# D8.7 Recommendations for new and retrofitted EeB HD standardisation

Deliverable Report: final version, issue date on October 23rd, 2017

**STREAMER - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood 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

# D8.7 Recommendations for new and retrofitted EeB HD standardisation


Main author Krzysztof Arnold, Piotr Dymarski
Co-authors Anna Rokicka, Aleksandra Luks, and others

Dissemination Public

Document history

| Version | Date | Status | Produced by | Comments |
|---|---|---|---|---|
| 0.1 | 18-02-2016 | Draft ToC | MAE | Under review of WP8 Leader (Bartosz Dubiński), needs to be refined with input from involved partners |
| 0.2 | 22-08-2016 | Deliverable proposal | MAE | This deliverable proposal is based on available group of STREAMER Deliverables from first 3 WPs to be discussed |
| 0.3 | 01-12-2016 | Final draft | MOW | Final draft of the document with inputs from Poland has been created |
| 04 | 17-07-2017 | Final draft for verification | MAE | Final draft verified by TNO, CSTB, IAA, DMO, DJG, LOC |
| 05 | 07-08-2017 | Final draft | | reviewed by Kevin Violant and Matthias Weise |
| 06 | 16-10-2017 | Approved | MAE | After final review meeting:<br>- UK added in part A,<br>- Terminology and Definitions moved to Appendix,<br>- ToC entry 4.5.4 fixed;<br>- Formatting corrected and unified<br>- References to deliverables in part B |

## Colophon




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

# Publishable executive summary

The main goal of the STREAMER Task 8.3 is to determine and recommend the most effective technologies for use to increase energy efficiency in newly build and retrofitted healthcare buildings in order to progressively enrich Healthcare Districts (HDs) with energy efficient, passive and zero energy buildings.

Moreover this task will promote at European level BIM and ICT building design practices which should result in significant cost- and time-wise improvement of EeB HD design processes and in increased competitiveness of the European AEC (architectural, engineering and construction) industry.

The main activities undertaken by the research teams included:

- Overview of legislation, standards and best practices in developing newly build and retrofitting existing HD buildings.
- Determination of the specific requirements for design of HD buildings under national and EU laws, including the efficiency and reliability of energy supply.
- Determination of the specific local conditions, including climate, that influence technological solutions selection for securing targeted energy and economy efficiency.
- Definition of the quantitative criteria based on the review of available standard regulations (e.g. comfort, air quality, fire safety) applicable in design, construction, operation and maintenance indicating necessary evolutions in the set of existing regulations and standards.
- Indication of the need for preparation of future design standards reflecting on: best practices, guidelines and standards, special IT tools, numerical simulation and design programs.
- Assessment and implementation of the most relevant means to leverage existing processes and foster BIM Europe-wide breakthrough – e.g. best practices dissemination, 'code of practice', regulatory constraints, etc.

**Based on the outcomes from the demonstration activities, Task 8.3 should elicit and shape the specific EeB HD methodological design guidelines based on semantic labelling BIM methodology of new and retrofitted HD design.**

**The aim of the project is to reduce by 50% energy consumption as well as $CO_2$ emission of newly build Healthcare Districts by 2030. The targeted reduction for retrofitted HDs is estimated at 30% level.**

In the course of the STREAMER development the project team decided to concentrate on the early design stage of EeB HD development due to the fact that the decisions made by designers and investors at this early stage are decisive for energy demand of the designed HD buildings, engineering and development costs, investment expenditures and future exploitation costs and conditions. The early design stage forms a technical base for tendering, final detailed engineering and construction works. In order not to aggravate early design costs and time of the early design stage and enabling execution of complex analyses in a short time, the STREAMER team decided to develop a design methodology supported by dedicated computing tools for EeB HD modelling, energy calculations and simulation studies to engineer optimal final EeB HD arrangement.

The Key Research Target is to develop an early design methodology of HD EeB which accommodates:

- HD specific requirements, decision criteria and priorities;
- Analysis of HD energy performance and economy in HD life cycle;
- Design and Engineering costs reduction;
- Interoperability of BIM and GIS with a set of necessary software interfaces.

The research project focuses on shortening early design processes in 3 main aspects of HD design and engineering:

- Building envelope and its spatial layout;
- MEP/HVAC installations;
- Hospital Campus Energy Grid managed by dedicated BMS software energy management methodology.

The targeted framework of the STREAMER Project enabling life cycle modelling of HD energy performance at the early design stage is a STREAMER Semantic EeHDBuildings approach consisting of:

- SBIM – Semantic Building Information Modelling;
- SBEM – STREAMER HD Building Energy Modelling;
- SLCC – STREAMER HD LCC Modelling;
- SMPV – STREAMER HD Master Plan Validation.

The above approach supported with GIS data (Geographic Information System) forms STREAMER EeB HD early design methodology presented in this Deliverable, which consists of 2 parts:

- Report on undertaken research activities within the STREAMER Project and drawn conclusions for new and retrofitted EeHDBuildings standardisation;
- Standard proposal draft of STREAMER approach to EeHDBuildings Early Design Methodology – Master Plan Design.

The recommended by STREAMER Project standard proposal draft presents methodology of an early design process for EeHDBuildings design, engineering and construction:

- EeHDBuildings Terminology & Definitions;
- EeHDBuildings Energy Demand and Consumption Modelling;
- EeHDBuildings Goals, Comfort and Safety requirements;
- EeHDBuildings Semantic Modelling;
- EeHDBuildings LCC analysis and NPV Calculation;
- EeHDBuildings KPIs calculations and final HD solution validation.

The above mentioned standardised methodology is been supported by a set of proposed computer aided design tools – the Early Design Configurator - presented in deliverable D 8.8 Recommendation to buildingSMART, OGC, WC3 on open standards improvement.

# Content

# Introduction and scope

Over the last 20 years we have been observing enormous progress in Healthcare technology as well as we have been confronted with substantial rise of HD investment expenses and operational costs. The STREAMER team has taken up a challenge to develop a methodology for cutting of HD engineering and development expenses as well as operational costs applying effective design procedures at early design stage of HDs.

This deliverable report consists out of 2 parts:

- **Section A: Reporting summary** on present national and EU legislations, regulations, and requirements concerning of EeB, renewable energy and low emission energy sources applicable in development and modernisation processes of HDs as well as results of research performed on modern effective technological solutions in design, engineering, development and exploitation of HD;
- **Section B: Recommendations** for standardisation of EeHDBuildings early design phase methodology for newly built and retrofitted HDs – Master Plan.

# A. Reports on EeHDBuildings Actual Status, Goals and Research Directions

This chapter presents overview of EeHDBuildings current status legislation, regulations, research directions and goals in EU and some of EU countries as well as in the USA.

## 1. Overview of Legislation and Regulations for HDs

Here beneath, this summary overview reports on current status of legislation and regulations which may influence HD new buildings development and modernisation of those in exploitation.

### 1.1. Poland

There are several governmental regulations which should be obeyed during new design or retrofitting of a hospital. Main documents which give guidelines and requirements for building design are:

- Regulation of the Minister of Infrastructure from 12 April 2002 with its amendments, on the technical conditions to be met by buildings and their location.
- Regulation of the Minister of Health on 2 February 2011 on the requirements to be met in terms of technical and sanitary premises and facilities in health care, with its amendments.
- Regulation of the Minister of Labor and Social Policy of 26 September 1997 on general safety and health at work with its amendments.
- PN EN standards, for design, commissioning and maintenance.

Regulation of the Minister of Health gives general construction and spatial requirements as well as requirements for patient care rooms, one day surgery rooms and central sterilization rooms. Document contains set of room type definitions regarding their sanitary-hygienic function and needed room equipment:

- General space requirement is that shape and area of the room should enable the proper placement, installation and use of medical apparatuses constituting its necessary equipment.
- It is necessary to distinguish medical zone and administration-technical zone in the health care facility.
- General construction requirement is that ground floor level should be 0,3m above the surroundings.
- Medical zone is divided into 4 purity zones:
- General purity zone (patient rooms, stuff rooms, internal ward communication, ward kitchens),
    - constant purity zone (clean materials magazine, sterilized materials magazine),
    - variable purity zone (ex. Operating Theatres),
    - constantly contaminated zone ( waste storage rooms, toilets, etc.).

However, after detailed examination of Polish legal regulations for HD design one may conclude that there is insufficient number of regulations and detailed information needed for healthcare facilities design. The lack of detailed space requirement for rooms, their comfort classes and contamination zones shall be fielded by new Ministry regulations. Moreover in older versions of Regulation of the Minister of Health some space indications were given but obligatory regulation does not contain minimal space requirements.

### 1.2. Netherlands

<u>Laws on building and working conditions</u>

A new design or retrofitting of a hospital building should at least comply with:

– the Dutch Building Decree 2012, especially regarding the requirements for a healthcare function (with a bed area and/or other healthcare functions);
– the Working Conditions Act, regarding the general safety and health of personnel at work.

Activities Decree by the Ministry of Infrastructure and the Environment

According to article 2.15 every institution with a yearly energy use of 50.000 kWh and/or 25.000 $m^3$ natural gas equivalents should take all energy saving measures with a payback time of 5 years or less.

Building guidelines Netherlands Board for Healthcare Institutions

The former Netherlands Board for Healthcare Institutions used to be responsible for the accommodation of intramural healthcare, which includes hospitals and other healthcare premises. The Board particularly felt responsible for an optimum quality of the healthcare infrastructure with sufficient capacity and a good price-quality ratio, and contributing in solving bottlenecks in healthcare. In 2008-2009 the financing of the construction of healthcare projects by the Dutch government stopped. Institutions themselves became responsible for their real estate and financial availability. The Netherlands Board for Healthcare Institutions was accommodated by TNO in 2010. Due to the change in funding, the building directives from the Netherlands Board for Healthcare Institutions also lost their formal status. In spite of the fact that these directives have no legal status, they are still used as a basis for a design, even today.

Working group Infection Prevention (WIP) guidelines

The WIP-guidelines are no law but guidelines. The new Dutch Law on Healthcare Quality, Complaints and Disputes mentions that the field shall define its own quality for delivering healthcare. The WIP-guidelines are considered by Dutch Health Care Inspectorate (IGZ), part of the Ministry of Health, Welfare and Sport, to be the defined quality. The IGZ therefore uses these WIP-guidelines for checks and enforcement. At the moment, the WIP is no longer active due to financial issues and is dis-incorporating itself. In practice the WIP-guidelines can still be seen as field standards in which the quality for delivering healthcare is defined and this quality is checked and enforced by the Dutch Health Care Inspectorate (IGZ).

### 1.3. France

In France, the construction of new hospitals or extensions to existing hospitals must fulfil the general regulatory framework for buildings. Moreover, there are specific requirements that apply to establishments open to the public (so-called "ERP" for "*Etablissements Recevant du Public*") and, in particular, to hospitals and healthcare facilities (ERP type U).

The main specific regulations and other related documents for healthcare facilities are the following, organized by domain:

Acoustic requirements

– **Decision of 25 April 2003 relating to noise reduction in healthcare facilities.**

This complements the general acoustic rules of the French Construction and Housing Code, and the circular of 25 April 2003 relating to the application of the acoustic regulations for all non-residential buildings.

Water and air circulation

- Decision of 11 July 2005 setting the rules to respect for air cooling in healthcare facilities.
- Decree of 11 July 2005 fixing the technical operating conditions imposed on healthcare facilities for air cooling.
- Circular of 5 April 2006 relating to air cooling in healthcare facilities.
- Circular of 22 April 2002 on the prevention of risk in respect to legionella in healthcare facilities.
- Circular of 26 June 2003 on the prevention of risk in respect to legionella in water cooling towers of healthcare facilities.
- NF EN ISO 14644-1 (February 2016) - Clean rooms and similar controlled environments - Classification of air particulate cleanliness.
- NF S90-351 (April 2013) - Healthcare facilities - Conditions relative to the control airborne contamination in clean rooms and similar controlled environments.
- Guidance on water in healthcare facilities (CSTB, July 2005).

Thermal performance

The main regulation that applies to all new buildings in France is called RT2012:

- Decree of 28 December 2012 relating to thermal characteristics and energy performance of buildings.
- Decision of 11 March 1988 relating to thermal equipment and characteristics in sanitary and social buildings.

Clean rooms

- NF EN ISO 14644-4 (July 2001) - Clean rooms and similar controlled environments - Part 4: Design, construction and start-up.
- NF EN ISO 14644-5 (December 2004) - Clean rooms and similar controlled environments - Part 5: Operations.

Fire safety

- Fire safety regulations in ERP – Articles U1 à U64 (ERP type U - healthcare facilities) & articles PU1 to PU6 (for small healthcare facilities).
- Circular of 27 January 1994 relating to fire safety in healthcare facilities.

Electricity

- NF C15-211 (August 2006) - Low-voltage electrical installations – Installations in medically used rooms.

### 1.4. Italy

The current legislation regarding healthcare buildings is both national and regional.

Below the only national one is listed.

Regulation may deal with general aspects, programming, typological and functional requirements and dimensional standard.

The most important decree for designing hospital facilities is the so-called “Bindi”, approved in 1997 (in bold text).

- Decree of the Head of Government 20/07/1939 – Instructions for hospitals buildings;
- Circular n. 4160 Ministry of Public Works 23/01/1968 – Modular coordination in buildings;
- Circular n. 13011 Ministry of Public Works 22/09/1974 - Physical-technical requirements for hospital building constructions. Thermal, hygrometer, ventilation and lighting properties;
- Ministerial Decree 05/08/1977 - Definition of technical requirements for private care homes;
- Law n. 421/1992 - Assignment to the Government for the rationalization and revision of the disciplines

of health, public employment, social security and territorial finance;

- Legislative Decree n. 502/1992 - Reorganization of health care legislation, according to Article 1, Law n. 421/1992;
- Legislative Decree n. 517/1993 - Amendments to the Legislative Decree n. 502/1992;
- Decree 24/07/1995 – Contents and procedures related to the efficiency and quality indicators in the National Healthcare System;
- Decree of the Ministry of Health 15/10/1996 - Quality Assistance Indicators. Approval of indicators for the assessment of the qualitative dimensions of the service regarding the personalization and humanization of care, the right to information and the progress of disease prevention activities
- Decree of the President of the Republic n. 37/1997 - Decree on minimum requirements for healthcare activities.
- Law n. 419/1998 - Assignment to the Government for the rationalization and revision of the disciplines of health, public employment, social security and territorial finance. Amendments to the Legislative Decree n. 502/1992.
- Legislative Decree n. 229/1999 - Rules for the rationalization of the National Health Service, according to Article 1 of Law n. 419/1998.

### 1.5. United Kingdom

In the United Kingdom new or retrofitted hospital building shall met requirements given in following country regulation listed for non-dwelling buildings:

- The Building Regulations 2010
- The Construction (Design and Management) Regulations 2015,
- Regulation of NHS hospitals, Department of Health,20.05.2013
- Approved Document L2A: conservation of fuel and power in new buildings, other than dwellings, 2013 edition with 2016 amendments
- Approved Document L2B: conservation of fuel and power in existing buildings other than dwellings, 2010 edition (incorporating 2010, 2011, 2013 and 2016 amendments)
- The Energy Performance of Buildings (England and Wales) Regulations 2012.

Moreover Department of Health(DH) has published DH building notes. According to official UK government website "Health building notes give best practice guidance on the design and planning of new healthcare buildings and on the adaptation or extension of existing facilities. They provide information to support the briefing and design processes for individual projects in the NHS building programme[1]."

- Designing health and community care buildings (HBN 00-01), 3 June 2014 Guidance
- Designing sanitary spaces like bathrooms (HBN 00-02), 25 May 2016 Guidance
- Designing generic clinical and clinical support spaces (HBN 00-03), 20 March 2013 Guidance
- Designing stairways, lifts and corridors in healthcare buildings (HBN 00-04), 16 April 2013 Guidance
- Resilience planning for NHS facilities (HBN 00-07), 30 April 2014 Guidance
- The efficient management of healthcare estates and facilities (HBN 00-08), 19 March 2015 Guidance
- Infection control in the built environment (HBN 00-09), 26 March 2013 Guidance
- Design for flooring, walls, ceilings, sanitary ware and windows (HBN 00-10), 20 March 2013 Guidance
- Designing and planning cardiac facilities (HBN 01-01) 20 March 2013 Guidance Cancer treatment facilities: planning and design (HBN 02-01), 20 March 2013 Guidance
- Adult mental health units: planning and design (HBN 03-01), 20 March 2013 Guidance

[1] https://www.gov.uk/government/collections/health-building-notes-core-elements

– Facilities for child and adolescent mental health services (HBN 03-02), 30 June 2017 Guidance
– Adult in-patient facilities: planning and design (HBN 04-01),1 December 2009 Guidance
– Critical care units: planning and design (HBN 04-02),20 March 2013 Guidance
– Designing facilities for diagnostic imaging (HBN 6), 1 January 2001 Guidance
– Satellite dialysis units: planning and design (HBN 07-01), 20 March 2013 Guidance
– Main renal unit: planning and design (HBN 07-02), 20 March 2013 Guidance
– Dementia-friendly health and social care environments (HBN 08-02),25 March 2015 Guidance
– Maternity care facilities: planning and design (HBN 09-02),20 March 2013 Guidance
– Neonatal units: planning and design (HBN 09-03),20 March 2013 Guidance
– Facilities for day surgery units (HBN 10-02), 1 May 2007 Guidance
– Facilities for primary and community care services (HBN 11-01),20 March 2013 Guidance
– Designing an out-patients department (HBN 12),1 January 2004 Guidance
– Planning and design of sterile services departments (HBN 13), 2 January 2004 Guidance
– Designing pharmacy and radiopharmacy facilities (HBN 14-01), 20 March 2013 Guidance
– Planning and designing facilities for pathology services (HBN 15), 28 April 2005 Guidance
– Planning and designing accident and emergency departments (HBN 15-01),11 June 2013 Guidance
– Designing hospital accommodation for children (HBN 23),1 January 2004 Guidance
– Facilities for surgical procedures in acute general hospitals (HBN 26)

### 1.6. EU

Apart from EPBD Directive, described further below, there were no EU directives or regulations found. It is assumed that each country has its own local regulations on the requirements to be met in terms of technical and sanitary premises and facilities in health care.

In the Netherlands EU standards are adopted by the NEN (Dutch normalization institute) as NEN standards and guidelines that are partly designated in the Dutch Building Decree 2012.

### 1.7. USA

In the United States hospital facilities follow state building codes or federal building codes. Each state has its own licensing regulations. In great number of states the FGI Guidelines for Design and Construction of Hospitals and Health Care Facilities were adopted. The model of local and state building codes basis on International Building Code IBC. Moreover National Fire Protection Association NFPA standards are used. There are also Guidelines for Health Care Facilities designing given by ASHRE.

## 2. Overview of Specific Regulations for EeHDBuildings

This section contains the summary of specific regulations concerning energy effective and low emission HDs.

### 2.1. Poland

Due to implementation of the EPBD EU directive in Poland set of Ministry Ordinances was introduced. The main document which regulates the Energy Performance of building including healthcare facilities is Regulation of the Minister of Infrastructure from 12 April 2002 on the technical conditions to be met by buildings and their location with its amendments. Last amendment from year 2014 sets new requirements for building energy performance. There are certain goals for heat transfer coefficient referred as U-value in W/m$^2$K for building external partitions, total building performance referred as building primary energy consumption in kWh/m$^2$year. This energy performance indicator EPI should be calculated according to Ministry Ordinance on certification methodology for buildings. In table below selection of the most important indicators for healthcare facilities are presented.

*Table 1 Energy performance requirements in Poland*

| Country | Shortcut | Unit | Definition | Description | Max value | Legislation |
|---|---|---|---|---|---|---|
| Poland | $E_{PH+W}$ | kWh/m$^2$/year | Non-renewable primary energy indicator for heating, DHW and ventilation | Indicator used for building certification. Value must be presented in construction project (design phase) due to receive planning permission. | 290<br>From 2021 190 | Ordinance of the Minister of Infrastructure and Development |
| | $E_{PC}$ | kWh/m$^2$/year | Non-renewable primary energy indicator for cooling | Indicator used for building certification. Value must be presented in construction project (design phase) due to receive planning permission. | =25*Af,c/Af | Ordinance of the Minister of Infrastructure and Development |

<table>
<tr><th>Country</th><th>Shortcut</th><th>Unit</th><th>Definition</th><th>Description</th><th colspan="3">Max value</th><th>Legislation</th></tr>
<tr><td rowspan="12"></td><td>$E_{PL}$</td><td>kWh/m$^2$/year</td><td>Non-renewable primary energy indicator for lighting</td><td>Indicator used for building certification. Value must be presented in construction project (design phase) due to receive planning permission.</td><td colspan="3">50(to<2500h/a) or 100(to>2500) (from2021 25 or 50)</td><td>Ordinance of the Minister of Infrastructure and Development</td></tr>
<tr><td rowspan="7">U</td><td rowspan="7">W/m$^2$K</td><td rowspan="7">Coefficient of heat transfer</td><td>Maximum values* for external partitions</td><td></td><td>2017</td><td>2021</td><td rowspan="7">Ordinance of the Minister of Infrastructure and Development</td></tr>
<tr><td></td><td>External wall</td><td>0,23</td><td>0,20</td></tr>
<tr><td></td><td>Roof</td><td>0,18</td><td>0,15</td></tr>
<tr><td></td><td>Floor</td><td colspan="2">0,30</td></tr>
<tr><td></td><td>Ceilings (to unheated rooms)</td><td colspan="2">0,25</td></tr>
<tr><td></td><td>Windows<br>Doors</td><td>1,10<br>1,50</td><td>0,90<br>1,30</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>$L_{max}$</td><td>W/m$^2$</td><td>Max. Value of light power unit</td><td>This value cannot be exceeded for installed lighting</td><td colspan="3">Basic level 15<br>Extended level 25<br>Full level with visual communication 35</td><td>Ordinance of the Minister of Infrastructure and Development</td></tr>
<tr><td rowspan="2">Specific fan power**</td><td>kW/(m$^3$/s)</td><td colspan="2">Supply air fan:<br>1)Air conditioning or sup.-exh. ventilation with heat recovery<br><br>2) sup.-exh. ventilation without heat recovery</td><td colspan="3">1,6<br><br>1,25</td><td rowspan="2">Ordinance of the Minister of Infrastructure and Development</td></tr>
<tr><td></td><td colspan="2">Exhaust air fan:<br>1)Air conditioning or sup.-exh. ventilation with heat recovery</td><td colspan="3">1,00<br><br>1,00</td></tr>
</table>

| Country | Shortcut | Unit | Definition | Description | Max value | Legislation |
|---|---|---|---|---|---|---|
| | | | 2) sup.-exh. ventilation without heat recovery<br><br>3)Exhaust installation | | 0,80 | |

- *Values will be applicable from 2017.
- ** Specific fan power can be extend if some additional elements are required ( higher filtration level, etc)

As main disadvantage of EPI calculation methodology is that energy consumption is calculated using average monthly meteorological data, this can cause huge gaps between calculated and real amount of consumed energy. In Poland average monthly temperature in summer period is lower than designed cooling temperature.

### 2.2. Netherlands

In table below selection of the most important indicators for healthcare facilities are presented.

*Table 2 Energy performance requirements in the Netherlands*

| Country | Shortcut | Unit | Definition | Description | Minimum value | | Legislation |
|---|---|---|---|---|---|---|---|
| Nether-lands | EPC | - | Energy Performance Coefficient | Minimal energy performance determined based on NEN 7120 | Bed area | 1,8 | Building Decree 2012 |
| | | | | | Other health care functions | 0,8 | Building Decree 2012 |
| | Rc | m² * K/W | Thermal isolation | Minimal thermal isolation determined based on NEN 1068 | External wall | 4.5 | Building Decree 2012 |
| | | | | | Roof | 6.0 | |
| | | | | | Floor | 3.5 | |
| | U | W/m²K | Coefficient of heat transfer | Maximum values* for external partitions | Windows Doors | 1,65 | Building Decree 2012 |
| | | | | | | | Activities Decree and (environmental) Activities Regulations by the Ministry of Infrastructure and the Environment |

### 2.3. France

In France the most recent thermal regulation is called RT2012. It also applies to healthcare facilities since the 1st of January 2013.


The RT2012 reflect the demands of the EPBD recast, with compliant buildings aiming to be approximately 40% more efficient than buildings built according to the 2005 regulation. As a result the code includes many dynamic requirements in order for this performance frame to be achieved, including mandatory renewable energy requirements, mandatory computer simulation, mandatory air-tightness testing for residential buildings, and bio-climatic design considerations.

The global objective is to limit the yearly primary energy consumption of new buildings (and extensions of existing buildings) to an average level of 50 kWh/m$^2$. Requirements should be fulfilled with regards to the 3 followings aspects:

– Intrinsic energy efficiency (linked to the envelope), defined by the “Bbiomax” coefficient;
– Conventional primary energy consumption, including heating, cooling, lighting, DWH production and auxiliary systems, defined by the “Cepmax” coefficient. This coefficient is equal to 50 kWh/m2/year and adjusted according to the geographic location, altitude, type of use, and CO2 emissions (in case of wood heating or heat network);
– Summer comfort, defined through the indoor temperature reached during a sequence of 5 hot days.

### 2.4. Italy

“After the first decree setting the basis for the national legislative EPBD framework enacted in 2005, a number of legal acts (legislative, ministerial and presidential decrees) have been issued to progressively define and specify all aspects of the national EPBD transposition.

In 2013, three new decrees were issued:

– Presidential Decrees 74/2013 and 75/2013 have completed the implementation of the EPBD in the sections related to inspections of the heating, ventilation and air- conditioning (HVAC) and domestic hot water (DHW) systems and qualification of energy assessors;
– Law 63/2013 (enacted by Law 90/2013) has implemented Directive 2010/31/EU, introducing significant modifications in Legislative Decree 192/2005 (the Directive 2002/91/EC transposition act);
– In 2014, Law 9/2014 partially modified the qualifications of the energy assessors included in Presidential Decree 75/2013.

Energy- related topics are a shared task between the State and the 21 Regions and autonomous provinces. Consequently, regional authorities may implement autonomous transpositions of the EPBD, as long as they do not contradict the general principles and requirements provided by national and EU regulations. The national regulation stays in force for the regions that have not issued their own legislation. At the end of 2014, 6 regions (Liguria, Emilia Romagna, Toscana, Val d’Aosta, Piemonte and Lombardia) and the 2 autonomous provinces (Trento and Bolzano) have fully transposed the EPBD. All other regions follow the national legislation, which, by itself, is a full transposition of the EPBD.rom the 6th of June 2013." (http://www.epbd-ca.eu/outcomes/2011-2015/CA3-2016-National-ITALY-web.pdf)

The plan for promoting and developing Nearly Zero-Energy Buildings contains:

– Energy performance values according to building type (energy performance for residential buildings is expressed in terms of kWh/m2 year of primary energy, while energy performance for non-residential buildings is expressed in terms of kWh/m3 year of primary energy), climatic zone, local degree days and surface-area-to-volume ratio of the building (figure 1 and table 3);
– The policies and financial measures for promoting Nearly Zero-Energy Buildings, including information on national contributions for the integration of renewable energy sources in buildings;
– Minimum requirements for retrofitting actions. They are differentiated according to the degree of the planned renovation. The minimum energy performance requirements for new buildings apply fully in case of: demolition/reconstruction or renovation of all building elements (for buildings with heated floor area >1,000 $m^2$) or building extensions over 20% of the original volume, only for the newly built section. In case of any degree of refurbishment, a set of basic requirements applies to single building elements.

Buildings used and owned by public authorities are expected to set an example and play a leading role. Therefore, energy performance and U- values are set 10% lower than those required for private buildings (Decree 59/2009).

In order to increase the energy efficiency of public buildings, especially school buildings and hospitals, the guarantee fund provided by Legislative Decree n. 28 can be used.

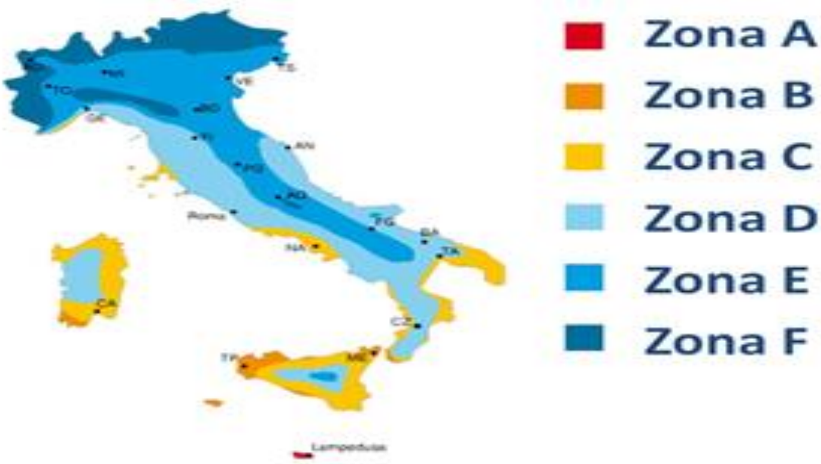



Figure 1 Italian climatic zones

*Table 3 Minimum energy performance requirements for heating (primary energy) in non-residential buildings (kWh/m²).*

| Surface area to Volume Ratio S/V | Climatic Zones (by degree days °C) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | | C | | D | | E | | F |
| | < 600 days | > 601 days | < 900 days | > 901 days | < 1400 days | > 1401 days | < 2100 days | > 2001 days | < 3000 days | > 3000 days |
| <0,2 | 2,0 | 2,0 | 3,6 | 3,6 | 6 | 6 | 9,6 | 9,6 | 12,7 | 12,7 |
| >0,9 | 8,2 | 8,2 | 12,8 | 12,8 | 17,3 | 17,3 | 22,5 | 22,5 | 31 | 31 |

Until new minimum requirements and calculation methodologies are introduced, existing requirements set by Legislative Decree 192/2005 and 311/2006 will stay into force. Current calculation methodologies are based on national standards derived from CEN.

Legislative Decree 192/2005 draws the general framework for the transposition of the EPBD, setting the minimum requirements for energy performance and the U- values for windows, walls, floors and roofs, in case of new buildings and major renovations. In 2009, Presidential Decree 59 extended the calculation methodologies and minimum requirements to the summer energy performance of cooling and lighting systems; it also updated the minimum requirements for the energy performance of buildings and of heating systems. A new ministerial decree setting the new requirements for new buildings (including NZEBs) and major renovations is near completion and will substitute DPR 59/2009.

Methodologies for calculating the Energy Performance are described in UNI TS 11300 1-2-3 (table 4).
In the calculation of the energy demand for winter air conditioning, the type of functional areas are considered (table 5).

*Table 4 Air changes UNI 10339 (UNI TS 11300)*

| | |
|---|---|
| Wards | 11 l/s per person |
| Sterile rooms | 11 l/s per person |
| Infectious rooms | Specified as needed |
| Living rooms | 8.5 l/s per person |
| Physical therapies | 11 l/s per person |
| Operating theatres | Specified as needed |
| Toilets | 8 volume/h extraction |

*Table 5 Air changes Circular 13011/74*

| Zone | Air changes per hour |
|---|---|
| Wards | 2 Volume/h |
| Paediatric Wards | 3 Volume/h |
| Diagnostic Wards | 6 Volume/h |
| Special Wards | 6 Volume/h |
| Isolation Ward | 12 Volume/h |
| Toilets | 10 Volume/h |
| Living rooms | 30 m3/H per person (minimum) |

Only the energy for ventilation is higher than the law limits.

