D1.4

Multi-scale and multi-stage scenarios for energy-efficiency retrofitting

Deliverable Report: D1.4 Final version

Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighborhood energy systems.
The Streamer project is co-financed by the European Commission under the seventh research framework programme FP7.EeB.NMP.2013-5; GA No. 608739)

Streamer
European research on energy-efficient healthcare districts

D1.4

Multi-scale and multi-stage scenarios for energy-efficiency retrofitting

Main author	Roberto Di Giulio (IAA), Danny Werensteijn (DJG)
Co-authors	Martin Aizlewood (TRF), Marc Koster (RNS), Beatrice Turillazzi (AOU), Roberto Traversari (TNO), Rizal Sebastian (DMO), Sander van Gennip (DMO), Kevin Voilant (APH)
Contributes by	Peter Sandö (NCC), Stefan Dehlin (NCC)
Dissemination	Public

Document history

Version	Date	Status	Produced by	Comments
V1	8th October 2016	Draft	IAA/DJG	
V1	13th October 2016	Final draft	WP leader	
V1	21st October 2016	Review	NCC	
V1	23rd October 2016	1st Revision	WP leader	
V1	24th October 2016	Review	DWA	
V1	27th October 2016	Final revision	WP leader	
V1	6 February 2016	Approved	Coordinator	
V1	7 February 2016	Submitted		

Colophon

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Abstract

The main scope of D1.4 is “Definition of retrofitting priorities over a staged approach, and creating generic retrofitting action plans that includes considerations of temporary moving and accommodations”.

Furthermore it is related to the objective of Task 1.2 that focuses on:

- mapping the problems;
- analysing the optimization potential;
- developing the most effective scenarios at the strategic real estate management level.

After an overview on the consolidated knowledge achieved in the last three years of research, focussing on the outcomes more consistent with the scope of D1.4, the report maps and describes the possible and realistic scenarios within which the Hospitals usually approach a retrofitting project.

Thus, the deliverable defines the retrofitting priorities over a staged approach and creates a general framework including the possible retrofitting action plans generated by the combination of the possible retrofitting scenarios and the different approaches that the development of a retrofitting project, within a certain scenario, could be based on.

Publishable executive summary

Introduction and scope

Over time, the current building stock needs to be adapted to meet the changing requirements of the occupants. The difference between demand and performance of a building grows as time is passing and leads to three general scenarios; move out to another existing building, demolish the building and build a new building or do a retrofit.

A retrofit scenario comes in many sizes and forms. However, all have in common that they also include opportunities to improve certain other aspects of the building than the original starting point as well. STREAMER focuses on making buildings more energy efficient, so research must be done to accommodate the goal of more energy efficient healthcare buildings in retrofit situations.

So the aim for this deliverable is to define retrofitting priorities over a staged approach, and to create generic retrofitting action plans that include considerations of temporary moving and accommodations.
(From the DoW - Description of Work)
The scenarios and action plans will focus on using the STREAMER approach and the related tools.

Retrofitting levels and solutions

In the previous deliverables implemented in WP1 and WP2, according to the design criteria and technologies, three main types of retrofitting actions have been identified:

- interventions on layout and space;
- interventions on building envelope;
- interventions on Mechanical, Electrical and Plumbing technology (MEP) systems.

The three types of intervention have to be considered strictly interrelated into an integrated design approach aimed to achieve, from the potential synergy, the best opportunity to improve energy and cost efficiencies. Depending on the retrofitting works implemented, it is possible to define three levels of interventions:

1. Retrofitting involving only the space layout, or the building envelope, or the Heating, Ventilation and Air (HVAC) systems (e.g. move of a department, replacement of a system, etc.)
2. Retrofitting operating on two different aspects among building layout, envelope, HVAC systems (e.g. implementation of External Thermal Insulation Composite System (ETICS) and replacement of the heating system, etc.)
3. Retrofitting including all the three types i.e. operating on the building envelope, the space layout and the HVAC systems (e.g. extension of a wing or a floor)

In the scope of the multi-scale and multi-stage scenarios for energy-efficiency retrofitting all the three possible levels will be considered. Furthermore the larger retrofit solutions, like extending a wing or build a new floor, can involve additional works that go beyond the three levels described. It has to be considered for example: the need to build temporary buildings or to extend a wing, the construction of a new floor, an inner courtyard that could be roofed, etc. (the figures 1 & 2 represent some examples of the larger retrofitting solutions described in the report).

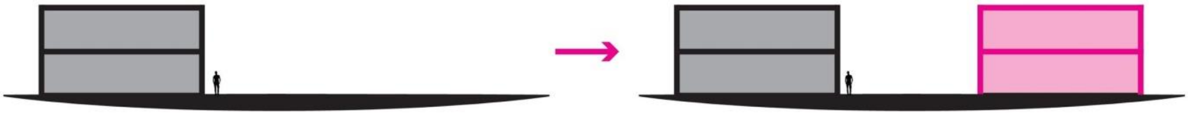

Figure 1: Diagram of temporary building

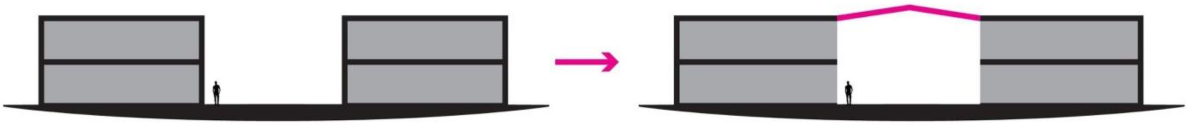

Figure 2: Diagram of a roofed internal space

Analysis and definition of a STREAMER approach to the multi-scales and multi-stages scenarios for energy-efficiency retrofitting project take account of the retrofitting solutions for envelopes and MEP systems reported in the deliverables implemented in WP2.

The need of an **energy efficiency audit**, to be carried out before intervention, has been considered and analysed as well. A “ten steps detailed guide to energy audit”, defined in details in the section 2.6 of this report, explains how to carry out a systematic survey, collection and analysis of parameters for the specific energy consumption and operating conditions of the building.

The survey procedure includes a technical and economic evaluation of energy flows of a specific building with the aim to:
- provide insights of the energy demand;
- identify the retrofit technologies;
- evaluate techniques and economic opportunities for each intervention;
- improve the comfort and safety;
- reduce operating expenses.

The STREAMER approach to the multi-scales and multi-stages scenarios for energy-efficiency retrofitting

Application of STREAMER procedures and tool in the retrofitting projects requires specifying, in more detail, how they have to be adapted, which data are required and how the benefits can support clients, design teams and building operators in the decision making on EeB solutions.

Building Information Modelling (BIM)

STREAMER recognizes the substantial value-added benefits BIM could add to a retrofitting situation compared to traditional 2D and document-oriented information handling. Information handling is integrated and all involved disciplines can individually or in a multi-disciplinary collaboration interact and explore the consequences of design alternatives. Capturing the existing buildings’ geometry and characteristics enable creating purpose-built models to be used for conducting different energy performance analysis. The integrative nature of BIM technology renders it an ideal tool to plan, supervise and capture as-built data in the actual retrofitting process and, along the way, ensure that the foreseen technical and functional goals are met as well as budget and time schedule.

The STREAMER project delivers the tools and a design methodology to enhance the early design stages. This clear back to end process described the situation for new build projects, where everything is built from scratch. However, the retrofit design process will mostly not follow this defined process.

Because of the ambiguity of the retrofit cases a single design process cannot be developed that will cover all the retrofit cases. Therefore, this deliverable provides the pieces from which a specific design process can be constructed. A matrix where the single steps are used to develop specific retrofit processes can be found in appendix 1 of this deliverable.

Energy calculation

For an energy calculation done at an early stage using a complex tool, the calculation input is based on so many assumptions that make the result unreliable.

In the integrated STREAMER process information is needed at the start of the process, so that changes can be made according to this information where it has the least impact on budget. But the traditional energy calculation tools need a lot of data, which is not precise or not available at all at the early stages of a design process. This means another kind of tool or process is needed.

At the start of a project, when little is known for sure, an energy analysis is a good option. In the STREAMER project data gaps at the beginning of a project are filled in with expert knowledge in the form of default values. For some of the needed data, the gap between the data requested and what can be delivered is filled in by labels. These labels give already some (indirect) information on aspects for an energy analysis. For instance the occupancy times are captured in the labels and make thereby a calculation possible of the hours to heat or cool a certain room during a year.

Therefore within STREAMER, after the choice of a certain MEP system is made, calculation can be implemented using weighing factors for KPIs, the Key Performance Indicators. These are subdivided in Financial, Quality and Energy key performance indicators and will be displayed by dashboards. The three indicators get a score from 1 to 10 on how they perform on certain predefined weighting-factors. The calculation, on how the building and MEP systems score with the chosen alternative on energy performance, is the energy analysis. The calculated score can support the decision for a certain alternative.

The score gives some indication on how good or bad the building will perform in energy efficiency. This score must always be put against the scores on quality and finance to choose a realistic alternative to develop further.

EDC (Early Design Configurator)

The EDC is a software tool used to generate geometry for a spatial layout proposal out of a PoR (Program of Requirements) and design rules. The EDC has several steps. At first a building size and shape must be given. This can be an existing building or a new building. In case of an existing building this is easy as only the current size, the shape and the main constraints must be given in the software. In the case of a new building, this information comes from a Master plan or a mass-study.

The second step is to place the building in an open map included in the EDC. Thereby giving the building orientation and place coordinates.

The third step is input of a PoR. This input needs among others room-name, room-type, functional area it belongs to, minimum floor area, minimum width and last but not least label values for each room. This list is used by the EDC to generate rooms and place them within the given building.

Another input is the list with design rules. These design rules determine the spatial relationships between the rooms. The rules have different priorities between them, because not every rule can be met and not every rule is as important as the other.

For the EDC to work, a fully completed PoR with labels, the location, size and shape of a building and design rules is needed. In a retrofit scenario, it is only recommended to invest in making a PoR with labels, sizes etc. of the existing if there is a reasonable expectation in a layout change. If this is not the case the EDC should be left out in the STREAMER process. However as the EDC can generate thousands different spatial layouts, some of the results can be unexpected and the threshold for using the EDC should be low. If the enriching of the current program with labels is already done, it is certainly worth the small effort to run the EDC to see if there are improvements possible.

EDC has focused mainly on new build design processes, applying this tool to the different strategies identified for retrofitting projects some recommendations have to be followed to make the EDC more compatible with retrofit scenarios. Recommendations relate to some constraints depending on the existing situations in the buildings to be retrofitted or refurbishes, specifically:

- position, shape and layout of horizontal and vertical circulation spaces (including escape routes), atria and entrances
- building components properties (e.g. structural components)
- MEP properties.

The EDC is developed as part of D6.2.

PoR (Program of Requirements)

A “PoR” is used by a client to document his wishes and demands for a new building. But it can also be used for retrofit situations. The PoR can be used to compare the current leading PoR with a new PoR. This gives insight in the changed wishes and demands and gives input for a decision to do a retrofit.

A second option is to use a PoR to compare it with the actual performance of the building. This will result in an overview of inconsistencies with the demand and supply. By comparing the PoR with the actual performance, insight is gained in the need for a retrofit and also highlights focus areas for a retrofit.

A label enriched PoR is needed as an input for the EDC to produce spatial layouts. So if a spatial layout change is expected or another spatial layout will be evaluated if this layout will improve the current conditions, a PoR is needed. The outcome of EDC in the form of an IFC (Industry Foundation Class) file can be compared to the current layout. Another software tool can be used to make a comparison between different layouts. This would be an IFC viewer with an option to give a colour representation of the attached labels.

Decision Support Tool

STREAMER Decision Support Tool (DST) brings together the results of the STREAMER early-design process and analysis, and visualizes these results for easy comparison, enabling users to compare case scenarios on specific aspects: quality, energy performance and life-cycle costs.

Based on a program of requirements and design rules the Early Design Configurator generates several case scenarios in the form of IFC models which serve as input for tools that make assessments of the Key Performance Indicators. These assessments are then added to the IFC models and imported into the DST.

The STREAMER DST is developed based on a state-of-the-art software tool; the DEMO RE Suite. Within the RE Suite, the application RE Maintenance is designed for condition assessment and planning of maintenance and refurbishment activities of existing buildings. The software application embeds the technical norm NEN 2767 which is widely used in the Netherlands and resulted from research in EU project Brite Euram 4213 on "Condition assessment and maintenance strategies for building and building components".

The DST is developed as part of D3.6.

Scenarios and approaches

The possible retrofitting scenarios and the corresponding approaches to their implementation and development are not solely depending on the functional needs and on the improvement of the energy efficiency. A third factor, that the choice of the retrofitting strategy to apply depends on, is the assessment of the financial feasibility and sustainability of interventions to be carried out. In other words: the opportunity to retrofit a building instead of replacing it with a new one.

There are different scenarios in which a retrofit design process can be developed. From small maintenance to large scale extensions, every scenario belongs to retrofit. So, when describing retrofit scenarios it is good to consider some differentiation because of the great differences between the scenarios in content. This in return will require a specific methodology for each scenario. Because of the different natures of all scenarios a survey is done among the four STREAMER hospital partners for establishing the main types which the number of possible scenarios can be referred to.

A list of 6 basic scenarios, described in their basic and general aspects, representing the main types of retrofitting projects have been implemented.

Since there can be several exceptions that don't fit the basic ones, the 6 scenarios – Shrinking / Maintaining current conditions / Changing for adaptation / Improving / Upgrading / Growth – have been further analyzed and then detailed in a matrix, annexed to this report, where they have been crossed with the possible approaches that the implementation of the actions related to each scenario can be based on.

The implementation of a retrofitting project within one of the six scenarios described in the report can be carried out more or less deeply, i.e. investing more or less extensively in the building(s) to be retrofitted.

Depending on the user needs, the functional goals, the resource available, the targets to be reached and other number of factors or constraints, each scenario, and its related strategy of intervention, can be carried out according to different approaches, corresponding to different extent of works.

As explained before, depending on the retrofitting works implemented, it is possible to define three levels of interventions. Considering all the possible combinations generated by the type of intervention included into the three levels - and adding a “level 0” corresponding to “do nothing” - a set of eight possible approaches can be listed and analysed with the aim to define:

- how the retrofitting project can be organised and carried out step by step
- which STREAMER tools and methods can be applied

The description (not exhaustive of course) of the different approaches has been further investigated, validated within the four demonstration projects and developed into a matrix that crosses the 8 approaches with the 6 scenarios. The matrix explains, for each of the 48 combinations scenarios/approaches, the step by step process for implementing the retrofitting project, the actions and calculation to do and the STREAMER tools to apply.

Fitting the four demonstration projects within the corresponding combination scenario/approach a set of validation forms have been implemented as well. (The matrix and the validation forms, included into this report as annexes, will be left open to updating and improvements, up to the final implementation of all the STREAMER tools applicable in the retrofitting projects)

Analyses of the carried out and/or ongoing refurbishment and retrofitting projects in the four STREAMER hospitals have been used for validating the taxonomy of scenarios and corresponding approaches. A set of forms attached to this report (Appendix 2) includes a deeper analysis and a more detailed description of each “real word example” referred to the corresponding scenario/approach combination, as defined in the matrix attached in the Appendix 1.

List of acronyms and abbreviations

APHP	Assistance publique – Hôpitaux de Paris
BCF	BIM Collaboration Format
BAM	Building Assembly Modelling
BIM	Building Information Modelling
BMS	Building Management System
CAD	Computer-aided design
CO2	Carbon dioxide
D	Deliverable
DoW	Description of Work
DST	Decision Support Tool
EeB	Energy efficient Buildings
EDC	Early Design Configurator
EMAS	Eco-Management and Audit Scheme
ETICS	External Thermal Insulation Composite System
ErP	Energy-related products
EU	European Union
GHG	GreenHouse Gasses
HVAC	Heating, Ventilation and Air Conditioning
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
IFD	Framework for Dictionary
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LCC	Life Cycle Costs
LCCA	Life Cycle Costs Analysis
MEP	Mechanical, Electrical and Plumbing technologies
MVD	Model View Definition
NBIMS	National BIM Standard
NEN	NL Norm
NPV	Net Present Value
PoR	Program of Requirements
PV	Photovoltaic
ROI	Return on Investment
TRF	The Rotherham Foundation
TRL	Technology Readiness Level
WP	Work Package

Definitions

Energy efficiency: Energy efficiency is using less energy to provide the same service/output.

Health Care District: A Health Care District is a campus area consisting of various buildings including: hospitals and clinics; research centres and laboratories; educational buildings; temporary care homes; rehabilitation and sport facilities offices, retails and logistic buildings; power and control facilities.

Label: property attached to spatial component, also called “semantic label”

Semantics: the study of meaning. It focuses on the relation between signifiers, like words, phrases, signs, and symbols, and what they stand for, their denotation”. (Source: Wikipedia) In the STREAMER context, examples of signifiers can be: a wall, a room, a KPI, the concept of natural ventilation etc.

Semantic rules for BIM: relationships between objects and/or information within the BIM environment.

BIM: 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, but not only – it’s relevant to the whole life cycle.

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1. Introduction and scope

Over time, the current building stock needs to be adapted to meet with the requirements of the occupants. The difference between demand and performance of a building grows as time is passing. This is because of two reasons; 1) the growing demands of the users of the building and 2) the performance of a building decrease over time. Ultimately the difference between demand and performance lead to three general scenarios; move out to another existing building, demolish the building and build a new building or do a retrofit. The scope for this deliverable is the latter.

A retrofit scenario comes in many sizes and forms. However, all have in common that they also include opportunities to improve certain other aspects of the building than the original starting point as well. When a retrofit is started, budget and times are reserved, so why not accomplish some other goals as well? STREAMER focuses on making buildings more energy efficient, so a research must be done to accommodate the goal of more energy efficient healthcare buildings in retrofit situations.

But one must not forget that a sole focus on EeB (Energy efficient Buildings) isn't realistic. If the focus is solely on EeB one will end up with windowless buildings for instance, as windows have a greater heat transfer then walls. Also other key performance indicators are taken into account. The Key Performance Indicators (KPIs) within STREAMER are divided in energy, quality and finance. This ensures a good balance in design alternatives for current and new buildings.

Next to the KPIs another aspect should be considered in retrofit scenarios; namely the daily operations of a healthcare building cannot be disturbed. The safety for patients and employees in Health Care Districts (HCD) is of great importance.

So the aim for this deliverable is to define retrofitting priorities over a staged approach, and to create generic retrofitting action plans that include considerations of temporary moving and accommodations. (From the DOW)
The scenarios and action plans will focus on using the STREAMER approach and the related tools.

These action plans define the step-by-step process in retrofit scenarios where energy efficiency is a high priority but not the sole focus area.

2. Available knowledge and experience

2.1 Label approach

The Streamer label approach is the basis for the design rules used to:

- give the EDC (Early Design Configurator) the input for automatically generating a layout in the early stage;
- carry out the selection of possible types of installations (MEP systems) and solutions for energy efficient construction (EeB solutions).

