

## ANNEX 1 CATALOGUE OF FIELD STUDIES

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## 1 FS 1.A CLUSTER RESIDENTIAL MASTERPLANS: MAC DONALD

### 1.1 FACT SHEET

General information	
<b>Description</b>	<p>Boulevard Mac Donald is an urban redevelopment masterplan in the north of Paris, France. It centres around the rehabilitation of the old Mac Donald warehouses. It consists of 15 multi-family apartment buildings. A kindergarten has been integrated into one building and shops are located on the ground floor. Another part of the rehabilitation has integrated offices and a school, but this part is not included in the analysis.</p> <p>ALTO Ingénierie was environmental consultant for the 15 building units. The buildings had to achieve the following certifications: “Habitat &amp; Environment (H&amp;E)”<sup>1</sup> and “Bâtiment Basse Consommation (BBC)”<sup>2</sup></p>
<b>Involved parties</b>	<p>ICADE PROMOTION LOGEMENT – Developer and design team manager            OMA – Architect (rehabilitation strategy)            Floris Alkemade et Xaveer de Geyter, Christian de Portzamparc, Nicolas Michelin, Gigon et Guyer, Raphaëlle Hondelatte et Mathieu Laporte, Brenac-Gonzales, Julien de Smedt, Mia Haag, AUC Djamel Klouche, Stéphane Maupin, DVVD – Architects            ARCOBA – Building services and Mechanical Structure Engineers            DVVD – Façade engineering &amp; Cost consultant            ALTO INGENIERIE – H&amp;E Consultant            MAIN CONTRACTOR – Vinci Construction</p>
<b>Year</b>	2015

Geographical and building characteristics						
Building	Climate zone, Location	Typology	Type	Scale	Stage	
N5	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	44 apartment units – 3 571m <sup>2</sup> SHON	In-use	
N6	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	60 apartment units – 4 544m <sup>2</sup> SHON	In-use	
S6	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	43 apartment units – 3 749 m <sup>2</sup> SHON	In-use	
S7	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	82 apartment units – 7 355m <sup>2</sup> SHON	In-use	
E1	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	147 apartment units – 4 174m <sup>2</sup> SHON	In-use	
N1	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	45 apartment units – 5 041m <sup>2</sup> SHON	In-use	
N2	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	90 apartment units – 5 905m <sup>2</sup> SHON	In-use	

<sup>1</sup> Habitat & Environnement certification, <http://www.qualite-logement.org/certification-et-labels/connaitre-les-certifications-de-qualite-neuf/autres-certifications/qualitel-habitat-environnement.html>

<sup>2</sup> BBC: Bâtiment Basse Consommation (Low Energy Building): Standards with related label for Low Energy Buildings in France. <http://www.norme-bbc.fr/>

S1	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	50 apartment units – 3 558m <sup>2</sup> SHON	In-use
S2	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	138 apartment units – 8 021m <sup>2</sup> SHON	In-use
O1	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	78 apartment units – 5 910m <sup>2</sup> SHON	In-use
N3	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	84 apartment units – 6 859m <sup>2</sup> SHON	In-use
N4	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	61 apartment units – 4 727m <sup>2</sup> SHON	In-use
S3	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	128 apartment units – 3 458m <sup>2</sup> SHON	In-use
S4	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	33 apartment units – 2 675m <sup>2</sup> SHON	In-use
S5	Central-Europe, Paris (FR)	Residential: Apartment block	New-build	42 apartment units – 3 279m <sup>2</sup> SHON	In-use

### Relevant professional context

Assessment according to specific criteria in a building scheme/tool:

- H&E version 2008 (updated 2009), profile “A” – level “performance”
- BBC Effinergie, according to French energy performance regulation RT 2005

## 1.1. MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

### 1.1.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Operational carbon emissions
- Embodied carbon emissions

#### → Improvement option(s)

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce energy consumption		
<b>RT 2005</b> : energy consumption considered by local regulation	Cep < Cep reference	ALL
Energy labelling " <b>BBC Effinergie</b> " Energy consumption and Air tightness requirements	Cep < 65 kWh/m <sup>2</sup> .year <1m <sup>3</sup> /(h.m <sup>2</sup> )	ALL
<b>Climate plan of the city of Paris:</b> local requirements for energy consumption	Cep < 50 kWh/m <sup>2</sup> .year	ALL
<b>Urban developer:</b> Building envelope	Imposition on U value, % of glazed	ALL

Evaluation criteria	Performance target	Project concerned
requirements	surface per orientation, thermal bridges value	
<b>Improvement option:</b> LZC energy sources To reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand.		
<b>Urban developer :</b> Reduce building regular energy consumption by using LZC energy	- 25% of total energy consumptions allowed by renewable energy - 30% of the energy consumption covered by renewable energy should concerned hot water consumption	ALL

#### Detailed discussion:

**Cep:** Conventional energy consumption of a building for heating, cooling, domestic hot water, electricity for pumps and fans, and lighting facilities are expressed in kWh/m<sup>2</sup> /year in primary energy.

**BBC Label EFFINERGIE:** the energy target is not given in absolute value. This label requires designing buildings more efficient than conventional buildings.

The target on residential buildings is Cep < 65 kWh/m<sup>2</sup>.year

**Air tightness** requirements are linked to BBC Effinergie energy label. Projects have to achieve this goal controlled by a third part and framed by a protocole.

#### → **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Regulation calculation tool	Climawin 4.2 1.0.3	RT 2005 New building	ALL
Air tightness measurement protocol	Measure for each building	NF EN 13 829 Manual GA P 50-784	ALL

#### → **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Regulation calculation tool	Design stage And checked ad Post construction stage	Contractors Mechanical Engineers	Architect + Environmental Consultant
Air tightness measurement protocol	Checked drawing's details and specification at design stage (ALTO's mission) Several check points during works and a final test at the end of	Air Tightness measure operator	Architect + Environmental Consultant + Contractors

	work completion		
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Detailed discussion:

In the building design phase, energy demand is calculated by taking into account the local regulation and energy label requirement.

Energy experts take the lead and have supports from architects. When an environmental consultant is associated to the projects, it could be lay stress on the fact that a complete control of values specified in prescriptions is done and checked in the case of certification process.

In the construction phase, the regular inspection of the quality of the construction works by the architect and responsible contractor is a very important task considering that some modifications could occur during works phase.

The execution of quality assurance tests (by a third party as for example the environmental consultant) is useful to indicate during the course of the construction works whether the final targets are realisable or to which specific issues extra attention should be paid.

Calculation of energy demand is required to get an energy label as BBC renovation.

It is often done by the general contractor or HVAC contractor.

Those data are updated in the final energy demand calculations of our cluster:

- in use ventilation rates verified via measurements by inspections
- results from duct air leakage tests according to NBN EN 12237
- performance of envelope's insulation and glazing
- air tightness measure results

#### 1.1.2. INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

Indicator	Unit of measurement	Scope
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>		
Q4Pa_Surf	m <sup>3</sup> /(h.m <sup>2</sup> )	After work completion
Primary Energy Consumption (Cep)	kWh/m <sup>2</sup> a	In Use due to heating, cooling, lighting, hot water, ventilation & auxiliary, and relative to thermal surface
Energy consumption covered by renewable energy	%	In Use due to heating, cooling, lighting, hot water, ventilation & auxiliary, and relative to thermal surface

##### → Indicator #1: Q4Pa\_Surf

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

##### **Technical specifications**

- **Unit of measurement :** m<sup>3</sup>/(h.m<sup>2</sup>)

- **Scope of indicator:** reduce energy consumption (and maximise global air quality)
  - o Associated data requirements: Volumetrics of the building, type of insulation, type of ventilation, structure, materials of construction (frame), surfaces
- Associated timeframe, conditions and requirements for measurement: respect of Manual GA P 50-784
- Supporting tools required to quantify/estimate performance: operator for testing material compliant with NF EN 13 829
- Source of indicator/metric and its scientific and market acceptance: sans objet

**Overview and results:**

Indicator	Results (As built)	
B1: Greenhouse gas emissions from building life cycle energy use		
Q4Pa_Surf	Building N5	0,67 m3/(h.m²)
	Building N6	0,49 m3/(h.m²)
	Building S6	0,66 m3/(h.m²)
	Building S7	0,1 m3/(h.m²) <i>Not reliable</i>
	Building E1	0,99 m3/(h.m²)
	Building N1/N2	0,54 m3/(h.m²)
	Building S1	0,74 m3/(h.m²)
	Building S2	0,64 m3/(h.m²)
	Building O1	0,69 m3/(h.m²)
	Building N3	0,45 m3/(h.m²)
	Building N4	0,27 m3/(h.m²)
	Building S3	0,44 m3/(h.m²)
	Building S4	0,35 m3/(h.m²)
	Building S5	0,33 m3/(h.m²)

→ **Indicator #2: Primary Energy Consumption (Cep)**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions, embodied carbon emission

**Technical specifications**

- **Unit of measurement :** kWh/m<sup>2</sup>a
- **Scope of indicator:** the net energy consumption includes all energy use for space heating, space cooling, domestic hot water, auxiliary energy and the energy use for collective functions such as elevators and outdoor lighting in the entire neighbourhood, and the household electricity is not taken into account for the theoretical calculation, however can be measured by metering data.
- Associated data requirements: building geometry, building materials, energy systems are needed to have this indicator
- Associated timeframe, conditions and requirements for measurement: manufacturers data and calculation from design team/contractor to specify systems
- Supporting tools required to quantify/estimate performance : specific software
- Source of indicator/metric and its scientific and market acceptance: ASHRAE 90,1-2007 Appendix G methodology has to be followed to achieve LEED requirements

**Overview and results:**

Indicator	Results (As built)	
B1: Greenhouse gas emissions from building life cycle energy use		
Primary Energy Consumption (Cep)	Building N5	63,4 kWh/m².an
	Building N6	57,4 kWh/m².an
	Building S6	63,7 kWh/m².an
	Building S7	64,4 kWh/m².an <i>Not reliable</i>
	Building E1	64,3 kWh/m².an
	Building N1/N2	61,7 kWh/m².an
	Building S1	60,8 kWh/m².an
	Building S2	62,4 kWh/m².an
	Building O1	55,1 kWh/m².an
	Building N3	56,8 kWh/m².an
	Building N4	53,6 kWh/m².an
	Building S3	59,3 kWh/m².an
	Building S4	61,36 kWh/m².an
Building S5	64,07 kWh/m².an	
Energy consumption covered by renewable energy	ALL	Heat district network CPCU <a href="http://www.cpcu.fr/">http://www.cpcu.fr/</a> Energy from combustion of organic material (wastes)

→ **Indicator #3: Energy consumption covered by renewable energy**

**Overview and results:**

Indicator	Results (As built)	
B1: Greenhouse gas emissions from building life cycle energy use		
Energy consumption covered by renewable energy	ALL	Heat district network CPCU <a href="http://www.cpcu.fr/">http://www.cpcu.fr/</a> Energy from combustion of organic material (wastes)

**1.1.3. LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

The targets required by the masterplan were not easy to combine with the architectural concepts. A specific expertise – steady state calculation methodology in line with the French Thermal Regulation 2005 – was provided by ALTO Ingénierie regarding energy consumption optimization to fulfill the masterplan requirements and at the same time support the designers in finding solutions that would meet the initial targets as much as possible. The required percentage of glazing per façade was not met.

The integration of new buildings alongside the existing 600 meter long building was a challenge in terms of structure and airtightness. Compromises had to be found to ensure BBC labelling and conservation of the existing structure. As a result, light-weight façades were chosen for some buildings to reduce the building energy loads as much as possible.

Data used for the energy certifications was derived from the as-built documents. Energy labelling and energy consumption requirements were already mandatory.

In the construction phase, it is very important that the architect and responsible contractor inspect the quality of the work in progress very regularly considering the fact that some modifications may occur during construction.

The execution of quality assurance tests (by a third party, for example the environmental consultant) during the construction work was useful to indicate whether the final targets were realistic or whether there were specific issues to which extra attention should be paid.

The calculation of energy demand is required to earn an energy label as a BBC renovation. It is often done by the general contractor or HVAC contractor. This data is then updated in the final energy demand calculations:

- o in use ventilation rates verified via measurements by inspections;
- o results from duct air leakage tests according to NBN EN 12237;
- o performance of building envelope's insulation and glazing;
- o airtightness results.

In Paris, checks from CERQUAL<sup>3</sup> - the HQE certification body – are getting stricter and stricter. This is not the case everywhere in France. As a result, the as-built construction may not always be at the same level of quality as the design. This third party check is important to ensure environmental performance.

## 1.2. MACRO-OBJECTIVE B3: WATER USE

### 1.1.2 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Water consumption

#### → Improvement option(s)

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce the consumption of potable water for sanitary use in buildings from all sources through the use of water efficient components and water recycling systems		
<b>H&amp;E Water economy:</b> requirements from section <i>Economie d'Eau</i> of certification scheme	<ul style="list-style-type: none"> <li>- WC 3/6L</li> <li>- Distance of 10m between production and point of use max</li> <li>- Pressure of 3 bars (NF EN 1567)</li> <li>- Plumbing classified ECAU / E1C2 (<a href="http://evaluation.cstb.fr/classement/ecau/">http://evaluation.cstb.fr/classement/ecau/</a>)</li> <li>- Showers and Bath with Thermostatic mixing valve</li> <li>- Plumbing certified "NF – Robinetterie de réglage et de sécurité."</li> <li>- Individual meters in each apartment</li> </ul>	ALL

<sup>3</sup> CERQUAL is the certification body in France for the BBC label



#### Detailed discussion:

The residential certification lead by CERQUAL<sup>4</sup> does not specify a limitation of water consumption per flat/home per day or year or person. As a result only a few requirements are linked to the certification schemes:

- Toilet flush WC 3/6 litres per flush;
- Maximum distance of 10m between production and point of use;
- Pressure of 3 bars (NF EN 1567);
- Sanitary appliances classified ECAU / E1C2<sup>5</sup>;
- Showers and bathtubs with thermostatic mixing valve;
- Individual meters in each apartment.

The certification scheme emphasizes the quality framed by French rate ECAU<sup>5</sup>. Class “E” is linked to the water flow rate (while C, A and U relate to ergonomic, acoustic and durability requirements respectively). Class "E" is split into the following performance levels:

- E0: (9 l/min  $\leq$  q < 12 l/min);
- E1: (12 l/min  $\leq$  q < 16 l/min);
- E2: (16 l/min  $\leq$  q < 20 l/min);
- E3: (20 l/min  $\leq$  q < 25 l/min) – Minimum for bath;
- E4: (25 l/min  $\leq$  q ).

Additionally, criterion C2 requires that sanitary appliance be equipped with an “economy position”, which implies that the flow rate has to correspond with category C2 (flow rate between 0,11L/s and 0,14 L/s).

#### → **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Manufacturer's literature and Design specification checking	-	Certification scheme	ALL

#### → **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Manufacturer's literature and Design specification checking	Design stage And checked ad Post construction stage	Environmental consultant	Architect + Plumbing Engineers + Contractors

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<sup>4</sup> CERQUAL is a French certification body for low energy building certifications in France

<sup>5</sup> CSTB (2016) *Le classement ECAU* [online], available at <http://evaluation.cstb.fr/classement/ecau/> [20/5/2016]

Detailed discussion:

During construction, performance of plumbing equipment are verified based upon manufacturer's data collected by the contractor.

**1.2.2. INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)**

→ **Overview**

Indicator	Unit of measurement	Scope
B3: Water Use		
Implementation of plumbing equipment required by H&E certification scheme	-	-

→ **Indicator #3: Implementation of plumbing equipment required by H&E certification scheme**

- *Macro-objective:* B3: Water Use
- *Specific aspect(s):* Water consumption

**Technical specifications**

- **Unit of measurement :** -
- **Scope of indicator:** checking compliance of specification and plumbing equipment installed
- Associated data requirements:-
- Associated timeframe, conditions and requirements for measurement: -
- Supporting tools required to quantify/estimate performance : -
- Source of indicator/metric and its scientific and market acceptance: manufacturer's literature

**Results**

Overview and results:

Overview and Results:		
Indicator	Results (As built)	
B3: Water Use		
Implementation of plumbing equipment required by H&E certification scheme	ALL	<ul style="list-style-type: none"><li>- WC 3/6L</li><li>- Distance of 10m between production and point of use max</li><li>- Pressure of 3 bars (NF EN 1567)</li><li>- Plumbing classified ECAU / E1C2 (<a href="http://evaluation.cstb.fr/classement/ecau/">http://evaluation.cstb.fr/classement/ecau/</a>)</li><li>- Showers and Bath with Thermostatic mixing valve</li><li>- Plumbing certified "NF – Robinetterie de réglage et de sécurité."</li><li>- Individual meters in each apartment</li></ul>

### 1.2.3. LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

Achieving H&E (HQE) certification was a priority from several standpoints: client expectation, the aims of the environmental management system of the developer and, most importantly, a mandatory requirement for certification set out in the masterplan. Overall, meeting the water consumption requirements for certification was not a significant challenge for the design team or contractors. It was possible to use the data received directly from suppliers in calculations and post-construction performance was checked to ensure it fulfilled design conditions. The design team felt an actual water consumption target would have been more interesting to work towards, but also more challenging.

