D7.10

Benchmarking of EeB design innovations in the EU

Deliverable Report: D7.10 Final version

Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
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Benchmarking of EeB design innovations in the EU

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Colophon

The Streamer project is co-financed by the European Commission under the seventh research framework programme with contract No. 608739 - FP7-2013-NMP-ENV-EeB. The information in this publication does not necessarily represent the view of the European Commission. The European Commission shall not in any way be liable or responsible for the use of any such knowledge, information or data, or of the consequences thereof.

Abstract

This deliverable is the second and final deliverable for the task 7.5 in the work package 7. The objectives of this task is that all the project partners conduct field surveys in their own countries, and to provide a benchmark for comparing them. The task is composed of two deliverables, in which the first deliverable (D7.9) reported on the state-of-the-art and the best practices at EU level, whereas the current deliverable (D7.10) is composed of two main parts, namely: i) a report on the validation of STREAMER's output performed at the different project demonstration sites and including the usage of STREAMER's tools and further technology, and ii) a benchmark performed at country level.

In the first part, the four demonstration sites in STREAMER briefly describe the performed tasks and report on the validation tasks and the obtained results. Each demonstration site reports on the proposed EeB solution, using STREAMER and further technologies (BIM, GIS, and semantic labels). The main conclusions highlight the importance of using semantic labels during early design phases, and how STREAMER and the different BIM tools allow optimizing building parameters and assist designers for achieving energy efficient designs.

In the second part, a benchmark is defined for each of the four countries of the demonstration sites, to compare energy-related metrics. The defined benchmark did not allow to draw conclusions as originally expected since much more detailed figures from hospitals were needed for comparing different hospitals and drawing significant conclusions. This is due to the fact that the original description of the task was certainly very ambitious.

Publishable executive summary

Work package 7 of STREAMER is intended to perform a two-level validation: at technical and strategic levels. The previous deliverables in this work package have already described the demonstration sites, the technical work to be done, and on the performed workshops and demonstration sessions. This deliverable is intended to complete the previous deliverables by reporting on the technical tasks performed and the obtained results, and on performing an energy-related benchmark at country level, in the countries of the demonstration sites; i.e., The Netherlands, The United Kingdom, Italy, and France. To better organise our report, we have divided it into two main chapters, namely: demonstration results, and benchmarking.

For the demonstration results, we briefly describe the demonstration sites, and for each, we provide more details on the performed validation tasks, and the obtained results. The STREAMER project has allowed: i) to explore the potential for micro-upgrades, small improvements in localized departments, and providing comparative estimations of the relative benefits and costs; ii) created a robust pipeline for consolidating the available information and reintegrating the results into a unified building information model; iii) the assessment of different alternatives, including different layout, envelope, and MEP system; iv) and to study different scenarios for architectural projects during the predesign phase and to compare them in terms of energy consumption, financial on the whole life cycle or operational quality. The validation tasks have also allowed to study and validate the defined semantic labels defined at the beginning of the project, and the BIM tools developed throughout the project.

For the benchmark, since energy data collected from different EU countries is not comparable side-by-side given that defining a unified comparison framework turned out to be a task that is too complex to fit in the scope of the STREAMER project, we have performed a country-level benchmarking in four countries, namely: The United Kingdom, The Netherlands, Italy, and France. The conclusions drawn from the benchmarking task are not as originally expected since such conclusions require deeper information and analysis for each hospital. Achieving such information was not possible during the planned time for this task since the original description of the task was certainly too ambitious. However, it is important to note that a unique energy benchmark framework for all the EU hospitals is not easy due to the fact that building conditions are different between the north and the south countries, further than the site activities, functions, type of buildings, and typology. Furthermore, it is important to notice that there is a performance gap between the energy performance predictions, energy performance estimates and actual measured results. However, solutions such as the degree days methodology could have worked in this case if all the information was available for the methodology.

Finally, the document finishes by providing a short summary on the demonstration and validation performed and on the conclusions and lessons learnt from STREAMER.

List of acronyms and abbreviations

AHU	Air Heating Unit
BIM	Building Information Model
BSRIA	Building Services Research and Information Association
CHP	Combined Heat and Power
COBie	Construction Operations Building Information Exchange
DEM	Digital Elevation Model
DTS	Dynamic Thermal Simulation
EU	Europe
FR	France
GbXML	Green Building XML
HVAC	Heating, Ventilation, and Air Conditioning
IFC	Industry Foundation Classes
IT	Italy
LOD	Level Of Details
MEP	Mechanical, Electrical, and Plumbing
MVD	Model View Definitions
NCM	National Calculation Method
NL	Netherlands
RASE	Requirements, Applicability, Selection and Exception
SACS©	System for the Analysis of Hospital Equipment
SBEM	Simplified Building Energy Model
TECT	TNO Energy Calculation Tool
VE	Virtual Environment
WP	Work Package
UK	United Kingdom
XML	eXtensible Markup Language

Definitions

Building Information Model

To be meant as the whole of the digital information relating to a given building. This wording especially applies to the digital information built and maintained at design time, and that is relevant to the whole life cycle.

Otorhinolaryngology

It is a surgical subspecialty within medicine that deals with conditions of the ear, nose, and throat (ENT)

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1. Introduction

The STREAMER project is intended to study and assist the design of healthcare building designs and their energy efficiency. It is about developing a new method for designing energy efficient hospitals. The semantic typology model of existing buildings and districts contains the morphology of buildings/districts and the multi-dimensional representation of existing objects, as well as the knowledge of the building operation, functional problems, and the optimization opportunities. Such a semantic model is intended to provide the different stakeholders with a common set of references for evaluating and assessing different types of information in healthcare districts in use, such as costs, quality and energy efficiency.

Work package 7, to which this task belongs, is intended to perform a two-level validation, namely: at technical and strategic levels. The previous deliverables in this work package have already described the demonstration sites, the technical work to be done, and on the performed workshops and demonstration sessions. This deliverable is intended to complete the previous deliverables by reporting on the technical tasks performed and the obtained results in WP7, and on performing an energy-related benchmark at country level, in the countries of the demonstration sites; i.e., The Netherlands, The United Kingdom, Italy, and France. To better organise our report, we have divided it into two main chapters, namely: demonstration results, and benchmarking.

The first part of this deliverable reports on the demonstration results. For each demonstration site (in UK, NL, IT, and FR), we briefly describe the demonstration sites and the chosen buildings for STREAMER. Then, we provide more details on the performed validation tasks, and the obtained results at each demonstration case. These cases are intended to show how the technology developed in STREAMER, and how BIM technology has assisted decision making for the three kinds of tasks: new construction, old construction, and refurbishment.

The main objective of a semantic model is to provide design teams, building operators, clients and occupants with a common set of references for evaluating and assessing different types of information, for instance about the expected performances from healthcare districts in use (costs, quality and energy efficiency). By attaching properties and characteristics to the different spatial entities of the semantic model in an early design stage, it will be possible to manage the implications of design choices. For instance when optimizing those ones influencing the energy efficiency of the buildings. Keystones in the STREAMER design method are the labels

As a conclusion from the demonstration cases, the STREAMER project has allowed: i) to explore the potential for micro-upgrades, small improvements in localized departments, and providing comparative estimations of the relative benefits and costs; ii) created a robust pipeline for consolidating the available information and reintegrating the results into a unified building information model; iii) the assessment of different alternatives, including different layout, envelope, and MEP system; iv) and to study different scenarios for architectural projects during the predesign phase and to compare them in terms of energy consumption, financial on the whole life cycle or operational quality. The validation tasks have also allowed to study and validate the defined semantic labels defined at the beginning of the project, and the BIM tools developed throughout the project.

The second part of this deliverable reports on the benchmarking tasks performed in this task. For benchmarking, energy data collected from different EU countries cannot be easily comparable side-by-side; i.e., it is not possible to compare the collected value due to the fact that it is not possible to compare different buildings with very different conditions, such as the climate, the function, and the location. For the previous reasons, we have performed a country-level benchmarking in four countries, namely: The United Kingdom (UK), The Netherlands (NL), Italy (IT), and France (FR). For each country, we have analysed a set of building parameters and tried to draw a conclusion. Please note that a possible solution for this issue could have been the use of degree-days method[1], but due to time restrictions and the impossibility to collect further data for the benchmark, this method was not performed.

The conclusions we can draw from the benchmarking task is that despite the valuable information we were able to collect from hospitals, the benchmark did not allow to draw conclusions as it was originally expected; i.e., performing a more complete benchmark for all the EU hospitals requires a deeper analysis of the current data collected, and the hospital features. Furthermore, it is important to notice that there is a performance gap between the energy performance predictions, energy performance estimates and actual measured results. Unfortunately, the degree-days method was not applied, which would had given accurate and complete comparison, but would require more information and deeper analysis.

In the following, Chapter 2 reports on the performed work and achieved results at each demonstration site, namely: Chapter 2.2 for UK demonstration site, Chapter 2.3 for NL demonstration site, Chapter 2.4 for IT demonstration site, and Chapter 2.4 for FR demonstration site. Then, we provide the benchmarking performed in each of these counties in Chapter 3. We finally provide a summary on the performed work and our conclusions.

2. Demonstration results

2.1 UK demonstration case study

2.1.1 Description of the technical work done during the last two years

The task of modelling TRF began in March 2015. It was clear that a fast track approach would be required to meet the expected date for delivery of a BIM model, set for the end of May 2015. It was clear that modelling the whole hospital campus to the level demanded by conventional BIM to simulation with all spaces, walls, partitions, and HVAC and lighting systems would not be practical. Two sections of the TRF estate were identified and a written and photographic review prepared. Initial modelling of just these two zones highlighted the large number of unknowns relating to spaces and components. Instead the key information relating to zones and systems was collected.

[1] http://www.degreedays.net/

A review of the scale and information needed for a conventional detailed BIM model was performed, and it was concluded that it was unlikely that the detailed information on activities, materials and components would be available. It was concluded that it was not practical nor necessary to model individual rooms, only to perform analysis based on the characteristics of the functional departments. Similarly, it was not practical nor necessary to model individual components, only to perform analysis based on the characteristics of the functional systems present including considering the external fabric as a system. Information on departmental activity and fabric and mechanical systems was available. It is necessary to transcribe the known parameters from the written report. In particular the facility was represented as a set of attributes and as a set of named physical systems (include fabric and MEP), classified by purpose, and as a set of named spatial zones corresponding to the functional departments classified by the Streamer 'layering' classification conventions (D1.1).

2.1.1.1 Options strategy

The outcome from mark-up of the report included cataloguing the proposed alternative upgrade options for the fabric and MEP systems. This catalogue of potential systems upgrades was analogous to the catalogue of new systems produced in WP2 deliverables.

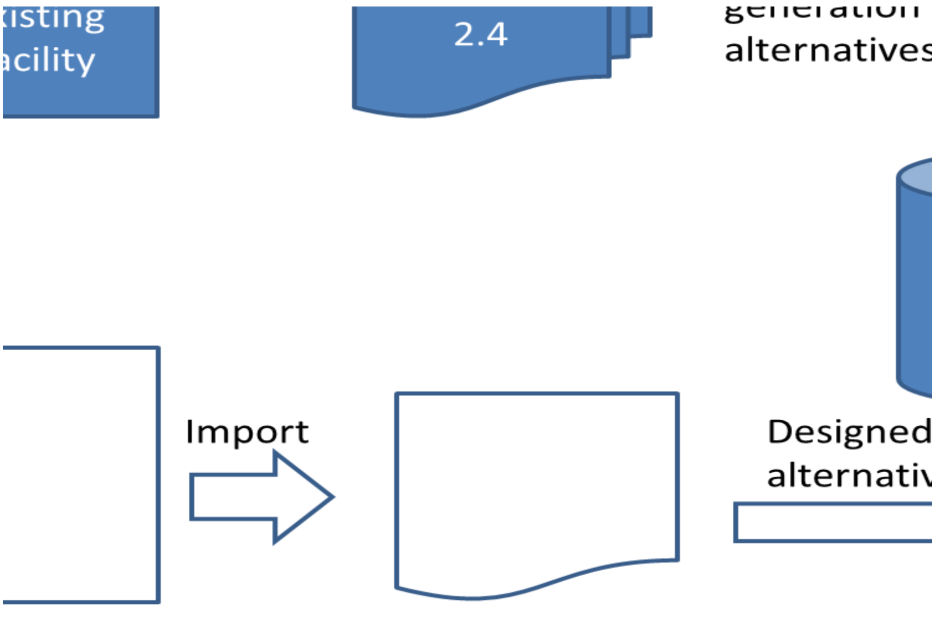


Figure 1: Acquiring a hospital design and alternative interventions where there is little structured information.

The transcription from the written report was performed manually and again automatically using structured mark-up. The transcription can be verified by regenerating the written description as a formal report from the knowledge captured in the mark-up. The target format was COBie. COBie is a structured multi-sheet spreadsheet designed to capture the design and construction information of facilities in preparation for handover to operations. It has a rich data structure that has strong correspondence to IFC and gbXML. (See US NBIMS v3 and BS1192 part 4).

Both IFC and to gbXML can be imported into some energy simulation applications. In particular mappings of IFC into UK NCM SBEM, the UK National Calculation Method Simplified Building Energy Model, was available.

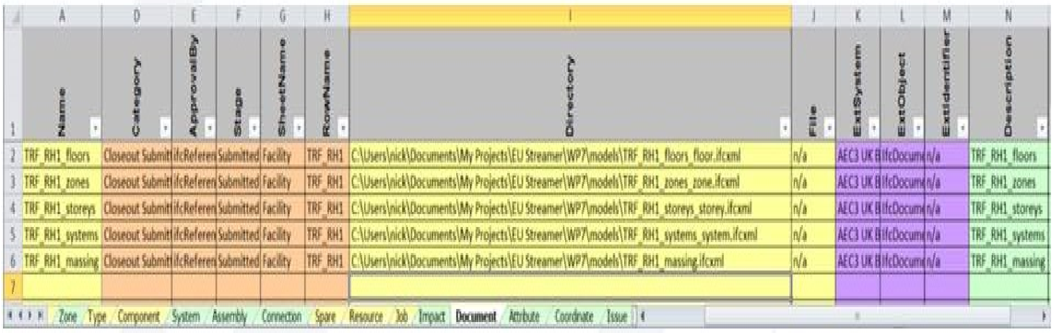
2.1.1.2 Additional information

The COBie document was enhanced with parametric rules to map known attributes (floor area, standard depth, overall volume) into plausible geometry for the systems and zones. The proposed alternative upgrade options for the Fabric and MEP systems were catalogued so as to be available to be iterated over to generate a set of alternative COBie models. Each COBie sub-model was then automatically mapped to IFC and merged with other sub-models.

2.1.1.3 Part models and merging

Each dataset acquired from TRF was treated as a partial model. Where possible the data was mapped directly to IFC using an AEC3 mapping tool. The datasets covered:

- Geolocation, the address, latitude, longitude, elevation and orientation of the TRF site
- Massing, the major shape of the main hospital building
- Floor naming, with datum heights.
- Departments and zones, with floor areas and heated volumes
- OPD (Out-patient Department D) and B6 (Ward B6 Ophthalmology) report
- Schedule of alternative Fabric and MEP System upgrades



Name	Category	ApprovalBy	Stage	SheetName	RowName	Directory	File	ExtSystem	ExtObject	ExtIdentifier	Description
TRF_RH1_floors	Closeout Submit	ifcReferen	Submitted	Facility	TRF_RH1	C:\Users\nick\Documents\My Projects\EU Streamer\WP7\models\TRF_RH1_floors_floor.ifcxml	n/a	AEC3 UK B	IfcDocumen	n/a	TRF_RH1_floors
TRF_RH1_zones	Closeout Submit	ifcReferen	Submitted	Facility	TRF_RH1	C:\Users\nick\Documents\My Projects\EU Streamer\WP7\models\TRF_RH1_zones_zone.ifcxml	n/a	AEC3 UK B	IfcDocumen	n/a	TRF_RH1_zones
TRF_RH1_storeys	Closeout Submit	ifcReferen	Submitted	Facility	TRF_RH1	C:\Users\nick\Documents\My Projects\EU Streamer\WP7\models\TRF_RH1_storeys_storey.ifcxml	n/a	AEC3 UK B	IfcDocumen	n/a	TRF_RH1_storeys
TRF_RH1_systems	Closeout Submit	ifcReferen	Submitted	Facility	TRF_RH1	C:\Users\nick\Documents\My Projects\EU Streamer\WP7\models\TRF_RH1_systems_system.ifcxml	n/a	AEC3 UK B	IfcDocumen	n/a	TRF_RH1_systems
TRF_RH1_massing	Closeout Submit	ifcReferen	Submitted	Facility	TRF_RH1	C:\Users\nick\Documents\My Projects\EU Streamer\WP7\models\TRF_RH1_massing.ifcxml	n/a	AEC3 UK B	IfcDocumen	n/a	TRF_RH1_massing

Zone / Type / Component / System / Assembly / Connection / Spare / Resource / Job / Impact / Document / Attribute / Coordinate / Issue

Figure 2: Partial models listed as 'Documents' in the COBie representation.

The generation of a single IFC model from COBie automatically includes these sub-models (***Figure 2***).

2.1.1.4 Geolocation

The address, latitude, longitude, elevation and orientation of the TRF site (Figure 3).

Figure 3: Open source mapping can provide the geolocation

2.1.1.5 *Massing*

The major shape of the main hospital building was documented from the published floor diagrams, and aligned with geo-imaging to obtain the appropriate building orientation (Figure 4).

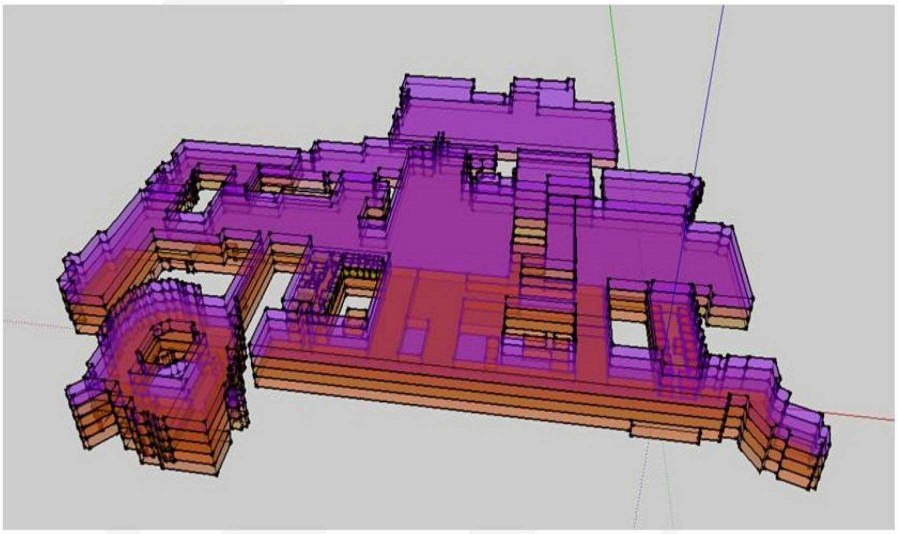


Figure 4: General arrangement captured using SketchUp with IFC export.

2.1.1.6 OPD and B6 report

The written report was marked up using a simple four-colour tool to identify the applicability, selectivity and declarations using the published RASE (Requirements, Applicability, Selection and Exception) methodology. Being a descriptive document, there were no exceptions found, and requirements appear as descriptions. For the illustrated example, the applicability (green) is narrowed down from the whole estate down to 'OPD' , then narrowed down further to cover 'Constructions' and down further to 'Windows'. The declaration (blue) gives the description of the window type (*Figure 5*).

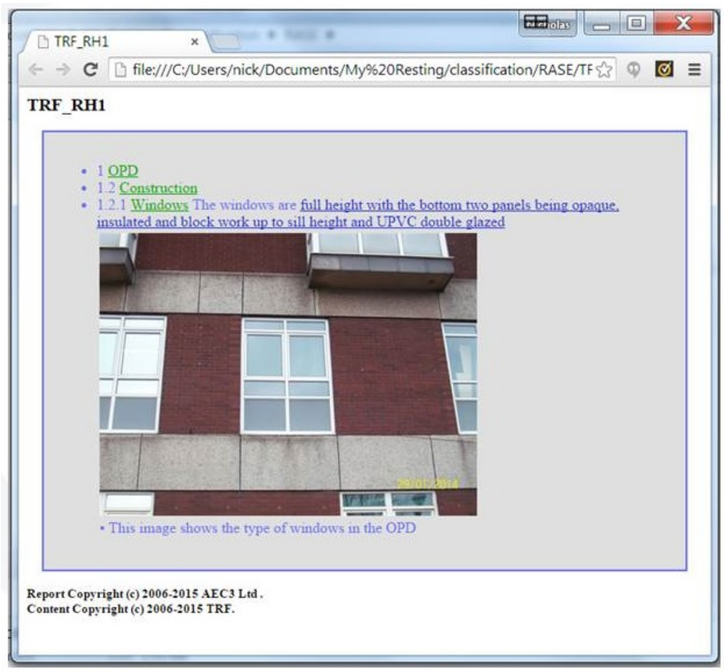


Figure 5: Marked up extract from the OPD and B6 written report

Space Name	Outpatients Department (OPD) - ADMIN	Ward B6 - Ophthalmology - Level B - HOTEL
Space ID	OPD	B6
Department	Outpatients	Ophthalmology
Shape	Crossbar	Ell
Level	0	B
Area (m2)	2023	623
STREAMER Use Labelling 2015	UO : Office Use	UH : Hotel Use
STREAMER Accessibility Labelling 2015	A2 : Patients, visitors and staff	A2 : Patients, visitors and staff
STREAMER Construction Labelling 2015	C1 : Office level	C1 : Office level
STREAMER Equipment Labelling 2015	E5 : Office level and medical gases, extra electrical power and extra ICT data point	E5 : Office level and medical gases, extra electrical power and extra ICT data point
STREAMER Hygiene Labelling 2015	H3 : Patient room, examination room, treatment room, etc.	H3 : Patient room, examination room, treatment room, etc.
STREAMER Operations Labelling 2015	O1 : Monday to Friday from 8 : 00–18 : 00	O4 : Continuous operation
Clear Height (mm)		
Heated Volume (m3)	5159	1589
HV % of Site HV	2.93%	90%
No. of Areas	8 (6 Receptions, ENT, Oral & Maxillofacial)	1 (Ophthalmology Ward)
No. of Rooms	68	25
No. of Corridors	4	2
No. of Rooms Heated		15
Heating Circuits	4 (via BMS)	1 (PR3 (w) via zone valve 12)
Electrical Metering	None	None
Heat Metering	None	None
Ventilation	Natural (no AHU)	Some Mechanical (supply only - no energy recovery)
Floor Construction	Concrete and Screed	Concrete and Screed
Floor Finish	Lino	Lino
Floor Notes	Stramit Boards between Floors	Stramit Boards between Floors
External Walls	Traditional Brick/Block with Cavity	Traditional Brick/Block with Cavity

Figure 6: Tabulated summary from the mark-up of the written report on OPD and B6

The results of extracting attribute information from the mark-up of the OPD and B6 report were tabulated for review (Figure 6). Additional classification information was added, following the STREAMER labelling conventions from D1-1. This spreadsheet was then mapped to IFC to create a partial model.

2.1.1.7 Storey (floor) naming

The massing and zones were assembled relative to the notional heights of the named floors. From the information provided a simple spreadsheet was prepared with datum heights (Figure 7). Again this spreadsheet was mapped to IFC to create a partial model.

Name	Description	Elevation	NominalHeight
R	Roof Level	6900	0
A	Top level	3270	3630
B	Ward level	-360	3630
C	Entry level	-3990	3630
D	Admin level	-7620	3630
E	Lowest level	-11250	3630

Figure 7: A summary of datum levels from TRF

2.1.1.8 Departments and zones

TRF provided a schedule of all the named Departments and Buildings in the district/campus. Where duplicate names had been used, these were distinguished by appending the floor letter (A-E) or a sequential number (1,2, …) to the name (Figure 8).

Level	Occupied	Name	Actual GIA owned	Occupied	Non Occupied	Heated Area	Heated Volume	Description
B	TRUE	Ward B6	623	623	0	623	1589	Ward B6
B	TRUE	Ward B5	629	629	0	629	1604	Ward B5
B	TRUE	Ward B4	585	585	0	585	1492	Ward B4
B	TRUE	Ward B3	612	612	0	612	1561	Ward B3
B	TRUE	Ward B2	683	683	0	683	1742	Ward B2
B	TRUE	Ward B1	667	667	0	667	1701	Ward B1
A	TRUE	Ward A7	623	623	0	623	1589	Ward A7
A	TRUE	Ward A6	525	525	0	525	1339	Ward A6
A	TRUE	Ward A5	611	611	0	611	1558	Ward A5
A	TRUE	Ward A4	585	585	0	585	1492	Ward A4
A	TRUE	Ward A3	646	646	0	646	1647	Ward A3
A	TRUE	Ward A2	594	594	0	594	1515	Ward A2
A	TRUE	Ward A1	602	602	0	602	1535	Ward A1
B	FALSE	Void	2784	0	2784	0	0	Void
A	TRUE	Vascular Access Team	32	32	0	32	82	Vascular Access Team
C	Leased	Unit 9 Costa Coffee (Compass)	283	283	0	283	722	Unit 9 Costa Coffee (Compass)
C	Leased	Unit 8 Florist (Helliwells)	23	23	0	23	59	Unit 8 Florist (Helliwells)

Figure 8: Extract from list of departments and buildings.

2.1.1.9 OPD and B6 schedule of alternative Fabric and MEP Systems

A schedule of alternative Fabric and MEP systems upgrades (Figure 9) was compiled from the written report. In each case the current, as-is, situation has been named Option 0, and other alternatives have been numbered sequentially Option 1… All the alternatives for a system have the same classification, in this case using Uniclass (2015). Further interviews and research was conducted to characterise these options from their descriptions (green), and the need to represent them in the analysis tools.