During the Streamer project the problem occurred that the room names during the initial phase of a design don't define the properties neither give the values for that spatial element (room). In STREAMER a hospital/healthcare design is evaluated on various KPIs at an early stage. To use an automated early design process and to perform an evaluation, at least (some) properties of spatial elements, construction elements and systems need a value.

The intention of using labels instead of the room name or function is to define the allowed (range) or default values for properties (of spatial elements) in an easy and structured way in the early design stage. Default values can be replaced if more detailed information is available, enriching the design. If the labels of a spatial element in the design are known it can easily be checked if the property values of this spatial element comply with the range of allowed values according to this label. The labels can also be used in an existing situation. If the labels of a room are known it can be checked if this spatial element (room) can be used for other functions if the requirements for this function are known. This can help designers during the retrofitting of a building or part of a building to quickly find out if spatial elements can be used for other functions as well.

Streamer labels can be valuable for adding properties and values to spatial elements (rooms) in the early design stage allowing optimization of the clustering of spatial elements (rooms) on other important aspects. For example energy demanding functions or functions with specific requirements for the time of use can be clustered.

Secondly, the Streamer labels can help evaluating the design, by checking if the property values in the design meet the allowed values as stated by the labels. This step can be repeated for each newly created solution in any design phase to verify if the solutions are still valid complying with the fundamental requirements.

The Streamer labels at room (object) level contain a lot of semantic information. This means that not all information is explicit in the labels and label levels, but a lot of information can be derived from them. For this the design rules also play an important role. Not only for the layout of the floor plan but also regarding the MEP and EeB systems.

2.2 Definition and level of retrofitting

In the previous deliverables implemented in WP1 and WP2, according to the design criteria and technologies, three main types of retrofitting actions have been identified:

- interventions on layout and space;
- interventions on building envelope;
- interventions on MEP systems.

The first type of retrofitting, involving building space and layout solutions, aims to improve both occupant indoor comfort and energy efficiency. For many and many years, healthcare buildings have not always been designed to meet any energy performance goals; consequently even the indoor comfort of users was very low. In order to correct this practice, energy performance should be considered in the earliest stages of the design process. In the retrofitting actions this means to take maximum advantage, when possible, from some factors that represent a constraint (e.g. orientation cannot be changed in an existing building, but façade composition can be optimized according to environmental inputs) or to correct some others. Design solutions comprehend the most indicative factors that influence an environmental design, by considering building space (morphology, orientation, glazing percentage). Anyway, this requires a detailed orientation/climate/natural resources analysis to quantify the potential for solar gains, day lighting, etc. to be improved.

The second type of intervention takes into consideration the envelope technologies (both façades and top closures) chosen and described in D2.4. Improvements consider the suitability to refurbishment actions and the improvement that a specific solution can achieve, by considering the specific performance of each technology (e.g. thermal transmittance U-value, use of thermal mass, control of solar heat gains, efficiency, etc.).

The third type of intervention is on MEP systems. After defining the energy balance throughout the boundary of the building (thermal exchanges by considering the U-value of the elements, orientation and solar gains, the surfaces extension) designers can approach the efficiency of MEP systems (primary energy).

The three types of intervention have to be considered strictly interrelated into an integrated design approach aimed to achieve, from the potential synergy, the best opportunity to improve energy and cost efficiencies. Anyway, a step-by-step approach that considers partial interventions can be considered being conscious that this can lead to a partial result that, if not correctly evaluated, cannot give the expected result in terms of energy consumption reduction.

In particular, the first type of retrofit actions is strictly connected to the second and third ones. As an example, limiting direct sunlight to avoid overheating via orientation control, solar shadings and related fenestration systems is a decision that will influence heating and cooling loads. One may not take care of these indications, and base the retrofit design on improving the MEP systems efficiency, for example using high – performing cooling systems. This may lead to a very good comfort indoor; nevertheless the overall energy consumption will be higher.

The design phase on layout and space identifies bundles of energy conservation measures that represent specific efficiency scenarios on which the levels of interventions on envelope and MEP systems start. Depending on the retrofitting works implemented, it is possible to define three levels of interventions:

1. Retrofitting involving only the space layout, or the building envelope, or the MEP systems (e.g. move of a department, replacement of a system, etc.)
2. Retrofitting operating on two different aspects among building layout, envelope, HVAC systems (e.g. implementation of ETICS and replacement of the heating system, etc.)
3. Retrofitting including all the three types i.e. operating on the building envelope, the space layout and the HVAC systems (e.g. extension of a wing or a floor)

In the scope of the multi-scale and multi-stage scenarios for energy-efficiency retrofitting all the three possible levels will be considered.

Furthermore the larger retrofit solutions, like extending a wing or build a new floor, can involve additional works that go beyond the three levels described. We should consider for example: the need to build a temporary buildings or to extend a wing, the construction of a new floor, an inner courtyard that could be roofed, etc. The larger retrofit solutions aren't mapped and researched in WP2, so some generic solutions are described in the next chapter. These solutions do (partly) follow a design process of a new building, with restrictions on some level. The current situation can be used to determine the relationships with the current program and MEP systems with that of the added program.

2.3 Retrofit solutions on a large scale

2.3.1 Roofed internal space

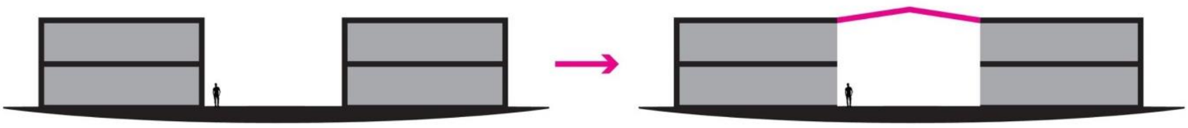


Figure 3: Diagram of a roofed internal space

A hospital is often made up of multiple buildings or wings. The spaces between those buildings or wings can be fully enclosed by buildings or just partly. In either case the space can be roofed and used as building space. There are two main subtypes that can be distinguished; an inner courtyard, which is at least enclosed on three sides or a more linear space which is enclosed on at least two sides. The first is more appropriate as a kind of gathering space, like an entrance or a restaurant. The latter serves more as a central connection.

What the two subtypes have in common is that they are usually a public space. This has to do with several aspects. First of all, covering up an internal space needs mostly an open and light solution. The former outer walls are now inner walls and will receive less light than before if they remain the same. The second aspect that stimulates the use as public space is the height. Covering up an internal space often means the roof will be placed on the current roof level. And because restrictions are at hand regarding daylight, no additional floors can be placed within the new structure without inflecting the daylight to the current building. So these aspects make the roofed space appropriate for public use.

Next to more space, this solution is appropriate for tackling some other goals or problems as well. An energy reduction can be realised because the former outer walls of the current building are now inner walls. In most cases this will reduce the surface area towards the outer climate and thereby the heat/cold transfer, especially if the new roof has high insulations values. The new space doesn't have to include the same climate standards as the old spaces. If the new space is used as a central hall, entrance hall or public corridor most people will use this space with a jacket on. So an in-between climate is possible, which requires less technical infrastructure and can act as a buffer for the other spaces.

Another way to reduce energy is to use the new space as an air outlet. Because of its height a stack effect will occur in the new space, thereby creating a negative pressure, which pulls the air out of the adjoining spaces. This will result in a smaller demand for ventilation.

In addition a reduction in energy for lighting can be made. Because the former outer walls are now inner walls, the walls could be taken away. If the former wall was a wall with a small glazing percentage this means a natural daylight can now flood into the building. Although this improvement is depending to a great extent on the orientation of the building, size of the internal space, height of the building and the chosen construction of the new roof. Opening the former outer walls can also contribute to a better orientation within the building.

2.3.2 Extending a wing

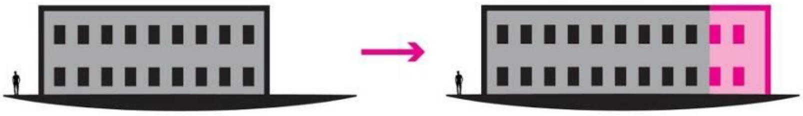


Figure 4: Diagram of extending a wing

A lot of hospitals have taken into account the possibility to extend their wings in the future. So more spaces can be added without a great inconvenience for the daily operations and no great adaptations in the supporting infrastructure are needed. In these cases where a new extension already is taken into account, no big changes are expected. So that is also true for energy efficiency.

To some extent the properties of the extension will probably be the same as the current wing. In most cases the building becomes slightly less energy efficient because the negative impact on outer surface / inner volume ratio. So the compactness of the building decreases as long volumes become even longer.

The loss of compactness can be countered if the HVAC systems and other climate installations weren't operating on their max capacity. With more building, more is asked from the MEP systems, and the systems will be more efficient at almost max capacity.

There are some ways to improve the energy efficiency of the whole building with extending a wing. One way is to simply build an extension with improved properties on energy related aspects. This could be a higher insulation value for the outer surface, a more efficient HVAC system, external sun-shading, more glassed area for more daylight or more efficient lighting. If the additional space is not needed immediately the extension could act as a buffer zone for retrofitting the current building to the same standards as the extension. Some rooms from the current building can be placed in the new extension. The old location of those rooms can now be improved, with more efficient systems, better insulation values etc. Then a few other rooms can move into the retrofitted part and start this cycle again until the whole wing is retrofitted. If then no extra space is needed the new extension could be demolished or a part of the old building can be demolished. In other cases the new space can be used to accommodate growing space needs.

The step by step type of retrofitting requires a lot of planning and predictions about future needs. As only one step at a time the current building can be upgraded, with as a maximum size, the size of the extension. If the extension has to facilitate an additional need for space immediately, the extension must be larger than the parts that are being retrofitted in one stage.

In most cases extension of a wing won't tackle other problems or goals than more space or energy efficiency. As it is more or less the same of what is already there. The quality and the LCC (Life Cycle Costs) could be improved if the current building is also retrofitted. The extension also gives more space to energy producing systems on the roof or the wall.

2.3.3 Vertical extension

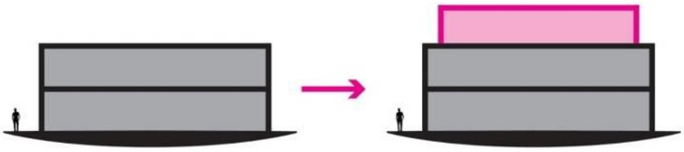


Figure 5: Diagram of vertical extension

A vertical extension can often be seen in retrofit scenarios, also in other cases than hospitals, to increase the floor area. This requires additional infrastructure like extending staircases and moving technical equipment that stands on the roof of the current building. Also the construction of the current building must be able to take the additional weight. So in most cases a flexible lightweight structure will be chosen for an additional floor or two on top of the current building that can easily adapt to the context. One of the construction methods is a wooden frame construction.

A step back from the current building envelop is sometimes required because of the visual appearance of the building or the new extension will block the sun from the lower streets. A positive effect of this setback is the ability to plan outdoor spaces in the setback area.

A vertical extension could contribute to a more efficient building by improving the compactness of the building. On top of high, narrow building the compactness will not be improved, but in most other cases this will be. Another advantage is that the current roof now can be isolated by the new space and the new building envelop. These new walls and roof should have a better performance to improve the current conditions regarding energy efficiency. It also opens up the possibility to have energy producing systems placed on top of the new extension. On the other hand this is more or less the same space on the roof that is already present.

As with the extension of the wing, current spaces can be placed in the new extension whereby the old locations of that space can be retrofitted. After the old location is retrofitted another function can take place in the retrofitted part, freeing up another part of the building for retrofitting and so on. One must be aware however that not every function is suitable for the upper floor. An extension of elevators is not always possible within the given resources. Some medical equipment is too big for placing it on higher levels and for example a radiation bunker is too heavy to place on an upper floor.
Therefore often more generic functions like offices or patient rooms are placed on vertical extensions.

2.3.4 Temporary building

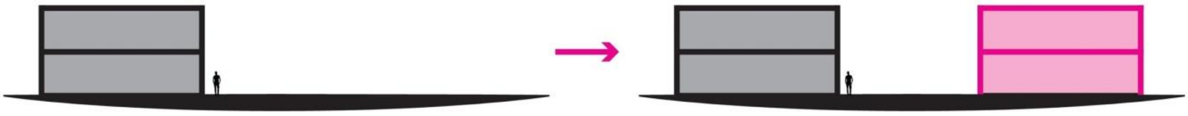


Figure 6: Diagram of temporary building

As the name suggests, this building is temporary. How temporary depends on the occasion and the goal of this building. When damage occurs to the current building, like a flood, this means that a temporary building is needed to continue the daily operations until the current building is renovated. This also brings opportunities to not only bring the damaged building to its original state but could also mean its properties can be improved. If the latter is the case, this means more preparation is needed and will lengthen the stay in the temporary building. It also depends on how badly and where the current building is damaged. If the façade is still in a good condition it is not common to replace this, but then again the opportunity to do so is there.

Another situation is when the current building needs an extensive renovation and/or upgrade. Until the renovation is done, the functions of the renovated part needs to placed elsewhere. This gives opportunities to renovate every aspect of the current without disturbing the daily operations much. If the renovation is planned for the whole building, the temporary building can be used for multiple departments, one renovation after another. It could also mean the temporary building has a more permanent character. If a growth is expected after the planned renovations, the temporary building can be used to house the extra spatial program.

Large renovations can take up a very long period, so it is worthwhile to invest in a good temporary accommodation. Consider the quality of the temporary building; could it provide the same services as the current situation? This has also a link to energy systems, often very temporary and flexible systems aren't able to comply with standards of "real" buildings. In the long term some additional investments at the start could also be an improvement in the cost over time. For example investing in better insulation will decrease the demand for heating energy. So the LCC and the ROI (Return on Investments) are very important for this solution.

2.3.5 Second façade

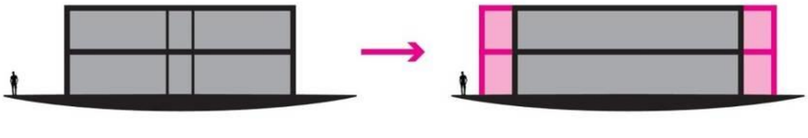


Figure 7: Diagram of second façade

A second façade is used in front of an existing façade; this solution can be used for several occasions. But it is mostly used in situation where the current façade cannot cope with the demands any more. It can improve the protection against the natural elements, protect against noise pollution and provide a climatologically buffer between the two façades. If this cavity is made wide enough, it also can be used to house some functions.

These functions shouldn't be primary functions as the space between the façades has an in-between climate. So it is appropriate, for instance, as a corridor. This corridor could be used to separate the traffic of public and that of staff or free up space at the current position of the corridor.

A second façade can also be placed as a bay window. This will result in a local extension of the façade. This small extension can house a small part of a function at most, but nothing significant. A sitting bench for a patient room, a prefab bathroom (mainly on the ground floor) are examples that can be attached to the existing. A bay window will probably not improve energy efficiency much, as it's only a small puncture in the whole building. The extension will also increase the outer surface of the building, which results in a larger heat/cold transfer.

Another possibility is that a second façade is a climate window. This will increase the insulation values in most instances but it also makes it possible to have more efficiency in a ventilation system. The air can be pre-cooled or preheated for instance, which also increases the comfort.

2.3.6 Covering current buildings

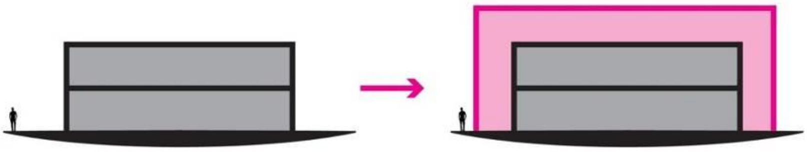


Figure 8: Diagram of covering current building

In some cases more space is needed, but it isn't possible to change the current building to great extents. This can be the case for monuments. A possible solution is to build a new building over the old building. In this way the old building is also protected by an additional skin and will not be affected by the elements. As with the double façade the extra skin can be used to reduce noise, to create a buffer zone or improve the performance of the skin. The current façade or roof can be opened towards the surrounding spaces, as these have an inner climate now.

This is also a solution to change the whole appearance of the building. A hospital could for example be covered with contemporary materials so that it sends out a message that it is a modern hospital with state of the art technologies.

The spaces between the new skin and the old are mostly used for public functions. These spaces are hard to close from the public. This space could also be an in-between climate. The placing of public spaces in the new zone, frees space in the old building for more private functions.

An important aspect that has to be taken into account is the reduction of (direct) sunlight in the current building. Unless the current skin is going to be opened towards the sun, the amount of natural light will decrease.

2.3.7 Placing an extra floor

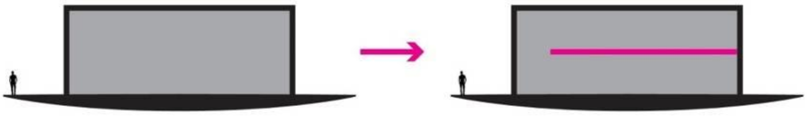


Figure 9: Diagram of placing an extra floor

In many old buildings the floor to ceiling height is more than enough to place an additional floor. If the floor to ceiling space is about 4,5 meters or higher this is possible. Thereby potentially double the useable floor-area, although some vertical connections must be made. This means also that no additional façade is needed and thereby also no additional heat/cold loss. It also means that some of the already present infrastructure can be reused, which will make the building more efficient.

Although some precautions need to be made as the heat load from equipment and people will increase and a greater demand for cooling is probably required. The height of the original space has a positive influence on the stacking effect of air and thereby lessening the demand of the ventilation system. This can still be achieved if the additional floors are open to the original space and air can flow without disruption. The people on the higher floors will probably be more affected by heat, as heat goes up.

2.4 Retrofitting solutions of energy efficient building envelope

The deliverable D2.5 presented an overview of technical and architectural solutions for envelope and space that can be applied in a retrofitting project in order to fulfil or improve the energy standards.

Technologies able to perform a determined performance have been listed considering:
- Design solutions, that analyse the most indicative factors that influence an environmental design (morphology, orientation, etc.);
- Vertical envelope (façades);
- Horizontal envelope (roofs).

The list of technologies collected in D2.5 cannot be considered as an exhaustive catalogue of each technology available on the market; they were searched, selected and briefly described according to a common list of topics. The result is a simplified list of the most appropriate technologies to use in hospital buildings which is able to give an indication on the suitability of a technology and on its benefit in terms of energy saving. The energy performances are the “driven-indicator” to which the choice of the system has to relate to.

The choice of the practicable strategies of intervention on the vertical envelope has to consider the improvement of performance that a specific solution can achieve, by the following classification:
- improvement of thermal and acoustic performance (External thermal insulating systems);
- improvement of ventilation, passive cooling, thermal inertia (Ventilating façades);
- improvement of overshadow, daylight control (Solar shadings);
- improvement of heat gain, solar cooling (Passive solar energy systems);

- renewable energy use, autonomous energy production (Active solar energy systems);
- improvement of the performances of fenestration (glass envelope, windows with high-performing glass).

Horizontal envelope technologies have been firstly classified considering the roof typology (plan/slope), which is a fundamental factor that influences the energy performance; then, the improvement of energy performance has been classified as follows:

- improvement of ventilation, passive cooling, (micro vented, single/double ventilation layers);
- improvement of thermal and acoustic performance (thermal insulation);
- improvement of thermal inertia and waterproof (green roofs);
- renewable energy use, autonomous energy production (Active solar energy systems).