### 1.3. REFERENCES

Entrepôt MacDonald (2016), *Entrepôt MacDonald*, available at : <http://www.entrepotmacdonald.com/> [1/8/2016]

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## 2 FS 1.B CLUSTER RESIDENTIAL MASTERPLANS: ECO-LIFE

### 2.1 FACT SHEET

General information					
Description	<p>The ECO-Life project comprises various sub-projects in the city of Courtray, Belgium. For this study, the following sub-projects are analyzed: the Venning district and two apartment blocks at Drie Hofsteden.</p> <p>Venning garden city was built in the 1960s on the far side of Kortrijk–Bossuit canal and consisted of 163 rental homes. In 2010, the neighbourhood was redeveloped with the objective of achieving a CO2-neutral social housing district. Three zones are distinguished. In Zone 1, 34 houses on the canal side were demolished in 2011 and replaced with 70 new energy self-sufficient apartments and 12 flats. Zone 2 consisted of 64 new homes and Zone 3 comprised the renovation of 50 existing homes. At present, all 196 homes in the neighbourhood are ready for occupation.</p> <p>“Drie Hofsteden” district contains two large apartment blocks. The building considered for this study is Block V, built from 1971 to 1974. This building is split into 108 apartments, all heated individually electricity. Renovation is on-going on one part of the building according to low-energy standards Europe has imposed for 2020. Electric heating is replaced by an economical, communal gas heating system.</p> <p>The following projects are not covered in the study but might be relevant, considering their relation with the discussed projects: social housing apartments Pottenbakkershoek (the other sub-project and part of ECO-Life) and block IV of “Drie Hofsteden” (120 apartments, part of the Living Lab dwelling renovation programme, funded by VLAIO<sup>6</sup>)</p>				
Involved parties	BURO II & ARCHI+I, Ghent University, Goedkope Woning				
Year	2010 – 2016				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Zone 1a	Central-Europe, Courtray (BE)	Residential: apartment blocks	New-build	3 buildings (70 dwelling units)	In-use
Zone 1b	Central-Europe, Courtray (BE)	Residential: multi-family house	New-build	1 building (12 dwelling units)	In-use
Zone 2	Central-Europe, Courtray (BE)	Residential: terraced	New-build	64 dwellings	In-use
Zone 3	Central-Europe, Courtray (BE)	Residential: terraced	Renovation	50 dwellings	In-use
Block V	Central-Europe, Courtray (BE)	Residential: apartment block	Renovation	1 building (108 dwelling units)	Construction
Building age of the renovated buildings: Apartment block: 1970s; single-family houses: 1960s					
Relevant professional context					
Field studies carried out by collaborative EU projects					
<p>The aim of the "ECO-Life project" is to demonstrate innovative integrated energy concepts throughout three countries in the EU where urban areas will be transformed into CO2-neutral communities. The three communities in the project are: Høje Taastrup in Denmark, Kortrijk in Belgium and Birstonas in Lithuania. The project is funded under the CONCERTO Initiative.</p> <p><b>Private or public sector buildings and portfolios</b></p> <p>The project is commissioned by the social housing company “Goedkope Woning” in Courtray. Both</p>					

<sup>6</sup> Flemish agency for innovation and entrepreneurship

the apartment blocks as the single family houses are part of the social housing.

## 2.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

### 2.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Operational carbon emissions

Phase 1 to 3 of the Venning District are monitored by the University of Ghent. Objective of the research project is to compare predicted performance to actual performance. Measurements on energy performance are executed such as blower door tests and thermographic analyses, in addition to monitoring of energy consumption and indoor environmental parameters (such as indoor temperature, humidity and CO<sub>2</sub> level). The study will provide us with much information on how residents handle the new facilities, and which facilities they find more suitable than others. De Venning is the first large-scale research project in which different construction and ventilation systems are studied, tested and compared against each other. During and after the study, discussions will be held with the residents to find out how optimal results can be achieved.

#### → Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
<b>Zone 1a</b> <b>Zone 1b</b> <b>Zone 2</b>	Thermal bridge free design; Passive house windows; Ventilation with heat recovery; Improved insulation; Airtight construction; Low temperature heating; On-site renewables;	Belgian Passiefhuis-platform (PHP) for residential buildings	<ul style="list-style-type: none"><li>• Space heating/cooling demand <math>\leq 15</math> kWh/m<sup>2</sup>year;</li><li>• Primary energy demand <math>\leq 120</math> kWh/m<sup>2</sup>year;</li><li>• Airtightness <math>\leq n50 - 0.6/h</math></li><li>• Risk of overheating <math>\leq 5\%</math></li></ul>
<b>Zone 1a</b> <b>Zone 1b</b> <b>Zone 2</b>	Thermal bridge free design; Passive house windows; Ventilation with heat recovery; Improved insulation; Airtight construction; Low temperature heating; On-site renewables;	Local EPBD-legislation	<ul style="list-style-type: none"><li>• E60</li><li>• K40</li></ul>
<b>Zone 3</b> <b>Block V</b>	Thermal bridge free design; Passive house windows; Ventilation with heat recovery; Improved insulation; Airtight construction; Low temperature heating; On-site renewables;	Local EPBD-legislation	<ul style="list-style-type: none"><li>• E90</li></ul>

#### Detailed discussion:

The target of the ECO-Life project is to establish zero-carbon neighbourhoods. This general target was translated into an unambiguous definition and a number of characteristics and requirements. In a zero-carbon neighbourhood the energy use is covered or compensated by energy generated in

the neighbourhood from sustainable zero-carbon energy sources. The metric of the balance is CO<sub>2</sub>-equivalents and the balancing period is one year. This means that the net amount of CO<sub>2</sub>-equivalents released on a yearly basis should be zero. At building level, the target is translated with flexibility, meaning that some buildings might perform better than the others, but the overall target remains the carbon neutral.

Energy supply sources include for example solar energy, geothermal energy and biomass from sustainable and reliable origin, and they are considered as zero-carbon sources in this project. The scope of the zero-balance stays at the neighbourhood scale, therefore the energy generation actually can happen both on building and neighbourhood level. The buildings and energy supply in the neighbourhood are connected to collective low temperature heating network on neighbourhood scale and to national electricity network, so the neighbourhood is not autonomous.

The buildings should comply with the Flemish regulation on energy performance and indoor climate, and the passive house requirements are taken as a guideline to reduce the energy demand for space heating and cooling drastically. Zone 1 has 82 newly built apartments, while zone 2 has 64 newly built houses. The building design of the new buildings in zone 1 and zone 2 are mainly guided by the passive house standards. 50 existed houses are renovated in zone 3, and the overall target is to perform two times better comparing with the local EPBD legislations in terms of energy performance and thermal insulation, while the thermal insulation target complies with the passive house requirements. Zone Block V is still under construction.

First and foremost, passive house requirements are used as the guideline at design stage. Design and implementation of the following principles can help the building to reach the passive house targets, and these measures include: ventilation with efficient heat recovery, envelope insulation with U value  $\leq 0.15 \text{ W/(m}^2\text{K)}$ , passive house windows with U value  $\leq 0.8 \text{ W/(m}^2\text{K)}$  and airtight construction. Specially, uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pa. In addition, local energy generation and low temperature heating network in this project are also active and pragmatic measures in order to meet the passive house requirement from energy perspective.

For new buildings in zone 1 and zone 2, airtightness is explicitly set as another important target for meeting the passive house requirement,  $0.6 \text{ h}^{-1}$  at 50 Pa. It should be pointed out that the airtightness blower door test is mandatory for passive house certificate in Belgium. Risk of overheating below 5% is another essential requirement of passive house, and the buildings in this project should reach this thermal comfort target, however this target will only be covered in section 1.3 for analysing the trade-offs between different macro objectives - being thermal comfort and energy saving in this case.

Apart from the passive house requirements, the performance targets of new and renovated buildings should also comply with the Flemish regulation on energy performance and indoor climate. In Flemish context, local EPBD standard is the transposition of the Energy Performance of Buildings Directive (EPBD) (2002/91/EG) and the revised EPBD (2010/31/EU) issued by the European Union. The EPBD standard has evolved in the course of the years. Equivalently, the passive house targets can also be found as E-level and K-level in Flemish EPB standard. The core value, E-level in the Flemish regulation is a dimensionless primary energy consumption calculation that includes heating, cooling, ventilation, domestic hot water and auxiliary energy (monthly balancing period). The E-level reflects the degree of energy consumption of a building, and it is the annual primary energy consumption divided by a reference consumption. The 2015 requirement for new building is E60, and nearly zero energy building (NZEB) in 2021 will be E30 for residential building.

Another key metric in the Flemish EPBD is the thermal insulation K-level. The K-level reflects the degree of global building thermal insulation. It depends on characteristics of thermal insulation exterior walls and the compactness of the building, such as the ratio between the volume and surface of thermal losses. The 2015 requirement for new building is K40, while K40 for NZEB as well. For the buildings in zone 1 and zone 2, the targets are even more strict than the requirements in EPBD legislation, setting as E25 – E30 and K15 for both apartment and house, and this is already below the NZEB requirements.

The 2015 Flemish EPBD requirement for buildings with major renovation is E90, while the actual performance targets for the renovated houses in zone 3 with quite some ambitions. The overall target is to perform two times better comparing with the local EPBD legislations. To be more specific, the net heating demand target for renovated houses is set as 15 – 30 kWh/m<sup>2</sup>, which actually comply with the low energy houses in Flanders. Besides, E30 – E37 and K20 for renovated houses are actually two times better than the current requirements for new buildings. Furthermore, the maximum U-values are also stipulated by the local EPBD standard.

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
<b>Zone 1</b> <b>Zone 2</b> <b>Zone 3</b>	Theoretical calculation (Energy, insulation)	EPBD tools	Local EPBD-legislation
<b>Zone 1</b> <b>Zone 2</b> <b>Zone 3</b>	Theoretical calculation (Energy)	PHPP	Passive house standards
<b>Zone 1</b>	Measurement campaign (Energy consumption, temperature)	Meters/Sensors installed at different levels/sub-levels	-
<b>Zone 1 (25 dwellings)</b>	Detailed simulation models (Energy, temperature)	TRNSYS software	-
<b>Zone 1 (17 dwellings)</b>	Quality assurance tests	Blower door test; Infra-red thermography; Ventilation flow rates inspection; Duct air leakage tests; Co-heating test	EN 13829 NBN EN 12237

Detailed discussion:

Energy demand is primarily calculated by different ways in design phase. Regulatory calculation is based Flemish EPBD regulation by using EPBD tools. As mentioned before, main outputs derived from Flemish EPBD tools are the E-level and K-level values. Furthermore, in order to meet the energy requirement in passive house standards, the energy demand is also calculated by using Passive House Planning Package (PHPP). PHPP is an easy to use planning tool for energy efficiency for the use of architects and planning experts. The reliability of the calculation results and ease of use of this planning tool has already been experienced by several thousand users. The main results include heating demand, cooling demand, frequency of overheating, demand for renewable primary energy, primary energy demand and renewable energy gains.

An important goal of the ECO-Life project is to reach the high energy performance targets and quality of life during operation and occupancy. To validate the actual energy performance, monitoring systems are installed at district, building and dwelling levels while measurement campaigns are conducted in different periods. Zone 1 was the first of the ECO-life project phases to be occupied and monitored in September 2013. During the first monitoring year, most of the meter readings were collected manually and therefore they are limited to the general energy monitoring meters: total heat use and total electricity use of each dwelling. In the dwellings, three levels of metering were identified: general metering in all dwellings, detailed metering in a sample of dwellings and additional metering in a small sample for in-depth studies. The monitoring details at different levels can be found in the table below. In addition to the individual dwelling units, the communal heat generation, the supply and return temperatures at the heating plant, the electrical energy delivered by PV systems as well as electrical energy used from the grid are also gathered. The resolution of the acquired monitoring data is 1 minute, 5 minutes, 15 minutes or at least once per hour automated meter readings.

All dwellings	Detailed (25% of dwellings)	Additional monitoring
Total heat use	Heat use for domestic hot water, space heating and pre-heating ventilation supply air	Windows's state (open/closed) (10% dwellings)
Total electricity use	Disaggregated electricity use (lighting, kitchen equipment, bathroom, exterior, storage room and auxiliaries)	Sunscreen's state (open/closed) (6% dwellings)
Temperature in the living room	Temperature in the main bedroom	Temperatures of ventilation: inlet/outlet and supply/exhaust air (4% dwellings)
Total water use	Relative humidity in the living room	

25 exemplary apartments are modelled and the effect of the identified defects on the heat demand and indoor temperature is investigated using TRNSYS software. Three different district heating substation models are set up for investigation of the overall energy use, energy efficiency and comfort issues.

Besides, to evaluate the actual operation of the building and systems, commissioning activities were executed not only during the construction works, but continued during the first years of occupancy. The commissioning activities are mainly quality assurances tests, such as airtightness tests, infra-red thermography, co-heating test and ventilation flow rate measurements, automated monitoring of the energy flows and indoor and outdoor climate.

## 2.2.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(s)

### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
<b>Carbon emission</b>	tCO <sub>2</sub> e	Building use stage <ul style="list-style-type: none"> <li>EPBD-calculation (design/post-construction stage)</li> </ul>	B1: Greenhouse gas emissions from building life cycle energy use
<b>Net energy demand</b>	[kWh/m <sup>2</sup> year]	Building use stage; total energy demand or energy demand for heating, cooling, domestic hot water and auxiliary energy <ul style="list-style-type: none"> <li>EPBD-calculation (design/post-construction stage)</li> <li>PHPP-calculation (design/post-construction stage)</li> <li>Metering and monitoring data for verification (in-use stage)</li> </ul>	B1: Greenhouse gas emissions from building life cycle energy use
<b>Primary</b>	[kWh/m <sup>2</sup> year]	Building use stage	B1: Greenhouse gas



<b>energy consumption</b>	or E-level	<ul style="list-style-type: none"> <li>• EPBD-calculation (design/post-construction stage)</li> <li>• PHPP-calculation (design/post-construction stage)</li> <li>• Metering and monitoring data with conversion factor for verification (in-use stage)</li> </ul>	emissions from building life cycle energy use
<b>Thermal insulation level</b>	K-level	Building construction stage <ul style="list-style-type: none"> <li>• EPBD-calculation (design/post-construction stage)</li> <li>• Measurement and tests (post-construction stage)</li> </ul>	B1: Greenhouse gas emissions from building life cycle energy use
<b>Air tightness</b>	[h <sup>-1</sup> ]	Building use stage <ul style="list-style-type: none"> <li>• Design/post-construction stage</li> <li>• Measurement and tests (post-construction stage)</li> </ul>	B1: Greenhouse gas emissions from building life cycle energy use

One remark is that TRNSYS is used to conduct the dynamic simulation in this project, both of the heat demand and indoor comfort are simulated, and heat demand is indirectly calculated by using the temperatures of the HVAC system.

#### → Indicator #1: CO<sub>2</sub> emission

- *Macro-objective: B1: Greenhouse gas emissions from building life cycle energy use*
- *Specific aspect(s): Operational carbon emissions*

#### **Technical specifications**

- Unit of measurement: tCO<sub>2</sub>e;
- Scope of indicator: Use stage;
- Life cycle stage (with reference to EN 15643): B6 in use stage;
- Midpoint(s) and/or parameters: not applicable;
- Functional unit: at district level, time scale is one year;
- Associated data requirements: data on building geometry, building materials, energy systems are needed to have this indicator;
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): not applicable;
- Supporting tools required to quantify/estimate performance: Flemish EPBD tools.
- Source of indicator/metric and its scientific and market acceptance: calculated in Flemish EPBD tools (with conversion factors, linked to primary energy), also commonly used in scientific publications to quantify the CO<sub>2</sub> emission;

#### **Results**

Project / case study	CO <sub>2</sub> Emission [tCO <sub>2</sub> e]
Zone 1a	0
Zone 1b	0
Zone 2	0
Zone 3	0
Block V	0

Detailed discussion:

As mentioned in previous sections, the target of the ECO-Life project is to establish zero-carbon neighbourhoods. This general target was translated into an unambiguous definition and a number of characteristics and requirements. In a zero-carbon neighbourhood the energy use is covered or compensated by energy generated in the neighbourhood from sustainable zero-carbon energy sources. The metric of the balance is tCO<sub>2</sub>e and the balancing period is one year. This means that the net amount of tCO<sub>2</sub>e released on a yearly basis should be zero.

It should be pointed out that this indicator of CO<sub>2</sub> emission is not evaluated at building level in this project. CO<sub>2</sub> emission is calculated at the district level with taking into account the global energy balance between generation and consumption.

#### ***Cross-links and trade-offs***

CO<sub>2</sub> emission is closely linked with energy performance, especially at the operation stage. CO<sub>2</sub> emission is usually calculated by multiplying the primary energy with a conversion factor.