Name	CreatedBy	CreatedOn	Category	ComponentNames	ExtSystem	ExtObject	ExtIdentifier	Description
B6 Ceilings Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_30_25_	B6 Ceilings Option 0	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Suspended ceilings with fibre board tiles with metal slatted ceilings to so
B6 External Glazing Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_25_60_	B6 External Glazing Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Full height wooden framed single glazed, bottom two panels opaque, ins
B6 External Glazing Option 1	nn@aec3.	2015-02-17T10:10:41	Ss_25_60_	B6 External Glazing Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Triple glazed units with greater natural light
B6 External Glazing Option 2	nn@aec3.	2015-02-17T10:10:41	Ss_25_60_	B6 External Glazing Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Solar tinted glass or film
B6 External Glazing Option 3	nn@aec3.	2015-02-17T10:10:41	Ss_25_50_	B6 External Glazing Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Solar shading
B6 External Walling Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_25_13_	B6 External Walling Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Traditional masonry brick and block construction
B6 Floors Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_30_12_	B6 Floors Option 0	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Concrete, screed and lino with Stramit boards installed between the floo
B6 Heating Circuits Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_60_40_	B6 Heating Circuits Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	One heating circuit PR3(W) via zone valve 12
B6 Heating Controls Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_75_70_	B6 Heating Controls Option	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Single temperature sensor heating control for whole zone
B6 Heating Controls Option 1	nn@aec3.	2015-02-17T10:10:41	Ss_75_70_	B6 Heating Controls Optio	eneral Spreadsheet to IFC converter	IfcSystem	Osys00000	Individual room/area wireless temperature sensor heating controls
B6 Heating Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_60_40_	B6 Heating Option 0	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Frenger heated ceilings with a small proportion of wet heating systems
B6 Heating Option 1	nn@aec3.	2015-02-17T10:10:41	Ss_60_40_	B6 Heating Option 1	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Underfloor heating system
B6 Insulation Option 0	nn@aec3.	2015-02-17T10:10:41	n/a	B6 Insulation Option 0	General Spreadsheet to IFC converter	IfcSystem	Osys00000	25-50mm thick fibre glass insulation to ceilings and mineral insulation to
B6 Insulation Option 1	nn@aec3.	2015-02-17T10:10:41	n/a	B6 Insulation Option 1	General Spreadsheet to IFC converter	IfcSystem	Osys00000	100mm thick insulation to ceilings and additional cavity insulation to ext
B6 Insulation Option 2	nn@aec3.	2015-02-17T10:10:41	Ss_25_20_	B6 Insulation Option 2	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Clad external walls with EWIS (External Wall Insulation System)
B6 Internal Partitions Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_25_10_	B6 Internal Partitions Optio	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Plasterboard internal walls
B6 Lighting Automatic Controls Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_70_80_	B6 Lighting Automatic Cont	General Spreadsheet to IFC converter	IfcSystem	Osys00000	No controls
B6 Lighting Automatic Controls Option 1	nn@aec3.	2015-02-17T10:10:41	Ss_70_80_	B6 Lighting Automatic Cont	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Occupancy sensor control and dimmable options
B6 Lighting Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_70_80_	B6 Lighting Option 0	General Spreadsheet to IFC converter	IfcSystem	Osys00000	5 foot, 65W, T12 fluorescent, two rooms have 4 x 18W modular fluoresc
B6 Lighting Option 1	nn@aec3.	2015-02-17T10:10:41	Ss_70_80_	B6 Lighting Option 1	General Spreadsheet to IFC converter	IfcSystem	Osys00000	LED 600x600mm 40W tile panel lighting and/or High Frequency T5 fluore
B6 Mechanical Ventilation Option 0	nn@aec3.	2015-02-17T10:10:41	Ss_65_: Ve	B6 Mechanical Ventilation	General Spreadsheet to IFC converter	IfcSystem	Osys00000	Some mechanical ventilation but supply only with no energy recovery

Figure 9: Extract form the schedule of alternative Systems

2.1.1.10 System monitoring

In parallel with the development of these part models, TRF had begun to collate their metering information and install additional metering on their heat distribution system and on the distribution boards and subsidiary circuits. Whilst these need not be part of the BIM model of TRF used for performance analysis, it was decided to review and absorb this additional information ready for comparisons later.

There are three fuel types involved, and meter readings for all three are available (Figure 10):

- Gas
- Heat
- Electricity

Date	Ward B6				Oral Maxillo				Eye Clinic				Reception A				Reception D			
	EB40	EB40 Cons	B40	B40 Cons	EC6	EC6 Cons	C6	C6 Cons	EC7A	EC7A Cons	EC7B	EC7B Cons	EC8A	EC8A Cons	EC8B	EC8B Cons	EC9A	EC9A Cons	EC9B	EC9B Cons
03/07/2014					2556		4106						653		502		3810		3299	
11/08/2014					2636		4102						2636	1983	2010	1508	8490	4680	7362	4063
02/09/2014	2031		438		2669		4103						3876	1240	2971	961	10903	2413	9391	2029
02/10/2014	3862	1831	787	349	2699		4105						5665	1789	4364	1393	14563	3660	12560	3169
05/11/2014	5740	1878	1142	355	2746		4113						7863	2198	6135	1771	18593	4030	15977	3417
03/12/2014	7305	1565	1422	280	2769		4122						9630	1767	7696	1561	21939	3346	18858	2881
19/12/2014					20		71													
13/01/2015	9526	2221	1811	389	465	445	1546	1475					12021	2391	9558	1862	26532	4593	22739	3881
21/01/2015									390	390	345	345								
30/01/2015	10568	1042	2004	1042	912	447	2934	1388	1577	1187	1411	1066	13314	1293	10639	1081	28688	2156	24534	1795
03/03/2015	12345	1777	2331	1777	1632	720	5014	2080	5436	3859	4881	3470	15387	2073	12378	1739	31788	3100	26939	2405
01/04/2015	13660	1315	2634	1315	2338	706	6799	1785	9043	3607	8137	3256	17234	1847	13867	1489	34920	3132	29259	2320
Totals		11629		5507		2318		6728		9043		8137		16581		13365		31110		25960
Average		1661		787		580		1682		2261		2034		1842		1485		3457		2884
Entries		7		7		4		4		4		4		9		9		9		9
Spread		391		594		154		315		1734		1565		383		304		879		807
Annual Estimate		20117		9526		8214		23842		42317		38077		22250		17935		41747		34836

Figure 10: Electric Meter collation for Ward B6 (and others)

The meter readings were interpreted to give an Estimated Annual Consumption and an average Power demand: for example, given readings in kWh

- Estimated Annual Consumption = 365 *(max (reading) – min (reading)) / *(max (date) – min (date))
- Average Power Demand = 1000 / 24 *(max (reading) – min (reading)) / *(max (date) – min (date))

2.1.1.11 Sub-circuit Monitoring

TRF also had installed instantaneous monitoring of its distribution boards and sub-circuits. This allows detailed performance predictions to be compared against actual, for specific purposes such as lighting, and the selection of suitable estimates of un-modelled consumption such as small-power. The installed monitoring system has three key components.

- Monitoring distribution boards so that the advanced energy monitoring system monitors every circuit, providing an in-depth understanding of energy usage.
- Smart meters take regular and accurate readings from gas and electricity meters, putting an end to estimated readings.
- A web-based reporting platform that turns the data from the smart meter, sub-meter reader and circuit level data into dashboards.

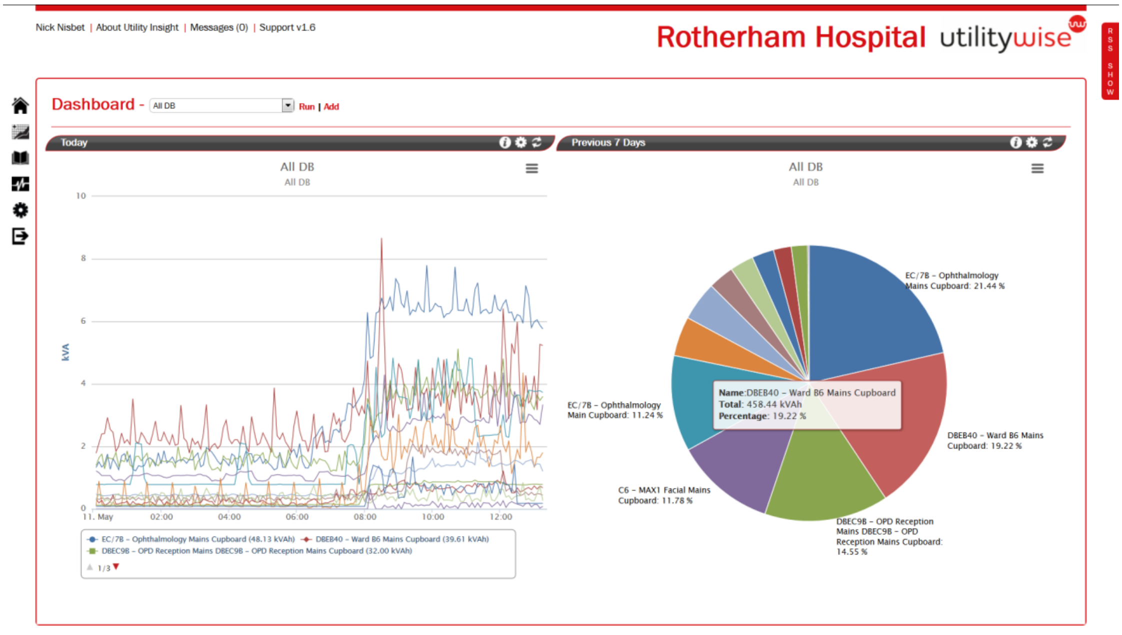


Figure 11: UtilityWise dashboard showing consumption from all monitored sub-circuits over 12 hours

Meters were modelled both as indicators of Systems, along with their terminals, and as Components in their own right, having a certain Type (specification). They served one (or more) departmental Zone. Where they served more than one Zone then their consumption was allocated to each department in proportion to the departmental areas.

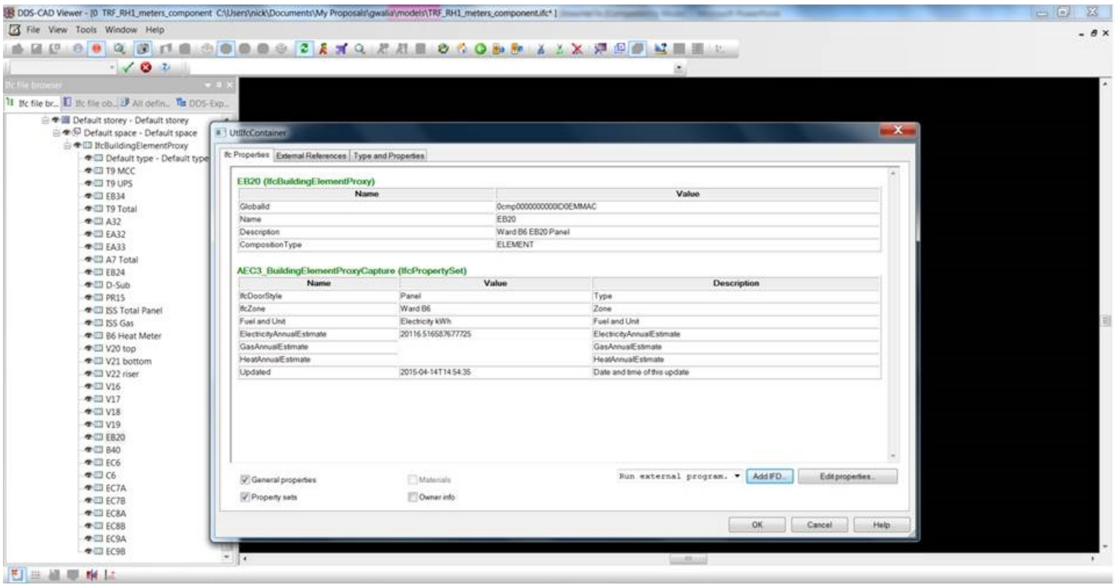


Figure 12: Ward B6 EB20 Distribution Panel show an Annual Estimated Consumption of electricity of 2016 kWh (IFC model)

2.1.1.12 Alternative upgrade proposals

The alternative designs for both as-is and for refurbishment schemes were expected to meet the Streamer model requirements ('model view definition') (D5-5) as a pre-requisite for the analysis stage. Some alternatives are shown in Figure 14 and Figure 15. For example, for the lighting upgrades, the key attributes are the luminaire type, emission efficiency and the indicative upgrade cost parameters.

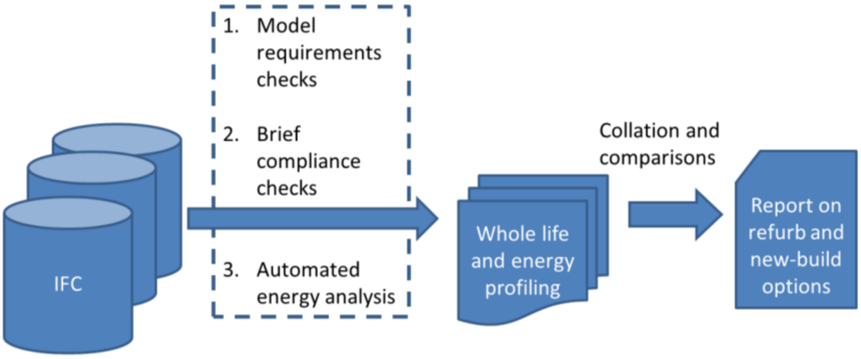


Figure 13: Designs can be checked and then analyzed, and the results collated

SystemLabel	RuleName	Description	Zone	Name	Classification	Lighting	Retrofitting	Funct. Area	Space Unit	Emission Efficiency	Construction Measure	Area of Construction (m2)	Cost Rate	LIGHT-TYPE	LIGHT-ACT-WATT	LIGHT-LUX-DESIGN
Lighting	OPC Lighting Option 0	Twin 6 foot 65W fluorescent T8, 4 x 18W modular fluorescent fittings and 38W 2D fittings	OPC	OPCLT0	Ss_70_80 : Lighting Systems	T8	YES	YES	YES	85	Floor Area	500	0.00		150	200
Lighting	OPC Lighting Option 1	LED 600x600mm 40W tile panel lighting and/or High Frequency T5 fluorescent fittings	OPC	OPCLT1	Ss_70_80 : Lighting Systems	T5	YES	YES	YES	76/90	Floor Area	500	50.00	LED	50	200
Lighting	B6 Lighting Option 0	5 foot, 65W, T12 fluorescent, two rooms have 4 x 18W modular fluorescent fittings	Ward B	WB6LT0	Ss_70_80 : Lighting Systems	LED / T12	YES	YES	YES	85	Floor Area	623	0.00		150	200
Lighting	B6 Lighting Option 1	LED 600x600mm 40W tile panel lighting and/or High Frequency T5 fluorescent fittings	Ward B	WB6LT1	Ss_70_80 : Lighting Systems	T5	YES	YES	YES	76/90	Floor Area	623	50.00	LED	50	200

Figure 14: Lighting as-is and upgrade options for both Departments

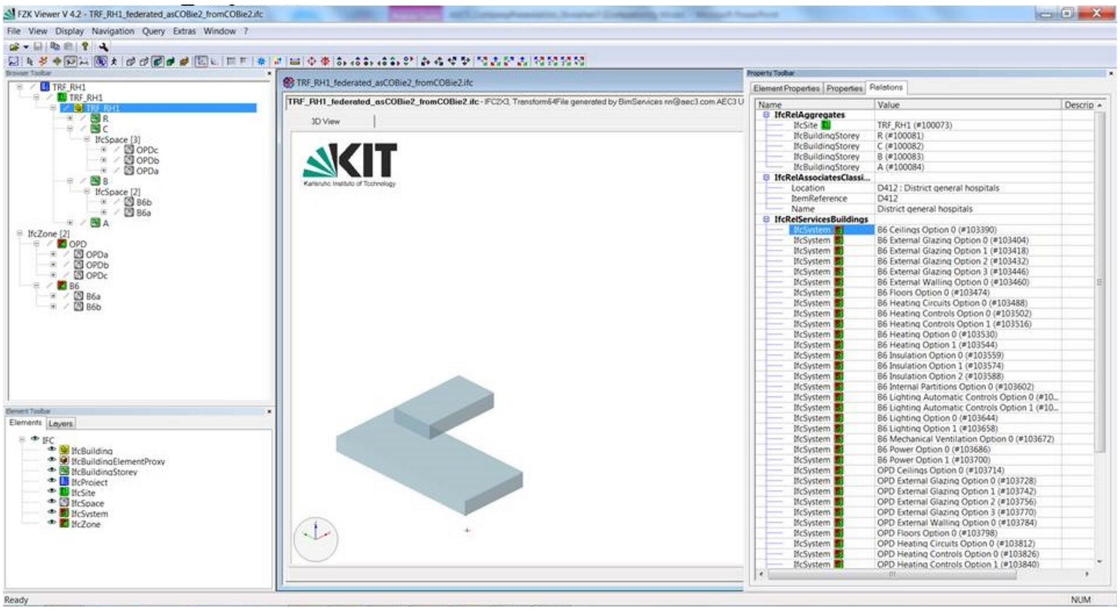


Figure 15: Ward B6 with all its optional System upgrades listed (IFC model)

2.1.2 Technical results

The energy consumption and demand for the whole hospital district, the proportion allocated to the two departments, the simulated figures for those departments and the metered usage can be tabulated. It can be noted that the energy consumption and demand predicted is seriously out of scale with the 2015 figures which use CHP (Combined Heat and Power), but not so markedly different from the 2007 pre-CHP figures. These figures are investigated further and compared against benchmarks in section 3 below

		District	Zones	Zones	Zones	Zones	Accuracy	Accuracy
		RH1	Proportion	SBEM	SBEM	Actual	SBEM	SBEM
	Unit			Consumption	Demand	Metered	Consumption	Demand
Area	m2	70072	1123	1123	1123	1123		
Heated Volume	m3	178067	2864					
Annual Electricity Consumption 2007	MJ	38659845	619577	808418	1228074		130%	198%
Annual Gas Consumption 2007	MJ	117861033	1888884	880512	880512		46%	46.%
Annual Electricity Consumption 2015	MJ	5252767	84182	808418	1228074		960%	1458%
Annual Gas Consumption 2015	MJ	146079687	2341127	880512	880512		37%	37%
Annual Energy Demand	MJ				2108587			
Annual Energy Consumption	MJ			1688931				
Heating energy demand	MJ	Gas			635001			
Auxiliary energy demand	MJ	Electricity			134026			
Lighting energy demand	MJ	Electricity			674391	210616		320%
Hot water energy demand	MJ	Gas			245511			
Equipment energy demand	MJ	Electricity			419656	107079		391%
Natural gas energy consumption	MJ			880512	880512			
Grid Supply Electricity energy consumption	MJ			808418	1228074			

The packages of fabric and system upgrades selected by the expert groups produced a range of results. One example strategy is shown here, created by the 'rdash' team at the first STREAMER implementers' workshop. The Upgrade project proposal and the Hospital District and two Departmental Zones are summarized, with the predicted annual energy consumption and demand. Each System Upgrade in the proposed package (whether applied to fabric or MEP) is documented with its 'constructed' (costing) area and estimated cost.

RH1 Refurbishment

The Rotherham NHS Foundation Trust	EU STREAMER REPORT	Streamer – European research on energy-efficient healthcare districts

Project: RH1 Project

Date: 2016-06-08T12:06:08

Prepared by: rdash

rdash-OPCLT1-OPCEG1-OPCIN1-WB6HT1-WB6HC1-WB6LT1-WB6LC1-WB6EG1-WB6IN1

Results			
Name	**Description**	**Value**	**Unit**
Project	**RH1 Project**	**RH1 Refurbishment**	
Phase	Option	rdash-OPCLT1-OPCEG1-OPCIN1-WB6HT1-WB6HC1-WB6LT1-WB6LC1-WB6EG1-WB6IN1	
Name	**Description**	**Value**	**Unit**
Site	**RH1 Site**	**Rotherham Hospital, Moorfield Road, Rotherham, RH1 9QX**	
Name	**Description**	**Value**	**Unit**
Building	**RH1 building**	**Rotherham Hospital**	
GrossAreaPlanned	GrossAreaPlanned	1123.00	m2
AnnualEnergyDemand	Energy demand	1603154.37	MJ
AnnualEnergyConsumption	Energy consumption	1183493.76	MJ
Capital Cost	Capital Cost	147954.75	£
Heating energy demand	Heating energy demand	675609.15	MJ
Auxiliary energy demand	Auxiliary energy demand	138790.45	MJ
Lighting energy demand	Lighting energy demand	33003.85	MJ
Hot water energy demand	Hot water energy demand	336094.81	MJ

Equipment energy demand	Equipment energy demand	419656.12	MJ
Natural gas energy consumption	Natural gas energy consumption	1011699.47	MJ
Grid Supply Electricty energy consumptions	Grid Supply Electricty energy consumptions	171794.29	MJ
Name	**Description**	**Value**	**Unit**
Zone	**OPC**	**OPC**	
BouwcollegeLayer	Four way classification of hospital spaces by activity	O	
AccessSecurity	Accessibility	A2	
Construction	Construction complexity	C1 : Office level Concrete and Screed Suspended Grid	
Equipment	Equipment density	EQ5 : Office level and medical gases, extra electrical power and extra ICT data point	
HygieneClass	HygieneClass	H3	
UserProfile	Usage profile	U1	
GrossAreaPlanned	GrossAreaPlanned	500.00	m2
Internal Gains from Persons	Internal Gains from Persons	109236.00	MJ
Internal Gains from Appliances	Internal Gains from Appliances	242072.00	MJ
Internal Gains from Lighting	Internal Gains from Lighting	1379.70	MJ
Internal Gains Total	Internal Gains Total	352688.00	MJ
Name	**Description**	**Value**	**Unit**
Zone	**Ward-B6**	**Ward B6**	
BouwcollegeLayer	Four way classification of hospital spaces by activity	H	
AccessSecurity	Accessibility	A2	
Construction	Construction complexity	C1 : Office level Concrete and Screed Suspended Grid	
Equipment	Equipment density	EQ5 : Office level and medical gases, extra electrical power and extra ICT data point	
HygieneClass	HygieneClass	H3	
UserProfile	Usage profile	U4	
GrossAreaPlanned	GrossAreaPlanned	623.00	m2
Internal Gains from Persons	Internal Gains from Persons	318212.00	MJ
Internal Gains from Appliances	Internal Gains from Appliances	175754.00	MJ

Internal Gains from Lighting	Internal Gains from Lighting	31624.20	MJ
Internal Gains Total	Internal Gains Total	525590.00	MJ
Name	**Description**	**Value**	**Unit**
System	**CHP**	**Combined Heat and Power**	
Zone	Collection of spaces sharing common requirements or properties	(district)	
Name	**Description**	**Value**	**Unit**
System	**OPCEG1**	**Triple glazed units with greater natural light**	
Zone	Collection of spaces sharing common requirements or properties	OPC	
Capital Cost	Capital Cost	21868.00	£
Area of Construction (m2)	Area of Construction (m2)	66.00	m2
Name	**Description**	**Value**	**Unit**
System	**OPCIN1**	**Additional cavity insulation to external walls**	
Zone	Collection of spaces sharing common requirements or properties	OPC	
Capital Cost	Capital Cost	3375.00	£
Area of Construction (m2)	Area of Construction (m2)	225.00	m2
Name	**Description**	**Value**	**Unit**
System	**OPCLT1**	**LED 600x600mm 40W tile panel lighting and/or High Frequency T5 fluorescent fittings**	
Zone	Collection of spaces sharing common requirements or properties	OPC	
Capital Cost	Capital Cost	25000.00	£
Area of Construction (m2)	Area of Construction (m2)	500.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6EG1**	**Triple glazed units with greater natural light**	
Zone	Collection of spaces sharing common requirements or properties	Ward-B6	

Capital Cost	Capital Cost	26838.00	£
Area of Construction (m2)	Area of Construction (m2)	59.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6HC1**	**Individual room/area wireless temperature sensor heating controls**	
Zone	Collection of spaces sharing common requirements or properties	Ward-B6	
Capital Cost	Capital Cost	6230.00	£
Area of Construction (m2)	Area of Construction (m2)	623.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6HT1**	**Underfloor heating system**	
Zone	Collection of spaces sharing common requirements or properties	Ward-B6	
Capital Cost	Capital Cost	21805.00	£
Area of Construction (m2)	Area of Construction (m2)	623.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6IN1**	**Additional cavity insulation to external walls**	
Zone	Collection of spaces sharing common requirements or properties	Ward-B6	
Capital Cost	Capital Cost	4680.00	£
Area of Construction (m2)	Area of Construction (m2)	268.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6LC1**	**Occupancy sensor control and dimmable options**	
Zone	Collection of spaces sharing common requirements or properties	Ward-B6	
Capital Cost	Capital Cost	7008.75	£
Area of Construction (m2)	Area of Construction (m2)	623.00	m2
Name	**Description**	**Value**	**Unit**
System	**WB6LT1**	**LED 600x600mm 40W tile panel lighting and/or High Frequency T5 fluorescent fittings**	
Zone	Collection of spaces sharing common	Ward-B6	

	requirements or properties		
Capital Cost	Capital Cost	31150.00	£
Area of Construction (m2)	Area of Construction (m2)	623.00	m2

The energy demand figures can be compared against those obtained by other team's proposals.

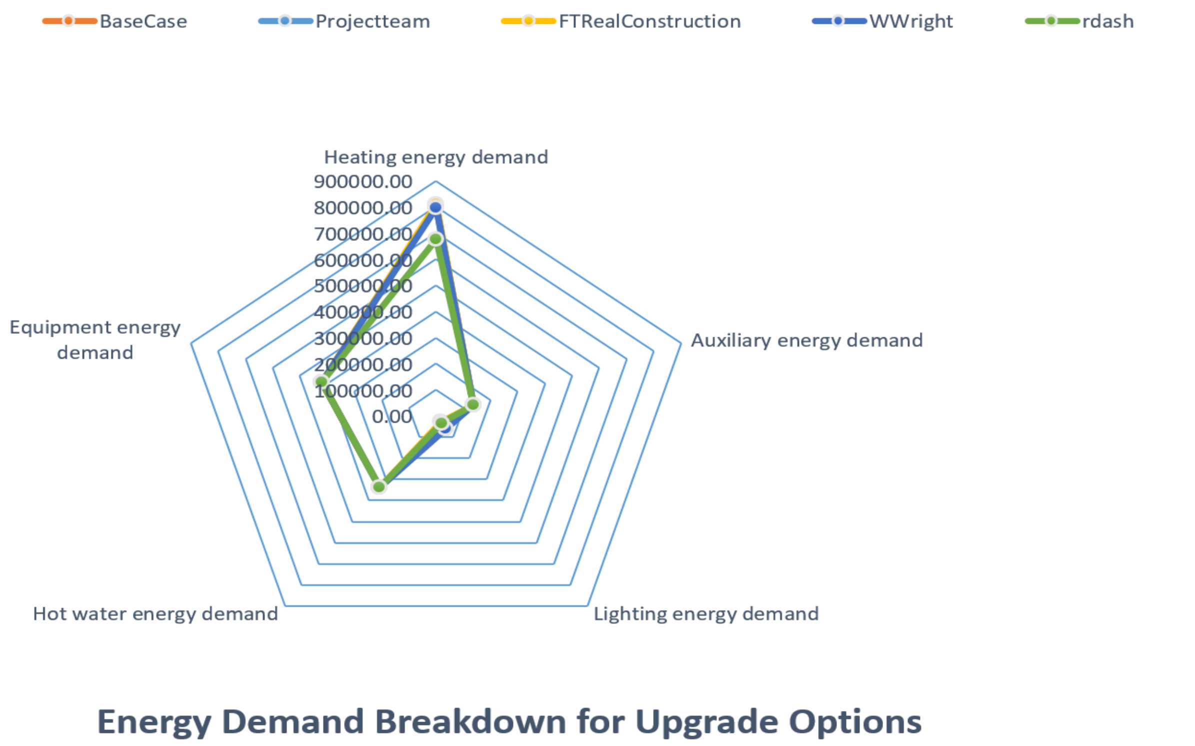


Figure 16: Various teams proposals can be compared for their imapct on different energy demand KPIs

More importantly for evaluating the final outcome, the energy consumption and demand figures are then compared to the base 'as-is' case to evaluate the benefit, and so obtain a benefit/cost ratio. The

KPI Measure	Unit	delta
Gross Area Planned	m2	0.00
Annual Energy Demand	MJ	-255430.81
Annual Energy Consumption	MJ	-255433.09
Capital Cost	£	147954.75
Heating energy demand	MJ	-280747.76
Auxiliary energy demand	MJ	0.00
Lighting energy demand	MJ	25316.95
Hot water energy demand	MJ	0.00

Equipment energy demand	MJ	0.00
Natural gas energy consumption	MJ	-280750.00
Grid Supply Electricity energy consumption	MJ	25316.91

Figure 17: Example delta detected from rdash proposed package of upgrades

The delta to energy demand can be converted to a cost saving ansd compared against the estimated capital cost, to give a payback period. The enrgy cost was taken as the anticipated cost of energy by 2020, £0.08/MJ

Option	Saving MJ/yr	Cost £	Payback yr
rdash	255430.81	147954.75	7

2.1.3 Implementers Community Follow Up Workshop (2nd workshop)

There was a second Implementers Community workshop held in London on 20/7/17 which aimed to generate discussion around the findings and results of STREAMER sessions.