Tables and forms attached in the Attachments to D2.5 provide assistance and energy savings recommendations to help design teams and owners produce high-efficiency hospitals.

The Design Solution Matrix and the Technical Solutions Matrix give the information to sort the technologies in relation to their effect on the retrofit action, by considering a range of benchmarking (KPIs) values to assess the best performance that can be obtained.

Prescriptive recommendations for the envelope are included: glazing, lighting systems (including solar shadings and day lighting) and their energy potential reduction on heating, ventilation, and air-conditioning (HVAC).

The matrices provide some indications for achieving energy savings goals by using architectural and technical solutions (envelope and space) that are feasible, operationally workable, and otherwise readily achievable. These recommendations should be merged with data and inputs related to MEP systems in order to reach the best energy saving performances.

The Design Solution Matrix concerns the layout, form typology, compactness, mass (glazing) and orientation of the hospital buildings which are mostly not suitable for retrofitting. Design decisions regarding these aspects/solutions are mainly made on building level.

The Technical Solutions Matrix is related to the vertical and the horizontal envelope and includes a set of solutions all suitable for retrofitting. Design decisions regarding the technical solutions are mainly made on building level. Only in some cases, as well as for the change of glazing systems or windows' type, can also be done on lower scale levels like the functional area or the space-unit. Most of the solutions (both design and technical solutions) can be used for all the defined labels on room level (hygienic class, equipment, user profile, comfort class, accessibility and construction), but there could be a few exclusions.

Based on the Technical Solutions Matrix a set of 47 forms, including description, energy efficiency related issues and technical parameters of each technical solution are available.

2.5 Retrofitting EeB solutions for MEP and energy systems

Analysis of EeB technologies and retrofitting solutions for MEP, described in the deliverables D2.1 and D2.2, provides information and data to determine the suitability and effectiveness of available technologies in various retrofitting scenarios.

Appropriate technologies have to fulfil organisational needs around activities within given boundary conditions by specific solution(s). This means a cost-effective, flexible system, responsive to variable demand to minimize energy waste and pollutants emission without compromising patient's needs.

Investigations of a large number of existing buildings within Europe showed that the reduction of ventilation and lighting electricity consumption in hospital facilities are the most promising strategies for energy efficiency optimisation.

The crucial step in ventilation optimisation is reduction of electricity demand for fans. Despite higher investment cost, taking into account effectiveness, reliability and maintenance, the overall cost is lower. Directive *Energy-related products* specify minimal requirements for motor driven fans. This regulation is an important step in increasing energy efficiency of MEP systems retrofitting for industry sectors of high ventilation share in total energy demand. The same directive comes into force introducing new regulations for all heating and hot water products. In 2009 an *ErP* (Energy related Products) directive also almost entirely abolished conventional incandescent light bulbs. Technical solutions that can save energy without affecting patient care or facility functionality are day lighting controls, controls enabling continuous dimming and occupancy sensors in spaces that are frequently unoccupied.

The electrical energy demand for lighting for hospitals is a complex issue due to their around the-clock nature and the effects of lighting on patients and hospital staff.
Nevertheless, commercially available cost-effective lighting technologies (i.e. LED, T8 fluorescent lamps) offer high energy-savings and reduce hospital operations and maintenance costs. Both low-tech and high-tech solutions for controlling lighting were proven to be effective. Many healthcare facilities have adopted an awareness campaign and trained staff to turn off the light when a room is not in use.

The following solutions, in accordance with BMS/BAM (Building Management System/ Building Assembly Modelling), can save energy without affecting patient care or facility functionality:

- day lighting controls in patient rooms and public spaces with large window areas;
- controls enabling continuous dimming (100 to 5 percent lamp power);
- occupancy sensors in spaces that are frequently unoccupied;
- sensors that include dimming and stepping options for spaces that utilize daylight;
- exterior motion sensors, which save energy and can enhance security.

To ensure that patients' and staff comfort is not affected and an efficient lighting retrofitting solution is chosen, refurbishment actions have to include proper arrangement of general light source (usually tubular bulb under the ceiling) as well as a spotlight in key places.
The design rules for intervention were considered for suitability regarding:

- Scale level - building, functional area, space unit;
- Relation with labels - Hygienic class, Equipment, User profile, Comfort Class, Accessibility, Construction;
- Relation with layers - Rating scale;
- KPIs - Energy performance, Financial Performance.

The **matrix** developed and attached to D2.2 includes the list of EeB solutions with design rules and a definition of Energy aspects and instances (the deliverable and its annexes include a detailed description of each part of the matrix). In addition to the matrix, D2.2 includes (Appendix 2) a list of design solutions and (Appendix 3) integrates retrofitting codes of action, parameters and relations to other labels.

Design filter rules for MEP systems and data on **energy demand** provide data and information to decide which retrofitting solution can be used in which circumstances. Values of parameters assigned to different solutions to estimate the impact on the **KPIs** in the early design stage - if no detailed information is available - provide to estimate effects of the different solutions on the KPIs (each EeB solution has an effect on all KPIs).

Design Filter rules: these rules are implemented to make decisions based on expert knowledge; the rules will filter the solutions on applicability according the label values of rooms and spaces. The according label values are given for each MEP and EeB solution.

- Solutions define whether a technical solution is adequate for retrofitting or new design. The aim of D2.2 is to help undertake decisions about retrofitting of existing buildings. Matrix for D2.2 will be developed and extended for the purposes of D2.3 "*New design solutions of integrated EeB solutions for MEP and energy systems*" > Values: *YES, NO, N/A*
- Scale levels give an insight if a technical solution is adequate for defined spatial area abstraction > Values: *YES, NO, N/A*
- Labels design rules describing relations with current main labels characterizing spatial area > Values: *main labels level assigned to MEP components\solutions*
- Layers give an insight if a MEP component is an available solution for different functional area abstractions > Values: *1-3, N/A*

In the end, the forms will support the decision making process for a certain MEP or EeB solution. Multiple can be tested as well, as different design alternatives and validated through a KPIs simulation and validation.

Energy consumption: defines the amount of energy being supplied to the building by third parties (e.g. national grid, district heating) taking into account MEP systems efficiency.

Energy demand: defines the total energy demand of a building, which relates to the thermal quality of the building and the assumed energy demand for special hospital functions in the design. Input for calculating KPIs.
Energy production: defines the amount of energy supplied to the building by own hospital MEP systems without third parties and auxiliary energy (i.e. PV (Photovoltaic), thermal collectors and wind turbine on site).

Energy storage: defines the amount of energy possible to store for future utilization by MEP systems without third parties.

Thermal energy: defines total energy for heating (including reheat, preheat and humidification) and DHW sanitary water:

- Heat – defines the amount of energy for space heating, process heat, humidification
- Cold – defines the amount of energy for cooling and dehumidification

Electrical energy: defines total energy for supplying lighting and mechanical devices – in this case ventilation (fans) and medical equipment.

Parameters: define MEP component regarding energy efficiency, factors to calculate Energy demand.

Input for energy labels: calculation product of Parameters.

Energy label: derivative of Input for labels, input for an inter-aspect schedule. Values: 1-4 or 1-6.

Input for KPIs: factors influencing Energy Performance, Financial Performance:

- Energy Performance - estimation or measurement of the energy efficiency, defined as the energy demand efficiency and energy consumption efficiency of a hospital design during operations.
- Financial Performance
    - Estimation or measurement of the Net Present Value (NPV) costs associated with the investment in (capital expenditure) and operational expenditure of a hospital design;
    - Estimation or measurement of the Annual costs associated with the operational cost of design.

2.6 Energy audit

For choosing the optimal solution and validation of the results after refurbishment is done, an **energy efficiency audit** before intervention is required. The main goal should be identification of key factors – building energy balance, envelope and MEP systems status and typical pattern of use.

The **energy audit** of the buildings is a systematic survey, collection and analysis of parameters for the specific energy consumption and operating conditions of the building. It includes a technical and economic evaluation of energy flows of a specific building.

Based on this analysis, designers can learn about the energy situation of a building such as consumption and energy costs, data on boundary (dispersing surface) and also data on space use.
Main goals are to:

- provide insights of the energy demand;
- identify the retrofit technologies;
- evaluate techniques and economic opportunities for each intervention;
- improve the comfort and safety;
- reduce operating expenses.

Energy audit can be developed according to the specifications settled within the Green@Hospital research project for example, as shown in its Deliverable D2.1 “Standard energy audit procedure” and in Deliverable D2.2 “Building

Management System" (WP2 Pilot's solution set data analysis). According to the reports, the first steps to follow to make an energy analysis are the collection and the analysis of the historical energy uses/requirements (first step) and the study of the building and its operational characteristics (second step).

The energy audits carried out in the Green@Hospital pilot hospitals (a research project funded by EC under the "Competitiveness and Innovation Programme" _ 2007-2013) is conducted differentiating functional areas and collecting the building(s) shell characteristics according to the following list:

- Total exposed above-grade wall area (m^2);
- Glazing area (% of exposed wall area);
- Roof area (m^2);
- Floor surface area exposed to outdoor conditions (m^2);
- Above-grade wall area common with other conditioned building (m^2);
- Total heated floor area (m^2);
- Materials and components.

The questionnaire analysis carried out in the four Green@Hospital pilot hospitals is a valuable reference for Streamer WP1, WP2, WP3 and WP7. Concerning the WP2, the reference suggests that a selection -focusing on the feasibility of data retrieval - of the parameters resulting from the D2.1 and D2. 4 State-of-the-Art (SOTA), may be appropriate and worthwhile due to its easier collection during the survey on the pilot sites and its easier implementation during the creation of BIM tool.

A detailed energy audit evaluates all energy using systems, envelopes, activities, equipment and includes detailed energy saving solutions and related costs. Required data can be acquired on site or from historical records. The methodology, scope and level of details strongly depend on particular country's legislation and locally established "good practice" of expert knowledge.

The energy efficiency audit is generally carried out in 3 phases: pre-audit phase, audit phase and post-audit phase. Before a full scale energy efficiency audit is performed a pre-audit helps to define the scope and future goals for a more systematic and detailed survey. Based on a performed audit the designer has an insight into building energy flows and is able to:

- identify the retrofit technologies,
- validate techniques, economic (factors like ROI, LCC etc.) and environmental (CO^2 (Carbon dioxide), GHG (Green House Gasses) and other pollutants) consequences of intervention,
- improve patients' and staff comfort,
- reduce maintenance and operating costs.

As a general recommendation a ten steps detailed guide to energy audit [Table 1] is presented.

Step No.	Plan of action	Purpose/Results
Phase I – pre-audit phase		
Step 1	- Plan and organize - Walk-through audit - Informal interview with Energy Manager / Facility Manager	• Resource planning • Establish/organize an energy audit team • Organize instruments and time frame • Macro data collection • Identification of facility activities • First hand observation and assessment of current level operation and practices
Step 2	Conduct of brief meeting / awareness program with all divisional heads and persons concerned	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation
Phase II – audit phase		
Step 3	Primary data collection, process flow diagram, energy balance diagram	• Historic data analysis, baseline data collection • Prepare process flow charts • All service utilities system diagram • Design, operating data and schedule of operation • Annual bill and energy consumption pattern
Step 4	Conduct survey and monitoring	• Measurements: Motor, insulation and lighting survey on site for collection additional and accurate data. • Confirm and compare operating data with design data • Trials/experiments: 24 hours power monitoring
Step 5	Conduct of detailed trials / experiments for selected main energy consumption components	• Load variations trends in MEP components • Equipment performance experiments
Step 6	Energy use analysis	• Energy and material balance and energy loss/waste analysis
Step 7	Identification and development of energy conservation opportunities	• Identification and consolidation of energy conservation measures • Conceive, develop and refine ideas • Review the previous ideas suggested by unit personnel • Review the previous ideas suggested by energy audit • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	Cost benefit analysis	• Assess technical feasibility, economic viability • and prioritization of energy conservation options for implementation • Select the most promising projects • Prioritize by low, medium, long term measures
Step 9	Report and presentation to the Top Management	• Documentation, report presentation to the top management
Phase III – post-audit phase		
Step 10	Implementation and follow-up	• Assist and implement energy conservation recommendation measures and monitor the performance • Action plan, schedule for implementation follow-up and periodic review

Table 1: Ten steps detailed guide to energy audit.

Results of an energy audit strongly depend of cooperation between auditor and hospital management. The people responsible for the facility should have good insight into processes' taken place under their jurisdiction. The process approach to management is very helpful in identifying the key factors of an energy audit. To identify those aspects a quality management system(s) should be adopted.

Common standards for hospitals are the ISO 9000 and ISO 14000 series of quality management systems standards. ISO 9000 describes the fundamentals of quality management systems, including management principles upon which the series of standards are based. ISO 9001 is the most widely used management tool and defines requirements for organizations to fulfil. The ISO 9000 series are oriented to ensure that hospitals meet the needs of customers and other stakeholders while meeting statutory and regulatory requirements related to a “product”.

The ISO 14000 series of standards provide guidelines to manage environmental responsibilities. ISO 14001 *Environmental management systems—Guidelines* for incorporating eco design and supporting documents such as ISO 14006 *Environmental management systems—Guidelines for incorporating eco design* and ISO 14040 series (14040 to 14049), *Life Cycle Assessment, LCA, discusses pre-production planning and environment goal setting* focus on environmental systems to achieve this. The other standards in the family i.e. focus on specific approaches such as audits, communications, labelling as well as environmental challenges such as climate change. The requirements of ISO 14001 are an integral part of the EU Eco-Management and Audit Scheme (EMAS).

3. The STREAMER approach for retrofitting scenarios

Application of STREAMER procedures and tool in the retrofitting projects requires specifying, in more detail, how they have to be adapted, which data are required and how the benefits can support clients, design teams and building operators in the decision making on EeB solutions. In the following chapters, the specific application in the retrofitting projects of the STREAMER tools and methodologies (implemented in particular in WP3 and WP6) is explained.

3.1 BIM

BIM is seen as a methodology to design, construct and maintain facilities using shared information assets with latest software tools and services in a more collaborative environment. A common accepted definition is: "*Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder (NBIMS)".*

STREAMER recognizes the substantial value-added benefits BIM could add to a retrofitting situation compared to traditional 2D and document-oriented information handling. Information handling is integrated and all involved disciplines can individually or in a multi-disciplinary collaboration interact and explore the consequences of design alternatives. Capturing the existing buildings' geometry and characteristics enable creating purpose-built models to be used for conducting different energy performance analysis. The integrative nature of BIM technology renders it an ideal tool to plan, supervise and capture as-built data in the actual retrofitting process and, along the way, ensure that the foreseen technical and functional goals are met as well as budget and time schedule.
The biggest difference to traditional 2D and document-oriented approach with subsequent and disconnected processes is that a BIM workflow dynamically connects design, analysis and documentation into a more concurrent workflow.

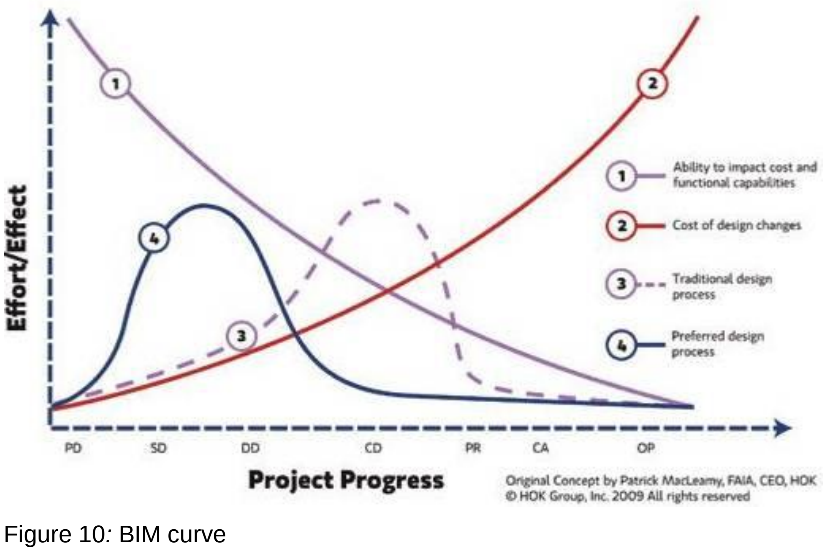


Figure 10*:* BIM curve

Figure **10** illustrates the consequences how much of the design work is shifted into schematic design and detailed design when the ability to impact project performance is relatively high and the cost of making design changes is relatively low. Client, architect and engineers can focus on design and optimizing the design instead of producing documentation.

One particular aspect of applying BIM is to focus on the "I" in the acronym "BIM": the information to be managed and exchanged through the whole life-cycle. In order to ensure efficient exchange of information in a virtual enterprise such as a hospital retrofit project, Building SMART recognizes and defines 3 pillars that need to be considered and met: a common exchange information format that must be shared and unique among parties, a common understanding on the information exchanged, and an explicit and synchronized orchestration of the exchanges (Fies and other, 2010). Now ISO standards, IFC (Industry Foundation Classes) creates a common exchange language; IFD (International Framework for Dictionary) is a formalized way for representing a vocabulary and IDM (Information Delivery Manual) is a way to represent processed and data exchanges. These and other information management and exchange and collaboration, aids such as MVD (Model View Definition) or BCF (BIM Collaboration Format) are described in STREAMER deliverable D5.1.

The STREAMER project delivers the tools and a design methodology to enhance the early design stages (See Figure 11 for the workflow). This clear back to end process described the situation for new build projects, where everything is built from scratch. However retrofit design process will mostly not follow this defined process.