#### **→ Indicator #2: Net energy demand**

- *Macro-objective: B1: Greenhouse gas emissions from building life cycle energy use*
- *Specific aspect(s): Operational carbon emissions*

#### ***Technical specifications***

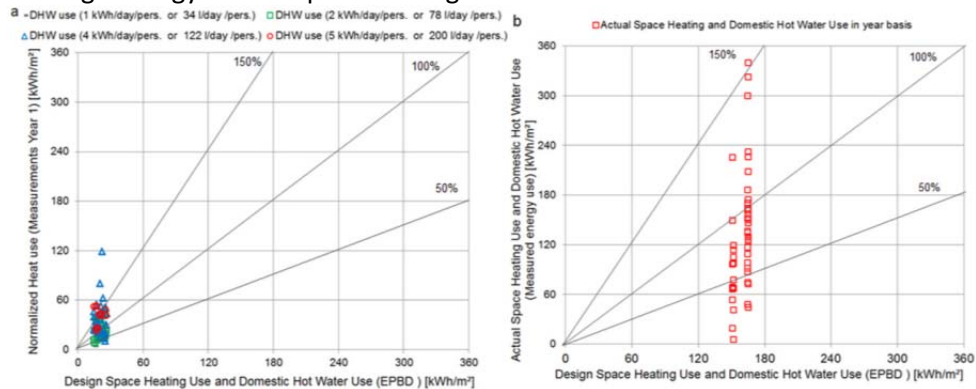
- Unit of measurement: kWh/m<sup>2</sup>year
- Scope of indicator: net energy demand includes all energy demand for space heating, space cooling, domestic hot water, auxiliary energy and the energy demand for collective functions such as elevators and outdoor lighting in the entire neighbourhood, and the household electricity is not taken into account for the theoretical calculation, however can be measured and verified by metering data. There are different calculation methods used in this project in order to calculate/measure this indicator, notably:
  - o EPBD-calculation (design/post-construction stage)
  - o PHPP-calculation (design/post-construction stage)
  - o Metering and monitoring data as verification (in-use stage)
- Life cycle stage (with reference to EN 15643): B6 in use stage;
- Midpoint(s) and/or parameters: not applicable;
- Functional unit: at building level, time scale is one year;
- Associated data requirements: data on building geometry, building materials, energy systems are needed to have this indicator;
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): Venning Phase 1 was the first of the ECO-life project phases to be occupied and monitored in September 2013. During the first monitoring year, most of the meter readings were collected manually and therefore they are limited to the general energy monitoring meters: total heat use and total electricity use of each dwelling.
- Supporting tools required to quantify/estimate performance: Flemish EPBD tools, PHPP software, energy meters for measurements.
- Source of indicator/metric and its scientific and market acceptance: calculated in Flemish EPBD tools, commonly used in either scientific publications or local regulations;

#### ***Results***

Project / case study	Design EPBD [kWh/m <sup>2</sup> a]	Measurement [kWh/m <sup>2</sup> a]
Zone 1a	6	30 (average metering value for heating)
Zone 1b	6	30 (average metering value for heating)

Zone 2	27 (system C) 15 (system D)	-
Zone 3	27 (system C) 15 (system D)	-
Block V	6	-

Actual and design energy use for space heating and domestic hot water in zone 1:



#### Detailed discussion:

Designed net energy demand is calculated by local EPBD tools, and the designed energy demand for the new buildings and the renovated ones are rather low. Meters are installed at different levels to measure and verify the designed energy demand. The gap between actual and designed energy performance can be seen above in the graphs. It can be seen from the results that energy demand for heating varies strongly between the dwellings.

#### **Cross-links and trade-offs**

Energy performance and insulation level are usually inherently linked together, and it is common to see that well insulated buildings theoretically usually perform better from energy perspective. Insulation level and airtightness are also usually linked together.

An important trade-off here is linked to thermal comfort (i.e. the overheating target: this target does not relate to reduction of carbon emissions but does target the trade-off with thermal comfort). The net energy demand is constrained through requirements for comfort and indoor climate.

#### → **Indicator #3: Primary energy consumption**

- *Macro-objective: B1: Greenhouse gas emissions from building life cycle energy use*
- *Specific aspect(s): Operational carbon emissions*

#### **Technical specifications**

- Unit of measurement: kWh/m<sup>2</sup>year
- Scope of indicator:
  - o EPBD-calculation (design/post-construction stage)
  - o Metering and monitoring data as verification (in-use stage) by multiplying primary energy factors
- Life cycle stage (with reference to EN 15643): B6 in use stage;
- Midpoint(s) and/or parameters: not applicable;
- Functional unit: at building level, time scale is one year;

- Associated data requirements: data on building geometry, building materials, energy systems are needed to have this indicator, primary energy factors;
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): same with the indicator of “net energy demand” (see previous section), with multiplying primary energy factors;
- Supporting tools required to quantify/estimate performance: Flemish EPBD tools, energy meters.
- Source of indicator/metric and its scientific and market acceptance: calculated in Flemish EPBD tools, commonly used in either scientific publications or local regulations;

### Results

Project / case study	Design EPBD E-level	Design EPBD [kWh/m <sup>2</sup> a]
Zone 1a	E25	final numbers not processed yet
Zone 1b	E25	final numbers not processed yet
Zone 2	E30 (houses with D-system) E37 (houses with C-system)	final numbers not processed yet
Zone 3	E30 (houses with D-system) E37 (houses with C-system)	final numbers not processed yet
Block V	E28	final numbers not processed yet

### Detailed discussion:

The designed E-level is more ambitious comparing with the requirement in local building code. For buildings in zone 2 and 3, the type of ventilation system has much larger impact on the difference in heating energy demand than the typology. Moreover, different magnitudes of houses appear (dwellings with 5 bedrooms, others with only 2 bedrooms) also have bigger impact than the typology of detached or terraced.

### Cross-links and trade-offs

The trade-offs and cross-links are similar with the ones from indicator of net energy demand (see previous section).

### → Indicator #4: Thermal insulation

- *Macro-objective: B1: Greenhouse gas emissions from building life cycle energy use*
- *Specific aspect(s): Operational carbon emissions*

### Technical specifications

- Unit of measurement: K-level, dimensionless
- Scope of indicator: building construction stage
  - o EPBD-calculation (design/post-construction stage)
  - o Measurement and tests as verification (post-construction stage)
- Life cycle stage (with reference to EN 15643): A5 construction stage
- Midpoint(s) and/or parameters: not applicable;
- Functional unit: at building level;
- Associated data requirements: building materials;
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): Co-heating
- Supporting tools required to quantify/estimate performance: Flemish EPBD tools
- Source of indicator/metric and its scientific and market acceptance: K-level is commonly used in Flemish region;

## Results

Project / case study	Design EPBD
Zone 1a	K15-K20
Zone 1b	K15-K20
Zone 2	K20
Zone 3	K21
Block V	K18

### Detailed discussion:

Thermal insulation level of the new buildings is K15 for the multi-family buildings and K20 for the single-family houses. The existing dwellings are deeply refurbished. The insulation level is around K20 by taking the passive house requirements as a tight guideline.

### **Cross-links and trade-offs**

The cross-links with energy related indicators are already discussed in section 1.3.3.

In addition, better building insulation usually means less air leakage, which is linked to the next indicator of airtightness.

### → **Indicator #5: Airtightness**

- *Macro-objective: B1: Greenhouse gas emissions from building life cycle energy use*
- *Specific aspect(s): Operational carbon emissions*

### **Technical specifications**

- Unit of measurement:  $n_{50} - h^{-1}$  or  $h^{-1}$  at 50 Pa
- Scope of indicator: Building use stage
  - o Design/post-construction stage
  - o Measurement and tests (post-construction stage)
- Life cycle stage (with reference to EN 15643): B1 in use stage;
- Midpoint(s) and/or parameters: not applicable;
- Functional unit: at dwelling level;
- Associated data requirements: pressure difference;
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): test of the air tightness of the building envelope is mandatory to get a passive house certificate in Flanders. Test is repeated in this project, initial test before delivery and re-test half a year after occupation;
- Supporting tools required to quantify/estimate performance: blower door test, fan;
- Source of indicator/metric and its scientific and market acceptance: airtightness level is required for passive houses certificate in Flanders;

## Results

Project / case study	Design PHPP [ $h^{-1}$ ]	Measurement
Zone 1a	0.6	$0.53 h^{-1}$ (initial test); $0.71 h^{-1}$ (after occupation)
Zone 1b	0.6	$0.53 h^{-1}$ (initial test); $0.71 h^{-1}$ (after occupation)
Zone 2	0.6	not finished, around 1 - 1.5
Zone 3	0.6	not finished
Block V	0.6	not started

### Detailed discussion:

The blower door test was repeated in phase 1 about one year after the initial test and half a year after the start of the occupancy. In the original tests, the n50 air change rate at 50 Pa was between 0.42 h<sup>-1</sup> and 0.62 h<sup>-1</sup>, average 0.53 h<sup>-1</sup>. The results increased after one year, 0.51 h<sup>-1</sup> and 0.84 h<sup>-1</sup>, average 0.71 h<sup>-1</sup>, which actually exceed the design value of 0.6 h<sup>-1</sup>. In phase 2 and 3, some houses didn't reach 0.6 h<sup>-1</sup> at all, on average 1.0 or 1.2 h<sup>-1</sup>, and this may be due to the existence of attic and ventilation openings.

In general, the airtightness remains a "low" difference (not significant when considering the low airtightness level); and the high air leakage can be caused by small things, for instance, measurement equipment error, leakage from small holes, unclosed windows, aging etc. Different people conduct the measurements might be the reason of the difference between two tests.

#### ***Cross-links and trade-offs***

One trade-off is related to comfort (ventilation). Higher airtightness requires a good ventilation strategy but ventilation usually means high air exchange rate.

### **2.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

#### **→ Project processes**

Methodology	Stage	Lead actor	Supporting actor
Theoretical calculation EPB&PHPP	Design stage	Energy expert	Architect
Measurement campaign	In-use stage	Researcher	Clients, inhabitants
Detailed dynamic simulation	In-use stage	Researcher	Clients, inhabitants
Quality assurance tests	Post-construction	Researcher, contractor	Clients, inhabitants, technical engineer, architect

#### Detailed discussion:

In the building design phase, energy demand is primarily calculated by taking into account the local EPBD legislation and passive house requirements, energy experts usually take the lead and have supports from architects.

In the construction phase, the regular inspection of the quality of the construction works by the architect and responsible contractor is a very important task. The execution of quality assurance tests (by a third party) is useful to indicate during the course of the construction works whether the final targets are realisable or to which specific issues extra attention should be paid. At the end of the construction works, before the delivery, the final quality assurance tests reassure the quality of the works, and the specific tests include:

- Blower door test: test of the air tightness of the building envelope, and in Belgium this is even mandatory to get a passive house certificate. This test is repeated in this project, initial test before delivery and re-test half a year after occupation.
- Infra-red thermography: inspection of the insulation quality and thermal bridges;
- Inspection of the ventilation flow rates. The ventilation flow rates were calibrated by tuning the supply air terminal units in the dwellings at the end of the construction phase, and also the actual ventilation flow rates were verified via measurements by inspections;
- Duct air leakage tests: similar to a blower door test, this test shows the air tightness of ventilation ducts, and the level of duct air tightness is obtained class C according to NBN EN 12237;

- Co-heating test: a somehow more demanding test in which the overall heat transfer ( $U \cdot A$ ) of a room or dwelling is evaluated.

To validate the actual energy performance and indoor climate, during the building use phase, actual energy consumption is measured and simulated by researchers from the University of Ghent, with the supports of clients and inhabitants in the tested buildings. Energy meters are installed at different levels for monitoring actual building energy consumption. The measurement campaign also includes the detailed measurements on HVAC systems, e.g. measurement of supply water temperature and supply air temperature. These measurements can be used to check the actual building operation status, then researchers can further detect and remedy the weak spots in the system.

It can be concluded that the in-depth commissioning of the building systems during use phase is a vital part of the completion and operational lifetime of a residential building project and a valuable contribution to its overall performance assessment.

#### → Evaluation of project experience using the indicator(s)

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?
  - Was the expertise already available within the design team/other project actors?  
Yes, all calculation in EPB is conducted by architect office.
  - How clear/informative was the associated guidance material?  
The proposed energy related indicators are defined and calculated by EPBD tools, and airtightness is highlighted in local passive house requirement.
- How readily available were the tools, data, test facilities etc.. required to use the indicator?
  - How reliable and/or comparable was the data and/or test methods used?
  - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*  
Local EPBD tools are mainly use for calculation. The E-level is the one reached before adding PV on the roof tops (that will further reduce the primary energy use), and before adding the impact of the biomass based district heating (that will augment primary energy use because of district heat losses). So these values will alter in the final results. In general, the design is such that the carbon emissions from heating, tap water, auxiliaries and communal electricity, taking into account conversion factors from EPB, have to be 0. The E-level will be E0 in Drie Hofsteden, but between E10 and E30 in Venning, because of the biomass used, that is not considered energy neutral.
- How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?
  - Was it suitable for the buildings evaluated? *If no, what issues arose?*  
Yes, in general the indicators are suitable for the buildings in this project.
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*
- How time and cost intensive was use of the indicator?
  - How easy was it for the auditor/assessor to verify performance?  
Different measurements/tests are conducted in selected buildings, including energy consumption measurements, co-heating test, airtightness tests. From the current experience of the researcher, and it can be sometimes difficult to execute good practical tests due to the measurement error or other issues (hard to interpret the results).

Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*  
*If available, post occupancy evaluation findings and issues identified e.g. performance gaps*  
This is already analysed in previous sections.

### 2.3 REFERENCES

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Eline Himpe, Researcher, University of Ghent (interviewed/called on 06 April 2016)



### 3 FS 1.C CLUSTER RESIDENTIAL MASTERPLANS: GHANDI & HOOGBOUWPLEIN

#### 3.1 FACT SHEET

General information	
<b>Description</b>	<p>The <i>Mahatma Gandhi district</i> is a social housing neighbourhood in Mechelen (Belgium). An architectural competition for renewal of the district was organized and three architectural offices were appointed to three zones: <i>KPW Architecten</i> (zone 1), <i>Comodo</i> (zone 2) and <i>Jef Van Oevelen</i> (zone 3). VITO was involved for the sustainability assessment at masterplan level and a feasibility study on water-neutrality of the district. Additionally, the project of <i>KPW Architecten</i> was selected for further research studies commissioned by the OVAM, the Public Waste Agency of Flanders (Belgium). In these studies the selective demolition of one of the apartment buildings was monitored and guidelines for adaptability and flexibility in design (Design for Change) were developed.</p> <p>Only zone 1 of the Gandhi district is considered for this study.</p> <p>The studies of the Gandhi district commissioned by the OVAM were performed in 2013. In 2015, OVAM commissioned a second study on Design for Change for developing an assessment and transitional framework. Within this study, the renovation of the VMSW apartment building on the Hoogbouwplein in Zelzate, a project also designed by <i>KPW Architecten</i>, was used as one of the two case studies to validate the gained insights and improved assessment framework. VMSW has the ambition to make this development into a pilot project for synthesising affordability and adaptable co-housing.</p>
<b>Involved parties</b>	<p>Ghandi district:</p> <ul style="list-style-type: none"> <li>- <i>KPW Architecten</i> – architect</li> <li>- <i>Woonpunt Mechelen</i> – client, social housing corporation</li> <li>- <i>OVAM</i> – consultant, public body environmental policy</li> <li>- <i>VUB, KU Leuven, VITO</i> – research consortium commissioned by the OVAM</li> </ul> <p>Hoogbouwplein:</p> <ul style="list-style-type: none"> <li>- <i>KPW Architecten</i> – architect</li> <li>- <i>VMSW</i> – client, external autonomous agency of the Flemish government within the policy domain of Spatial planning, Housing policy and Immovable heritage</li> <li>- <i>OVAM</i> – consultant, public body environmental policy</li> <li>- <i>VITO, VUB, KU Leuven</i> – research consortium commissioned by the OVAM</li> </ul>
<b>Year</b>	<p>Ghandi district:</p> <ul style="list-style-type: none"> <li>- Initiation stage: 2010</li> <li>- Design stage: 2011</li> <li>- Start demolition: November 2012</li> <li>- Start construction: February 2015</li> <li>- Completion: (expected) 2018/2019</li> </ul> <p>Hoogbouwplein:</p> <ul style="list-style-type: none"> <li>- Originally build in: 1960</li> <li>- Design competition: 2013</li> <li>- Feasibility stage: 2013-2014</li> <li>- Design stage: 2013-2016</li> <li>- Completion: (expected) 2017</li> </ul>

## Geographical and building characteristics

Building	Climate zone, Location	Typology	Type	Scale	Stage
Ghandi Zone 1	Central-Europe, Mechelen (BE)	Residential: apartment block	New-build	2 buildings, 51 units	Under construction
Hoogbouwplein	Central-Europe, Zelzate (BE)	Residential: apartment block	Renovation	1 building	Post-design

## Relevant professional context

### Private or public sector buildings and portfolios

The clients of both building projects are from the public sector. The Gandhi district is property of the social housing corporation Woonpunt Mechelen and the apartment building Hoogbouwplein Zelzate is property of VSMW, an external autonomous agency of the Flemish government. The research projects were commissioned by the OVAM, the Public Waste Agency of Flanders.

## 3.2 MACRO-OBJECTIVE B2: RESOURCE EFFICIENT MATERIAL LIFE CYCLES

### 3.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

Material utility: Re-use and adaptability of whole structures and/or elements to extend their life span

- The *future adaption potential* of structures, e.g. change of function, change of client specifications; change of performance requirements;
- The *ease of dismantling/separation* of hot spot building elements for re-use or recycling.

#### → Improvement option(s)

In this field study covering both housing projects, striving to 'resource efficient material life cycles' (cf. macro-objective B2) was not an explicit design objective in the Gandhi district project (at least not in the early stages of the design), but more an outcome of the **design and building strategy Design for Change**. In the Hoogbouwplein project, efficient use of material resources over the expected service life of the building was aspired by the design team and the building client from the early conception of the building 're-design'. The same design strategy is used. How Design for Change is interpreted within both projects is explained in the subsection on 'Methodologies, evaluation tools and/or standards used'.

#### *Ghandi district, Mechelen*

Within the Gandhi district the concept of Design for Change was **only considered**, as the design stage was already so advanced that it was not possible anymore to implement the improvement option without resulting in too much delay within the development. The research consortium commissioned by the OVAM evaluated the design by KPW Architecten based on the framework that they developed and gave advice in how to improve the design to make it more material resource efficient by applying the concept of Design for Change (Paduart et al., 2013). By doing so awareness of and enthusiasm for efficient material use was created at KPW Architecten.