STREAMER UK Implementers Community Workshop 2 with buildingSMART UKI Building Room

"Energy Modelling and Existing Buildings"

Venue and date University of Liverpool in London, 33 Finsbury Square, EC2 20th July 2017 6:00-8:30

Attendance

Martin Simpson	University of Liverpool
John Cartwright	TRF
Martin Aizlewood	TRF
Nick Nisbet	AEC3
Bob Wakelam	AEC3
Julian Schwarzenbach	dpadvantage ltd
Liam Murphy	LJM Ltd
Jeff Stephens	previously Vinci UK plc

Agenda

The problem of existing buildings and energy. Martin Simpson – Centre for Digital Built Environment (UoL)

10 years in the life of Rotherham Hospital – How has 31% reduction in carbon emission been achieved in 10 years: John Cartwright and Martin Aizlewood - TRF

BIM without modelling – How the EU STREAMER project led to a new approach to energy modelling focussing on whole zones and systems. Nick Nisbet - AEC3

Gaming Energy Refurbishment – How does "gaming" work and what might be in impact on existing facilities? Bob Wakelam – AEC 3

Discussion

Close

The presentations led into a detailed discussion. The major discussion points were:

1. Energy analysis is torn between two poles: ‘it has to be worth it, it has to be perfect’
2. STREAMER / Rotherham approach was judged to have strengths and weaknesses:
    a. Strong methodology
        i. Merging of existing data sources using IFC
        ii. Use of simple STREAMER labelling
        iii. Automated energy modelling
        iv. Collaborative gaming as a research method
    b. Weakness of UK NCM SBEM energy simulation tool
        i. CHP (Combined Heat and Power) was not correctly simulated
        ii. The presence of additional Heating controls was ignored
        iii. Known loads and activities could not be incorporated.
    c. Opportunity
        i. ‘Gaming’ (five-minute response time) but ‘Learning’ would need immediate response.
        ii. Online self-assessment as an open opportunity to explore, game and learn
        iii. Mixed modelling tools using detail where available but generic zone and systems where not
    d. Threats
        i. Over modelling may not produce proportionate improvements in results
        ii. Confusion of comparative and absolute predictions means that thermal modelling may lack credibility.
3. Existing BIM authoring and energy simulation tools are exclusively component and space focussed, and generally poor at Systems and Zones.
4. UK NCM SBEM proved insensitive to CHP and heating controls, and known power consumption. TRNSYS or IES might have been better.
5. Progressive analysis, coping with increasing and uneven levels of design development is needed
6. Batch-mode tools are needed for both formal optimisation and for gaming/learning experiences.

2.1.4 Conclusion

The STREAMER project has allowed TRF to explore the potential for micro-upgrades, small improvements in localized departments as the next stage of their energy strategy. Using the simplifications implied by the STREAMER labelling methodology, a system and zone based approach has been effective in giving comparative estimations of the relative benefits and costs. The range of available options and the costs associated to these were necessarily different from the options and costs associated to new build fabric and systems developed in WP2.

The project created a robust pipeline for consolidating the available information, supplying the UK NCM SBEM application with a zone and system model and reintegrating the results into a unified building information model. This was then used to create a ‘gaming’ environment where different stakeholders could collaborate in discussion and choose the combinations of upgrades they thought would give the most effective or largest positive benefit. The simulation gave feedback within a few minutes, which was suitable for a competitive environment but perhaps not fast enough for a continuous learning experience.

2.2 NL demonstration case study (RNS, DJG, TNO)

2.2.1 Description of the technical work done during the last two years.

The main objective of a semantic model is to provide design teams, building operators, clients and occupants with a common set of references for evaluating and assessing different types of information, for instance about the expected performances from healthcare districts in use (costs, quality and energy efficiency). By attaching properties and characteristics to the different spatial entities of the semantic model in an early design stage, it will be possible to manage the implications of design choices. For instance when optimizing those ones influencing the energy efficiency of the buildings. Keystones in the STREAMER design method are the labels[2].

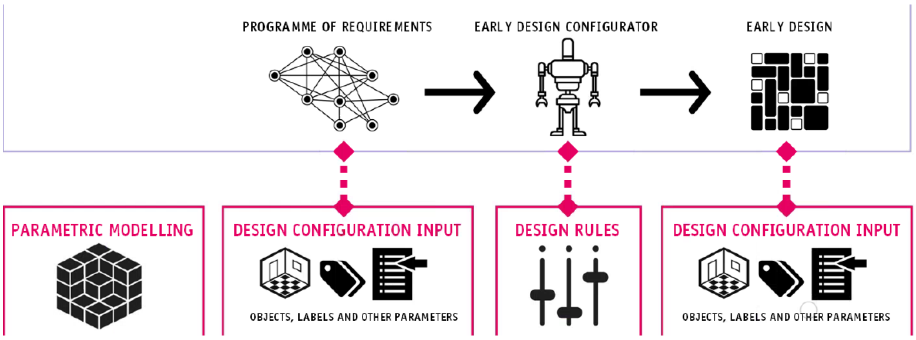


Figure 18: Labels in an early design process

The labels arranged along different levels: district, building, functional area, space unit and component. In this case we're focusing and monitoring on the room level.

2.2.1.1 Validation of the labels

The labels are representing values of requirements for KPI calculation. We distinguish several label names[3], as described below.

BouwcollegeLayer	Typology of the room according the Bouw College
Construction	Has a relation with floor strength, shielding against radiation, floor height, air tightness
Hygienic class	Has a relation with amount of ventilation, air tightness, cleaning, materials, windows
Equipment	Electrical power
User Profile	Opening timeslot
Comfort class	Has a relation with daylight, amount of ventilation, temperature, lighting, relative humidity and indoor noise
Access security	Accessibility

[2] See STREAMER Deliverable D1.2 Semantic typology model of existing buildings and districts, Roberto Di Giulio (IAA) 3rd September 2015.
[3] Based on the STREAMER labels release version 11082016

2.2.1.2 Rijnstate Hospital

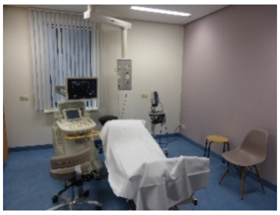
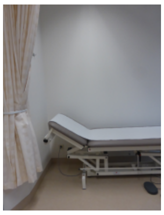
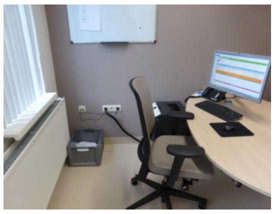
Currently Rijnstate has finished (March 2016) a 5.500 m2 large-scale extension project (North-East Extension). This extension aims to add several new outpatient services, to improve public space for visitors, to create treatment environment and several dedicated high-quality workspaces.

Figure 19: Rijnstate Hospital in Arnhem, The Netherlands

The project includes 3 stories and a basement. The medical activities are related to oncology treatment and outpatient activities in the field of otorhinolaryngology, vascular and internal medicine as well as related office facilities. In terms of usage a mixture of daily used patient and office spaces can be observed. Functionally, the most rooms in the extension are mainly rooms for consultation and rooms for treatments.

The following table shows the characteristics of the rooms, which are mainly situated in the extension. The room characteristics are as built in the extension. The STREAMER labels are based on the design requirements.

Table 2.1 Room characteristics

	Room 118	**Room 119**	**Room 140**	**Room 141**
Name	Consultation + examination room	Consultation + examination room	Vascular treatment rooms	Vascular treatment rooms
Picture				
Floor area [m²]	20	20	16	16
Stage	First Floor	First Floor	Second Floor	Second Floor
Building				
Walls				
Window	HR++ glazing, with internal sun and privacy screens	Yes, with internal sun and privacy screens	Yes, with internal sun and privacy screens	Yes, with internal sun and privacy screens
MEP				
Heating	Preconditioned fresh air from central AHU, with room thermostat for temperature control	Preconditioned fresh air from central AHU, with room thermostat for temperature control	Radiation nd conditioned fresh air with room thermostat	Radiation (858W) and conditioned fresh air with room thermostat
Cooling	Preconditioned fresh air from central AHU, with room thermostat for temperature control	Preconditioned fresh air from central AHU, with room thermostat for temperature control	conditioned fresh air from central AHU	conditioned fresh air from central AHU
Ventilation	Ventilation type D :	Ventilation type D:	Ventilation type D:	Ventilation type D :

Lighting	TL5 with light motion sensor control	TL5 with light motion sensor control	TL5 with light motion sensor control	TL5 with light motion sensor control
STREAMER labels from WP1.				
Acces Security	A2	A2	A2	A2
Bouwcollege Layer	O	O	O	O
Comfort Class	CT4	CT4	CT4	CT4
Construction	C1	C1	C1	C1
Equipment	EQ2	EQ2	EQ2	EQ2
Hygienic Class	H3	H3	H3	H3
Type Object	Room	Room	Room	Room
User profile	U1	U1	U1	U1

We want to validate the STREAMR room labels in a real case to check if the values, representing by the STREAMER labels are correct, realistic and useful in an early design process.

By monitoring the requirements in a real case we will validate the room labels. But only the characteristic label values of the room's as described above. Because there are only a limited number of spaces in the project, validation is only possible from a limited number of labels. In the table below we describe the validation method.
The table below shows the requirements of the representing STREAMER labels and the method of validation of that requirement.

Table 2.2 Label validation

Label description	**Requirements**	**Validation method**
Hygienic Class	Ventilation type	Visual inspection
	Supply Air Quality	Visual inspection
	Air Thightness	CO_2-monitoring and calculation
	Air Flow	CO_2-monitoring and calculation
	MEP context	Visual inspection
	Door type	Visual inspection

Label description	Requirements	Validation method
Equipment	Electric Power	Monitoring electricity
User profile	Timeslot	Monitoring CO_2-emission and timescale of ventilation and light control
Comfort Class	Daylight	Visual inspection
	Air flow	CO_2-monitoring and calculation
	Temp range	Temperature monitoring
	Lighting	Lighting motion monitoring
	Relative Humidity	Relative humidity Monitoring
	Control of lighting	Visual inspection

This validation is only on the labels as described below. Other parameters are out of scope.

2.2.1.3 Monitoring plan

The monitoring took place a period of several weeks. This makes it possible to focus on long term trends and exclude short term events (internal and external). The measurement interval is set to every 15 minutes. Some areas serve as a reference for monitoring. It is sufficient to monitor two pairs of reference areas. These areas include two day treatment rooms and two bedrooms. Preferably, adjacent areas are chosen, in order to be able to monitor thermal interaction. The measurement starts at the end of April and will last for about 6 weeks.

2.2.2 Technical results

The next room labels are monitored and could be validated.

2.2.2.1 Hygienic class

Table 2.3

STREAMER labels	Room label	Value Requirements	Monitoring	Validation
Hygienic Class	H3	Mechanical ventilation	Visual inspection	Present
		EN 13779 IDA 1 (F9)	Visual inspection	Present

Explanation:

The ventilation system is a ventilation type D: mechanical supply and mechanical extract. With air supply 160 m³/h per room (118 and 119)

The ventilation system is a ventilation type D: mechanical supply and mechanical extract. With air supply 130 m³/h per room (140 and 141). The central AHU does have an F9 filter on the supply air flow.

2.2.2.2 Equipment

Table 2.4

STREAMER labels	Roomlabel	Value Requirements	Monitoring	Validation
Equipment	EQ2 (office)	0.001 kW/m² (0.08 kW for each workstation)	Monitoring electrical equipment	Partially meet requirement

Explanation

The results of the monitoring of the electrical power is presented in the table below.

Table 2.5 Monitoring power usage

	Value Requirements	Room 118	Room 119	Room 140	Room 141	Average
Average Power Usage during 'in-use phase' [kW/m²]	0,001	0,002	0,010	0,001	0,001	0,003

The power usage is never equal during a period. There the average power compared.

The average power usage during 'in-use phase' is for 2 rooms more than the value of the requirements, with in room 119 is the biggest deviation. That's explainable because of the electric equipment in that room. It is not a typical EQ2 room. The streamer label EQ2 is designed for offices and speaking rooms, like Room 140 and 141. And Room 118 and room 119 does have other functions. These rooms are wrongly classified. These rooms should have another Equipment label.

2.2.2.3 User Profile

Table 2.6

STREAMER labels	Roomlabel	Value Requirements	Monitoring	Validation
User profile	U1	Office timeslot Mo-Fr 8:00 – 18:00 (30%)	Monitoring CO_2-concentration,	Meets the requirements

Explanation

The schedule timeslot of the rooms is Monday to Friday, between 8:00 and 18:00u. The CO_2-concentration in the rooms is monitored, to determine the presence of people in the rooms. Keep in mind that the CO_2-concentration is influenced by people, but also by the open doors. The closed or open position of the door is not monitored. Thus, the CO_2-concentration monitoring gives a good impression of the STREAMER label, however the CO_2-concentration is not full controlled by the ventilation system.

The figures below shows the CO_2-concentration during the 'in use' phase. The Y-axis represent the CO_2-concentration and the X-axis represent the hours during the monitoring period in the timeslot.

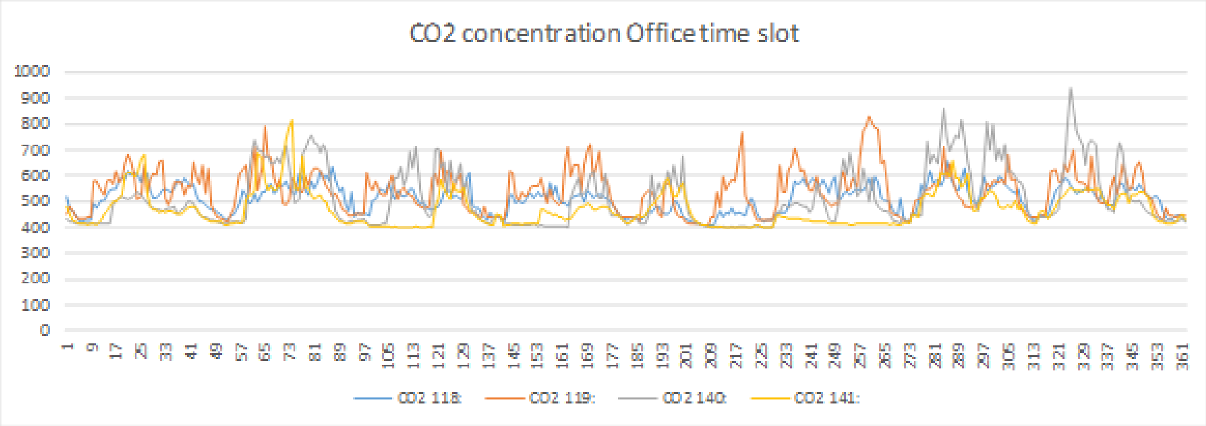


Figure 20: CO2-concentration in the rooms during Office time

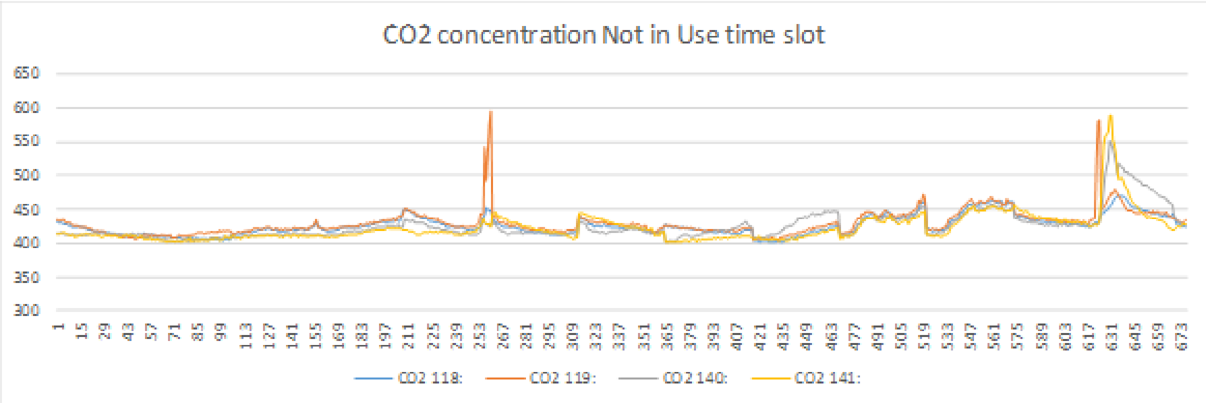


Figure 21: CO2-concentration in the rooms during the 'not-in-use' period

Except on Wednesday May 10 room 119 early in the morning and Wednesday May 17, all the rooms were in use in the evening.

The user profile is also validated by monitoring the light control in room 140. In the room, the light is controlled by a motion sensor. In the figure below the result of the control is visualized bot during office time and during the 'not in use' phase. The Y-axis represent the switch-on (1) and switch-off (0) of the lamp and the X-axis represent the timeslot of monitoring.

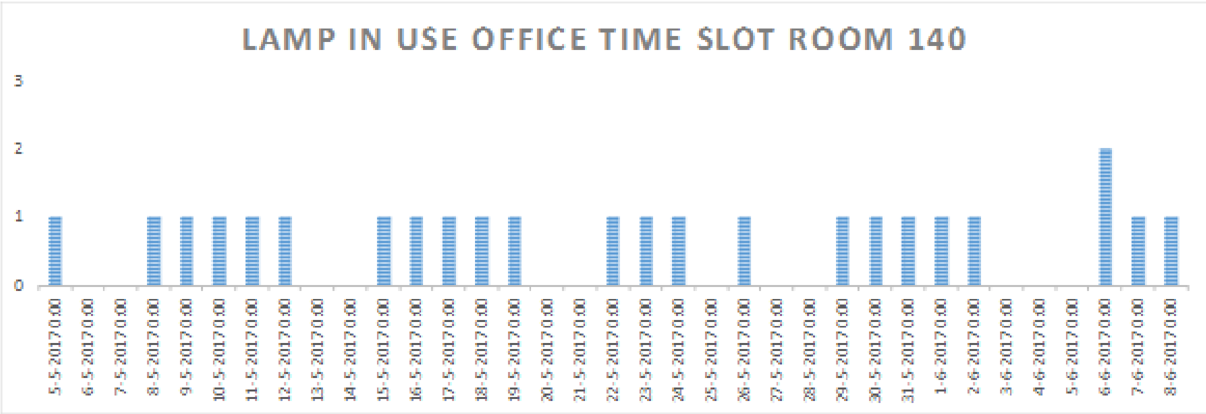


Figure 22: Light control switch in room 140 office time slot

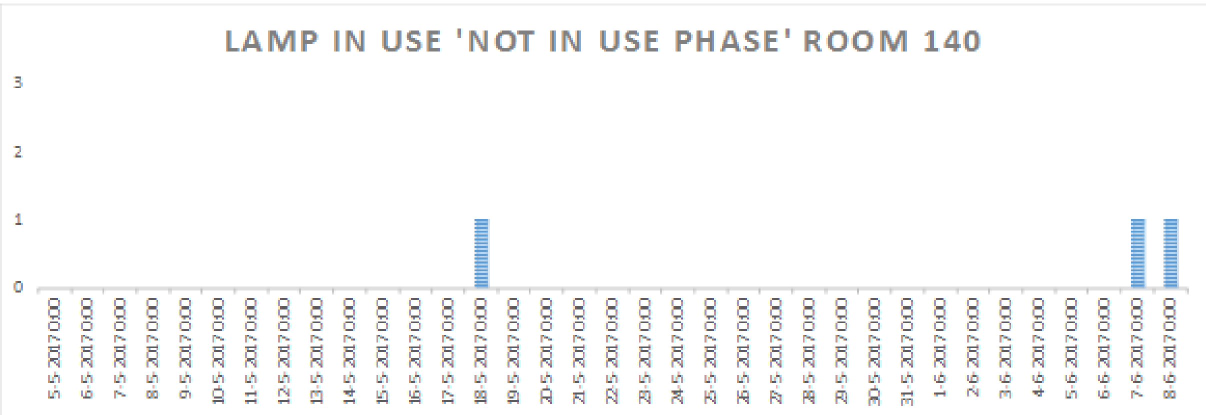


Figure 23: Light control switch in room 140 'Not in Use time slot

Except on May 18 and June 7 and 8, the light was switched off during the 'Not in Use phase'. The User profile of the rooms in accordance with the STREAMER label User profile U1.

2.2.2.4 Comfort Class

The requirement values behind the comfort class label are presented below. The temperature, relative humidity and CO_2 concentration is monitored during a few weeks. These are compared with the requirement to validate the labels.

Table 2.7

STREAMER labels	**Roomlabel**	**Value Requirements**	**Monitoring**	**Validation**	**comments**
Comfort Class	CT4	direct daylight and view outside obligatory	Visual inspection	Present	
		Airflow: 2 / 1.4 dm³/s/m² ("in use" according to prEN 167981-1; 2015. Non low-polluting buildings, category I)	Measuring ventilation flow, Monitoring CO_2-emission and timeslot AHU	Supply Airflow is conform label During the night the central AHU is switched off.	Timeslot of the central AHU is 6:00 to 19:00u
		Temp range: 21 - 25.5 / 20 - 26 °C ("in use" according to prEN 167981-1; 2015. Bedroom, category I)	Monitoring temperature	Temperature range is conform the label	
		Lighting: 500 lux	Measuring	Not yet determined	
		Relative humidity: 30 - 50 / 25 - 60 °C ("in use" according to prEN 167981-1; 2015. Category I)	Measuring	Relative humidity range is mainly conform the label, but the requirements are a little bit too stringent	
		Control of lighting: screens an adaptive control	Visual inspection	Screens present; Automatic lighting control is present	

Explanation

The airflow is measured in the rooms during the ‘in use period. The results are displayed in the table below

Table 2.8 Measured supply and exhaust airflow

Air flow		Room 118	Room 119	Room 140	Room 141
Measured airflow	[m3/h]	152	147	102	111
STREAMER label	[m3/h]	144	144	115	115
Ventilation outlet capacity	[m3/h]	160	160	130	130

The supply and exhaust airflow is during the in use phase (almost) conform the streamer label requirements. Only room 140 is a little bit below the requested capacity. During the not in use phase, there is now airflow (see also the CO_2-concentration figure above). That is not according the streamer label requirements.

The Temperature is measured in the rooms during the ‘in use’ period. The results are displayed in the figure below

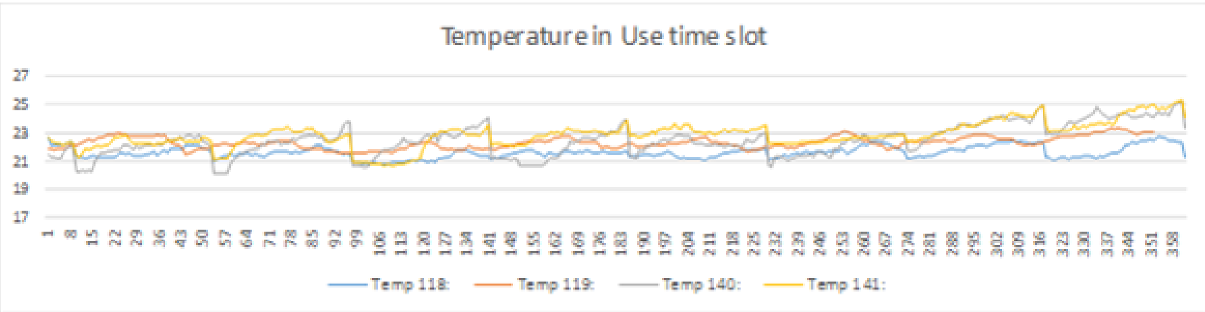


Figure 24: Indoor air temperature during In Use period

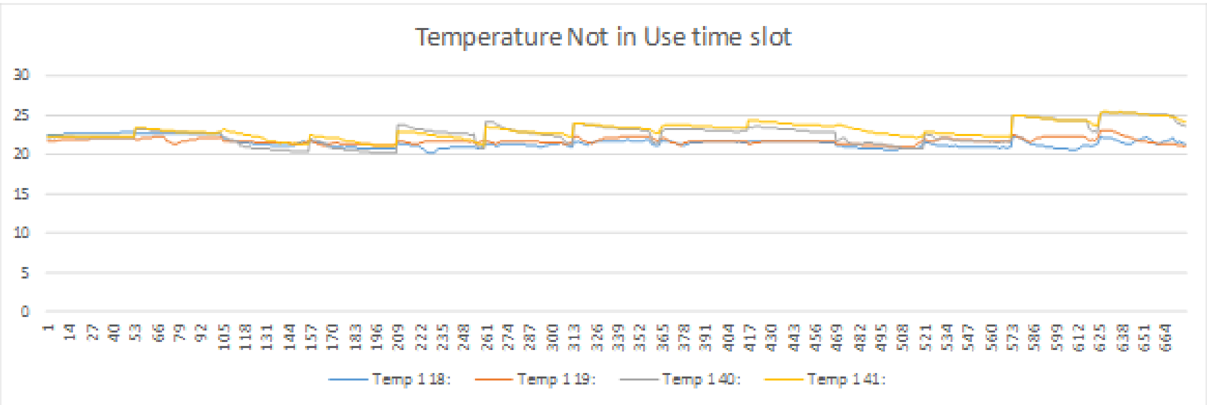


Figure 25: Indoor air temperature during the Not in Use period

During Office time: the indoor air temperature is between 20°C and 25°C. That is a little bit lower than the streamer label requirement minimum of 21°C.

In the remaining time the temperature range is even between 20°C and 25°C. That's between the requirements limits.

The relative humidity is monitored too. The results are shown in the figure below. The Y-axis represent the indoor relative humidity and the X-axis represent the timeslot of monitoring.