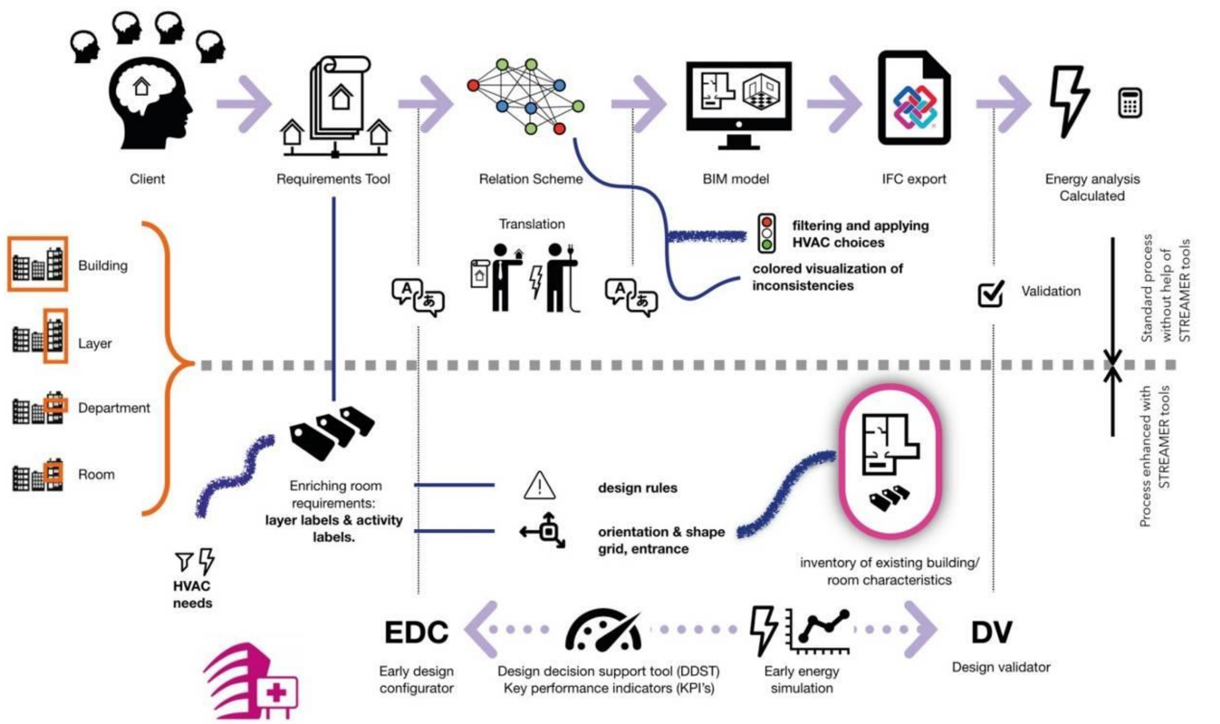
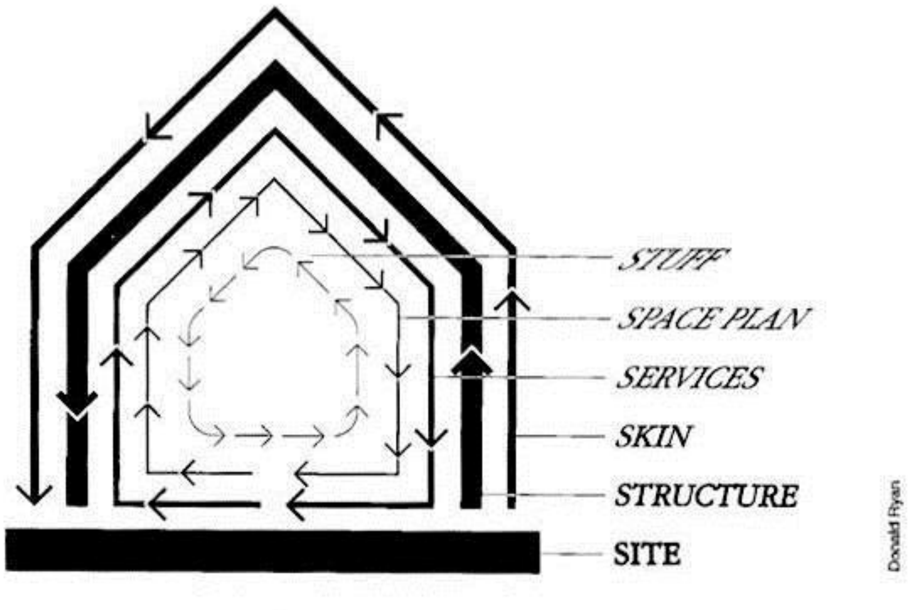


Figure 11: Basic STREAMER design methodology

Most of the retrofit situation will not follow the pre-described process for new buildings as it will only relate to certain aspects of a building. As identified in the previous chapter, a retrofit process can relate to a layout, MEP or envelop change of a building. The retrofit can also relate to more than one aspect of the building. The reason behind the ambiguity of process is clearly explained by Brand [Brand-1995]; a building consists of several layers. These layers have different lifecycles; with as a consequence that one layer is still performing as required while the other is already out-dated. (See Figure 12, where the thickness represents the time span of a layer).



SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

Figure 12: Brand layers, How Buildings Learn (1995) [Brand-1995]

Because of the ambiguity of the retrofit cases a single design process cannot be developed that will cover all the retrofit cases. Therefore this deliverable provides the pieces from which a specific design process can be constructed. A matrix where the single steps are used to develop specific retrofit processes can be found in appendix 1 of this deliverable.

3.2 Energy calculations

An important notion is the distinction between an energy calculation and an energy analysis. An energy calculation is a precise instrument to predict the energy consumption, energy flows, energy generation and comfort satisfaction of a building. This type of simulation needs a lot of precise data and a complex calculation tool to come up with accurate results. This data includes among others; insulation values, transparent percentages of the outside boundaries, energy efficiency of MEP systems, orientation of building and solar blinds types. In a traditional process this detailed energy calculation comes rather late in a design process, after most of the design work is already done. Therefore changes cannot be made without great impacts on budget. In this case energy efficiency is rather late on the agenda.

If an energy calculation is done at an early stage using a complex tool, the calculation input is based on so many assumptions and the result becomes unreliable. The illustration Figure 13 below shows that it is necessary to find an optimal level of complexity that provides an acceptable uncertainty in the output results.

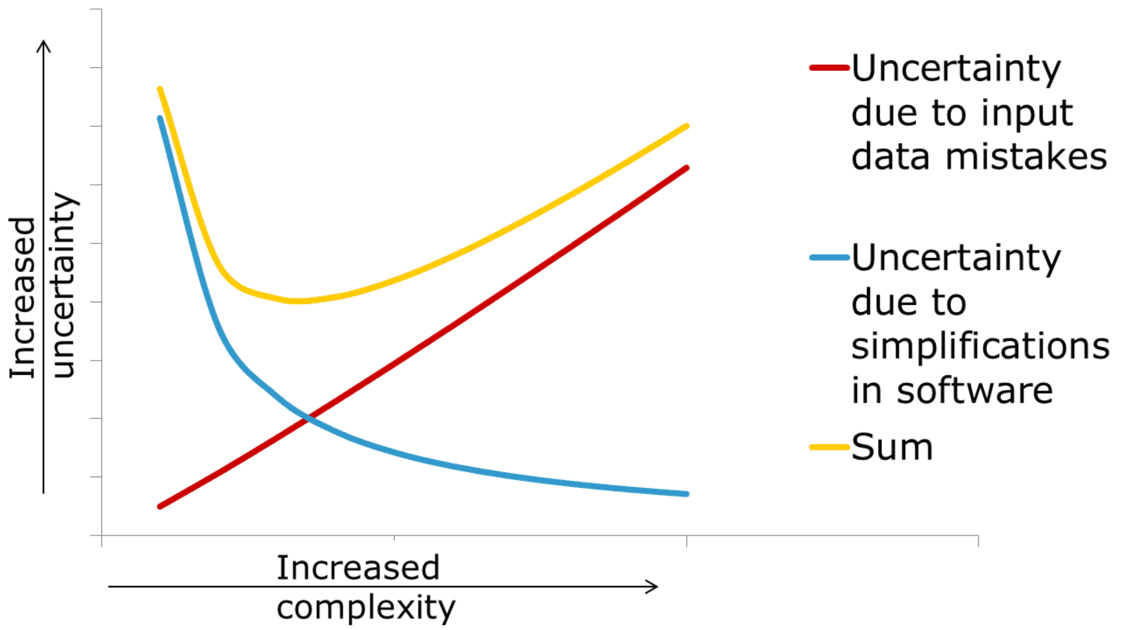


Figure 13: Relationship between complexity and uncertainty

In the integrated STREAMER process, information about energy performance of a design is more at the start of the process available, so that changes can be made according to this information where it has the least impact on budget. But the traditional energy calculation tools need a lot of data, which is not precise or not available at all at the beginning of a process. This means another kind of tool or process is needed. At the early stages of a design project an energy analysis is a better option. An energy analysis requires less data and will do assumptions on the basis of experience and expert knowledge.

In the STREAMER project, information gaps at the beginning of a project are filled in with expert knowledge in the form of labels and typologies. These labels give already some (indirect) information on aspects for an energy analysis. For instance the occupancy times are captured in a label category and will be used to predict the hours to heat or cool a certain room during a year.

Another application of the labels is that the labels of the rooms are used to filter the appropriate MEP systems. Some MEP systems, for example natural ventilation inlet, aren't applicable where high hygienic standards (the STREAMER hygienic label class) are needed (e.g. an operating theatre).

The MEP systems that are still applicable after the filtering occurs need to be translated to an overall MEP scheme. Because it is often impossible to have a room by room based system, the choice must be made for a certain system on the level of a group of rooms or even a whole building. The highest requirements for the MEP system will often determine the MEP system for the group. Different configuration can be seen as design alternatives and compared to each other. This is often a balance between a general, flexible but highly demanding system or a more specific, less flexible and lower demanding system.

Daniel Overbey [Overbey-2014] explains in his article that energy models are always wrong. But this is OK when the models and predictions are used as a way to compare alternatives. They can also be used to support certain hypotheses or predict the way some aspects have an impact on energy. But always keep some error range in mind when doing so and certainly at the moment where little information is available.

The developers of the energy calculation tool Sefaira have the same opinion on the point that models are always wrong and also agree on the way the models have to be used, namely for comparison and understanding[Sefaira-2015]. According to the developers the reason that the models are always wrong because of 4 reasons:

1. The default numbers to compare different energy outcomes are too generic or are not highly ambitioned. So the outcome of an energy simulation of a new building in relation to the default numbers is almost always positive.
2. The simulation uses “perfect” conditions. Such as clean piping and ventilation grills. No thermal leaks by corners or joints etc. So the real world number will differ because the conditions of the real world building aren't perfect.
3. A lot of assumptions need to be made about occupancy, operation, internal loads etc. These numbers are often unrealistic. Real numbers will be less than these best practice numbers. Also conditions can change during the use of the building which will impact the numbers.
4. General weather files are used for simulations. These files will differ from the actual weather.

The recommendations from the developers of Sefaira are threefold:

1. Use relative numbers and not real numbers. Like percentages or a score.
2. Collect data which is relevant for the stage of design. So from very rough and generic in the early design and to precise at a far developed design.
3. Analyse different extremes (e.g. in occupancy). This will provide an error range.

Therefore within STREAMER, after the choice of a certain MEP system is made, calculation can be implemented according weighing factors for KPIs, the Key Performance Indicators. These are subdivided in Financial, Quality and Energy key performance indicators and will be displayed by dashboards. The three indicators get a score from 1 to 10 on how they perform on certain predefined weighting-factors. The calculation, on how the building and MEP systems score with the chosen alternative on energy performance, is the energy analysis. The calculated score can support the decision for a certain alternative.

The score gives some indication on how good or bad the building will perform in energy efficiency. This score must always be put against the scores on quality and finance to choose a realistic alternative to develop further. To put it bluntly, the energy score will be high if there are no windows in a building. Because a window is a greater energy leak then a wall. But this will result in an undesirable situation for quality, because people need some view to the outside. To another end a fully glazed wall has a higher quality regarding views and day lighting but will increase the costs of a building, since the consumption of heating and cooling increases.
After the choice is made for a layout (note: this can be also the existing layout) and a MEP system, an energy calculation can be made for the first time. This is still not very precise, because for instance no facade is developed

at this point, so no accurate numbers on heat transmission of the outer wall can be given, so a default will be used. But it does give an indication if the energy demand is at a satisfying level, with an error rate in mind. If the numbers aren't near satisfying numbers, a few steps back must be taken in the design process.

A possible application of an energy analysis is to validate upgrading (or downgrading) the current MEP systems. As described in chapter 2 of this deliverable in D2.2 and D2.5 different technical and envelope solutions are analysed. These are grouped in such a way that an upgrade or downgrade of the same type of solution can be selected. The differences at the performance in KPIs are also captured so a well-balanced decision can be made for an upgrade or a downgrade, without having much information available.

3.3 EDC

The EDC is a software tool used to generate geometry for a spatial layout proposal out of a PoR and design rules. The process of the EDC has several steps. At first a building size and shape must be given. This can be an existing building or a new building. In case of an existing building the current size, the shape and the main constraints must be given in the software. In the case of a new building, this information derives from a Master plan or a mass-study.

The second step is to place the building in an open street map in the EDC. This will give the building orientation and place coordinates. At the moment the EDC only passes this information through to other tools, like energy calculation tools, in the tool itself this information won't be used for generation of spatial layouts.

The third step is the input of a PoR. This input needs among others; room-names, room-types, functional areas the rooms belong to, minimum floor area, minimum width and label values for each room. This list is used by the EDC to generate rooms and place them within the given building.

Another input is the list with design rules. These design rules determine the spatial relationships between the rooms. The rules have different priorities between them, because not every rule can be met and not every rule is as important as the other. For instance rules regarding fire safety have to be met otherwise the proposed building won't be accepted by the authorities. Another application of the rules is to optimize the spatial layout with certain Key Performance Indicators in mind. A prioritization of a certain KPI (energy, finance or quality) can be made by prioritizing the rules which influence those KPIs the most.

After the required input the EDC can generate layout options with the rooms from the PoR and spaces that are not included in the PoR, like stairs and corridors. The tool generates numerous different layouts and the generation can be stopped at any moment. The EDC will then save the best scoring layout option, which can be exported as an IFC file. This IFC file will be used by the simulation tools to validate the design on the three KPIs.

At first glance the EDC won't be used in retrofit scenarios as the software generates new spatial layouts, where in retrofit scenarios the layout could be fixed. Neither is a PoR always necessary in retrofit scenarios. However there are occasions when the EDC can be applied in retrofit scenarios.
In scenarios where the hospital needs to change its spatial layout, the EDC tool can be used. For the rooms or functions which stay on the same place there will be a function in the EDC to lock the positions. The locked rooms can then be used as a reference through the use of design rules for the new or shifted rooms.

For the EDC to work it needs input from a fully filled in PoR with labels, the location, size and shape of a building and design rules. This is the case also in a retrofit scenario, which means that it is only recommended to invest in making a PoR with labels, sizes etc. of the existing if there is a reasonable expectation in a layout change. If this is not the case the EDC should be skipped in the STREAMER process. However as the EDC can generate thousands different spatial layouts, some of the results can be unexpected and the threshold for using the EDC should be low. If the enriching of the current program with labels is already done, it is certainly worth the small effort to run the EDC to see if there are improvements possible.

3.4 A label enriched PoR

A Program of Requirements is used by a client to document his wishes and demands for a new building. This document can be used through the whole design process to compare the new design with the demands and wishes of the client. Normally not all demands and wishes can be met within the given time and budget. The data that is needed for a PoR is rather extensive and not all demands and wishes can be foreseen before any design is on paper. So a PoR also changes over time. The completed building could also give insights into new or altered wishes, as do changing regulations over time.

The quality of materials, MEP systems and equipment decrease over time and will at a point not be able to comply with the demands of the client. When the gap between the performance and demand is too great, the client will choose to move out, lower its demands or do a retrofit of the building. The PoR is the tool to map all those demands and wishes and can be used to check how far the gap between the demands and performance is. As stated before a lot of data is needed for the PoR; Room-names, Room-types, sizes, construction demands, climate demands, relationships, building regulations, logistics, appearance and quality must be described in a PoR.

For STREAMER a slightly different approach is developed. As the PoR needs a lot of data and this data isn't always available at the early stages of a project, another approach is needed. Instead of capturing precise data, the demands and wishes on quality, logistics, relations, appearance, building regulations, climate demands and construction demands are captured in labels. These labels replace the precise data with more global and generic demands which can be used for the early design. But if more precise data is available, this will be used.
The PoR is a useful tool for developing a new project. But it can also be used for retrofit situations. It can be used for instance to compare the previous PoR with a new PoR. This gives insight in the changed wishes and demands and will support the choice for doing a retrofit.

A second option is to use a PoR to compare it with the actual performance of the building. This will result in an overview of inconsistencies with the demand and supply. By comparing the PoR with the actual performance, insight is gained in the need for a retrofit and also highlights focus areas for a retrofit.

A label enriched PoR is needed as an input for the EDC to produce spatial layouts. So in situations where a spatial layout change is expected or if it is to evaluate a spatial layout change, a PoR is needed. The outcome of EDC in the form of an IFC file can be compared to the current layout.

A coloured (3D) representation of the spatial layout can be used for comparing a possible alternative with the current spatial layout. It also can be used as a useful tool to check if there are inconsistencies within a current layout or in a design alternative. The coloured representation gives insight in rooms with labels that don't match in its context.

For instance when a room with a user profile (time occupancy of a space) label value of U1 (Mo-Fr 8:00-18:00) is in a department which has a user profile label value of U4 (24*7). By moving the room with U1 to a group with other rooms with label value U1, the lighting of a corridor to rooms with U1 can be switched off for a longer time. This in return means a save in energy and indirectly also an increase in quality. As no longer people walk by closed and dark rooms after 18:00 in the department with the U4 label value (Figure 14).

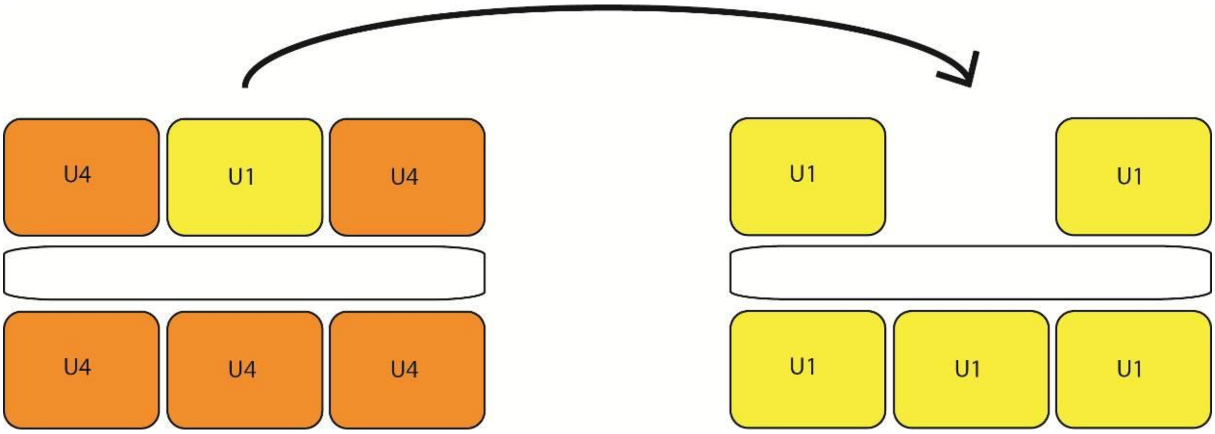


Figure 14 colour representation to validate the rooms in their context

Another use for a PoR is to analyse the MEP systems. The labels attached to the rooms in a PoR can be used to filter the possible MEP systems. For retrofit the possible MEP alternatives are filtered room by room. So alternative MEP systems are identified and can be researched. The filtering will also identify a possible mismatch between rooms with an actual MEP system if this system does not occur after the filtering.

3.5 STREAMER Decision Support Tool

STREAMER Decision Support Tool (DST) brings together the results of the STREAMER early-design process and analysis, and visualizes these results for easy comparison, enabling users to compare case scenarios on specific aspects: quality, energy performance and life-cycle costs.

Based on a program of requirements and design rules the Early Design Configurator generates several case scenarios in the form of IFC models which serve as input for tools that make assessments of the Key Performance Indicators. These assessments are then added to the IFC models and imported into the DST.
The Graphical User Interface and main components of the DST are shown below:

1. The **process navigator**: this control can be used to navigate through the various functions of the application.
2. The **menu bar**: the menus contain all items that are also contained within the process navigator with some additions like edit functions and online help.