The specific design recommendations given by the research consortium that were considered zone 1 of the Ghandi district regarding resource efficient material life cycles:

- The **reversibility of building elements** and the possibility to **reuse compound components** can be increased by applying building methods that uses (dry) reversible connections (as an alternative to masonry). Currently available dry system solutions for partition walls come with dry connections (e.g. screws), however the finishing layer and the choice of materials still leads to destructive deconstruction of these walls without any reuse possibility of building components. However, for external walls there are solutions available on the market that allows a large reversibility (and reuse) of the various layers of an external wall. Due to the higher amount of layers in e.g. ventilated facades with demountable panels on aluminium rails, it is possible to renew, enhance or adjust (e.g. the insulation layer) without having to remove other layers permanently.
- The **versatility of the building structure** can be increased by integrating well-considered adaptable building elements within a versatile frame structure. A frame structure offers more advantages in case of changing the layout of residential units (including a greater design freedom for future renovations) than a structure with load-bearing walls.
- Considering solutions based on **Design for Change** (adaptability, reversibility, possibility for reuse, etc.) can be **specifically targeted** on the internal walls with a higher frequency of adaptation (based on representative renovation scenarios for the different dwelling types in a building). From an environmental and financial life cycle approach, it is recommended to apply a combination of masonry walls on the one hand, and adaptable, reusable walls with dry connections on the other hand for the internal walls with a low and high demand for adjustments respectively within the building. (Paduart et al., 2013)

#### ***Hoogbouwplein, Zelzate***

Based on the experience within the Ghandi project, the OVAM and the research consortium learned that in order to implement improvement options based on the concept of Design for Change the "interventions" need to happen in the early design stage. Thus for the second study on Design for Change, they looked for case studies that still were in the early design stage in which they could intervene in order to realise more material resource efficient projects. One of the case studies used was the renovation project of the apartment building on the Hoogbouwplein in Zelzate also designed by KPW Architecten.

Compared to the Gandhi project similar general recommendations were made. See above. Nevertheless, some specific improvement measures for the refurbishment of the apartment building were identified:

- During the consultancy programme, the qualitative assessment was a catalyst for an innovative and future-oriented design process. The process was developed as an investigative design exercise using **future scenarios** and the development of a **"family tree" of compatible housing configurations**. Thanks to this approach, KPW Architects became increasingly aware of the long-term consequences of their design choices.
- On strategic locations on each level of the building, **multi-purpose co-housing rooms** were envisioned. These rooms have either collective purposes (e.g. space for recreation, meeting or temporary stay of nursing personnel) or can easily be integrated to adjacent apartments to support changing individual user conditions (e.g. a growing family, or informal care of ageing dwellers)
- The existing building will be stripped to its bearing structure. Existing non-bearing internal walls will be replaced by new ones on a **design grid**, allowing prefabrication of internal walls, partition walls, and floor and ceiling elements.
- Based on the future scenarios and "family tree" of compatible housing configurations, **adaptable, reusable wall components with dry connections are strategically selected** for

internal and partition walls with a high expected frequency of adjustments. This has been assessed by combining life cycle assessment (LCA) and life cycle costing (LCC).

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
<b>Ghandhi district zone 1, Mechelen</b>	Design for Change assessment framework (version 1: only a qualitative assessment)	Design for Change assessment framework (version 1): qualitative evaluation guidelines	Not applicable
<b>Hoogbouwplein, Zelzate</b>	Design for Change assessment framework (version 2: qualitative and quantitative assessment); for the quantitative assessment the MMG assessment framework	Design for Change framework (version 2): qualitative evaluation guidelines; and for the quantitative assessment the MMG calculation model in Excel based on Life Cycle Assessment by using adapted ecoinvent data exported from SimaPro	The MMG assessment framework is based on the EN 15804 and EN 15978 standards (and includes additional impact categories in line with the Product Environmental Footprint Guide, ILCD or PROSUITE)

Discussion:

Within the two studies commissioned by the OVAM regarding Design for Change, a framework has been developed and further refined for assessing the level of compliance with the concept of Design for Change. The Design for Change assessment framework was used to translate macro-objective B2 'Resource efficient material life cycles' in the projects of this field study and that resulted in the above-described improvement options.

The assessment framework used in both case studies is almost the same. Based on experiences in the Gandhi project and others, the assessment framework used in the Hoogbouwplein project has been refined by revising and completing the assessment criteria and focussing on the building and building element level. In the following paragraphs only this latest version of the Design for Change assessment framework is explained. The entire framework is publically available through the webpage of OVAM.<sup>7</sup>

The Design for Change assessment framework is widely applicable within the built environment and includes a qualitative and a quantitative part. The qualitative part consists of a set of 23 practical Design for Change criteria on district, building and element level. To allow a systemic approach, all criteria are divided into 3 characteristics per level: i.e. the interfaces between components, the characteristics of those (sub) components and their composition (See Figure 1)

<sup>7</sup> <http://www.ovam.be/veranderingsgerichtbouwen>

	Interfaces	Sub-components	Composition
Element	Reversibility Simplicity Speed	Durability Reused Compatibility	Pace-layered Independence Prefabrication
Building	Accessibility	Demountability Reusability Extensibility	Versatility
Neighbourhood	Clear Adaptable	Retrofitted Dimensioned Removable	Unified Multipurpose Diverse Densifiable

*Figure 1: Overview of all 23 Design for Change criteria; a breakdown by scale (element, building, neighbourhood) and by theme (interfaces, sub-components, composition) makes it possible to establish a comprehensive and clear qualitative assessment of the design and construction of a building.*

Each design criterion is discussed and illustrated on a separate sheet. These sheets include design guidelines, practical information and key questions ('verifiers') to assess a design solution. This set of design criteria allows designers, developers and policy makers to set design targets and compare different design alternatives in a qualitative way. No scores have been attributed per criterion, nor on an aggregated level.

Once a set of design alternatives is selected, the environmental and financial characteristics of each alternative are quantified. The calculation of the initial and life cycle environmental impact (IE and LE, respectively) is based on the Belgian assessment method MMG<sup>8</sup>, in line with EN15978<sup>9</sup> and ILCD Handbook<sup>10</sup>. Within the MMG method, environmental impacts are expressed in individual impact indicators (expressed in kg impact-equivalent/m<sup>2</sup> net floor area), but also as an aggregated indicator, based on external environmental costing<sup>11</sup>. The calculation of the initial and life cycle financial cost (IF and LF, respectively) is based on the Belgian Science Policy project SuFiQuaD<sup>12</sup>, and is in line with...

<sup>8</sup> Allacker K., Debacker W., Delem L., De Nocker L., De Troyer F., Servaes R., Spirinckx C., Van Dessel J. (2013), *Environmental profile of building elements*, study commissioned by the Public Waste Agency of Flanders (OVAM), available through [http://www.ovam.be/sites/default/files/FILE1368696514672Environmental\\_profile\\_buildig\\_elements\\_LR.pdf](http://www.ovam.be/sites/default/files/FILE1368696514672Environmental_profile_buildig_elements_LR.pdf)

<sup>9</sup> CEN (2011), EN 15978 Sustainability assessment of construction works – assessment of environmental performance of buildings – calculation method

<sup>10</sup> Joint Research Centre (JRC) of European Commission (2011) - Institute for Environment and Sustainability (IES), International Reference Life Cycle Data System (ILCD) Handbook – Recommendations for Life Cycle Impact Assessment in the European context – based on existing environmental impact assessment models and factors. First edition.

<sup>11</sup> De Nocker L., Debacker W. (2014), Annex: Update monetisation of the MMG method, available through <http://www.ovam.be/sites/default/files/atoms/files/Annex-update-monetarisatie-MMG-2014.pdf>

<sup>12</sup> Allacker K., De Troyer F., Trigaux D., Geerken T., Debacker W., Spirinckx C., Van Dessel J., Janssen A., Delem L., Putzeys K. (2011), Sustainability, Financial and Quality evaluation of Dwelling types “SuFiQuaD”, Final Report, Belgian Science Policy, Research Programme Science for a Sustainable Development, Brussels, 107 p.

Based on different adjustment scenarios, defined by the design team and the building clients, initial and life cycle characteristics of all selected design alternatives are plotted against each other. For the Hoogbouwplein project, environmental and financial costs have been depicted over time. Separate graphs are used for the environmental and financial results, as preferences can sometimes be different. Fictive results for an internal wall with an expected adjustment frequency of 15 years in a building with an estimated life span of 60 years are shown in Figure 2 and Figure 3, respectively.

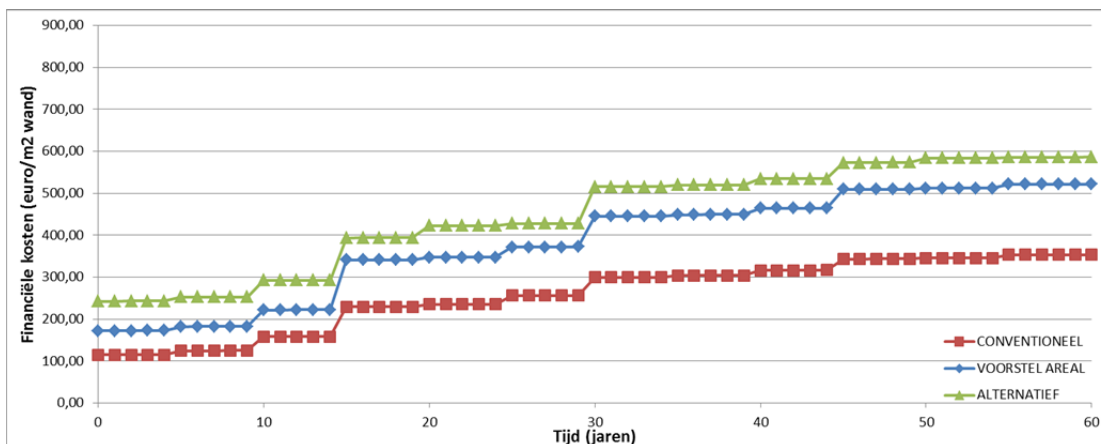


Figure 2: Financial costs in euro per m<sup>2</sup> of an internal wall over time, with an expected adjustment frequency of 15 years in a building with a estimated life span of 60 years.

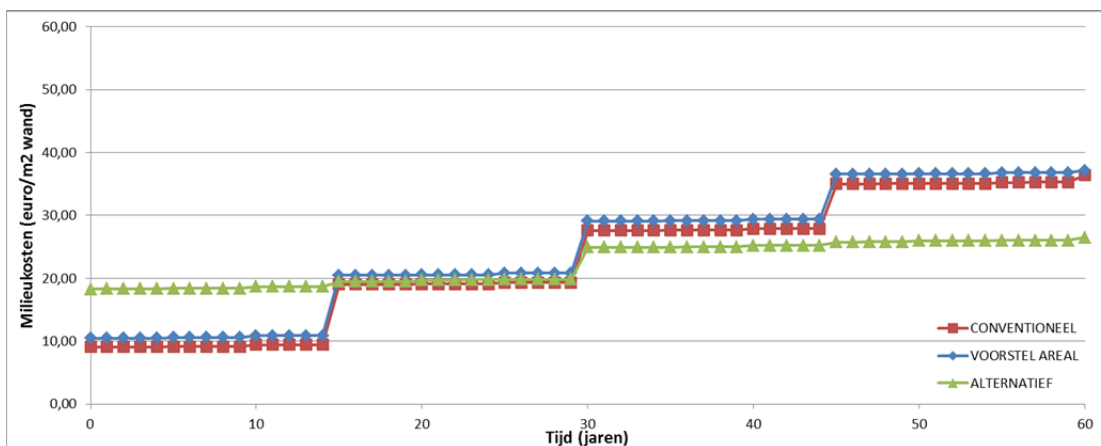


Figure 3: External environmental costs in euro per m<sup>2</sup> of internal wall over time, with an expected adjustment frequency of 15 years in a building with a estimated life span of 60 years.

## → Project processes

In addition to the specific design recommendations, the research consortium formulated general design recommendations targeted to the architects and engineers on the one hand, and building material and building system manufacturers on the other hand.

The recommendations targeted at architect, engineers and engineering consultants:

- Determine the frequency of adaptation for each building element;

- Apply reversibility, independency and reuse to elements with a high frequency of adaptation;
- Redesign existing building products to arrive at building element solutions based on the concept of Design for Change, due to the limited choice in already existing solutions that are based on the concept;
- When designing solutions based on Design for Change, prefer standardised connections and assembly techniques and components to optimise selective demolition and future reuse;
- However, the first step is to focus on the internal layout of the building that allows different usage possibilities (by applying multipurpose rooms; clustering/subdivision of space, services and traffic facilities; and adaptable and multipurpose building structure). The second step is the integration of Design for Change building components, or at least hybrid building elements (i.e. a combination of static and adaptable components). (Paduart et al., 2013)

The recommendations for the building material and building system manufacturers:

- Apply system and life cycle thinking to come to innovations in system and product development; to develop new building systems in line with the Design for Change concept and new building materials to support the concept.
- At the short term it is feasible to further develop hybrid building elements, which can be financially and/or ecologically more beneficial than complete demountable and reusable element components. (Paduart et al., 2013)

### **3.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)**

#### **→ Overview**

Key indicators identified regarding 'resource efficient material life cycles' are:

- Compliance to a set of qualitative Design for Change criteria [unit: /]
- Initial environmental impact [kg impact-equivalent/m<sup>2</sup> NFA or external environmental cost in €/m<sup>2</sup> NFA]
- Life cycle environmental impact [kg impact-equivalent/m<sup>2</sup> NFA or external environmental cost in €/m<sup>2</sup> NFA]
- Initial financial cost [€/m<sup>2</sup> NFA]
- Life cycle financial cost [€/m<sup>2</sup> NFA]

#### ***Cross-links and trade-offs between other macro-objectives***

A strong relation has been identified between measures for 'resource efficient material life cycles' (and more particular Design for Change measures) on the one hand and life cycle environmental impacts (cf. macro-objective B2 – reduction of environmental impact) and life cycle financial costs (cf. macro-objective B6) on the other hand.

### 3.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

#### → Evaluation of project experience using the indicator(s)

Future consideration of the disassembly potential and transformation capacity of a building are new and difficult concepts for design teams and clients. There are no mature indicators to measure disassembly, reuse and the ability to easily change buildings. Nevertheless, some Design for Change principles have been used extensively in some niche building applications, such as light industrial buildings, warehouses and temporary exhibition spaces.

From a standardisation perspective, EN 15643-3/EN 16309 provides some limited pointers as to measures to increase adaptability. ISO 20887 Design for Disassembly and Adaptability of Buildings is under development by TC 59/SC17, initiated by proposals from the Canadian Standards Associations (CSA), and will provide architects, planners and building owners a set of design principles and quantifiable metrics to design and assess adaptable buildings and demountable building systems.

Within sustainability building schemes, the state of the art is a category scoring for different Design for Change aspects/themes. Through DGNB a separate score is given to ease of disassembly, scope of disassembly and viability of disassembly. Within the Dutch version of BREEAM weighted scores are given to flexibility characteristics of partitioning, adaptability characteristics of a (dwelling/work) unit within a building, and multi-functionality characteristics of the building. The assessment in DGNB and BREEAM-NL are not completely in line with the Design for Change assessment framework analysed in the two case studies - because the latter takes into account more design aspects - but the (weighted) category scoring systems could be placed on top of it. (Weighted) Category scoring could form the basis for the development of a (set of) indicator(s), with the scope defined in order to focus attention on hot spot building elements.

For the time being this is the best way to go forward. Bear in mind that currently there are other ongoing initiatives (such as in the Horizon 2020 project BAMB: Building as Material Banks) contributing to the development of such a set of indicators. Furthermore, there are clearly links (sometimes trade-offs) between Design for Change (adaptability, disassembly, reuse,...) and environmental impacts (LCA) and financial costs (LCC). It would be wise to allow future amendments to the indicators developed in this assessment framework.

### 3.3 REFERENCES

Paduart, A., De Temmerman, N., Trigaux, D., De Troyer, F., Debacker, W., Danschutter, S. (2013). *Casestudy ontwerp van gebouwen in functie van aanpasbaarheid: Mahatma Gandhivijk Mechelen*. OVAM, Mechelen. Available via: [www.ovam.be/afval-materialen/materiaalbewust-ontwerpen-produceren-en-aankopen/dynamisch-of-veranderingsgericht-bouwen/gandhivijk](http://www.ovam.be/afval-materialen/materiaalbewust-ontwerpen-produceren-en-aankopen/dynamisch-of-veranderingsgericht-bouwen/gandhivijk) (last accessed March 2016).



## 4 FS 2. CLUSTER ALTO OFFICES, NEW-BUILD

### 4.1 FACT SHEET

#### 4.1.1 GENERAL INFORMATION

This cluster consists of three new-build office projects from the building practice of ALTO ingénierie.