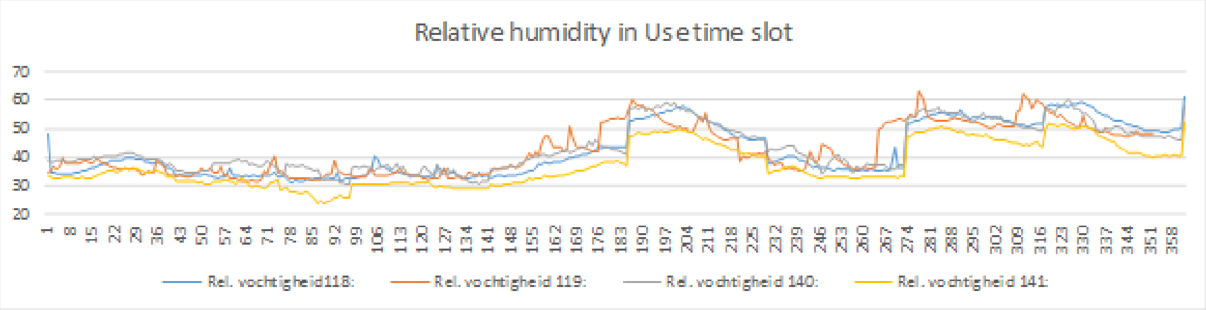


Figure 26: Relative humidity during the in use phase

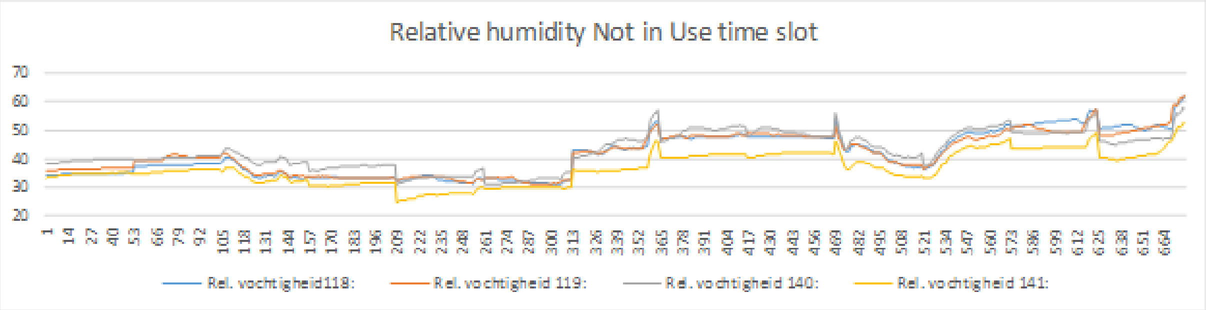


Figure 27: Relative humidity during the Not in use phase

Generally speaking, the relative humidity is most of the time within the requirement of the label, both during office time and the 'not-in-use' period. There are a few times during office time, the relative humidity is a little bit below 30 (during a week) and more often above 50, almost half the monitoring period. It seems that the relative humidity requirements are not fit with the label.

2.2.3 Conclusion

Based on our validation work, the following conclusions can be drawn:

- The room labels itself are easy to validate. But not all labels with the requirements are completely validated in this document. Seven STREAMER room labels out of 39 STREAMER room labels are validated in this document. Because these are the only rooms typologies in the project.
- The room label Hygienic class is partly validated. These requirements are achieved;
- The electric power usage is monitored to validate room label Equipment. There is a difference in the average electric power usage between the Consultation + examination room and the Vascular treatment

rooms, but the roomlabel is the same for both type of rooms. For the Consultation + examination room, the Equipment room label should redefined;

- The room label User Profile is validated by monitoring the CO_2-concentration. Except a small deviation of higher CO_2-concentration than the label required, the room label is the same as the user profile of the rooms;
- The requirement of room label Comfort Class is monitored too. The airflow during in use period is in accordance with the label. During the not in use time, there is no airflow, because the AHU is switched off. The temperature range is between the requested range. Both during in use and not in use time period . The Relative humidity is generally speaking between the range, but has a certain deviation too. It look likes the requested range of the label is to strict. The question is if that is a problem. Based on the European standard EN 13779:2007, to avoid microbial growth, the ventilation system   should be designed so that the relative humidity always stays in a frame below 90% and so that the average relative humidity for three days is less than 80% in all parts of the system, including the filters. During the remaining time the relative humidity is between the frameworks.
- The requirements of the labels are absolute. There is no possibility for (temporary) higher values.

2.3 IT demonstration case study (IAA, BEQ, AOC)

2.3.1 Description of the technical work done during the last two years.

The real case in Italy deals with retrofitting process. Considering the planning of future interventions on the estate [01-02], the AOUC has chosen to use the oncology centre named “San Luca”, which consists of three buildings, as the case study for validating the research results.

The STREAMER knowledge has been used to achieve the following objectives:

1. The enhancement of the SACS© (a customized software that drives Autocad to manage and analyse digital plans of Careggi buildings) to take into account energy, applied on a single building at first, then possibly extended to other ones,
2. The evaluation of the older building (San Luca Vecchio), relying on BIM (definition and planning of building intervention),
3. The development of a better district-level planning and management of energy production.

The work has been settled according to a four-step approach which lists the steps as here follows:
Step 1: Identify buildings and use cases.
Step 2: Identify and define the information for BIM necessary for the uses cases.
Step 3: Choose the KPIs.
Step 4: Map the STREAMER tools and third-party tools that will be used.

Therefore, STREAMER becomes a strategic tool to make the choice between renovation or demolition / rebuilding of the San Luca Vecchio, based on energy efficiency criteria. During the last two years, the technical work and its outputs (design models, performance simulations and assessment tools) has been done according to the following process:

- modelling with Archicad;
- exporting IFC from Archicad;
- importing and processing in Revit;
- exporting gbXML from Revit;
- energy simulation with Design Builder (Energy Plus);
- processing of the IFC file with SimpleBim;
- use of the Dashboard;
- use of the enhanced SACS© system.

This process and details of each item are briefly described in the followings paragraphs, whereas a detailed description of the process is reported in Deliverables 7.6 as well.

SACS© has been the reference for defining the BIM of the case study and three different types of software were used - GIS, DEM (Digital Elevation Model) and BIM - according to the different scale for the district and its buildings to be represented. Information contained in SACS© has been matched to the 3Dzone of the model: elements as medical equipment, HVAC terminals, etc. have been included in the model as data rather than single 3Dmodel objects.

The enriched and geo-referenced bi-dimensional SACS© files (dwg format) of each building of the district has been the base for building up the tri-dimensional model. The GIS and CityGML modeling has been useful for taking into account the orientation of the buildings and the types of networks of the district. The San Luca Vecchio **BIM model** has been made using the software **Archicad** (Cigraph). The work has been started using Archicad since it was the software originally and currently used by the Careggi technical staff. The model has been deepest detailed – for example libraries with all kind of walls and windows have been expressly made – and, later, it has been simplified according to the scope of EDC to avoid importing/exporting problems.

The compatibility of the SACS© system with the STREAMER tools has been achieved matching the relevant classifications with clear correspondence. 284 types of room (named as “classi”) contained in SACS© have been paired to the 89 ones (named as “Room Type”) defined in the STREAMER vocabulary: thus the STREAMER standard label values (7 labels for each Room Type) are now describing the 15.000 rooms of the whole Careggi District. Matching SACS© and STREAMER vocabularies did not face any relevant issue.

Then, a desk and field survey has been done to identify the seven existing label values of each room inside the San Luca Vecchio building. Both the default and the existing label values have been included in the BIM. The survey pointed out the level of compatibility between the use and the characteristics of the rooms: the presence and the level of discrepancies have been considered during the definition of the refurbishment Programme of Requirements (PoR) for satisfying the change of needs and the functional reorganization of the existing building. In addition to the change of lay-out, the refurbishment works include the retrofitting of facades and MEP systems for an improvement of the energy efficiency and the reduction of energy consumption. The new PoR and the expected label values have been included in the BIM (see D4.2 and D1.4 for further information related to the scenario and the approach of the case study).

Revit, instead of Archicad, has been the software used for the case study to:

- **exporting an IFC file** containing the exact space boundaries (feature suitable for almost the energy simulation software using IFC file format as input);
- properly exporting the model made with gbXML analytical spaces (feature required by Design Builder: energy simulation software chosen for the case study).

The model has been imported from Archicad to **Revit** via the Connection plugin to preserve the IFC structure.

For being processed by Design Builder, the file exported in **gbXML format** from Revit (application unavailable in Archicad) has required the calculation of the analytical surfaces: that is the “collapse” of the layers of the materials in a single surface, usually corresponding with the centre of the component itself. The physical characteristics and the performance of the component have been assigned to this theoretical surface via the energy simulation tool.

Revit has also been used for **exporting IFC** with exact space boundaries to be processed by energy simulation tools as Simergy. Lots of tries has been made with Simergy but no certain results have been achieved due to its beta version and to the complexity of the model. The test related to the use of the only IFC file format for the entire process.

The energy simulation of an existing building is challenging due to interchange problems between BIM modelling software and energy simulation software. In this case study, three applications have been tested to find the one mainly compatible with the process requirements:

1. Simergy (Digital Alchemy) – (with Energy Plus simulation engine, the most common and accurate simulation engine). It has been developed to perform IFC format; the commercial version has been recently put on sale. It has been used to import simple models (it allows also the importing of space property-set, as energy simulation set point) but more complex models are uncontrollable especially regarding the boundaries of the rooms. It has been abandoned because of the outcome full of errors.
2. IDA ICE - This software does not have the Energy Plus simulation engine. It has been tested to evaluate its capacity of importing the IFC file format: the result was lacking because only the geometry is imported.
3. DESIGN BUILDER – (with Energy Plus simulation engine) - It is designed to be compatible with gbXML format, nor the IFC format. However, it is the only software able to manage properly the input from the BIM (BIM made with the only software - Revit - dealing with gbXML format). The gbXML format allows the correct and detailed energy simulation of a detailed model.

Therefore, the **energy simulation** has been done with **Design Builder** notwithstanding that it is designed to be compatible with gbXML format, nor the IFC format. However, it is the only software able to manage properly the input from the BIM (BIM made with the only software - Revit - dealing with gbXML format). The gbXML format allows the correct and detailed energy simulation of a detailed model.

The exporting of the results has been made through .xls (or .csv) worksheet and, later, it has been associated to the IFC file with the Simple BIM software. Models regarding the occupancy, the use, the set point of temperature and the MEP systems (existing and based on the label values) have been made to ease the energy simulation.

The setting of requirements, occupancy and use related to each single zone have been combined and manually assigned to the San Luca Vecchio model based on the Bouwcollege Layers (Office, Hotel, Hot Floor, and Industry): this lack of automatic procedure is the biggest weakness of the chosen simulation process.
The energy simulations aiming to validate the STREAMER process in the Italian case study have been done according to 7 scenarios (see Deliverable 1.4):

0. State of the art
0.1 State of the art with label values in each room
1. Changes on layout of the first floor
2. Changes on envelope
3. Changes on MEP system
4. Changes on layout of the first floor, envelope and MEP system
5. Changes on layout of the first floor and envelope
6. Changes on layout of the first floor and MEP system
7. Changes on envelope and MEP system

Design Builder provided also the calculation of two parameters processed by the Dashboard:

- the annual carbon emission (kWh/m2/year);
- the thermal comfort (annual hours of deviations from comfort air temperature set point).

This data has been included with SimpleBim or directly in the Dashboard.

SimpleBim[4] is software used to check the presence of information inside an IFC file. Meanwhile, it allows the enrichment of the IFC file with further data set: directly on the file by a graphical interface or applying models starting from an Excel file. In the process, the use of SimpleBim has been crucial due to various key functions as:

- Control and check of the exported file,
- Compatibility with the EDC output and link with PoR (labels added automatically),
- Adding numerical values related to the labels.

The final step of the process has been the comparison among the solutions analysed with the **Dashboard**. The Dashboard can upload IFC format models (currently belonging only to the STREAMER standard) and supplementary information (energy consumption values or further KPIs) aiming to a better assessment.
The set of KPIs chosen for evaluating the 7 scenarios / solutions has been:

- Thermal Comfort (data obtained by the energy simulation) - Quality
- Energy consumption (data obtained by the energy simulation)
- Carbon emission (data obtained by the energy simulation)
- Life Cycle Cost (data obtained with an internal tool of the Dashboard that correlates the cost to the surface and the labels of every single room. Currently the costs are referred to the Dutch Legislation but the improvement of the reference values concerning other European Countries is expected).

[4] http://www.datacubist.com/

2.3.2 Technical results

The following software have been used and tested during the second and the last period of the research project (see D7.6); the long-lasting trial allowed to discard those ones ineffective or negative for the case study (Figure 28).

a. BIM modelling
   1. **Archicad** (importing *.dwg Autocad file format from SACS©)
b. Exporting - and processing - the output file
   1. **Revit** (importing IFC and exporting IFC+gbXML for the energy simulation) with Archicad Connection Plugin
   2. **SimpleBim** – Datacubist (importing IFC and exporting IFC validated and enriched with additional data)
   3. **Solibri** model Viewer – Optimizer (tool suited to reduce the IFC file dimension, required for the proper importation inside the Dashboard)
c. Energy simulation
   1. **Design Builder** (Energy Plus) – software selected for the case study
   2. Simergy – software tested - but not used - on the case study
   3. Ida Ice – software tested - but not used - on the case study
   4. ***CEN tool*** – TNO's software (still being processed and tested on the Careggi case study) aimed to be included inside the Dashboard
d. STREAMER tools
   1. PoR
   2. **Dashboard** (Decision Support Tool) – DEMO

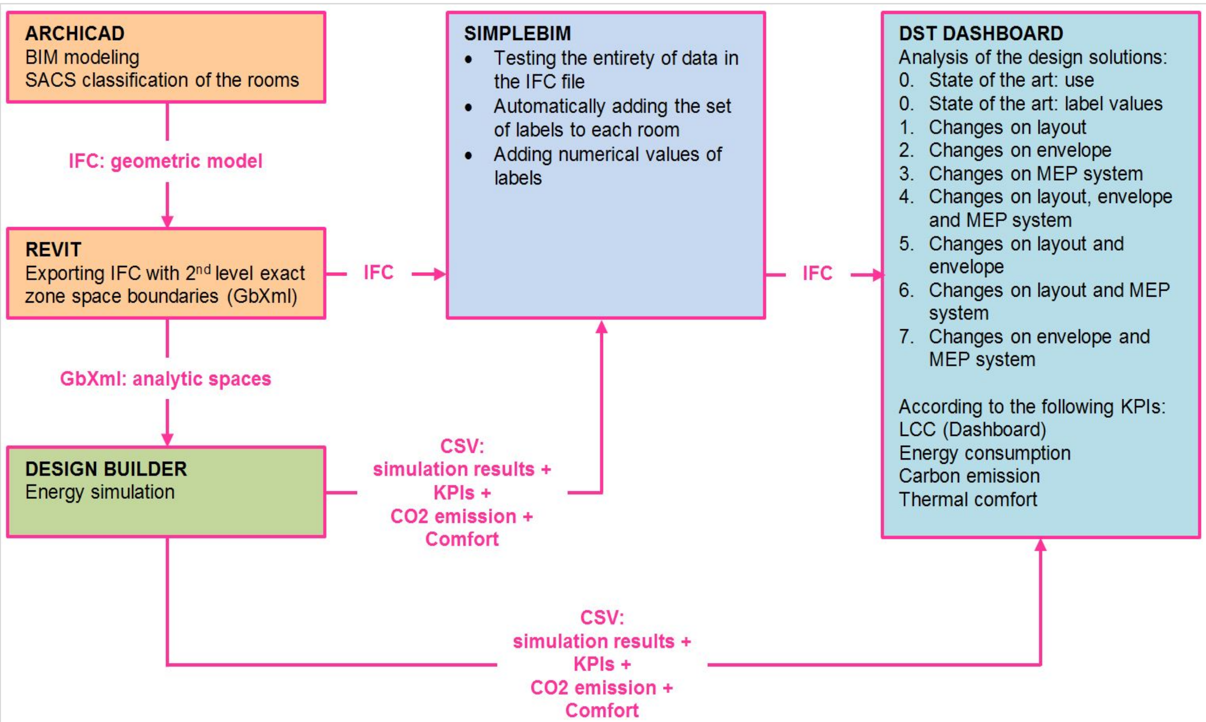


Figure 28: Process related to the exportation, energy simulation and KPIs addition for the case study

From a technical point of view, the Early Design Configurator could not be used for the Italian case study, because of its nature of retrofitting intervention. The EDC cannot import IFC files and existing constraints (stairs, lifts, bearing walls, etc.) cannot be settled. (Note that some additional improvements on the EDC at the end of the project can address those constraints, but this could not be included in the Italian case study anymore.)
The starting point was **not a simplified and standard model** made by the EDC but a **manually detailed model**. So, the goal of the case study turned into the merging of traditional tools with STREAMER innovative tools, EDC excluded.
The Dashboard, as part of the Decision Support Tools, has been designed to be able to import IFC files generated by the EDC. Those files currently comply with the IFC 2x3 standard, but with additional custom properties.
In order to carry on the work on the case study, "bridge" software has been used to:

- Verify the IFC exported from the BIM software (entirety of data),
- Add automatically set of properties and properties to the IFC file in order to make it similar to the EDC exported file.

2.3.3 Conclusion

The different approaches that the retrofitting project could be based on within the Scenario "SC3 - CHANGING FOR ADAPTATION", have been analysed and compared by the AOC technical staff for evaluating the strategy to follow (according to the Matrix implemented in D1.4).

Aiming to satisfy the change of needs and the functional reorganization of the oncological department of the Careggi Health District, the refurbishment programme to be undertaken in the "S. Luca Vecchio" would require a substantial reorganization of spaces since the activities of a spatial area/department need to be partially or completely modified.

Due to the extent of changes, an in-depth analysis about the convenience of a retrofitting intervention instead of a demolition and reconstruction project should be implemented. For this reason, all the approaches have been considered analysing the results of a retrofitting project related to the KPIs. In particular, for each approach an energy simulation has been developed according to the procedures and using the tools described in the previous chapter.

It has been assessed that the extent of works was directly proportional to the targets achieved: the approach including the change of layout + envelope + MEP system resulted as the more convenient compared to the demolition and reconstruction of a new building.

On the other hand it has also been assessed that the original project limited to the change of layout was not sustainable (the energy efficiency after the intervention, for example, would have been almost the same). Therefore, the outcomes of the strong, sometime frustrating, research activity just described can be considered effective and promising. The last months of the research will be used to enhance the performance of the Dashboard in retrofitting cases, especially to implement the STREAMER tools into the SACS© Systems (Figure 29).

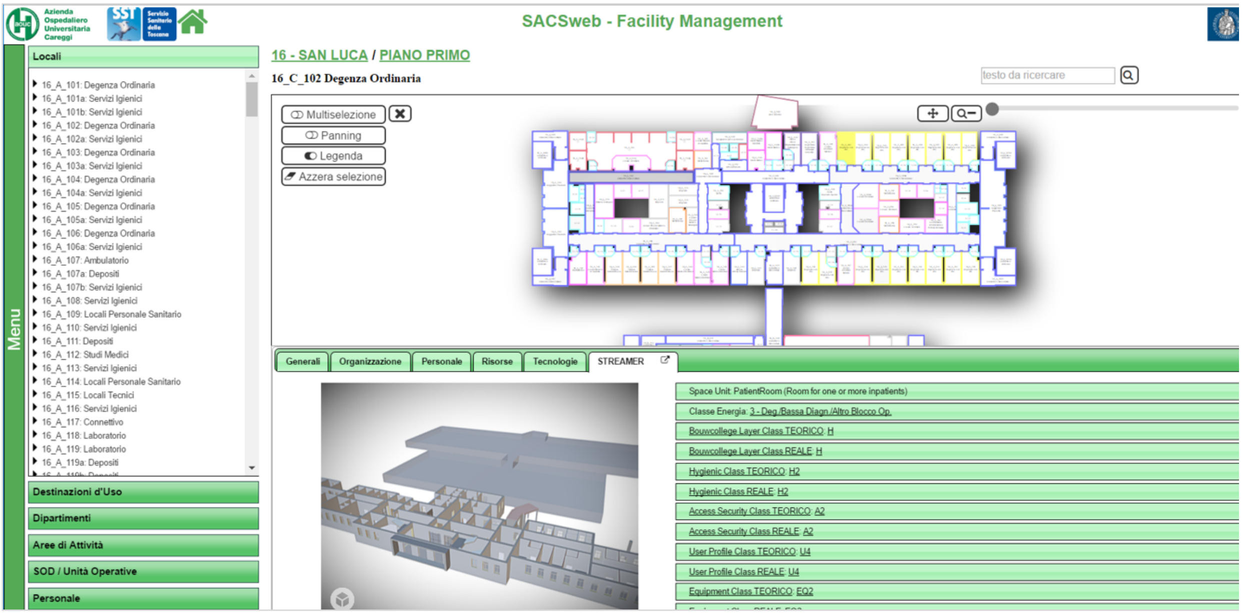


Figure 29: Streamer dedicated section in SACS©

2.4 FR demonstration case study (APH, BOU, CST, CEA)

2.4.1 Description of the technical work done during the last two years.

Brief recap of the French study case and objectives

The demonstration cases for Streamer in France are located in the Pitié Salpêtrière healthcare district which belongs to the Assistance Publique – Hôpitaux de Paris, which is the public university medical centre of Paris and of the close neighborhood. The descriptions of AP-HP and of the Pitié Salpêtrière district were presented in the deliverable 7.4 (Demonstration project in France – delivered in February 2015).

The demonstration cases concern two buildings:

- Gaston Cordier building
- Endocrinology, Metabolic Diseases and Internal Medicine (E3M) Institute

Detailed descriptions of these two buildings were presented in deliverable 7.7.

For these two buildings, the objectives within the STREAMER project were:

- Regarding the Gaston Cordier building:
    - o to carry out two BIM's (Building Information Modelling):
        - first BIM: with the features of the current existing building;

- second BIM: as part of an imaginary retrofitting plan for this building, and using STREAMER tools, we would see what improvements could be done in order to improve the energy efficiency and the re-arrangement of building spaces for a selection of floors compared with the current situation (thanks to technological solutions, creating more 1-person rooms, etc.).
- to test the tools developed by Streamer (PoR, Design Rules, EDC and dashboard) in order to see what layouts and equipment could improve the current situation and in which proportion.

- Regarding the E3M Institute building:
    - Compare the results of real energy performances with the initial forecast performances carried out by Bouygues during the design phase and to perform an analysis of the deviance.
    - Change the hypothesis used during the design phase (degree-day, temperature set point, occupation rate, etc.) to “stick” to the real conditions and see if the “new theoretical” data matches the real ones
    - Generate a BIM model from the EDC and perform energy simulation to check whether the new proposal is as efficient as real consumptions
    - We also wanted to take the opportunity, insofar as possible, to use the results of STREAMER to compare the theoretical energy consumptions obtained thanks to STREAMER technologies with the real data. This makes it possible to validate (or not) the tools develop by the consortium by comparing these performances and see if the results are consistent.

Work performed for the Gaston Cordier building

Since the BIM model of the building was not available, Bouygues performed a simplified six floor BIM model and an energy simulation from this simplified model. The next diagram shows the different phases and steps followed to study the building energy consumptions with STREAMER tools.

- In phase A, a model is generated;
- In phase B, a simulation is performed on that model;
- In phase C, simulation results are displayed

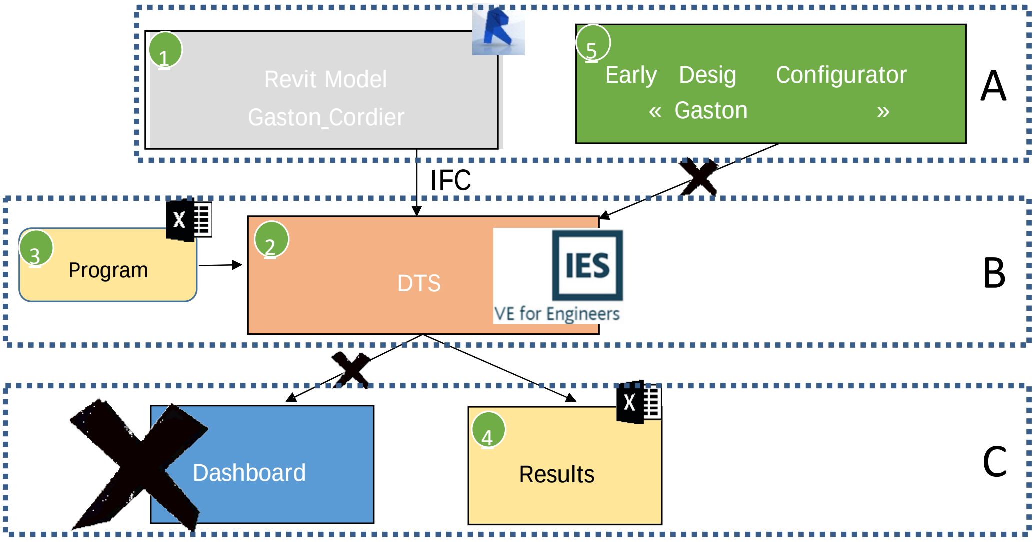
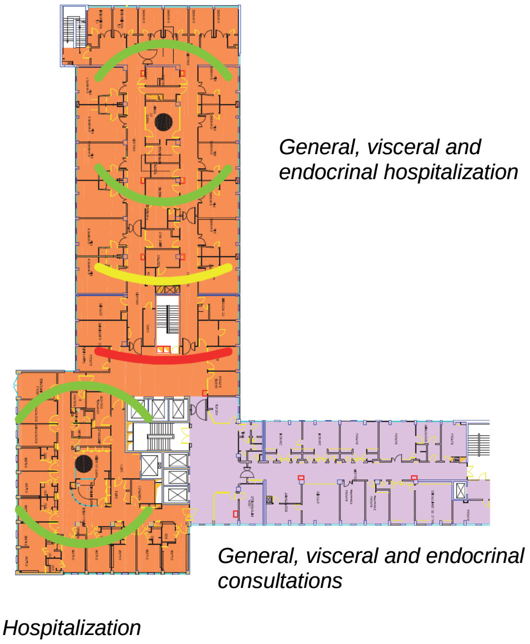


Figure 30: Different stages realized on Gaston Cordier Building

As the EDC was not ready to export a usable IFC file at that moment, we managed to get an IFC from Revit (Step 1). In the step 2, an interoperability process was developed and used to transfer the model from REVIT to IES VE via IFC. In step 3, the using profiles (STREAMER labels values) were imported in IES VE. As the Dashboard was not ready to integrate the results, we managed to put the results in an Excel sheet.

As a reminder, Gaston Cordier is a 7-storey building above ground. The 2nd floor was chosen as a reference, and the model was completed with some information measured during the field surveys (floor-to-floor heights, slab-to-slab heights, height of windows) in order to build the 3D model. Basements, ground floor and first floor have not been modelled.