Buildings meeting the performance requirements stated by Legislative Decree 192/2005, both for the envelope and the technical installation, do not meet the standards for energy demand (kWh/m3).

### 2.5. United Kingdom

In UK every building which belongs to Public authority has to have Display Energy Certificate (DEC) where information about building`s energy use and carbon emission are presented. Hospitals are assigned to this group.

DECs last for 1 year for buildings with a total useful floor area more than 1,000 square metres and for 10 years when the total useful floor area is over 250 square metres and up to 1,000 square metres.

Certificate shows following parameters:

- Energy Performance Operational Rating;
- Total CO2 Emission Rating;
- Previous Operational Ratings;
- Technical Information;
- Administrative Information.

Energy Performance Operational Rating is expressed using grades from A to G, where A is the most efficient grade.

The more specific requirements are given in The Building Regulation 2010 ( Document L2A and L2B). For building other than dwelling the Target CO2 Emission Rate (TER) and Building Emission Rate (BER) has to be calculated at design stage and issued to Building Control Body (BCB) together with details of its specification. This calculation together with Energy Performance Certificate (EPC) shall be done after building is completed and delivered to BCB. TER, BER and EPC can be calculated using approved simulation software (Approved Dynamic Simulation Models (DSMs)) or by using the Simplified Building

Energy Model (SBEM). Methodology for calculation is given in the National Calculation Methodology. In table below selected energy requirements are shown according to Document L2A.

| Country | Shortcut | Unit | Definition | Description | Minimum value | | Legislation |
|---|---|---|---|---|---|---|---|
| UK | U | W/m$^2$K | Coefficient of heat transfer | Maximum values* for external partitions | External wall | 0,35 | The Building Regulation 2010 Document L2A |
| | | | | | Roof | 0,25 | |
| | | | | | Floor | 0,25 | |
| | | | | | Windows Doors | 2,2 | |
| | | | | | Vehicle access and similar large doors | 1,5 | |
| | | | | | High usage entrance doors | 3,5 | |
| | | | | | Roof ventilators | 3,5 | |

### 2.6. EU

Legal documents which set the requirements for Building Performance are:

- DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the energy performance of buildings;
- DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

EC proposed an update to the EPBD directive on November 2016 to help to promote the use of smart technologies in buildings. Information about documents mentioned above can be found at European Commission official website, see References.

### 2.7. USA

Set of Energy efficiency goal can be found in EO 13693 PLANNING FOR FEDERAL SUSTAINABILITY IN THE NEXT DECADE.

The main aim of this executive order, according National Institute of Building Science website, is "to cut the federal government's greenhouse gas emissions 40% over the next decade from 2008 levels and increase the share of electricity the federal government consumes from renewable sources to 30%. In addition, the executive order directs federal agencies to ensure 25% of their total energy (electric and thermal) consumption is from clean energy sources by 2025; reduce energy use in federal buildings by 2.5% per year between 2015 and 2025; reduce per-mile greenhouse gas emissions from federal fleets by 30% (from 2014 levels) by 2025 and increase the percentage of zero-emission and plug-in hybrid vehicles in federal fleets; and reduce water intensity in federal buildings by 2% per year through 2025."

# 3. Overview of Specific Requirements for Comfort and Safety in HDs

This summary overview presents existing requirements for comfort and safety in HD and various types and use of buildings which may influence energy and economic effectiveness HD EeBs.

## 3.1. Poland

**Comfort**

Main regulations shall be found in Construction Law and Regulation of the Minister of Spatial Planning and Construction on the technical conditions to be met by buildings and their location. Provisions about Indoor Air Quality are following:

– Air condition and Ventilation systems shall provide adequate indoor air quality: air changes rate, temperature, air purity, humidity, air velocity given in PN-B-03430:1983/Az3:2000. This standard is withdrawn but there is no replacement that is why it is still used by engineers. In standard it is said that in rooms for permanent people residence pure (outdoor) air flow should be no less than 20m$^3$/h/person. In air-conditioned and mechanically ventilated rooms air flow should be no less than 30m$^3$/h/person.

The most important information regarding comfort design can be found in PN EN 15251:2012 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics. Its requirements were described further in paragraph 2.3.6.

**Fire protection**

Provisions for the fire protection in Poland can be found in:

– Construction Law;
– Fire protection Law;
– Regulation of the Minister of Spatial Planning and Construction on the technical conditions to be met by buildings and their location;
– Regulation of the Minister of the Internal Affairs on the fire protection of buildings, other buildings and land;
– Regulation of the Minister of Internal Affairs on detailed rules for fire water supply, technical rescue, and chemical and environmental conditions to be met by fire roads;
– Regulation of the Minister of Economy, Planning and Construction on the introduction of the obligation to use some Polish Standards in the field of construction, spatial and municipal geodesy and cartography;
– Regulation of the Minister of Internal Affairs on the introduction of the obligation to use Polish Standards and industry standards;
– Regulation of the Minister of Internal Affairs on the scope, procedure and principles of reconciliation construction project in terms of fire protection;
– Regulation of the Minister of Economy, Planning and Construction on approvals and technical criteria for construction products;
– Regulation of the Minister of Internal Affairs on the issue of the certificate of approval (certificate) the use of products used for fire protection;
– The law on standardization;
– The law on research and certification;

At the early stage of design, the most important regulations, are those given on the technical conditions to be fulfilled by buildings and their location. The section about Fire Protection states:

– The building and the equipment associated with it should be designed and constructed in such a way that in the event of fire:
    1) provide the load-bearing capacity of the construction for the time given in The Regulation,
    2) limit the spread of fire and smoke in the building,
    3) limit the spread of fire to adjacent buildings,
    4) secure the possibility of evacuation of people,

    also taking into account the safety of rescue teams.
– Evacuation route from the rooms farthest from the place where a man can stay to the emergency exit on the escape route or to another fire zone or outside the building should be ensured, with a length not exceeding 40 m, (in case of Hospital buildings). Length of the pass can be increased by 50% in case of sprinklers installation or by automatic smoke exhaust devices activated by smoke detection system. Incensements can be summed up.
– In high (25-55m) and very high buildings (>55m) it should be at least two staircases enclosed and separated from the horizontal evacuation route.
– For high and very high building staircases and fire porches, representing an escape route for the fire zones should be equipped with smoke prevention devices.
– The minimum corridor width is 0,90m.
– Moreover regulation gives permissible surface of fire protection zones. Area depends on building height and for hospitals is from 5000m$^2$ in low buildings (<12m) 3500 m$^2$ in medium height buildings (12-25m) and 2000 m$^2$ in high and very high buildings. Area of the zone can be increased by 200% due to use of sprinklers (100%) and smoke prevention devices(100%). However there are some exceptions for high and very high buildings.

Presented above regulations are only the selection of extensive text of the Fire protection section from Ministry Ordinance. More regulations shall be found in the original document.

**Electrical installations**

Polish Regulation of Ministry of Health for technical and sanitary premises as well as facilities in health care, require that reserve sources of electrical energy supply should be installed: - an electricity generator equipped with the auto-start function, providing at least 30% of the peak power needs, with uninterruptible power supply with the appropriate backup power and possibly batteries.

### 3.2. Netherlands

**Comfort**

Main regulations on ventilation can be found in the Dutch Building Decree 2012:

– A hospital function should have a ventilation provision of at least 12 dm³/s per person for the bed area and 6.5 dm³/s per person for other health care functions.
– A toilet room should have a fresh air supply of at least of 7 dm³/s.
– A bathroom should have a fresh air supply of at least 14 dm³/s.

The Building Decree also enhances other regulations on comfort, like requirements for noise protection, moisture proofing, daylight, emergency lighting etc.

**Fire protection**

The minimal building related requirements for fire safety are given in the Dutch Building Decree 2012. It includes requirements on fire and smoke compartments, fire escape routing and fire resistance of building materials. The specific fire safety regulation is too complex to summarize in a few words.

The organisational aspects of fire safety, like the emergency response of hospital personnel, are captured in the Dutch Working Conditions Act.

**Electrical installations**

The electrical safety in medically used spaces is captured in the NEN1010: 2015, the standard on low voltage electrical installations, and Dutch interpretation of the HD-IEC 60364-series. According to the NEN1010:2015 a risk assessment shall take place to determine the risks related to the type of patients. Based on this risk assessment the proper measures shall be defined.

### 3.3. France

**Comfort**

In France, for healthcare facilities, the standardized weighted acoustic insulation (in dB) between the various types of spaces must not be less than the given values.

Other requirements concern the acoustic insulation from external noises, the standardized weighted sound pressure level of shock noise and the reverberation times, depending on the type of rooms.

**Fire safety**

Articles U1 à U64 of the fire safety regulations in ERP set specific requirements for ERP type U (healthcare facilities) whose size of the public they receive is above 100 (or have more than 20 hospital beds). It complements the general rules applying to all establishments open to the public.

Generally speaking, the fire security level mainly relies on the capabilities for horizontally transferring people that can't move by themselves towards contiguous areas adequately protected. The vertical evacuation should only be considered in case of extreme circumstances. In particular, it implies that each floor should contain at least two protected areas.

For buildings of more than one level on ground floor that include sleeping rooms, the main structural elements should have a fire stability of at least one hour (R 60), and floors should have a fire resistance of at least one hour (REI 60). Inside walls used for delimiting protected areas should also have a fire stability of at least one hour.

More binding provisions have been set up for isolating specific spaces (e.g. operating theatres).

Besides, particular requirements on ventilation and smoke extraction exist for spaces presenting specific risks of fire hazards.

In terms of clearance, circulations should have at least two "passage units" (unit of exit width), and bedroom doors should have a minimum width of 1.10 m. The maximal distance that public has to cover to a staircase should not exceed 40 meters from any point of the building.

Other requirements concern interior fittings (e.g. interior claddings), smoke extraction (with particular requirements for spaces presenting specific risks of fire hazards), HVAC installations, and safety lighting.

### 3.4. Italy

**Comfort**

The definition of "Hygienic - Environmental Requirements" refers to the hygienic - environmental conditions that can be found within healthcare facilities and which can be a risk for staff (and users).
The matter is regulated by the Legislative Decree n. 81/08 (included subsequent modifications and integrations)

The risks can be due to:
– Physical agents;
– Chemical agents;
– Biological agents.

Physical agents: Microclimate

Especially in high sterile rooms, thermo-hygrometric conditions and levels of environmental thermal comfort are relevant to staff and patients.

Articles 180 and 181 of the Decree deal with altered microclimatic conditions to be evaluated according to limits set by technical regulations (UNI EN ISO 7730:2006).
UNI EN ISO 7726 e UNI EN ISO 7730 are reference for methods of control of microclimate conditions.

Physical agents: Lighting

UNI EN 12464-1 defines the characteristics of lighting in healthcare buildings, especially regarding lighting levels, dazzling and chromatic performance.

Physical agents: ionizing radiation
Legislative Decree n. 230/95.

Physical agents: non-ionizing radiation

Legislative Decree n. 81/08 (Title VIII, Chapter 4, and 5) deals with exposure to electromagnetic fields and to artificial optical radiation.

Chemical agents

Legislative Decree n. 81/08 (Title IX, Chapter 1 and 2) deals with chemical protection and Protection against carcinogenic and mutagenic agents.

Chemical agents: anaesthetics'
Circular of the Ministry of Health n. 5 (14/03/1989) "Exposure to anaesthetics' in the operating room" is the only regulation dealing with anaesthetics agents.

Biological agents
Legislative Decree n. 81/08 (Title X).

**Fire protection**

The Decree of the Ministry of Interior 18/09/2002 deals with fire safety to be guaranteed inside health care facilities.

The zones of the hospital are classified as follows:

- § Type A: areas or facilities with specific risk, defined as activities to be controlled by fire fighters according to Ministerial Decree 16/02/1982 and Decree of the President of the Republic n. 689/1959 (Heat production plants, generating set, etc.);
- § Type B: areas with specific risk accessible to only staff members (laboratories, deposits, laundries, etc.), located inside Type C or D areas;
- § Type C: Areas for outpatient medical services (outpatient clinics, diagnostic centers, consultants, etc.) where there is no hospitalization;
- § Type D: Areas for hospital and/or residential care as well as areas dedicated to special units (intensive care, neonatology, resuscitation department, operating rooms, etc.);
- § Type D: Areas for other activities (offices, conference rooms, canteen, etc.).

The Interministerial Decree 19/03/2015 updated the above fire prevention technical regulation and deals with the design, the construction and the operation of public and private healthcare facilities.

The new law include annex I and II (replacing Title III and IV of the previous law) and annex III (new Title V). The main novelties are:

- – Annex I: contains indications for healthcare facilities with hospital or residential care with more than 25 beds existing at the date of entry into force of the 2002 Decree, which have not completed the adaptation to the provisions;
- – Annex I: contains indications to adapt daily care facilities existing at the date of entry into force of the 2015 Decree;
- – Annex I: contains regulations related to security management system aimed at fire-fighting. It establish the Technical Manager for fire safety.

**Electrical installations**

Law n. 186/68 “Instructions concerning the production of materials, equipment, plant and electrical and electronic equipment” is the basic reference to guarantee safety against the dangers arising from electrical systems. It requires all electrical system and their components to be “in accordance with best practice”, that means according to IEC (International Electrotechnical Commission) technical regulations.

The Ministerial Decree 37/08 and the Legislative Decree 81/08 have completed the reference framework. The main legislative decrees concerning safety for electrical accident prevention, are:

- – Law n. 1341/64 – Overhead cables;
- – Law n. 186/68 - Provisions relating to electrical equipment and materials
- – Law n.791/77 - Implementation of the EEC Directive n. 72/23 on the security guarantees to be provided for electrical equipment to be used within certain voltage limits;
- – Ministerial Decree 15/12/1978 - Designation of the Electrotechnical Committee of Electrical and Electronics Normalization;
- – Law n. 46/90 - Safety Standards for Installations;
- – Directive 06/95/CEE (12-12-2006) - CE marking of electrical equipment;
- – Legislative Decree n. 79/99 - Implementation of Directive 96/92/EC on common rules for the internal market in electricity;

- Law n. 36/01 - Protection against electric, magnetic and electromagnetic fields exposure
- Ministerial Decree n. 37/08 – Regulations related to technical installation in buildings;
- Legislative Decree n. 81/08 – Safety Act.

### 3.5. United Kingdom

**Fire safety**

The Building Regulations (Part B) specifies five aspects of fire safety in the construction of buildings:

- Requirement B1 - Means of early warning of fire and adequate means of escape from the building (including emergency lighting and fire exit signage).
- Requirement B2 - Control of Internally fire spread (linings) The wall lining i.e. plaster, plasterboard or wooden boards on the walls and ceiling will resist the spread of flames and give off only reasonable levels of heat, if on fire.
- Requirement B3 - Control of Internal fire spread (structure) will be maintained during a fire, and fire spread will be prevented. Fire and smoke will be prevented from spreading to concealed spaces in a building's structure by Fire Stopping and Fire Cavity Barriers.
- Requirement B4 - External fire spread – The external walls and roof will resist spread of fire to walls and roofs of other buildings. However, Not all buildings are required to have non-combustible exterior finishes.
- Requirement B5 - The building will be accessible for firefighters and their equipment, without delay. Tall and Large buildings to have Fire Lifts and Fire Mains (Dry or Wet riser pipes), etc.

What is more said in Building Regulation 38 that the designer and/or constructor have to give the fire safety information (for a description of the information required – see Appendix G of approved document B) to the Responsible Person, upon completion. This is to enable a competent person to carry out a fire risk assessment.

**Electrical Installations**

Regulations for Electrical installations are given in British Standard BS 7671 "Requirements for Electrical Installations. IET Wiring Regulations". It is the national standard in the United Kingdom for electrical installation and the safety of electrical wiring in domestic, commercial, industrial, and other buildings, also in special installations and locations, such as marinas or caravan parks.

Sections 710 is dedicated to Medical Location, Section 444 to Electromagnetic disturbances and Section 729 to Operating and maintenance gangways.

### 3.6. EU

**Comfort**

European Standard EN 15251 introduces comfort classes and requirements.

According to this standard four comfort classes are defined for:

- thermal comfort,
- operating temperature,
- lighting and lighting control,
- humidity
- noise.

Comfort Class I – high level expectation - recommended for spaces occupied by disabled persons, children or elderly.

Comfort Class II – normal level expectation - to be applied for new buildings and renovations.

Comfort Class III – acceptable, moderate level expectation - to be applied for existing buildings.

Comfort Class IV – values outside the criteria for the above categories - this category should only be accepted for a limited part of the year.

Comfort classes are presented in table below.

*Table 6 Comfort classes according to EN15251*

| Comfort class | Thermal Comfort requirements | | Operative Temperature range | | Ventilation | | Lighting | Relation with envelop | Humidity | Additional requirements | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PPD[2] (%) | PMV[3] (/) | Winter 1.0clo/1.2met [°C] | Summer 0.5clo/1.2 met [°C] | $CO_2$ Above outdoor [ppm] | Air flow [m3/h/m2] | [lux] | View and/or daylight | Relative humidity [%] | Control of lighting | Indoor noise [<dB(A)] |
| I | < 6 | -0.2 < PMV < + 0.2 | 21.0-23.0 | 23.5-25.5 | 350 | >10.8 | 1000 | direct daylight and view outside obligatory | 30-50 | Screens and adaptive control | 35 |
| II | < 10 | -0.5 < PMV < + 0.5 | 20.0-24.0 | 23.0-26.0 | 500 | >7.6 | 500 | direct daylight and view outside preferred | 25-60 | Adaptive control | 35 |
| III | < 15 | -0.7 <PMV < + 0.7 | 19.0-25.0 | 22.0-27.0 | 800 | >4.3 | 300 | direct daylight and view outside preferred | 20-70 | No requirement | 45 |
| IV | > 15 | PMV > + 0.7 | < 19.0-25.0< | <22.0-27.0 < | 800< | Not required | 150 | direct daylight and view outside not required | <20-70< | No requirement | 48 |

[2] PPD - Predicted Percentage of Dissatisfied

[3] PMV - Predicted Mean Vote

**Fire protection**

In the framework of the European Union testing standards, marking the evaluation system, the rules for issuing technical approvals and attestation are standardized. Rules for buildings remain diverse in membership countries.

### 3.7. USA

**Comfort**

US Green Building Council gives two option with comfort requirements:

- ASHRAE standard 55-2004 or non-U.S. equivalent;
- ISO 7730: 2005 & CEN standard EN 15251: 2007.

HVAC systems shall meet local codes or current 2010 FGI Guidelines for Design and Construction of Health Care Facilities (Table 2.1-2: Ventilation Requirements for Areas Affecting Patient Care in Hospitals and Outpatient Facilities), if local codes cannot be apply.

Moreover permanent monitoring system is required to ensure that the building performs to the desired comfort criteria as determined above.

**Fire protection**

Fire protection regulation are given by National Fire Protection Association. NFPA provides building Codes and Standards which are used not only in USA but worldwide. Information about available documents can be found at NFPA official website, see References. NFPA 99 refers to Health Care Facility Codes.

**Electrical Energy safety supply**

According to USA standard 2008 NEC Article 700 of NFPA 7 Section 700.12 The emergency lighting and emergency power must be available within 10 seconds of a failure of the normal building power supply.

This can be accomplished by:

- a storage battery that can maintain the load for a minimum of 1.5 hours without a voltage drop below 87.5% of normal;
- generator set that automatically starts on failure of normal service that has an automatic transfer switch for all required circuits (if the generator requires greater than 10 seconds to develop power, an auxiliary power supply must be provided until the generator can pick up the load);
- a UPS that meets the requirements of one of the two means described above;
- separate service (where approved by the authority having jurisdiction);
- fuel cell with a rating and capacity to supply and maintain the total load for not less than two hours of full demand operation.

# 4. Overview of requirements for EeB HD technical installations

This section of the report covers specific regulations and requirements for HVAC and MEP installations of different specific use in HDs as well as for BMS functionality applied in HDs.

## 4.1. Poland

HVAC installation shall be designed according to Polish applicable rules, standards and technical knowledge. Regulation for design can be found in:

– Building Law;
– Regulation of the Minister of Spatial Planning and Construction on the technical conditions to be met by buildings and their location, as amended;
– Regulation of the Minister of Health on 2 February 2011 on the requirements to be met in terms of technical and sanitary premises and facilities in health care, as amended.

**For Ventilation and Air-conditioning** design applicable are:

– PN-B-03430:1983/Az3:2000 Ventilation in residential and public buildings. Requirements;
– PN-EN 15251:2012 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics;
– PN-EN ISO 14644-1:2015 Cleanrooms and associated controlled environments -- Part 1: Classification of air cleanliness by particle concentration;
– PN-EN 13779:2008 Ventilation for non-residential buildings. Performance requirements for ventilation and room-conditioning systems
– And:
  - CEN 1752, 1998 Ventilation for buildings- Design criteria for Indoor Environment;
  - ASHRE Standards for Ventilation;
  - VDI regulation rules.

Minimal air flow rates given in Polish regulations and PN EN 15251 are presented in table below:

*Table 7 Minimal air flow rates given in Polish regulations and PN EN 15251*

| Room type | Air flow |
|---|---|
| Pharmacy | 2 1/h |
| Archives | 2-4 1/h |
| Laboratories | 7-15 1/h |
| Offices | 0,5 1/h<br>0,1-0,2 $l/s \cdot m^2$ |
| Examination room | 2 1/h |
| Treatment room | 3-4 1/h |
| Treatment room with anesthesia | 10 1/h |
| Sterilization room | 5 1/h |
| X-Ray room | 1,5 1/h |
| X-Ray dark room | 3 1/h |
| Other rooms | 1,5 1/h |
| Toilets | 2 1/h |
| Douche | 80-100 $m^3/h \cdot$douche |

**For heating** design applicable are:

– PN-EN 12831:2006 Heating systems in buildings. Method for calculation of the design heat load;
– PN-EN ISO 6946:2008 Building components and building Elements – Thermal resistance and Thermal transmittance – Calculation Method;
– And:
  - Guidelines given by manufacturers of heating system components;
  - Engineering experience.

**Calculation parameters according to PN 76/B-03421 are** :

*Table 8 Indoor air calculation parameters for winter and summer*

| **Winter** | | | | |
|---|---|---|---|---|
| Physical activity | Temp. | Humidity | | Air velocity |
| | ºC | optimal | Min. | |
| | | % | % | m/s |
| Low | 20-22 | 40-60 | 30 | 0,2 |
| Average | 18-20 | | | |
| High | 15-18 | | | 0,3 |

| **Summer** | | | | | | |
|---|---|---|---|---|---|---|
| Physical activity | Optimal parameters (Air-conditioning) | | Permissible values | | | Air velocity |
| | Temp. | Humidity | Temp. for heat gains referred to $1m^2$ of floor | | Max. humidity | |
| | ºC | % | $<50W/m^2$ | $>50W/m^2$ | % | m/s |
| Low | 23-26 | 40-55 | $t_z+3$ | $t_z+10$ | 70 | 0,3 |
| Average | 20-23 | 40-60 | | | | 0,4 |
| High | 18-21 | | | | | 0,6 |
| $t_z$- outside air temperature | | | | | | |

Outdoor air calculation parameters are also given in **PN 76/B-03421.**

### 4.2. France

Airborne contamination control

Requirements for controlling airborne contamination in healthcare facilities are detailed in standard NF S90-351. For instance, the following table provides performance guide values (in non-operative state) depending on the level of risk:

| Classe de risque | Classe de propreté particulaire | Cinétique d'élimination des particules | Classe de propreté micro-biologique | Pression différentielle (positive ou négative) | Plage de températures | Régime d'écoulement de l'air de la zone à protéger | Autres spécifications, valeur minimale |
|---|---|---|---|---|---|---|---|
| 4 [a] | ISO 5 | CP 5 | M1 | 15 Pa ± 5 Pa | 19 °C à 26 °C | Flux unidirectionnel | Zone sous le flux<br>Vitesse d'air de 0,25 m/s à 0,35 m/s<br>taux d'air neuf du local ≥ 6 volumes/heure |
| 3 | ISO 7 | CP 10 | M10 | 15 Pa ± 5 Pa | 19 °C à 26 °C | Flux unidirectionnel ou non unidirectionnel | taux de brassage ≥ 15 volumes/heure |
| 2 | ISO 8 | CP 20 | M100 | 15 Pa ± 5 Pa | 19 °C à 26 °C | Flux non unidirectionnel | taux de brassage ≥ 10 volumes/heure |

[a] Le taux de brassage, dans le cas particulier d'un flux unidirectionnel, doit être fixé indépendamment pour la zone située sous le flux et pour l'ensemble du local considéré.

Exemple de calcul : pour une salle d'opération de 200 $m^3$ équipée d'un flux unidirectionnel recycleur de 3 m × 4 m.

Un plafond de 3 m × 4 m qui souffle à 0,3 m/s produit **12 960 $m^3$/h**.

Le volume de la zone sous flux est de 40 $m^3$ ce qui donne un taux de brassage de **324 vol/h**.

Si l'on considère que **6 vol/h** d'air neuf sont suffisants pour assurer la surpression de la salle et l'élimination des polluants, le débit nécessaire sera de **1 200 $m^3$/h** d'air neuf.

Si l'air neuf est introduit dans le flux unidirectionnel, la zone sous flux sera balayée par 11 760 $m^3$/h d'air recyclé et 1 200 $m^3$/h d'air neuf.

Il faut donc pour les zones à risque 4 (ou à risque 3 si un flux unidirectionnel est mis en place) :

— choisir un flux unidirectionnel de taille suffisante pour protéger toute la zone à risque pour le patient ;

— fixer une vitesse d'air suffisante pour assurer la propreté de l'air sur l'ensemble du volume sous le flux ;

— choisir un taux d'air neuf suffisant pour évacuer les polluants présents dans la salle et assurer une surpression par rapport à son environnement.

The level of risk (from 1 to 4) depends on the type of space and associated activity. For instance, a standard hospital bedroom will have a risk level of 1, and an organ transplant room a risk level of 4.

<u>Management of risks linked to legionella</u>

Legionella develop in water systems when the temperature is between 25 and 43 °C, the water remains stagnant and in case of mineral deposits, metal residues, etc. Legionella infections are likely to be more severe in hospitals where certain illnesses may cause an increased susceptibility.

Appropriate preventive actions should be taken for the design and maintenance of installations, and for controlling water temperature.

### 4.3. Italy

**MEP system**s in healthcare facilities are regulated by the Decree of the President of the Republic n. 37/97 and the Decree of the Ministry of Interior 18/09/2002 (included subsequent modifications and integrations) Regarding the design of the indoor environment, the regulation to be taken in account is the UNI EN 15251 "Indoor environmental parameters for assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics": it defines the parameters of the indoor environment affecting energy performance.

– Other standards to be used as reference are as follows:
– Ministerial Circular n. 13011/74 - Physical-technical requirements for hospital buildings. Thermal, hygrometer, ventilation and lighting properties;

– UNI 10339 – Aeroulic plants;
– UNI 8199 - Measurement in operation and noise assessment produced in heating, air conditioning and ventilation systems.

### 4.4. United Kingdom

Requirements for building installation are given in the Building Regulation 2010 where:

– Part F gives requirements for Ventilation referring to:
  - NHS Activity data base'
  - Health technical Memorandum (HTM) 03'
  - Health Building Notes (HBN)- various'
  - CIBSE Guide B:2005, Section 2.3.13'
  - CIBSE AM10:2005 for natural ventilation'
  - CIBSE AM13:2000 if mixed mode;
– Part G gives requirements for Sanitation, hygiene and water efficiency.
– Part H. gives requirements for Drainage and waste disposal.
– Part J. gives requirements for Combustion appliances and fuel storage systems.
– Part L. gives requirements for Conservation of fuel and power.
– Part M. Access to and use of buildings.

### 4.5. EU

Special requirements are given for operation theatres where air purity has significant influence on patient safety. That is why direct air flow systems are recommended for this type of space. Requirements for air conditions and one direction air flow (laminar) in hospital rooms regarding EU countries and USA are presented in tables below.

*Table 9 Air parameters in operation theatre*[4]

| | Poland | Germany | Switzerland | Austria | Great Britain | USA |
|---|---|---|---|---|---|---|
| Standard | Guidelines for general hospital design | DIN 1946 p.4. | SWKI Schriftenreihe Band 35 | ÖNORM H 6020 | DHHS | ANSI/ ASHRAE Std. 62.1 |
| Year | 1984 | 2008 | 1987 | 1999 | 1986 | 2004 |
| Air temp. ºC | 22-25 | 19-26 | 19-24 | 21-26 | 18-21 | 17-27 |
| Humidity, % | 55 ± 5 | - | 45-60 | 40-60 | 40-60 | 45-60 |
| Max. air velocity, m/s | 0,4-0,5 | - | 0,45 | - | 0,25 | - |
| Min. vent. Air flow, $m^3/h$ | 12 000 | 5000 | 2000-3000 | 2400 | 2340 | 25 $h^{-1}$ |

[4] Source: Lecture materials, Anna Charkowska, Warsaw University of Technology

| | Poland | Germany | Switzerland | Austria | Great Britain | USA |
|---|---|---|---|---|---|---|
| Min. fresh air flow, $m^3/h$ | 12 000 | 1200 | 80 per person | 1200 | 2340 | 5 $h^{-1}$ |
| Air recirculation | No | Yes | Yes | Yes | No | Yes |
| Max. noise level, dB(A) | 35 | 48 | 45-50 | 40-45 | 50 | - |

*Table 10* ***Requirements for one direction air flow (laminar) in hospital rooms***

| Requirements for one direction air flow (laminar) in hospital rooms[5] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Country | Information in the table refers to all rooms with high purity | Information in the table refers to defined nearby operation theaters | Dimensions of the laminar ceiling ( or other requirement) | Air recirculation | Minimal fresh air volume | Air velocity, m/s | Supply and exhaust air tem. Difference |
| **France** | | **ISO 5** | **>= 50$h^{-1}$** | **yes** | **>=6$h^{-1}$** | **>0.20** | |
| **Germany** | | **Class 1a** | **3,2m x 3,2 m** | **yes** | **1200$m^3/h$** | **0,18-0,25 (0,23 recommended)** | **0,5-0,3K ( 1K recommended)** |
| **Switzerland** | **X** | | **9$m^2$** | **yes** | **100$m^3/(h$ per.) (>=1000$m^3/h$)** | **0,2** | **-1K** |
| **Netherlands** | **X** | | **8-9$m^2$** | **yes** | **20h^-1** | **0,24 ÷0,40** | **-1 ÷ +2 K** |
| **Austria** | **X** | | | **yes** | **20m3/hm2** | **0,45** | |
| **Spain** | | **>=10CFU/$m^3$ air** | **2,8m x 2,8m** | **yes** | | **0,2 ÷0,4** | |
| **Poland** | | **I class (to 70bacteries/1$m^3$ air) high aseptic conditions** | **full area of ceiling or wall 2,7m x 2,7m** | **For special conditions, some permits are required** | **0,45$m^3/(sm^2)$ (min. 80$h^{-1}$)- horizontal displacement system or vertical full wall/ceiling surface<br><br>12 000$m^3/h$- operating cabin with vertical laminar air flow<br><br>With recirculation 2400$m^3/h$ - laminar ceiling 1200$m^3/h$- turbulent air flow** | | |

[5] source: Anna Charkowska, Warsaw University of Technology, Foreign guidelines for the design of ventilation and air conditioning systems in hospitals

| Requirements for one direction air flow (laminar) in hospital rooms[5] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Country | Information in the table refers to all rooms with high purity | Information in the table refers to defined nearby operation theaters | Dimensions of the laminar ceiling ( or other requirement) | Air recirculation | Minimal fresh air volume | Air velocity, m/s | Supply and exhaust air tem. Difference |
| | | **II class (to 300bacteries/1m³ air) operating rooms aseptic, septic, halls gypsum operations team, intensive care with hotel part,etc.** | | | | | |
| **CHU- colony forming unit** | | | | | | | |

### 4.6. USA

Regulations for **HVAC** design can be found in :

– International Building Codes (IBC);

– ASHRAE standards and guidebooks for HVAC design;

– NFPA standards;

– FGI Guidelines for Design and Construction of Health Care Facilities.