3. The **object navigator**: this control is used to select objects that are used within the selected process; it can also be used to search for / filter on specific objects.
4. The **working area** for the currently selected process, in this case an edit panel for case definitions.
5. (Optional) a list of items contained within the currently selected object, in this case a list of case alternatives belonging to the currently selected case definition.

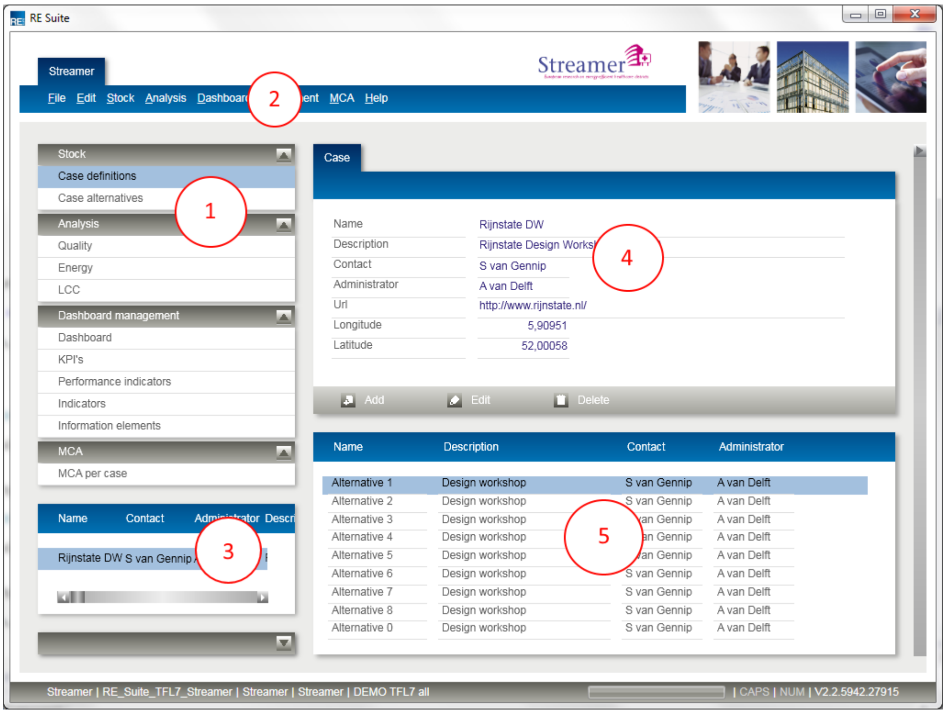


Figure 13: Overview RE Suite

<u>Potential use of the Decision-Support Tool for maintenance and refurbishment of existing buildings</u>

The STREAMER DST is developed based on a state-of-the-art software tool; the DEMO RE Suite. Within the RE Suite, the application RE Maintenance is designed for condition assessment and planning of maintenance and refurbishment activities of existing buildings. The software application embeds the technical norm NEN 2767 which is widely used in the Netherlands and resulted from research in EU project Brite Euram 4213 on “Condition assessment and maintenance strategies for building and building components”.

The aim of this software application is to assist real estate managers to put more emphasis on result-oriented actions while effectively managing financial and building technical risks through long-term maintenance and refurbishment planning. Maintenance and refurbishment schedules can be adjusted depending on the insight into the impact of such activities in terms of real estate policy.

The software application has the following features:

- Property Management: import and modify object data.
- Inventory: import and modify inventory data.
- Inspection: import and modify inspection data.
- Analysis: for developing maintenance plans, creating scenarios, setting service levels and shifting activities.

- Reporting: for the preparation of reports in Word, Excel, PDF.
- Management: for organizing and editing files with components, activities and lack lists, selection criteria and policy labels.
- Configuration: for adjusting and increasing standard business and user settings.

4. Scenarios and approaches for retrofitting

4.1 Preliminary information on lifecycle

The possible retrofitting scenarios and the corresponding approaches to their implementation and development are not solely depending on the functional needs and on the improvement of the energy efficiency. A third factor, that the choice of the retrofitting strategy to apply depends on, is the assessment of the financial feasibility and sustainability of interventions to be carried out. In other words: the opportunity to retrofit a building instead of replacing it with a new one.

As explained in chapter 3.2 a building is made up of layers that have different lifecycles as they contribute to different requirements and thereby the layers have different attributes. For example, a structure has a completely different life cycle than furniture. A picture (see Figure 12) used by S. Brand in *How Buildings Learn* [Brand-1995] describes the different layers using different thickness of arrows that gives an indication of the lifespan of the layers.

The different rates of lifecycle are defined as follows:

- Site Eternal
- Structure 30-300 years
- Skin 20 years
- Services 7-15 years
- Space plan 3-30 years
- Stuff 1 day-1 month

The different lifecycle rates of the different layers imply that at the point of a retrofit it is most likely that not all of the layers need to be retrofitted. The façade (skin) would be at the end of its life after 20 years of use. So the façade needs replacement, but the structure of the building, having a different lifespan, can last longer without any adaptation needs after 20 years.

If it's worthwhile to do a retrofit depends greatly on the difference between the retrofit costs or the cost of a new build alternative. In general if the different layers are deeply attached to each other, but have totally different lifecycles, this will introduce more effort to change one layer. Consequently the costs will rise in terms of resources to do a retrofit. This will likely result in two scenarios: the building stays the same and no adaptations are made to accommodate the new requirements or the effort for retrofit is far too great and the opportunity of a new building has to be considered.

For hospitals there is one major difference to other real estate. Next to services there is also a layer of medical equipment. Normal medical equipment as a MRI scanner has a lifespan of about 10 years. But there are some fields where the innovation for equipment develops fast. In the Netherlands, for instance, the proton beam therapy has just been introduced. This new equipment needs specific spaces that are often not foreseen at the current moment or in the past. As a consequence a new kind of equipment can drastically change the lifespan of a building.

An important tool to analyse the value of the equipment and if it needs replacement is Equipment Life Cycle Cost Analysis (LCCA). Equipment Life Cycle Cost Analysis begins from the time the equipment is requested through to the end of its useful life or until it is disposed of. The purpose of the LCCA is to make informed decisions based upon available alternatives in order to achieve the most economical process from inception to decommissioning. LCCA takes into account the design, equipment selection, operation, maintenance and final disposal costs over its lifespan.

As hygiene and climate control, due to health and safety reason, are significant for hospitals, the MEP system are consequently considered important. Lifecycle of MEP (Mechanical, Electrical and Plumbing) systems includes a holistic approach from owners and design teams who will evaluate the performance, life expectancy, maintenance and operating costs as well coordinating cost-effective implementation of these systems. MEP systems are then designed for new constructions, renovations and upgrades with time/space relationships determined and uploaded in the Building Information Modelling (BIM) that provides a virtual construction outcome that includes design cost and lifecycle.

Thus, one of the most important aspects to determine if a retrofit is necessary for a certain aspect or layer in general is the Life cycle costing (LCC) analysis.

LCC is the cost of an asset throughout its life whilst fulfilling its performance requirements. It is basically a simple concept – it answers the question “If I build this building what future costs will I be letting myself in for?”

It is therefore a projection of the costs that result from commissioning a building, which will be the responsibility of the client. It allows the client to work out if they can afford to build and run a structure, and to control the design development within the running costs and the capital cost budgets.

4.2 Scenarios

There are different scenarios in which a retrofit design process can be developed. From small maintenance to large scale extensions, every aspect belongs to retrofit. So, when describing retrofit scenarios it is good to consider some differentiation because of the great differences between the scenarios in content. This in return will require a specific methodology for each scenario. Because of the different natures of all scenarios a survey is done among the four STREAMER hospital partners for establishing the main types which the number of possible scenarios can be referred to.

Table 2 includes a list of 6 basic scenarios, described in their basic and general aspects, representing the main types of retrofitting projects

Since there can be several exceptions that don’t fit the basic ones, the 6 scenarios have been further analysed and then detailed in a matrix, annexed to this report, where they have been crossed with the possible approaches that the implementation of the actions related to each scenario can be based on.

RETROFIT SCENARIOS **Strategies/Actions**

TYPE AND TYPICAL AIM OF RETROFITTING PROJECTS	DESCRIPTION
S1 | SHRINKING **Sale, Dismantling, Reconversion for other than hospital use**	
Reduction of dimensions	Shrinking due to a reduction of patients or some budget cuts. Implementation of a strategy for being more efficient and competitive: smarter medical care (shorter inpatient stays and staff cuts) and delivering/outsourcing of services (i.e. physiotherapy).
Reduction of services offered	
Reduction of activities	
Reduction of work time	
S2 | MAINTAINING CURRENT CONDITIONS **Refurbishment, minor rebuilding, restorative works**	
Repair of damages after physical events (fire, storm, flood, etc.)	Activities and functional organisation remain the same. Interventions are mainly addressed to repair, refurbish or replace what is requested to preserve the current condition as it is.
Renovation of aged and dilapidated wards/buildings	
Refurbishment or replacement of aged and unserviceable equipment and installations	
S3 | CHANGING FOR ADAPTATION **Internal reorganization of spaces**	
Hospitals-organisations working together	Activities of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).
Change of internal organisation	
S4 | IMPROVING **Refurbishment**	
Compliance with new or changed national and international legislative standard/requirements	Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.
Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.	
S5 | UPGRADING **Internal extension of department, increase of services, upgrading of technologies**	
Increase of patients numbers	Internal extension of services and activities modify substantially the layouts. Interventions include significant changes of envelope and/or MEP for complying with the requested upgrade.
Extension of opening times	
Introduction of new medical equipment	
Introduction of new ICT equipment	
S6 | GROWTH **Extension/additions to current estate, new buildings**	
Start up of new activities and services	Upgrading of services, huge extension of existing buildings and addition of new buildings.
New or supplementary department needs	

Table 2: The six retrofitting scenarios

4.3 Approaches

The implementation of a retrofitting project within one of the six scenarios described in the previous chapter can be carried out more or less deeply, i.e. investing more or less extensively the building(s) to be retrofitted.

Depending on the user needs, the functional goals, the resource available, the targets to be reached and other number of factors or constraints, each scenario, and its related strategy of intervention, can be carried out according to different approaches, corresponding to different extent of works.

As explained in Chapter 2.2 (based on the outcome of the deliverables implemented in WP1 and WP2), depending on the retrofitting works implemented, it is possible to define three levels of interventions:

1. Retrofitting involving only the space layout, or the building envelope, or the HVAC systems (e.g. move of a department, replacement of a system, etc)
2. Retrofitting operating on two different aspects among building layout, envelope, HVAC systems (e.g. implementation of ETICS and replacement of the heating system, etc.)
3. Retrofitting including all the three types i.e. operating on the building envelope, the space layout and the HVAC systems (e.g. extension of a wing or a floor)

Considering all the possible combinations generated by the type of intervention included into the three levels - and adding a “level 0” corresponding to “do nothing” - a set of eight possible approaches can be listed and analysed with the aim to define:

- how the retrofitting project can be organised and carried out step by step
- which STREAMER tools and methods can be applied

The description (not exhaustive of course) of the different approaches has been further investigated, validated within the four demonstration projects and developed into a matrix that crosses the 8 approaches with the 6 scenarios.

The matrix explains, for each of the 48 combinations scenarios/approaches, the step by step process for implementing the retrofitting project, the actions and calculation to do, the STREAMER tools to apply.

Fitting the four demonstration projects within the corresponding combination scenario/approach a set of validation forms have been implemented as well.

The matrix and the validation forms, included into this report as annexes, will be left open for updating and improvements, up to the final implementation of all the STREAMER tools applicable in the retrofitting projects

4.3.1 A0. Zero approach, do nothing

The strategy of the zero approach can be sometimes the best option. This doesn’t exclude regular maintenance from the strategy, as this supports keeping the performance of the building as requested.
The zero approach can also be a reference, a baseline, for comparing design alternatives. The current conditions can be compared to the new predicted performance of an alternative design and to what costs these new performances come.

STREAMER tools and methods that can be applied

- PoR tools, like BriefBuilder, dRofus or a sheet to map the requirements.
- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit.

- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
- Current requirements for program and performance, can be a sheet like database in excel or in a tool like BriefBuilder
- Information about glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.

Disruption of daily operations

- This scenario doesn't have a great impact on daily operations; maintenance can be regular scheduled within the best periods to do so. Most of the maintenance can be done on a small scale and will not affect the daily operations much.
- Only small replacement of larger elements for comparable elements can cause some trouble to fit in. Although these replacements can be planned ahead and therefore the impact will be relative low.

4.3.2 **A1. Retrofit on one level: Retrofit on space layout**

This approach is focused on the change of the space layout without changing the building envelope and MEP systems. This means in general that only minor changes can be made because the structure will be largely the same. The presence of false ceilings can make it hard to change the layout, because the internal walls cannot be moved without affecting the MEP systems.

Therefore retrofitting on space layout only is in general a move of similar functions between the existing conditions. Only functions with lower or the same requirements can be placed on a specific spot. Departmental shifts (i.e. growth of one department and shrinking of another) can be accommodated by moving the functions of the growing department towards the shrinking department. Large open floor plans can be also changed as these are often fitted for changes in the layout.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.
- A tool to generate different layout alternatives, this can be the EDC or a modelling tool that is capable of producing an IFC export of the layout. The EDC operates with the restrictions of a retrofit, producing layouts by placing functions only in compatible spaces/places regarding performance of the building and the requirements from the PoR.

- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit. Also to see if a new layout improves the performance of the building.
- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
- Current requirements for program and performance, can be a sheet like database in excel or in a tool like BriefBuilder.
- Design rules (spatial relationships) if the EDC is used. Preferable is also the mapping of the current building conditions (MEP and Building performance) to generate compatible layouts. Also used to check if other layouts perform better than the current layout.
- Information about glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.

Disruption of daily operations

- As this retrofit approach only changes the layout and not the MEP and Building Envelop, large construction works will not occur. The nature of this approach is often moving similar function regarding requirements. Therefore even the furniture is often compatible with the new function and a moving can be completed in a very short time. So this will not cause a great impact on daily operations. Only by great shifts in functions, the nature of similar functions can cause some problems. As in a short time a group of functions cannot operate. This means careful planning and a staged approach is preferable.

4.3.3 A2. Retrofit on one level: Retrofit on building envelope

This approach leaves the MEP and the layout as it is and only retrofits the building envelope. This means that the requirements of the functions behind the envelope and the performance of the MEP systems stay the same. Because the layout stays the same no internal dimension changes are expected.
Retrofit solution that can be expected are for instance: insulation of the wall cavity, replacing a single glazed window for a HR+ window, placing vents, insulation the outside of the wall and cosmetic upgrades (painting, stucco) of the wall. In some cases windows can be enlarged or closed. A characteristic of this approach is that the retrofit will fall within the dimensions of the wall or takes place on the outside of the building.

STREAMER tools and methods that can be applied

- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope and goal for the retrofit.

- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.
- Possibly the usage of the EeB solution Matrix for Envelope Solutions of WP2. Possible upgrades or downgrades can be mapped with the help of this matrix.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
- Goals for the insulations, glazing percentage and other attributes of the envelope, to monitor if the different alternatives are fulfilling the goals.
- Information about current glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.

Disruption of daily operations

- Due the nature of a retrofit within the dimensions of the envelope or on the outside of the envelope, most retrofits can be done without disturbing the daily operations. Mainly noise and dust from construction work can be an issue which needs to be carefully planned especially for vulnerable functions.
- In some cases a room cannot be used during construction works. For instance when a window is replaced. Therefore a staged approach must be considered, on a room by room bias. So that only a small amount of rooms is out of order for a short period.

4.3.4 A3. Retrofit on one level: Retrofit on MEP

This approach is for replacing MEP systems without affecting the layout or envelope. Replacing solely the MEP system often occurs when the current system is obsolete. This gives opportunity to replace the current system with a more energy efficient, cost efficient and/or comfort improving system. The replacement can be done in two ways. One is by replacing the so called flow terminal, this is the distribution system, like a lighting fitting. Or two by replacing the source system, like a water boiler. A third option is to add a MEP system where there was none, for instance by placing a photovoltaic-cell on the roof for providing electrical energy.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.
- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit.
- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.

- Usage of the Matrix for MEP solutions of WP2. Possible upgrades or downgrades can be mapped with the help of this matrix.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
- A set of requirements, that can be summarized within a sheet including the program and requirements on comfort class, user profile and equipment. This can be compared to the actual deliverance of the current systems and the new designs.
- Goals for the MEP systems to monitor if the different alternatives are fulfilling the goals.
- Information about current glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.

Disruption of daily operations

- The range for disruption is very broad. When placing a MEP system, where there was none, this will not affect daily operations to a large extent. As this is a system added to the whole and the current performance will be still in place. When replacing the distribution system, this can be done on a room by room bias for minimal disruption. The replacement of a source system should be done at a low peak moment. For instance a water boiler should be replaced when the heating demand by a water system is the lowest.

4.3.5 A4, Retrofit on two levels: Retrofit on space layout and building envelope

This combined approach is predicted when the building envelope retrofit determines relevant changes in the configuration and organization of the layout. Also when changes of the envelope change the performance and thereby the internal conditions drastically. The latter makes space behind the changed building envelope suitable for other functions than the current function. So it is at least good to consider a change of layout for optimal performance of the whole building when the envelope drastically changes.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.
- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope and goal for the retrofit.
- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools capable of calculating the three KPIs are needed.
- Usage of the EeB solution Matrix for Envelope Solutions of WP2. Possible upgrades or downgrades can be mapped with the help of this matrix.
- A tool to generate different layout alternatives, this can be the EDC or a modelling tool that is capable of producing an IFC export of the layout. The EDC operates with the restrictions of a retrofit, producing layouts by

placing functions only in compatible spaces/places regarding performance of the building and the requirements from the PoR.

Required data

Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.

- Goals for the insulations, glazing percentage and other attributes of the envelope. To monitor if the different alternatives are fulfilling the goals.
- Information about current glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.
- Current program of requirements and performance (it can be a sheet like database in excel or in a tool like BriefBuilder).
- Design rules (spatial relationships) if the EDC is used. Preferable is also the mapping of the current building conditions (MEP and Building performance) to generate compatible layouts. But also to check if other layouts perform better as the current layout.

Disruption of daily operations

- This kind of retrofit can have a considerable impact on daily operations. When the envelope is being retrofitted, the adjacent rooms cannot be used for a while. If the layout changes are considerable the large displacements will make it impossible to operate those functions if there are no temporary locations for the current functions and/or the new functions. This means that a temporary building must be build, unused space must be temporarily used or some function will not be operational for a while.

4.3.6 A5. Retrofit on two levels: Retrofit on space layout and MEP systems

In some cases the change of a space layout can result in a change of the MEP system; for example when a function is replaced and is not compatible with current MEP systems because of performance or because of dimensions.

An internal reorganization of the layout could imply a change of the location of the internal walls, which could inflict with the distribution system.