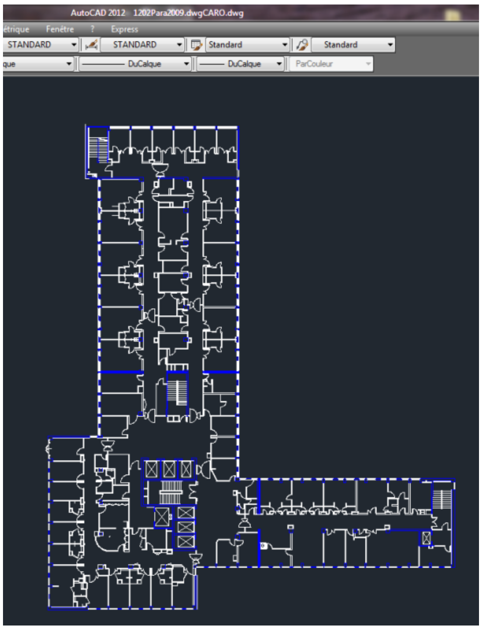


Figure 31: R+2 - Gaston Cordier

The Autocad plans were available so they were imported into Revit. The second step consisted in importing the Revit 3D model through the gbXML file import assistant and gets its geometry in Virtual Environment (VE) an, energy analysis and performance modeling software , which is able to recognize the different rooms built in Revit

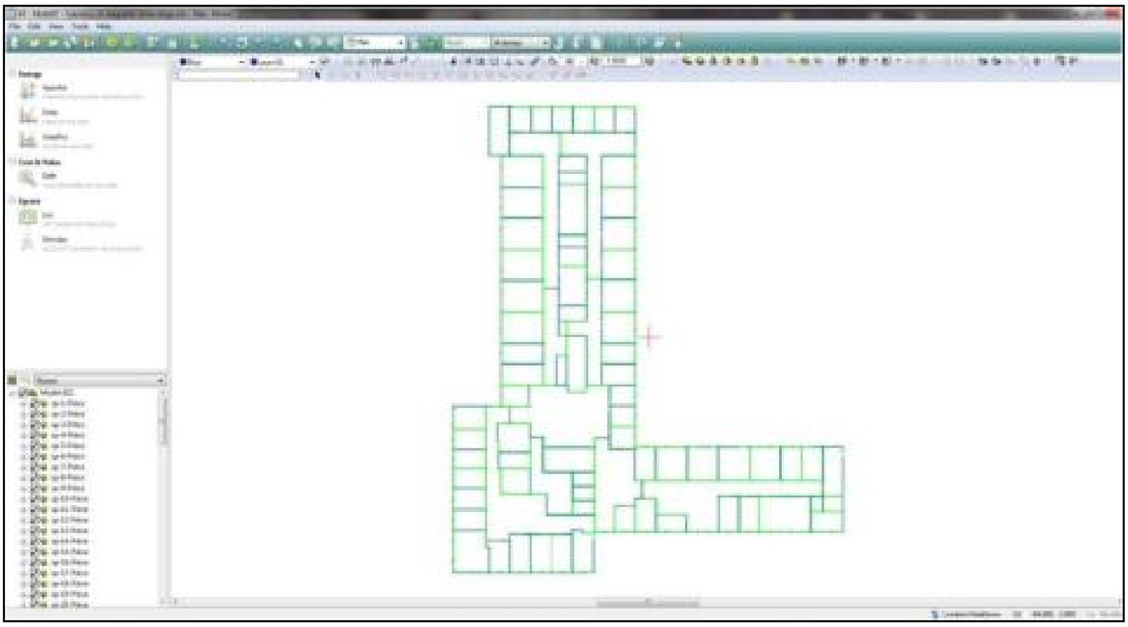


Figure 32: Information from Revit imported into VE

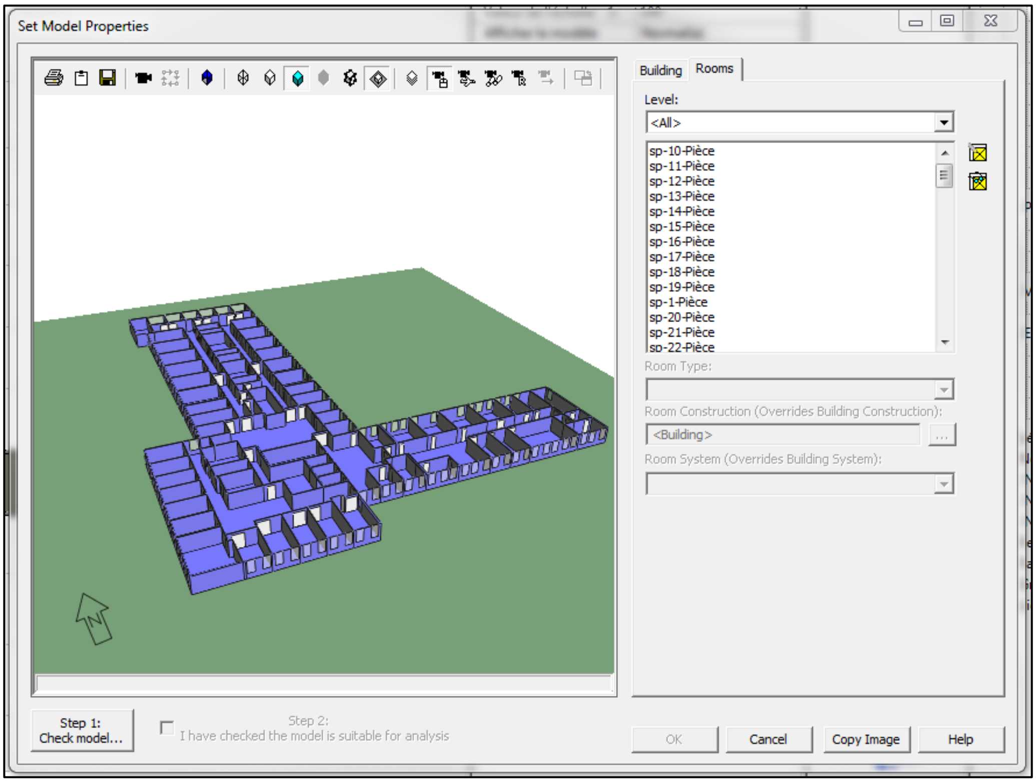


Figure 33: gbXML file import assistant in Revit

At the end, we were able to get the the 7-storey building 3D model:

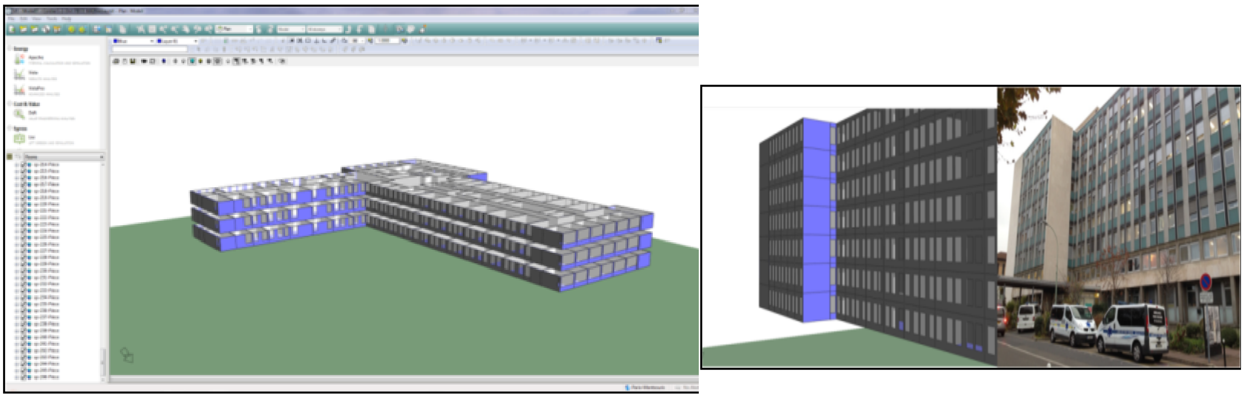


Figure 34: example of the Gaston Cordier BIM

The next step in the VE study was to define the various scenarios that organize the building life and use the same typology as defined in Streamer documents for the space units and functional areas zoning. As discussed with the different consortium members, the following information was needed:

- Number of people in each room (patients, visitors, physicians, residents, nurses, etc.), occupancy

- Assumptions of use (lighting, heating, cooling, system, internal gains, air exchanges, etc.)

The following chart shows the zoning on one floor and allows to check the accuracy on a technical point of view.

Figure 35: Zoning of the 2nd floor

Then, thermal zones were used to add STREAMER labels to each room. The following layer shows the STREAMER labels added to each room via thermal zones:

Zone thermiquex	Surface	Bouwcollege layer	Hygienic Class	Access Security	User Profile	Equipment	Comfort Class	Room labels
Accueil	229.8	O	H1	A1	U4	EQ1	CT2	O-H1-A1-U4-EQ1-CT2
Bibliothèque	74.8	O	H1	A2	U2	EQ2	CT1	O-H1-A2-U2-EQ2-CT1
Bureaux	1444.2	O	H1	A4	U1	EQ3	CT3	O-H1-A4-U1-EQ3-CT3
Chambres	1244.1	H	H3	A2	U4	EQ2	CT4	H-H3-A2-U4-EQ2-CT4
Chambres 2 lits	1851.6	H	H3	A2	U4	EQ2	CT4	H-H3-A2-U4-EQ2-CT4
Circulations chauffees	3565.8	H	H1	A2	U4	EQ1	CT2	H-H1-A2-U4-EQ1-CT2
Consultations	438.2	O	H3	A3	U3	EQ3	CT3	O-H3-A3-U3-EQ3-CT3
Office Alimentaire	117.4	I	H5	A4	U3	EQ5	CT8	I-H5-A4-U3-EQ5-CT8
Pharmacie	61.3	I	H5	A5	U3	EQ5	CT6	I-H5-A5-U3-EQ5-CT6
Poste de Soins	371.2	HF	H4	A3	U4	EQ6	CT7	HF-H4-A3-U4-EQ6-CT7
Salle de repos	88.9	O	H1	A4	U3	EQ2	CT4	O-H1-A4-U3-EQ2-CT4
Salle de reunion	237.1	O	H1	A4	U1	EQ2	CT3	O-H1-A4-U1-EQ2-CT3
Sanitaires	333.3	O	H2	A2	U4	EQ1	CT2	O-H2-A2-U4-EQ1-CT2
Stockage	520.6	I	H5	A5	U1	EQ4	CT8	I-H5-A5-U1-EQ4-CT8

Based on the heating energy consumption of Gaston Cordier (from an energy audit performed in 2011 at building level - it has to be noted that the energy consumption of the building per energy use was estimated as there is no meter on it), we were able to compare the obtained results at room level obtained during the audit through with the Dynamic Thermal Simulation (DTS) results performed in 2015.

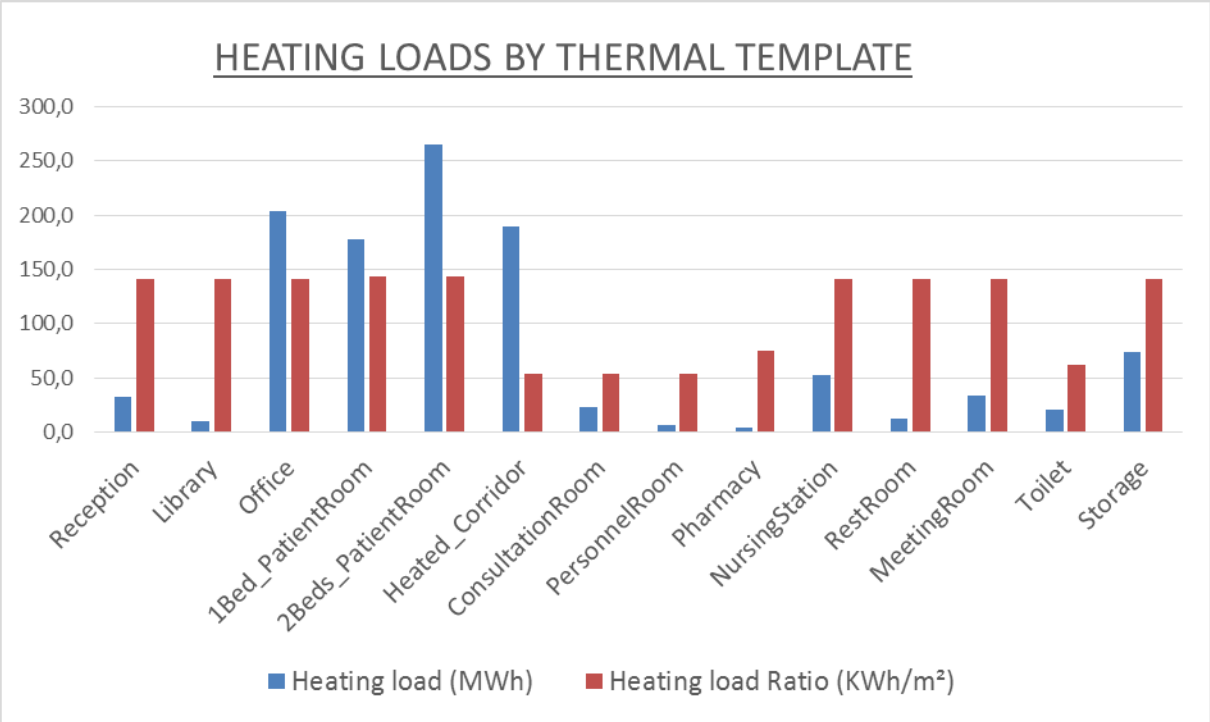


Figure 36: Heating for Gaston Cordier (whole building) - estimate

Then, APH worked on a fictitious scenario for these 6 floors: based on the assumptions made regarding the future use of these levels (layout change), APH filled in the Program of Requirements as well as the Design rules.

Floor number	Current situation	Fictitious future scenario
7	Orthopaedics	Offices
6	Orthopaedics	Orthopaedics
5	Urology	Urology
4	Urology	General surgery
3	General surgery	Urology - Orthopaedics - General surgery
2	General surgery	Day hospital and consulations

RoomName	RoomType	Amount	Area	FunctionalAreaType	BouwcollegeLayer	HygienicClass	AccessSecurity	UserProfile	Equipment	Construction	ComfortClass
Office	Office	48	16	Admission	O	H2	A4	U2	EQ2	C1	CT3
Meeting rooms	GroupRoom	3	35	Admission	O	H2	A2	U2	EQ2	C1	CT3
Patient room with one bed and bathroom	PatientRoom	45	18	LowCareWard	H	H2	A2	U4	EQ3	C1	CT4

Figure 37: extract of the PoR - Gaston Cordier

```
//2
[negotiable]
Rule "Grouping functional areas with similar access security values":
    all functional area with equal "access security" must be clustered horizontally and vertically;
```

Figure 38: extract of the design rules - Gaston Cordier

Then, APH used the EDC (March and July 2016 versions) in order to see what layout was proposed and what the energy consumptions could be with this scenario. Nevertheless, the version of the EDC we used at that time was not able to read the design rules files and we were not able to export the IFC file properly because when we wanted to do so during the 1st semester 2016, there were some export problems with the EDC. Consequently, for this case, the French consortium decided not to go further and to focus on the IE3M building.

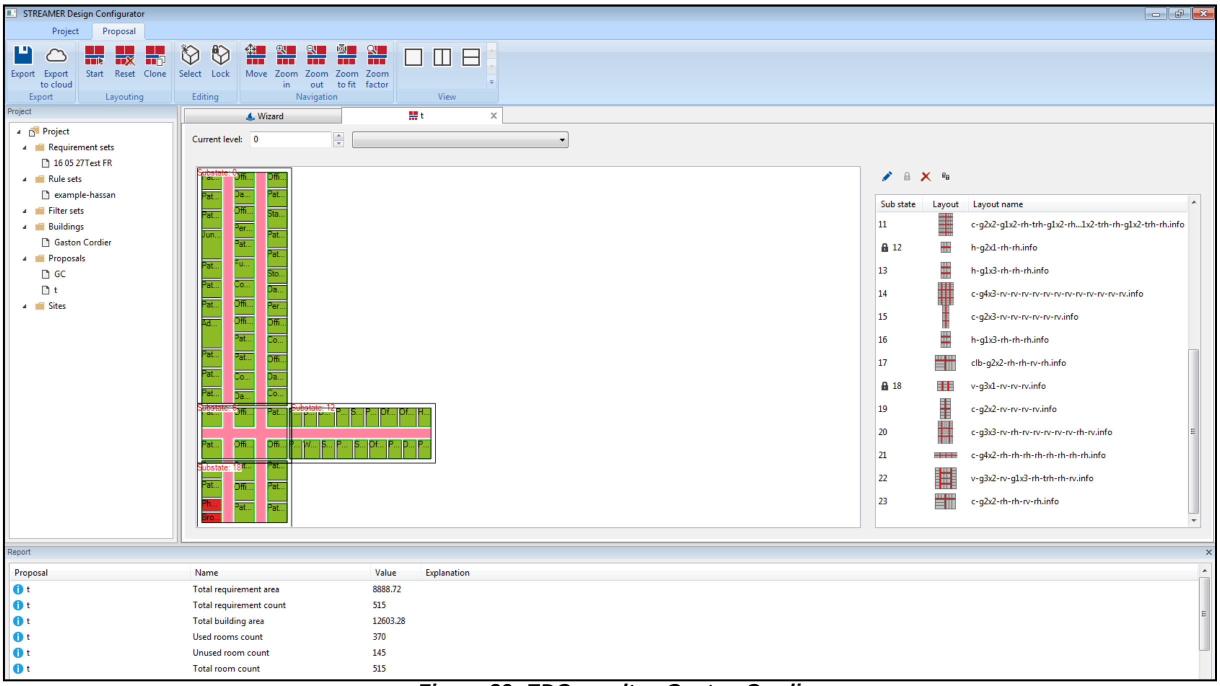


Figure 39: EDC results - Gaston Cordier

Work performed for the E3M Institute building

The study of this building in STREAMER was performed for two reasons:

- To use accurate data that was not available for the Gaston Cordier building, such as energy consumptions which were measured on the E3M building but not on Gaston Cordier.
- To integrate the EDC in the process as it was ready to export a "usable" IFC

So, the French consortium decided to study E3M building.

For E3M building, the quantity of the information available regarding energy consumption was much more important. Indeed, it was a recent building (2013) with a lot of meters so the energy consumption can be measured with precision. BOU performed a BIM model of the building and an energy simulation to check the real consumption data with the theoretical consumptions estimated during the design phase (with hypothetical operating conditions) and the theoretical consumptions updated through the actual operating conditions. Then, thanks to the wide range of tools developed by the Streamer (PoR, Design rules, EDC), we wanted to calculate new theoretical energy consumption and compare it to the reality. Indeed, as we have meters on the building, we are then able to know the consumptions per energy use and, theoretically speaking, compare them with the results we could have obtained from Streamer tools.

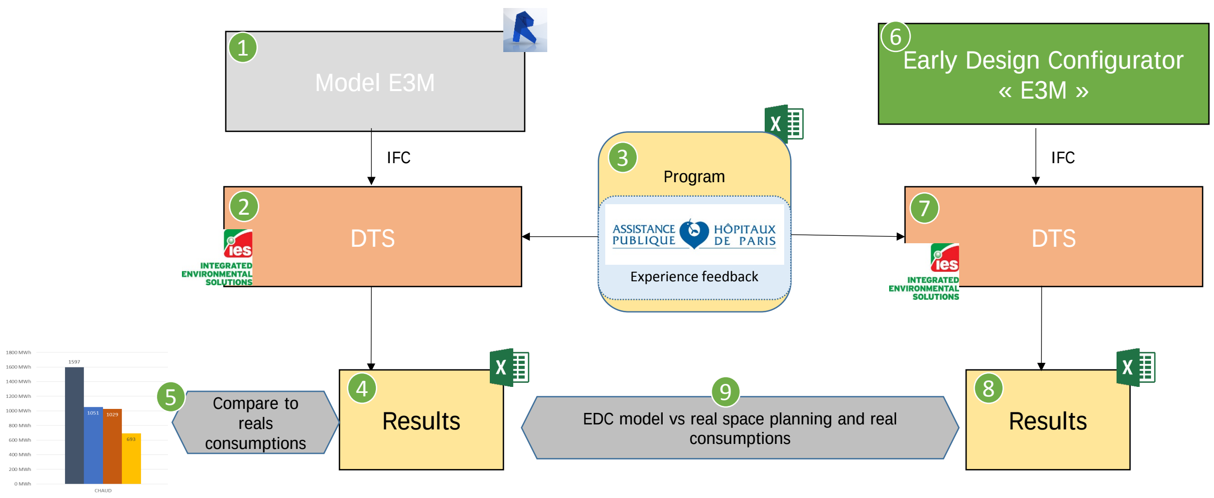


Figure 40: E3M building Workflow

The steps 1, 2, 3 and 4 are the same as on Gaston Cordier building (Fig.30) and were performed to validate the DTS model by comparing its results with energy consumptions values given by the operator (step 5; detailed in fig 41). After that validation, the DTS model was then the DTS reference model. At that moment, the latest version of EDC was able to export an IFC file that we could integrate in IES VE (step 6). Then, on the step 7, BOU performed a DTS with a model from EDC and extracted results on step 8. The Step 9 was about comparing simulation results of 2 models: EDC-model and Revit-model (equals to actual consumptions).

Step 5 details

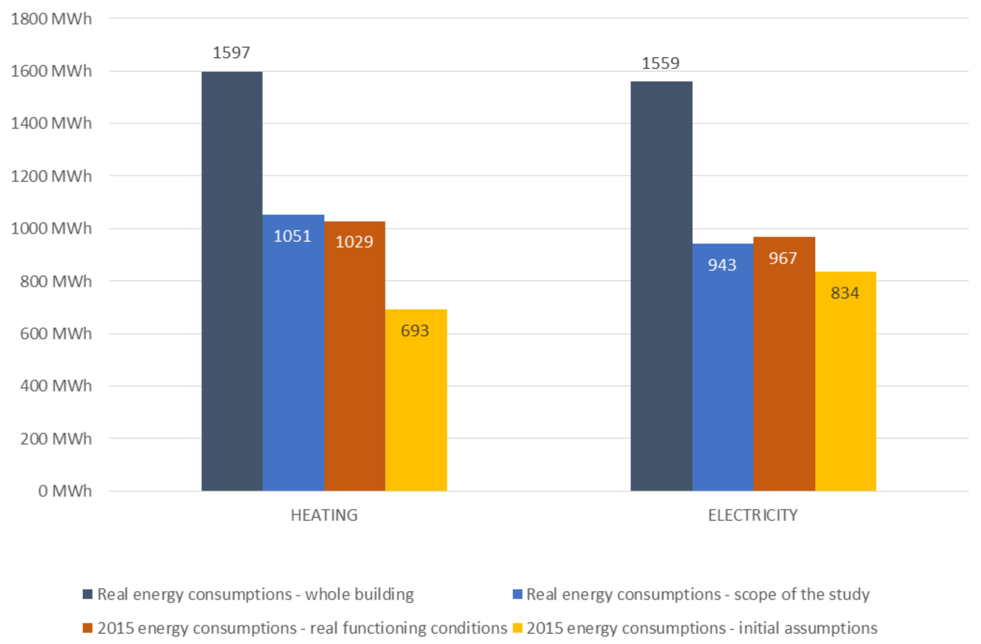


Figure 41: Comparisons between actual and theoretical data

- real energy consumptions – whole building : actual energy consumptions of the IE3M building
- 2015 energy consumptions – real functioning conditions: the scope of the study taken into account in the DTS is limited (around 60-65% of the total building consumption): only the heating, lighting, cooling and auxiliaries consumptions were taken into account here. So this graph corresponds to the theoretical data we have through the DTS based on the actual functioning conditions.
- Real energy consumptions – scope of the study: actual energy consumption of the building on the above-described scope.
- 2015 energy consumptions – initial assumptions: during the design phase, some assumptions were made regarding the functioning conditions. This graph represents the theoretical energy consumptions obtained through the DTS with these hypothetical conditions on the above-described scope.

Nevertheless, we can see that, on this scope, the gap between the real consumptions and the theoretical consumptions based on the actual operating conditions is very low (both for electricity and heating values).

Details of Step 6 to 9

Then, APH filled in the PoR based on the real program of the project, the Design rules and ran the EDC (October 2016 version). Then, BOU used the IFC file to perform an energy simulation based on the results obtained. BOU also compared energy results of an EDC-model with actual consumptions. For the remaining weeks, the objective is to see if it is possible to perform an energy simulation thanks to the tool developed by TNO (TECT) – because this is the only tool that can read the filter set for MEP systems - and then, to upload the results into the dashboard.

2.4.2 Technical results

The main technical results we noticed as part of the French demonstration case were mainly about the EDC because thanks to the fact that we used it, we were able to point out some significant areas of improvements. These improvements were discussed with the institutions in charge of the development of the EDC, namely mainly KIT and then DMO. We organized two specific working sessions in Karlsruhe (2nd of May, 2016 and during the General Assembly, 23rd of March, 2017) and 1 in Paris with the WP7 (4th and 5th of July 2016) and we discussed the following points:

- It is not possible to have a perfect geometry of the building shape. Consequently, it was necessary to simplify it with a minimal number of blocks:

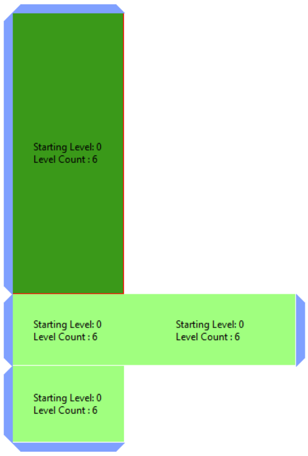


Figure 42: modeled Gaston Cordier building

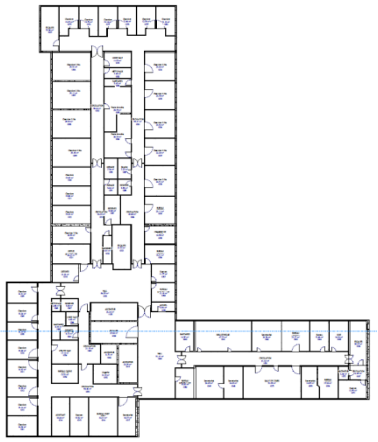


Figure 43: real Gaston Cordier building

Figure 44: modeled IE3M building

Figure 45: real IE3M building

- It is not possible to have a given room over two blocks in the EDC
- The height of each floor is the same (cannot be changed)

- Not possible to import data from REVIT to EDC (for the retrofitting cases)
- The glazing and length/width ratios that were determined during the project (and that was fixed in the EDC) need to be adjusted. For example, the glazing ratio is too small and then, the energy calculation that is performed is wrong.

We also noticed some areas of improvement regarding:

- The PoR: some important structuring space units (lifts, staircases, etc.) are not available in the PoR and it was complicated to modify it. Consequently, for the French cases, we have to « cheat » and add a fictitious / hypothetical room (which are considered as a lift or as staircase). It could be necessary to have the possibility of adding space units and functional areas if needed in future developments.
- The Design rules: based on the rule types determined by the consortium, we wanted to include the 4 rules in the IE3M building case. However, 2 out 4 typologies crashed the EDC / did not work with the October 2016 version (maxOuterBoundarySeparation and travellingDistance). We had different discussions about this situation with KIT and DMO in February and March 2017 and this issue should be solved by the end of the project. Besides, some corrections needed to be done in the xml file (especially regarding unknown tags) but seems to be solved in the last version. It also be a good solution to have the possibility of choosing on which exact floor we want to fix a space unit and if we want to cluster horizontally OR vertically (and not AND). Indeed, sometimes, it is essential to have a functional area on the same floor (horizontal clustering) but for others purposes, it is essential to have a given space unit or functional area located above another.

For the E3M building, we had different design rules and for one of them for example (functional area with (name ="OutpatientDepartment") must be clustered horizontally and vertically), we faced a problem. As we would expect, all the rooms should have been placed on the same floor but in the simulation, they have been placed on 2 different floors (blue color in the 2 figures hereinafter) and not on one specific floor. According KIT, one solution to solve this problem would have been to run the EDC longer than we did (about 5 hours).