# 5. Good Practices in EeHDBuildings Controlled by BMS

The section reports on good practices in EeB HD sustainable design, engineering, construction and HD exploitation management with special focus on buildings energy consumption.

## 5.1. Poland

By now, there aren't any Polish specific regulations for BMS that would be obligatory in Poland except those used by international construction and installation companies developing and modernizing HDs. However one should observe recently more and more use of BMS mainly for HVAC and power supply installations, eg.: air conditioning.

## 5.2. Italy

The transposition decree (Law 63/2013 enacted by Law 90/2013) for Directive 2010/31/EU provides that the design, installation and maintenance specifications of active control systems, such as automation, control and monitoring, aimed at energy savings, will be identified by the new decrees under definition. Some Regions, as part of their legislative autonomy in the transposition of the EPBD, have already issued regulations to this regard. The Region of Emilia- Romagna, for example, has enacted minimum levels of active energy savings (the so- called Building Automation Control System – BACS) for new buildings since 2008. All buildings are actually divided into four classes on the basis of performance of control and automation systems (home automation for energy efficiency).

The guidelines and legislation related to the design and the installation of BMS in healthcare buildings are as follows:

– UNI EN 15232:2007 Energy performance of buildings - Impact of automation, control and technical management of buildings;
– UNI 7550:1985 Requirements for water for steam generators and related treatment plants;
– Deliberation 27/10/2011 Italian Authority for Energy 9/11 Updated Guidelines for the preparation, execution and evaluation of the projects referred to Article 5, paragraph 1 of the Ministerial Decrees 20/07/2004 and for the criteria and methods definition for energy efficiency certificates;
– Directive 2004/22/CE (31/03/2004) transposed with Legislative Decree n. 22/2007;
– UNI EN 13779:2008 Performance requirements for ventilation and air conditioning systems.

## 5.3. United Kingdom

In the UK for BMS British Standard BS EN15232:2012 *Energy performance of buildings, Impact of Building Automation, Controls and Building Management is in use*.

## 5.4. EU

ISO recommends to apply ISO 50001 with PCDA methodology and ISO 14001 for BMS development in functionally advanced EeB HDs.

## 6. Climate Influence On Securing Targeted Energy Efficiency

Local climate conditions strongly influence applied solutions, in principle, there are 3 main climate zones distinguished in Europe – 2 extremes and 1 intermediate - :

- Nordic & continental – cold winters and moderate summers – mainly requiring heating in winter,
- Southern & sea type – warm simmers and moderate winters – mainly requiring cooling in summer,
- Intermediate – mixture of both – requiring heating and cooling.

In general climate is warming up so more frequently cooling is becoming an issue. In earlier days simple solutions were applicable using solar energy in south countries and central heating supported by coal or oil fired boilers – not anymore. Also a request for more advance renewable energy sources is being observed e.g. heat pumps are getting operationally more sophisticated, working in two modes: - cooling and heating with energy storing facilities supported by low emission high efficient fuel cogeneration or even tree-generation power plants.

The above mentioned solutions are expensive so they require sophisticated methods of control and management.

# 7. Summary on EeB HD Actual Status, Goals and Research Directions

Presented above review shows a variety of Pan European and several European countries individual regulations concerning energy effective buildings as well as requirements concerning Healthcare Buildings however in general they do not deal with energy efficiency of HD buildings - EeHDBuildings. Only report from USA is dealing with energy effectiveness of hospital buildings but at the moment it is already outdated.

Since there are ambitious goals of lowering by 50% energy consumption to be achieved in the nearest future, there is a need for long term valid recommendations concerning rules of design and development of Healthcare Districts Buildings.

In the segment B of this Deliverable 8.7 a methodology based on STREAMER Project findings for an early design phase of HD planning for newly developed and retrofitted EeHDBuildings is presented in form of standard proposal draft. The methodology recommendations lead to fulfilment of the targeted EeHDBuildins goals, allowing for evaluation at the early design stage of energy demand and consumption as well as significantly shorten HD buildings Master Plan completion.

**The recommended methodology is based on:**

– Breitfuss and Bouwcollege concepts extended to cover travelling and junction spaces and layered block of building storeys;
– Semantic Labelling approach developed to drive Semantic 3D BIM HD buildings modelling;
– Energy auditing with the use of new EU ISO 52016 for EeHDBuildings energy demand and consumption calculation including MEP installations;
– Trias Energetica and REAP concepts been adopted to develop sustainable RES and local HD low emission energy sources supported by energy storage for Energy supply safety and peek demands shaving, controlled by BMS with BEM for HD energy supply and consumption economy – leading to smartEeHDBuildings concept;
– Economic efficiency analysis Life Cycle Cost concept been adopted for HD economic efficiency analysis;
– Set of KPIs and design validation methodology been developed for final early design validation of MHD Master Plan.

The proposed in this document methodology is a stepwise approach which leads to comprehensive design of EeHDBuildings at the early design stage – Master Plan design.

Step I – Formulation of functional and operational HD Programme of Requirements;
Step II – HDBuildings Modelling supported by STREAMER Semantic Labelling approach;
Step III – Generation of feasible HDBuildings Solutions;
Step IV – Energy Auditing of EeHDBuildings;
Step V – LCC calculation;
Step VI – HD KPIs calculation;
Step VII – Validation by means of weighted multidimensional criterion of the final EeHD.

The above mentioned methodology is implemented in the STREAMER Early Design Configurator – a set of tools for EeHDBuilding design at early design stage, operating on ARCHICAD with REVIT platform producing results on Dashboard – see STREAMER deliverable D8.8 Recommendation to building SMART, OGC, WC3 on open standards improvement.

# B. EeHDBuildings Early Design Methodology – Standard Proposal Draft

## FOREWORD

STREAMER is an European research and development project on energy-efficient healthcare districts. The aim of the project is to develop design methodologies and computer aided design tools for development of operationally economic, energy-efficient healthcare districts (HDs) integrated with neighbourhood technical infrastructure guarantying energy and media supply safety for hospital campuses (HCs).

The project team of specialists consists of 19 partners: 5 IND + 6 SME + 4 PUB + 4 RES form 9 EU member states from 5 regions of Europe as indicated below in the table.

| No. | Participant organisation name | Acronym | Country | Type | Key competence |
|---|---|---|---|---|---|
| 1 Coordinator | Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek | TNO | NL | RES | Applied research institute |
| 2 | Ipostudio Architetti Srl | IAA | IT | SME | Architect & urban designer |
| 3 | De Jong Gortemaker Algra | DJG | NL | SME | Architect & building engineer |
| 4 | Becquerel Electric Srl | BEQ | IT | SME | MEP & energy system engineer |
| 5 | DWA BV | DWA | NL | SME | Environment, MEP, energy engineer |
| 6 | AEC3 Ltd | AEC | UK | SME | ICT specialist (BIM) |
| 7 | Karlsruher Institut fuer Technologie | KIT | DE | RES | ICT specialist (GIS) |
| 8 | DEMO Consultants BV | DMO | NL | SME | ICT specialist (software) |
| 9 | Bouygues Construction | BOU | FR | IND | Construction company |
| 10 | NCC AB | NCC | SE | IND | Construction company |
| 11 | Mostostal Warszawa S.A. | MOW | PL | IND | Construction company |
| 12 | Stichting Rijnstate Ziekenhuis | RNS | NL | PUB | Hospital (building owner/user) |
| 13 | Assistance Publique - Hopitaux de Paris | APH | FR | PUB | Hospital (building owner/user) |
| 14 | The Rotherham NHS Foundation Trust | TRF | UK | PUB | Hospital (building owner/user) |
| 15 | Azienda Ospedaliero-Universitaria Careggi | AOC | IT | PUB | Hospital (building owner/user) |
| 16 | Mazowiecka Agencja Energetyczna | MAE | PL | IND | Agency for energy management |
| 17 | Commissariat a l'Energie Atomique et aux Énergies Alternatives | CEA | FR | RES | Commission for energy research |
| 18 | Centre Scientifique et Technique du Batiment | CST | FR | RES | Applied research institute |
| 19 | Locum AB | LOC | SE | IND | Property developer & manager |

The project is been co-financed by the European Commission under the seventh research framework program FP7, for research, technological development and demonstration under grant agreement no 608739.

## 1. Introduction

Hospitals are building complexes which consume significant amounts of energy – up to 2.5 times more than offices. They are open 24/7 and operate 24/7. In the EU, there are some 15,000 hospitals, responsible for at least 5% of the annual EU's carbon emissions.

Designing a hospital is a complex task. The place and shell-form of buildings can be under constraints from the shape of building plot or other buildings in the neighbourhood. From the one hand, the staff wants an efficient layout of rooms and corridors for medical processes as well as daylight in offices. From the other hand visitors want an easy-to-understand floorplan while patients want comfortable rooms. There are also many regulations to pay attention to.

Hospital campuses have to be equipped with mechanical, electrical and plumbing installations (MEP) of different producers claiming that there are the unique ones, so in order to design an HD building it is necessary to possess multidisciplinary knowhow to be in position to assess correctness of proposed wide range HD building solutions guarantying functional and operational sustainable comfort and safety. **The role of presented here standardized methodology is to deliver the necessary minimum of multidisciplinary expertise for formulation of reasonable HD Programme of Requirements as well as to understand set of designing processes at an early design stage which would lead to EeHDBuildings limited energy demand and consumption for reasonable and justified amount of invested money.**

The challenge is to design a hospital that satisfies expectations of interested groups of people involved and in addition as energy-efficient as possible bearing in mind that location climate in many cases counteracts to these expectation, calling for increase of investment capital as well as for increase of exploitation costs.

The aim set for the project was to quickly respond to growing capital investment and operational cost of the new HDs under development and those under modernization processes by providing innovative design methodology for planning and developing energy efficient Healthcare Districts focusing on shortening an early design phase of HD planning which includes at early design phase comprehensive energy demand and consumption modelling and analysis, operationally proven in demonstration hospitals.

The Key Research Targets were to develop innovative designing and engineering methodology at an early design stage which exploits:

- standardisation of HD Programme of Requirements introducing into an early design stage semantic labelling approach for HD buildings modelling;
- interoperability of updated within STREAMER Breitfuss and Bouwcollege concepts of HD design applied with 3D BIM design methodology enriched by STREAMER semantic labelling concept;
- standardisation of HD PoR, adequate analysis of LCC HD operational models as well as design validation methodology based on weighted KPI multidimensional criterion.
- shortening time-consuming designing and engineering processes in early design phase – HD Master Plan development with energy performance modelling – and cost reduction by application of the

Streamer Early Design Configuration methodology and EDC – Early Design Configurator – set of IT tools that effectively support process of HD designing;

– improvement of HD energy performance and HD investment economy.

The developed design methodology is applicable for EeHDBuildings newly designed as well as retrofitted.

## 2. Scope

Hospital Campuses (HC) consisting of various functional buildings (e.g. hospitals and clinics, research and educational, offices, as well as industrial areas) are usually located in a closed territory integrated with energy and media supply networks forming a Healthcare District (HD).

The research project team focuses on 6 main crucial aspects of time consuming HD design and engineering processes which cover:

– analysis of HC functional PoRs, with classification of needed spaces functional characteristics;
– HC buildings modelling implementing BIM with STREAMER semantic label concept;
– MEP/HVAC installations engineering;
– “Trias Energetica” concept combined with REAP;
– LCC analysis to select the most economic and functionally and operationally validated suitable solutions;
– Hospital Campus energy grid interfaced with neighbourhood media and energy supply networks.

The targeted framework which enables life cycle modelling of HD energy performance at early design stage is Building Energy Modelling (BEM), consists of:

– Early Design Configurator using BIM enhanced by STREAMER semantic labelling concept;
– Energy demand and consumption calculation according to EN ISO 52016;
– HD LCC analysis and HD early design Validation Methodology.

The duty of the project team is to produce final report on project results in a draft form of standardized documentation. The STREAMER Project standardisation proposal draft covering recommendations for HD energy efficiency methodology at early design stage consists of:

- EeHDBuildings Terminology & Definitions;
- EeHDBuildings Energy Demand and Consumption Modelling;
- EeHDBuildings Goals, Comfort and Safety Requirements;
- EeHDBuildings Semantic Modelling using BIM;
- EeHDBuildings LCC analysis and NPV Calculation;
- EeHDBuildings KPI calculations and Master Plan Validation.

## 3. EeHDBuildings – Terminology and Definitions

The aim of this Part is to present a multidisciplinary glossary which defines unique terminology and abbreviations used all over through this Energy efficient Healthcare Districts Buildings standardisation proposal draft.

Proposal of the recommended glossary is presented as an Appendix to the B Part of this D8.7 document.

# 4. EeHDBuildings – Energy Demand and Consumption Modelling

The energy demand and consumption of Healthcare District buildings depends upon:
- climate of a given HD GIS location;
- district and building typology, construction solutions and materials applied;
- operational HD characteristic and interaction with other buildings.
- operational efficiency of MEP installations.

It is been estimated that about 35% of electricity demand of a hospital is caused by the ventilation – air transport through buildings, 26% is used for lighting and 6% is used for (medical) equipment. HD energy demand modelling due to its specific functional characteristics as well as comfort, hygienic and safety requirements is rather challenging so it requires well defined proven methodology.

## 4.1 Scope

Dough the main topic of this standardization methodology proposal for the early design stage is energy efficiency of HDs we cannot concentrate only on energy efficiency of modern HD buildings. Due to specific functional requirements of HD buildings requirements it is necessary to present complete and coherent methodology which covers all the aspects connected with sustainability of HD buildings energy performance and it should also include recommended RES and low emission solutions. Thus this part covers complete analysis of HD buildings energy demand and consumption modelling aspects otherwise proposed HD early design solutions would be incomplete.

This Part covers:
- energy efficiency goals for modern HDs with respect to HD location, functional and operational, sustainability and low emission requirements;
- taxonomy of Healthcare Districts and its functional requirements variety;
- HD operational patients and staff comfort and safety requirements;
- recommended HD MEP installation solutions in relation to energy consumption efficiency;
- requirements for energy management needs.

This Part has been worked out on the basis of Streamer group of Deliverables mainly: – D1.3, D1.4, D1.5, D2.1, D2.2, D2.3, D3.4, D3.5, D6.4, D7.9, D7.10 – see also **Bibliography**, Streamer Deliverables.

## 4.2 Energy efficiency improvement assessment

Commercial ESCO firms on the EU market offer up to 45% HD exploitation guarantied savings by HD buildings retrofitting with modernisation financing still earning money. But this is not just by increasing energy efficiency of building envelopes. Apart from building envelopes thermal modernisation which yields up to 20-30%, 5-10 is possible to save on lighting, in addition to those - modernisation of HD management system may lead to 10 - 15% savings. Also quite significant saving may come from MEP installations modernisation. So 50% of savings is manageable in newly build HDs. This also indicates that even above 35% as a target in retrofitting is also manageable.

There are already examples of 50% energy consumption reductions in Nordic European countries. However with warming up climate savings possibilities on heating may be relatively easy to achieve. Warming up will put pressure on energy consumption in summer period for cooling.

## 4.3 Energy demand and consumption

Building collects, accumulates and loses thermal energy by heat exchange with the atmosphere, solar radiation or internal heat losses and heat gains e.g. ventilation, lighting, people breathing as well as lighting and medical diagnostic and treatment equipment.

**The energy demand** in kWh/h of HD defines the maximum level of energy needed for buildings:

– purely in relation to typical building characteristics and functions e.g. building construction characteristics as well as comfort, hygienic and safety requirements (ventilation, air conditioning, lighting) - building bioclimatic energy demand (Bbio).;
– and in relation to healthcare specific functions performed in the HD buildings e.g. diagnostic and treatment equipment needs, transportation (lifts), etc..

**Energy power demand** (in kW/MW) defines energy supply ability needed to cover energy peek demands and consumption. The total energy power demand defines energy supply safety requirements of a healthcare districts.

**The energy consumption** defines the amount of energy being consumed by HD buildings within defined period of time (annually) usually from third party supplies (e.g. national grid, heat supplied by district heating systems). Calculating HD energy consumption apart from building thermal and comfort requirements we take into account energy distribution, energy conversion (e.g. electricity for cooling media) and energy generation installations efficiencies as well as energy storage systems, etc. Figure 1 shows the principles of calculating the energy demand and consumption for a hospital. In this phase of the design the emission efficiency, the distribution, conversion and generation efficiency should be taken into account as well as in emission calculations.

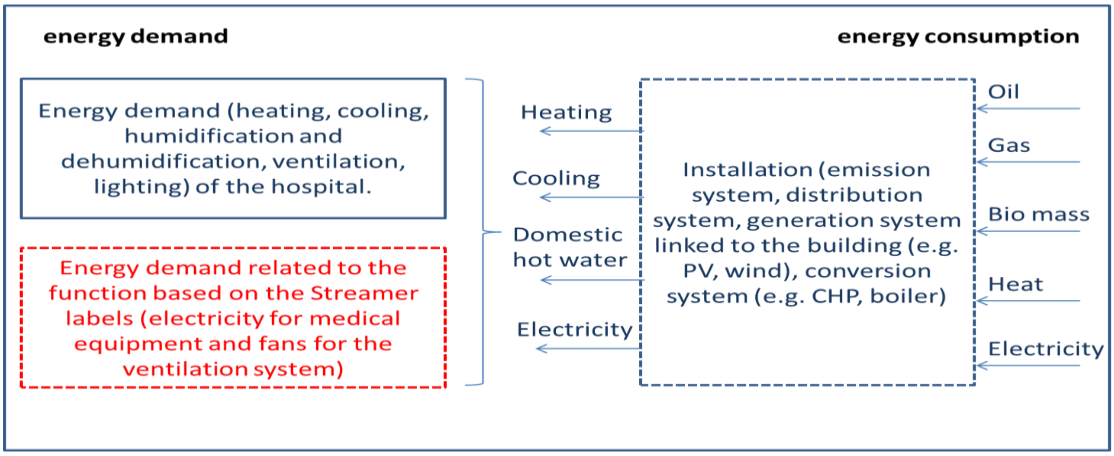



Figure 1 **Principles for calculating the energy demand (need) and consumption of a hospital.**

There are 2 basic indicators of building energy efficiency:

– building morphology index ($A_H/V$) – ratio of the total building envelope surface to building cubature;
– building time constant (see: EN 13790:2009) which characterizes the thermal inertia of the building.

The Building Morphology Index ($A_H/V$) – the ratio of total building envelope heat exchange surface (including roof and building base) to building cubature illustrates the compactness of the building which is one of the two fundamental parameters affecting the building energy effectiveness.

The building time constant depends on characteristics of outside walls (including roof and building base) and specific heat parameters of materials used in walls and windowing as well as building surface finishing and internal heat gains and heat losses (lighting, ventilation, medical equipment etc.). Building time constant is used in building heating and cooling calculations.

Taking into account the building morphology index - $A_H/V$, it is important to mention that energy demand and consumption significantly depends on HD building space units comfort requirements – compactness of the rooms – product of room surface and height. Heat losses resulting from more spatial rooms may be corrected by building envelope with higher time constant but this results in higher investment expenditures.

The same logic is applicable in case of increasing windowing surfaces in outside walls, however in this case some gains are possible from lighting savings.

While analysing HD morphology index it is important not to analyse indexes of particular buildings but also the index of the whole building and HD, because direct adiabatic connections between buildings and building segments are lowering the total district building envelope and cubature which results in lowering HD energy power demand due to heat losses diminishing, media and energy distribution lines as well as inside staff travelling it also lowers investments costs.

### 4.3.1. Geographic location of HD – climate zones

Buildings also have GIS properties such as location, orientation, position, technical and road infrastructure etc.), which may influence energy demand and consumption. Climate significantly influences energy consumption, moreover its characteristics are seasonal yearly, weekly and daily.

There are significant changes in climate influence on building energy characteristics, HD location climate data should be used in energy demand and consumption analysis.

Regional climate data should be used for the energy calculation as there might be several climate zones within one country. There are 7 climate zones defined in STREAMER.

*Table 1 Climate labels and assigned countries based on Eurostat*

| Label Outside climate | Climatic zone | Countries within climatic zone |
|---|---|---|
| Outside climate 1 | Southern Dry | Portugal, Spain |
| Outside climate 2 | Mediterranean | Cyprus, Greece, Italy |
| Outside climate 3 | South-Continental | Bulgaria, France, Slovakia |
| Outside climate 4 | Oceanic | Belgium, Ireland, Netherlands |
| Outside climate 5 | Continental | Austria, Czech Republic, Germany, Hungary, Luxembourg, Romania, Slovakia |
| Outside climate 6 | North-Continental | Denmark, Lithuania, Poland |
| Outside climate 7 | Nordic | Estonia, Finland, Latvia, Sweden, Norway |

Basing on ASHRAE "Advance Energy Design Guide for Large Hospitals" and national regulations, energy consumption of HDs in relation to climatic zones are presented [4],[5] in the table below. It has been assumed that process loads and lighting, as they do not depend on climate, are equal in every zone.

*Table 2 Evaluation of HD energy consumption for climatic zones*

| Outside climate Label | HVAC, kWh/m²/year | Process loads, kWh/m²/year | Lighting, kWh/m²/year | Total, kWh/m²/year |
|---|---|---|---|---|
| Outside climate 1 | 180 | 120 | 60 | 360 |
| Outside climate 2 | 155 | | | 335 |
| Outside climate 3 | 185 | | | 365 |
| Outside climate 4 | 155 | | | 335 |
| Outside climate 5 | 185 | | | 365 |
| Outside climate 6 | 200 | | | 380 |
| Outside climate 7 | 200 | | | 380 |

### 4.3.2. Seasonality of Energy Demand and Consumption

Energy consumption strongly varies according to yearly thermal seasonality, the highest demands for heating are observed in winters, in opposite the highest demands for cooling occur in summers, in spring and autumn energy consumption is moderate.

In Nordic countries taking into account the process of warming up climate, characteristics of energy consumption may behave differently than forecasted on the basis of earlier behaviour. Yearly energy consumption may drop down significantly due to warmer winters, where efficient heating coupled with heat recovery from outlet ventilation air may lead to significantly lower heating demand. In summer cooling demands are rather limited in comparison to energy consumptions in southern countries.

From the other hand in South countries the demand for lower efficient cooling generated from electricity is booming up, while due to development of technology to provide efficient heating in winter is relatively easy.

Nowadays developing sustainable economically efficient solutions for HD energy system require thoughtful analysis of energy demand taking into account weekly and daily operational characteristics for all type of energy demands.

It is also important to stress that development of the right concept of HD energy system at the early design stage is vital because later on it may be difficult and expensive.

### 4.3.3. Heating and Cooling Days

Considering climate influences on heating and cooling demand, energy efficiency goals are defined based on the Heating degree days (HDD) and Cooling degree days (CDD).

“The degree-days are a summation of the differences between the outdoor temperature and a specified base temperature $Tbase$ over a specified time period (generally one year).”[6]

Formulas for heating degree days and cooling degree days:

$$HDD_{Tbase} = \sum_{d=1}^{365} \left(T_{base} - \overline{T_{amb}(d)}\right) \quad for\ the\ days\ "d"\ when\ \overline{T_{amb}(d)} < T_{base}$$

$$CDD_{Tbase} = \sum_{d=1}^{365} \left(\overline{T_{amb}(d)} - T_{base}\right) \quad for\ the\ days\ "d"\ when\ \overline{T_{amb}(d)} > T_{base}$$

Where,

$HDDT_{base}$- number of heating degree days during the year,

$CDDT_{base}$- number of cooling degree days during the year,

$T_{base}$- heating/cooling base temperature, ºC (15 ºC for heating, 21 ºC for cooling)

$T_{amb}(d)$ – mean daily temperature, ºC

## 4.4 Recommendations for MEP systems

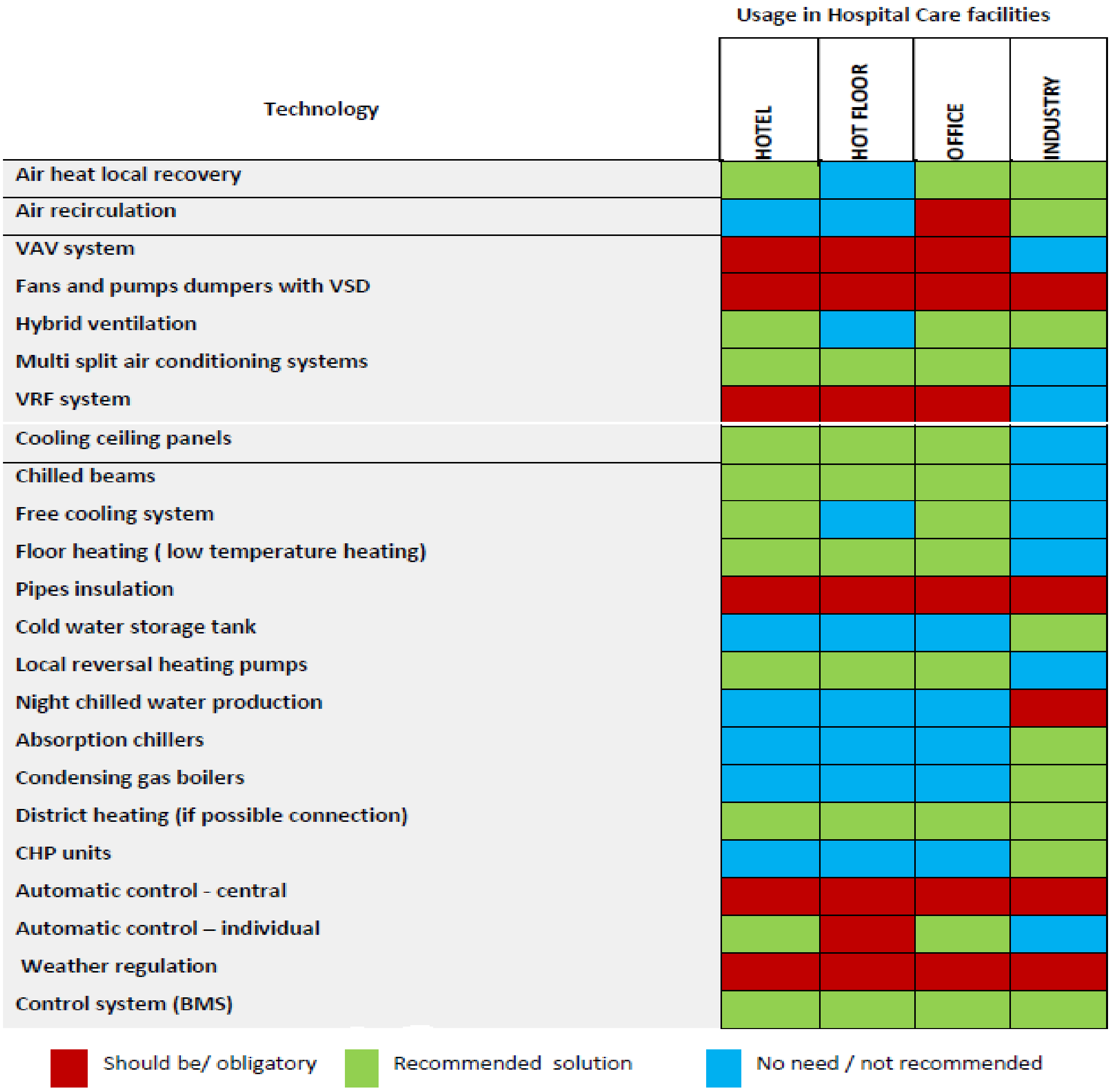
Apart from HD buildings structure (morphology), building envelope thermal characteristics and medical equipment specification, the HD energy consumption also depends on comfort requirements, functional characteristics and operational characteristics of the HC in use, as well as the type of HVAC installations applied and source of energy supply.

Energy can be supplied to HD buildings directly from the town networks, it mainly concerns electricity and cold domestic water – DCW – mainly for cooking and sanitary usage, to lesser extend heat (from district heating networks) for heating and hot domestic water - DHW, also in some cases chilled water - for cooling

[6] EU Project iNSPiRe , D2.3 RES availability survey and boundary conditions for simulations

may as well be supplied from town networks. However this is not always the case because district heating networks are not everyway available and in such cases heating and cooling should be provided out of local HD installations. Considering these solutions it is necessary to bear in mind needs for energy conditioning on site and sanitary requirements. Energy supply safety requires doubling to some extend energy sources in order to provide continuation of HD operational indispensable functionality.

This sector covers recommendations for MEP installations applied for medias and energy generation, conversion, conditioning and distribution within HD buildings e.g.: – water, fresh air and technical gases as well as energy used for: – heating, cooling, ventilation and lighting in HD buildings. Varies types of energy may be transported by means of different carriers and distribution systems.




*Obligatory solutions are these which significantly improve energy efficiency and comfort, while recommended solutions which moderately contribute to energy savings can be applied as an optional choice. "No need" - marks solutions which are considered to be an improper for use in hospital space.*

*Figure 2. HVAC system technologies application in hospital spaces*

It is recommended to recover residual energy and energy carriers and convert them into their desirable final form for further reuse or eventually for storage and later reuse when needed. Applied installation solutions depend on climate as well as functional requirements.

### 4.4.1. Heating

In cases where district heating is not available, just for heating and HDW, NG (natural gas) or LPG (liquefied petroleum gas) boilers with economizers should be applied, because they are characterized by their highest efficiency ($\eta$>0.90) and low emission and ensure the reliability and required operability of heat supply throughout the year.

For rooms thermal conditioning a system consisting of floor heating and ceiling cooling is recommended because its usage guaranties use of low level temperature regime of heat exchange and high energy effectiveness.

### 4.4.2. Cooling

It is recommended to provide ceiling cooling together with floor heating system for heating, this solution applied together with preconditioned air use for ventilation provides precise thermal control of spaces within well controlled comfort range.

### 4.4.3. Ventilation

Air circulation in the rooms is not advisable. Unless more sophisticated solutions are required, in general it is recommended to apply mechanical ventilation with preconditioned air use and heat recovery from outlet air. Such a solution is recommendable in industrial areas.

If more sophisticated systems are required, it is recommended to control fresh air supply in relation to required $CO_2$ concentration in the room. VAV (Variable Air Volume) highly efficient control system maintains settings of fans which adjust the amount of air supply to the amount of people staying in the room and allows for reduction of energy consumption associated with primary air treatment not interfering with the heat-recovery zone systems.