<b>Description</b>	<p>The building CBKII comprises office spaces and a corporate catering. The building has 4 basement levels with car parks and corporate catering. There are 2 buildings called Kennedy and Tour.</p> <p>The building is located in Luxembourg, in the town of LUXEMBOURG.</p> <p>Construction:</p> <ul style="list-style-type: none"> <li>▪ Outside walls : curtain wall</li> <li>▪ Flat roof : concrete with warm deck</li> <li>▪ Floor: reinforced concrete slab</li> <li>▪ Heating: District heating</li> </ul> <p>Cooling: Refrigeration group</p>
<b>Involved parties</b>	<p>BGL BNP PARIBAS – Client, End occupier and future facility manager</p> <p>BNP PARIBAS – Developer and design team manager</p> <p>M3 ARCHITECTES – Architect</p> <p>GOBLET LAVANDIER &amp; Ass. – Building services Engineers</p> <p>ARCORA – Curtains wall Engineers</p> <p>SGI - Mechanical Engineers</p> <p>ALTO INGENIERIE – BREEAM, HQE, DGNB Consultant</p> <p>MAIN CONTRACTOR – ORTP / CLE</p>
<b>Year</b>	Construction in progress

<b>Description</b>	<p>The building LA MARSEILLAISE comprises office spaces and a corporate catering. There will be 31 floors of office spaces.</p> <p>The hard landscaped area is the garden in the centre of the operation.</p> <p>It is located in Marseille, in the South of France (13).</p> <ul style="list-style-type: none"> <li>▪ Outside walls : curtain wall</li> <li>▪ Concrete structure</li> <li>▪ Heating/ Cooling: Urban district network linked to marine geothermal energy<sup>13</sup></li> <li>▪ Ventilation: Mechanically ventilated</li> <li>▪ Hot water: production by electrical hot water tank for offices</li> </ul>
<b>Involved parties</b>	<p>CONSTRUCTA – Developer</p> <p>JEAN NOUVEL – Architect</p> <p>ALTO INGENIERIE – Building services Engineers &amp; HQE LEED consultant</p> <p>ARCORA – Curtains wall Engineers</p> <p>SIDF – Mechanical Engineers</p> <p>DUMEZ / VINCI Construction – Main Contractor</p>
<b>Year</b>	Construction in progress

<sup>13</sup> Thassalia: <http://www.plateformesolutionsclimat.org/wp-content/uploads/2014/12/140911-plaquette-euromed.pdf>

<b>Description</b>	<p>The building ZENORA comprises Office spaces and a corporate catering. There will be 3 levels underground with car parks and 8 floors of office spaces. It is located in France, in the town of ISSY LES MOULINEAUX (92130). It is in the nearest suburb of PARIS.</p> <ul style="list-style-type: none"> <li>▪ Outside walls : curtain wall</li> <li>▪ Flat roof : concrete with inverted deck or warm deck</li> <li>▪ Floor: Solid hardwood flooring (22mm)</li> <li>▪ Heating/Cooling Heat pumps using underground water</li> <li>▪ Ventilation: Mechanically ventilated</li> <li>▪ Hot water: production by electrical hot water tank for offices and solar and electrical hot water for catering</li> </ul>
<b>Involved parties</b>	<p>BNP PARIBAS IMMOBILIER – Developer and design team manager  Jean-Paul VIGUIER et associés – Architect  BARBANEL – Building services Engineers  ARCORA – Curtains wall Engineers  Structure IDF - Mechanical Engineers  ALTO INGENIERIE – BREEAM &amp; HQE Consultant  MAIN CONTRACTOR - GCC</p>
<b>Year</b>	2015

#### 4.1.2 GEOGRAPHICAL AND BUILDING CHARACTERISTICS

##### Geographical and building characteristics

Building	Climate zone, Location	Typology	Type	Scale	Stage
Kennedy CBKII	Central-Europe, Luxembourg	Office: medium-rise	New-build	9 storeys 3 basements 15 619 <sup>2</sup> SHON <sup>14</sup>	Under construction
Tour CBKII	Central-Europe, Luxembourg	Office: high-rise	New-build	18 storeys 3 basements 26 903m <sup>2</sup> SHON	Under construction
La Marseillaise	Southern Europe, Marseille (FR)	Office: high-rise	New-build	31 storeys	Post-design
Zenora NODA	Central-Europe, Paris (FR)	Office: medium-rise	New-build	7 storeys; net area 23.600 m <sup>2</sup>	In-use

#### 4.1.3 RELEVANT PROFESSIONAL CONTEXT

Project	Certification Manual / Level Achieved	Energy Label Or Other environmental aspect
CBKII	<p>HQE International v2011 / Level Exceptional  BREEAM International v2009 Issue 1.1 / Level Excellent  DGNB pilot NOA10 v2012 / Level Silver</p>	

<sup>14</sup> *Surface HorsOeuvre Nette* - Adjusted gross floor area, calculated by deducting the floor areas of non-convertible lofts and basements, open areas, parking spaces, agricultural units, and greenhouses for production use from the *Surface Hors Oeuvre Brute (SHOB)* of the same building - see Section R. 112-2, *Code de l'urbanisme* (French Town Planning Regulations). SHO = Gross floor Area

LA MARSEILLAISE	HQE v2011 updated 2012/ Level Excellent LEED v3 2009 / Level Gold	
ZENORA (NODA)	HQE v2008 Offices / Level Exceptional BREEAM International v2009 Issue 1.1 / Level Outstanding	BBC Effinergie (RT 2005) HQE Performance

## 4.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

### 4.2.1 TRANSLATION OF THE MACRO-OBJECTIVE INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- ☒ Operational carbon emissions
- ☒ Embodied carbon emissions

#### → Improvement option(s)

- ☒ Operational carbon emissions

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> Optimisation of the thermal building envelop to reduce energy demand		
<b>HQE, criterion 4.1.1:</b> Optimise the thermal envelope; EPBD-regulation in France ( <i>réglementation thermique</i> (RT) 2005)	$U_{bât} < U_{bât, base}$ $U_{bât, base} = 0,930 \text{ W/m}^2.K$	ZENORA NODA
<b>HQE, criterion 4.1.1:</b> Optimise the thermal envelope; EPBD-regulation in France ( <i>réglementation thermique</i> (RT) 2012)	$B_{BIO} < B_{BIO, max}$ $B_{bio, max} = 164,42 \text{ (LA MARSEILLAISE)}$ $B_{bio, max} = 134,8 \text{ (ZENORA)}$	LA MARSEILLAISE
<b>CPE</b> (Energy Performance Certificates, " <i>Certificat de Performance Energétique</i> " in French) (local regulation): "wärmeschutzklasse" EPBD-regulation in Luxemburg	$Cpe < 43,2$	CBKII
<b>HQE, criterion 4.1.2 :</b> air tightness of the building envelope	$< 0,30 \text{ m}^3/(\text{h.m}^2)$	CBKII
<b>DGNB + CPE :</b> air tightness of the building envelope; EPBD-regulation in Luxemburg (CPE)	$< 1,6 \text{ m}^3/(\text{h.m}^2)$	CBKII
<b>Improvement option:</b> Reduce primary energy consumption during use stage		
<b>CPE</b> (local regulation) : " <i>Energieeffizienzklasse</i> "	$> 264,2 \text{ kWh/m}^2 \text{ CPE.year}$	CBKII
<b>HQE, cible 4.2.1 :</b> Reduce building primary energy consumption RT 2005	$Cep < Cep \text{ reference}$ $Cep \text{ reference} = 150,51 \text{ kWh/m}^2 \text{ a}$	ZENORA NODA

Evaluation criteria	Performance target	Project concerned
<b>HQE, cible 4.2.1</b> : Reduce building primary energy consumption RT 2012	Calculation has been done for ZENORA NODA for information Bbio max = 134,8	LA MARSEILLAISE
<b>DGNB criterion 10-11</b> : Reduce building final energy consumption	Reduction compared to DGNB reference project (5388 MWh Ef/y)	CBKII
<b>DGNB</b> : Reduce building final energy consumption	Reduction compared to DGNB reference project (128,47 kWh/m <sup>2</sup> NFA.year)	CBKII
Energy label " <b>BBC Effinergie</b> "	$C_{ep} < C_{ref} - 40\%$	ZENORA NODA
<b>BREEAM, ENE 1</b> : building primary energy consumption; Local EPBD-regulation	Reduction of 37% as minimum compared to $C_{ep}$ reference to get 10 credits <b>CBKII</b> Reduction of 40% compared CPE reference 264,3 <b>LA MARSEILLAISE</b> $C_{ep}$ reference = 167,10 kWh/m <sup>2</sup> a <b>ZENORA NODA</b> $C_{ep}$ reference = 15,51 kWh/m <sup>2</sup> a	CBKII ZENORA NODA
<b>LEED EAP2 EAC1</b> : Minimum Energy Performance Option 1; Local EPBD-regulation	10% improvement as minimum in the proposed building performance rating compared with the baseline building performance rating	LA MARSEILLAISE
<b>Improvement option:</b> To reduce CO2 emissions		
<b>HQE, cible 4.3.1</b> : Reduce CO2 emissions generated by energy use	Reduction of 30% compared to HQE reference project	ALL
<b>DGNB</b> : Reduce CO2 emissions generated by energy use - Criterion 1 Global Warming Potential	Reduction compared to DGNB reference project (25,52 kgCO <sub>2</sub> /m <sup>2</sup> NFA.year)	CBKII
<b>Improvement option:</b> To reduce SO2 emissions		
<b>HQE, cible 4.3.1</b> : Reduce SO <sub>2</sub> emissions generated by energy use	Calculation of SO <sub>2</sub> emissions linked to energy consumption	ALL
<b>DGNB</b> : Reduce building SO <sub>2</sub> emissions generated by energy use - Criterion 4 acidification potential	Reduction compared to DGNB reference project (28,06 kgSO <sub>2</sub> /m <sup>2</sup> .NFA.year)	CBKII
<b>Improvement option:</b> Low Zero Carbon (LZC) energy sources To reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand.		
<b>HQE 4.2</b> : Reduce building regular energy consumption by using LZC energy	Building energy needs must be covered by 10 to 40 % of LZC energy sources compared with global consumption	CBKII ZENORA NODA
<b>BREEAM, ENE 5</b> : Low or zero carbon technologies	A local LZC energy technology must be installed in line with recommendations of a feasibility study led by an energy specialist and this method of supply	ZENORA NODA

Evaluation criteria	Performance target	Project concerned
	results in more than 15% reduction in the building's CO <sub>2</sub> emissions (not achieved in the project but the study has been conducted)	
<b>LEED EAC2</b> : Reduce building regular energy consumption by using LZC energy	% of total energy covered by on site renewable energy sources. If ≥1% of calculated energy cost are covered by LZC energy sources = 4pts achieved	LA MARSEILLAISE

Detailed discussion:

To reduce energy consumption and CO<sub>2</sub> (and SO<sub>2</sub>) emissions, there are 3 classical goals for conception team:

- Optimize thermal envelop
- Efficient technical installation
- Low Zero Carbon(LZC) energy source

The criteria of the certification schemes correspond with the performance targets of local regulation, but might differ in terms of reference value or scope considered (e.g. floor surface or energy use included). This partly explains the significant difference between the results of the same indicator for different certification schemes.

$$U_{\text{bat,max}} = U_{\text{bat,réf}} + 25\%$$

$U_{\text{bat}}$ : Heat loss of a building by transmission through the walls (including thermal bridges) and windows expressed in W/m<sup>2</sup>.K. Average of all U-values of the building envelope: wall, roof, windows...) The lower  $U_{\text{bat}}$  is, the better the building envelope is performing.

Cep: Primary energy consumption (in French: "*Coefficient d'Energie Primaire*") or the conventional energy consumption of a building for heating, cooling, domestic hot water, electricity for pumps and fans, and lighting facilities are expressed in kWh/m<sup>2</sup> per year

Label "*Bâtiment Basse Consommation*" (BBC, French for "Low Energy Building") of EFFINERGIE<sup>15</sup>: Low energy building label in France, issued by the certification body Effinergie. This label requires buildings twice as efficient as conventional buildings. For non-residential buildings, this requires a primary energy consumption is 50% of the reference building, calculated according to the French EPBD-regulation (in this case, RT 2005).

The "*warmeschutzklasse*" (German for "*thermal insulation class*") is a label, which expresses the building energy demand, regarding thermal insulation, envelop quality, air tightness and orientation.

The "*Energieeffizienzklasse*" (German for "*energy efficiency class*") is a label, which expresses the energy performance of the building (i.e. primary energy consumption)

- ☒ Embodied carbon emissions

<sup>15</sup> <https://www.effinergie.org/web/index.php/les-labels-effinergie/bbc-effinergie>

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To recognise and encourage the use of construction materials with a low environmental impact over the full life cycle of the building.		
<b>DGNB 01-05:</b> total primary energy demand and proportion of renewable primary energy	Reduction compared to DGNB reference project (5388) kWh <sub>ep</sub> /m <sup>2</sup> NFA.year	CBKII
<b>DGNB 01:</b> global warming potential	Reduction compared to DGNB reference project	CBKII

#### Detailed discussion:

To reduce embodied carbon emissions, all materials were chosen with attention. Only the DGNB certification scheme specifically addresses Global Warming Potential. The other certification schemes only assess Global Warming Potential as part of an overall environmental impact assessment.

#### *DGNB*

To evaluate the criterion “Global Warming Potential,” the building’s ecological effects are combined into one common parameter, the average annual value over the reference study period for certification:

$$GWP_B = GWP_C + GWP_O$$

$GWP_B$  the global warming potential of the entire life cycle of the building

$GWP_C$  the global warming potential of the construction, replacement of components, dismantling, and disposal of the building and building services. This is given as an average annual value of global warming potential during the reference study period [kg CO<sub>2</sub> equiv./((m<sup>2</sup><sub>NFA</sub> \*a))]

$GWP_O$  predicted annual global warming potential for operation of the building as constructed, derived from end energy demand according to Life Cycle Energy Modelling multiplied by the corresponding emission factors from ESUCO [kg CO<sub>2</sub> equiv./((m<sup>2</sup><sub>NFA</sub> \*a))]

European Sustainable Construction (ESUCO) database roots in the German Ökobau-Database based on EPD (prEN 15804). It contains environmental data of construction materials (i.e. concrete, timber, plastics, metals, binders, stones etc.) and country specific data on the use stage of buildings as heating, cooling, electricity and services such as elevators in buildings etc. Production technology of core materials is based on European average industry data. All data on resources, energy and preliminary products are adapted to European average conditions. The database is provided by the DGNB on a web server.

#### → **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Regulation calculation	Climawin 4.2 1.0.3	Local EPBD-regulation in	ZENORA NODA

Methodology used	Evaluation tools used	Standards used	Project concerned
tool		France (RT 2005, RT 2012)	LA MARSEILLAISE
	Software “Solar - Computer Energieeffizienz Gebäude”, version 5.09.02	Local EPBD-regulation in Luxemburg (Regulation of grand-ducal 31 <sup>st</sup> august 2011)	CBKII
Mock-up blower test and final blower test measure	Blower-door	DIN EN 13829 Standards	
Dynamic thermal simulation : Feasibility and comparison study with DTS as decision support tools	Virtual Environment” software: edited by IES Software Ltd, with APACHE calculation code	ASHRAE 90,1-2007 Appendix G methodology	CBKII
LCA	ELODIE	NF P01-010 December 2004	CBKII LA MARSEILLAISE ZENORA

#### Detailed discussion:

Energy demand is primarily calculated in design phase and updated during construction. Regulatory calculation is based on French *Règlementation Thermique 2005* (ZENORA NODA) and 2012 (LA MARSEILLAISE) regulation by using Climawin software (but it is not compulsory, over software are validated to realise this calculation). Furthermore, in order to meet the energy requirement for Leed certification scheme, the energy demand is also calculated by using ASHRAE 90,1-2007 Appendix G methodology and Virtual Environment” software: edited by IES Software Ltd, with APACHE calculation code .

The project CBKII located in Luxembourg follows the local regulation of grand-ducal 31<sup>st</sup> august 2011 and led a thermal modelling simulation realized using ASHRAE 90,1-2007 Appendix G methodology.

Regulation calculation tool isn’t enough precise to use it for HQE and DGNB, that oblige to do a specific Dynamic Thermal Simulation.

Please note that ZENORA NODA led calculations under RT2005 and RT2012 to inform the client about the energy efficiency of the building regarding the thermal regulation applicable at the end of construction works, which is not compulsory.

#### → Project processes

Methodology	Stage	Lead actor	Supporting actor
Regulation calculation tool	Preliminary design, Technical design and building specifications and Construction	Contractors Mechanical Engineers	Architect / environmental consultant in preliminary/technical

Methodology	Stage	Lead actor	Supporting actor
			design phase and contractor in construction
Dynamic thermal simulation : Feasibility and comparison study with DTS as decision support tools	Preliminary design, Technical design and building specifications and Construction	Environmental consultant	Architect/engineer in preliminary/technical design phase and contractor in construction
LCA	Preliminary design, Technical design and building specifications Check of respect of specifications during Construction	Environmental consultant	Architect/engineer in preliminary/technical design phase and contractor in construction

#### Detailed discussion:

In the building design phase, energy demand is calculated by taking into account the local regulation and energy label requirement.

Energy experts take the lead and have supports from architects. When an environmental consultant is associated to the projects, it could be lay stress on the fact that a complete control of values specified in prescriptions is done and checked in the case of certification process.

In the construction phase, the regular inspection of the quality of the construction works by the architect and responsible contractor is a very important task considering that some modifications could occur during works phase.

The execution of quality assurance tests (by a third party as for example the environmental consultant) is useful to indicate during the course of the construction works whether the final targets are realisable or to which specific issues extra attention should be paid.

Calculation of energy demand is required to get an energy label as BBC effinergie.

It is often done by the general contractor or HVAC contractor.

Those data are updated in the final energy demand calculations of our cluster:

- in use ventilation rates verified via measurements by inspections
- results from duct air leakage tests according to NBN EN 12237
- performance of envelope's insulation and glazing

Commissioning of the building systems after work completion is an important part of the completion and operational lifetime of building project and a valuable contribution to its overall performance assessment. It has been done for ZENORA NODA project.