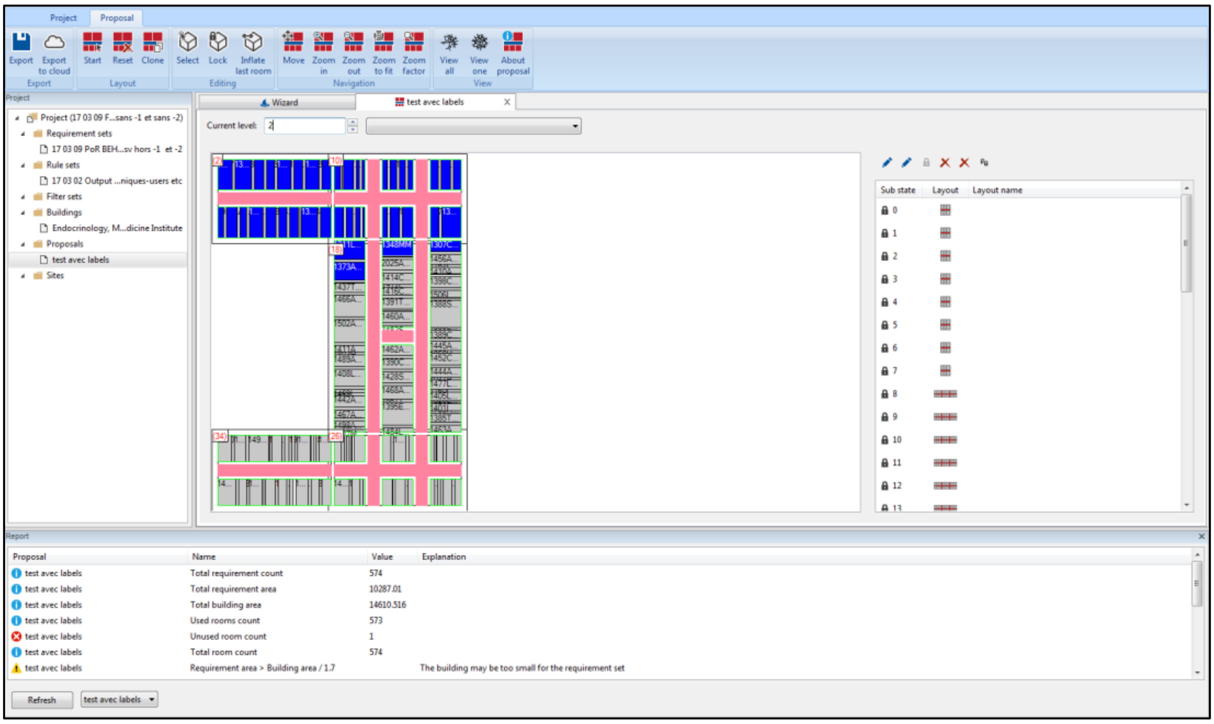


Figure 46: Floor 2

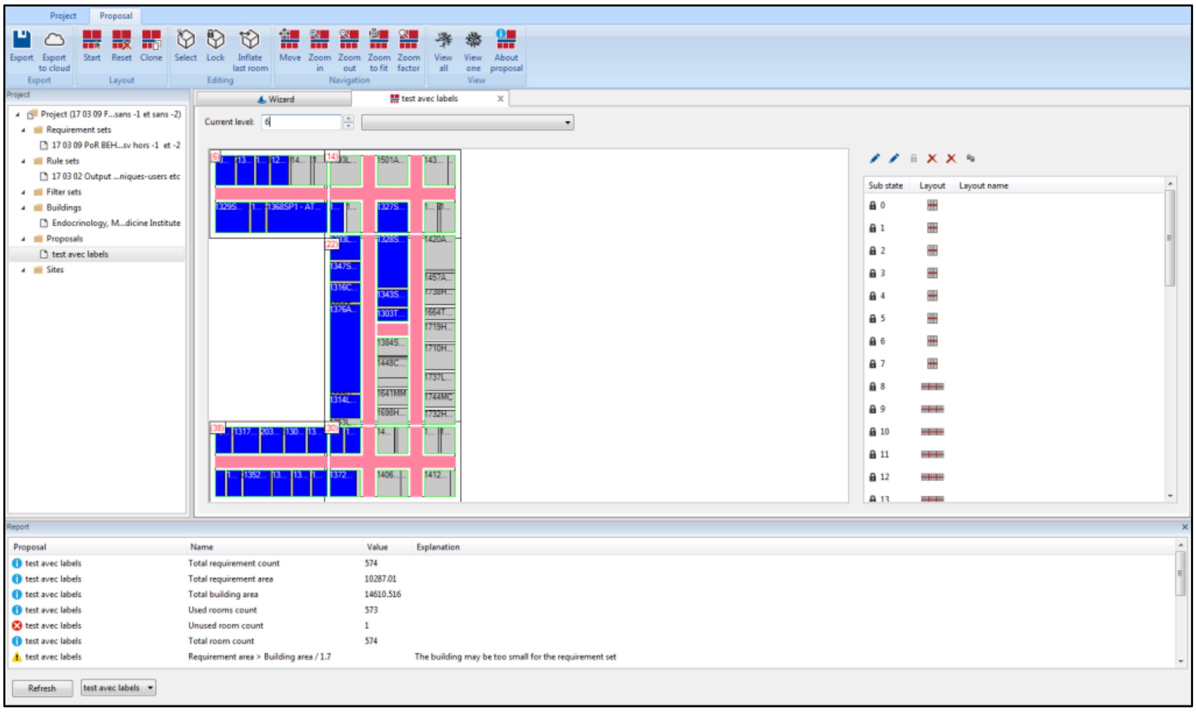


Figure 47: Floor 6

About the IFC file coming from EDC, we noticed that:

- It is not possible to import directly the IFC file to the energy simulation tool used by BOU (Virtual Environment). That tool can only handle IFC files with space boundaries at the “2nd level”. Therefore, we had to pass the file through Revit, add the space boundaries, export an IFC from Revit and import it to Virtual Environment.

Note that Revit-IFC file does not contain STREAMER labels. Therefore, to launch the simulation, we used the same input values of the scenarios (occupancy, ventilation, temperature, etc.) as the actual use of building. We are currently trying to see with TNO if it is possible to use the tool they developed within their organization.

- As the HVAC system filters are not included in the EDC October 2016 version as a design rule. We can see that the EDC proposals are not quite realistic. The figure below shows a proposal of rooms with the same ventilation scenario that are far from each other.

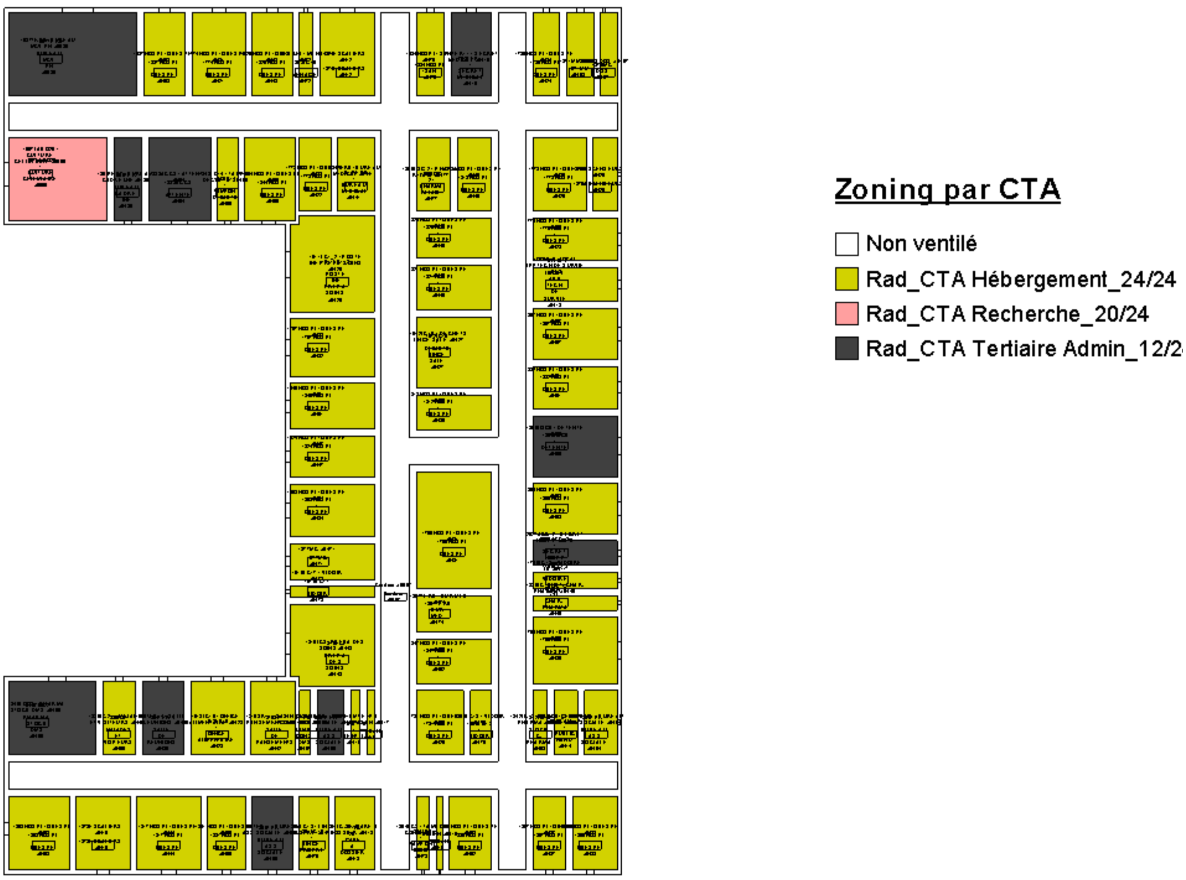


Figure 48: air handling unit zoning

- As mentioned above, the glazing ratio on the EDC model we obtained (≈ 6%) is smaller than the As-built model (≈ 30%). For the moment, only KIT can change this parameter.

In order to compare accurately EDC model and as-built model, BOU created a third model in Virtual Environment which is the combination of both the EDC model with a real façade. The chart in Figure 49 below displays the results of the 3 models.

We would have liked to test the whole Streamer process with the different tools but unfortunately, the only energy tool able to calculate energy consumption based on the labels defined in the PoR is the TECT but as it has been developed at the very end of the project, we were not able to test it and to test the dashboard (and consequently, the financial and quality KPI's).

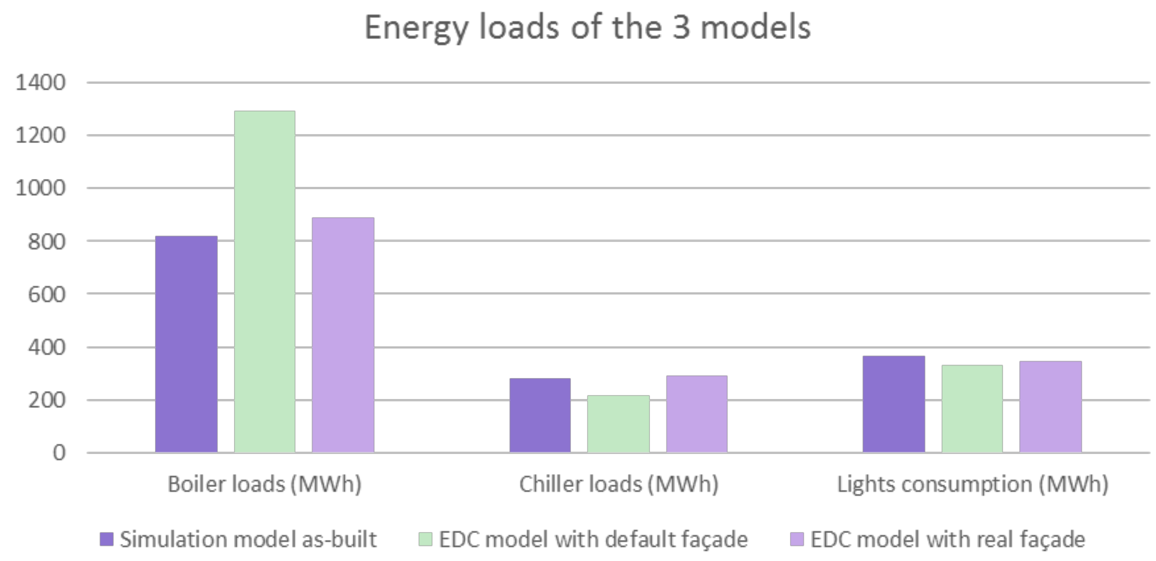


Figure 49: Energy loads of an EDC model

2.4.3 Conclusion

STREAMER has allowed to analyze, theoretically and in a simple way, different scenarios for different architectural projects during the predesign phase and to compare them in terms of energy consumption, financial on the whole life cycle or operational quality. This makes it possible to test several hypotheses quickly and also to have a more objective decision regarding design choices (this is a real help for decision makers). We consider that the different tools (and especially the EDC) are very useful, innovative, simple and convenient to have shared and standardized structure.

As a matter of fact, the PoR makes it possible to have standardized names for functional areas/space units and labels which are related to them and which described them in a very simple but relevant way. The "design rules" editor enables to establish rules which are then taken into account in the EDC, whose interest cannot be denied since it designs a building, based on the requirements and rules mentioned very quickly.

We also notice that BIM technology and interoperability offer a lot of possibilities and cannot be excluded of hospital projects. Interoperability between BIM tools and Energy tools allows to avoid re-entering model data, hence to get more reliable data and save time.

Since the modeling of energy simulation model is time-consuming, it was very helpful to use interoperable tools to quickly perform simulations for each project. As we mentioned before, all these tools and files are promising, nevertheless, it remains clear that they still are “proof of concept” and need further developments to be used in “real life”. That is what we highlighted during the French demonstration cases during which we had the opportunity to test these different tools and files developed by the consortium at different levels of maturity.

As a matter of fact, some questions remain unsolved to date especially regarding:

- The future functionalities of the EDC (geometry of the envelope, integration of staircases and lifts, etc.) which are not completely developed to date but which are really necessary for the users in “real life”. These are key issues if this tool is planned to be commercialized.
- The integration of all the rules chosen by the consortium is also an essential issue because they should make it possible to organize the functional areas and space units with each other.
- it could be useful to have the possibility to import IFC file into the EDC (for refurbishment cases – and if a BIM Model exists)
- technology breakthrough can generate worry for traditional sectors - we have to be careful and good at explaining what the tools can / cannot do (it is developed to help the decision- makers but not able to perform further studies)
- avoid to type data regarding the labels and, to the extent possible, to have standardized values – nevertheless it is difficult to have common requirements between European hospitals as the legislations are not the same

The workshop that was organized as part of the French demonstration case in November 2016 made it possible to confirm the interest regarding the STREAMER project and its methodology for professionals. The persons who attended this workshop have shown great interest and to this project and the discussions we had confirmed the relevance of the project. Besides they also highlighted the necessity of having new technological decision tools and to have a collaborative approach for the hospital of tomorrow.

3. Benchmarking

3.1 Introduction

This chapter is intended to provide a benchmarking for healthcare buildings in the EU.

Due to the fact that we did not have access to the healthcare energy data, and the different kind of data being collected at different hospitals, it was impossible to define a benchmark at EU level, instead, we performed benchmarking at country level; i.e., we performed a benchmarking in 4 EU countries (UK, NL, IT, and FR), in which data was compared side by side, and conclusions were drawn.

3.2 Benchmarking at UK level

This section will introduce published benchmark figures for energy consumption in general hospitals, and compare these against Rotherham's, and the simulation results.

3.2.1 Defined benchmark

In the UK, BSRIA (Building Services Research and Information Association) publish guidance KPI figures for various building types including hospitals.

Table 1: UK BSRIA hospital energy consuption guidance

Total	MJ/m2/yr	including	MJ/m2/yr
Electricity	324	Small power	789
Thermal	1512	Heating	2525

3.2.2 UK Government Department for Health portfolio measurements

The UK Government Department for Health collates and shares annual performance KPIs for the hospital portfolio. In order to accommodate regional variations in climate and health needs, hospital campuses are compared to neighboring facilities. All the KPIs measured for Rotherham Hospital are benchmarked against similar facilities and are color coded by their performance compared with the variations across the hospital portfolio. Six KPIs are highlighted in the graphic, along with the previous year's assessments. .

1. Total running costs
2. Occupied floor area
3. Reported capital expenditure required to eliminate CIR /m2 (maintenance backlog)
4. Maintenance
    a. Condition, Appearance and Maintenance
    b. Total reported maintenance backlog
5. Reported capital investment required to eliminate CIR

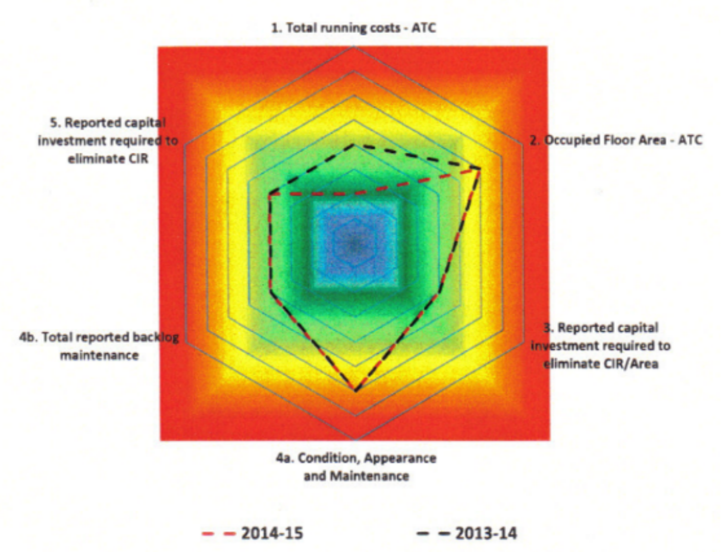
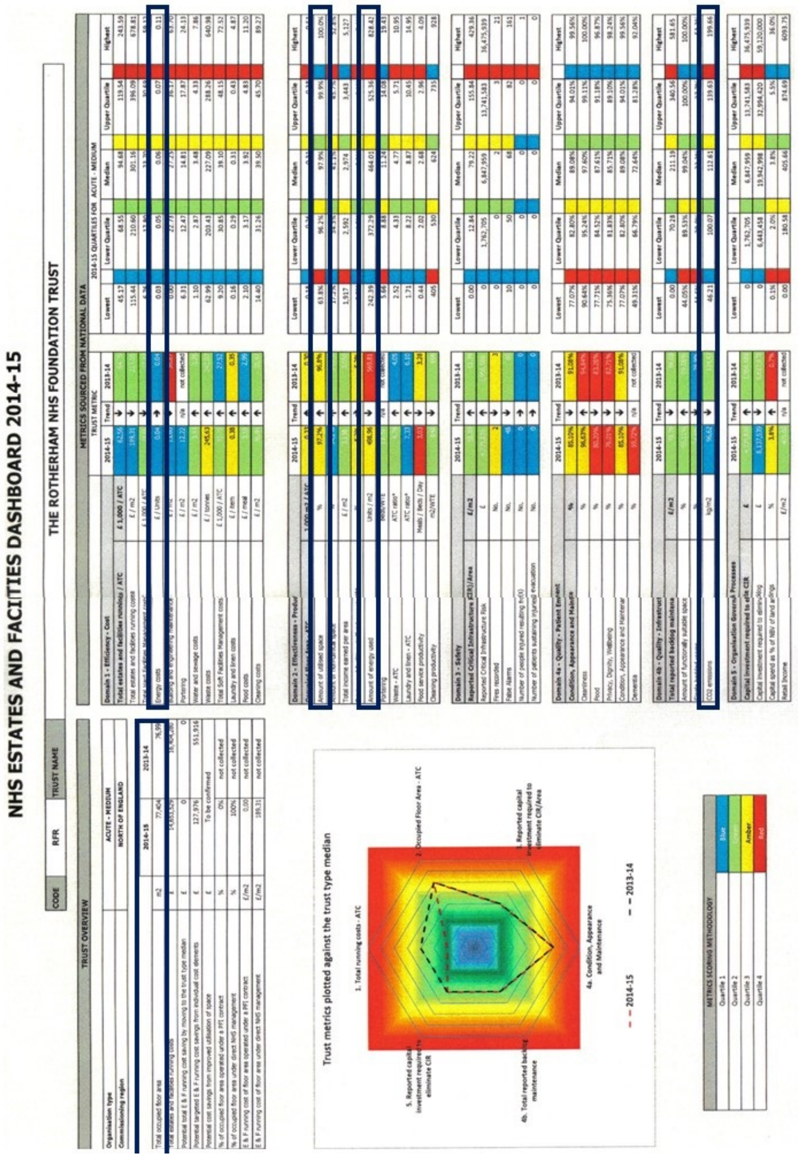


Figure 50: Trust metrics plotted against the trust type median


NHS ESTATES AND FACITIES DASHBOARD 2014-15
THE ROTHERHAM NHS FOUNDATION TRUST

3.2.3 KPI summary

Site / Hospital (2015-16)	Rotherham	Doncaster & Bassetlaw	Barnsley	Sheffield Children's Hospital	Sheffield Teaching Hospital	North Lincs & Goole	Chesterfield	Leeds Teaching Hospital	Bradford	Calderdale & Hudersfield	York	Harrogate	Airedale
Type of Hospital	Acute Medium	Acute Large	Acute Small	Acute Specialist	Acute Teaching	Acute Large	Acute Small	Acute Teaching	Acute Teaching	Acute Large	Acute Teaching	Acute Small	Acute Small
Location	S. Yorks	S. Yorks	S. Yorks	S. Yorks	S. Yorks	Humberside	Derbyshire	W. Yorks	W. Yorks	W. Yorks	N. Yorks	N. Yorks	W. Yorks
Surface Area (m^2)	80,040	163,952	75,921	47,915	414,114	143,729	98,970	509,378	145,059	152,928	204,404	81,537	64,929
Occupied floor area (m^2)	78,297	162,562	75,618	47,515	406,201	142,138	98,970	448,381	140,570	143,511	188,870	81,537	61,007
Volume (m^3)	216,329	420,781	193,820	105,381	900,357	382,386	215,053	1,271,885	334,152	261,115	387,454	143,883	157,543
Year of Construction	1978	1955-64	1965-74	1955-64	1948-54	1955-64	1975-84	1955-64	1948-54	1955-64	1955-64	1965~2004	1965~1994
Number of beds	470	937	323	194	1,838	No info	No info	2,140	85	74	1,277	379	343
Number of in-patients only	32,931	42,871	26,207	11,712	66,352	22,284	26,027	87,795	22,387	24,448	32,202	22,786	12,435
MEP system	No info	No info	No info	No info	No info	No info	No info	No info	No info	No info	No info	No info	No info
Electricity from supplier (kWh)	1,281,043	17,695,603	1,527,867	7,603,370	47,195,129	18,109,481	11,372,507	41,564,070	11,502,342	20,061,494	14,046,336	1,976,578	1,020,295
Renewable electricity (kWh)	179,667	0	25,327	0	0	0	0	0	927,608	0	5,269,156	5,269,156	0
On-site electricity generation (kWh)	9,495,488	2,934,248	8,167,000	0	0	0	0	146,641,371	5,455,349	0	9,224,046	2,717,206	6,627,800
Total electricity consumed (kWh)	10,956,198	20,629,851	9,720,194	7,603,370	47,195,129	18,109,481	11,372,507	188,205,441	17,885,299	20,061,494	28,539,538	9,962,940	7,648,095
Exported electricity (kWh)	0	0	0	0	0	0	0	89,288,799	0	0	0	0	0
Total electrical energy consumed per occupied floor area (kWh/m^2)	140	127	129	160	116	127	115	420	127	140	151	122	125
Natural gas for heating (kWh)	13,640,955	37,262,485	13,073,218	12,245,043	81,218,997	29,812,654	25,271,724	11,882,303	23,884,833	37,363,657	67,997,230	21,535,423	8,524,027
Natural gas for CHP (kWh)	26,630,874	9,233,759	23,737,400	0	0	0	0	568,092,684	17,160,560	0	22,973	8,491,270	19,092,704
Natural gas for process use (cooking, labs, etc)	305,862	0	0	0	0	0	0	0	0	0	0	0	0
Primary fossil energy (kWh)	40,577,691	46,496,244	36,810,618	12,245,043	81,218,997	29,812,654	25,271,724	579,974,987	41,045,393	37,363,657	68,020,203	30,026,693	27,616,731
Thermal energy utilised from CHP (kWh)	791,000	4,162,523	11,859,000	0	0	0	0	185,944,862	7,730,576	0	12,790,838	3,749,744	4,917,078
Total thermal energy consumed per occupied floor area (kWh/m^2)	184.32	254.83	329.71	257.71	199.95	209.74	255.35	441.20	224.91	260.35	427.74	310.11	220.32
Total thermal energy consumed per heated volume (kWh/m^3)	67	98	129	116	90	78	118	156	95	143	209	176	85
Purchase of other fuels (eg, oil, coal, steam)	0	0	44,000	50,706	12,000	3,370,260	70,566	1,038,894	421,891	313,497	0	701,400	0
CO_2 emissions attributable to electricity use (t/CO_2)	4,923	9,269	4,367	3,416	21,206	8,137	5,110	84,564	8,036	9,014	12,823	4,477	3,436
CO_2 emissions attributable to gas use (t/CO_2)	7,452	8,539	6,760	2,249	14,916	5,475	4,641	106,512	7,538	6,862	12,492	5,514	5,072
Total CO_2 emissions (t/CO_2)	12,375	17,808	11,128	5,665	36,122	13,612	9,751	191,077	15,574	15,876	25,315	9,991	8,508
Total CO_2e emissions (t/CO2)	13,488	19,858	12,117	6,413	40,770	15,393	10,880	210,018	17,352	17,856	28,156	10,993	9,284
CO_2 emissions per occupied floor area (t/CO_2)	158	110	147	119	89	96	99	426	111	111	134	123	139
CO_2e emissions per occupied floor area (t/CO_2)	172	122	160	135	100	108	110	468	123	124	149	135	152
Energy need (kWh/m^2/year)	654	435	769	414	310	333	370	1,873	460	376	535	536	619
Share of renewable energy (%)	12.3%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	72.7%	0.0%

3.2.4 Comparison

In order to make as clear a comparison as possible, the following table consolidates the energy performance figures obtained during the STREAMER project in W/m^2. Other units, such as kWh/m^2/year and MJ/m^2/year are less intuitively comprehensible.