### 4.4.4. Heat recovery

Heat recovery significantly reduces the costs (up to 80%) of ensuring adequate temperature in the building.

Various types of heat exchangers are used to recover heat from the air:
- cross - efficiency of about 60%;
- counter-current - efficiency up to 90%;
- rotational - efficiency 80%.

Counter-current heat exchangers are recommended for the highest efficiency.

### 4.4.5. Lighting

Total energy demand for lighting depends on the amount, type and size of the spaces lighted as well as on the type of light source applied.

First of all the use of LED lights is recommended, due to their high energy efficiency and long cycle of life, it is recommended a very efficient solution to be applied wherever possible, which is the combination of low power general lighting with LED spot lights.

The below presented figures are an outcome of study on energy efficient HVAC solutions.

Below is a list of recommended lighting with lighting power supply solutions in hospitals.

| Technology | Usage in Hospital Care facilities: HOTEL | HOT FLOOR | OFFICE | INDUSTRY |
|---|---|---|---|---|
| Installing low energy consuming lighting | Recommended solution | Recommended solution | Recommended solution | Recommended solution |
| Passive Infra Red sensors in bathrooms and staircases | Recommended solution | No need / not recommended | Recommended solution | No need / not recommended |
| Energy saving technologies in elevators (LEDs, energy regeneration) | Recommended solution | Recommended solution | Recommended solution | Recommended solution |
| Emergency Power system | Should be/ obligatory | Should be/ obligatory | Should be/ obligatory | Should be/ obligatory |
| PV cells for electrical energy production | Recommended solution | No need / not recommended | Recommended solution | Recommended solution |
| DC grid | Recommended solution | Recommended solution | Recommended solution | Recommended solution |
| Smart grid | Recommended solution | Recommended solution | Recommended solution | Recommended solution |

Should be/ obligatory · Recommended solution · No need / not recommended

*Figure 3. Electrical systems technologies in correlation to hospital spaces*

For hot floors and treatment rooms is required higher lighting intensity of 1000 lux and 500 lux, respectively. This is dictated by the intended use of the premises. For corridors, storages, waiting rooms and offices, toilets, shops is only required lighting 150 and 300 lux, respectively.

## 4.5 Low emission energy supply requirements

Minimization of the energy demand and consumption should be achieved, first of all by thoughtful design of HD and later on its exploitations by the HD management. Minimization of the hospital demand for energy can be realized by:

– minimization of the total energy loss through external partitions by building compactness and right increase of thermal building inertia above 250 h of building constant;
– reasonable exposition of building interiors to day light, application of internal lighting as a combination of lower intensity, energy saving general lighting with spotlights as well as lighting control presence detectors where ever needed;
– reasonable sizing of external walls windowing and usage of right type of window glazing class;
– reasonable use of the solar radiation heat gains options and protection against not needed solar radiation;
– application of appropriate insulation of heating and domestic water piping with circulation to limit heat

and water wasting;

- effective use of ventilation with heat recovery in combination with precondition air supply control according to the needs;
- reuse of the waste heat and water from DHW system;
- reasonable local RES energy sources in hybrid systems – cogeneration, RES and heat pumps;
- energy peak shaving – elimination of seasonality in energy and media use by energy storage low prised energy deliveries and adequate seasonal RES.

The principle for the calculation of the energy consumption with local energy sources of a hospital in an early design phase is given in figure 4, hereunder.

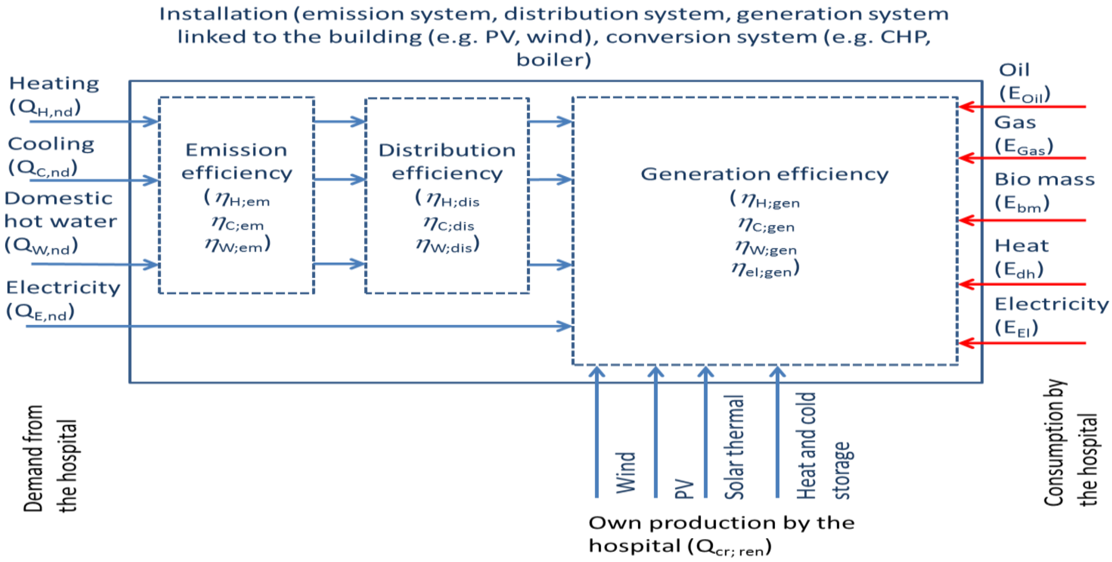



*Figure 4. Principle for calculating the energy consumption of a hospital.*

### 4.5.1. Use of renewable energy

Each EU membership country is obliged by EU directive 2010/31/EU – the so called EPBD directive – to increase share of Renewable Energy Sources (RES) in total energy consumption. This can be achieved by implementing renewable energy sources linked to HD energy distribution system see fig 2. While choosing the RES solution local climate conditions should be analysed. In table 8 a range of possible RES applications in different building technical systems are listed below.

*Table 3 Usage of renewable energy sources in different building technical systems.*

| Source | Energy | Technical system | Unit |
|---|---|---|---|
| Sun energy | Heat | Domestic hot water<br>Heating | Solar panels |
| | Electricity | Lighting,<br>External lighting,<br>Building equipment, | PV panels |

| Source | Energy | Technical system | Unit |
|---|---|---|---|
| Wind energy | Electricity | Lighting,<br>External lighting,<br>Building equipment,<br>Medical equipment, | Wind turbines mainly with vertical axle |
| Geothermal and air, waste heat | Heat | Central heating,<br>Domestic hot water,<br>Ventilation (in air preparation unit)<br>Sterilization (if high temp. unit)<br>Steam | Heat pumps,<br>CHP (geothermal water) |
| | Electricity | Lighting,<br>Sterilization,<br>Building equipment,<br>Medical equipment, | CHP (geothermal water) |
| Biogas | Heat | Heating,<br>Domestic hot water,<br>Sterilization,<br>Kitchens, | Local plant<br>CHP |
| | Electricity | Lighting,<br>Sterilization,<br>Building equipment,<br>Medical equipment, | CHP |
| Biomass | Heat | Heating,<br>Domestic hot water,<br>Sterilization,<br>Kitchens, | Local plant<br>CHP |

In HD retrofitting projects renewable energy sources should be applied after auditing and final acceptance of energy efficiency improvement solutions in order to avoid uneconomic, oversized renewable energy sources applications.

**a. Solar energy**

External parameters which influence on energy conversion performance:

– geographical location (solar radiation intensity);
– shading (shadow of surrounding buildings, trees, etc.);
– available surface for placing collectors (roof area, etc.).

**b. Wind energy (vertical axis)**

External parameters which influence on the energy conversion performance:

– geographical location (wind velocity);
– urbanistic plans and acceptance;
– national law requirements for wind power plants.

**c. Heat pumps**

There are several types of heat pumps. The choice of the appropriate technology should be supported by experts.

External parameters which have influence on the energy conversion performance:
- type of unit;
- type of low temperature source;
- type of installation ( air/water/brine);
- type of compressor (scroll, ect.).

Additionally for ground sourced units:
- soil heat capacity;
- time for soil regeneration, permafrost prevention especially while vertical loops.

**d. Biogas power plant if applicable or local sewage plant**

External parameters which have influence on energy conversion performance:
- area of the appropriate size;
- social factor.

**e. Biomass heating plant**

External parameters which have influence on energy conversion performance:
- availability of biomass extraction, preparation and storage;
- access to transport infrastructure;
- choice of combustion technology.

Seasonal renewable energy sources should be integrated with energy and media storage systems forming “energy peak shaving” and uninterrupted power supply systems.

### 4.5.2. Use of low emission highly efficient fossil fuels

To realize this strategy in HDs, highly efficient cogeneration plant is recommended, powered by. Low emission fossil fuels such as NG, LNG or LPG should be considered. Highly efficient technologies of fuel conversion to electricity should be applied. The energy demand should influence the choice of the CHP unit. Application of LNG allows for low cost cooling and improvement of efficiency in CCGT generation.

*Table 4 presents basic CHP technologies and their power efficiency.*

| CHP power generation technology | Power range (applied to CHP) | Power efficiency range (peak,%) |
|---|---|---|
| CCGT* | 5MW-600MW | 30-63 |
| Gas turbine | 2MW-500MW | 20-45 |
| Steam turbine | 500kW-100MW | 15-40 |
| Reciprocating engine | 5kW-10MW | 25-40 |
| Micro-turbine | 30kW-250kW | 25-30 |
| Fuel cell | 5kW-1MW | 30-40 |
| Sterling engine | 1kW-50kW | 10-25 |
| ORC | 100kW-22MW | 20 |

### 4.5.3. Energy storage

Since there is a seasonality in HD energy demand and consumption, the shape of consumption curve is more or less daily, weekly and yearly sinusoidal, it is necessary to order energy at max power demand to cover the max needs, which is expensive because HD is not able to use the ordered energy. So it makes sense to store energy surplus and to use it later on at energy peek demands. If such a solution is precisely managed HD is able to shave peek demands and in consequence it is possible to order lower than peak demand amount of supplied energy and to consume more or less the whole ordered energy.

Similarly it is possible to apply energy storage solutions in case of RES usage, because there are seasonal. The energy generation surplus and gaps may occur, it makes sense to store it for use at periods of lower RES generation efficiency or to cover energy peak demands or current demand.

Energy storage systems used should be of long life cycle time and high efficiency as well as allow for supporting uninterrupted power supply energy systems to be economic.

For more information see Technologies of Energy Storage in STREAMER deliverable D2.1.

The economy of the above mentioned solutions is also justified by the fact that we have to use energy storing on HD side anyhow to support uninterrupted power supply system in case of energy supply conventional system is malfunctioning.

There are short term storing systems – described above as well as long term e.g. reversible ground heat pumps which provide heat from the ground at HD heating period and by reversing their operation cycle it is possible to use them for HD cooling and storing heat in the ground to improve heat pump efficiency later on in heating season.

### 4.5.4. Hybrid energy generation and conversion systems

Hybrid energy generation and conversion system it's an advanced mix of RES and highly efficient low emission energy sources coupled with energy conversion units and energy storage systems equipped with BEM – energy management system and formed in order to minimize or even eliminate yearly, weekly and daily seasonality (peak shaving) of energy consumption from outside of HD networks. The purpose of such a system development is to:

- elimination of energy consumption seasonality;
- improve economy of energy purchasing by long term energy from outside sources;
- secure uninterrupted energy supply;
- lowering energy generation emission.

Such a system usually consists of CHP engine or turbine cogeneration units, seasonal RES and reversible heat pumps and chillers as well as energy storage systems UPS – uninterrupted power supply and BEM units.

Application of local low emission energy supply sources (recommended NG cogeneration units) in parallel with RES and for safety reason at low level powered from city grid leads to hybrid energy generation solutions which thoroughly designed and managed by BMS may lead to very efficient, financially effective and operationally save solutions – smartHD grid.

They concept should be work out at an early HD designed stage to avoid later on overinvestments.

#### 4.5.5. EeHDBuildings energy real-time management

The HD energy power demand and energy consumption differs significantly from that of any other building, due to variety of functional and operational performance characteristics of HD buildings and building spaces e.g.: - diagnostic space units (rooms) may be used for 24 hours due to emergency services provided but for most of the time their medical diagnostic equipment may be energetically in a standby status because their start up period require high power of energy supply. So over this relatively short period energy consumption may be much higher than at relatively much longer standby period. More over most of this devices nowadays realises diagnostic measurements in a very short period of time. The group of this kind of medical devices is marked with red colour on the figure above.

It is important to stress that economical and energy efficient management of HD buildings requires thoughtfully performed over a long time analyses of HD exploitation characteristics with results specific for a given medical group of HD equipment and specific HD location (patients age, illness statistics and accident characteristics).

The operational performance of HD should be on-line monitored to inform about any malfunctioning situations in HD operation as well as about HD performance. However just monitoring functions are not enough to guaranty HD efficient, safe and economic operations. Modern HD building systems should be properly managed by a technical crew and supervised by technicians equipped with and supported by BAS/BMS and security systems even more advanced than nowadays in hotels and office buildings.

The basic functions of BMS – Building Management System are listed below:

- data acquisition & monitoring of HD processes for safety and security;
- operating conditions control and regulation of the MEP HD systems;
- balancing and reporting on HD media and energy consumption;
- management of HD MEP and energy systems;
- operational and climate learning functions to build up knowledge for HD supervisory control and safety management;
- switching off parts or areas which are not in use;
- applying analysis of media and energy consumption according to ISO standards.

HD BMS should be functionally specified to manage functions foreseen in ISO 9 001, ISO 14 001, ISO 50 001 with PDCA methodology standards.

# 5. EeHDBuildings Goals, Comfort and Safety Requirements

STREAMER approach aims for reduction of HD energy demand and consumption in HDs by thoughtful HD buildings modelling and energy installations planning as well as HD operation Life Cycle modelling at the early design stage. This approach will allow to perform HD operation simulation study at the early design stage in order to select the most effective HD design solution for further detailed engineering and development. Streamer methodology secures implementation of the most effective energetically, financially and emission wise Healthcare Campuses to be exploited. The goal of the project team is to reduce HD energy consumption by ca 50% in newly build HDs and ca 35% in retrofitted till 2030 as well as to provide specific computer aided design tools to reduce significantly HD early design time and to guaranty significant improvement of HD energy efficiency by thoughtful and sophisticated operational solutions in energy generation and management. The methodology presented covers also needs for effective and economic retrofitting of already existing HDs.

This Part has been worked out on the basis of Streamer group of Deliverables mainly: – D1.1, D1.2, D1.6, D2.4, D2.5, D2.6, D2.7, D2.8, D4.1, D4.4, D4.5, D6.2, D6.3, – see also **Bibliography**, Streamer Deliverables.

## 5.1 Goals

The ambitious energy efficiency goals are to be achieved without worsening HD comfort and safety requirements. In terms of comfort requirements a reasonable minimum acceptable comfort level has to be defined and maintained.

It is also important to obey low emission requirements as well as economic efficiency in terms of economic effectiveness evaluated by LCC modelling and NPV calculations for both type of newly build and modernised HDs ventures.

Such a reduction of energy consumption would be difficult to achieve just by energy efficiency improvements so, it is assumed that a more advanced approach would be necessary including RES and BEM implementation for HD buildings energy management.

## 5.2 HD comfort requirements

Comfort requirements space wise lead to an increase of usable HD surface and in consequence to building envelope surface increase, so it is necessary to establish a reasonable and acceptable recommendations for HD functional space units surface and height requirements of HD functional spaces.

### 5.2.1. Space Requirements

Space requirements while planning new hospitals or an expansion of the existing HD buildings are important factors for energy effectiveness of HD buildings. Minimum functional and operating space size must be evaluated to fulfil comfort and safety requirements. The number hospitalised and daily clinic patients as well as medical functional specification of HC services determines the required sensible usage area of HD buildings.

**In order to achieve expected EeB parameters in HD and at the same time economical effectiveness of HD investments it is a must to standardised space, comfort and safety requirements at the minimum acceptable level for functional spaces.**

Reasonable design at an early stage of a project will allow to avoid expensive corrections at later stages of detailed design, construction as well as building maintenance.

An example for HD required area assessment per bed including annexes, technical and storage rooms are presented here according to French Red Cross [2]:

- area: from 70 $m^2$ to 100 $m^2$,;
- volume: from 200 $m^3$ to 280 $m^3$;
- an advised area sharing in a common hospital:

| | | |
|---|---|---|
| **Goods supply/wastes discharge** | $m^2$/bed | 30-50 |
| **Patient care** | $m^2$/bed | 19-25 |
| **Intensive care** | $m^2$/bed | 30-40 |
| **Operating theatre** | $m^2$/theatre | 30-160 |
| **Re-education** | $m^2$/unit | 19-22 |
| **Radiology** | $m^2$/bed | 60-70 |
| **travelling space** | $m^2$/bed | 25-30 |
| **Reception** | $m^2$/unit | 140-160 |
| **Maternity unit** | $m^2$/unit | 85-100 |
| **Specialized services** | $m^2$/unit | 55-75 |

Except thermal comfort given in EN 15251 there were no EU general requirements for space found.

The above example is complex, however one may claim that in case of patient care there are popular cases with 18 $m^2$/bed and this value should be considered as recommended.

### 5.2.2. Comfort classes

Comfort classes and their requirements are given according to the EN 15251 norm. Specific units assigned to the comfort class are given in table 10. Specific requirements for each comfort class are given in the above mentioned norm. There are four comfort classes defined according to required:

- thermal comfort;
- operative temperature;
- lighting and lighting control;
- humidity;
- noise.

Com**fort Class I** – High level of expectation, is recommended for spaces occupied by disabled persons, children or elderly;

**Comfort Class II –** Normal level of expectation, should be used for new buildings and renovations;

**Comfort Class III** – An acceptable, moderate level of expectation, may be used for existing buildings;

**Comfort Class IV** – Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year.

*Table 5 FMA assignment to Comfort class*

| Comfort class | Functional macro area |
|---|---|
| **I** | Accident and Emergency*, Diagnostic treatment*, Operating block*, Wards, IT server centre* |
| **II** | General facilities, Ward |
| **III** | Public facilities, General facilities |
| **IV** | Public facilities |
| ***This FMAs have space units which require some special conditions for indoor environment, regarding air purity and pressure as well as daylighting and HVAC system.** | |

#### 5.2.3. STREAMER Comfort Classes

STREAMER recommends 8 comfort classes in relation to:

- ventilation system;
- relation to building envelope;
- supply air quality air tightness;
- air flow (during the "in use" period: minimum / during the "not in use" period: minimum);
- temperature range (during the "in use" period: from - up to / during the "not in use" period: from - up to);
- lighting (during the "in use" period: minimum / during the "not in use" period: minimum);
- relative humidity (during the "in use" period: from - up to / during the "not in use" period: from - up to);
- indoor noise <dB (A), caused by noise from outdoors, adjacent rooms and installations <dB(a). (during the "in use" period: maximum / during the "not in use" period: maximum);
- lighting control.

### 5.3 Safety requirements

Operational safety of HD is of profound importance, general media and energy should be supplied uninterruptedly to provide HD services in safe for patients and staff way. There is a need for back-up installations and supply lines to support the most important HD activities for a period of time to necessary for repair of broken down installations and supply lines.

More over HDs should be equipped with SCADA and BMS systems to be informed in advance about upcoming problems to undertake appropriate actions.

#### 5.3.1. Waste treatment

There are several groups of waste in HDs so wastes disposal is a complicated process, influenced by legislation and rules. Main groups of waste are:

- Infectious waste;
- Sharps waste;
- Pharmaceutical waste;
- Radioactive waste: not in every hospital;
- Pathological and anatomical waste: Human tissues, blood, etc.;
- Biodegradable wastes: Kitchen and food scraps, etc.;
- Recyclable waste: Paper, plastic, metal and glass are the most widely recycled materials.

Waste treatment regulation may differ in each country. However biodegradable and recyclable waste should be segregated and recycled as they have low hazardous potential.

It is recommended to implement ISO 14001 for hospital waste management. [5]

### 5.3.2. Contamination risk zones (infectious isolation ward)

It is recommended to specify 4 zones of space units categories due to contamination risk according to NF S 90-351:2003 is presented in table below.

*Table 6 Contamination risk zones*

<table>
<tr><th colspan="4"></th><th>Air flow</th><th>Air changes per hour</th></tr>
<tr><td>Zone 1</td><td>Minimal level of risk</td><td colspan="2">Halls, offices, administration rooms, technical rooms, nursing home</td><td>Turbulent</td><td>According to room destination</td></tr>
<tr><td>Zone 2</td><td>Average level of risk</td><td colspan="2">Corridors, elevators, staircase, waiting rooms, examination rooms for outpatients, exercise rooms, wards for pregnant women, long term patients rooms, psychiatric care, laundries, toilets, pharmacy, central sterilization room (washing zone)</td><td>Turbulent</td><td>n=15-20</td></tr>
<tr><td>Zone 3</td><td>High level of risk</td><td>Intensive care, operation theatre for minor surgery, after surgery room, delivery room, neonatology, surgery, dialysis, radiology, central sterilization room (clear zone), autopsy room</td><td rowspan="2">Haematology, haematooncology, haemodynamic, oncology treatment supported by electronic imaging</td><td rowspan="2">Laminar</td><td>n=25-30</td></tr>
<tr><td>Zone 4</td><td>Very high level of risk</td><td>Neonatology, operation theatre, emergency ward, wards for burned people</td><td>n>50 air[7]</td></tr>
</table>

### 5.3.3. Energy supply safety

Operational safety requirements call for:

- local back-up stations of energy generation and water supply;
- uninterrupted media supply should be supported by energy storage (batteries) and water tanks;
- safety requirements apply not only for supply but also for energy, water and air distribution in form of double, circular supply systems.

[7] Source: Lecture materials, Anna Charkowska, Warsaw University of Technology

# 6. EeHDBuildings Semantic Modelling

Semantic Labelling approach to HD early design methodology developed within STREAMER Project is an extension of Breitfuss and Bouwcollege concepts implemented on 3D BIM designing approach. This part is based on D1.1, D1.2., D1.4, D1.6, D2.5, D2.6 – see also **Bibliography**, Streamer Deliverables

## 6.1. HD New Development

Out of the earlier made data presentations and considerations it looks that in case of HD new development energy efficiency savings target set at 50% of energy consumption reduction is feasible, however it requires thorough full analysis of HDs at an early design stage and HD exploitation conditions control and management.

### 6.1.1. HDBuildings Taxonomy

In principal, in newly built HDs it is feasible to achieve expected energy efficiency improvements, however it is necessary to apply solutions financially justified and adequate to the climate of HD location.

In general, in retrofitting process it may be difficult to achieve the expected energy efficiency improvements as for newly built HDs, so in such a case it is recommended to do what is financially feasible.

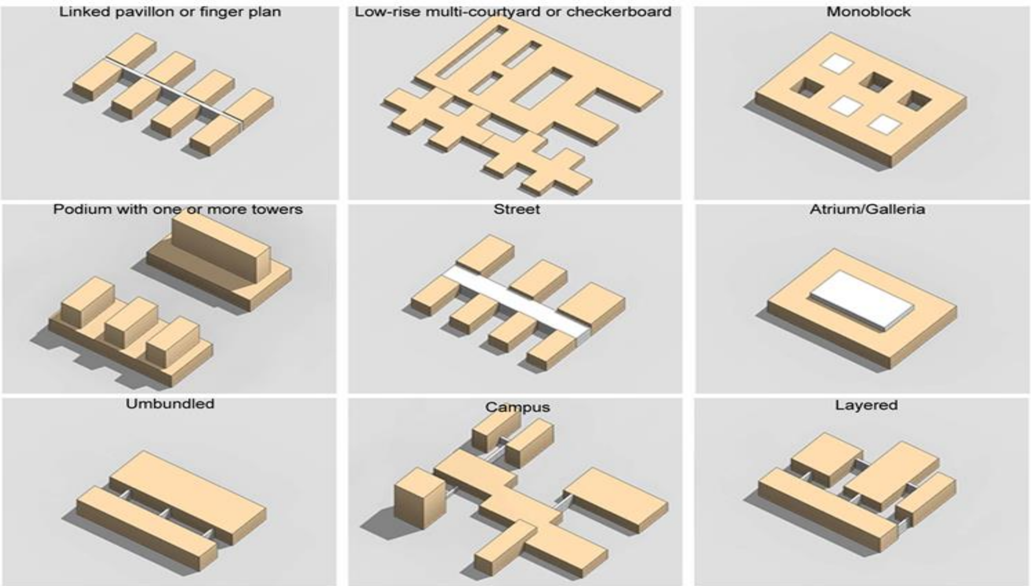



*Figure 5 HD Examples of HD buildings configuration typologies*

While selecting a HD typology it is recommended to consider:

– Climate/location
– compactness
– footprint;
– energy distribution piping;
– vertical transport energy consumption;
– roof space for RES or other locations;
– usage of natural daylight;
– outside view opportunity.

### 6.1.2. HD functional characteristic

A HD building is a construction that include several functional areas. Relationship and interdependency between functional areas in functional aggregative configurations of areas have a decisive impact on characteristics of the buildings.

A Functional area - FA - is a group of space units generally related to homogeneity of interdependencies between functions and spaces. Functional areas are classified considering their functional and technical properties, characteristics as well as their energy-related features.

Each functional area is described mainly according to functional aggregative aspects, more than the technical aspects. The technical aspects of FA mainly depend on performance characteristics of special units in a given functional area.

The main homogeneous functional areas that are defined in STREAMER model of HD are here listed in table 3. They have been clustered into the functional macro-areas. For description and relation between FMAs and FAs see table below.

*Table 7 Some examples of Functional Areas and Macro Areas.*

| Category (Functional Macro Area) | Functional Area |
|---|---|
| ACCIDENT AND EMERGENCY | *Accident and Emergency (A&E)* |
| DIAGNOSTIC TREATMENT | *Blood sampling/testing* |
| | *Diagnostic imaging* |
| | *Endoscopy* |
| | *Nuclear medicine* |
| | *Outpatient department* |
| | *Pre-hospitalization* |
| | *Radiotherapy* |
| | *Rehabilitation* |
| | *Transfusion centre (blood bank)* |
| GENERAL FACILITIES | *Admission (reception, information, reservation)* |
| | *Anatomical pathology laboratory* |
| | *Canteen* |
| | *Cleaning facilities* |
| | *Dressing rooms for staff* |
| | *Garbage room and special materials disposal* |
| | *General storages* |
| | *Health physics* |
| | *Internal pharmacy* |
| | *Kitchen* |
| | *Medical archive with IT servers* |
| | *Medical testing laboratory* |
| | *Mortuary* |

| Category (Functional Macro Area) | Functional Area |
|---|---|
| | *Sterilization centre* |
| | *HD management centre* |
| OPERATING BLOCK | *Interventional radiology* |
| | *Operating theatre* |
| PUBLIC FACILITIES | *Central hall* |
| | *Public cafeteria / restaurant (excl. kitchen)* |
| | *Shops* |
| WARDS | *Day surgery* |
| | *High care wards* |
| | *Intensive care ward* |
| | *Low care wards* |
| | *Maternity ward* |
| | *Medical day hospital* |
| | *Oncological day hospital* |

Functional areas consist of space units. Within functional areas there are groups/categories of space units which work for 24-, 16- or 10- hours per day with some exceptions at weekends – they form functional subareas, because from operational point of view they form different groups and may require different supplies, services, control and management, as well as operational procedures and management strategies.

### 6.1.3. Space units

A space unit is a single space or room and is the lowest spatial entity that can be identified by specific functions and properties (operating rooms, patient rooms, nurse offices, etc.). Space units are classified considering both their functional and technical properties including operational and energy-related characteristics.

*Table 8 Some examples of Space Units*

| Space Units | | |
|---|---|---|
| *Air lock* | *Holding* | *Recovery room* |
| *Ambulance hall* | *Isolation room* | *Recycling room* |
| *Analysis room* | *Kitchen* | *Refrigerating room* |
| *Ante-room* | *Kitchen cleaning room* | *Relatives room* |
| *Archives* | *Kitchenette* | *Resting room Patient* |
| *Baby-changing room* | *Laboratory* | *Operation theatre, Hybrid* |
| *Basement* | *Laundry room* | *Toilet for disabled people* |
| *Breast feeding room* | *Library* | *Trauma room* |
| *Canteen* | *Medication room* | *Treatment room* |
| *Central hall* | *Non-sterile washing room* | *Treatment room/Emergency room ER* |
| *Changing room (personnel)* | *Nursing station* | *Unpacking room* |
| *Conference room* | *Observation room* | *Utility room* |
| *Conservation room* | *Office* | *Waiting room* |
| *Consultation + examination room* | *On-call staff room* | *Waste room* |

| Space Units | | |
|---|---|---|
| *Corridor* | *Operation theatre* | *Weighing room* |
| *Darkroom* | *Operation theatre, Hybrid* | *Patient room* |
| *Day room* | *Patient room* | *Resting room Personnel* |
| *Delivery room* | *Patient room (birth suite)* | *Resuscitation room (not only for children)* |
| *Disinfection room* | *Patient room (day hospital)* | *Room for "minor" surgery (biopsy for example)* |
| *Dialysis* | *Patient room (Intensive care)* | *Room with coffee/vending machines* |
| *Examination room CT* | *Personnel room* | *Sanitation room* |
| *Examination room ECG* | *Pharmacy* | *Shop* |
| *Examination room Endoscopy* | *Photocopier/IT room* | *Shower* |
| *Examination room MR* | *Plaster cast room* | *Shower for disabled people* |
| *Examination room Triage* | *Prayer room* | *Sterile store, Infection control* |
| *Examination room Ultrasound* | *Preparation room* | *Store room* |
| *Examination room X-ray* | *Preparation room for staff* | *Swimming pool* |
| *Exercise rooms (revalidation)* | *Radiotherapy* | *Technical room* |
| *Group room* | *Reception* | *Toilet* |
| *IT Server centre* | *Uninterrupted power supply centre* | *HD management room* |

Space units of the same functional type may form functional areas, which in turn may form with other functional areas functional 5 macro areas:

– Hotel – patients rooms plus space units to assure required services to patients, e.g. on duty space units;
– Office – group of open space office areas plus single rooms for high rank staff and meeting rooms including outpatient clinics usually working up to 10 hours per day excluding weekends and holydays;
– Hot floor – a block of functional units with high level requirements;
– Industry – diagnostic and technical infrastructure spaces;
– Public areas – areas open to public providing some necessary services working up to 16 hours;

supported by:

– Travelling areas as well as building junction areas – horizontal: - corridors and routs crossing spaces, and vertically interconnected: - staircases and lifts (used randomly after working hours, use of lifts is blocked at emergency evacuation situations) - special attention should be given to:
  - the system of emergency evacuation routs: - corridors, crossing spaces and staircases – they should provide 2-way routs of escape;
  - shafts and ducts for media distribution accessed randomly in case of breakdowns.

HDs should be equipped with dedicated in/out entries:

– public entry;
– accidents and emergency for patients delivered by ambulances;
– goods delivery;
– waists removal;
– emergency evacuation.

Macro functional areas may form blocks of functional layers (e.g. storeys). Layers can form HD departments or wards.

The presented above developed design approach allows to perform optimisation of HD layouts from functional and operational (spatial) point of view by performing relation analysis in between functional spaces location.