#### **4.2.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)**

##### **→ Overview**



Indicator		Unit of measurement	Scope
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>			
Key	Primary Energy Consumption (Cep)	kWh/m <sup>2</sup> year	Operational Energy Average of all U value of facade element: wall, roof, windows...
Key	Specification of low or zero carbon technologies	% reduction in the building's CO <sub>2</sub> emissions	Operational Energy
Key	Specification of construction materials with a low environmental impact over the full life cycle	% of surface	Operational Energy
Supporting	Envelope capacity to restrict losses (Ubât)	W/m <sup>2</sup> .K	Operational Energy Average of all U value of facade element: wall, roof, windows...
Supporting	CO <sub>2</sub> emissions	kg eq. CO <sub>2</sub> /m <sup>2</sup> SHON/year	Operational Energy due to heating, cooling, lighting, hot water, ventilation & auxiliary, and relative to thermal surface
Supporting	SO <sub>2</sub> emissions	g éq. SO <sub>2</sub> /m <sup>2</sup> SHON/year	

#### → Primary Energy Consumption (Cep)

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions

#### Technical specifications

- **Unit of measurement** : kWh/m<sup>2</sup>year
- **Scope of indicator**: the net energy consumption includes all energy use for space heating, space cooling, domestic hot water, auxiliary energy and the energy use for collective functions such as elevators and outdoor lighting in the entire neighbourhood, and the household electricity is not taken into account for the theoretical calculation, however can be measured by metering data.
- Associated data requirements:
  - o Thermal zoning
  - o Opaque constructions
  - o Glazed constructions
  - o Occupancy
  - o Lighting
  - o Fresh air rates
  - o Heating and cooling systems description
  - o Temperature set points
  - o Air Tightness
  - o Meteorological data
- Associated timeframe, conditions and requirements for measurement: manufacturers data and calculation from design team/contractor to specify systems

- Supporting tools required to quantify/estimate performance : specific software
- Source of indicator/metric and its scientific and market acceptance: ASHRAE 90,1-2007  
Appendix G methodology has to be followed to achieve LEED requirements

#### Results

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
Primary Energy Consumption (Cep)	<b>ZENORA NODA</b> Cep RT 2005 = 53,81 kWh/m <sup>2</sup> y (improvement of 64,25%) Cep RT2012= 68,7 kWh/m <sup>2</sup> y (improvement of 40,1% against Cepmax of 114,7 kWh/m <sup>2</sup> y) <b>LA MARSEILLAISE</b> Cep RT2012 = 115,80 kWh/m <sup>2</sup> y (improvement of 30,70%) <b>CBKII</b> Energieeffizienzklasse (grand ducal) = 155,9 kWh/m <sup>2</sup> CPE.year Energieeffizienzklasse (ASHRAE) = 101 kWh/m <sup>2</sup> CPE.year

#### → Specification of low or zero carbon technologies

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions, embodied carbon emission

#### Technical specifications

- **Unit of measurement** : % of improvement against a reference
- **Scope of indicator**: the percentage of improvement is calculated from the energy consumption calculation
- Associated data requirements: energy study to compare different production proposals with or without LZC study
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Results (As built)
SPECIFICATION OF LOW OR ZERO CARBON TECHNOLOGIES	<b>ZENORA NODA</b> 53% of reduction of CO2 emissions > 15% Heat pumps (geothermal water source) are specified for the project Emissions with LZC energy sources : 231 kg CO2/m <sup>2</sup> per year Emissions with gaz source: 231+ 255 tonnes CO2 per year  <b>CBKII</b> 77% of reduction of CO2 emissions > 15% District heating system is specified for the project Emissions with LZC energy sources: 84 tonnes CO2 per year Emissions with gas source: 363 tonnes CO2 per year

→ **Envelope capacity to restrict losses (Ubât)**

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions

**Technical specifications**

- **Unit of measurement** : W/m<sup>2</sup>.K
- **Scope of indicator**: envelop performance compared to a reference supervised by regulation calculation methodology (Average of all U value of facade element: wall, roof, windows...)
- Associated data requirements
  - o U value of façade, floor slabs, roof element
  - o Volumetry of the building
- Associated timeframe, conditions and requirements for measurement: manufacturers data
- Supporting tools required to quantify/estimate performance: specific software
- Source of indicator/metric and its scientific and market acceptance: not concerned

**Results**

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
Envelope capacity to restrict losses (Ubât RT 2005)	<b>ZENORA NODA</b> Ubât = 0,703 W/m <sup>2</sup> .K
Envelope capacity to restrict losses (Bbio RT 2012)	<b>ZENORA NODA</b> Bbio = 109,2 <b>LA MARSEILLAISE</b> Bbio = 127,80
Envelope capacity to restrict losses (UWert local regulation)	<b>CBKII</b> UWert = 0,42 W/m <sup>2</sup> .K

→ **CO2 emissions**

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions, embodied carbon emission

**Technical specifications**

- **Unit of measurement** : kg éq. CO2 /m<sup>2</sup> SHON/an
- **Scope of indicator**: the CO2 emission is calculated from the energy consumption calculation
- Associated data requirements: CO2 emission of the hot and cold production
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance: not concerned

**Results**

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	

Indicator	Results (As built)
CO2 emissions	<b>ZENORA NODA</b> Ref = 1,72 kg éq. CO2 /m <sup>2</sup> SHON/y <b>LA MARSEILLAISE</b> Ref = 4,2 kg éq. CO2 /m <sup>2</sup> SHON/y <b>CBKII</b> Ref = 23 kg eq CO2/m <sup>2</sup> .y

#### → SO2 emissions

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions, embodied carbon emission

#### Technical specifications

- **Unit of measurement :** g éq. SO2/m<sup>2</sup> SHON/an
- **Scope of indicator:** the SO2 emission is calculated from the energy consumption calculation
- Associated data requirements: SO2 emission of the hot and cold production
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Results (As built)
SO2 emissions	<b>ZENORA NODA</b> Ref = 6,68 g éq. SO2 /m <sup>2</sup> SHON/y <b>LA MARSEILLAISE</b> Data not available <b>CBKII</b> Ref = 23kg eq SO2/m <sup>2</sup> .y

#### 4.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

1. *How accessible and easy to use was the indicator and the associated methodology?*
  - *Was the expertise already available within the design team/other project actors?*

In the case of CBK II, the designers and contractors were not familiar with DGNB, as the version used was a pilot version. Other certifications (such as HQE, BREEAM) are more familiar in France.

LEED is not well known by French designers but the methodologies and tools are easily available and well-explained.

2. *How readily available were the tools, data, test facilities etc... required to use the indicator?*  
*How reliable and/or comparable was the data and/or test methods used?*  
*What was the experience using calculation tools?*

ZENORA

Data is provided by the as-built documents, as a result they are reliable and readily available. The building has been certified for HQE and BREEAM for Post Construction Phase and the energy label BBC Effinergie has been validated.

#### CBKII

Data was provided during Design stage. While the DGNB guidelines were well-explained, at that time, not all the DGNB tools were available, due to the fact that it was a pilot version.

#### LA MARSEILLAISE

Data used is derived from the documents during Design stage.

3. *How useful was the indicator by the design team, contractor and/or in communication with clients (as applicable) in order to improve performance?*
  - *Was it suitable for the buildings evaluated? If no, what issues arose?*
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*

#### ZENORA

Data used is derived from the as-built documents. The building has been certified for HQE and BREEAM for Post Construction Phase and the energy label BBC Effinergie has been validated.

Conventional energy performance calculation tools (according to local regulation) have been used.

#### LA MARSEILLAISE

Specific presentations to the investors are done especially to justify achievement of energy goals. This helps the team in taking decisions and proposing improvement till the final achievement. Working with the investor is really beneficial and we hope it will implies as less modifications as possible during works on energy aspects.

4. *How time and cost intensive was use of the indicator?*

Performance has been followed during design stage thanks to certification process and has been checked at post construction stage.

LA MARSEILLAISE (LEED) and CBKII (DGNB) required dynamic thermal modelling and new knowledge on new requirements for the team.

Project specific lessons learned are::

ZENORA – The client was really engaged on this project to set ambitious environmental targets which was a major incentive to reach high certification levels and environmental performance. CBKII – The pilot version of DGNB proofed to be difficult for the design team: they were not always familiar with the different methodologies and units and the differences with the indicators and methods used (for instance, for local energy calculations) was sometimes confusing and difficult to understand for the design team

5. *Based on their experience, would you make any suggestions for improvement? These could be in relation to any aspect of its use*

The three projects tried to reach high performance on several certification schemes. From ALTO's experience, achieving those goals are often linked to the ambition of achieving a high score related to energy performance. Project specific lessons learned are: CBKII – a general contractor could have been of great value for the project. Separated lots created difficulties regarding the certification process.

### 4.3 MACRO-OBJECTIVE B2: RESOURCE EFFICIENT MATERIAL LIFE CYCLES

#### 4.3.1 TRANSLATION OF THE MACRO-OBJECTIVE INTO ACTION AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- ☒ Circular flows
- ☒ Material utility
- ☒ Environmental impact

##### → Improvement option(s)

- ☒ Circular flows

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> Reduction of construction and demolition waste disposed to landfill		
<b>BREEAM:</b> diversion from landfill	Targets are set without performance required to reduce waste generated on site. Plus at least 3 key waste groups are identified and diverted from landfill	ZENORA
<b>DGNB</b> Waste sorting to ensure diversion from landfill	mineral waste, recyclable material, mixed construction waste, problematic substances, and waste containing asbestos	CBK II
<b>HQE:</b> % by weight diverted from landfill	50% (base performance) 80% (highest performance)	ZENORA
<b>LEED:</b> % by weight diverted from landfill	75%	LA MARSEILLAISE
<b>Improvement option:</b> Recycled content of building products		
<b>LEED:</b> Recycled content	10% 20%	LA MARSEILLAISE

##### ZENORA

ZENORA is a new-build office building with eight floors. It is certified according to HQE, BREEAM and HQE performance. Regarding site construction, the project achieved a diversion from landfill of 91.3% for a production of 3057 t of construction waste streams (initial target was set at 80%, see further). Achieving this target was not difficult in this project, as waste platforms in France are familiar with these criteria and associated indicators and as a result, have improved their activities and way of working to reflect this. However, this is still a challenge in places where buildings are not often certified.

##### LAFFITE, LA MARSEILLAISE and CBKII

The LAFFITE, LA MARSEILLAISE and CBKII projects are at design stage or beginning of construction works but goals are set for construction waste: 80% of waste diverted from landfill (in weight) for

LA MARSEILLAISE and 50% for CBKII. LEED certification requires a minimum of 75% for a maximum credit for waste diversion.

In LA MARSEILLAISE, specific LEED goals are set regarding circular flows. The LEED certification scheme gives credits for “recycled content”. Points can be earned when materials are used that incorporate recycled materials (at least 10% or 20%). Furthermore, points are rewarded when regional materials are used. Hereby, LEED aims to reduce impacts from the extraction and processing of virgin materials and transport (LEED 2009 for commercial interiors).

The project aims to achieve the recycling requirements for concrete, aggregates, carpet tiles and suspended ceilings. The concrete will reach the requirement for a regional material (more than 10% of the total cost of materials must be extracted and/or produced from a distance <800km).

☒ Material utility

Evaluation criteria	Performance target	Project concerned
<b>Improvement option: Ease of dismantling of building components</b>		
<b>DGNB criterion 27:</b> Deconstruction and Disassembly checklist and rating system	Limit, reference and target values for rating	CBK II
<b>HQE:</b> Conduct a study on adaptability and disassembly	No performance targeted, the design team must prove the possible adaptability for future occupants	CBKII La Marseillaise ZENORA
<b>Improvement option: Future adaptation potential of the building</b>		
<b>DGNB criterion 17:</b> Flexibility and adaptability checklist and rating system	Space Efficiency Factor $S_{eff} > 0,75$	CBK II
	Limit, reference and target values for rating	CBK II

HQE requires a building life estimation and to design in line with this duration. Three of the building project described above are HQE certified (LAFFITE, LA MARSEILLAISE and CBKII). Studies are linked to environmental product declarations on which expected life duration is detailed for building elements. This exercise is only an approach and its goal is to list which elements will have to be replaced before end of life fixed by the client. It has to be kept in mind that values in EPDs are not always realistic and EPDs are not systematically verified by a third person. As a result, consequences on design are not strong. Reality also shows that buildings are renovated before the usual declared duration of 50 years.

Regarding another aspect, adaptability of buildings and design to disassembly of building components, HQE is not really clear on what must be specified.

As a result, a specific study is produced but projects often stress the fact that floor covering and suspended tiles are installed from a layout plan which enables adaptability of the building and the same reflection is done with other building systems (e.g. lighting and emitters). Moreover, the building plan considered a % of available power superior to the needs on HVAC aspects and spaces for cables are provided to permit evolution in the building. It can be noticed that integration of the tenant in the conception at an early stage can provide more credits on the global performance.

For the CBKII project, the German certification system DGNB was used to ensure adaptability. Here are some of the requirements for the DGNB certification:

- Indoor clearance height is greater than 2.75 m
- Non-load bearing, room-separating elements can be added to, converted, or removed without too much effort and with building operation continuing as normal (minimal limitations on operation )
- Non-load bearing, room-separating elements can be dismantled, and there is a possibility of temporarily storing unnecessary elements
- Power and media conduits run to easily accessible supply shafts, cable ducts, or false floors and/or are the lines visible
- Less than 80 % of the capacity of the supply shafts and ductwork for power and media conduits utilized
- Waste water removal/supply system's distribution and connections designed in such a way that they could be modified for other types of use

Moreover, the DGNB certification system uses the space efficiency factor ( $S_{eff} = \text{Usable floor area} / \text{Gross floor area}$ ) to determine the efficient use of floor area. To get a maximum score, the space efficiency factor must be at least 0.75.

The  $S_{eff}$  cannot be maximized without limit. Legal requirements for the size of work areas and trafficked areas must be considered.

☒ Environmental impact

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To recognise and encourage the use of construction materials with a low environmental impact over the full life cycle of the building.		
<b>BREEAM MAT 1:</b> Materials specification (Major building elements)	Assessment study of influence of 100% of family products elements	CBKII ZENORA NODA
<b>HQE 2.3:</b> Limited environmental impact on building	Knowledge of environmental impact on building components (structure and coverings) against EN 15804 and ISO 21930	CBKII
	Knowledge of environmental impact on building components against EN 15804 and ISO 21930	CBKII
	Knowledge of environmental impact on 50% of surface area of 4 covering families et 2 structure families of the building components against NF P01-010	LA MARSEILLAISE ZENORA NODA

→ **Methodologies, evaluation tools and/or standards used**

☒ Circular flows

See previous section "Improvement options"



- ☑ Material utility

See previous section “Improvement options”

- ☑ Environmental impact

Methodology used	Evaluation tools used	Standards used	Project concerned
LCA	ELODIE	NF P01-010 December 2004	CBKII LA MARSEILLAISE ZENORA
	MAT 1 calculator tool from BRE	Green Guide	CBK II ZENORA
Labels	PEFC and FSC label on woods products	Forest Stewardship Council requirements	CBKII LA MARSEILLAISE ZENORA

This aspect is considered in the 3 certifications concerned on this cluster. Unfortunately, credits have not been researched for LEED. As a result, there is no feedback on this project.

#### BREEAM (CBKII)

A technical study has been prepared in design stage and provides a summary of the MAT 1 calculator, framed by GREEN GUIDE rating, which is part of BREEAM (<https://www.bre.co.uk/greenguide/podpage.jsp?id=2126>). This green guide allows the comparison of several materials and components. Materials and components are arranged on an elemental basis so that designers and specifiers can compare and select from comparable systems or materials as they compile their specification.

The Green Guide rating covers the following issues: climate change, water extraction, mineral resource extraction, stratospheric ozone depletion, human toxicity, ecotoxicity to freshwater, nuclear waste, ecotoxicity to land, waste disposal, fossil fuel depletion, eutrophication, photochemical ozone creation, acidification.

#### BREEAM (ZENORA)

Four building elements have been studied using ELODIE as a nationally recognised LCA tool to evaluate their carbon footprint. For each building element, the solution with the lower environmental impact has been implemented in the development. Comparative analyses of a typical local building with the building assessed have been done with the Green Guide and the ELODIE LCA tool.

This report demonstrates that the outcome has influenced design choices for several building elements:

- External wall (choice for insulated concrete walls),
- Upper floor slabs (choice for hollow core slabs),
- Windows (choice for a mix of single and double skin façades).

#### HQE (ALL)

Environmental impact is analysed from French EPDs (FDES, <http://www.inies.fr/accueil/>). FDES is a standardised document that shows the results of a product's life cycle analysis as well as health information, used to calculate the environmental and health performance of an eco-design building. Since 2004 FDES documents have been regulated by the AFNOR NF P 01-010 standard and, since 2014, by the NF EN 15804+A1 standard and its national supplement XP P01-0641CN. They take the product's entire life cycle into account, from extracting the raw materials to the end

of its life, not forgetting the inclusion of transport, implementation, and even the product's usage. FDES sheets thus constitute a major multi-criteria tool that helps professionals make choices that will make their building more sustainable, with limited impact on the environment, all while creating a healthy atmosphere for future users. The aim is to push manufacturers to have environmental data on their products and production and inform their clients.

In LA MARSEILLAISE, wood components will be PEFC or FSC certified (<http://www.pefc.org/>) in order to comply to HQE and LEED certification.