BSRIA benchmarks for general hospitals	W/m^2
Electricity	10.3
Thermal	47.9
Small power	25.0
Heating	80.1

Rotherham Hospital	W/m^2
Electricity from supplier	1.9
Renewable electricity	0.3
On-site electricity generation	13.8
Total electrical energy consumed	16.0
Natural gas for heating	19.9
Natural gas for CHP	38.8
Natural gas for process use (cooking, labs, etc)	0.4
Primary fossil energy	59.2
Thermal energy utilised from CHP	1.2
Total thermal energy consumed	21.0
Energy need	74.6

	Published	SBEM	Metered
Annual Electricity Consumption 2007	17.5	34.7	
Annual Gas Consumption 2007	53.3	24.9	
Annual Electricity Consumption 2015	2.4		
Annual Gas Consumption 2015	66.1		
Annual Energy Demand		59.5	
Heating energy demand (gas)		17.9	
Auxiliary energy demand (electricity)		3.8	
Lighting energy demand (electricity)		19.0	5.9
Hot water energy demand (gas)		6.9	
Equipment energy demand (electricity)		11.8	3.0

rdash proposal package	Delta W/m2
Heating energy demand	-25.0
Lighting energy demand	+2.3

3.2.5 Discussion

The tabulated figures of power density (in W/m^2) highlight that

(1) Rotherham hospital is performing considerably better than the BSRIA and UK Government benchmarking

(2) The UK NCM SBEM calculation used to priorities upgrade interventions are consistently overestimating the electricity and gas consumption. The figures are closer to the 2007 figures, suggesting the CHP, lighting upgrades, and user engagement programs are not being fairly reflected in the predicted results. D7.1 has discussed systematics weakness of the UK NCM SBEM analysis, including its ignoring the impact of heating controls.

(3) The proposed upgrades are producing relatively small value, even allowing for anticipated carbon tax policies, for relatively large investments. This means that the figures obtained may be more sensitive to the assumptions made, and so a disclaimer was included to the main STREAMER energy performance results – that little reliance should be made on the figures without more detailed scrutiny.

3.2.6 Conclusions

There is widespread acknowledgement that there is a performance gap between the energy performance predictions, energy performance estimates used in the UK regulatory process and actual measured results. However, the UK NCM SBEM is not intended to be an energy prediction tool, but is an energy comparison tool. Its primary purpose is to compare proposed designs to a notional benchmark building built to 1990 standards. So the variation in the figures between actual and predicted, whilst disappointing, do not invalidate the use of UK NCM SBEM for performing comparative evaluations of options.

Whilst most professionals would argue that more detailed modelling would help close these gaps, this is frequently not possible nor practical, especially when considering existing campuses. The UK example supports the case made by other STREAMER work-packages for the use of more up-to-date generic occupancy, fabric and system profiles.

D7.5 presented a selection of observatory case studies (8 NHS Trusts) across the UK depicting a series of building energy solutions that would result in lowering carbon emissions. These include:

- Wind turbines
- Biomass heating systems
- Low energy lighting
- Intuitive lighting controls
- Solar shading / brise soleil
- External cladding
- Voltage optimisation
- Super-efficient transformers
- Software to shut down IT equipment after a pre-determined time
- Ground source heat pumps
- Air source heat pumps
- Pipe insulation
- Advanced heating controls
- Combined Heat & Power units
- Boiler optimisation
- Solar PV
- Solar thermal
- Absorption chillers
- Smart grids / demand Response
- Energy efficient equipment
- Underfloor heating
- Double / triple glazed windows
- Window film
- Cavity insulation

All of the above innovations have been implemented at the sites in the 8 case studies and are contributing to a significant reduction in energy consumption and carbon emissions. Each Trust has identified its own measures to achieve the necessary energy and carbon reduction targets. Various methods have been used to procure these means including self-finance, low interest loans and Energy Performance Contracts with shared savings schemes.

The work being carried out within the NHS is a largely retrofit solution but best practice, in terms of design solutions, is also an important part of the overall picture. The stated aim of Project STREAMER is to provide an assessment approach in which energy related metrics measured or estimated at one facility are compared to those from other facilities and/or specific targets. This will allow building designers and engineers to make an informed, scientific decision as to which building interventions are the most appropriate in order to provide the optimum outcome.

It is clear from the case studies that when considering building energy improvements many factors should be scrutinised and what works for one building may not work for another.

3.3 Benchmarking at NL level (RNS, DJG, TNO)

3.3.1 Defined benchmark

In the Netherlands there is no government organized benchmark for hospitals in general. Where government funded academic hospitals are obliged to work on energy programs and reduction of their carbon footprint, the general (private funded) hospitals are not obliged to work on energy programs nor, as a part of such a program, participate in a benchmark. This may change over the coming years through the (voluntary) participation in the so called the Green Deal. But there are a lot of benchmarks for hospitals in The Netherlands, which are described below.

Rijnstate is a member of Milieu Platform Zorg [5](MPZ) and participates in the MPZ benchmark. The MPZ plays an important role in the Netherlands by stimulating different organizations to participate. Hospitals that are participating in the MPZ energy audit, (more than 100) are exempted from the EED (European Energy Efficiency Directive), which is obligatory since 2017.

Data from CBS (Dutch National Statistics database) could be used as a reference. Having said that it should be clear that comparing data is problematic because no distinction has been made between different types of hospitals or different types of typologies. On top of that, data on energy consumption is not corrected for climate. However this database is the largest.

3.3.2 Comparison

Using data from MPZ benchmark, a comparison between different hospitals can be made.
It should be noted however that no correction on the data for weather conditions or climate has been made, which make data hard to compare.

Comparison of energy has been made between ECN benchmark 2016, Quadrance benchmark 2016 and MPZ benchmark on kWh / m2, m3 gas / m2, and GJ/m2. To be able to compare data from different hospitals, GJ is used as value for comparing different hospitals. Within the MPZ benchmark comparison can be made on electricity, gas and GJ.

Electricity

The figure below shows the electricity consumption of Rijnstate Hospital. Electricity = purchase + CHP production. On the X-axis is the years of monitoring (Figure 51).

[5] https://milieuplatformzorg.nl

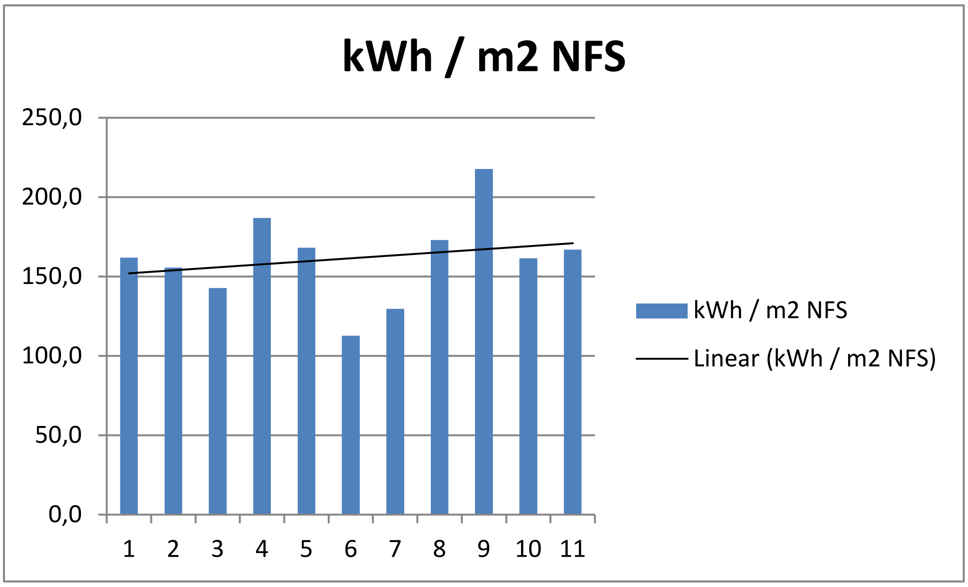


Figure 51: Rijnstate hospital electicity intensity

Deviation comparing different data from different benchmarks. As described in Chapter 2.2, there is no reference. By comparing the different databases we can compare them.

ECN database 49 kWh/m²

Quadrance database +/- 120 kWh/m²

MPZ database +/- 156 kWh/m²

Deviation within Dutch hospitals is limited. Average electricity consumption is 161 kWh / m²and SDEV is 28 kWh / m². As a conclusion, we can find a big difference in output.

Gas

The figure below shows the gas consumption of Rijnstate Hospital. On the X-axis is the years of monitoring (Figure 52).

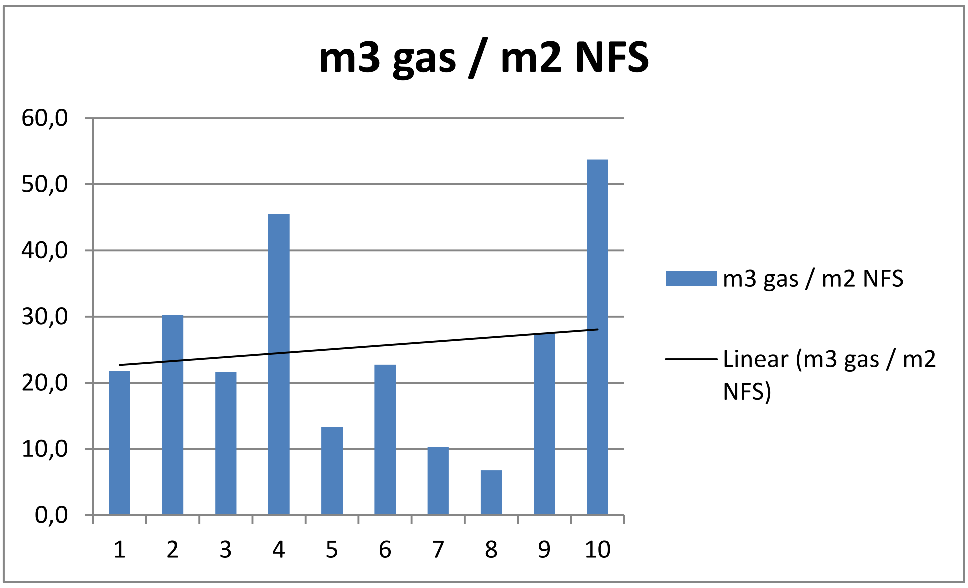


Figure 52: Gas comsumption by Rijnstate Hospital

Deviation comparing different data from different benchmarks. As described in Chapter 2.2, there is no reference. By comparing the different databases we can compare them.

MPZ database	26 m³ gas / m²
ECN database	23 m³ gas / m²
Quadrance database	25 m³ gas / m²

Deviation within MPZ benchmark is quite large. Average gas consumption in Dutch Hospitals is 26 m³ gas / m² with SDEV 14,4 m³ gas / m².

Conclusion: the average gas consumption of the hospitals does not differ very wide. There is no reason to believe that this is not a coincidence.

Primary energy

The figure below shows the primary energy consumption of Rijnstate Hospital. On the X-axis is the years of monitoring (Figure 53).

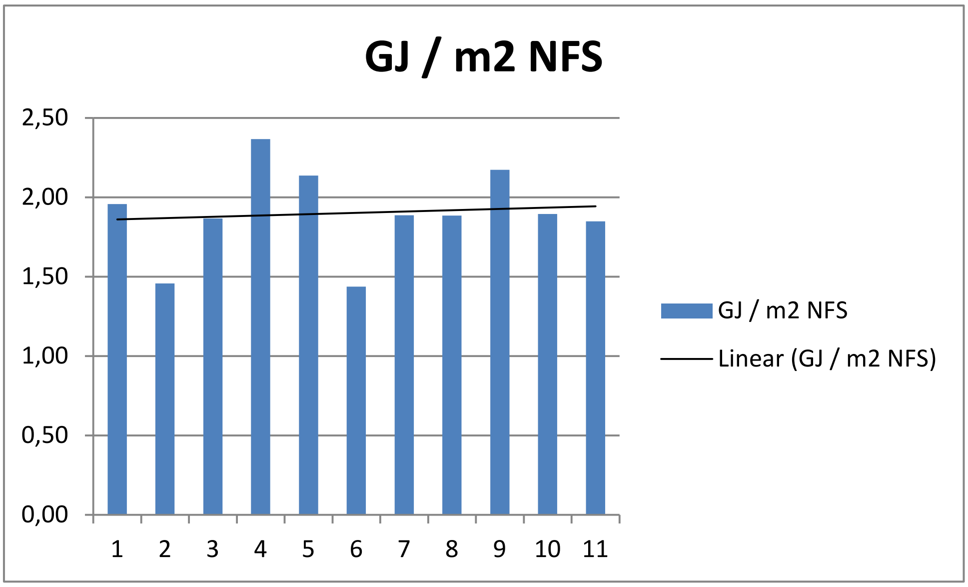


Figure 53: Primary energy consumption by Rijnstate Hospital

Deviation comparing different data from different benchmarks. As described in Chapter 2.2, there is no reference. By comparing the different databases we can compare the[6]m.

ECN database	0,8 GJ / m²
MPZ = database	1,9 GJ / m²
Quadrance database	1,3 GJ / m²

Deviation within Dutch hospitals is limited. Average primary energy consumption is average value 1,9 GJ / m² with SDEV 0,28 GJ / m². As a conclusion, we can see a big difference in output.

3.3.3 Discussion

Based on the defined benchmark at NL, we can conclude that it is not easy to compare different hospitals. In the following, we distinguish a few difficulties that were faced for this benchmark:

- Different functions: Base hospital, Teaching hospital and University hospital
- Different year of construction, for example: influencing the amount of isolation

[6] Primary energy. Groningen Gas Equivalent (heating value of 35.17 MJ/Ncm

- Different typology gives a different energy usage
- Different climate circumstances over the years, gives a different energy usage.
- Different power plants, with or without Combined Heat Plant, or using gas or not
- Different definition of energy usage, for example primary energy, or needed energy of thermal energy.
- Different size: for example benchmark Quadrance small hospital < 40.000 m2, big hospital > 80.000 m2

Trend

Because there is no correction of energy usage because of the outdoor circumstances, a trend over the years give not an accurate display of the energy usage, by usage of the building.

Having said this, there is also the assumption that it is very unlikely that the energy consumption will decrease in the nearby future, due to effects of:

- Increasing legislation: more ventilation
- Climate change: more cooling
- Increase in comfort: more ventilation
- Shift from gas > electricity because of cooling
- New equipment: more electricity
- Innovations: EPF: data center: more electricity

  Data not corrected for climate circumstances (only part of energy consumption due to climate differences)

It calls for far-reaching measures to reduce the energy consumption of a hospital
We could realize energy efficiency:

- Better energy monitoring (energy monitoring is not the field of expertise of a common hospital, focus is on maintenance of installed base, rather than on efficiency)
- Asset management: replacing equipment before end of life because new equipment is more efficient; would not decrease energy demand, but decrease carbon footprint

Having said that: it looks like newly built wing (North East) does not show significant increase in energy consumption.

3.3.4 Conclusions

The following conclusions can be drawn from our previous analysis:

- It is very difficult to compare different hospitals within The Netherlands.
- There are several databases for hospitals, but the data is not corrected, or there is no separation between hospitals, based on size, typology e.g.
- On country level it will take quite some effort to have proper monitoring and benchmarking, which is not available now.
- Trending data over a number of years would be advisable

3.4 Benchmarking at Italian level

This chapter investigates the existence of typical energy demand patterns in healthcare facilities, in order to identify similar behaviours that recur in hospital that have similar characteristics in terms of volumes, geographical locations and, moreover, specific end uses and facilities. This task is very important since the acknowledgement of these patterns may help to optimize exact tailor made solutions built directly on the real hospital demand, saving time, money and, of course, energy. This possibility is strongly enhanced thanks to the powerful instruments provided to the designers by the usage of BIM software.

The first subchapter, titled “*Defined benchmark*”, presents the energy demand of the sanitary district of Careggi, specifically focusing on San Luca Pavillons, where the most of the in site analyses have been run. A detailed overview of the consumptions is given together with a description of the architectural and MEP state of the art.
This hospital represents both the scope of the research and the reference benchmark from where we started in the seeking of the energy recurrent patterns.

In the second chapter, “*Comparison* “, we provide reports of the results of previous researches focusing on some north Italian hospitals, where, similarly, to Careggi, we have recovered the exact energy demand at its the state of the art, identifying, through a sensitivity analysis, every characteristic energy behaviour that worth whiles further investigation to recognize the typical patterns. Besides, the sample of hospitals under investigation may be considered is very thorough, counting more than 20 facilities whose energy demands were fully disclosed.

The third chapter, “*Discussion*” illustrates the findings of the analyses developed by comparing facilities that present similar dimension and hospital activities. In this section, we present some results that have already been published, extending the analysis to Careggi as well. As a finding, it is possible to demonstrate the existence of some typical behaviour that often recurs in the energy demand of similar hospital, thus validating the benchmark analyses. Finally, the “*Conclusions*” are presented in the final subchapter 4.

3.4.1 Defined benchmark

Careggi is today an important hospital in Italy, whose size is so considerable that it results in an energy demand that can be compared to the one of a small city. The number of users (patients, doctors, nurses, employees, visitors, etc.) that daily populate Careggi, in fact, is not far from the number of inhabitants of this ideal city.

The managers of the hospital daily monitor the energy demand of the facility with specific reference to each single activity that takes place in the healthcare district.
In the next paragraphs an analysis of the demand, split into the major end uses, is provided together with brief explanations of the devices that are responsible to its generation.

- Thermal demand - heating and sanitary water

According to the collected data and the monitoring devices that operate in Careggi, only an indirect analysis of the demand is possible through the reading of the energy bills, by considering the average efficiencies of the boilers and the global fuel consumptions in term of oil BTZ and natural gas. Even though this computation yields a very precise picture of the primary energy associated to heating and sanitary water production, however it does not allow site specific energy analysis focused on every singular building of the district, such as the Careggi pavillons.

The following table summarizes the primary energy requirements associated to the thermal heating/sanitary water end uses of Careggi from 2008 to the summer of 2014, together with the average monthly needs determined considering the same period.

	2008	2009	2010	2011	2012	2013	2014	Average Year
Period	kWhp	kWhp	kWhp	kWhp	kWhp	kWhp	kWhp	kWht
January	11.069.189	9.395.704	10.386.547	9.930.650	9.298.742	9.133.493	9.791.000	9.869.054
February	7.566.165	8.931.804	7.585.814	6.553.469	10.116.312	9.068.161	8.215.600	8.303.621
March	11.002.819	7.340.649	9.739.848	9.342.850	5.833.866	9.085.476	7.948.710	8.724.251
April	6.965.714	4.397.044	5.250.631	4.857.398	5.093.040	6.000.028	8.189.130	5.427.309
May	3.846.261	3.473.056	3.696.870	3.266.297	2.617.656	3.977.728	4.860.850	3.479.645
June	3.566.145	2.610.143	4.166.667	3.525.527	2.652.098	3.474.331	4.802.550	3.332.485
July	4.020.617	3.006.317	3.168.532	2.263.578	2.915.687	3.595.870	5.264.200	3.161.767
August	3.668.003	2.355.831	3.601.114	2.932.057	3.116.254	3.198.580	5.408.540	3.145.307
September	3.934.136	2.209.965	3.344.768	1.809.613	3.350.608	3.531.420		3.030.085
October	3.437.293	4.335.433	3.851.665	3.738.116	2.995.563	3.690.840		3.674.818
November	4.218.320	6.106.649	8.071.301	5.166.916	6.148.734	6.817.020		6.088.157

Figure 54 shows the pattern of the same consumptions throughout the average year of the surveyed period underlining the major peak during winter.

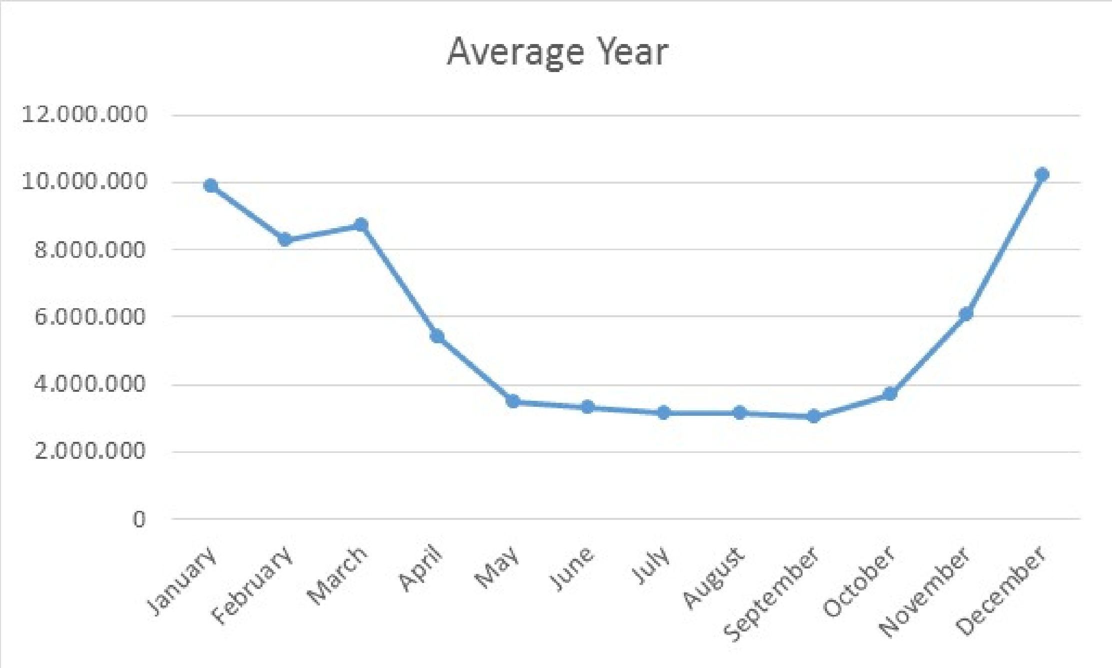


Figure 54: Monthly primary energy (kWhp) associated to thermal end uses (average in year period 2008-2014).

December	13.359.677	12.671.518	9.124.117	6.232.408	10.532.280	9.487.010	-	10.234.502
Year	76.654.338	66.834.112	71.987.875	59.618.880	64.670.839	71.059.957	54.480.580	68.471.000
Note: requirements associated to heating thermal end uses are expressed in terms of primary energy - fuels: natural gas and fuel oil BTZ – considering the correspondent lower calorific value								

Table 3.4.1 Historical primary energy requirements associated to heating and sanitary water production

- Thermal demand - cooling

Cooling demand is mainly associated to the production of cooled water, feeding the cooling exchangers of the air handler units or directly the terminals (fan coils, radiating floors, etc.) that serve the hospital rooms. In general, cooling is provided both in accordance to a centralized scheme (cooling central plant) and to local devices/terminals (splits and local small air handler units), the last directly installed in the air conditioned rooms as it happens in many indoor spaces of San Luca Pavilions.

Unfortunately, the metering of these data was not directly available; however, a reliable standard procedure has been adopted to get a first good approximation, of their amount. Due to the specific climate of central/northern Italy, it can be assumed that the necessity of cooling mainly concentrates during the hot season (from May to September), being associated mainly to the necessity of fresh-air with considerable flow rate to maintain the high standard air quality, especially within indoor hot floors, such as operating theatres and intensive care units. This task is fulfilled thanks to the operation of mechanical air ventilation where the cooling exchangers, used to cool and de-humidify the external hot air, request a continuous and energy intensive operation of compression chillers, themselves fed by electric power.

The delta of the consumed electricity between the hot summer months and a standard 'fresh' period (*e.g.* April, taken as reference), yields the demand, that is likely to be ascribed to compression chillers – cooling end uses.

Table 3.4.2 and Figure 55 provide an estimation of the cooling demand, determined thanks to the procedure described above

	Average Year	Delta	Cooling Demand Average Year
Period	kWhe	kWhe	kWht
January	3.259.597		
February	3.031.612		
March	3.170.937		
April	3.224.004		
May	3.442.715	218.711	656.133
June	3.824.657	600.653	1.801.958
July	4.341.036	1.117.032	3.351.097
August	4.476.205	1.252.201	3.756.603
September	3.839.833	615.829	1.847.488
October	3.572.768		
November	3.325.207		
December	3.439.186		
Year	42.947.757	3.804.426	11.413.277

Table 3.4.2- Esteem of the cooling needs indirectly determined from summer delta in electric demand and assuming an average COP = 3 for compression chillers

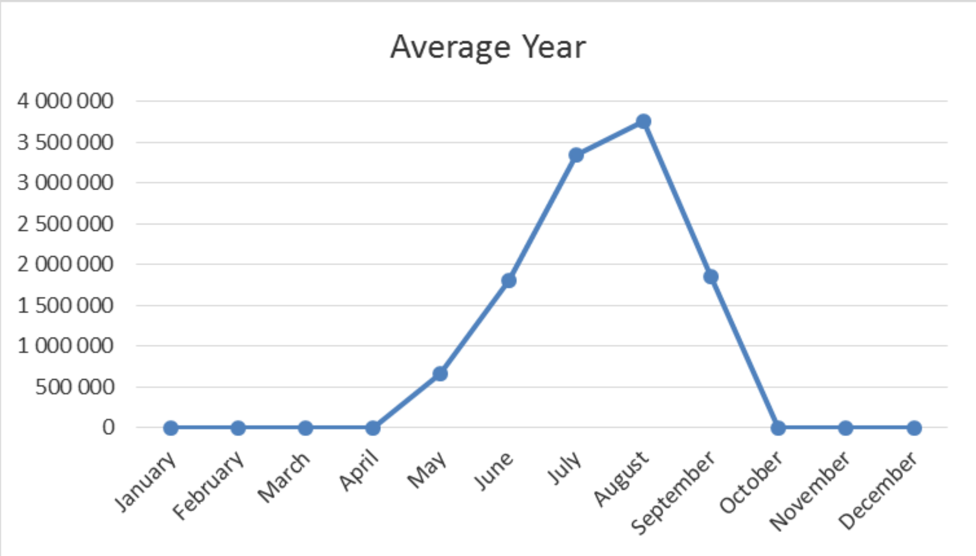


Figure 55: Monthly thermal cooling requirements (kWht) (average in-year period 2008-2014)

- Electricity demand

If one considers the whole Careggi hospital, table 3.4.3 shows the electric requirements from 2008 to the summer of 2014, together with the average monthly needs, determined within the same period. These data have been collected from the energy bills and from the recording of some meters that are installed in some of the facilities. Historical series of electric requirements are available since 2008, both for the whole hospital district and for its major parts. ENEL (*i.e.* the Italian company locally distributing electricity) meters are in fact spread in the hospital campus, separating hence the electricity supply to a multiplicity of end users.

In Figure 56, the typical pattern of the same consumptions is displayed throughout the average year of the surveyed period underlining the major peak during summer.