### 6.1.4. Layering approach and Functional approach

The combination of the layering approach and the functional approach is recommended. It allows for defining a more universal system within which the typology could be approached from the more appropriate perspective for the specific hospital organization.

The layering approach has been developed as a result of STREAMER approach to hospital arrangements. This approach divides the function package of a hospital according to building typology into four layers:

– hot floor, i.e. the capital intensive high-tech functions that are unique to the hospital;
– hotel, which includes the larger part of the patient accommodations;
– office, with the outpatient units, accounting, management and training functions;
– industry, which accommodates the laboratories, CSSD, pharmacy, catering, laundry, plant rooms, IT space and the production kitchen.

The layers approach should be used to develop accommodation models that provide optimum support to the hospital's performance of its functions and to its operations.

The relationship among functional areas should be analysed with the use of two diagrams/matrixes shown below. The first one defining the functional relationship (Fig. 1) and the second one the spatial relationship (Fig. 2). The spatial relationship matrix takes into account the flow of patients, staff and goods and proximity of spaces as the main factor for the analysis. While the functional relationship matrix analyses the virtual connection between different functions location.

The relationship in between spaces are marked up at 4 levels: required high relationships, required medium relationships, required basic relationships, required low relationships. The set of these relationship information should be taken into account while building up structural organisation of HD.


*Figure 6. Functional relationship between functional areas*

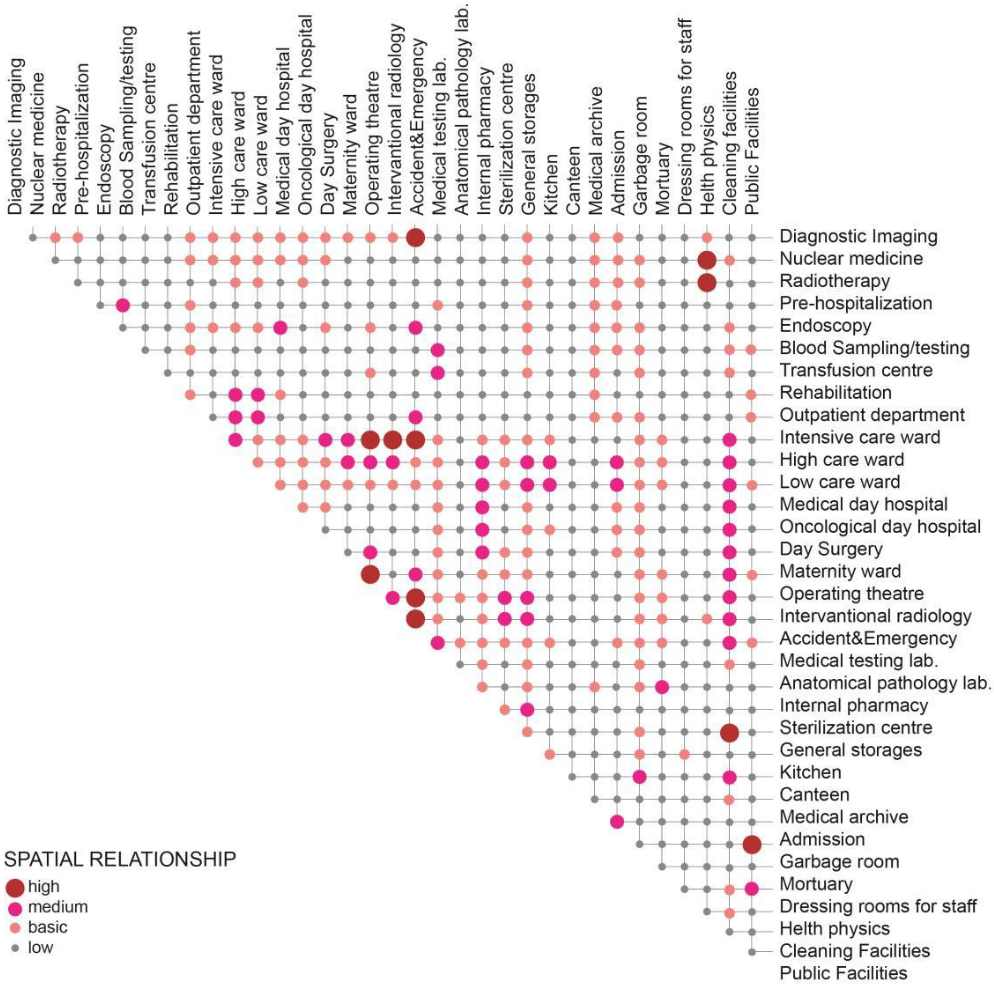



*Figure 7. Spatial relationship between functional areas*

Five main different levels of the existing BIM typologies should be distinguished in building up a Healthcare District structure. These levels identified are: Component (level 1), space-unit (level 2), Functional area (level 3), Building (level 4), District (level 5).

Space units compatible with the two approaches should be implemented crossing different criteria of classification with the levels of Healthcare Districts (e.g. layers, energy related-features, etc.) defined in the breakdown of Healthcare Districts. This would allow iterative optimization of EeB-technologies on different levels.

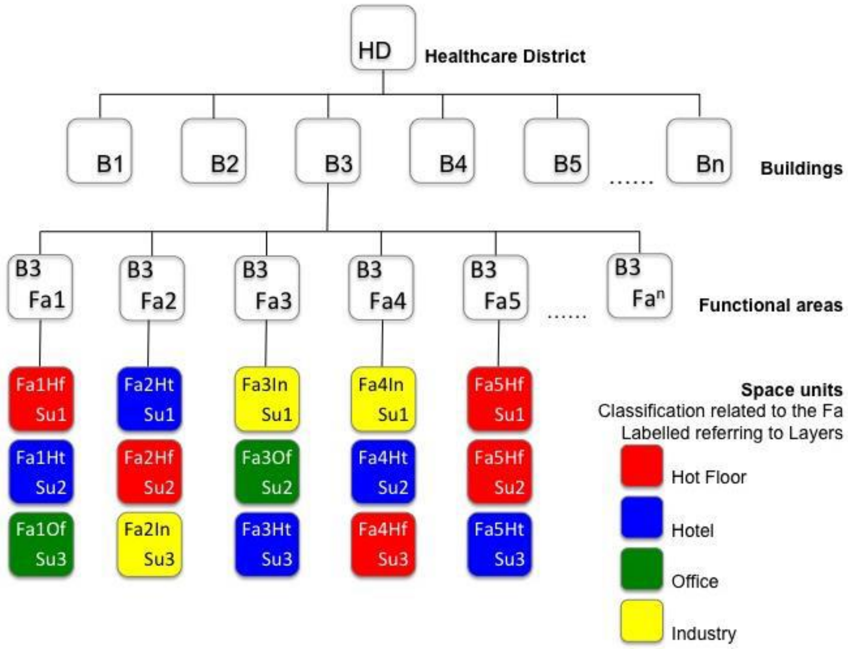



*Figure 8. Crossing of Layers approach categories with functional breakdown of the HD system*

The breakdown system has been shaped in a flexible way to be adaptable to different arrangements of existing HD and buildings and to be integrated into operating database and management tools.

### 6.2. Semantic EeHDBuildings Modelling – Labelling System

Propositions of requirements were made basing on overview of BIM design principles, standards and new STREAMER design approach. The last one has developed additional fifth layer in labels system (described in table 1) except Bouwcollege layers - travelling areas. It describes corridors, lifts, stairways and evacuation / exits associated with the movement of staff and patients. The fifth layer is important in terms of wasting time on the move.

The semantic labelling method in conjunction with the 3D BIM in assistance with GIS system data for design and construction of EeHDBuildings. It introduces a set of codes and design references that allows to identify the space through the relations between spatial, functional and energy related features. The labels enable to attach properties and characteristics to the different spaces which allows optimizations for energy performance, activity levels or access levels.

The labelling method as a first element of recommended design solution allows to:

- formulation of design principles;
- logical grouping of rooms in a building;
- collision / problems detection;
- definition of energy profiles;
- formulation of safety requirements, flexibility, logistics, comfort of people;
- limiting the number of variations of MEP solutions;
- calculation of several KPI.

The labelling methodology allows for the construction or refurbishment of a hospital, combining both the building energy characteristics with the practical rooms arrangement. In a wider and more practical view, the labelling system entails the identification of the parameters and information that will implement the BIM model.

In the construction industry, BIM technology is well known on the market and it has initiated STREAMER. BIM is a tool to design simulation integrating the time plan, cost estimate and energy efficiency with the 3D building model, creating a modern form of visualization of the construction process (semantic BIM model database). A BIM model consists of several elements (eg. walls, windows, doors). Elements of the model are displayed simultaneously with the progress of construction activities over time.

The third element – GIS IT system allows for the consideration of the impact of the environment on the building (eg. the size and age of adjacent buildings or the surrounding infrastructure and noise). GIS provides data related to soil composition (load-bearing properties, groundwater data, etc.); energy (energy profiles on building- and neighbourhood scale); buildings (information about other buildings, such as size, function, age, etc.) and traffic (public transport, road capacities, noise pollution, etc.).

### 6.2.1. Labeling system

Considering the complexity of healthcare districts requirements, the labelling system is applicable to each of the three main scale levels that build up healthcare districts: buildings, functional areas and space units. The labelling system should provide each level with parameters and factors informing the BIM model on spatial, functional and energy related features.

The labels formulate a basic mechanism for controlling space-related elements in the BIM, such as rooms and functional areas. They finally must respond to the following requirements:

- objective measurability;
- relation with physical aspects of the space;
- relation with the use/function of the space;
- relation with energy.

The Table 9. below presents a complete list of the labels and the clusters to which they belong and the levels that make up the label.

| LABELS CLUSTER | **LABEL** | **LABELS'S DEFINITION** | **LABELS DESCRIPTION** |
|---|---|---|---|
| Layering labels | Bouwcollege layers | This label has a relation with the type of functions and the requirements related | **HF** Hot floor layer: capital intensive high-tech functions that are unique to the hospital |
| | | | **H** Hotel layer: Patient accommodations |
| | | | **O** Office layer: Outpatient units, accounting, management and training functions |

| LABELS CLUSTER | LABEL | LABELS'S DEFINITION | LABELS DESCRIPTION |
|---|---|---|---|
| | | | **I** Industry layer: laboratories, kitchen, etc. |
| | Additional STREAMER layers | | **Travelling areas:**<br>corridors;<br>lifts;<br>staircases;<br>evacuation / exits;<br>communication node (corridors cross) |
| Operational/ Usage labels | Hygienic class | This label has a relation with amount of ventilation, air tightness, cleaning, materials, windows necessary to meet the hygienic conditions requirements | **H1** hygienic requirements related to reception, office etc. activities |
| | | | **H2** hygienic requirements related to bathroom, toilet etc. activities |
| | | | **H3** hygienic requirements related to patient room, examination room, treatment room etc. activities |
| | | | **H4** hygienic requirements related to operating room, insulation room etc. activities |
| | | | **H5** hygienic requirements related to laboratory, production pharmacy etc. activities |
| | Accessibility | This label has a relation with the position inside the hospital, safety/protective/security device | **A1** public |
| | | | **A2** accessible to patients, staff and visitors |
| | | | **A3** accessible to patients and staff |
| | | | **A4** accessible to staff (access is protected by a lock (e.g keycard)) |
| | | | **A5** accessible only to specific staff members |
| | Usage profile | This label has a relation with the usage time of spaces and the operating hours | **U1** Monday to Friday 08:00 - 18:00 (office timeslot) |
| | | | **U2** Monday to Friday 08:00 - 20:00 (extended office timeslot) |
| | | | **U3** Monday to Friday 08:00 - 18:00 with emergency function outside timeslot |
| | | | **U4** 24*7 (continuous operation e.g. ward, ICU, emergency) |
| | | | **U5** Monday to Sunday 08:00 - 18:00 (office timeslot including Saturday and Sunday) |
| Equipment labels | Equipment | This label has a relation with the type of function, high electric power needed | **EQ1** no additional electric power is needed (to feed medical equipment) |
| | | | **EQ2** office |
| | | | **EQ3** office + emergency power supply |
| | | | **EQ4** electric power higher (1.6 times) than an office + emergency power supply and additional safety measures |

| LABELS CLUSTER | LABEL | LABELS'S DEFINITION | LABELS DESCRIPTION |
|---|---|---|---|
| | | | **EQ5** high electric power demand (1.5 kW/m$^2$) + emergency power supply |
| | | | **EQ6** special equipment and requirements regarding safety |
| Technical/ Structural labels | Construction | This label has a relation with floor strength, shielding against radiation, floor height, air tightness | **C1** office |
| | | | **C2** office + extra floor strength |
| | | | **C3** office + extra floor height |
| | | | **C4** office + extra floor strength and height |
| | | | **C5** accessible from the outside with heavy load |
| | | | **C6** shielding against radiation (radiotherapy, 10 MeV) |
| Environmental labels | Comfort class | This label has a relation with daylight, amount of ventilation, temperature, lighting, relative humidity and indoor noise | **CT1** archive room |
| | | | **CT2** corridor |
| | | | **CT3** office |
| | | | **CT4** patient room |
| | | | **CT5** |
| | | | **CT6** laboratory |
| | | | **CT7** operating room |
| | | | **CT8** special |

*Table 9.. List of the STREAMER labels*

The cluster "Layering labels" defines the performance requirements for each type of building accommodation. This label provides the information to assess the validity of the design solutions adopted (e.g. adjacency between different type of accommodation, preliminary energy analysis, etc.). Each layer consists different characteristics providing to the definition of the supposed energy demand.

The cluster "Operational/usage labels" includes all those labels which deal with the operational efficiency of spaces and functions. They act as a set of rules to be respected in order to guarantee the healthiness and safety of patients and staff, as well as to optimize the hospital efficiency in terms of space and energy use of.

The cluster "Equipment labels" defines the level of equipment necessary within a space in order to allow a proper development of the activity related to the space type. This label has implications on the energy use of the whole hospital, as, for instance, it defines for which spaces extra power is needed. Extra power applies to specialized medical diagnostic devices and to the operation of installations or technical facilities providing thermal and hygienic conditions meeting the requirements of hospitals.

The cluster "Technical/structural labels" provides information for designing hospital spaces according to the constructive characteristic.

The cluster "Environmental labels" contains all the comfort requirements of a space or a function, which consequently define the preconditions for HVAC solutions, which will directly affect the building energy use. STREAMER recommends eight comfort classes with default values shown in Table 10.

| Name | Description | Default values for: | Ventilation system | Relation to building envelope | Supply air quality | Air tightness | Air flow (during the "in use" period: minimum / during the "not in use"period: minimum) | Temp. range (during the "in use" period: from - up to / during the "not in use"period: fom - up to) | Lighting (during the "in use" period: minimum / during the "not in use"period: minimum) | Relative humidity (during the "in use" period: from - up to / during the "not in use"period: fom - up to) | Indoor noise <dB (A), coused by noise from outdoors, adjacent rooms and installations <dB(a). (during the "in use" period: maximum / during the "not in use"period: maximum) | Control of Lighting |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT1 | (e.g. archive room) | | | direct daylight and view outside not required | | | Not required | > 16 / > 16 °C | Not required | | Not required | No requirements |
| CT2 | (e.g. corridor) | | | direct daylight and view outside preferred | | | Not required | > 18 / > 18 °C | 150 Lux* | | Not required | No requirements |
| CT3 | (e.g. office) | Office | | direct daylight and view outside obligatory | | | 1.4 / 0.8 dm³/s/m² | 20 - 26 / 18 - 28 °C | 500 Lux* | 25 - 60 % / N/A | 40 / N/A dB(A) | Screens and adaptive control |
| CT4 | (e.g. patient room) | Hotel | | direct daylight and view outside obligatory | | | 2 / 1.4 dm³/s/m² | 21 - 25.5 / 20 - 26 °C | 500 Lux* | 30 - 50 / 25 - 60 % | 25 / 25 dB(A) | Screens and adaptive control |
| CT5 | | | | (in)direct daylight and view outside | | | 1.4 / 0.8 dm³/s/m² | 20 - 26 / 18 - 28 °C | 500 Lux | 25 – 60 % / N/A | 40 / N/A dB(A) | Adaptive control |

| Name | Description | Default values for: | Ventilation system | Relation to building envelope | Supply air quality | Air tightness | Air flow (during the "in use" period: minimum / during the "not in use"period: minimum) | Temp. range (during the "in use" period: from - up to / during the "not in use"period: fom - up to) | Lighting (during the "in use" period: minimum / during the "not in use"period: minimum) | Relative humidity (during the "in use" period: from - up to / during the "not in use"period: fom - up to) | Indoor noise <dB (A), coused by noise from outdoors, adjacent rooms and installations <dB(a). (during the "in use" period: maximum / during the "not in use"period: maximum) | Control of Lighting |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT6 | (e.g. laboratory) | Industry | | (in)direct daylight and view outside obligatory | | | 5 / 2.5 dm³/s/m² (vv = 6) | 20 - 26 / 18 - 28 °C | 1 000 Lux* | 20 – 70 % / N/A | 40 / N/A dB(A) | |
| CT7 | (e.g. operating room) | Hot floor | | (in)direct daylight preferred | | | 16 / 5 dm³/s/m² (vv = 20) | 18 - 24 / 18 - 24 °C | 1 000 Lux* | 30 – 50 % / 25 – 60 % | 50 / N/A dB(A) | |
| CT8 | | Special | | (in)direct daylight and view outside | | | | | | | | |

*Table 10. Default values for STREAMER Comfort Class*

* Note: Values for lighting should be separated into spot and basic lighting.

Using the labels system makes it possible to attach properties and characteristics to the different spaces, which allows optimizations to be made for energy performance, activity and access levels. For instance, concentrating spaces with the same user-profile label U1 (a limited use of the space per day) makes it possible to realize a building area with a limited energy use for a large part of the day.

Energy systems related to ventilation have a relation with four labels: Hygienic class, Usage profile, Comfort class and Equipment. Natural ventilation is compatible with a limited amount of label values, whereas mechanical ventilation is compatible with all label values. Natural ventilation is only compatible with the Outpatient department, and mechanical ventilation systems are compatible with the Outpatient and the Intensive care department. Table 3 shows relation between four labels and energy parameters.

| Label | **Hotel** | **Hot floor** | **Office** | **Industry** |
|---|---|---|---|---|
| Hygienic class | Mechanical ventilation | Mechanical ventilation | Mechanical exhaust | Mechanical ventilation, recirculation of air is not allowed |
| Usage profile | 24*7<br>Mo-Su<br>8:00 – 18:00 | 24*7<br>Mo-Su<br>8:00 – 18:00 | Mo-Fr<br>8:00 – 18:00 | Mo-Fr<br>8:00 – 18:00 |
| Comfort class | 2 / 1,4 $dm^3/s/m^2$<br>21-25,5 / 20-26 °C<br>500 lux<br>30-50 / 25-60 %<br>direct daylight | 16 / 5 $dm^3/s/m^2$<br>18-24 / 18-24 °C<br>1 000 lux<br>30-50 / 25-60 %<br>indirect daylight | 1,4 / 0,8 $dm^3/s/m^2$<br>20-26 / 18-28 °C<br>500 lux<br>25-60 %<br>direct daylight | 5 / 2,5 $dm^3/s/m^2$<br>20-26 / 18-28 °C<br>1000 lux<br>20-70 %<br>indirect daylight |
| Equipment ( electric power usage) | 0,001 $kW/m^2$ (0,08 kW for each workstation) | 0,016 $kW/m^2$ (0,128 kW for each workstation) | 0,001 $kW/m^2$ (0,08 kW for each workstation) | Not defined e.g. high electrical safety |

Table 11. Relation between labels and energy characteristics

### 6.2.2. Outside/In and Inside/Out approaches

The "Outside/In" approach (Fig. 4) – called "designer's view" – defines the typology starting from a spatial classifications based on the layers approach. It starts from the definition of the Healthcare District. Matrix of relationships, interdependencies and functional aggregative configurations are analysed starting progressively from the district level to the single spaces level. This approach allows to define a functional classification method that identifies the linkages of spaces with similar functions. A clear scheme of relationships, interdependencies and functional aggregative configurations allows to analyse and identify the non-technical "energy features" (e.g. how many incorrect locations of a space or activities may become an indirect factor of energy consumption increase).

The "Inside/Out" approach (Fig. 4) – called "engineer's view" – defines the typology starting from a spatial classifications based on the technical properties and features of the single spaces. It starts from the definition of Space Units and Functional Areas included in the Healthcare District as the starting point for the design methodology. It is based on the categorization of Functional Areas depending on the relationships, interdependencies and functional aggregative configurations of Space Units in each Functional Area. This approach allows for definition of energy performance at the early stage of analysis, entailing a classification of spaces on the basis of energy-related features.

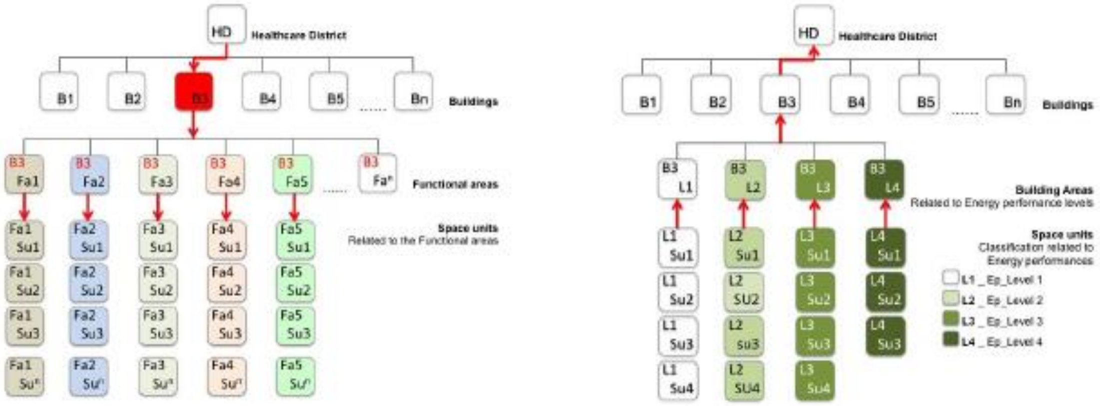



*Figure 9. Outside/in approach (left) and Inside/out approach (right)*

The analysis has been related to the EeB factors identification, comparison of different arrangements and the implementation of a methodology for classifying and labelling functional areas and spaces. The definition of energy-related features at Space units level allows a better control of the energy efficiency indicators at the highest level (Building and District level).

Considering the complexity of healthcare districts requirements, the labelling system is applicable to each of the three main scale levels that build up healthcare districts: buildings, functional areas and space units. The labelling system should provide each level with parameters and factors informing the BIM model on spatial, functional and energy related features.

### 6.3. HD Retrofitting

In general, in retrofitting process it may be difficult to achieve the expected energy efficiency improvements as for newly built HDs, so in such a case it is recommended to do what is economically justified and leads to energy consumption reduction. Semantic labelling use may as well be justified and helpful, however due to buildings layout and construction reasons, it is necessary to accept an increase of space units variety in terms of their definitions as well as sizes.

First of all in case of retrofitting it is necessary to start from energy auditing of HD buildings. Methodology for energy demand and consumption modelling and related to that calculations should be based on the EN ISO 52016 standard as well as NEN 2916:2014.

There are several types of retrofitting, here below the 4 basic are presented:

a. thermo-modernisation + lighting;
b. thermo-modernisation + modernisation of HVAC installations + lighting;
c. thermo-modernisation + modernisation of HVAC installations + lighting + internal layout rearrangement;
d. HD building or the HD complex extension.

It is recommended to realise retrofitting with implementing BMS with BEM because its application may produce 10% to 15% saving and increased safety and comfort of HD exploitation.

The case D may be treated as development of new HDs while a. and b. case are pure retrofitting cases.

The case c. is a complex modernisation of a part or a whole HD building and it is necessary to stress that the range of it depends very much on building construction solutions originally applied. So it is recommended in such a case to consider an analysis of economy of such a modernisation undertaking against new building development if such due to location constrains is possible.

In general, in retrofitting process it may be difficult to achieve the expected energy efficiency improvements as for newly built HDs, so it is recommended at the early stage of design to analyse in parallel to retrofitting programs an investment program (to build a new building) as a one of possible variants of the solutions and finally to do what is economically feasible and leads to energy consumption reduction.

# 7. Life Cycle Costs Analysis

Life cycle cost analysis allows to economically verify reasonability of undertaken HD new development or retrofitting.

This Part has been worked out on the basis of Streamer group of Deliverables mainly: – D3.6, D4.3, D5.3, D5.5, D5.6, D2.6, – see also **Bibliography**.

## 7.1. Scope

This document gives guidelines for the performing economic profitability analysis of investments or upgrades in HD - using the LCC method.

## 7.2. Life Cycle Costs (LCC) Methodology

Each healthcare project has budgetary constraints which calls for lowering investment expenditures with little consideration to the current life cycle cost of the facility exploitation. A financial consideration must be a key component to enable decision making on a cost/benefit basis. A preferred and recommended approach should be a life cycle cost method where the capital cost of the works is coupled with the operating costs of the project, in particular energy and maintenance costs.

### 7.2.1. LCC Definition

Life Cycle Costs are all costs occurring in the life cycle of the building, costs of construction, operation (related to the building), maintenance and disposal. This method may be used for refurbishment and new built scenarios.

Thus, the following (costs) aspects are covered by the life cycle cost method:

- Investment costs (capital costs);
- MOM expenses (Management, Operation and Maintenance), also referred to as building-related running costs. These costs include, among others: maintenance, energy and cleaning. These expenses have a large impact because every square meter built has to be also maintained during the entire life cycle. Moreover, a relatively old building generally has higher MOM expenses than a newly-completed building;
- Development cost. It covers the cost of adaptations during the life span as a result of new regulations and social and medical-technological developments. These costs also vary per function;
- Life cycle. The life cycle is a variable that can be set, as hospitals can no longer be seen as a constant value of 40 years. Life cycles can be selected for specific parts of the building or building elements in case of a refurbishment according to life cycle assessment. The different building layers have been recommended the following life cycles:
    - Hot floor – 20 years
    - Office – 50 years
    - Hotel – 50 years
    - Industry – 25 years

  The ability to differentiate life cycles for functional parts of the building allows for calculating different scenarios for decision making.
- Adaptability, a building must fulfil its functional requirements. Post-completion adaptations always cost more than those made during design or at construction. By varying levels of adaptability at the onset of the design process, the LCC model enables different alternatives (in terms of flexibility/adaptability) to be calculated and compared according to these aspects.

LCC analysis indicates the importance of maintenance costs, which often exceeds the cost of construction.

The below listed cost items are excluded from LCC analysis:

- Demolition and major renovation costs;
- Financing costs (how investments are financed; e.g. interests on loan);
- Revenue (economic benefits) generated by the building;
- Residual value (assuming that at the end of the lifetime, the asset has no commercial value).

In order to consider a LCC analysis the following information is required:

**Discount rate:** A consistent rate for all options and differenses between the public and private sector.

**Selecting the study period**: This period must be the same for each option considered. This is a key time period after which the facility may be changed.

**Building the data:** To understand the timing and the cost implications of investment.

**Net Present Value models:** A mathematical model is constructed for the cost elements in each option with the latter reflecting changing costs over the agreed study period.

**Conclusion to the LCC analysis:** The lowest cost represents the most economically advantageous figure and is the best value option from a LCC perspective.

Financial evaluation is essential when comparing investment options for a new facility and a refurbished facility. The broad requirements to develop this analysis are illustrated in Figure 1.

| | |
|---|---|
| **STEP 1** | Define the problem |
| **STEP 2** | Develop the models |
| **STEP 3** | Perform calculations |
| **STEP 4** | Sensitivity analysis |
| **STEP 5** | Interpret the results |

*Table 12. The stages to Life Cycle Cost analysis*

Life Cycle Costing is a major assessment criteria for project decision making. Figure 2 shows a typical assessment required for project decision making.

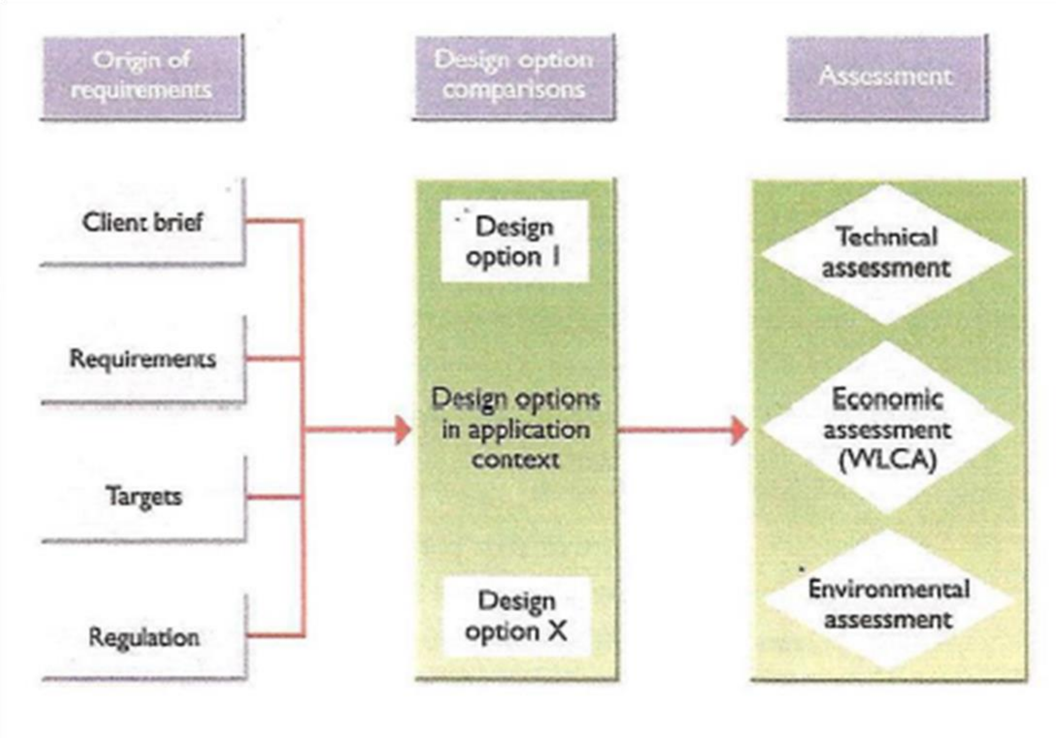



*Figure 10. Investment project decision making process diagram [1]*

Using a life cycle costing method as the financial basis in case of investments is a required way of considering the long term financial implications of important project decisions. It is a desirable approach to take.

### 7.2.2. Calculation Methodology

The financial analysis based on the life cycle cost of the investment uses the concept of discounted cash flows or simple time of return depending on the complexity, scale and schedule of project analysis. The first method is recommended for investments in hospitals.

The net present value (NPV) is the net sum of the discounted future cash flows (the sum of the discounted earnings/benefits less the sum of the discounted costs). The NPV can also be calculated by subtracting the initial investment cost from the discounted net cash flow.

