of the Busway line increased over the last years up to 9400 MWh/year. This number will allow in the next parts of the implementation of the action to assess the energy impact of the replacement of part of theses buses by electric ones. It will also provide useful information when dimensioning and defining the technical specifications of the charging stations infrastructure.

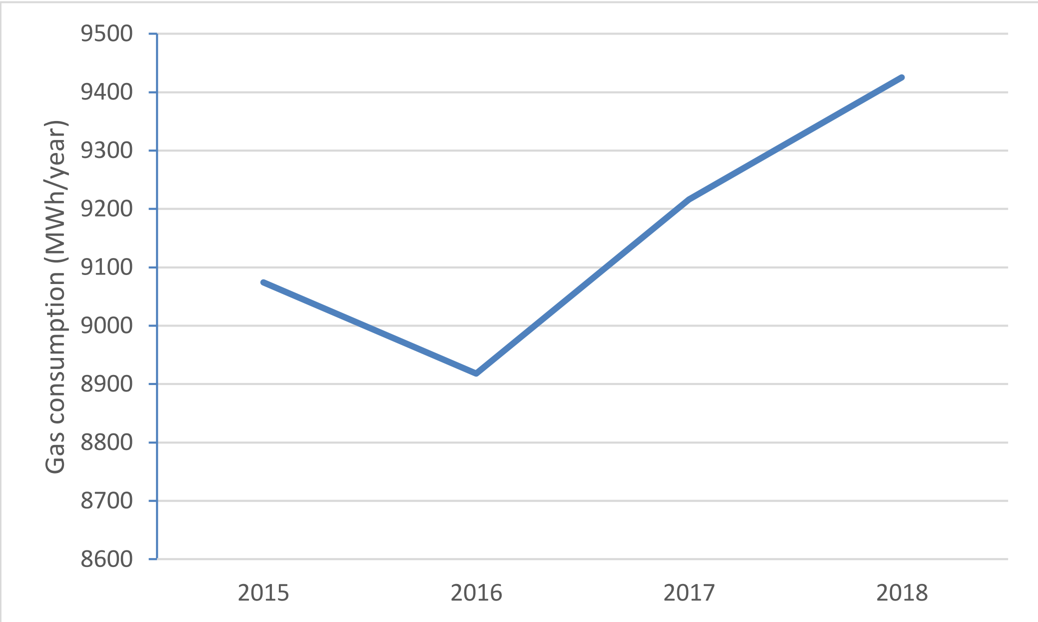

Figure 36: Gas consumption of the Busway line during the last years (in MWh/year)

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6. Conclusions

This deliverable has presented different types of results.

Section 3 focused on the methodological approach to apply a model in an urban transformation action. The choice of a model must be justified as a function of the stage of development of the action, the spatial and temporal perimeters of the action, the objectives of the action, the list of key design parameters, the information available, and the targeted level of detail of the results. Chosing the right model, at the right moment, and knowing to which extent we can confide in its result are key elements in every urban transformation action. This task has been getting more and more complex over the last years due to the increasing number of model and simulation tools available on the market.

Section 4 gives a quick overview of the different types of models which can be useful in urban transformation actions, and especially in the ones related to energy. In mySMARTLife a limited number of models have been used, they are representative of what can be implemented for the development of smart actions.

Section 5 presents different types of results obtained in the context of mySMARTLife actions in Nantes, based on the application of various simulations and measurements, where available. An interesting approach for the development of smart actions is to achieve to establish a relevant link between the analysis of the initial state of the context (e.g. based on measurement or bills) and the potential transformed state after implementation of the action (through simulations). Being able to compare the two states provide the required information for successful feasibility condtions (energy, economic, environmental). The results presented here generally correspond to information gathered prior to the definition of the baseline (cf Deliverable 2.1) and thus prior to the monitoring actions and KPIs delivery (cf Work Package 5).

Beyond the results presented here in the context of the actions of mySMARTLife, simulation softwares are very powerful tools at the moment of assessing the replication potential of solutions at a larger scale. For a city, in order to reach the targets in terms of energy management and renewable energy over a whole territory, models will play a crucial part to learn from the demonstrated results and extrapolate this information to different or larger contexts. The replication of the methods and technological solutions of mySMARTLife are a crucial component of the project: models and simulation tools offer here opportunities to plan the deployment of solutions at a larger scale (whole district, whole city, whole metropolitan area), and also in different contexts, for any ambitious city.

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7. References

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