	2008	2009	2010	2011	2012	2013	2014	Average Year
Period	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe
January	2.951.955	3.040.250	3.105.891	3.194.713	3.316.818	3.947.957	3.917.917	3.259.597
February	2.852.238	2.706.694	2.916.768	2.890.506	3.267.810	3.555.658	3.454.760	3.031.612
March	3.012.124	2.926.049	2.844.068	3.199.379	3.233.590	3.810.409	3.962.730	3.170.937
April	2.948.133	2.990.375	3.250.397	3.141.229	3.270.857	3.743.033	3.832.920	3.224.004
May	3.228.576	3.396.697	3.202.701	3.387.232	3.419.507	4.021.576	3.976.770	3.442.715
June	3.536.258	3.522.558	3.740.135	3.826.515	4.154.243	4.168.230	4.251.970	3.824.657
July	4.083.685	4.188.630	3.229.272	4.216.089	5.206.054	5.122.488	4.769.250	4.341.036
August	4.029.727	4.312.974	3.229.272	4.224.866	4.990.265	6.070.125	4.598.850	4.476.205

	2008	2009	2010	2011	2012	2013	2014	Average Year
Period	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe	kWhe
September	3.498.256	3.677.080	3.125.103	4.059.551	4.282.886	4.396.123		3.839.833
October	3.335.720	3.236.785	3.229.272	3.498.940	4.095.971	4.039.920		3.572.768
November	3.041.968	3.000.158	3.125.103	3.143.522	3.803.330	3.837.158		3.325.207
December	3.006.124	3.128.378	3.250.005	3.324.941	3.951.082	3.974.588		3.439.186
Year	39.524.764	40.126.628	38.247.987	42.107.483	46.992.413	50.687.265	32.765.167	42.947.757

Table 3.4.3 - Historical Careggi electric energy requirements (kWhe)

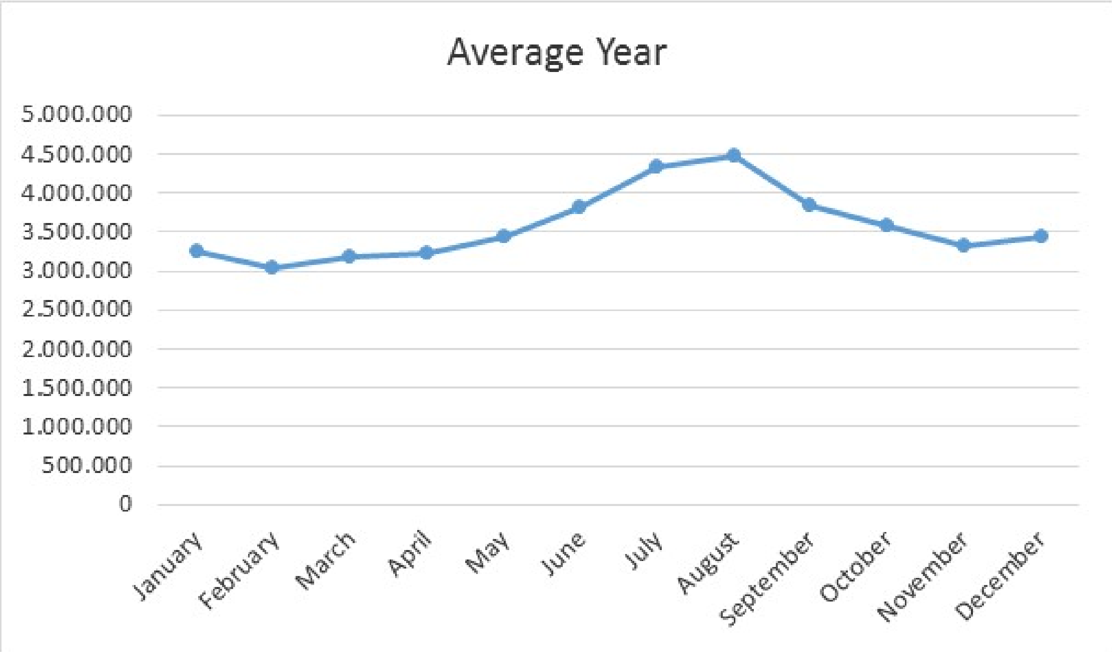


Figure 56: Monthly electric demand (kWhe) (average in-year period 2008-2014)

- Primary energy demand

To compute the overall primary energy demand of all the Careggi District one has to sum all the contributions given by every single end uses: it means that if the data were not already available (e.g. through the reading of the bills) there was necessity to consider the energy balance equations, listed below, under certain specific general assumptions (such as the typical efficiency of the electricity taken from the national database).

The primary energy demand, associated to thermal requirements, in terms of gas and/or oil BTZ, is already directly available for what it concerns, whereas the quote associated to electricity, has to be found by converting the available data into primary energy through the application of the average efficiency of the 'equivalent Italian thermoelectric power plant', provided by literature (see below) and taken as constant in the period 2008-2014.

According to the conventional plant scheme operating in an Italian ''typical'' hospital, in fact, heat and power requirements are assumed to be provided by conventional systems: electricity is imported from the grid and produced in fossil fuel-fired thermo-electric power plant whereas heating is supplied by high efficiency gas-fired boilers. Cooling needs are normally satisfied with compression chillers (please see Figure 57).

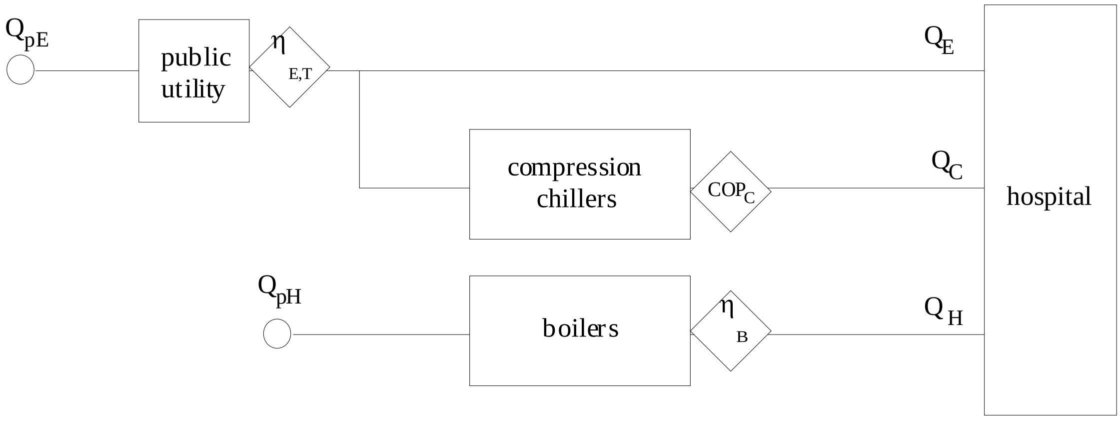


Figure 57: Conventional plant lay-out.

Hence, the hospital primary energy requirements can then be easily estimated in accordance to the following energy balances and are summarized in Figure 58:

$$Q_P = Q_{PE} + Q_{PH} = {}^{[Q_E + (Q_C/3)]}/_{\eta_{E,T}} + {}^{Q_H}/_{\eta_H}$$

Where the following numerical values have been adopted considering conventional plants, operating in the ''typical'' hospital as long as the beginning of 2014 (*i.e.* not considering the last two years when the new CHP tri-generator has started its operations):

- Q_{pE} is the primary energy demand associated to hospital electric requirements in kWh_p
- Q_{pH} is the primary energy demand associated to hospital thermal requirements in kWh_p
- Q_E are the hospital electric requirements in kWh_e
- Q_H are the hospital thermal heating requirements in kWh_t
- Q_C are the hospital thermal cooling requirements in kWh_t
- $\eta_{E,T}$ public utility mean electrical efficiency $\eta_{E,T}$= 46% (Enel 2011 Official Report [24]);
- η_H boilers thermal efficiency η_H= 85%;
- Lower calorific value of natural gas 9,626 kWh_p/sm^3.
- Lower calorific value of fuel oil BTZ 11,630 kWh_p/kg.
- Compression chillers COP = 3

	2008	2009	2010	2011	2012	2013	2014	Average Year
Period	kWhp	kWhp	kWhp	kWhp	kWhp	kWhp	kWhp	kWhp
January	18.199.515	16.739.303	17.888.699	17.647.348	17.310.380	18.669.621	19.254.567	16.955.135
February	14.455.629	15.469.712	14.631.147	13.535.368	18.009.573	17.656.706	16.560.431	14.894.082
March	18.278.480	14.408.400	16.609.579	17.070.818	13.644.470	18.289.363	17.520.522	15.617.592
April	14.086.808	11.620.172	13.101.831	12.444.908	12.993.661	15.041.170	17.447.391	12.436.014
May	11.644.754	11.677.639	11.432.863	11.448.017	10.877.335	13.691.679	14.466.575	11.795.381
June	12.107.831	11.118.737	13.200.810	12.768.317	12.686.501	13.542.520	15.073.009	12.570.786
July	13.884.590	13.123.780	10.968.706	12.447.368	15.490.696	15.969.029	16.784.128	13.647.362
August	13.401.643	12.773.643	11.401.288	13.137.048	15.170.034	17.860.718	16.516.873	13.957.396
September	12.384.030	11.091.801	10.893.326	11.615.292	13.695.744	14.150.075	0	12.305.044
October	11.494.588	12.153.754	11.651.839	12.189.662	12.889.213	13.449.101	0	11.441.705
November	11.566.069	13.353.407	15.619.859	12.759.965	15.335.521	16.085.518	0	13.316.866
December	20.620.846	20.227.986	16.974.371	14.263.666	20.075.956	19.087.464	0	17.710.994
Year	172.124.783	163.758.334	164.374.318	161.327.777	178.179.083	193.492.965	133.623.495	166.648.357

Table 05 - Careggi primary energy demand (kWhp) 2008 – 2014

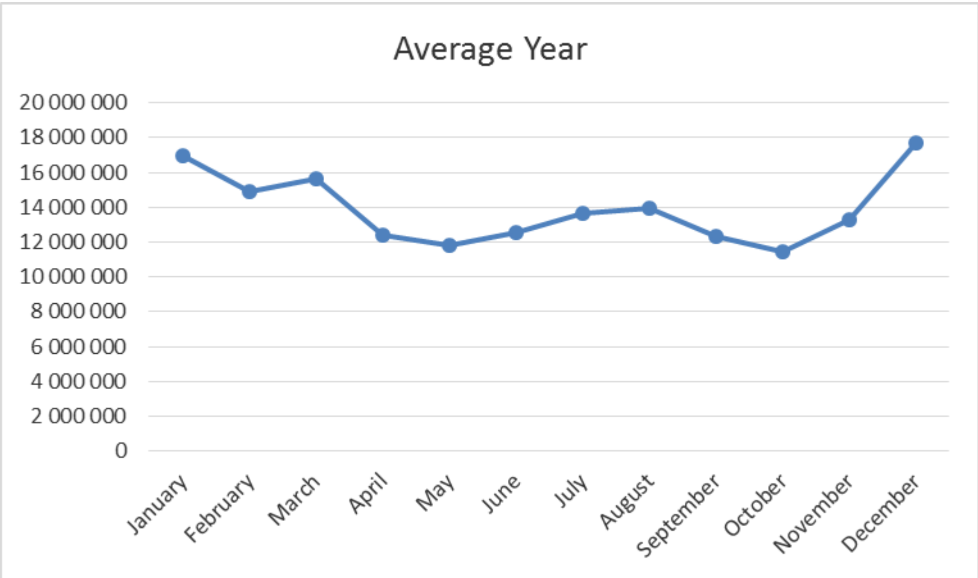


Figure 58: Careggi primary energy demand (kWhp) 2008 – 2014

- The 'Benchmarking'

After having presented the energy demand of the facilities, some considerations can be introduced with specific reference of benchmarking: as most of the Italian hospitals, in fact, Careggi shows typical patterns in its energy demand. These common energy behaviours can be summarized as follows.

1. *Thermal heating demand for heating and sanitary water*. This end use is mainly concentrated during the cold season of the year with peaks occurring normally between December and February (In Firenze the outdoor temperature is, for instance, continuously monitored by the Osservatorio Ximeniano di Firenza meteo station[7]). In hospitals as large as Careggi, however, thermal requirements never zero, even during the hot season, since the needs of thermal energy for sanitary water and for the input to exchangers of air handler units, that in climates such as Firenze's one, are necessary to dehumidify the introduction air.
2. *Thermal cooling demand.* This end uses concentrates only in the hot season. In the past, Careggi cooling demand has been provided mainly thanks to the operation of compression chillers (shifting hence from thermal to electric demand) and some absorption chillers as well. This causes the characteristic summer peak in the curve of monthly electric consumptions that will be described in the next subchapter. With the recent start-up of the tri-generation plant, the role of absorption chillers has been enhanced, helping in the fulfilment of a significant primary energy saving and emission abatement. This shift is not yet completely visible in the diagrams but it is certainly underway.
3. *Electric demand is significant*, ranging at the actual hospital configuration, between 40 to 45 GWh per year. These requirements correspond to the demand of about 13,000 families; the equivalent of a small Italian city, helping in giving a clear picture of how big is this facility. Literature (regional energy plans) in fact gives an expected electricity requirements ranging from 2,700 to 3,000 kWh/year for a typical family in Toscana and Emilia Romagna).
4. The electric demand is related to the operation of several categories of devices that have been described in the previous paragraphs. These devices range from the standard appliances usually installed in hospitals rooms (e.g. TV, chafing dishes, hand dryer, hairdryer, etc.), to the lighting of indoor spaces, to some electromotive force devices (such as elevators, compressors, etc.), and, finally, to specific medical devices whose consumptions shall be treated as singularities in the analyses since their variable and item-specific demand profile.
5. In Careggi, the curve of consumptions shows a peak during summer months confirming a trend that is common of all the large hospitals that are located in zone with hot and humid climate during summer.
6. The peak, in fact, is mainly due to the high operations of compression chillers providing cooling energy to the cold heat exchanger of the air handler units. Hospitals that are characterised by a considerable use of mechanical ventilation (*i.e.* hospitals with big operating theatre departments) are hence the most energy intensive and show the highest peak of electricity consumptions during the hot season. Differently, healthcare facilities more focused to hotel and inpatient departments, show a more regular pattern, sometimes displaying two peaks, one in summer and one during winter because of the higher lighting requirements.
7. In any case, every intervention, such as the installation of photovoltaic plants or of a CHP, better if within a trigeneration framework (as done in Careggi), that results in a peak cut, limiting the operation of compression chillers, shall be welcomed since it rationalises the energy balance of the facilities. The benefits, in fact, descend both from the more regular use of the systems (energy and environmental), and from the prospect to define better supply contracts with the providers (economic benefits) being the latter normally set over the peak of the demand.
8. A specific focus on electricity demand benchmarking will be presented in the next chapters.
9. *Natural gas and oil BTZ consumptions* are available as well. The boilers, providing heating to the several thermal end uses that have been previously described, are fed by these fuels. The energy manager has held a precise

[7] http://www.ximeniano-firenze.it/main/metereologica.html

register of the natural gas needs for the last years. The description of the facility primary energy requirements is then available for the past years, even though it has to been determined indirectly.

3.4.2 Comparison

Similarly to Careggi, several investigations have been carried out helping in defining the typical energy demand of more than 20 medium and large hospitals in central and northern Italy. The analyses were illustrated in the paper "On energy requirements and potential energy savings in Italian hospital buildings" that was presented during the Conference "Sustainable City 2006" that was hold in Tallin [16]. The investigations, by considering a considerable time laps of many years, demonstrate that there are recurrent patterns in the electricity demand of hospitals.

Other detailed analysis on hospital energetic, carried out by Bizzarri et al. [18-19, 21-22, 23], indeed confirmed that these recurring patterns characterize all the hospitals located in Italian sites at least with continental climate. In particular, the more detailed investigation [18], considered the electricity needs of twenty-three hospitals located in Emilia-Romagna, north Italy, not far from Firenze. Being the results not so recent (the available data was from the period 2000-2004), an attempt has been made to update the old database with more recent data. Unfortunately, because of the secrecy of the data and the necessity of getting specific authorization from Entities not involved in Streamer it was not possible to acquire this new information in time. Nevertheless, since the abundance of the old data and the reliability of the results, published in some of the most referenced journals of the sectors, the findings of the cited researches can be considered still valid and reliable for being compared with the requirements of Careggi.

The methodology adopted, considered to break down the electricity consumptions into their main end-uses confirming that compression chillers, supporting the HVAC systems during the hot season, represent the major electricity end-use and is essentially to be considered as the responsible for the summer peak in electricity demand. Finally, it has been detected the existence of a strict correlation between electricity requirements and cooling needs.

The same analyses have been carried out both from Careggi hospital as a whole and for San Luca Pavilions confirming the interesting correlation with the literature findings that are presented in the next paragraphs.
The graphs public in Fig. 5, for instance, shows clearly that the pattern of the electricity demand follows the same characteristic trend of the largest hospitals investigated in the past, as it will be further illustrate in the next Chapter.

3.4.3 Discussion

As already presented in the Deliverable 7.5, having the availability of a good sample of data (metering and bills), one can detect a clear recurrent correlation in the electricity demand in large Italian hospitals. In every temperate area, such as Italy, the cooling operations of HVAC systems mainly concentrate during the hot summer months, from May to September. In this period, significant increases in the electricity requirements are observed, especially in all those structures characterized by considerable energetic requirements. This peak of consumptions normally implies significant expenses, being the contracts between the users and the electricity producers normally negotiated both on real consumptions and on demand peak. A policy that reduces the electricity requirement or, at least, that rationalizes them through a peak cut, could hence achieve a considerable financial saving. This appears to be particularly desirable for all those users, as hospitals, that need a guaranteed grid connection calibrated on the peak of the demand. The comprehension of the electricity end uses should be a pivotal issue for every hospital administration since it has to be considered as the basic step in order to assess the impact of different retrofit strategies on energy savings and pollutant emissions reduction.

In recent years, studies on electricity demand patterns have been carried on by many researchers for different categories of users all over the world. In these researches the electricity consumptions have been broken down by major electricity end users in office [03, 04] and residential buildings [05-08], hotels [09], shopping malls, supermarkets [10-13] schools [14, 15] and hospitals [16].

There is clear evidence that, when buildings are supplied with air conditioning systems, those are expected to be the major end use in terms of electricity consumptions. In the past some realistic correlations [12, 13, and 17] have been found between air conditioning and the related electrical energy consumptions. Nevertheless, being the HVAC systems usage patterns weather influenced, every achieved formula has to be considered site specific, being reliable only if referred to the local scenario. Study on electricity use characteristics in hospitals received less attention in the past [18-22] even though this topic should be of particular interest since the considerable amount of the hospitals electricity consumption and the necessity of these structures to be largely air-conditioned.
This fact, as well as the considerable difference in sizes of the hospitals investigated, has suggested defining a procedure/methodology in order to compare the electricity consumption of such a heterogeneous sample of facilities.

The first step of the procedure consists in the computation of the daily electricity consumptions characterizing each reading period. In the past, as soon as these values were calculated, it has been clear that the same data needed to be further processed by introducing a parameter that could account for the hospitals' size. In literature, it is a common practice to define this normalized parameter by dividing the consumption data by the gross floor area of the corresponding hospital. In this case, however, this *modus operandi* appeared not to be consistent with the cases of study: hospitals are frequently unsteady samples, meaning that they often show departments that vary from time to time from use, to unused, or, simply, were under restoration at the time of the survey. A different way to normalize the data should then be found. The daily electricity consumptions have been then divided by the corresponding January value (with reference to both hospital and year).

Such a choice has been subsequently validated by observing the occurrence of the characteristic base load in the demand: an almost weather independent energy use that remains constant throughout the year, being essentially linked to the operation of the several devices that assist all the hospital activities.

This January value is characteristic especially for cold months when cooling systems do not operate. Finally, these normalized consumption data have been averaged over the four-year period providing a normalized electricity consumption parameter (NEP) defined as the averaged normalized electricity consumption characterizing the typical day, from January to December, in each single hospital, computed on a monthly basis throughout the year

It is true that the NEP approach has not been shared with the other case studies, however this approach has been found to be reliable at least for Italy, by several peer reviews [18, 19, 21].

In particular, three clear patterns, in relation to the different size of hospitals, might be discovered: if one compares the normalized electricity demand. In fact, as it is depicted in Table 3.2.1, by comparing hospitals NEPs it is possible to outline three major trends. As it has been demonstrated in previous researches, and confirmed here in Careggi as well, this differentiation in NEPs patterns is mainly due to the differences in appliances operations and human activities in the hospitals, and, to a lesser extent, to the structures size.

The first group NEPs (Figure 59) is characterized by a significant growth during the hot months, from June to September, while they slightly fluctuate around a constant base value during the cold and the mid-season. It can be expected it has been clearly demonstrated [Bizzarri Tallin conference], that this base load is mainly related to non-weather sensitive end uses (i.e. lighting, medical appliances, elevators), while the summer peak has to be considered strongly influenced by the intensive use of air-conditioners during the hot period of the year.

Figure 59: First group NEPs

Many important hospitals in the sample, i.e. Mirandola, Modena, Guastalla, Cento, Sassuolo, Scandiano, Argenta, and Careggi belongs to the group as well, are included in this group. The most of these structures are characterized by electricity consumptions usually higher than 100,000 kWh per month.

These hospitals are the largest in their territories and are the ones that normally provide full medical and emergency services. It implies that they are normally provided by surgery departments and are largely air-conditioned. Besides, the Italian law binds to supply each operating theatre with a mandatory minimum air-exchange of 15 volumes per hour. Besides Careggi as a whole, also its part, San Luca pavilions, if considered separated, can be assimilated to the first group of healthcare facilities for both the consumptions and the active functions. The several splits and room chillers, together with the air handler units, in fact characterise the typical summer peak.

The hospitals grouped in the second category (Figure 60) show smaller electricity consumptions (seldom higher than 100,000 kWh per month). In this group the NEPs between June and September do not show a very significant growth with respect to the other months in the year, sometimes they can be considered almost constant. In few cases they show a slight rise (always lower than 25%) with reference to the January values. These structures normally offer limited emergency services preferring to privilege in-patient department activities and out-patient care facilities. The lower growth in the summer peak may be explained considering that these facilities normally show lower volumes served by ventilation units, thus a lower requirement of electricity to feed compression chillers in summer.

Figure 60: Second group NEPs

Finally, few structures cannot be ascribed to any of the former categories, not being any clear pattern indicating any specific NEPs variation during summer. The random fluctuations characterizing the third group NEPs might be attributed to temporary closings of some departments due to frequent restoration works or, simply, to the fact that they are peripheral facilities providing limited healthcare services. This third category includes smaller facilities with less or no department served by ventilation.

3.4.4 Conclusions

In conclusion, the analysis of the electricity requirements of Careggi hospital confirms hence the findings of previous researches developed over the sample of the twenty-three hospitals of Emilia-Romagna, demonstrating the reliability of this benchmarking analysis at this step for the electricity demand.

Other analyses have been carried out to find if there were major correlations in the thermal demand as well. Even though previous researches have demonstrating that there is a clear link between volumes served by HVAC and the energy demand, also helping in find useful guidelines in the dimensioning of combined heat and power generation, in the case of Careggi the operation period of the tri-generation plant, even though it is already confirming the expected consistent benefits, is not yet sufficient to have reliable data for a comparison with the trends found in the analyses of the other hospitals taken in the benchmarking investigation.

3.5 Benchmarking at FR level

3.5.1 Defined benchmark

The French benchmark is based on the 2016 data of 11 French university hospitals (that have been anonymized). The level of the information available is then quite macro since university hospitals have different sites and each site has different buildings (between 1 and 90). Unfortunately, there is no benchmark available at a more precise level in France. The hospital names were anonymized due to privacy sensitive information related to some of the given university hospitals.

3.5.2 Comparison

	Total surface (m^2)	Number of beds	Electricity purchased (MWh) - except laundry and kitchen	Ratio kWh/m²	Thermal consumption (gas and district heating) MWh - low heating value	Ratio kWh/m²	Total energy consumed (MWh)	Total energy consumed per occupied floor area (kWh/m2)
University hospital 1	943 000	5 043	118 910	126	142 702	151	261 612	277
University hospital 2	3 664 349	22 720	456 491	125	614 936	168	1 071 427	292
University hospital 3	696 624	3 141	103 528	149	74 781	107	178 309	256
University hospital 4	309 106	2 452	33 200	107	35 188	114	68 388	221
University hospital 5	415 600	2 574	53 442	129	48 790	117	102 232	246
University hospital 6	430 986	3 018	54 507	126	64 169	149	118 676	275
University hospital 7	302 771	1 879	31 869	105	58 673	194	90 542	299
University hospital 8	361 088	2 158	50 727	140	59 307	164	110 034	305
University hospital 9	263 000	1 480	26 000	99	27 261	104	53 261	203
University hospital 10	267 721	1 788	37 878	141	43 168	161	81 046	303
University hospital 11	286 164	1 537	61 693	216	63 490	222	125 183	437
Average	721 855	4 345	93 477	129	112 042	155	205 519	285

3.5.3 Conclusions

The conclusions we can draw from these figures are quite limited. Electricity consumption: we can see that the electricity consumption per square meter is quite homogeneous except for 4 university hospitals (one is very high and need to be confirmed and one of the 3 other is new).

Regarding the thermal consumptions, it can be noted that for the north of France and areas where winter climate is very cold the ratio per square meter is higher. To go deeper in the analysis, we would need to have much more information such as the energy consumption by site, site activities, type of buildings, etc.).

4. Conclusions

In this deliverable, we have reported on both: the technical work performed at each demonstration site, and on the benchmark performed in four European countries to compare hospital energy information.

As a conclusion from the demonstration cases, STREAMER and other BIM tools and guidelines have allowed to assist the design and refurbishment of different healthcare buildings in different countries. It has allowed to explore the potential for micro-upgrades, small improvements in localized departments, and providing comparative estimations of the relative benefits and costs. Furthermore, STREAMER has created a robust pipeline for consolidating the available information and reintegrating the results into a unified building information models. STREAMER, with the help of some existing BIM tools, has allowed the assessment of different design alternatives, including different geometries, different layouts, envelopes, and MEP systems. Finally, it has also been possible to study different scenarios for architectural projects during the predesign phase and to compare them in terms of energy consumption, financial on the whole life cycle or operational quality. The validation tasks have also allowed to study and validate the defined semantic labels defined at the beginning of the project, and the BIM tools developed throughout the project.

According to the performed tasks during STREAMER project, it is possible to achieve one of the main objectives of STREAMER, which is reducing the energy consumption of healthcare districts by 50%. This conclusion can be obtained from the already reported studies in the deliverable D7.9, where the four studied university hospitals in Sweden (Tasks 1.2, 1.3, and 7.5) demonstrated the possibility to exceed this objective of energy efficiency. However, this can only be achieved by using the right technology that allows assisting the design decisions for reducing the energy consumption. It shall be said that such decisions could be expensive, such as isolating the building envelope, or moving departments, so a cost analysis is essential to check the return of investment.

The second part of this deliverable reports on the benchmarking performed in this task. Since energy data collected from different EU countries is not comparable side-by-side due to the fact that it is not possible to compare different buildings with very different conditions, such as the climate, the function, and the location, we have performed a country-level benchmarking in four countries, namely: The United Kingdom, The Netherlands, Italy, and France. At each country we have analyzed a set of building parameters and tried to draw a conclusion.

The benchmarking task did not allow us to draw the conclusions as originally planned despite the valuable information we were able to collect from hospitals. Performing a more complete benchmark for all the EU hospitals requires a deeper analysis of the current data collected, and the hospital features. A solution for this issue could have been the use of the degree-day method[8], but as mentioned before, the time restrictions for this

[8] http://www.degreedays.net

deliverable and the long process for acquiring hospital data did not help performing this method, which would have given an accurate and complete comparison, but would require more information and deeper analysis.

Furthermore, it is important to highlight that STREAMER has also allowed to study and compare the Energy Simulation Tools (ESTs), and that according to our analysis of five ESTs, we can conclude that we had different results obtained for the same area, which has also showed that it was better to use some tools for heating energy, whereas it was better to use different ones for cooling energy. Our analysis has also highlighted that some of the compared tools require professionals with high knowledge to manage these tools.

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