Since the discounted building related earnings/benefits of a hospital are difficult to estimate, the NPV method in the LCC calculation is only based on the building related costs.
To calculate costs is used following general formula:

$$LCC = I_o - \frac{R}{(1+r)^n} + \sum_{y=1}^{y=n} \frac{U_{t,y}}{(1+r)^{y-1}} \qquad (1)$$

$$NPV = \sum_{y=1}^{y=n} \frac{U_{t,y}}{(1+r)^n} - I_o \qquad (2)$$

where:

$I_o$ - Initial Investment Cost

$R$ - Residual value

$r$ - Discount rate (-)

$n$ - Life time (years)

$U_{t,y}$ - Payments in year $y$

In such an approach, NPV gives clear indications of investment decisions. Under these conditions the investment is accepted if its NPV ≥ 0 and rejected when NPV < 0.

### 7.2.3. LCC model levels

LCC analysis has a four levels that describe the different phases of the project.

LCC model levels:

a. Global phase/Early design phase: if there is little more than a target number of square meters per relevant function (OR, nursing). No specific information is available at this point.
b. Strategic phase: the investments can be calculated at main element level (architectural, electrical/technical, etc.) and the MOM expenses are categorized.
c. Design phase: this phase entails calculations at element level. The MOM costs are subdivided into 16 aspects (cleaning, energy, etc.).
d. Calculation phase: detailed calculation at material level takes place in this phase. It is even possible to state the frequency of maintenance and replacement per individual material type.

Measurement in the design phase is accomplished with the help of an assessment, using life cycle costing, on the basis of investment costs and the estimated costs in the rest of the life cycle of the building.

Measurement in the use stage should take place with the help of assessment, using life cycle costing, on the basis of estimated cost related to the maintenance and refurbishment and verified cost of operation.

## 7.3. LCC and KPIs

Life cycle cost analysis integrates the investment costs and operational costs into one measure of financial performance through a net present value calculation and for comparison reasons the annual costs. But to make a decision on the cost-effectiveness of investments, Key Performance Indicators (KPIs) should also be taken into account. Fulfilling them all attains success.

# 8. EeHDBuildings KPIs and HD Buildings Design Validation

A multi-criterion methodology has been developed for Validating HD buildings early design enriched with energy and economic efficiency analysis.
This Part has been worked out on the basis of Streamer group of Deliverables mainly: – D3.1, D3.2, D3.3, D7.1, D7.2, D7.3, D7.4 – see also **Bibliography**, Streamer Deliverables.

## 8.1. Introduction

This document was developed to specify the Key Performance Indicators which can be used in the decision making process during the early design stage. KPIs calculated for each alternative designs scenarios can be compared taking into account building energy performance, comfort and life cycle cost.

## 8.2. Scope

This document gives guidelines for Key Performance Indicators (KPIs) calculations, which are applied during the early design stage of the health care facility in order to support decision making process. KPIs are sensitive to building-oriented factors and process-oriented factors.

## 8.3. Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

– ISO 15686-5:2008 - Buildings and constructed assets - Service-life planning - Part 5: Life-cycle costing;
– FprEN 15603:2014 - Energy performance of buildings- Overall energy use and definition of energy rating;
– EN 15251- 2007 - Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.

## 8.4. Key Performance indicators

STREAMER Key Performance Indicators (KPI`s) help during early design decision process, they are sensitive to building-oriented factors and process-oriented factors. Calculation methods are based on the information available at an early stage of the design. Indicators are grouped into three categories in relation to energy, financial and quality performance (Scheme1).

| KPI | Unit |
|---|---|
| Energy demand | • kWh/(m² / Year)<br>• kWh/(WPU / Year) |
| Energy consumption | • kWh/(m² / Year)<br>• kWh/(WPU / Year) |
| Carbon emission efficiency | • kg $CO_2$ / m²<br>• kg $CO_2$/ WPU |
| Life cycle costs and annual costs | • €<br>• €/m²<br>• €/WPU |
| Patient satisfaction | • Patient satisfaction score: range 1-5 |
| Overall quality | • Total quality score (maximum score 47points) |
| Thermal comfort | • Hours of temperature deviation from the standard per year |

| | |
|---|---|
| Operational efficiency (building efficiency and travel time efficiency) | • Ratio between net and gross floor area (percentage)<br>• Hours/ m²<br>• Hours/ WPU |

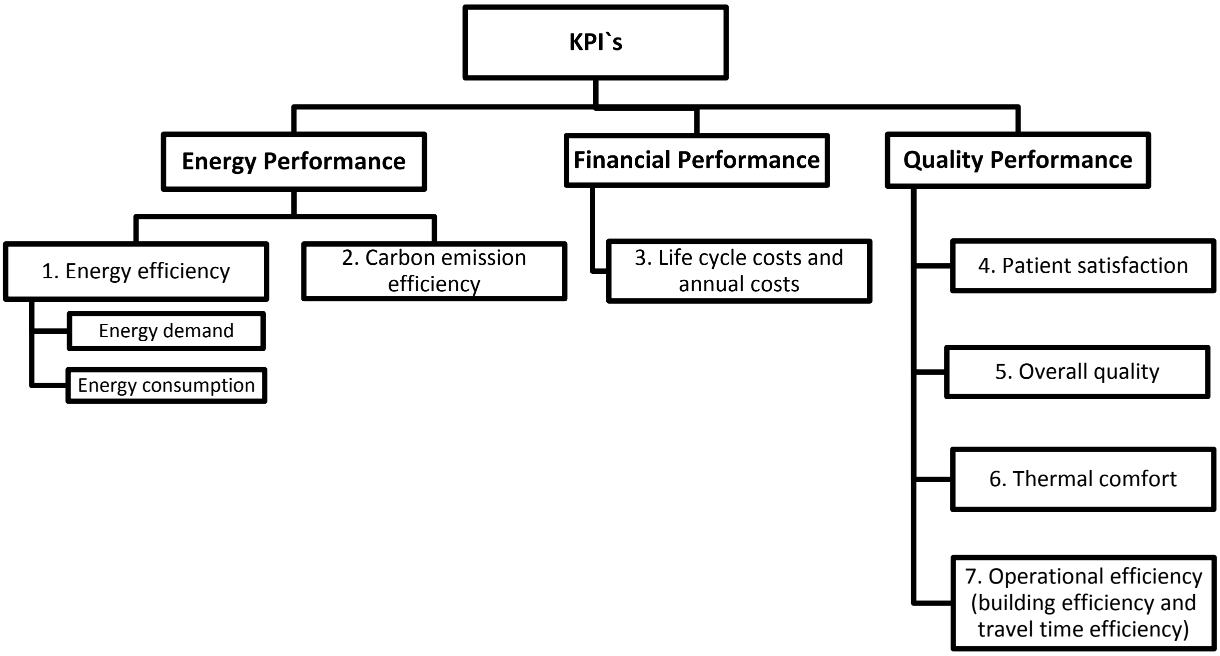



***Figure** 11. Building performance indicators developed in STREAMER Deliverable D3.2 Building and process-oriented EeB KPIs operationalized for all (re)design phases*

### 8.4.1. Useful area

The useful (net) floor area ($A_{use;zi}$ [m$^2$]) is the floor area needed as parameter to quantify specific conditions of use that are expressed per unit of floor area (e.g. occupancy), as basis for specifying the reference floor area and for the application of the simplifications and the zoning and (re-) allocation rules [SOURCE: FprEN 15603:2014], calculation using Formula 1.

$$A_{use;zi} = \sum_i A_{med;i} \qquad (1)$$

Where:

– Amed,I is a net floor area of the function (i) derived from the design (floor plan);
– m$^2$ is a zone or room.

### 8.4.2. Weight Patient Unit

**The WPU** is a weighted summation of the number of weighted intakes, the number of weighted first outpatient visits, the number of nursing days and the number of day nursery days. The weighing factors for these four parts are:

– Weighted number of intakes: 10
– Number of nursing days: 0.49
– Number of “day nursery” days: 3.4

– Weighted number of first outpatient visits: 1.22.

See: - STREAMER deliverable D 3.2 “Building and process oriented KPI`s”

### 8.4.3. Energy efficiency

#### 8.4.3.1. Energy demand efficiency

Calculate the performance indicator energy demand efficiency by dividing the total energy demand (SD 8.7.4) by the number of square meters useful (net) floor area or WPU.

#### 8.4.3.2. Energy consumption efficiency

Calculate the performance indicator energy consumption efficiency by dividing the total energy consumption (SD 8.7-4) by the number of square meters useful (net) floor area or WPU.

### 8.4.4. Carbon emission efficiency

Estimation or measurement of the total carbon emission per hospital complex during operations, measured per number of square meters useful floor area and WPU, calculate using Formula 2. If there are no conversion factors for fuels given by country regulation use values from Table 1.

$$CO_2 = \frac{E_{cr} \cdot W}{A_{use}\ (or\ WPU)} \tag{2}$$

Where:

$E_{cr}$ is a sum of the energy consumption per energy carrier, *MWh*
$W$ is a conversion factor, *kq/MWh (Table 1)*
$A_{use}$ is a useful area , $m^2$
WPU is a weight patient unit, -

| **Fuel type** | **Emission factor $CO_2$** kg/MWh |
|---|---|
| Natural gas ($CO_{2;gas}$) | 182,16 |
| Electricity ($CO_{2;el}$) | 564,94 |
| District heating (coal/oil powered) ($CO_{2;coal;oil}$) | 315,72 |
| Waste incineration ($CO_{2;wi}$ ) | 113,04 |
| Wood. biomass ($CO_{2;wd;bm}$) | 0.0 |

Table 11**3**. Conversion factors for $CO_2$ emission.

### 8.4.5. Life cycle cost and annual costs

Life Cycle Costs are all costs occurring in the life cycle of the building construction, related to the building operations, maintenance and disposal costs. The described method allows to assess the expected financial performance of at an early design process and compare design scenarios based on this performance during operations for a specific function of the building.

This method could be used for refurbishment and new built scenarios.

**The following costs are included in the life cycle cost of LCC KPI:**

- Investment costs (capital costs);
- Operational costs (including costs in design, construction, operation and maintenance phase).
  Operational cost include: Energy, Water, Cleaning, Maintenance, Security, General management and technical support (based on SS-ISO 15686-5:2008).

**The following cost items are excluded:**

- Demolition and major renovation costs;
- Financing costs (how investments are financed; e.g. interests on loan);
- Revenue (economic benefits) generated by the building;
- Residual value (we assume that at the end of the lifetime, the asset has no commercial value).

A financial performance KPI integrates the investment costs and operational costs into one measure of financial performance through a net present value calculation. Only the annual costs are compared.

#### 8.4.5.1. LCC performance indicator – net present value

The net present value (NPV) is the net sum of the discounted future cash flows (the sum of the discounted earnings/benefits less the sum of the discounted costs). The NPV can also be calculated by subtracting the initial investment cost from the discounted net cash flow. If the NPV is positive the investment is profitable and the greater positive value of the NPV it is the more profitable is the investment. Since the discounted building related earnings/benefits of a hospital are difficult to estimate, the NPV method in the LCC calculation is only based on the building related costs. LCC can be calculated using Formula 3 (see: - D3.6).

$$LCC = I_o - \frac{R}{(1+r)^n} + \sum_{y=1}^{y=n} \frac{U_{t,y}}{(1+r)^{y-1}} \tag{3}$$

Where:

$I_o$ is an Initial Investment Cost (country currency)

$R$ is a Residual value (country currency)

$r$ is a Discount rate (-)

$n$ is a Life time (years)

$U_{t,y}$ is a Payments in year y (country currency)

The LCC performance indicator is calculated with Formula 4:

$$\frac{LCC}{A_{use}(or\ WPU)} \tag{4}$$

### 8.4.6. Patient satisfaction

Patient satisfaction is an estimated self-reported patient satisfaction of the patient room and outpatient clinic on room/clinic level or total building level (average of all room/clinic scores).

An algorithm to calculate patient satisfaction (range 1-5) based on physical characteristics of the patient room and outpatient clinic. Appendix A provides the input sheets based on which design characteristics a prediction can be made. The algorithm is based on the Formula 5:

$$\mathbf{Y} = \frac{\mathbf{1}}{\mathbf{1} + \mathbf{e}^{-(\omega_1 \mathbf{DC}_1 + \omega_2 \mathbf{DC}_2 + \omega_3 \mathbf{DC}_3 \ldots + \omega_n \mathbf{DC}_n + \theta)}} \quad (5)$$

Where

Y is an estimated patient satisfaction.

$\omega_i$, represents the weights connecting design characteristics (DC) to patient satisfaction indicators (which can be estimated based on design characteristics, as the algorithms are based on 400 patient surveys, evaluating 48 patient rooms in four hospital (see: - D 3.2).

$DC_i$ depict the measured value of a design characteristic.

θ is a constant. The score can be defined per room/clinic. A building/department score can be calculated by averaging the room and clinic scores of the building/department.

**NOTE**
Patient satisfaction can be calculated in detailed design stage.

### 8.4.7. Overall quality

Overall quality is a total score on the quality scan of the hospital environment. For evaluation use software like in ex. ASPECT tool developed by The National Health Service of England. The tool can be applied to new and existing buildings, fulfilling the requirement of consistency of the unit of measurement and that of an existing tool. Although the tool does not measure/predict the indicated performance indicators, it evaluates aspects of a ‘therapeutic environment’

### 8.4.8. Thermal comfort

Thermal comfort is the thermal feeling of a space perceived by its occupants. It is recommended to use EN 15251-2007*:Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.*.

**NOTE**
Thermal comfort can be calculated at detailed design stage.

### 8.4.9. Operational efficiency

Operational efficiency is a level of performance that describes a process that uses the lowest amount of inputs to create the greatest amount of outputs. In terms of a building this relates to how efficient the building is in supporting the operational activities within the building (building efficiency); and how efficient are the processes in the building. For instance, the logistic plan of a hospital may impact the efficiency of processes due to increased or decreased travel time. To describe Operational Efficiency two indicators are defined:

- a building efficiency indicator
- a travel time efficiency indicator.

#### 8.4.9.1. Building efficiency indicator

The building efficiency is defined as the calculated ratio between net and gross floor area of the hospital design. The higher to one, the more efficient the building is. Net and gross floor area shall be calculated according to the same calculation method.

#### 8.4.9.2. Traveling time efficiency

Total daily weighted travel time of personnel (including staff only and patient transport times) per square meter and weighted patient unit.

Determine the routes to include in the analysis. Be aware that the optimal designs for these routes are calculated. Routes that are not included are out of scope, thus make sure important routes are included based on frequency of use or medical relevance. Frequent patient transport routes include: Operating department - General nursing/child nursing, Emergency Department - imaging & diagnostics.

Total daily weighted travel time of personnel is calculated with Formula 5.

$$(TWTT) = V1+V2+\ldots Vn_{\text{patient transport}} + V1+V2+\ldots Vn_{\text{staff only}} \quad (6)$$

Where

$V_{\text{patient transport}} = RTT_{\text{patient transport}} * F$ (times 2 when two staff members are needed to transport patients in bed) (7)

$$V_{\text{staff only}} = RTT_{\text{staff only}} * F \quad (7.1)$$

$$RTT = (Rt1+ Rt2+ Rt..)/\text{number of routes}) \quad (7.2)$$

$$Rt_{\text{patient transport}} = \text{distance of route}/ 0{,}85 + \text{height difference} * 6{,}4 + 60 \text{ (if } \neq 0) \quad (7.3)$$

$Rt_{\text{staff only}}$ = distance of route/ 1,4 + height difference * 6,4 + 60 (if ≠0) $TRTT_{\text{patient transport}} = RR1 + RR2+ RR..n_{\text{patient transport}}$ (7.4) (7.5)

$TRTT_{\text{staff only}} = RR1 + RR2+ RR..n_{\text{staff only}}$

*Route*

Route is the (shortest) distance to travel from one department to another and is measured from the access to access of a department and in the center of a corridor.

*Route-time (Rt)*

The time needed to travel the indicated route. This includes waiting time and use of elevators/stairs. We calculated an average walking speed of 0,85 m/s (3,0 km/h) for patient transport (walking with bed) and 1,4 m/s (5,0 km/h) for staff only. Average waiting time for elevator use is assumed on average 20 seconds, average handling time and entering/leaving on average 40 seconds and average elevator transition time to next floor 6, 4 seconds (based on standards used by elevator suppliers REF).

*Relative travel time (RTT)*

The average travel time is the average time when multiple routes are possible between departments. If only one route exists the Rt applies.

*Total relative travel time (TRTT)*

The sum of all RTT's of selected routes.

*Frequency (F)*

The frequency determines how often the route is used on a daily basis, expressed in total number travels/day.

*Weighted travel time (WTT)*

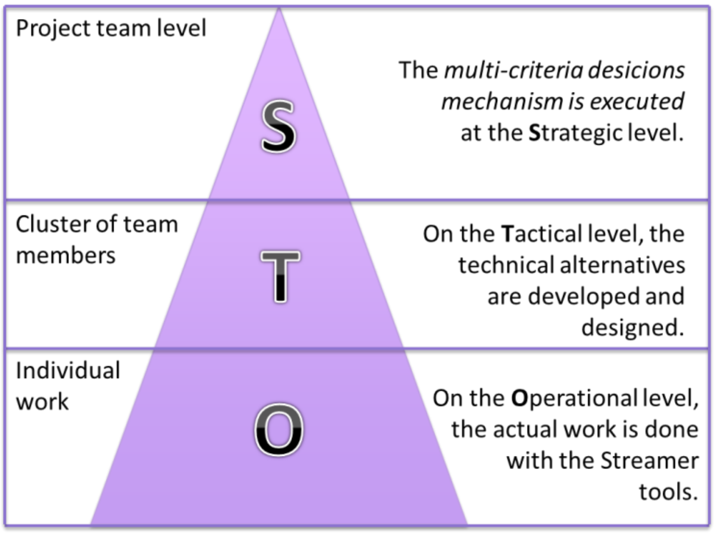
This is the product of the frequency of a route and the RTT. The total weighted travel time is the sum of the WTT's of the selected routes.

## 8.5. Master Plan Validation

The design process - via the decision-support tool – is based on common understanding and agreement of design criteria. The core team has the responsibility to establish design criteria and weights that are accepted by all core partners. The criteria and weights are project specific. KPIs take into account the process of design, construction and operation of the facilities and set out the issues that should be considered in the practical establishment of a set of KPIs.

### 8.5.1. Design decision-making mechanism

Design decision-making process is an iterative process that follows the organization hierarchy of the project core team, engineering team (specialists) and the individual level (specialist). The alternative designs are processed according to the main steps in order to refine the alternatives and create information that supports the decisions.



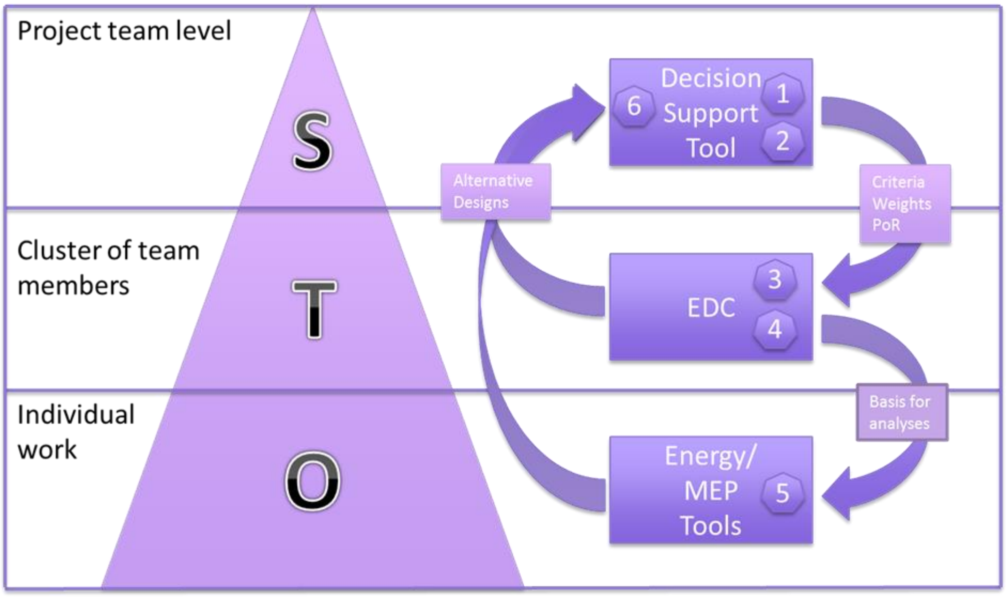



*Figure 13: The iterative decision-making process and the inter-level connections*

The following main steps have been identified:

i. Project core team establishes and develops the program of requirements (PoR).

ii. Project core team develops criteria and weights the criteria by means of weighting matrix at the designer/investor workshop meeting. In the weighting matrix each of the criterion is valued against each of the other criteria. It is valuable that all the core partners perform their own weighting and produces a priority list. The lists of weighted criteria of the different partners are then discussed until a common list of criteria has been established. As a help for developing the criteria, the list of presented above KPI:s can be used.

iii. The engineering team develops and formulates the rules on the basis of the POR and the weighted criteria.

iv. The engineering team develops early design HD building alternatives (layouts of buildings) with entry data sets which allows for energy demand and consumption calculations and MEP system analyses to be performed on the design alternatives.

v. Further down set of KPIs are calculated as an entry data for validation criterion.

vi. On the basis of the design alternatives and the energy/MEP analyses, the project team makes decision for the weighting criterion structure and initiates calculations and analysis.

The process may be iterated until a feasible solution that is commonly accepted among the core partners is achieved.

There are numerous examples for criteria weighing methods. In Table 2, an example of the weighting procedure is presented.

*Table 14. Weighting matrix of criterion. Two criteria are considered to be most important, energy and carbon targets developed as industry benchmarks and the use of renewable technology.*

| | Reduced primary energy and carbon emission | Energy and carbon targets within country regulations | Energy and carbon targets within EU regulations | Energy and carbon targets developed as industry benchmarks | Energy and carbon targets developed through international best practice | Passive system integration | Active system integration | Use of renewable technology | Resilience risk considered and managed | Sum | Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Reduced primary energy and carbon emission | | x | x | o | o | x | x | o | o | 4 | 0,7 |
| Energy and carbon targets within country regulations | o | | x | o | o | o | o | o | o | 1 | 0,2 |
| Energy and carbon targets within EU regulations | o | o | | x | x | o | o | o | o | 2 | 0,3 |
| Energy and carbon targets developed as industry benchmarks | x | x | o | | x | x | o | x | x | 6 | 1,0 |
| Energy and carbon targets developed through international best practice | x | x | o | o | | o | o | x | x | 4 | 0,7 |
| Passive system integration | o | x | x | o | x | | o | o | o | 3 | 0,5 |
| Active system integration | o | x | x | x | x | x | | o | o | 5 | 0,8 |
| Use of renewable technology | x | x | x | o | o | x | x | | x | 6 | 1,0 |
| Resilience risk considered and managed | x | x | x | o | o | x | x | o | | 5 | 0,8 |

The strategic definition identifies and defines business goals and user needs on a strategic level, and shall be integrated into the programming, pre design and design phase. This will secure a planning and decision making process that is transparent and holistic where the consequences of alternative options can be calculated and measured against Key Performance Indicators (KPIs) and evaluation criteria.

Either applied in a traditional design and construction processes, or in a project based on the Integrated Project Delivery (IPD) processes, decisions remain to be based on defined criteria and evaluation of alternative solutions against the criteria.

# References

## Normative Documents

The following documents are referred to in the text above in such a way that some or all of their content constitutes requirements of this document.

**British Standards**

[1] BS 6229:2003, *Flat roofs with continuously supported coverings. Code of practice*

**Italian (UNI) Standards**

[2] UNI 8627:2013, Sistemi di copertura

[3] UNI 11018:2003, Rivestimenti e sistemi di ancoraggio per facciate ventilate a montaggio meccanico - Istruzioni per la progettazione, l'esecuzione e la manutenzione - Rivestimenti lapidei e ceramici

**German Standards**

[4] DIN 1946-4:2008 Ventilation and air conditioning - Part 4: VAC systems in buildings and rooms used in the health care sector, DIN, 2008

[5] VDI 2167 Part 1. Building services in hospitals. Heating, ventilation and air-conditioning. December, 2004.

**American standards**

[6] ASHRAE Standard 55

[7] ASHRAE Standard 170-2013 Ventilation of health care facilities

**Other**

[8] NFPA 99

**ISO Standards**

[9] ISO 5151, Non-ducted air conditioners and heat pumps — Testing and rating for performance

[10] ISO 8185, Respiratory tract humidifiers for medical use — Particular requirements for respiratory humidification systems

[11] ISO 9346, Hygrothermal performance of buildings and building materials — Physical quantities for mass transfer — Vocabulary

[12] ISO 10209, Technical product documentation — Vocabulary — Terms relating to technical drawings, product definition and related documentation

[13] ISO 10303-11, Automation systems and integration – Product data representation and exchange

[14] ISO 10303-21, Industrial automation systems and integration -- Product data representation and exchange -- Part 21: Implementation methods: Clear text encoding of the exchange structure

[15] ISO 10916, Calculation of the impact of daylight utilization on the net and final energy demand for lighting

[16] ISO 12736, Petroleum and natural gas industries — Wet thermal insulation coatings for pipelines, flow lines, equipment and subsea structures

[17] ISO 13790, Energy performance of buildings — Calculation of energy use for space heating and cooling

[18] ISO 13943, Fire safety — Vocabulary

[19] ISO 14040, Environmental Management – Life cycle Assessment – Principles and framework

[20] ISO 14452, Network services billing — Requirements

[21] ISO 14817-1, Intelligent transport systems — ITS central data dictionaries — Part 1: Requirements for ITS data definitions

[22] ISO 15042, Multiple split-system air-conditioners and air-to-air heat pumps — Testing and rating for performance
[23] ISO 16813, Building environment design — Indoor environment — General principles
[24] ISO 16818, Building environment design — Energy efficiency — Terminology
[25] ISO 17215-2, Road vehicles — Video communication interface for cameras (VCIC) — Part 2: Service discovery and control
[26] ISO 18292, Energy performance of fenestration systems for residential buildings — Calculation procedure
[27] ISO 19101-1, Geographic information – Reference model
[28] ISO 19152, Geographic information — Land Administration Domain Model (LADM)
[29] ISO 19439, Enterprise integration — Framework for enterprise modelling
[30] ISO 19859, Gas turbine applications — Requirements for power generation
[31] ISO 19903, Petroleum and natural gas industries — Fixed concrete offshore structures
[32] ISO 21007-1, Gas cylinders — Identification and marking using radio frequency identification technology — Part 1: Reference architecture and terminology
[33] ISO 28258, Soil quality — Digital exchange of soil-related data
[34] ISO 29481-1, Building information models — Information delivery manual — Part 1: Methodology and format
[35] ISO 30400, Human resource management — Vocabulary
[36] ISO 50047, Energy savings — Determination of energy savings in organizations
[37] ISO/IEEE 11073-10201, Health informatics — Point-of-care medical device communication — Part 10201: Domain information model
[38] ISO/IEC 2382, Information technology — Vocabulary
[39] ISO/IEC 13273-1, Energy efficiency and renewable energy sources — Common international terminology — Part 1: Energy efficiency
[40] ISO/IEC 14772-1, Information technology — Computer graphics and image processing — The Virtual Reality Modelling Language — Part 1: Functional specification and UTF-8 encoding
[41] ISO/IEC 25062, Software engineering — Software product Quality Requirements and Evaluation (SQuaRE) — Common Industry Format (CIF) for usability test reports
[42] ISO/IEC TR 27019, Information technology — Security techniques — Information security management guidelines based on ISO/IEC 27002 for process control systems specific to the energy utility industry
[43] ISO/IEC/IEEE 24765, Systems and software engineering — Vocabulary
[44] ISO/TR 15916, Basic considerations for the safety of hydrogen systems
[45] ISO/TR 21245-1, Railway applications — Rail project planning process — Part 1: Stakeholders and their needs/interests
[46] ISO/TS 19159-2, Geographic information — Calibration and validation of remote sensing imagery sensors and data — Part 2: Lidar
[47] ISO/TS 22002-1, Prerequisite programmes on food safety — Part 1: Food manufacturing
[48] ISO 14644-1:2015 Cleanrooms and associated controlled environments -- Part 1: Classification of air cleanliness by particle concentration
[49] ISO/DIS 52010-1 Energy performance of buildings -- Overarching assessment procedures of external environment conditions -- Part 1: Calculation procedures
[50] ISO 7730: 2005

[51] SS-ISO 15686-5:2008 - Buildings and constructed assets -- Service-life planning -- Part 5: Life-cycle costing

[52] ISO 9 001:2015 Quality management systems -- Requirements

[53] ISO 14 001:2015 Environmental management systems -- Requirements with guidance for use

[54] ISO 50 001:2011 Energy management systems -- Requirements with guidance for use

**European Union (EN) Standards**

[55] EN 410, Glass in building. Determination of luminous and solar characteristics of glazing

[56] EN 15459, Economic evaluation procedure for energy systems in buildings

[57] EN 12098-3 Controls for heating systems. Outside temperature compensated control equipment for electrical heating systems

[58] EN 12098-5 Controls for heating systems. Start-stop schedulers for heating systems

[59] EN 12831-3 Heating systems and water based cooling systems in buildings - Method for calculation of the design heat load Part 3: Domestic hot water systems heat load and characterisation of needs

[60] EN 15316-4-1 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, combustion systems (boilers)

[61] EN 15316-4-2 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, heat pump systems

[62] EN 15316-4-3 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Heat generation systems, thermal solar systems

[63] EN 15316-4-4 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Heat generation systems, building-integrated cogeneration systems

[64] EN 15316-4-5 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, the performance and quality of district heating and large volume systems

[65] EN 15316-4-6 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Heat generation systems, photovoltaic systems

[66] EN 15316-4-7 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, biomass combustion systems

[67] EN 15316-4-8 Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies. Space heating generation systems, air heating and overhead radiant heating systems

[68] EN 15316-3-1:2007 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)

[69] EN 15316-3-2:2007 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-2: Domestic hot water systems, distribution

[70] EN 15316-3-3:2007 Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3-3: Domestic hot water systems, generation

[71] EN 15603 Energy performance of buildings- Overall energy use and definition of energy rating

[72] EN 12831:2003 Heating systems in buildings - Method for calculation of the design heat load

[73] EU Project iNSPiRe , D2.3 RES availability survey and boundary conditions for simulations

[74] EN 15251- 2007:Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics

[75] EN ISO 52016-1Energy performance of buildings -- Calculation of the energy needs for heating and cooling, internal temperatures and heating and cooling load in a building or building zone -- Part 1: Calculation procedures

[76] FprCEN/TR 16244:2011 (E) FINAL DRAFT TECHNICAL REPORT FprCEN/TR 16244:2011 (E), April 2011 Ventilation for hospitals

[77] prEN 167981-1;2015 - Residential buildings, other spaces, category II

[78] prEN 167981-1;2015 - Office, category II

[79] prEN 167981-1;2015 - Bedrooms, category I

[80] prEN 167981-1;2015 - Non low-poluting buildings, category I

[81] prEN 167981-1;2015 - Non low-poluting buildings, category II

[82] prEN 167981-1;2015 - Category I

[83] prEN 167981-1;2015 - Category II

[84] prEN 167981-1;2015 - Landscaped offices, Category II

[85] NEN 2916:2014

### EU Directives

[86] 2010/31/UE of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

[87] 2009/28/EC on promotion of the use of energy from renewable sources established accounting criteria for the 2020 targets on renewable energy sources.