#### → Project processes

##### ☒ Circular flows

Methodology	Stage	Lead actor	Supporting actor
Minimise waste disposal to landfill	Construction End-of-Life (Demolition)	Waste contractor, Waste platforms	Architect, manufacturers
Recycled content	Production	Manufacturer	Waste platforms, recycling facilities

##### ☒ Material utility

Methodology	Stage	Lead actor	Supporting actor
Checklist with adaptability and disassembly criteria	Conception Construction	Architect	manufacturers

##### ☒ Environmental impact

Methodology	Stage	Lead actor	Supporting actor
LCA	Conception Construction	Architect Engineers (mechanical, electrical, structural)	Manufacturers

#### 4.3.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

Potential indicators identified:

- Waste arising during construction and/or demolition
- Material recovery ratio / Proportion of waste diverted from landfill
- Adaptability score
- Ease and scope of disassembly
- Knowing environmental impact of components

→ **Key Indicator: Specification of construction materials with a low environmental impact over the full life cycle**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Embodied carbon emission

**Technical specifications**

- **Unit of measurement :** % of building components with A+ rating
- **Scope of indicator:** % of building components with A+ rating entered into the BREEAM assessor's MAT 1 calculator on external walls, windows, roof and upper floor slabs could imply the achievement of 3 BREEAM credits
- Associated data requirements: materials/elements should have a Green guide rating. In specific cases, it is possible to request ratings with BRE with supporting information such as technical information provided by the manufacturer
- Associated timeframe, conditions and requirements for measurement: not applicable
- Supporting tools required to quantify/estimate performance : MAT 01 Calculator from BRE
- Source of indicator/metric and its scientific and market acceptance: Green Guide

**4.3.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

1. *How accessible and easy to use was the indicator and the associated methodology?*
  - *Was the expertise already available within the design team/other project actors?*

LEED has not been achieved yet on LA MARSEILLAISE but the goal is to obtain the credits linked to materials environmental impact.

Data were accessible for HQE and BREEAM requirement and even if some environmental data were not found for BREEAM Green Guide rating, BRE created a rating pretty quickly after our request.

2. How readily available were the tools, data, test facilities etc... required to use the indicator?  
How reliable and/or comparable was the data and/or test methods used?  
What was the experience using calculation tools?

GREEN Guide and BREEAM tools related are really easy to use.

ELODIE enables a higher score on BREEAM but conclusions on design are the same on ZENORA.

3. *How useful was the indicator by the design team, contractor and/or in communication with clients (as applicable) in order to improve performance?*
  - *Was it suitable for the buildings evaluated? If no, what issues arose?*
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*

Clients did not give us a feedback on B2 indicators which could have helped them to sell/rent the buildings.

Interviews are not complete on this point, we will continue to ask question on this point and try to compare selling documents to certifications requirement if accessible.

4. *How time and cost intensive was use of the indicator?*

Performance has been followed up during design stage thanks to certification process and has been or will be checked at post construction stage.

Cost and time linked to the energy efficiency and studied linked to macro objective B2 have been included in the contracts.

5. Based on their experience, would you make any suggestions for improvement? These could be in relation to any aspect of its use

The BREEAM requirement to encourage and recognise the specification of responsibly sourced materials for key building elements is almost impossible to reach in France.

Efforts could be done but local infrastructures are not ready to answer to BREEAM requirements (EMS certificate as for example).

Concerning the DGNB criterion linked to the space efficiency factor, this indicator illustrates an initial goal of the client regarding surface optimization in the building. As a result, the certification did not directly imply a modification on our project but the indicator may help some other clients to improve this aspect.

#### 4.4 MACRO-OBJECTIVE B3: WATER USE

##### 4.4.1 TRANSLATION OF THE MACRO-OBJECTIVE INTO ACTION AT PROJECT LEVEL

→ Aspects covered of the macro-objective

☒ Water efficiency

→ Improvement option(s)

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce the consumption of potable water for sanitary use in buildings from all sources through the use of water efficient components and water recycling systems		
<b>HQE-cible 5.1:</b> Réduction de la consommation d'eau distribuée	Improvement against referenced consumption specific for each project	ALL
<b>BREEAM-WAT1:</b> Water consumption	Minimum 5,5 m <sup>3</sup> /person/year	CBKII ZENORA
<b>DGNB 14:</b> Potable water demand and Wastewater volume	dynamic reference value ≥ calculation result	CBKII
<b>Improvement option:</b> Strategies to reduce the water demand		
<b>DGNB cr 14:</b> Potable water demand and Wastewater volume	Demonstration of the implementation of the water concept in the design decisions, with an indication of gray water use	-
<b>BREEAM-WAT1:</b> Water consumption	If any greywater recycling system is specified, percentage of building's WC/Urinals using greywater to meet flushing demand must be determined	-
<b>Improvement option:</b> Monitor water consumption		
<b>BREEAM-WAT2:</b> Water-meter	Meters on the main water supply	CBKII

Evaluation criteria		Performance target	Project concerned
	of each building and/or green areas where demand will be equal to or greater than 10%		ZENORA
<b>HQE - 7.4.3:</b> Water monitoring systems	Meters per areas or use, green areas		CBKII ZENORA LA MARSEILLAISE
<b>Improvement option:</b> Reduce water footprint of the construction site			
<b>HQE-cible3:</b> Construction site with low environmental impact	Development of strategies to reuse and limit water on construction site (planning for irrigation of roads, reuse of rainwater to wash equipment on site, efficient equipment in the lockers...)		ALL

Detailed discussion:

The performance targeted differs for each certification scheme (HQE, BREEAM, LEED, DGNB) and the year of registration. The following improvement options were identified.

*Reduction of water consumption in use stage*

During construction, performance of sanitary appliances are verified based on manufacturer's data sheets provided by the contractor. Calculations are be updated in case of variation.

- HQE: The consumption (L/person/day) of the assessed building is compared to a reference consumption value
- BREEAM: The consumption (m<sup>3</sup>/person/day) of the assessed building is compared to a baseline performance. BREEAM credits are awarded if consumption value is less than 5,5m<sup>3</sup> per person per year. Maximum credits can be achieved when consumption is lower than 1,5m<sup>3</sup>/p/y
- LEED: The consumption (L/person/day) of the assessed building is compared to a baseline performance and is expressed in a % of reduction.
- DGNB: Limit values are calculated for each project in (m<sup>3</sup>/year). The target value can be reached with savings from innovative water-saving installations (for example, waterless urinals), intelligent irrigation strategies, use of grey water and/or use of rainwater. The "water use value" is created by adding the calculated potable water demand and the volume of waste water. This value is a clear representation of the water management in the building.

*Strategies to reduce the water demand (rainwater harvesting, grey water harvesting, etc.)*

Grey water recycling or rain water reuse are not necessary to respect HQE water criteria but to get the maximum environmental value under DGNB, BREEAM and LEED projects have to specified those systems. The calculation methodology is detailed in the DGNB Scheme.

Rainwater harvesting : Additional local regulation is considered in case of tour La Marseillaise (imposition on peak rate of run off and predicted volume of rainwater discharge linked), Zenora (special planning district which require reuse of rainwater) and CBK II (reuse of rainwater is common in Luxembourg).

Greywater reuse is considered in the BREEAM 2009 calculation tool. HQE do not consider the reuse of grey water at present time. DGNB and LEED consider the reuse of grey water in calculation (for

instance, in DGNB grey water that is used instead of potable water is subtracted from the water demand )

#### *Monitor water consumption by installing water meters and a Building Management System (BMS)*

All certification schemes require sub-meters and this is also now required by French regulation on new projects. BMS is not mandatory but this is often linked to the energy performance required by regulation. Projects certified under HQE often provide a BMS to the tenants.

#### *Reduce water footprint of the construction site*

BREEAM does not require specific targets but does encourage the process of setting, monitoring and reporting targets, related to water use during construction.

Monthly measurements of water consumption will be recorded and displayed on site and appropriate target levels of water consumption will be set from Constructing Excellence' Environmental KPI benchmarks or contractor's experience. Compliance is verified by a third party.

#### *Adjusted requirements in case of water scarcity*

In some cases the stringency of the requirements is adjusted to reflect local water scarcity. For example BREEAM refers to three precipitation zones.

### → Methodologies, evaluation tools and/or standards used

Methodology used	Evaluation tools used	Standards used	Project concerned
Calculation based on technical data et occupation assumptions compared to a reference fixed by certification scheme	HQE tool sheet	Certification scheme	ALL
	BREEAM tool sheet - Linked to 3 precipitation zones		ZENORA CBKII
	LEED tool sheet		LA MARSEILLAISE
	DGNB tool sheet		CBKII

#### Detailed discussion:

Regarding the methodologies used to verify the building performance regarding efficient water use, each certification scheme uses its own calculation tool. Calculations are based on technical data and occupation assumptions compared to a reference value and are stipulated by each certification scheme. In general the calculation methods fall into two broad categories

- Determine consumption based on reference data for building occupant consumption patterns
- Determine consumption based on reference data or manufacturers data for sanitary fittings.

Outdoor water usage then tends to be handled as a separate calculation.

In some cases certification schemes distinguish between uses where potable water is required and those where other lower grades of water may be used. A link is then made to how these lower quality grade uses are serviced e.g. using rain water, grey water

*Table 1: Overview of reference values for the flow rates of sanitary appliances according to the different certification schemes*

	HQE	BREEAM	LEED	DGNB
Toilets	6 L per use	6 L per use	6 L per use	9 L per use
Urinals	3,8 L/min	1,5 L/min	6 L/flush	3 L/flush
Showers	14 L/min	14 L/min	9,5 L/min 6bars	15 L/min
Tap (lavatories)	10 L/min	12 L/min	2 L/min 4bars	9 L/min
Tap (kitchen sink)	-	-	-	-
Additional comments	-	-	-	-

## HQE

HQE's Water Calculation Tool is used to estimate water consumption (L per person per year) for the building based on the installed sanitary fittings.

Default values used to calculate improvement are those ones

- Regular taps for wash hand basins (10 litres/minute) – it is considered that 1 use lasts 15s
- High flow shower (14 litres/minute) – it is considered that 1 use lasts 10min
- WC (6 litre cistern)
- Urinal = 3,8 litres per use (flush)

Gender, visitors, number of permanent workers in the building, frequency of sanitary water use can be modified in the tool.

Different level of improvement performance enable the achievement of higher scores (CC is conventional consumption):

BASE : CC common sanitary blocks  $\leq$  CCref common sanitary blocks

PERFORMANT : CC common sanitary blocks  $\leq$  0,70 CCref common sanitary blocks

HIGH PERFORMANCE (3 POINTS) : CC common sanitary blocks  $\leq$  0,60 CCref common sanitary blocks

HIGH PERFORMANCE (6 POINTS) : CC common sanitary blocks  $\leq$  0,50 CCref common sanitary blocks

HIGH PERFORMANCE (12 POINTS) : CC common sanitary blocks  $\leq$  0,40 CCref common sanitary blocks

To integrate a provision of rainwater which may cover % of sanitary water needs, design team has to justify by a separate calculation this %.

Then, it is integrated to the HQE tool.

Greywater recycling is not considered.

Reduction of water consumption linked to irrigation can add a value by achieving more point if it represents 40% when CC common sanitary blocks  $\leq$  0,60 CCref common sanitary blocks and 20% when CC common sanitary blocks  $>$  0,60 CCref common sanitary blocks.

Please note that water consumption tool is modified at each certification scheme's evolution.

## BREEAM

BREEAM's Water Calculation Tool is used to estimate water consumption (m3 per person per year) for the building based on the installed sanitary fittings.

When entering flow rates for wash hand basin taps into the Water Calculation Tool, the flow rate is taken as 2/3 of the maximum flow rate quoted by the manufacturer. The maximum flow rate can be the flow rate achieved with a flow restrictor i.e. where flow restrictors are specified, 2/3 of the flow rate with the restrictor installed should be taken.

Where specified taps have a 'break-point' at the mid-range of the flow (often referred to as 'click taps' or two stage mixer taps), the flow rate should be taken as the maximum flow rate quoted by the manufacturer for the lower range before the water break. This is typically 50 per cent of the maximum flow rate for the total range, however this should not be assumed and manufacturer's information must always be used.

The water calculator determines water consumption for the assessed building using a default occupancy figure of 1 person per 10m<sup>2</sup> of nett lettable area. Even for instances where building occupancy is known, the default occupancy figure must be used to ensure a consistent assessment. The tool allows the assessor to account for any rainwater or greywater collection by offsetting the contribution from these sources from the total estimated water consumption figure.

Calculation tool only requires flow rate for plumbing equipment.

Default values used to calculate improvement are those ones

- Regular taps for wash hand basins (12 litres/minute)
- High flow shower (14 litres/minute)
- WC (6 litre cistern)
- Cistern serving single urinal = 10 litres per use (flush).
- Cistern serving two or more urinals = 7.5 litres per use (flush).
- Urinals with manual flush on each stall or automatic pressure flushing valves = 1.5 litres per use.

Those information have to be justified by the design team but are not requirement in the tool in case of reuse of rainwater and/or greywater recycling:

- a. Annual rainfall for the site location (mm)
- b. Rainwater catchment area (m<sup>2</sup>)
- c. Catchment type e.g. pitched roof, flat roof
- d. Rainwater filter co-efficient
- e. Rainwater collection tank capacity
- f. Percentage of tap and shower water collected and used for WC/urinal flushing.
- g. Percentage of building's WC/urinals using greywater to meet flushing demand.

Please note that water consumption tool is modified at each certification scheme's evolution.

Different level of improvement performance enables the achievement of higher scores thanks to efficiency of equipment, reuse of rainwater and/or greywater recycling:

- One credit where consumption is 4.5 - 5.5m<sup>3</sup> per person per year
- Two credits where consumption is 1.5 - 4.4 m<sup>3</sup> per person per year
- Three credits where consumption is <1.5 m<sup>3</sup> per person per year

## **LEED**

Calculations are based on estimated occupant usage and includes only the following fixtures and fixture fittings (as applicable to the project scope): water closets, urinals, lavatory faucets, showers, kitchen sink faucets and pre-rinse spray valves.

Different level of improvement performance enables the achievement of higher scores thanks to efficiency of equipment, reuse of rainwater and/or greywater recycling (ranging from 30% to 40% reduction).

## **DGNB**

The evaluation of potable water demand and the volume of waste water primarily take into account measures that can be influenced during the design of the building.



$$WKW = (WBMA + AWMA) + (WBR + AWR) + (AWRW * fr)$$

WKW water use value [m<sup>3</sup>/a]

WBMA employee potable water demand [m<sup>3</sup>/a]

AWMA employee waste water volume [m<sup>3</sup>/a]

WBR potable water needed for cleaning [m<sup>3</sup>/a]

AWR volume of waste water from cleaning [m<sup>3</sup>/a]

AWRW portion of rainwater diverted to the drain system [m<sup>3</sup>/a]

fr corrective reduction factor of 0.5

Water use considered:

Potable water required by staff for bathroom sinks, toilets, urinals, showers, and kitchen sinks

Potable water required for cleaning

Potable water needed to water plants

Default values used to calculate improvement are those ones:

- Regular taps for wash hand basins (0,15 litres/sec)
- High flow shower (0,25 L/sec)
- WC (9 litre cistern)
- Urinal = 3litres per use (flush)

#### → Project processes

Methodology	Stage	Lead actor	Supporting actor
Calculation based on technical data et occupation assumptions compared to a reference fixed by certification scheme	Preliminary design, Technical design and building specifications Check compliance of the technical specifications during Construction	Environmental consultant	Architect, Plumbers and Engineers Contractors
Construction with low site impact	Construction	Contractors	Environmental consultant

#### Detailed discussion:

In the case of project which follow a certified assessment process, environmental requirements and recommendations are provided to design team.

From those, sanitary equipment are specified ensuring consistency with environmental goals and in order to reach a water consumption as low as possible.

In this case, the environmental consultant takes the lead to recommend best performance but the team will also consider esthetical indicator, cost and efficiency of the equipment.

During construction works, performance of sanitary equipment are checked from manufacturer's data collected by the contractor. Calculation could be updated in case of variation.

Concerning the goal of having low construction site impacts, those requirements have to be respected and checked by a third party:

- Monthly measurements of water consumption will be recorded and displayed on site.

- Appropriate target levels of water consumption will be set and displayed (targets could be annual, monthly or project targets). These should be based on the actual consumption figures from previous projects and should be appropriate to each construction stage.
- As a minimum, monitoring will/did include checking the meters and displaying some form of graphical analysis in the site office to show consumption over the project duration and how actual consumption compares to targets set.
- The design/site management team will/did nominate an individual responsible for the monitoring and collection of data.

Targets for water consumption during the construction process should be set using Constructing Excellence' Environmental KPI benchmarks. These documents do not specify targets but facilitate projects in setting appropriate targets.

[www.constructingexcellence.org.uk/zones/kpizone/default.jsp](http://www.constructingexcellence.org.uk/zones/kpizone/default.jsp) or  
[http://www.ccinw.com/sites/kpi\\_pages.html?site\\_id=5&section\\_id=171](http://www.ccinw.com/sites/kpi_pages.html?site_id=5&section_id=171)

BREEAM does not require targets to be met but is encouraging the process of setting, monitoring and reporting targets.