The new functions can also have other or higher comfort demands, making the current MEP systems incapable of fulfilling the requirements. For example the capacity of a boiler could be impacted when heating demand is increased. On the other side an update of a MEP system could also be a trigger to move a function towards a more suitable place.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.
- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit.

- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools capable of calculating the three KPIs are needed.
- Usage of the Matrix for MEP solutions of WP2. Possible upgrades or downgrades can be mapped with the help of this matrix
- A tool to generate different layout alternatives, this can be the EDC or a modelling tool that is capable of producing an IFC export of the layout. The EDC operates with the restrictions of a retrofit, producing layouts by placing functions only in compatible spaces/places regarding performance of the building and the requirements from the PoR.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
- Current requirements for program and performance, can be a sheet like database in excel or in a tool like BriefBuilder.
- Design rules (spatial relationships) if the EDC is used. Preferable is also the mapping of the current building conditions (MEP and Building performance) to generate compatible layouts. But also to check if other layouts perform better than the current layout.
- Information about glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.
- Goals for the MEP systems to monitor if the different alternatives are fulfilling the goals.

Disruption of daily operations

Additional space is preferable in most cases to house the parts that are being retrofitted. The additional space can be accommodated through a temporary building or an unused space. Replacing MEP systems should be planned at a low peak moment.

4.3.7 A6. Retrofit on two levels: Retrofit on building envelope and MEP systems

In some cases a change in building envelope can cause a need for change of a MEP system or the other way around. As soon as for instance the building envelope is made airtight the ventilation system needs to be adapted. A better solar control by the building envelope can lower the cooling demand.
The other way around, a change of the ventilation system could mean that the envelope needs vents. The retrofit of the two levels without a spatial layout change can occur when there is a need for energy savings, comfort requirements change or at the moment when the envelope or MEP system is obsolete.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.

- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit.
- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.
- Usage of the Matrix for MEP solutions of WP2. Possible up- or downgrades can be mapped with the help of this matrix.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations.
  A set of requirements, this can be a sheet with the program and requirements on comfort class, user profile and equipment. This can be compared to the actual deliverance of the current systems and the new designs.
- Goals for the MEP systems to monitor if the different alternatives are fulfilling the goals.
  Information about current glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed.
- Goals for the insulations, glazing percentage and other attributes of the envelope. To monitor if the different alternatives are fulfilling the goals.

Disruption of daily operations

- Because of the comprehensive nature of this approach larger groups of rooms must be taken into account for retrofit. So if the functions that take place on the location of retrofit need to be kept in operation, it is often easier and cheaper to temporary move those functions into temporary buildings or unused spaces. It is more applicable for more generic function like offices then for instance operating theatres. The more specific functions need to be retrofitted in smaller steps and in more stages to minimise the impact on daily operations.
- It is advisable to plan retrofit work on MEP systems at the moments with the least demand for them. With for instance a retrofit on the cooling system in the winter and for a heating system in the summer.

4.3.8 A7. Retrofit on three levels: Retrofit on space layout, building envelope and MEP systems

This approach is basically a new design within a few boundaries. Every aspect is handled and is open for discussion. A general red line is the structure; this means in most cases the construction but could also mean the location of the stairs, elevators, entrances, courtyards and place of the corridor. It is however not unthinkable to change the nature of those elements, when roofing a courtyard for instance. As all the aspects are being retrofitted it is possible to follow the STREAMER methodology for new buildings with the exception of the restriction on some aspects of the structure.

STREAMER tools and methods that can be applied

- PoR tool, like BriefBuilder, dRofus or a sheet to map the requirements.

- A tool to generate different layout alternatives, this can be the EDC or a modelling tool that is capable of producing an IFC export of the layout. The EDC operates with the restrictions of a retrofit, producing layouts by placing functions only in compatible spaces/places regarding performance of the building and the requirements from the PoR.
- A sheet or model to compare current performance with the requirements. This is needed to map the differences between the requirements and the current performance. And thereby the scope for the retrofit. Also to see if a new layout improves the performance of the building.
- Decision Support Tool, for comparison between alternatives and insights in the cost and performance on the three main KPIs: Energy, Quality and LCC. Therefore also tools are needed capable of calculating the three KPIs.
- Usage of the EeB solution Matrix for Envelope Solutions of WP2. Possible upgrades or downgrades can be mapped with the help of this matrix.
- Usage of the Matrix for MEP solutions of WP2. Possible up- or downgrades can be mapped with the help of this matrix.

Required data

- Current program with performance translated to labels, this can be a sheet like database or even a BIM model. The BIM model is preferable to be used also as input for energy calculation and other calculations. This can be compared to the actual deliverance of the current systems and the new designs.
- Current requirements for program and performance, can be a sheet like database in excel or in a tool like BriefBuilder
- Design rules (spatial relationships) if the EDC is used. Preferable is also the mapping of the current building conditions (MEP and Building performance) to generate compatible layouts. But also to check if other layouts perform better as the current layout.
- Information about glazing percentage, status of MEP systems (maintenance costs, write-off, energy costs, efficiency etc.), insulation values, etc. In general more data available generates more precise calculation results and can then be used for more precise decisions on a smaller scale.
- Investment budget and operational budget, to define the range of possibilities and to make a comparison between the operational budget (predictions) and the LCC. If the operational costs are higher than the operational budget, changes are needed..
- Goals for the insulations, glazing percentage and other attributes of the envelope. To monitor if the different alternatives are fulfilling the goals.
- Goals for the MEP systems to monitor if the different alternatives are fulfilling the goals.

Disruption of daily operations

These kinds of retrofits cannot be done without disturbing the current program in their daily operations devoid of external accommodations. A consideration is to build a building that serves for multiple retrofit occasions. If one part of the building is retrofitted a part of the program can be placed into the new retrofitted part of the building. The building that was used to temporarily house those functions can house now another part of the function, so that piece of building can be retrofitted.

5. Real world examples by STREAMER hospitals

5.1 Introduction

Analysis of the carried out and/or on going refurbishment and retrofitting projects in the four STREAMER hospitals have been used for validating the taxonomy of scenarios and corresponding approaches presented in the previous chapter.

The following paragraphs explain strategies and actions carried out in the four hospitals and how the application of the STREAMER tools could enhance and improve the expected results.

A set of forms attached to this report (Appendix 2) includes a deeper analysis and a more detailed description of each "real word example" referred to the corresponding scenario/approach combination, as defined in the matrix attached in the Appendix 1.

5.2 Rijnstate hospital NL (RNS)

Rijnstate Hospital is a Teaching Hospital which was opened in 1996 on the site of a former hospital. The current building measures 82,150 m², in an area of approximately 89,000 m². Its total energy consumption is 128.705 GJ/year (425 kWh/m²/year).

The hospital is in need of an expansion of 10,000 m² to incorporate necessary services. With the knowledge that Rijnstate Hospital will need a midlife renovation around the year 2020 and knowing that the hospital will require future expansion, research has been started. In particular, it is investigated how to achieve these ambitions to expand in a most sustainable and cost effective manner, reducing, at the same time, the output of carbon dioxide gasses as much as possible.

A master plan design process has been developed (for the planned extension of 10,000 m²) and parallel to that, the main infrastructure project was initiated. The outcome of the main infrastructure project includes five possible design scenarios. Later on in the process an additional scenario was added. Parallel to this, Rijnstate has stated its ambition to reduce the carbon footprint by 50% in 2020.

The scope of the Rijnstate case study in STREAMER is as follows: the newly developed expansion 'North East' of 5,000 m² (phase one of the above mentioned master plan) was proposed as real case, together with the final design of the MEP systems. As the real project was already partly developed, the STREAMER case study is a so-called "shadow engineering project", meaning the design was already available in 2D drawings, and would be redesigned in semantically-enriched 3D BIM. At the same time, Rijnstate started to make use of a requirements tool (BriefBuilder® software). Next to the newly built wing, Rijnstate needs to refurbish and expand its Operating Complex, its Intensive Care department and its Mother and Child healthcare department.

5.3 Careggi hospital IT

The refurbishment programme to be undertaken in the "S.Luca Vecchio" aims to satisfy the change of needs and the functional reorganization of the oncological department of the Careggi Health District.

The works concentrate on the re-arrangement of the first floor, currently used as standard wards; a new layout is expected to host the following activities:

1. Oncological Day Hospital (Haematology)
   - Reception and waiting room;
   - Patient rooms with toilets;
   - Treatment rooms;
   - Consultation and examination rooms;
   - Nursing station and kitchenette;
   - Store rooms, technical rooms and toilets for visitors.
2. Consultation and examination rooms for haematology and bone marrow transplantation
   - Reception and waiting room;
   - Consultation and examination rooms;
   - Nursing station and changing room for personnel;
   - Store rooms, technical rooms and toilets for visitors.

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. Facades will be retrofitted with an Exterior Insulation and Finishing System (EIFS) and the installation of new windows. Works on the MEP systems will include the installation of:

- heat pumps to replace the existing split system (including the complete removal of the old heat systems);
- an energy efficient lighting system.

Outcomes assessed using the Streamer tools (to be implemented after the completion of the Streamer tools and the tests on the demonstration projects) and current available energy calculation software are as follows:

1. Energy:
   - Demand by purpose (room equipment, lighting, heating, cooling, hot water) in kWh;
   - Consumption by fuel type (electricity, other) in kWh;
   - Total consumption for the whole building and divided for each thermal zone in kWh;
   - Kg of CO_2/year
2. Finance
   - LCC of retrofit scenario – with the DST (Dashboard);
3. Quality
   - Thermal comfort (number of hours – data from Design Builder/Simergy, only with a detailed energy simulation tool).

5.4 Rotherham hospital UK

When deciding upon retrofitting and refurbishment, TRF (The Rotherham Foundation) would usually favour projects with the most attractive paybacks, i.e. the best ROI in the shortest time.

In the past there has been a Ward Refurbishment Programme which would see improvements to the 23 wards at the hospital on a rotational basis. This would ideally be over an eight or nine year term. However, due to restraints on capital expenditure this programme was discontinued several years ago and refurbishment work now takes place when areas of need are highlighted and the most cost effective solution is selected.

At present TRF are undertaking a major construction project to provide a new Emergency Department (adjoining the current A&E Dept.). This has triggered a number of ward moves in order to accommodate changes to the A&E resulting in relocation to Ward B1. Consequently other ward moves have been carried out and the opportunity has been utilised to carry out minor refurbishment works as wards have become empty. Works such as installation of energy efficient lighting, MEP works and spatial re-design have been undertaken during this window of opportunity.

Ideally, there would be a managed plan or Gantt chart that would accommodate future works on a 12 or 24 month period, e.g. Ward A1 in April, Ward B6 in July etc. and a refurbishment programme would be devised. A staged approach would be formulated where situations that may dictate the course of work would be identified.

For instance, work would be avoided between November and February due to winter pressures, as there is no way that the hospital could function with a ward closed during this period.

It would also make operational sense to carry out any improvement works to the heating systems during the summer months when there would not be as much call for heating, and cooler / chiller plant works could be scheduled for the winter period when it would be possible to utilise free cooling, allowing the chiller to be stood down.

5.5 APHP (Assistance Publique – Hôpitaux de Paris) hospital FR

Gaston Cordier (26,300 m² - net floor area) is a building located on the Pitié-Salpêtrière University healthcare district and is representative of a lot of buildings built at the end of 1960's / beginning of 1970's. Gaston Cordier is a building with a lot medical activities and the question of refurbishing it in order to ensure its longevity is a very complex issue (without stopping the activities inside).

First of all, it is important to keep in mind that there is currently no project on this building in "real life": all the scenarios and retained hypothesis are fictitious. However, this project is a good practical and representative case regarding the retrofitting of a current building:

- for financial reasons (investment cost and loss of medical activity), it is not always possible to demolish and build new – retrofitting can be a better solution;
- the medical staff and patients expectations have dramatically changed since the 60's/70's (new operating requirements or new technologies for biomedical equipment for example);
- the energy efficiency audit performed in 2011 on this building revealed that it is very energy-consuming and that its facades are porous.

For this building, and as part of an imaginary retrofitting plan, the objective is to realize BIM on the current existing building. We will 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 single bed rooms, etc.). Different hypotheses will be considered:

- 4 floors would be changed into full-hospitalization beds (medicine and surgery) with a maximum of single bed rooms;
- 1 floor would be changed into day hospital facilities;
- One floor would be changed into offices – tertiary activities.

In all cases, there will be a renovation of the envelope and even the installations / equipment in order to have better energy efficiency and improved patient comfort (thermal comfort, noise, lighting, etc.).

6. Identifying optimization potential for STREAMER approach

As stated in a Memo [Bomhof-2016] from the Project Coordinator during the General Assembly meeting in Warsaw on 6 September 2016, the proposal is made to increase the Technology Readiness level (TRL) of the prototype software tools in order to bring the innovative results from STREAMER closer to the practical use by the end-users in hospital building/district projects.

As written in the Description of Work (DoW version 2015-12-21, Part B, page 89), the STREAMER software tools should reach TRL 6 at the minimum. The current progress monitored at Month 36 shows that this TRL has been achieved.
This achievement has been observed by the potential end-users represented both in the Project Consortium as well as the Implementers Community (IC). However, they have also expressed their wishes to have the TRL of the STREAMER software tools enhanced beyond TRL 6 to allow a major transition from research and experiment to real life implementation and commercialization (with time-to-market within 2 years).

In response to the current achievements and observed demands, the Coordinator and Technical Committee propose an integral approach to enhance the TRL of the EDC and DST by focusing on:

1. Extending the capabilities of the EDC and DST for use in hospital retrofitting projects, including the retrofitting considerations of the MEP systems.
2. Increasing the user-friendliness of the EDC and DST, especially in relation with the end-user tool for defining the Programme of Requirements (PoR), i.e. BriefBuilder, embedding the STREAMER semantic design labels.
3. Improving the software stability as well as the quality and richness of the output data (IFC files).

6.1 Recommendations for EDC in retrofit scenario

As the EDC is a proof of concept (TRL6), not everything can be realised within the scope of STREAMER. Therefore some recommendations are done for the remainder of resources and suggested enhancement or for a future developer that picks up the EDC after STREAMER is ended. The current version of the EDC has been developed as a proof-of-concept for new building design projects with limited functionalities. With some adjustments, the tool is also eligible to be used for retrofitting design projects. Now the different strategies are identified for Retrofit some recommendations can be described to make the EDC more compatible with retrofit scenarios.

One of the key attributes of retrofit is that there are constraints depending on the existing situation. The constraints are essential for the EDC to consider for applying retrofit scenarios. The objects that are considered are following:

- **Corridors**, the horizontal transportation spaces are often related to the building shape, construction and organisation. The corridors are often more static then the adjacent rooms, as the corridor is part of the infrastructure.

  Within STREAMER corridors are applied to the building through templates. These templates can be locked for each defined building block in the EDC. However, with the current set of templates not every existing building can be reconstructed. Adding more templates to the EDC or applying a different method of constructing the corridors in the EDC will support the reconstruction of an existing place. The new method should then reflect a more freely way of constructing the corridors.

In the above mentioned memo, a feasibility study is done regarding the possible enhancements; Placing corridors manually and defining ranges in which the corridors may be moved by the optimization algorithm.

- Vertical transportation (**elevators, stairs & fire escape stairs**) are often static in a building. Regularly the shafts for elevators and fire escape stairs are structural elements for stability of the building or used for construction purposes. As these elements are static, the fire regulation maximum escape routes are an important factor in retrofitting for the placement of rooms. The location of the static vertical transportation points will determine the maximum distance for spaces as they are bound to regulation. Subsequently it is highly recommended that the vertical transportation can be fixed in the EDC to be able to refer to them when placing the rooms.
- **Atria** and other voids are decisive for the layout of a building. In the current version of the EDC, there is no way to construct voids in floor plans. The only work around is to shape the building as if the void is an outside courtyard. However a void will influence the energy performance of the building significantly. In retrofit scenarios the simulation results will differ from the real situation. So it would be a real asset to the EDC to include floor openings. In the above mentioned Memo this is part of the technical feasibility study; Being able to define areas that cannot be used
- **Entrance** as an object in the EDC is discussed during the STREAMER project. It is however not in the latest version of the EDC and therefore mentioned here. The layout of a building has a strong relation with an entrance (not necessarily the same as *the* entrance of the building, it could also be the connection with another building). Advisable is to have the option to point an entrance at a certain location in the EDC, so through design rules rooms can be related to the entrance.
- **Spaces**. Not every space will be relocated for a retrofit. An approach could be to leave the spaces that will stay fixed out of the EDC project. But for the deployment of spaces the relations between the spaces is very important. As well the relation between rooms that are relocated and rooms that will remain at their current location. Next to the relations, energy simulation is dependable on the adjacent rooms. Otherwise the simulation tool will simulate as if the next “space” is on the outside and will have outside properties (i.e. temperatures and insulation values). The simulation results will differ substantially with the real situation
- **Building performance** properties; the EDC will produce an IFC file which will have default values and assumptions for some of its objects. For instance a wall will have certain insulation properties. For a retrofit scenario some of these properties will be fixed for the current situation. So it would be preferable to include the current conditions in the IFC file, to have a better simulation result later.

  A step further is to relate the PoR by design rules to the actual performance of the building. For instance place a room with daylight requirements at a location with a window. Or place the room with the highest demands regarding temperatures at the location with the highest insulation values. Another example is to only place rooms requiring a certain construction level at the location where its requirements are met.

  It is uncertain if the performance parameters will be added by the EDC or by an energy simulation tool like CEN. The development of CEN includes an external file where inputs can be given for the properties on objects like: walls, windows, roofs and floors.
- **MEP properties** are, as well as the building performance, properties that could be fixed for retrofit scenarios. One approach is to place a room according to a certain MEP property of a location that is compatible with the room requirements.

Another approach is more difficult to apply. The MEP filter rules according the requirement labels of the rooms are applied in the EDC. So if the layout and the shape stay fixed in the retrofit design and the filter rules need to be applied, the input of the building and the spaces are still needed in the EDC. Because the building shape editor is native to the EDC, the user needs to set the building shape and load in a PoR for the placement of the room. Currently the lock function, to fix a position of a room is not operational, next to that the user cannot place rooms at a certain location. This is a matter of chance dependable on the placing algorithm of the EDC. So this is not a preferable workflow. Only after developing the current building shape, applying design rules and importing a PoR, the EDC can filter the possible MEP alternatives according to the properties of the rooms.

One option to improve this workflow is to have an import option in the EDC. So the native EDC building shape editor will not be necessary and the rooms will be placed already at their current positions. This would mean a significant change of the EDC and will not be implemented within the scope of STREAMER.

A possible workaround is to use an existing BIM model with placed rooms enriched with labels in Revit. With the support of a plug-in for Revit (Dynamo) an automated script can be run to apply the filtered MEP systems to the Rooms.

6.2 Recommendations for DST in retrofit scenario

As with the EDC the importance of certain constraints in the Decision Support Tool is evident. To be useful in retrofit scenarios the LCC module could have constraints for different objects to be fixed or only upgraded instead of using the key figures for new build situations. This differentiation accounts for construction, MEP systems, interior walls, outer walls and furniture. Now the LCC is based on the square meters only and is not differentiated for the different objects in a design.