# Bibliography

## Streamer Deliverables

D1.1 – Taxonomy of healthcare districts focussing on EeB morphology and features

D1.2 – Semantic typology model of existing buildings and districts

D1.3 – Mapping of energy-related problems and potential optimisation

D1.4 – Multi-scale and multi-stage scenarios for energy efficiency retrofitting

D1.5 – Coherent-state-of-art design guidelines for energy-efficient healthcare districts

D1.6 – Semantic baseline design model for energy-efficient healthcare districts

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 configurations

D2.6 – New design solutions of energy-efficient building envelope and spatial configurations

D2.7 – EeB technologies for synergy between building and neighbourhood energy systems

D2.8 – Set of EeB solutions for district level

D3.1 – Building-oriented EeB KPIs of newly designed and retrofitted buildings

D3.2 – Process-oriented EeB KPIs in the operation, maintenance , (re)construction phases

D3.3 – Review and benchmarking of energy performance simulation tools corresponding to the typology models of energy-efficient healthcare districts

D3.4 – Simulation tool of the energy performance for newly designed and retrofitted buildings

D3.5 – Semantic interface of the simulation tools based on the semantic design configurator

D 3.6 "Design decision-support and lifecycle validation tool"

D4.1 – Framework for management of information flow, design actors and collaboration in virtual design and construction

D4.2 – Process roadmap of participatory semantic-driven design

D4.4 – Techniques of knowledge management in participatory semantic-driven designing

D4.5 – IPD contract recommendations and best practices

D5.3 – PLM architecture for EeB within the context of healthcare districts

D5.4 – PLM solutions based on Semantic Web technologies

D5.5 – Parametric modelling technics for EeB

D5.6 – Framework for the open-source library of parametric design solutions

D5.8 Intermediate Framework for the open-source library of parametric design solutions

D6.1 Configurator of workflow and building process Requirements

D6.2 – Configurator of parametric design solutions

D6.3 – Energy modelling interface IFC – CityGML

D6.4 – Energy simulation model of smart grid in a healthcare district

D6.5 Advance Mapping Structures and Standards

D7.1 – Real case in UK: Description and outline designed plan

D7.2 – Real case in UK: Validation through participatory design session

D7.3 – Real case in NL: Description and outline designed plan

D7.4 – Real case in NL: Validation through participatory design session

D7.9 – State-of-the-art of energy-efficient healthcare districts

D7.10 – Benchmarking of EeB design innovations in EU

## Other Bibliography

[B.1] Berners-Lee 2009,

[B.2] Bouwcollege, Building Differentiation of Hospitals: Layers approach, Report number 611, 2007

[B.3] ASHRAE Advance energy design guide for large hospitals

[B.4] R. Beith "Small and Micro Combined Heat and Power (CHP) Systems, Advanced Design, Performance, Materials and Applications"

[B.5] French Red Cross "A Source of Design Reference Standards Handbook to Build an Hospital"

[B.6] Anna Charkowska, Warsaw University of Technology, Foreign guidelines for the design of ventilation and air conditioning systems in hospitals

[B.7] Jakub Pędziński, Bartosz Pędziński "Effective waste management in health care" http://www.nowinylekarskie.ump.edu.pl/uploads/2007/3/265_3_76_2007.pdf

[B.8] Whole building Design Guide https://www.wbdg.org/FFC/FED/EO/eo13693.pdf

[B.9] US Green Building Council http://www.usgbc.org/credits/eq61

[B.10] National Fire Protection Association http://www.nfpa.org/

[B.11] BSRIA Guide BG 5/2008 – Whole-Life Cycle Costing Analysis

[B.12] J. P. Pols „STREAMER Label validation”

[B.13] STREAMER labels release

[B.14] Polish Regulation of the Minister of Infrastructure and Development of 27 February 2015 on methodology for determining the energy performance of a building or part of a building and energy performance certificates

[B.15] Polish Regulation of the Minister of Transport, Construction and Maritime Economy of 5 July 2013 amending the Regulation on technical conditions to be met by buildings and their location

[B.16] The Construction (Design and Management) Regulations 2015, http://www.legislation.gov.uk/uksi/2015/51/memorandum/contents

[B.17] The Building Regulations 2010, http://www.legislation.gov.uk/uksi/2010/2214/contents/made

[B.18] Conservation of fuel and power in new buildings other than dwellings L2A http://www.ribabookshops.com/uploads/cd2629a3-997a-1004-41d3-fd6c7a9249a1.pdf

[B.19] The Energy Performance of Buildings (England and Wales) Regulations 2012. http://www.legislation.gov.uk/uksi/2012/3118/contents/made

[B.20] Department of Health building notes https://www.gov.uk/government/collections/health-building-notes-core-elements

## Web sites

[WS.1] European Commission: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

[WS.2] Energy performance: https://www.gov.uk/check-energy-performance-public-building

[WS.3] Comfort: https://www.carbontrust.com/media/39216/ctv024_hospitals.pdf

[WS.4] Fire Safety: http://www.mtbeurope.info/content/ft1110001.htm

[WS.5] Ogólne: https://en.wikipedia.org/wiki/Building_regulations_in_the_United_Kingdom

# Appendix – Streamer Terminology & Definitions

The purpose of this Appendix is to standardise unique terminology and abbreviations used all over through **D8.7 Recommendations for new and retrofitted EeHDBuildings** – standardisation proposal draft.

This chapter performs a role of a glossary containing terms & definitions specific for the STREAMER project.

The aim of this chapter is to avoid misunderstandings in reading the text of this standardised proposal draft covering specific mix of interdisciplinary terms and definitions as well as in interpretation of acronyms and abbreviations use.

The ISO Standard Dictionary doesn't cover all terms and in some cases the ISO definitions aren't close enough to the specific one required in the set of these documents so it's been decided to present all specific terms and abbreviations used in the whole set of 6 standard Parts, marking those already defined in ISO dictionary by index ISO.

New terms specific for the STREAMER Project are defined in an unambiguous and unique way.

## A.1. Scope

This segment consists of 2 chapters:

- **Terms & Definitions –** list of terms with their acronyms or abbreviations and definitions presented in numbered alphabetical groups according to the first letter of the first word of the term;
- **Acronyms & Abbreviations –** alphabetically grouped according to the first letter of them whit full name expanding.

Mechanism of indexing applied within the text of this chapter is given in examples below:

- **Terms & Definition –** building[T;B.3)]: T – stands for Terms & Definitions, B – points to the group of "**B,b**" terms; 3 – points to the position within the group of "**B,b**";
- **Acronyms & Abbreviations** – BAS[A;B,b)]: – stands for Acronyms & Abbreviations, B – points to the group of Acronyms starting from letter "**B,b**";
- **Normative References –** ISO XYZ[NR;ISO.3)]: NR – stands for Normative References, ISO – points to the group of "ISO" standards within "Normative references"; 3 – points to the position within the group of "ISO";
- **Other References –** Trias Energetica[OR.3)]: OR – stands for Other References; 3 – points to the position within the group of Other References.

## A.2. Terms and Definitions

**A,a**

A.1. **Accumulation efficiency**

In this document the ability to collect and store energy and its recovery at a time when it is needed for use

A.2. **Activity Focus Area**

In this document an area of the healthcare district characterized by defined demand amount of energy

A.3. **Air flow rate**

Volume of air transferred to or from a system divided by time. Definition according to ISO 9346[NR;ISO.3)]

A.4. **Air gap ventilation speed**

The flow of air in a cavity as a result of pressure or temperature differences. Definition according to UNI 11018[NR;UNI.2)]

A.5. **Attribute**

In this document something where you can say "X has Y" where Y is attibute

A.6. **Average Energy Consumption = Average Energy Usage**

In this document primary energy consumed annually on average by a device, installation or building for its operation, refers in [kWh]

A.7. **Azimuth angle**

In this document angle between the south vector and the perpendicular projection of a certain element of the envelope (origin)

**B,b**

B.1. **BIM Bots**

In this document online system that triggers on an event. It can perform an analyses or simulation on BIM data and enriches the model by adding detailed objects, splitting it for specific use or perform any other task on data

B.2. **BriefBuilder**

In this document on-line tool for overall evaluation of building management quality

B.3. **Breitfuss model hospital**

In this document building guideline for hospitals architectural modelling

B.4. **Building (B)**

In this document the isolated architectural structure dedicated to perform some functions of HD activity

B.5. **Building Assembly Modelling (BAM)**

In this document digital representation of building assembly processes

B.6. **Building Automation System (BAS)**

In this document on-line data acquisition and control system for the whole building and its technical infrastructure – a part of BMS[T;B.12)]

B.7. **Building bioclimatic energy demand index (Bbio)**

In this document it defines the impact of bio-climatic design on building energy performance, regardless of energy demanded by equipment installed in the building; it sums up building demands for heating, cooling and electric lighting and indicates the building design efficiency

B.8. **Building Energy Modelling (BEM)**

In this document digital representation of building energy demand and consumption, that includes: BIM[T;B.10)], BAM[T;B.5)], and BOOM[T;B.14)]

B.9. **Building Energy Monitoring System (BEMS)**

In this document system giving the opportunity for performance management (energy, comfort, installation and process). It is the dynamic control system with real-time calculation and comparing of the installation performance related to the design parameter

B.10. **Building Information Modelling (BIM)**

Shared digital representation of physical and functional characteristics of building which allows for modeling and simulation studies of building operational performance. Definition according to ISO 29481-1[NR;ISO.26)]

B.11. **Building Heating System**

In this document heating system provides heat for a building

B.12. **Building Management System (BMS)**

In this document on-line data acquisition system of all building technical infrastructure and safety installations for monitoring, control (including BAS[T;B.6)]), and management to achieve building operational efficiency

B.13. **Building Morphology (A/V)**

In this document building shape expressed by the heat exchange surface of a building to its volume ratio (the compactness of a building is one of the fundamental parameters affecting the building energy consumption)

B.14. **Building Operation Modelling (BOOM)**

In this document digital representation of building operational characteristics

B.15. **Building Orientation**

In this document building orientation in relation to the sun passage across the sky is a fundamental indicator of passive solar gains and overheating building interiors as well as needs for sun glare reduction

B.16. **Building time constant**

In this document building time constant characterizing the thermal inertia of the building

**C,c**

C.1. **Campus Level**

In this document on healthcare inter-building ("urban") level at the campus

C.2. **CEN Tool**

In this document energy simulation tool capable of using label information (from STREAMER labels[T;S.20)]) as input for simulation. Requires an IFC[T;I.3)] file to calculate the energy KPI [T;K.1)]

C.3. **Circular Economy**

In this document in a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value

C.4. **CityGML**

In this document GML profile for representing the built environment in 3D

C.5. **Co-simulation**

In this document different subsystems which form a coupled problem are modelled and simulated in a distributed manner. The coupled simulation is carried out by running the subsystems in a black-box manner. During the simulation, the subsystems will exchange data

C.6. **Coefficient Of Performance (COP)**

Ratio of the heating capacity to the effective power input to the device at any given set of rating conditions. Definition according to ISO 15042[NR;ISO.14)]

C.7. **Comfort class**

In this document a label representing requirements for light, daylight, ventilation and design temperatures

C.8. **Compactness factor**

In this document the building parameter affecting the building energy consumption (see also B.13. Building Morphology (A/V))

C.9. **Compatibility**

Communication ability between two different systems. Definition according to ISO 21007-1[NR;ISO.24)]

C.10. **Component**

In this document element of building and MEP[T;M.1)] included into a “not spatial level” to implementation of data for the BIM model

C.11. **Cooling degree day**

For any one day, when the mean temperature is more than the base temperature, there are as many degree-days as degrees Celsius temperature difference between the mean temperature for the day and the base temperature. Definition according to ISO 16818[NR;ISO.16)]

**D,d**

D.1. **Dashboard**

In this document a visual representation of important information needed to achieve one or more objectives, consolidated and arranged on a single screen so that information can be comprehended in a glance

D.2. **Data exchange requirements**

In this document checks completeness of data required by a specific process, thus typically linked to workflow and task descriptions

D.3. **Daylight Factor (DF)**

Ratio of the illuminance at a point on a given plane due to the light received directly and indirectly from a sky of assumed or known luminance distribution to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, where the contribution of direct sunlight to both illuminances is excluded. Definition according to ISO 10916[NR;ISO.7)]

D.4. **Decomposition**

It is a process of splitting a complex structure into its elements, a split can done according to predefined criteria. Definition according to ISO 19439[NR;ISO.21)]

D.5. **De Facto Standard**

In this document when a solution is given by a dominant person in a team, forcing others to be compatible with it. In this way, all systems can communicate together

D.6. **Degree days**

Difference in temperature between the outdoor mean temperature over a 24 h period and a given base temperature. Definition according to ISO 16818[NR;ISO.16)]

D.7. **Demonstration Site**

In this document general terms to designate the facilities that are targeted in the four STREAMER[A;S,s)] building design demonstration projects

D.8. **Design Methodology**

A set of design and communication methods implemented to perform design tasks ordered by an investor. Definition according to ISO/IEC/IEEE 24765[NR;ISO.35)]

D.9. **Design Phase**

In this document a particular step in the design process, that has defined inputs, outputs, and may include various activities / tasks

D.10. **Design Programme**

In this document programme setting out the strategic dates in relation to the design process. It is aligned with the Project Programme but is strategic in its nature, due to the iterative nature of the design process, particularly in the early stages

D.11. **Design rationale**

In this document capturing of reasoning behind design decisions

D.12. **Design rules**

Recommendations for a good design that may be prioritized or overruled. Definition according to ISO 19903[NR;ISO.23)]

D.13. **Design Tool**

In this document specific tool that can be used as support for one or a set of activities (e.g. simulation tool, CAD[A;C,c)] tool, PLM[A,;P,p)] tool)

D.14. **District (D) = District level**

In this document in the healthcare campus that includes several (third part) healthcare buildings

D.15. **District Heating**

A centralized system of heat generation, distribution and supply to a group of residential and/or commercial clients at given location. Definition according to ISO 14452[NR;ISO.12)]

**E,e**

E.1. **Early Design Configurator (EDC)**

In this document application developed by the Karlsruhe Institute of Technology that iteratively generates various amount of design layouts that conform to the program of requirements, building form and the design rules

E.2. **Energy consumption**

In this document the amount of energy being consumed by HD[T;H.1)] buildings within defined period of time (hourly, monthly or annually) usually from third party supplies (e.g. national grid, heat supplied by district heating systems). Energy consumption includes energy distribution, energy conversion (e.g. electricity for cooling media), and generation installations including distribution losses, efficiency of generation and storage systems, energy conversion etc.

E.3. **Energy demand**

In this document the maximum level of energy needed for buildings in relation to typical building characteristics and functions e.g. building construction characteristics as well as comfort, hygienic and safety requirements (ventilation, air conditioning, lighting) - building bioclimatic energy demand and in relation to healthcare specific functions performed in the HD buildings e.g. diagnostic and treatment equipment needs etc [in kWh]

E.4. **Energy efficiency**

In this document using less energy to fulfill set requirements, expressed by output energy divided by input energy

E.5. **Energy efficient Buildings (EeB)**

In this document technology innovation of building including: building typologies, energy technologies, and the performance optimization

E.6. **Energy Efficiency Ratio (EER)**

Ratio of the total cooling capacity to the effective power input to the device at any given set of rating conditions, derived from watts/Watt. Definition according to ISO 5151[NR;ISO.1)]

E.7. **Energy Management System (EMS)**

A computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of electrical generation and transmission facilities so as to assure adequate security of energy supply at minimum cost. Definition according to IEC 61970-2013a[NR;EN.86)]

E.8. **Energy power demand**

In this document energy supply ability needed to cover peek demands for energy. The total energy power demand defines energy supply safety requirements of a healthcare buildings [in kW or MW]

E.9. **Energy Storage**

Temporary storage of energy, like electricity or heating, for example day/night. Definition according to ISO/IEC 13273-1[NR;ISO.31)]

E.10. **Entity**

A class of information defined by common properties. Definition according to ISO 10303-11[NR;ISO.5)]

E.11. **ERIC**

In this document the main central data collection for Estates & Facilities services from the NHS. Trusts enter data (e.g. energy consumption[T;E.2)] and cost) into the system which provides real time performance indicator information allowing organisations to benchmark their performance

E.12. **Eureka**

In this document web-based search engine developed in ASP.NET that allows users to perform free-text queries on the data stored in the SACS [T;S.1)] database, performing real-time reports

E.13. **Extensible Mark-up Language (XML)**

A mark-up language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. Definition according to ISO 28258 [NR;ISO.25)]

**F,f**

F.1. **Façade factor**

In this document the ratio of Façade surface to gross floor area

F.2. **Feature**

A feature is an abstraction of real world phenomena. Definition according to ISO 19101-1 [NR;ISO.19)]

F.3. **Flat Roof**

British Standard BS 6229[NR;S.1)] defines a flat roof as "having a pitch less than 10° (22,22%) to the horizontal". Italian Standard UNI 8627[NR;UNI.1)] defines a flat roof as having a pitch less than 1% (0,45°) and a sub-horizontal roof as having a pitch between 1% (0,45°) and 5% (0,9°)

F.4. **Framework**

In this document broad overview, outline or skeleton of interlinked items which supports a particular approach to a specific objective, and serves as a guide that can be modified as required by adding or deleting items. In the case of STREAMER[A;S,s)] the Framework consists of multiple data structures, building elements and rules that represent expert knowledge

F.5. **Functional Approach**

In this document this approach (relevant for hospitals) analyzes and categorizes single spaces, functional areas, departments, buildings and healthcare districts considering proximity and interdependencies between spaces and functions

F.6. **Functional Area (FA)**

A group of spaces generally related to homogeneity of interdependencies between functions and spaces. Definition according to ISO 10209[NR;ISO.4)]

F.7. **Functional Macro-area (FMA)**

In this document FMA reflect the main medical activities conducted in hospitals. The main FMA are Diagnostic and Treatments, Wards, Operating blocks, Accident and Emergency (A&E[A;A,a)]), General Facilities, Public Facilities

**G,g**

G.1. **gbXML Interface (gbXML)**

In this document open programming tool defined to facilitate the transfer of building properties stored in 3D building information models (BIM[T;B.10)]) to engineering analysis tools

G.2. **Geographic Information System (GIS)**

Computer system made for capturing and displaying positions on the earth's surface and portraying data in many different ways on maps. Definition according to ISO/TS 19159-2[NR;ISO.38)]

G.3. **Geospatial Information System (GIS)**

In this document computer system used to acquire, manipulate and store geographic information

G.4. **Grid**

In this document network infrastructure for energy transfer and exchange applying carriers as steam, hot water, cooling water or electricity

**H,h**

H.1. **Healthcare District (HD)**

In this document district is a campus area consisting of various buildings including: hospitals and clinics; research centers and laboratories; educational buildings; temporary care homes; rehabilitation and sport facilities offices, retails and logistic buildings; power and control facilities

H.2. **Heat capacity**

Amount of thermal energy required to raise the temperature of an object by one Kelvin. Definition according to ISO 13943[NR;ISO.10)]

H.3. **Heating, Ventilation, Air Conditioning (HVAC)**

In this document set of installations, and control systems for the heating, ventilation, and climatic demands of the building

H.4. **Heating degree day**

For any one day, when the mean temperature is less than the base temperature, there are as many degree-days as degrees Celsius temperature difference between the mean temperature for the day and base temperature. Definition according to ISO 16818[NR;ISO.16)]

H.5. **Hierarchy**

In this document a structure of people or things organized into successive ranks of groups in which some of lower rank groups are subordinated to a group or groups of higher rank, usually hierarchical structures communicate or cooperates in a predefined, accepted way

H.6. **Horizontal Envelope of Roof**

In this document the horizontal outer skin of a building: it comprehends the covering and framing or structure which supports the covering. It's an interface between interior space and exterior environment

H.7. **Hot floor**

In this document the layer with capital intensive high-tech functions that are unique to the hospital

H.8. **Hotel**

In this document the layer which includes the larger part of the patient accommodations

H.9. **Humidity**

The percentage ratio of the partial pressure of water vapor in the air to a saturated vapor pressure of water at the same temperature. Definition according to ISO 8185[NR;ISO.2)]

H.10. **HVAC emission system**

Part of a technical building system that performs a specific function (heat generation, heat distribution, heat emission). Definition according to ISO 52016-1[NR;ISO.75)]

H.11. **Hydraulic grade line**

In this document the surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is that level water would rise to in a small, vertical tube connected to the pipe

H.12. **Hygienic class**

In this document hygienic requirements related to premises activities in terms of the conditions of ventilation

H.13. **Hypertension**

In this document in clean rooms or traditional laboratory premises some constant hypertension must be provided in relation to adjacent rooms, for example hallway. This prevents the escape way or the ingress of contaminated air into the environment

**I,i**

I.1. **Indoor quality**

Quality of air inside non-industrial buildings, described in terms of odour, chemical and biological pollutants, is related to the ventilation rate, air distribution patterns and pollution sources to ensure human health, olfactory comfort and perceived comfort. Definition according to ISO 16813[NR;ISO.15)] Furthermore, in this document also needs for daylight inside building and view outside

I.2. **Industry**

In this document the layer with the medical supporting functions (laboratories) and facilitating functions (the production kitchen)

I.3. **Industry Foundation Classes (IFC)**

In this document data model intended to describe building and construction industry data. It is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors

I.4. **Information and Communication Technology (ICT)**

In this document European Union refers to this under the terms e-Inclusion and e-Accessibility. A three-way approach is proposed: goods which can be accessed by nearly all potential users without modification or failing that, products being easy to adapt according to different demands, or using standardized interfaces that can be accessed simply by using assistive technology

I.5. **Inside-out approach**

In this document the “engineer’s view” by defining the typology based on the technical properties of the room (e.g. the energy-related features of an operating room, a patient room, a nurse office, …) and building MEP[T;M.1)] systems (e.g. the energy-related features of a sandwich-panel facade system, a certain type of ventilation system, etc.)

I.6. **Insolation**

The sum of solar radiation at the time and on the surface describing solar energy resources in a given place and time. Usually expressed in kWh/m² or MJ/m², per day, month or year. Definition according to ISO 16818[NR;ISO.16)]

I.7. **Integrated Project Delivery (IPD)**

In this document project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication and construction. IPD team includes the basic triad of owner, architect and contractor

I.8. **Interoperability**

The capability of a product or system whose interfaces are fully known to work with other existing products or systems without any restricted access. It enables various systems to communicate directly. It relies on the use of an open standard. Definition according to ISO/IEEE 11073-10201[NR;ISO.29)]

I.9. **Inter-aspect schedule**

In this document expert knowledge in the research fields of energy, GIS[T;G.2)], BIM[T;B10)], KPI[T;K.1)] and semantic labels

I.10. **Internal Rate of Return (IRR)**

In this document method of calculating rate of return. The term “internal” refers to the fact that its calculation does not incorporate environmental factors (e.g., the interest rate or inflation)

**J,j**

**K,k**

K.1. **Key Performance Indicator (KPI)**

An indicator evaluates the success of an organization or of a particular activity. Often success is the periodic achievement of some levels of operational goal (e.g. zero defects, 10/10 customer satisfaction, etc.), and sometimes success is defined in terms of making progress toward strategic goals. Definition according to ISO 30400[NR;ISO.27)]

K.2. **Knowledge Based Engineering (KBE)**

A technology based on dedicated software tools that are able to capture and reuse product and process engineering knowledge. The main objective of KBE is the reduction of time and costs as well as ability to improve the quality of product development by means of: ● automation of interactive, non-creative, design tasks, ● support of multidisciplinary design optimization in all the phases of the design process LaRocca2011[OR;5)]

K.3. **KPI Thermal Comfort**

The thermal sensation of a space that is perceived by its occupants. Definition according to EN 15251[NR;EN.74)]

K.4. **KPI Overall Quality**

In this document performance criteria used to assess the overall quality of design alternatives based on seven performance indicators such as: 1) Privacy, company and dignity; 2) Views; 3) Nature and outdoors; 4) Comfort and control; 5) Legibility of place; 6) Facilities; 7) Staff

K.5. **KPI Patient Satisfaction**

In this document estimated self-reported factor of the patient room and outpatient clinic on room/clinic or total building level (average of all room/clinic scores) based on an algorithm and model developed by TNO

K.6. **KPI Operational Efficiency**

In this document level of performance indicator related to how efficient a building is in supporting the operational activities within it (building efficiency) and how efficient the processes in the building, given the building (process efficiency) are

**L,l**

L.1. **Label**

Property attached to spatial component, also called “semantic label”. Definition according to ISO/TS 22002-1[NR;ISO.39)]

L.2. **Labels Approach**

In this document classification and labelling method introduces a set of codes and references that allow to identify the spaces through the relations between spatial, functional and energy related features

L.3. **Labels category**

In the STREAMER[A;S,s)] project different categories of labels are used. Each label category covers aspects that are useful in the early design phase. Within STREAMER the following categories are used: Construction, Hygienic class, Equipment, Usage profile, Comfort class, Accessibility, Layout

L.4. **Layers Approach (Bouwcollege)**

In this document this approach (relevant for hospitals) divides functional package of a hospital into four layers (a layer = a building storey block). Each of these layers (Hot floor, Hotel, Office, Industry) has its own properties profile as regards specificity, investment costs, growth/downsizing requirements, and marketability of the property

L.5. **Level of Detail (CityGML)**

CityGML[A;C,c)] a profile in computer graphics. The level of detail describes the complexity of the representation of a 3D object. Beside the geometrical complexity of the object, CityGML introduces different semantic levels for each level of detail CityGML2012[OR;3)] Definition also according to ISO/IEC 14772-1[NR;ISO.32)]

L.6. **Life cycle assessment (LCA)**

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. Definition according to ISO 14040[NR;ISO.11)]

L.7. **Life span**

Expected lifetime for component (or system) normally specified in years. Definition according to EN 15459[NR;EN.2)]

L.8. **Linked data**

In computing, linked data describes a method of publishing structured data so that it can be interlinked and become more useful through semantic queries. It builds upon standard Web technologies, but rather than using them to serve web pages for human readers, it extends them to share information in a way that can be read automatically by computers. This enables data from different sources to be connected and queried LinkedData2015[OR;6)]

L.9. **Linked open data (LOD)**

Linked Open Data is Linked Data[T.L.8)], which is released under an open license, which does not impede its reuse for free Berners-Lee 2009[OR.1)]

**M,m**

M.1. **Mechanical, Electrical, Plumbing technologies (MEP)**

In this document systems that consume the most energy for every energy aspect

M.2. **Microgrid**

In this document group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. It can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode

M.3. **Microservice**

In this document variant of the service-oriented architecture (SOA)[A;S,s)] architectural style that structures an application as a collection of loosely coupled services

M.4. **Model consistency**

In this document fundamental checks of proper model semantics

M.5. **Model View Definition (MVD)**

This model defines a subset of the IFC[T;I.3)] schema that is needed to satisfy one or many Exchange Requirements of the AEC[A;A,a)] industry. Definition according to ISO 29481-1[NR;ISO.26)]

M.6. **mvdXML**

In this document Model View Definition XML file in which, together with the IFC[T;I.3)] schema subset, a set of implementation instructions and validation rules, called **MVD**[T;M.2)] **Concepts**, are published

**N,n**

N.1. **Narrow plan**

In this document the concept and a key driver in the clinical needs of patients of the future supporting a reduction in energy, when use of daylight and natural ventilation are properly included in the MEP[T;M.1)] concept

N.2. **Neighbourhood Energy Systems (NES)**

In this document system producing steam, hot water or chilled water at a central plant. Includes energy carrier, generation and production, distribution, exchange, storage and other technologies

**O,o**

O.1. **Object**

In this document data construct that provides a description of anything known to a computer and defines its method of operation

O.2. **Office**

In this document the layer with the outpatient units (diagnostics and examinations), accounting, management and training functions

O.3. **Ontology**

Ontology is a theory closely related with Taxonomy[T;T.3)], in this document it helps dealing with HD nature and its current real status, it also deals with concepts and relationships in between these concepts on what can be done to improve HD performance, as well as it defines terminology for presenting all these

O.4. **openBIM**

In this document universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows

O.5. **Organic Rankine Cycle (ORC)**

In this document system based on the vaporization of a high pressure liquid which is in turn expanded to a lower pressure thus releasing mechanical work. Used for electricity and heat production or hot water production

O.6. **Otorhinolaryngology**

In this document surgical subspecialty within medicine that deals with conditions of the ear, nose and throat

O.7. **Outside-in approach**

The “designer’s view” by defining the typology based on the 4 Bouwcollege[OR.2)] spatial classifications, as well as the campus-building taxonomy and organizational categories (e.g. local hospital, regional hospital, general hospital, academic hospital, etc.)