7. References

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STREAMER deliverables:

D2.1 _ EeB technologies for MEP systems of healthcare buildings.

D2.2 _ Retrofitting solutions of integrated EeB solutions for MEP and energy systems

D2.3 _ New design solutions of integrated EeB solutions for MEP and energy systems

D2.4 _ EeB technologies for building envelope and space of healthcare buildings

D2.5 _ Retrofitting solutions of energy-efficient building envelope and spatial configuration

D3.6_ Design decision-support and lifecycle validation tool

D5.1 _ State-of-the-art review of advancements and challenges in ontology research

D6.2_Configurator of parametric design solutions

APPENDIX 1 - Matrix Scenarios/Approaches

D1.4 Matrix Scenarios-Approaches.xlsx

Matrix Scenarios/Approaches crossing of S1/A0

SCENARIOS	A0. Do nothing
S1.SHRINKING **Sale, Dismantling, Reconversion for other than hospital use** **Shrinking due to a reduction of patients or some budget cuts.** **Implementation of a strategy for being more efficient and competitive: smarter medical care (shorter inpatient stays and staff cuts) and delivering/outsourcing of services (e.g. physiotherapy).** **Shrinking can be also due to:** **- Reduction of dimensions** **- Reduction of services offered** **- Reduction of activities** **- Reduction of work time** **- (...)**	Description Interventions aim to rearrange the spaces according to the reduction of activities. Part of the spaces are dismantled and reconverted for other use. The remaining/reduced activities are rearranged in the spaces still used without any change of layout, building envelope and MEP. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Definition of remaining activities 6) Updating labels of remaining spaces with the allocated activities into the BIM 7) Calculation of KPIs of new solution 8) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S1/A1

SCENARIOS	A1. Layout change
S1.SHRINKING **Sale, Dismantling, Reconversion for other than hospital use** **Shrinking due to a reduction of patients or some budget cuts.** **Implementation of a strategy for being more efficient and competitive: smarter medical care (shorter inpatient stays and staff cuts) and delivering/outsourcing of services (e.g. physiotherapy).** **Shrinking can be also due to:** **- Reduction of dimensions** **- Reduction of services offered** **- Reduction of activities** **- Reduction of work time** **- (...)**	Description Interventions aim to rearrange the spaces according to the reduction of activities. Part of the spaces are dismantled and reconverted for other use. The remaining/reduced activities are rearranged in the spaces still used changing the layout. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Definition of remaining activities 6) Design of new layout(s) and labelling new rooms 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S1/A3

SCENARIOS	A3. MEP change
S1.SHRINKING **Sale, Dismantling, Reconversion for other than hospital use** **Shrinking due to a reduction of patients or some budget cuts.** **Implementation of a strategy for being more efficient and competitive: smarter medical care (shorter inpatient stays and staff cuts) and delivering/outsourcing of services (e.g. physiotherapy).** **Shrinking can be also due to:** **- Reduction of dimensions** **- Reduction of services offered** **- Reduction of activities** **- Reduction of work time** **- (...)**	Description Interventions aim to rearrange the spaces according to the reduction of activities. Part of the spaces are dismantled and reconverted for other use. The remaining/reduced activities are rearranged in the spaces still used. MEP systems are changed for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Definition of remaining activities 5) Design of retrofitting solutions for MEP 6) Calculation of KPIs after MEP change 7) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S1/A5

SCENARIOS	A5. Layout & MEP change
S1.SHRINKING **Sale, Dismantling, Reconversion for other than hospital use** **Shrinking due to a reduction of patients or some budget cuts.** **Implementation of a strategy for being more efficient and competitive: smarter medical care (shorter inpatient stays and staff cuts) and delivering/outsourcing of services (e.g. physiotherapy).** **Shrinking can be also due to:** **- Reduction of dimensions** **- Reduction of services offered** **- Reduction of activities** **- Reduction of work time** **- (...)**	Description Interventions aim to rearrange the spaces according to the reduction of activities. Part of the spaces are dismantled and reconverted for other use. The remaining/reduced activities are rearranged in the spaces still used changing the layout and the MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Definition of remaining activities 6) Design of new layout(s) and labelling new rooms 7) Design of retrofitting solutions for MEP 8) Implementation of BIM of new layout(s) 9) Calculation of KPIs of new layout(s) with MEP change 10) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S2/A0

SCENARIOS	A0. Do nothing
S2.MAINTAINING CURRENT CONDITIONS **Refurbishment, minor rebuilding, restorative works** **Activities and functional organisation remain the same. Interventions are mainly addressed to repair, refurbish or replace what is requested to preserve the current condition as it is.** **Maintainig current conditiond can be due to:** **- Repair of damages after physical events (fire, storm, flood, etc.)** **- Renovation of aged and dilapidated wards/buildings** **- Refurbishment or replacement of aged and unserviceable equipment and installations** **- (...)**	Description Interventions are limited to repair damages, to renovate aged building and MEP components, to replace aged and unserviceable equipment and installations. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Definition of components to be repaired and/or replaced 6) Calculation of KPIs after repairs and replacement 7) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S2/A3

SCENARIOS	A3. MEP change
S2.MAINTAINING CURRENT CONDITIONS **Refurbishment, minor rebuilding, restorative works** **Activities and functional organisation remain the same. Interventions are mainly addressed to repair, refurbish or replace what is requested to preserve the current condition as it is.** **Maintainig current conditiond can be due to:** **- Repair of damages after physical events (fire, storm, flood, etc.)** **- Renovation of aged and dilapidated wards/buildings** **- Refurbishment or replacement of aged and unserviceable equipment and installations** **- (...)**	Description Interventions aim to refurbish or replace aged and unserviceable equipment and installations. Part of MEP systems to be replaced can be upgraded for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of solutions for MEP to be replaced 5) Calculation of KPIs after MEP change 6) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A0

SCENARIOS	A0. Do nothing
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions are limited to the change of activities without any change of layout, building envelope and MEP. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Definition of new activities using labels 6) Updating labels for new activities into the BIM 7) Calculation of KPIs of new solution 8) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A1

SCENARIOS	A1. Layout change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include the change of activities changing the layout, without changing building envelope and MEP Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Implementation of BIM of new layout(s) 7) Calculation of KPIs of new layout(s) 8) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A2

SCENARIOS	A2. Envelope change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include minor retrofitting of the envelope, as a consequence of the internal reorganization of spaces and activities, for adapting and improving E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for envelope 5) Calculation of KPIs with new envelope 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A3

SCENARIOS	A3. MEP change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include minor retrofitting of the MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for MEP 5) Calculation of KPIs after MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

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Matrix Scenarios/Approaches crossing of S3/A4

SCENARIOS	A4. Layout & Envelope change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include the change of activities changing the layout and minor retrofitting of the envelope, as a consequence of the internal reorganization of spaces and activities, for adapting and improving E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for envelope 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new envelope 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A5

SCENARIOS	A5. Layout & MEP change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include the change of activities changing the layout and minor retrofitting of the MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for MEP 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new MEP 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A6

SCENARIOS	A6. Envelope & MEP change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions includeminor retrofitting of envelope and MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for envelope and MEP 5) Calculation of KPIs with new envelope and MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S3/A7

SCENARIOS	A7. Layout & Envelope & MEP change
S3.CHANGING FOR ADAPTATION **Internal reorganization of spaces** **The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).** **Changes can be due to:** **- Hospitals-organisations working together** **- Change of internal organisation** **- (...)**	Description Interventions include the change of activities changing the layout and minor retrofitting of envelope and MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for envelope and MEP 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new envelope and MEP 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A1

SCENARIOS	A1. Layout change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the change and the functional improvement of the layout (relevant changes in the internal walls and finishing), without changing building envelope and MEP. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Implementation of BIM of new layout(s) 7) Calculation of KPIs of new layout(s) 8) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A2

SCENARIOS	A2. Envelope change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the retrofitting of the envelope (facade or roof or both) for improving E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for envelope 5) Calculation of KPIs with new envelope 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A3

SCENARIOS	A3. MEP change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the retrofitting of the MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for MEP 5) Calculation of KPIs after MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case .

Matrix Scenarios/Approaches crossing of S4/A4

SCENARIOS	A4. Layout & Envelope change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the change and the functional improvement of the layout (relevant changes in the internal walls and finishing) and retrofitting the envelope (facade or roof or both) for improving E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for envelope 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new envelope 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A5

SCENARIOS	A5. Layout & MEP change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the change and the functional improvement of the layout (relevant changes in the internal walls and finishing) and retrofitting of the MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for MEP 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new MEP 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A6

SCENARIOS	A6. Envelope & MEP change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the retrofitting of the envelope (facade or roof or both and MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for envelope and MEP 5) Calculation of KPIs with new envelope and MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S4/A7

SCENARIOS	A7. Layout & Envelope & MEP change
S4.IMPROVING **Refurbishment** **Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.** **Improving can be due to:** **- Compliance with new or changed national and international legislative standard/requirements** **- Humanization of hospital spaces related to functional aspects (simplification of flows, comfortable waiting room and welcome area, etc.) or to the use of materials and colours.** **- (...)**	Description Interventions include the change and the functional improvement of the layout (relevant changes in the internal walls and finishing) and retrofitting of the envelope (facade or roof or both)and MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Design of retrofitting solutions for envelope and MEP 7) Implementation of BIM of new layout(s) 8) Calculation of KPIs of new layout(s) with new envelope and MEP 9) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S5/A3

SCENARIOS	A3. MEP change
S5.UPGRADING **Internal extension of department, increasing of services, upgrading of technologies** **Internal extension of services and activities modify substantially the layouts.** **Interventions include significant changes of envelope and/or MEP for complying the requested upgrade.** **Upgrading can be due to:** **- Increase of patients number** **- Extension of opening times** **- Introduction of new medical equipment** **- Introduction of new ICT equipment** **- (...)**	Description Aimed to produce a substantial upgrade, interventions can include, without involving layout and envelope, relevant replacements and retrofitting of the MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for MEP 5) Calculation of KPIs after MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Streamer
European research on energy-efficient healthcare districts

Matrix Scenarios/Approaches crossing of S5/A6

SCENARIOS	A6. Envelope & MEP change
S5.UPGRADING **Internal extension of department, increasing of services, upgrading of technologies** **Internal extension of services and activities modify substantially the layouts.** **Interventions include significant changes of envelope and/or MEP for complying the requested upgrade.** **Upgrading can be due to:** **- Increase of patients number** **- Extension of opening times** **- Introduction of new medical equipment** **- Introduction of new ICT equipment** **- (...)**	Description Aimed to produce a substantial upgrade, interventions can include, without involving the layout, relevant replacements and retrofitting of envelope and MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Design of retrofitting solutions for envelope and MEP 5) Calculation of KPIs with new envelope and MEP change 6) Comparison and evaluation using the dashboard Streamer Tools Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S5/A7

SCENARIOS	A7. Layout & Envelope & MEP change
S5.UPGRADING **Internal extension of department, increasing of services, upgrading of technologies** **Internal extension of services and activities modify substantially the layouts.** **Interventions include significant changes of envelope and/or MEP for complying the requested upgrade.** **Upgrading can be due to:** **- Increase of patients number** **- Extension of opening times** **- Introduction of new medical equipment** **- Introduction of new ICT equipment** **- (...)**	Description Interventions include relevant changes of the layout due to re-organization of spaces and services. Changes include the extensions of spaces within the existing buildings (e.g. roof top extensions, covering of internal spaces, partial extension of wings, etc.) and relevant changes and retrofitting of the envelope and MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR 5) Design of new layout(s) and labelling new rooms 6) Implementation of BIM of new layout(s) 7) Calculation of KPIs of new layout(s) with new envelope and MEP 8) Comparison and evaluation using the dashboard Streamer Tools PoR Labels Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

Matrix Scenarios/Approaches crossing of S6/A7

SCENARIOS	A7. Layout & Envelope & MEP change
S6.GROWTH **Extension/additions to current estate, new buildings** **Upgrading of services, huge extension of existing buildings and addition of new buildings.** **Growth can be due to:** **- Start up of new activities and services** **- New or supplementary department needs** **- (...)**	Description Interventions include relevant changes of layouts, extensions of spaces within the existing buildings (e.g. roof top extensions, covering of internal spaces, partial extension of wings, etc.), addition of new buildings. Within the existing buildings there are relevant changes and retrofitting of the envelopes and MEP systems for improving their E-F-Q performances. Actions/steps 1) Analysis of existing E-F-Q performances 2) Implementation of BIM of the existing layout 3) Labelling rooms of existing layout 4) Implementation of PoR (for existing and new buildings) 5) Design of new layout(s) and labelling new rooms 6) Implementation of BIM of new layout(s) 7) Implementation of new buildings lay-out using EDC 8) Calculation of KPIs of new layout(s) with new envelope and MEP for existing buildings 9) Evaluation of KPIs of solutions implemented by EDC 10) Comparison and evaluation using the dashboard Streamer Tools PoR Labels EDC (for new buildings) Dashboard Calculation Tools Energy performance: ... (type of tools, methods) Financial performance: ... (type of tools, methods) Quality performance: ... (type of tools, methods) The detailed info on tools will be explained in the forms reporting the 4 hospital specific case.

APPENDIX 2 - Demonstration Projects Forms

RNS | Scenario S5 – Approach A7

SCENARIO S5 UPGRADING

Internal extension of department, increase of services, upgrade of technologies. Internal extension of services and activities modify substantially the layouts. Interventions include significant changes of envelope and/or MEP for compliance with the requested upgrade.

APPROACH A7 LAYOUT & ENVELOPE & MEP CHANGE

Interventions include relevant changes of the layout due to re-organization of spaces and services. Changes include the extensions of spaces within the existing buildings (e.g. roof top extensions, covering of internal spaces, partial extension of wings, etc.) and relevant changes and retrofitting of the envelope and MEP systems for improving their E-F-Q performances.

Description

At Rijnstate Hospital a new extension is already built; the North East Wing. For STREAMER this new built wing will serve as a so called shadow engineering project. The shadow engineered project will be used to validate the STREAMER workflow. To accomplish the validation two workflows are needed, the one described as in the scenario/approach/strategy matrix and the shadow engineering project.

The new wing project is designed in 2D CAD and has been redesigned in 3D-BIM. Together with the STREAMER partners, a shadow engineering design flow was set up. The redesign process as described in this deliverable will be followed as well, when the STREAMER tools are fully developed.

For the first step in the shadow engineering project, a requirements tool (BriefBuilder software) was used to gather information for the PoR. Labels as agreed in the Streamer project were added to the PoR. An export from BriefBuilder can be made in an Excel file with CSV extension.

Simultaneously the current new built wing is engineered in Revit. The original CAD drawings were used as a reference and geometry was added on: walls (and columns), doors, windows, floors and roofs. Next to the geometry Revit Rooms are placed into the model. By exporting the room list to Excel, the Excel file from BriefBuilder is combined according the room number which was manually set in Revit. This excel file is then imported into Revit with help of the plug-in ARUtils. Another option is to use the plug-in BIM Connect in Revit to place rooms directly from the BriefBuilder database. This will create a live link between the Revit model and the BriefBuilder database. If something changes in BriefBuilder, the data can be updated in the Revit model through BIM Connect. In both ways the data from BriefBuilder is now mapped to the Revit model, specifically to the rooms.

From Revit an IFC model is generated that has more or less the same properties and attributes as the EDC outcome would have. This IFC model will be validated by the CEN Tool energy simulation and possibly also by the LCC module and Quality module in the Decision Support Tool when the tools are ready to be applied.

All data will be stored in the dashboard of the DST.

Action / Steps	Description
1. Development of enriched PoR	A new tool BriefBuilder® (web based) was used to develop the PoR. Typologies can be used to select multiple rooms at the same time and assign certain labels to larger groups.
2. Labelling rooms of new layout	Labels as defined within Streamer were added to the PoR. In BriefBuilder a matrix is available for fast assigning labels to larger groups of rooms. Previous information can be reused
3. Export from PoR into Revit	The enriched data is exported from BriefBuilder and imported into Revit through Excel. For Revit first an export of all the spaces that were modelled is made and then the combined room list is imported again.
4. Export of IFC data from Revit	The enriched room data, together with the modelled geometry is exported from Revit into an IFC4 file.
5. IFC file is read into CEN tool	Based on IFC file, an energy calculation is performed. And possibly also later within STREAMER simulations on Quality and LCC can be done in the DST.

Description future way of working

Action / Steps	Description
1. Analysis of existing E-F-Q performances	A KPIs analysis can be done through the pre-described workflow. The IFC model will also serve as a zero-option; an option where nothing changes. This only applies when not developing a large extension which is the case for Rijnstate. In a case with a large extension the data most derive from available sources like energy monitoring (or energy bill), the financial department and quality surveys.
2. Implementation of BIM of the existing layout	The existing building is already made in the previous step. But it would be advisable to model the adjacent existing situation as well, as the adjacent rooms will impact the performance of the new extension. For instance the adjacent rooms will have different temperature attributes than in a situation with only adjacent outside spaces. The current CAD drawing will be used to develop a 3D BIM model in Revit.
3. Labelling rooms of existing layout	Also done in step 1. Will be done according how the labels are defined within STREAMER. As this is a shadow engineer project, the requirements on room level will probably be the same as the current realised layout. BriefBuilder® (web based) will be used to develop the PoR and also to store the current conditions. The database will be linked by Revit through Excel files and a plug-in.

4. Implementation of PoR	CSV file exported from BriefBuilder in required and pre-described format.
5. Definition of remaining activities	The CSV file can be imported in the Early Design Configurator, as well with the building shape of the new wing, its locations and orientation and design rules. These design rules will be based on needed functional relationships, departmental relationships, energy efficient relationships, quality efficient relationships and building regulations.
6. Design of new layout(s) and labelling new rooms	Different options for the lay out are generated by the EDC to be compared with the current layout.
7. Design of retrofitting solutions for MEP	Different options could also be different MEP options based on the filtering of the EDC and choices of the advisor.
8. Implementation of BIM of new layout(s)	An IFC file can be exported from the EDC. (Several IFC files can be compared). Possibly integrated with the BIM model of the adjacent rooms.
9. Calculation of KPIs of new layout(s) with MEP change	The Energy will be calculated through the CEN tool. The Quality and LCC KPIs will be simulated through modules in the DST.
10. Comparison and evaluation using the dashboard	Based on calculations with different IFC files from different layouts, selection of most likely layout. Different lay outs and calculations can be compared using the dashboard in the DST.