**P,p**

P.1. **Parameter**

A parameter is an input for an algorithm. The output depend on it. Definition according to ISO 17215-2[NR;ISO.17)]

P.2. **Parametric extension of IFC format**

In this document extension provides material to express the fact that attributes of IFC[T;I.3)] objects are computed from parameters and algorithms

P.3. **Parametric modelling**

In this document parametric modelling uses parameters to define a model

P.4. **Performance category**

In this document category for which KPIs[T;K.1)] are operationalized in order to quantify the performance of this category. For STREAMER[A;S,s)] three performance categories were defined: Energy, Financial and Quality performance

P.5. **Performance Indicators (PIs)**

In this document KPIs[T;K.1)] can consist of multiple performance indicators to define and calculate the KPI. In this way PIs can be regarded as 'sub-KPIs'. For example, the energy efficiency KPI consist of the PIs: energy demand efficiency and energy consumption efficiency

P.6. **Pitched Roof**

In this document a roof made up of two angled pieces which meet in the middle, with gables at either end. The pitch of both sides of the roof is generally the same, although they may be pitched at different angles. A single pitched roof is a roof made of one flat segment installed at an angle. The angle of the pitch varies considerably, depending on the size of the building and the size of the segments

P.7. **Power Plant**

An industrial facility for the generation of electric power also referred to as a generating station, powerhouse or generating plant. Definition according to ISO 19859[NR;ISO.22)]

P.8. **Primary energy**

Energy contained in a raw fuel or distribution network, which has not been conversed or transformed. Definition according to ISO 50047[NR;ISO.28)]

P.9. **Primary energy consumption index (Cep)**

In this document index defining the building's primary energy use, for conventional use of heating , domestic hot water, cooling, lighting and auxiliaries, expressed in kWh/m²

P.10. **Program of Requirements (PoR)**

In this document an ordered collection of data about housing demands and the performance required in respect of the site, building, areas, rooms, parts of the building and facilities in the building and on the site

**Q,q**

**R,r**

R.1. **RE-Suite**

In this document tool with several applications which ultimately shows results (KPIs[T;K.1)]) of the simulations in a dashboard. It also includes an internal IFC[T;I.3)] viewer and modules for simulating the LCC[A;L,l)] and Quality KPI

R.2. **Reason / Reasoning**

The capacity for consciously making sense of things, applying logic, establishing and verifying facts, and changing or justifying practices, institutions, and beliefs based on new or existing information. Definition according to ISO/IEC 2382[NR;ISO.30)]

R.3. **Regulations**

In this document rules with a legal background that must be satisfied to be built

R.4. **Retrofitting**

Incorporation of new technology or new design parts resulting from an approved engineering change to an already supplied item in order to maintain performance. Definition according to ISO/TR 21245-1[NR;ISO.37)] Furthermore, in this document in order to improve efficiency

R.5. **Ribbon**

In this document user interface concept representing a menu in several tabs with each containing a toolbar

R.6. **Room Data Sheet (RDS)**

In this document room data sheets give a detailed description of all the finishes, fixtures and fittings, mechanical and electrical requirements that will be required for each room. Room data sheets will not be necessary for all types of buildings

R.7. **Rotterdam Energy Approach and Planning (REAP)**

In this document method for maximising energy efficiency developed to support energy-neutral urban planning in a structured, incremental way. It combines reduction energy demand, reusing waste streams, production sustainably and exchange energy at inter-building level

**S,s**

S.1. **SACS**

In this document tool that provides the information about the current use of spaces

S.2. **Scenario (energy)**

In this document image of how the future could unfold (neither prediction nor forecast). It is useful tool for investigating alternative future developments and their implications, for learning about the behaviour of complex systems, and for policy-making

S.3. **Seasonal Energy Efficiency Ratio (SEER)**

In this document parameter used for estimation of the seasonal performance of coolant system (chillers, air conditioners). This is dimensionless unit

S.4. **Seasonal Performance Factor (SPF)**

Total heating output of a heat pump during its normal annual usage period for heating, divided by the total electric energy input during the same period. Definition according to ISO 16818[NR;ISO.16)]

S.5. **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. In the STREAMER[A;S,s)] context, examples of signifiers can be: a wall, a room, a KPI[T;K.1)], the concept of natural ventilation etc. Definition according to ISO 14817-1[NR;ISO.13)]

S.6. **Semantic (baseline) design model**

In this document a collection of design guidelines and the relationships between them

S.7. **Semantic BIM template**

In this document template for applying and supporting the semantic (baseline) design model[T;S.6)] in a BIM [T;B.10)] process

S.8. **Semantic rules for BIM**

In this document relationships between objects and/or information within the BIM[T;B.10)] environment

S.9. **Semantic typology model**

In this document the morphology of buildings/districts covering component, system, building and neighbourhood levels aiming to help establish the required performance and carry this information forward to the design team

S.10. **Serviced area**

In this document reference unit used to describe size of the area which can be served, refers in [$m^2$]

S.11. **Simplified Building Energy Model (SBEM)**

In this document refers to the computer programme used to assess how energy efficient a commercial property is based upon the building's energy usage and carbon dioxide emissions from month to month

S.12. **Smart grid**

A smart grid is a system which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficiency resources. Definition according to ISO/IEC TR 27019[NR;ISO.34)]

S.13. **Solar factor (G)**

The ratio between the thermal energy globally transmitted from the glass pane and that incident on it. Definition according to EN 410[NR;EN.1)]

S.14. **Solutions**

In this document a means of solving a problem or dealing with a difficult situation

S.15. **Spatial Unit (SU)**

Single spaces or rooms are the lowest spatial entity that can be identified by specific functions and properties (operating rooms, patient rooms, nurse offices, etc.). Definition according to ISO 19152[NR;ISO.20)]

S.16. **Standard**

In this document standard is a document that provides requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose

S.17. **Standardisation**

In this document the process of implementing and developing technical standards based on the consensus of different parties that include firms, users, interest groups, standards organizations and governments

S.18. **STEP Physical File (SPF)**

A clear-text file format defined in the Standard for the Exchange of Product Data (STEP[A;S.s)]) and specified in the ISO 10303-21[NR;ISO.6)]

S.19. **Storage capacity**

In this document capacity of energy which can be stored within the device and used later for the process

S.20. **STREAMER labels**

In this document performance requirement attached to space levels aiming to create a methodology that makes it possible to use standardised requirements that are linked to the type of use of a space in the early stage

S.21. **Structural compliance**

In this document compliance with a given data format or ontology. The type of checks depends on the used modelling language and may enables to do encode sophisticated model checks

S.22. **Sub-functional area (SFA)**

In this document the sub-functional areas correspond to typologies of space (with homogenous characteristics) that can be generally found within each FA[T;F.6)]. Each of these layers has its own properties profile as regards specificity, investment costs, growth/downsizing requirements, and marketability of the property

S.23. **Summer thermal comfort index (Tic)**

In this document specific index to the building which defines the conventional interior temperature, which must be below a reference value

S.24. **Syntactical compliance**

In this document compliance with the file format, lowest level of model checks relevant for file-based data exchange

**T,t**

T.1. **Tab**

In this document page selector on a ribbon[T;R.5)] or another user interface element with page elements

T.2. **Tag**

In this document non-hierarchical keyword or term assigned to a piece of information, in information systems. This kind of metadata helps describe an item and allows it to be found again by browsing or searching

T.3. **Taxonomy**

The science or technic of classification and description of processes and systems according to their set of interrelation, functionality, structure etc. Definition according to ISO/IEC 25062[NR;ISO.33)]

T.4. **Technical building system**

Technical equipment for heating, cooling, ventilation, humidification, dehumidification, domestic hot water, lighting and electricity production. Definition according to ISO 13790[NR;ISO.9)]

T.5. **Technology Readiness Level (TRL)**

In this document Technology Readiness Level has been estimated for each Key Exploitable Results (KER). The levels vary from 5 to 8. TRL 5 – technology validated in relevant environment; TRL 6 – technology demonstrated in relevant environment; TRL 7 – system prototype demonstration in operational environment; TRL 8 – system completed and working in practical situations

T.6. **Technology Strategy**

In this document the strategy established at the outset of a project that sets out technologies, including Building Information Modelling (BIM)[T;B.10)] and any supporting processes, and the specific software packages that each member of the project team will use

T.7. **Thermal comfort**

A condition in which a person feels that his body is in a state of sustainable heat balance, ie. does not feel neither heat or cold. Definition according to ISO 16813[NR;ISO.15)]

T.8. **Thermal conductivity (Heat conductivity coefficient)**

Heat-transfer rate per unit area of a material divided by the temperature gradient causing the heat transfer. Definition according to ISO/TR 15916[NR;ISO.36)]

T.9. **Thermal transmittance**

Heat flow rate in the steady state divided by area and by the temperature difference between the surroundings on each side of a system. Definition according to ISO 18292[NR;ISO.18)]

T.10. **Times the air changes**

In this document determines the demand for air ventilation in areas with constant and a small amount of occurrence of harmful and burdensome health and applied simple ventilation devices

T.11. **Toolbar**

In this document group of horizontally or vertically aligned buttons

T.12. **Typical meteorological year**

In this document collation of selected weather data for a specific location, generated from a data bank much longer than a year in duration

**U,u**

U.1. **U coefficient (U value) (Ubat)**

Average heat transfer coefficient of the envelope. Definition according to ISO 12736[NR;ISO.8])

U.2. **Unit average efficiency**

In this document primary energy delivered to the unit dived by energy gained after the conversion. Can be given in % or in fraction. Efficiency for some devices can be higher than one

U.3. **Urban Energy System**

A formal system that represents the combined process of acquiring and using energy to satisfy the energy service demands of a given urban area Keirstead2012[OR;4)]

**V,v**

V.1. **Variable-Speed Drive (VSD)**

In this document equipment used to control the speed of machinery. Where applications demand adjustment of flow a pump or fan, varying the speed of the drive will save energy compared with other techniques for flow control

V.2. **Vertical envelope (facades)**

In this document the vertical outer skin of a building. As the interface between interior space and exterior environment, a building’s skin plays a crucial role in heat and light exchange. Its performance in that role affects occupant comfort and productivity, energy use and running cost

**W,w**

W.1. **Web Service**

In this document service offered by an electronic device to another electronic device, communicating with each other via the World Wide

**X,x**

**Y,y**

**Z,z**

## A.3. Acronyms & Abbreviations

**A,a**

**A** – Area

**A.d.a** – Area di Attivita (Activity Area)

**AC** – Air Conditioning

**AC** – Alternating Current

**ACA** – AutoCAD Architecture

**ACC** – Automatic Compliance Checking

**ADE** – Application Domain Extension

**AEC** – Architecture, Engineering and Construction

**AEEG** – The Italian Energy Authority

**AGESI** – Italian Association of Energy and Facility Management

**AGORIA** – Green Building platform

**AHU** – Air Handling Unit

**AIA** – the American Institute of Architects

**ALKIS** – Amtliches Liegenschaftskatasterinformationssystem

**ANSI** – American National Standards Institute

**AOUC** – Azienda Ospedaliero-Universitaria Careggi

**APES** – Association of Energy Services Companies of the Czech Republic

**APHP** – Assistance Publique Hopitaux de Paris

**API** – Application Programming Interface

**Apros** – Advanced Process Simulation Environment

**ASD** – Adjustable Speed Drive

**ASF** – Apache Software Foundation

**ASHE** – American Society for Healthcare Engineering

**ASHP** – Air Source Heat Pump

**ASHRAE** – American Society of Heating, Refrigerating and Air-Conditioning Engineers

**ASSOESCO** – Italian Association of ESCO

**AssoEGE** – Italian Association of Energy Management Experts

**ATES** – Aquifer Thermal Energy Storage

**ATL** – Adaptive Temperature Limits

**A/V**[T;B.13)] – Building Morphology ( Area/Volume)

**A&E** – Accident and Emergency

**B,b**

**B**[T;B.4)] – Building

**BAM**[T;B.5)] – Building Assembly Modeling

**BAS**[T;B.6)] – Building Automation System

**Bbio index**[T;B.7)] – Building bioclimatic needs index

**BCF** – BIM Collaboration Format

**BELESCO** – Belgian association of ESCO's energy service providers

**BEM**[T;B.8)] – Building Energy Modeling

**BEMS**[T;B.9)] – Building Energy Monitoring System

**BHE** – Borehole Heat Exchanger

**BIGCC** – Biomass Integrated Gasification Combined Cycle

**BIM**[T;B.10)] – Building Information Modeling

**BIMSie** – BIM Service Interface Exchange

**BIPV** – Building Integrated PV

**BMD** – Bone Mineral Density

**BMS**[T;B.12)] – Building Management System

**BOOM**[T;B.14)] – Building Operation Modeling

**BOOT** – Build-Own-Operate-Transfer

**BOS** – Balance Of System

**BPEL** – Business Process Execution Language

**BPIE** – Building Performance Institute Europe

**BPMN** – Business Process Modeling Notation

**BREEAM** – Building Research Establishment Environmental Assessment Methodology

**BRep** – Boundary Representation

**BS** – British Standards

**BSI** – British Standard Institution

**BSRIA** – Building Services Research and Information Association

**bSDD** – buildingSMART Data Dictionary

**bSI** – buildingSMART International

**BTES** – Borehole Thermal Energy Storage systems

**BTZ –** Basso Tenore di Zolfo (low sulphur level)

**C,c**

**CAAD** – Computer Aided Architectural Design

**CAD** – Computer Aided Design

**CADDET** – Centre for the Analysis and Dissemination of Demonstrated Energy Technologies

**CAT** – Computer-aided Tomography

**CAV** – Constant Air Volume (in mechanical ventilation systems)

**CB-NL** – Concept Library the Netherlands

**CC** – Combined Cycle

**CC** – Comfort Cooling

**Cchp** – Combined cooling, heating and power

**CCS** – Crown Commercial Service

**CEM** – Contract Energy Management

**CEN** – Comite Europeen de Normalisation (European Committee for Standardization)

**Cep**[T;P.9)] – Primary Energy Consumption Index

**CFD** – Computational Fluid Dynamics

**CHP** – Cogeneration or Combined Heat and Power

**CHPC** – Chemical Heat Pump Container

**CIFE** – Center for Integrated Facility Engineering

**CIGS** – Copper Indium Gallium Selenide

**CIM** – Common Information Model

**CityGML**[T;C.4) T;L.5)] – City Geography Markup Language

**CM** – Construction Management

**CME** – Continuing Medical Education

**CMIS** – Content Management Interoperability Services

**CMIS** – Content Management Information System

**CMO** – Concept Modeling Ontology

**CMS** – Content Management System

**COBie** – Construction Operations Building Information Exchange

**COM** – Component Object Model

**CoM** – The Covenant of Mayors

**COP**[T;C.6)] – Coefficient of Performance

**CPC** – Compound Parabolic Collectors

**CPCU** – Parisian Urban Heating Company

**CPV** – Concentrated photovoltaics

**CRC** – Carbon Reduction Commitment

**CRS** – Coordinate Reference System

**CSG** – Constructive Solid Geometry

**CSO** – Collective Self-Organised housing approach

**CSPE** – Centro Studi Progettazione Edilizia

**CSR** – Corporate & Social Responsibility

**CSSD** – Central Sterile Services Department

**CSV** – Comma Separated Value (file format)

**CT** – Computed Tomography

**CTO** – Centre for Orthopaedic Trauma

**D,d**

**D**[T;D.14)] **–** District; District level

**D** – Deliverable

**D.LGS** – Decreto Legislalivo (Legislative Decree)

**DAI** – Integrated Activity Departments

**DALI** – Digital Addressable Lighting Interface

**DB** – Design and Build contract

**DBB** – Design – Bid – Build contract

**DBFM** – Design, Build, Finance and Maintain

**DC** – Direct Current

**DC** – Delivery Contracting

**DC** – Design Characteristics

**DD** – Developed Design

**DEC** – Display Energy Certificate

**DEM** – Digital Elevation Model

**DF**[T;D.3] – Daylight Factor

**DGBC** – Dutch Green Building Council

**DHC** – District Heating and Cooling

**DHN** – District Heating Network

**DHW** – Domestic Hot Water system

**DIMOSIM** – District Modeler and Simulator

**DIPINT** – Dipartimento integrato interistituzionale (integrated inter-institutional department)

**DNO** – District Network Operator

**DOW** – Document of Work

**DoW** – Description of Work

**DP** – Dew Point

**DPL** – DIgSILENT Programming Language

**dPoW** – digital Plan of Work

**DR** – Demand Response

**DSL** – Domain Specific Language

**DST** – Decision Support Tool

**DTD** – Document Type Definitions

**DTM** – Digital Terrain Model

**DTS** – Dynamic Thermal Simulation

**DV** – Design Validator

**DWG** – AutoCAD Drawing Database

**DXF** – Drawing Interchange Format

**E,e**

**E3M Institute –** Endocrinology, Metabolic Diseases and Internal Medicine

**EA** – Environment Agency

**EBD** – Evidence Based Design

**EC** – European Commission

**ECG** – Electrocardiography

**ECHAA** – European Centre for Health Assets and Architecture

**ECM** – Electronically Commutated Motors

**EDC**[T;E.1] – Early Design Configurator

**EDM** – Electronic Document Management

**EDRA** – Forintek Envelope Drying Rate Analysis

**EeB**[T;E.5] – Energy efficient Buildings

**EED** – Energy Efficiency Directive

**EEE-F** – European Energy Efficiency Fund

**EEI** – Energy Efficiency Index

**EeHDBuildings** – Energy effective Healthcare Buildings

**EER**[T;E.6)] – Energy Efficiency Ratio

**EER** – Extended Entity Relationship model

**EES** – Energy Efficiency Scheme

**EESI** – European Energy Service Initiative

**EIFS** – Exterior Insulation and Finishing System

**EIP** – European Innovation Partnerships

**EIR** – Employer Information Requirements

**ELCD** – European Reference Life Cycle Database

**EMAS** – Eco-Management and Audit Scheme

**EMCS** – Energy Management and Control System

**EMEEES** – Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services

**EMP** – Estimated Maximum Price

**EMPD** – Effective Moisture Penetration Depth model

**EMS** – Environmental Management System

**EMS**[T;E.7)] – Energy Management System

**EN** – European Norm

**ENEA** – Italian National Research Energy Agency

**ENEL** – Ente nazionale per l'energia elettrica (National electricity board)

**ENTSO-E** – European Network of Transmission System Operators for Electricity

**EP** – Energy Performance index

**EPB** – Energy Performance of Buildings

**EPBD** – Energy Performance of Buildings Directive

**EPC** – Energy Performance Certificate

**EPC** – Energy Performance Coefficient

**EPC** – Energy Performance Contracting

**EPCC** – EU Energy Performance Contracting Campaign

**EPD** – Environmental Product Declaration

**EPN** – Energy Performance Standard

**EPRI** – Electric Power Research Institute

**EPRP** – Energy Performance Related Payments

**EPS** – Extracellular Polymeric Substances

**EPS** – Emergency Power System

**EPSG** – European Petroleum Survey Group

**ER** – Emergency room

**ER** – Exchange Requirements

**ERIC** – Estates Return Information Collection

**ERP** – Enterprise Resource Planning

**ERPD** – Energy Related Products Directive

**ESB** – Enterprise Service Bus

**ESC** – Energy Supply Contracting

**ESCO** – Energy Services Company

**ESCOROM** – Romanian Association of ESCO Companies

**ESD** – Energy Services Directive

**ESEER** – European Seasonal Energy Efficiency Ratio

**ESHP** – Exhaust Air Source Heat Pump

**ESS** – Exploitation Strategy Seminar

**ETC** – Evacuated Tube Collectors

**ETICS** – External Thermal Insulation Composite System

**ETIM** – European Technical Information Model

**EU** – European Union

**EUA** – End User Application

**EUETS** – European Union Energy Trading Scheme

**EUHPN** – European Union Health Property Network

**EUI** – Energy Utilization Index

**EVA** – Ethylene Vinyl Acetate

**EVO** – Efficiency Valuation Organizations

**F,f**

**FA**[T;F.6)] – Functional Area

**FC** – Fan Coil

**FEDERESCO** – Italian Federation of ESCO

**FIRE** – Federazione Italiana per l'uso Razionale dell'Energia

**FITs** – Feed In Tariffs

**FM** – Facility Management

**FMA**[T;F.7)] – Functional Macro-area

**FME** – Feature Manipulation Engine

**FMECA** – Failure Modes, Effects and Criticality Analysis

**FMEG** – Fan Motor Efficiency Grade

**FP** – Framework Program

**FPC** – Flat Plate Collectors

**FP7** – 7th Framework Program for Research and Technological Development

**FTE** – Full Time Equivalent

**G,g**

**G**[T;S.13)] – Solar factor

**gbXML**[T;G.1)] – green building XML definition

**GCV** – Gross Calorific Value

**GE** – General Electric

**GFA** – Gross Floor Area

**GH** – "Groupes Hospitaliers" (Hospital Groups)

**GHG** – Green House Gas

**GIS**[T;G.2)] – Geographic Information System

**GIS**[T;G.3)] – Geospatial Information System

**GML** – Geography Mark-up Language

**GSHP** – Ground Source Heat Pump

**GTO** – Weighted Temperature Exceeding Hours

**GUI** – Graphical User Interface

**GUID** – Global Unique Identifier

**GWP** – Global Warming Potential

**<u>H,h</u>**

**HAI** – Healthcare Associated Infection strategy

**HAS** – French Health Authority

**HC** – Heating / Cooling systems

**HD**[T;H.1)] – Healthcare District

**HCU** – High Care Unit

**HCD** – Hospital Campus District

**HGL** – Hydraulic grade line

**HHP** – Hybrid Heat Pump

**Hi-Fu** – High Intensity Focused Ultrasound

**HIS** – Hospital Information System

**HIU** – Heat Interface Unit

**HRI** – Heat Reflectance Index

**HTM** – Health Technical Memorandums

**HTML** – Hypertext Markup Language

**HTS** – High-temperature systems

**HTTP** – Hypertext Transfer Protocol

**HVAC**[T;H.3)] – Heating, Ventilation, Air Conditioning

**HWS** – Hot Water System

**<u>I,i</u>**

**IAI** – International Alliance for Interoperability

**IAQ** – Indoor Air Quality

**IC** – Implementers Community

**ICC** – International Code Council

**ICT**[T;I.4)] – Information and Communication Technology

**ICU** – Intensive Care Unit

**ID –** Identifier

**IDM** – Information Delivery Manual

**IEC** – Integrated Energy Contracting

**IEC** – International Electrotechnical Commission

**IEE** – Intelligent Energy Europe

**IFC**[T;I.3)] – Industry Foundation Classes

**ifcOWL** – Web Ontology Language representation of the IFC schema

**IFD** – International Framework for Dictionary

**IFD** – Industrial, Flexible and Demountable Building (Dutch standards)

**IG** – Insulated Glazing

**IGCC** – Integrated Gasification Combined Cycle

**IGES** – Initial Graphics Exchange Specification

**ILCD** – International Reference Life Cycle Data system

**INSPIRE** – Infrastructure for Spatial Information in Europe

**IPCC** – Intergovernmental Panel on Climate Change

**IPD**[T;I.7)] – Integrated Project Delivery

**IPR** – Intellectual Property Rights

**IPS** – Indoor Positioning System

**IRR**[T;I.10)] – Internal Rate of Return

**ISG** – Implementation Support Group (buildingSMART)

**ISO** – International Organisation for Standardisation

**ISPO** – Istituto per lo Studio e la Prevenzione Oncologica (Cancer Prevention and Research Institute)

**IT** – Information Technology

**ITT** – Istituto Tumori Toscano (Institute for Cancer of Tuscany)

**J,j**

**JRC** – Joint Research Centre

**JSON** – JavaScript Object Notation

**K,k**

**KBE**[T;K.2)] – Knowledge Based Engineering

**KBS –** Knowledge Based System

**KER** – Key Exploitable Results

**KIT** – Karlsruhe Institute of Technology

**KML** – Keyhole Markup Language

**KPI**[T;K.1)] – Key Performance Indicator

**L,l**

**LCA**[T;L.6)] – Life Cycle Assessment

**LCC** – Life Cycle Cost

**LCCA** – Life Cycle Costs Analysis

**LCDN** – Life Cycle Data Network

**LCI** – Life Cycle Inventory

**LCIA** – Life Cycle Impact Assessment

**LCS** – Local Coordinate System

**LCV** – Lower Calorific Value

**LED** – Light Emitting Diode

**LFR** – Linear Fresnel Reflector

**LHV** – Lower Heating Value

**LoD**[T;L.5)] – Level of Detail / Level of Development

**LOD**[T;L.9)] – Linked Open Data

**LOI** – Level of Information

**LowE** – Low Emissivity or Low thermal Emissivity

**LPG** – Liquid Petroleum Gas

**LTHW** – Low Temperature Hot Water

**LTS** – Low-temperature systems

**M,m**

**MCA** – Multi Criteria Analysis

**MCDA** – Multi Criteria Decision Analysis

**MCDM** – Multi Criteria Decision Making

**MDM** – Mobile Device Management

**MDU** – Main Destination of Use

**md5** – Message Digest Algorithm 5

**MEP**[T; M.1)] – Mechanical, Electrical, Plumbing technologies

**MOA** – Project Owner (Maîtrise d'Ouvrage)

**MOE** – Project Supervisor (Maîtrise d'Oeuvre)

**MOM** – Management, Operation, Maintenance (costs)

**MRI** – Magnetic Resonance Imaging

**MSG –** Model Support Group (buildingSMART)

**MVD**[T;M.5)] – Model View Definition

**mvdXML**[T;M.6)] – model view definition eXtensible Markup Language

**N,n**

**NBHI** – Netherlands Board for Healthcare Institutions

**NBIMS** – National BIM Standard

**NCM** – National Calculation Method

**NCV** – Net Calorific Value

**NCV** – Net Cash Value

**NEN** – NL Norm

**NEP** – National Energy Plan

**NEP** – Normalized Electricity consumption Parameter

**NES**[T;N.2)] – Neighbourhood Energy System

**NHBI** – Netherlands Board for Healthcare Institutions

**NHS** – National Health Service

**NIBS** – National Institute of Building Sciences

**NIC** – Nuovo Ingresso Careggi (New Entrance Careggi)

**NIST** – National Institute of Standards and Technology

**NMF** – Neutral Model Format

**NMR** – Nuclear Magnetic Resonance

**NOK** – Not OKay

**NPV** – Net Present Value

**NZEB** – Near Zero Energy Buildings

**O,o**

**OBS** – Organization Breakdown Structure

**OEI** – Optimal Energy Infrastructure

**OGC** – Open Geospatial Consortium

**OMG** – Object Management Group

**OPD** – Out-patient Department

**OR** – Operating room

**ORC**[T;O.5)] – Organic Rankine Cycle

**OSM** – Open Street Map

**OSS** – Open Source Software

**OU** – Operative Unit

**OWL** – Web Ontology Language

**OWP** – Operational Work Plan

**P,p**

**PBS** – Product Breakdown Structure

**PC** – Project Coordinator

**PCM** – Phase-Changing Material

**PD** – Participatory Design

**PEP** – Polish Energy Policy

**PET** – Positron Emission Tomography

**PI**[T;P.5)]– Performance Indicator

**PICO** – Public Internal Performance Contracting

**PLM** – Product Lifecycle Management

**PMO** – Product Modelling Ontology

**POE** – Post Occupancy Evaluation

**POI** – Point Of Interest

**POP** – Product, Organization and Process

**PoR**[T; P.10)] – Program of Requirements

**POU** – Point-Of-Use electric storage

**PPP** – Public – Private Partnership

**PROST** – Public Procurement of Energy Saving Technologies in Europe

**PSC** – Project Steering Committee

**PTC** – Project Technical Committee

**PTS** – Program for Technical Standard

**PUDF** – Plan for Use and Dissemination of Foreground knowledge

**PUE** – Power Usage Effectiveness

**PUR** – Polyurethane

**PV** – Photovoltaic

**PVC** – Polyvinylchloride

**PVT** – PV Thermal

**Q,q**

**QUIPP** – Quality, Innovation, Productivity and Presentation

**R,r**

**RAP** – Room Appliance Program

**RASE** – Requirements, Applicability, Selection and Exception

**RDF** – Resource Description Framework

**RDFS** – Resource Description Framework Schema

**RDS**[T;R.6)] – Room Data Sheet

**RE** – Real Estate

**RE-Suite**[T;R.1)] – the existing real estate software tool of DEMO Consultants (P9)

**REAP**[T;R.7)] – Rotterdam Energy Approach and Planning

**ReqCap** – Requirements Management Tool

**RES** – Renewable Energy Sources

**RIBA** – Royal Institute for British Architects

**RIF** – Rule Interchange Format

**RMS** – Root Mean Square

**RNS** – Rijnstate Hospital

**ROI** – Return on Investment

**RTD** – Research Technology Development

**RTT** – Relative Travel Time

**<u>S,s</u>**

**S** – Surface area

**SACS**[T;S.1)] – System for the Analysis of Hospital Equipment (Sistema di Analisi delle Consistenze Strutturali)

**SALAR** – Swedish Association of Local Authorities and Regions

**SAP** – Standard Assessment Procedure

**SBEM**[T;S.11)] – Simplified Building Energy Model

**SBT** – Space Boundary Tool

**SC** - Subcommittee

**SCADA** – Supervisory Control And Data Acquisition

**SCBU** – Special Care Baby Unit

**SCOP** – Seasonal Coefficient of Performance

**SDC** – Semantic Design Configurator

**SDMP** – Sustainable Development Management Plan

**SDT** – Support-Decision Tool

**SDU** – Sustainable Development Unit

**SDU** – Secondary Destination of Use

**SEAP** – Sustainable Energy Action Plans

**SEER**[T;S.3)] – Seasonal Energy Efficiency Ratio

**SFA**[T;S.22)] – Sub-functional area

**SHP** – Separate Heat and Power

**SIG3D** – Special Interest Group 3D of German Spatial Data Infrastructure

**SKOS** – Simple Knowledge Organization System

**SMC** – Solibri Model Checker

**SOA** – Service-Oriented Architecture

**SOS** – Sensor Observation Service

**SoTA** – State of the art technology

**SPA** – Simple Partnership Agreement

**SPARQL** – SPARQL Protocol and RDF Query Language

**SPF**[T;S.4)] – Seasonal Performance Factor

**SPF**[T;S.18)] – STEP Physical File

**SPS** – Sensor Planning Service

**SQL** – Structured Query Language

**SRHR** – Single Room Heat Recovery

**SRI** – Solar Reflectance Index

**STEP** – Standard for the Exchange of Product Model Data

**STIL2** – Research into energy consumption in non-residential buildings by the Swedish Energy Agency

**STOR** – Short Term Operating Reserve

**STREAMER** – Semantics-driven Design through Geo and Building Information Modeling for Energy efficient Buildings Integrated in Mixed-use Healthcare Districts

**SU**[T;S.15)] – Spatial Unit

**SVN** – Version Control System

**SW** – Semantic Web

**SWG** – Standard Working Group (OGC)

**SWOP** – Semantic Web-based Open Engineering Platform

**SWRL** – Semantic Web Rule Language

**T,t**

**TBC** – TopBraid Composer (editor)

**TC** – Technical Coordinator

**TC** – Technical Committee

**TCO** – Transparent Conductive Oxide

**TCO** – Total Cost of Ownership

**TEA** – Tradable Emissions Allowances

**TECT** – TNO Energy Calculation Tool

**Tic**[T;S.23)] – Summer Thermal Comfort Index

**TIM** – Transparent Insulation Material

**TPF** – Third-Party Financing

**TRFT** – The Rotherham Foundation Trust

**TRL**[T;T.5)] – Technology Readiness Level

**TSV** – Tab Separated Value

**Turtle** – Terse RDF Triple Language

**U,u**

**U value (Ubat)**[T;U.1)] – U coefficient

**UCTE** – Union for the Coordination of the Transmission of Electricity (now ENTSO-E)

**UML** – Unified Modeling Language

**UNDP** – United Nations Development Programme

**UNI** – Italian National Body for Standardization (Ente Nazionale Italiano di Unificazione)

**Uniclass 2015** – UK Unified classification tables for the construction industry

**UPS** – Uninterruptible Power Supply

**UPVC** – Unplasticized Polyvinylchloride

**URI / URL** – Uniform Resource Identifier / Locator

**URN** – Uniform Resource Name

**USL** – Unita Sanitaria Locale (local health authority)

**UTM** – Universal Transverse Mercator

**UV** – Ultra Violet

**V,v**

**V** – Volume

**V-Con** – Virtual Construction for Roads

**VAV** – Variable Air Volume (in mechanical ventilation systems)

**VDA-FS** – Verband der Automobilindustrie – Flachenschnittstelle

**VDC** – Virtual Design in Construction

**VE** – Virtual Environment

**VFD** – Variable-Frequency Drive

**VL** – Ventilation

**VO** – Voltage Optimisation

**VRF** – Variable Refrigerant Flow system

**VRML** – Virtual Reality Modeling Language

**VSD**[T;V.1)] – Variable-Speed Drive

**W,w**

**W3C –** World Wide Web Consortium

**WBS** – Process Breakdown Structure

**WCS** – Web Coverage Service

**Web-EMCS** – Web-based Energy Management and Control System

**WFS** – Web Feature Service

**WG** – Working Group

**WHO** – World Health Organisation

**WHR** – Waste Heat Recovery

**WLC** – Whole Life Cost

**WMS** – Web Map Service

**WMTS** – Web Map Tile Service

**WP** – Work Package

**WPL** – Work Package Leader

**WPS** – Web Processing Service

**WPU** – Weighted Patient Unit

**WPU** – Weighted Personnel Unit

**WSHP** – Water Source Heat Pump

**WWW** – World Wide Web

<u>**X,x**</u>

**XMI** – XML Metadata Interchange

**XML**[T;E.13)] – eXtensible Markup Language

**XPS** – Expandable Polystyrene

**XSD** – XML Schema Definition

**XSLT** – Extensible Stylesheet Language Transformation

<u>**Y,y**</u>

<u>**Z,z**</u>