STREAMER TOOLS	Description
PoR	PoR will be used as an input for the simulation tools through a loop with BriefBuilder and Revit for the current situation. Or as an input for the EDC and eventually for the simulation tools by an export in BriefBuilder in the predefined STREAMER structure and imported in the EDC. As it is a shadow engineering mapping differences will not occur, as the PoR will be the same.
LABELLING SYSTEM	Currently the label version implemented in November 2015 is used to label the Rooms. BriefBuilder is capable of fast selecting labels and attach them to room typologies. A danger is the change management of the labels, a new version of the labels is available and the current database needs an update towards the new labels definition. As the Functional Areas are no objects in the EDC, or used in the simulation tools, the FA's only serve as a consistency check. A room can be checked on its FA according the adjacent room FA properties and look if the room has other properties as its context.
EDC	The EDC is used to produce design alternatives. A danger is that the current shape cannot be modelled in the EDC due the missing

	of some corridor templates which need to be applied and the way a building has to be created in the EDC. No import option is currently available or to lock some parts as a reference for instance a staircase. This will reduce the realistic value of the EDC output in comparison of the real project.
DECISION SUPPORT TOOL (DASHBOARD TOOL SET)	The DST will be used to validate the different outcomes of the EDC with the current design through the dashboard showing of the KPIs. It will also be used through the LCC and Quality modules to simulate results for the Finance and Quality KPIs. Currently the LCC is only based on square meters and it is not differentiated. So it cannot be used to compare layouts with the same building shapes, as the square meters for all layouts with the same shape will be same, as well as the LCC outcome.

CALCULATION TOOLS USED BY RNS	Description Description of the other software and tools used for collecting information, making calculations and implementing data to be processed by the STREAMER tools
BriefBuilder	BriefBuilder is used to collect Room Data and with a template make a PoR based on the STREAMER structure. Also a matrix is added to the online tool to fast apply labels to the room typologies. The validation module could theoretically be used to validate the requirements and the actual performance and map the differences between them. But for Rijnstate a shadow engineering model will be made so no differences between the requirement PoR and the actual performance will occur. BriefBuilder is not able to directly save a CSV file; this has to be done with an intermediate step through Excel.
Revit	Used to develop 3D geometry of the North East Wing for the Shadow Engineering process. Capable of re-using CAD data for the development of geometry. Also capable of linking databases (BriefBuilder) through Excel or a plug-in. In this way the label information is attached to the BIM model. Also applied is a plug-in called Dynamo; a visual scripting tool. This is used to apply the MEP system labels according the mapped room property labels. So the step normally taken in the EDC of applying filtered MEP systems can also be done without the need of making the building shape in the native EDC shaper and placing the rooms through a PoR in the building shape. The model is exported as an IFC4 file. The only problem is the settings of the Psets. In Revit the settings are limited to map

	parameters in a certain structure. Until now the export is therefore somewhat different than the EDC output and research is going on if this structure can be used by the CEN Tool among other simulation tools.
CEN Tool	The CEN tool is an energy simulation tool, capable of fast simulation results on room level. Currently the CEN tool has some difficulties in handling the IFC output of Revit as it has a somewhat different structure. Also the import option for MEP and solution systems is not operational, which is important in retrofit scenarios to have somewhat similar conditions as in the real life building.

AOUC | Scenario S3 – Approach A7

SCENARIO S3 CHANGING FOR ADAPTATION
Internal reorganization of spaces. The activities of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).

APPROACH A7 LAYOUT & ENVELOPE & MEP CHANGE
Interventions include the change of activities changing the layout and minor retrofitting of envelope and MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances.

Description

The refurbishment programme to be undertaken in the "S.Luca Vecchio" aims to satisfy the change of needs and the functional reorganization of the oncological department of the Careggi Health District.
The works concentrate on the re-arrangement of the first floor, currently used as standard wards; a new layout is expected to host the following activities:

1. Oncological Day Hospital (Haematology)
   - Reception and waiting room;
   - Patient rooms with toilets;
   - Treatment rooms;
   - Consultation and examination rooms;
   - Nursing station and kitchenette;
   - Store rooms, technical rooms and toilets for visitors.
2. Consultation and examination rooms for haematology and bone marrow transplantation
   - Reception and waiting room;
   - Consultation and examination rooms;
   - Nursing station and changing room for personnel;
   - Store rooms, technical rooms and toilets for visitors.

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. Facades will be retrofitted with an Exterior Insulation and Finishing System (EIFS) and the installation of new windows. Works on the MEP systems will include the installation of:

- heat pumps to replace the existing split system (including the complete removal of the old heat systems);
- an energy efficient lighting system.

Outcomes assessed using the Streamer tools (to be implemented after the completion of the Streamer tools and the tests on the demonstration projects) and current available energy calculation software are as follows:

1. Energy:
   - Demand by purpose (room equipment, lighting, heating, cooling, hot water) in kWh;
   - Consumption by fuel type (electricity, other) in kWh;

- Total consumption for the whole building and divided for each thermal zone in kWh;
- Kg of CO_2/year

2. Finance
   - LCC of retrofit scenario – with the DST (Dashboard);
3. Quality
   - Thermal comfort (number of hours – data from Design Builder/Simergy, only with a detailed energy simulation tool).

Action / Steps	Description
1. Analysis of existing E-F-Q performances	The first analysis of the existing conditions has been implemented focusing on the E-F-C parameters and related KPIs. **E** KPIs has been calculated using DesignBuilder and the available data **F** calculation has been implemented applying the standard values defined in the D3.2 **Q** only the thermal comfort has been assessed using DesignBuilder (data for the calculation of the other KPIs are not available or not applicable)
2. Implementation of BIM of the existing layout	A BIM model of the existing building has been implemented using ArchiCad. Due to some problems of compatibility between Archicad and the used energy calculation software, the IFC file has been first imported in Revit (to make a correct exportation of the file for the energy simulation tool) and then in SimpleBIM (that has been used for adding labels to each room and numeric values based on labels).
3. Labelling rooms of existing layout	A detailed survey of all rooms, as they are in the current layout and condition, has been implemented; a Streamer label, with the corresponding value, has been attached to each room into the BIM model.
4. Implementation of PoR	The rooms have been labelled again using the value of the PoR for assessing the under-performing and the over-performing rooms.
5. Design of new layout(s) and labelling new rooms	A new layout of the first floor has been implemented; all the rooms have been labelled again according to the new activities and the corresponding PoR.
6. Design of retrofitting solutions for envelope and MEP	Definition and implementation of construction design of the retrofitting works to be carried out on facades and MEP systems. Implementation of technical details for:

	- Exterior Insulation and Finishing System (EIFS) - installation of new windows - removal of the old heat systems - installation of heat pumps - installation of an energy efficient lighting system These technical changes have been directly implemented on the simulation software, modifying the template sheets of the state of the art.
7. Implementation of BIM of new layout(s)	A BIM model of the new configuration of the building (including data on retrofitted facades and MEP systems) has been implemented using ArchiCad. As in the previous step the IFC data has been imported in SimpleBIM that has been used for the further calculations (for instance in the DST for the LCC).
8. Calculation of KPIs of new layout(s) with new envelope and MEP	Changes on typology, Envelope and MEP system have entailed changes on the KPIs: Energy efficiency (data from detailed energy simulation – Design Builder or Simergy) Carbon emission efficiency (data from detailed energy simulation – Design Builder or Simergy); Life cycle cost – (data from DST – Dashboard)
9. Comparison and evaluation using the dashboard tool set	Energy simulation results (CSV file), IFC file (with geometry, labels and related values) and KPIs have been merged in one SimpleBIM file and then imported in the Dashboard for comparison.

STREAMER TOOLS	Description
PoR	The existing and the retrofitted configuration of the rooms were manually identified using the Streamer template for the PoR.
LABELLING SYSTEM	Labels were associated to each rooms of the existing building and to each rooms of the new configuration.
DECISION SUPPORT SYSTEM (DASHBOARD TOOL SET)	Energy simulation results (CSV file), IFC file (with geometry, labels and related values) and KPIs have been merged in one SimpleBIM file and then imported in the Dashboard for comparison.

CALCULATION TOOLS	Description Description of the other software and tools used for collecting information, making calculations and implementing data to be processed by the STREAMER tools
ARCHICAD	3d modelling and geospatial location have been created and exported as IFC.
REVIT	Revit has been used for a correct exportation of the input of the energy simulation tool. Archicad cannot export correctly a GbXml file (essential for import in Design Builder) and an IFC file with correct second level space boundaries (essential for import in Simergy). Input IFC – Output correct IFC or GbXml.
SIMPLEBIM	The software has been used to align the IFC file exported from Archicad (or from another 3d modelling software) with the output of EDC, in order to create a file compatible with the Dashboard. Furthermore, with this tool, errors due to the exportation have been corrected and labels with related numeric values have been added. After Energy simulation and KPIs calculation, through SimpleBIM it has been possible to add this information in the IFC file, in order to create only one complete file for the importation in the DST.
DESIGNBUILDER and SIMERGY (Tested software) **CEN**	Various software have been tested for the energy calculation: Design Builder and Simergy allow a very detailed energy simulation with Energy Plus; CEN tool (developed by TNO) allows an energy simulation at the early design stage. Input Design Builder – GbXml – Energy simulation is done for the state of the art and for the modified states – Output is a CSV sheet. Input Simergy – IFC – Energy simulation is not yet done, due to some problems with the exportation of second level space boundary of the model from Archicad and from Revit – Output is a CSV sheet. Input CEN – IFC file – Energy simulation test (with default values) is done (by TNO) but the software is in development in order to increase the opportunity of making custom settings of energy simulation – Output of CEN is a IFC file containing results of simulation (both of the thermal zones and the whole building)

TRF | Scenario S4 – Approach A6

SCENARIO S4 IMPROVING

Refurbishment. Improvement of layout, envelope or MEP for complying with changed standard and legislative requirements (fire safety, asbestos, electrical hazards, new medical protocols, etc.), or changes of needs in the functional organization.

APPROACH A6 ENVELOPE & MEP CHANGE

Interventions include the retrofitting of the envelope (facade or roof or both and MEP systems for improving their E-F-Q performances.

Description

The UK case study is based on two departments within the main hospital building.

The Outpatient's Department (OPD) is the Bouwcollege Office Area and was built in 1978. It is of traditional masonry construction with the building fabric brick and block type. The windows are full height with the bottom two panels being opaque, insulated and block work up to sill height and UPVC double glazed. The floors are concrete, screed and vinyl floor covering whilst the ceilings are a combination of suspended ceilings with fibre board tiles and metal slatted ceilings, where a Frenger heated ceiling provides the heat. Similarly, Ward B6, which is the Bouwcollege Hotel Area, is of identical construction with the exception that the windows are wooden framed with single glazing.

The case study is modelling these two departments in sufficient detail to make an analysis of the strategic choices in the planning of asset improvement. To date, the necessary KPIs have been identified and a process of data acquisition executed. This has resulted in a federated BIM, based on existing information resources and inputs.

Targeted improvements of both areas include:

- A major upgrade of the BMS and improved heating controls
- Improved thermal insulation
- Replacement UPVC double/triple glazed units
- Installation of energy efficient lighting

The hospital already has a Building Management System (BMS) which is quite old but is being upgraded on an ad hoc basis, and major improvements of the overall building fabric are being planned.

Currently energy models are being developed and energy data is being collected using an acquisition model.

The project TRF have proposed as a demonstrator for STREAMER is centred around the upgrading of Building Management Systems and improvements in building fabric which will allow us to evaluate proposed changes that can be made to some of the building stock and therefore understand the benefits of such changes in terms of energy savings, Capex versus return on Investment, quality metrics.

Through constructing energy models of the building and then testing the potential solutions to prioritise physical changes to structure, fabric and systems that may be made as part of an ongoing asset improvement plan which was the key driver for TRF to participate in the project and therefore through the development of the Streamer tools to make such informed decisions.

The STREAMER project has offered TRF the opportunity to explore and find new ways and technologies to facilitate an informed Energy Efficient design decision-making process. We have seen developments in BIM modelling we didn't know of. Going forward data exchange between different systems will facilitate the design process which will allow the client to make informed decisions when committing capital expenditure both on new build and when the building is in use.

Outcomes assessed using the Streamer tools.

1. Energy:
   - Demand by purpose (heating, lighting, small power, hot water)
   - Consumption by fuel type (gas, electricity)
   - Total and by departmental zone.
   - By annual MJ and annual kg CO²e
2. Finance
   - Approximate upgrade cost (system upgrade rate times relevant zone area measure)
   - Total and by system upgrade by departmental zone
   - By £ (GBP)
3. Quality
   - Not changed but documented as gross floor area
   - Total and by departmental zone.
   - By m²

Action / Steps	Description
1. Analysis of existing E-F-Q performances	A 'Baseline' model was prepared and analysed. Energy monitoring and metering reports were collected for comparison.
4. Implementation of BIM of the existing layout	Existing FM data was merged with a block model and departmental outlines. Schedules of systems were also included, including the profiles of the district-wide CHP and DHW systems.
5. Labelling zones of existing layout	Two departmental zones were profiled with their labels and gross space and construction areas.
6. Design of retrofitting solutions for envelope and MEP systems	Schedules of optional system upgrades were also included, along with indicative cost rates. An interactive web-page was generated to allow participants to select combinations of upgrades.
7. Calculation of KPIs with new envelope and MEP changed systems	The 'Baseline' and suggested upgrades were mapped to the UK NCM SBEM format and simulation performed.
8. Comparison and evaluation using the dashboard	Simulation results and costs were merged back into the models for use by the dashboard. Results and costs were also reported for review.

STREAMER TOOLS	Description
Zone and System approach	In order to focus on the overall performance of the departmental zones and the major features of the installed and the upgraded

	envelope and MEP systems for the whole hospital district, modelling was confined to the zones and systems.
Labels	Labels were associated to the departmental zones. These determined the occupancy profile, environmental conditions demand, lighting and small power demands.
Dashboard	Simulation results and costs were merged back into the models for use by the dashboard. Results and costs were also reported for review.

CALCULATION TOOLS	Description Description of the other software and tools used for collecting information, making calculations and implementing data to be processed by the STREAMER tools
SKETCHUP with Q1 add-on	Block modelling and geospatial location exported as IFC
AEC3 BIM Services Transform1	_from Spread sheet - converted spread sheets to IFC _from Meters - converted meter reading tables to IFC _from UtilityWise - converted 30 minute sub-circuit measures _merge - unified sub-models
AEC3 Implementers Community Web Page	Collected team name, members emails and selected options Prepared and ran the simulation Prepared and merged back and reported the results Notified members and AEC3 of results obtained
AEC3 BIM Services Transform1 **UK NCM SBEM** **AEC3 BIM Services Transform1**	_as SBEM prepared models for UK NCM SBEM predicted energy demand and consumption _from SBEM converted results to IFC and prepared report

APHP | Scenario S3 – Approach A7

SCENARIO S3 CHANGING FOR ADAPTATION

Internal reorganization of spaces. The activity of a spatial area/department are partially or completely modified (e.g. operating theatres turned into offices).

APPROACH A7 LAYOUT & ENVELOPE & MEP CHANGE

Interventions include the change of activities changing the layout and minor retrofitting of envelope and MEP systems, as a consequence of the internal reorganization of spaces and activities, adapting improving their E-F-Q performances.

Description

Gaston Cordier (26,300 m² - net floor area) is a building located on the Pitié-Salpêtrière University healthcare district and is representative of a lot of buildings built at the end of 1960's / beginning of 1970's. Gaston Cordier is a building with a lot medical activities and the question of refurbishing it in order to ensure its longevity is a very complex issue (without stopping the activities inside).

First of all, it is important to keep in mind that there is currently no project on this building in "real life": all the scenarios and retained hypothesis are fictitious. However, this project is a good practical and representative case regarding the retrofitting of a current building:

- for financial reasons (investment cost and loss of medical activity), it is not always possible to demolish and build new – retrofitting can be a better solution;
- the medical staff and patients expectations have dramatically changed since the 60's/70's (new operating requirements or new technologies for biomedical equipment for example);
- the energy efficiency audit performed in 2011 on this building revealed that it is very energy-consuming and that its facades are porous.

For this building, and as part of an imaginary retrofitting plan, the objective is to realize BIM on the current existing building. We will 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.). Different hypotheses will be considered:

- 4 floors would be changed into full-hospitalization beds (medicine and surgery) with a maximum of 1 person rooms,
- 1 floor would be changed into day hospital facilities,
- 1 floor would be changed into offices – tertiary activities.

In all cases, there will be a renovation of the envelope and even the installations / equipment in order to have better energy efficiency and improved patient comfort (thermal comfort, noise, lighting, etc.).

Outcomes assessed using the Streamer tools

Energy:

Comparisons between the current situation and the different fictitious scenarios – kWh/m² (final and primary energy) > to be completed

Finance

Comparison between the different fictitious scenarios > to be completed

Quality

Comparison between the different fictitious scenarios > to be completed

Action / Steps	Description
1. BIM of existing situation	A BIM of the existing building (floors 2 to floors 7) based on the information available and some hypotheses taken for the missing data has been realized. The tool used is Revit Architecture
2. Estimate of energy consumptions	Bouygues made an estimate of the energy consumptions based on the information available in the energy efficiency audit report and some hypotheses taken for the missing data. The tool used is Virtual Environment
3. Implementation of PoR (new scenario)	AP-HP has imagined a fictitious new layout for the floors 2 to 7 and determined a list of the space units for each floor
4. Labelling new rooms	For each room, AP-HP determined the different labels based on the descriptions given in the Streamer templates
5. Design rules	Some priority rules have been written down by AP-HP in order to be included in the Early Design Configurator
6. Design of retrofitting solutions for envelope and MEP	This step needs to be developed because the templates were not available so far. It will give the opportunity to have different options in order to simulate different scenarios regarding the technical equipment
7. Use of the Early Design Configurator	Once all the files necessary to run the EDC are achieved, it will be possible to run this tool. We have started to get accustomed to the EDC to anticipate and be ready to use it.
8. Implementation of BIM of new layout(s)	This step has not started yet. The BIM model will be based on the export from the EDC
9. Calculation of KPIs of new layout(s) with new envelope and MEP	This step has not started yet. Once the BIM model is created, the KPIs will be calculated thanks to the tools developed by the different partners.
10. Comparison and evaluation using the dashboard	This step has not started yet. Once the KPIs are calculated for different scenarios, the dashboard will make it possible to compare them in an easy way.

STREAMER TOOLS	Description
PoR	For its demonstration case, AP-HP used the PoR. Nevertheless, this document needs to be completed especially regarding the vertical components of the structure (lifts, stairs) which are not available in the PoR. Consequently, the PoR should give the possibility to include new functional areas/space units.
Labels	For its demonstration case, AP-HP used the labels. The difficulty here is to have a clear view/understanding regarding the technical features for each label
Dashboard	We plan to use this tool but we have not started to get accustomed to it yet.

CALCULATION TOOLS	**Description** Description of the other software and tools used for collecting information, making calculations and implementing data to be processed by the STREAMER tools
Virtual Environment	Dynamic Thermal Simulation tool used to draw conclusions on energy use, occupant comfort, light levels, airflow, and much more from a model designed on Revit.
TRNSYS	Energy simulation program. It includes a graphical interface, a simulation engine, and a library of components that range from various building models to standard HVAC equipment to renewable energy and emerging technologies. This simulation tool is used for analysis and sizing, multi-zone airflow analyses, electric power simulation, solar design, building thermal performance and analysis of control schemes.
LCC tool	TNO developed, together with the Norwegian company, Multiconsult, a model that enables to calculate the effect of the intended investments of a hospital on the operating budget to be forecasted during development of the construction plans. The purpose of the model is to weigh-up the capital costs against the building-related costs over the entire life cycle of the building.
Quality tool	TNO has developed a method to calculate the travel time needed for patient transport based on a design layout and to calculate the FTE reduction by changing the layout.