#### 4.4.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

Indicator		Unit of measurement	Life cycle stage
<b>B3: Water Use</b>			
Key	Water consumption during use stage	m <sup>3</sup> /person.day L/person.day	Use
Key	Reduction of water consumption	%	Use
Key	Water consumption during construction	m <sup>3</sup> and Dispositions on site construction	Construction

Supporting indicators:

- flow rate of sanitary appliances (l/flush for cisterns, urinals; l/minute for washbasins, showers)
- grey water re-used (% in relation to total grey water)
- rain water re-used (% in relation to total rainwater harvested)
- Installation of water metering, including sub-metering for high water using functions

##### → Water consumption reduction

- *Macro-objective:* B3: Water Use
- *Specific aspect(s):* Water consumption

### Technical specifications

- **Unit of measurement** : % of improvement
  - o **HQE** max defined by a reference which has to be calculated for each project
  - o **BREEAM** max 5,5m<sup>3</sup>/p/y
  - o **LEED** max defined by a reference which has to be calculated for each project
  - o **DGNB**
- **Life cycle stage**:
  - o Use stage: B7 operational water use
- **Scope of indicator**:
  - o In case of reuse of rainwater, water demand for irrigation or some other use is required
  - o
- Associated data requirements:
  - o **HQE** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to sanitary equipment
  - o **BREEAM** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to plumbing equipment
  - o **LEED** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to plumbing equipment. The consumption (L/person/day) of the assessed building is compared against a baseline performance.
- Associated timeframe, conditions and requirements for measurement: not applicable
- Supporting tools required to quantify/estimate performance : specific calculator updated for each specification scheme
- Source of indicator/metric and its scientific and market acceptance: not concerned

### Results

Indicator	Result
Water consumption reduction	<b>HQE requirements</b> <b>CBKII</b> 43% - CC common sanitary blocks = 11m <sup>3</sup> per day ≤ CC <sub>ref</sub> common sanitary blocks = 26 m <sup>3</sup> per day 12m <sup>3</sup> for reuse of rainwater for sanitary use, irrigation and washing parking area. <b>ZENORA NODA</b> 36% - CC common sanitary blocks = 3,79m <sup>3</sup> per day ≤ CC <sub>ref</sub> common sanitary blocks = 10,47 m <sup>3</sup> per day <b>LA MARSEILLAISE</b> 35% - CC common sanitary blocks = 11m <sup>3</sup> per day ≤ CC <sub>ref</sub> common sanitary blocks = 26 m <sup>3</sup> per day
	<b>BREEAM requirements</b> <b>CBKII</b> 3,71 m <sup>3</sup> /person.year <b>ZENORA NODA</b> 4,09 m <sup>3</sup> per person per year
	<b>DGNB requirements</b> <b>CBKII</b>

	11 160 m <sup>3</sup> /year
	<i>LEED requirements</i> <b>LA MARSEILLAISE</b> 32,39% from a calculated baseline design CC common sanitary blocks = 3,96m <sup>3</sup> per day ≤ CC <sub>ref</sub> common sanitary blocks = 5,86 m <sup>3</sup> per day

#### → Water consumption during construction

- *Macro-objective:* B3: Water Use
- *Specific aspect(s):* Water consumption

#### Technical specifications

- **Unit of measurement** : m<sup>3</sup> and dispositions on site
- **Life Cycle Stages:** A4-5 Construction
- **Scope of indicator:**
  - o **HQE / BREEAM** Development of strategies to reuse and limit water on construction site (planning for irrigation of roads, reuse of rainwater to wash equipment on site, efficient equipment in the lockers...)
  - o **BREEAM** Monitor, report and set targets for water consumption arising from site activities
- 
- Associated data requirements: water meter reporting
- Associated timeframe, conditions and requirements for measurement: monthly report and checked by a third party
- Supporting tools required to quantify/estimate performance : not applicable
- Source of indicator/metric and its scientific and market acceptance:

#### Results

Indicator	Result
Water consumption during construction	<b>CKII</b> Not known at present time <b>ZENORA NODA</b> 952 m <sup>3</sup> – goal of 770 m <sup>3</sup> <b>LA MARSEILLAISE</b> Not known at present time

#### 4.4.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

##### *CBK II, Luxembourg*

In Luxembourg, reuse of rainwater is common as a result high performance on the goal of water consumption reduction was easily accessible. It can be pointed out that client was aware of the cost, utility and accessibility of this measure as a result.

Concerning B3 but also all the certification requirements, the design team as well as the contractors are not always aware of the impact that these high environmental ambitions might have on their normal way of working. This was illustrated in the case of CBK II, where achieving the

goals linked to the triple certification (DGNB, BREEAM, HQE) during design and construction proved to be difficult to manage for the environmental consultant.

Even though the DGNB certification scheme is not common in France, the tool is relatively practical to use and understandable, owing to the fact that the methodology is well-explained methodology in the certification scheme manual. Furthermore, the integrated approach makes it possible to compare the water use values of different projects to one another, which is not always the case for the calculation tools in the other certification schemes (as it is not always transparent to know which assumptions are made). For instance, BREEAM under 2009 scheme is a “black box”. Project manager highlighted the fact that the calculation tool did not exist initially. However, associated guidelines for the calculation methodology are clear.

#### *LA MARSEILLAISE, Marseille*

The LEED V3 scheme is linked to American standards, which are more difficult to achieve than the European schemes (i.e. HQE, DGNB, BREEAM). The methodology is not easy and it is hard to fulfil to all the requirements (the project is at design stage at present time), mainly as a result of the more stringent reference values used for the sanitary appliances (for instance, 8.5 liter/minute for washbasins in contrast to 9 liters/minute (DGNB), 10 liter/minute (HQE) 12 liter/minute (BREEAM); 9,5 liter/minute for showers in contrast with 14 liters/minute (BREEAM), 14 liters/minute (HQE) and 15 liters/minute (DGNB))

Certification scheme implied on this project to have more vegetalised surfaces to respect rain water regulation.

Penalties were specified in the contractor’s agreement in case of not achieving the certifications goals. The design team can have to share in these costs.

#### *ZENORA, Paris*

Reuse of rainwater for irrigation and sanitary use and grey water recycling had been withdraw and then reintegrated to the project to get more credits. This was not simple because design team really wanted to achieve a good compromise between efficiency, cost and design.

The methodology of DGNB’s calculation tool and the provided clarification of the accompanying guidelines are of high value, as it does not leave too much room for interpretation and different assumptions (which can be the case for the calculation tools of the other certification schemes). This increases the comparability of the water use of buildings.

Finally, it should be noted that the standard ambitions levels of the certification criteria are not difficult to achieve

## **4.5 MACRO-OBJECTIVE B4: HEALTHY AND COMFORTABLE SPACES**

### **4.5.1 TRANSLATION OF THE MACRO-OBJECTIVE INTO ACTION AT PROJECT LEVEL**

#### **→ Aspects covered of the macro-objective**

- ☒ Ventilation strategy
- ☒ Hazardous substances

#### **→ Improvement option(s)**

- ☒ Ventilation strategy

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce the risk to health associated with poor indoor air quality		
<b>HQE 11.1/13.1:</b> ensuring an efficient ventilation	25 m3/h.pers in offices spaces	ALL
<b>BREEAM HEA 8:</b> Indoor Air quality	36 m3/h.pers in offices spaces	ZENORA CBKII
<b>BREEAM HEA 8:</b> Indoor Air quality	CO2 sensors in assembly rooms, auditorium	ZENORA CBKII
<b>LEED IEQp1-IEQc2</b> minimum Indoor Air Quality Performance Increased Ventilation	CO2 sensors in assembly rooms, auditorium	LA MARSEILLAISE
<b>LEED IEQp1-IEQc2</b> minimum Indoor Air Quality Performance Increased Ventilation	Design Outdoor Air Intake flow have to achieved LEED specific recommendations. For example > 13,7 cfm for office space	LA MARSEILLAISE

Detailed discussion:

Clients laid stress on energy performance more than health and comfort.

As a result, efforts have not been done on the projects with low general score under BREEAM.

☒ Hazardous substances

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To recognise and encourage a healthy internal environment through the specification of internal finishes and fittings with emissions of VOCs and formaldehyde known as much as possible		
<b>HQE 2.4/13.2 :</b> choosing building components to limit the sanitary impact of the construction/control of internal pollution level	Knowing VOC and formaldehyde emissions for 100% of the surface in contact with internal air (occupied spaces)	ALL
<b>BREEAM HEA 9:</b> Volatile organic Compounds	Respect of criteria for paintings, wood panels, timber structures, wood flooring, resilient textile and laminated floor coverings, suspended ceiling tiles, flooring adhesives, and wall covering for 100% of the surface in contact with internal air (occupied spaces)	ZENORA CBKII
<b>DGNB Criterion 20:</b> Indoor Air quality	3000 VOC // 120 formaldehyde	CBKII
<b>DGNB Criterion 20:</b> Indoor Air quality	Respect of category III of annex B of EN 15251	CBKII
<b>DGNB Criterion 6:</b> Local environmental impact	Respect of all DGNB criteria, 100% of level 2 (Avoided or reduced risks to human health by substituting materials with less harmful equivalents. A qualitative evaluation of the materials specified is	CBKII

Evaluation criteria	Performance target	Project concerned
	therefore required to ensure that the materials specified represent a lower risk.)	
<b>LEED IEQc4.1 to 4.4</b> Low emitting materials	All adhesives and sealants, paints and coating, flooring, ceiling walls and thermal + acoustic insulation and composite wood used on the interior of the building (i.e., inside of the weatherproofing system and applied on-site), must comply with LEED requirements	LA MARSEILLAISE
<b>LEED IEQc5</b> Indoor Chemical and Pollutant Source Control	Design to minimize and control the entry of pollutants into buildings and later cross-contamination of regularly occupied areas	LA MARSEILLAISE

Detailed discussion:

HQE certification's goal is to encourage the provision of environmental data more than consistency of value: FDES (French *fiches de données environnementales et sanitaires*) which follow the same norm as EPD (environmental product declaration - NF P 01-010) are not always checked.

BREEAM certification (2009 scheme) required a test certificate for each product supervised by European testing methodology.

Please note that at present time, BRE accepts eco labels which does not always means that a test supervised by European methods has been led.

→ **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Calculation of fresh air rates	-	French regulation	ALL
	-	EN 13779	CBKII ZENORA
Measure	Accreditation of the measurement institute	EN ISO 16000-6 EN ISO 16000-3	CBKII

Detailed discussion:

About CO2 sensors, areas of the building subject to large and unpredictable or variable occupancy patterns have CO2 sensors linked to the mechanical ventilation system and provide demand-controlled ventilation to the space. There is no specific methodology used.

Indoor TVOC concentrations for DGNB's scheme are determined based on the relevant standards (EN ISO 16000-6, SO 16000-3).

The TVOC content of indoor air must be determined by chemical analysis no more than four weeks after building completion and before furniture is installed. The minimum number of rooms to be tested is specified in the following table. The chemical compounds to be tested for include all of those which fall under the German Building Product Testing and Evaluation Scheme developed by the German Committee for Health-related Evaluation of Building Products (AgBB). In addition, concentrations of formaldehyde in the indoor air are tested.

→ **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Calculation of fresh air rates	Preliminary design, Technical design and building specifications Check of respect of specifications during Construction	Mechanical Engineer and Contractors	Architect and Environmental consultant

Detailed discussion:

Data of calculations are updated along the design process and construction of the building. This is certification's requirement to get the credits and to respect the assessment method.

The role of engineers is to design the installation in a first part but they also have to check the updated calculation made by contractors during Construction.

**4.5.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(s)**

→ **Overview**

Indicator		Unit of measurement	Scope
<b>B4: Healthy and comfortable spaces</b>			
<i>Key</i>	Fresh Air rate	m3/h.pers	Use
<i>Key</i>	Low emissions of VOCs	% of surface which respect HQE requirement about VOCs emissions (obligation of 80%)	Use
<i>Supporting</i>	Design of unpredictable or variable occupancy patterns	Providing CO2 sensors linked to mechanical ventilation	Use
<i>Supporting</i>	Design to minimize and control the entry of pollutants into buildings and later cross-contamination of regularly	Respect of LEED requirement	Use



Indicator		Unit of measurement	Scope
	occupied areas		

#### → Fresh Air rate

- *Macro-objective:* B4: Healthy and comfortable spaces
- *Specific aspect(s):* Ventilation strategy

#### Technical specifications

- **Unit of measurement :** m<sup>3</sup>/h.pers
- **Scope of indicator:** The aim is to reduce the risk to health associated with poor indoor air quality. The building has been designed to provide fresh air rates to dilute pollutants in accordance with local regulation for HQE, EN 13779 for BREEAM and LEED. It is also possible to work under ASHRAE Standard 62.1-2007
- Associated data requirements: calculation from mechanical engineer in design stage and contractor in post construction stage
- Associated timeframe, conditions and requirements for measurement: Fresh air rates are checked by measure after work completion.
- Supporting tools required to quantify/estimate performance
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Result
Fresh Air rate	<b>CBKII</b> 36 m <sup>3</sup> /h.pers <b>ZENORA NODA</b> 25 m <sup>3</sup> /h.pers <b>LA MARSEILLAISE</b> 25 m <sup>3</sup> /h.pers

#### → Low emissions of VOCs

- *Macro-objective:* B4: Healthy and comfortable spaces
- *Specific aspect(s):* Hazardous substances

#### Technical specifications

- **Unit of measurement :**
  - o % of surface (e.g. HQE, LEED)
  - o Emission class (e.g. BREEAM)
  - o µg/m<sup>3</sup>
- **Scope of indicator:**
  - o In general, Volatile Organic Compounds (VOCs) and aldehydes (in particular formaldehyde)
  - o HQE limits the scope to building materials in contact with the indoor air in occupied spaces.

- BREEAM also limits the requirements to key internal finishes and fittings integral to the building (wood panels, timber structures, wood flooring, textile and laminated floor coverings, suspended ceiling tiles, flooring adhesives, wall-coverings) but excludes furnishings (e.g. office desks). In particular for wood-based panels (such as OSB), BREEAM uses the formaldehyde emission classes E1 and E2 as referenced in the harmonised European standard EN 13986.
- LEED considers the following product categories: adhesives and sealants; paints and coatings; flooring systems; composite wood and agrifiber products.
- The proportion of the surface area that has to comply, depends on the desired certification scheme and the desired performance level. For instance, HQE requires a compliance for 50%, 80% or 100% of the surface area in contact with the indoor air, to acquire respectively base, performant or very performant rating levels. BREEAM on the other hand requires a surface area proportion of 100% for five out of the seven product types to acquire credits on this criterion.
- Associated data requirements: manufacturer's literature to know the VOCs emissions of component
- Associated timeframe, conditions and requirements for measurement
- Supporting tools required to quantify/estimate performance ELODIE (not an obligation)
- Source of indicator/metric and its scientific and market acceptance not concerned

#### Results

Indicator	Result
Low emissions of VOCs	<i>% of surface which respect HQE requirement about VOCs emissions (obligation of 80%)</i> <b>CBKII</b> 76% <b>ZENORA NODA</b> 76% <b>LA MARSEILLAISE</b> <75%
	<i>% of surface which respect BREEAM requirement about VOCs emissions (obligation of 100%)</i> <b>EULER</b> 100 % <b>MEDERICK</b> <100% - criterion not respected
	<i>% of surface which respect DGNB requirement about VOCs emissions (obligation of 100%)</i> <b>CBKII</b> 100 %
	<i>% of surface which respect BLEED requirement about VOCs emissions (obligation of 100%)</i> <b>LA MARSEILLAISE</b> Not known at present time

#### → Design of unpredictable or variable occupancy patterns

- *Macro-objective:* B4: Healthy and comfortable spaces
- *Specific aspect(s):* Ventilation strategy

- **Unit of measurement** : Providing CO2 sensors linked to mechanical ventilation
- **Scope of indicator**: In mechanically ventilated spaces, the sensors are linked to the mechanical ventilation system and provide demand-controlled ventilation to the space to ensure indoor air quality and reduce the risk to health

### Results

Indicator	Result
Design of unpredictable or variable occupancy patterns	CO2 sensors installed in meeting rooms dedicated spaces.

### 4.5.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

Certification to BREEAM (2009 scheme) required a test certificate for each product supervised by European testing methodology. All the projects had difficulties in particular with flooring adhesives and paints and varnishes that were used in internal spaces instead of their intended use for external spaces (but classified for the two uses by manufacturers). This is because they prove to result in higher VOC emissions than allowed for internal spaces although they comply with the Decopaint Directive<sup>16</sup> as a result of their double classification.

HQE's aim is understood to be the encouragement of the provision of environmental data more than achieving consistency in the values. Test certificates are not required and VOC performance is often linked to a label or manufacturers data.

Please note that at the present time, BRE accepts eco labels for products which does not always mean that a test carried out according to European methods has been used. Concerning the trade-off between energy performance and indoor air quality, clients tend to prioritise energy performance more than health and comfort. As a result, for projects with a low general score under BREEAM, and in order to achieve the necessary credits, energy tends to be prioritised over IAQ efforts.

## 4.6 MACRO-OBJECTIVE B6: OPTIMISED LIFE CYCLE COST AND VALUE

### 4.6.1 TRANSLATION OF THE MACRO-OBJECTIVE INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- ☒ Life Cycle Cost

#### → Improvement option(s)

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<sup>16</sup> Decopaint Directive: Directive 2004/42/CE of the European Parliament and of the Council of 21 April 2004 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products and amending Directive 1999/13/EC

Evaluation criteria	Performance target	Project concerned
To recognise and encourage the development of a Life Cycle Cost (LCC) analysis model for the project to improve design, specification and through-life maintenance and operation		
BREEAM	Analysis model for the project to improve design, specification and through-life maintenance and operation	ZENORA CBKII
DGNB	Life Cycle Cost Analysis Goal of the project: net value 2615 eur /m <sup>2</sup> (GFA <sup>17</sup> )	CBKII

In the CBK II project, LCC analyses were conducted both for BREEAM and DGNB.

The DGNB LCC analysis has been realized to determine whether the project meets the clients performance requirements against ISO 15686-Part5.

All the costs from project development to construction and handover of the building are defined as acquisition costs.

Maintenance and operation costs are determined at net present value over a period of 50 years.

Costs are given as a net value per m<sup>2</sup> of gross floor area. In addition, the ecological performance is compared to reference buildings.

Goal of the project: net value 2615 eur /m<sup>2</sup>(GFA<sup>18</sup>)

The BREEAM Life Cycle Cost analysis was initiated in July 2012 and updated in October 2012. This analysis synthetises the different costs given by the design team and is realised on 30 years and 60 years.

The lowest discounted LCC solutions identified in the LCC analysis were:

- Glazing
- Lighting

In the ZENORA project, a BREEAM LCC analysis was initiated in January 2012 and updated in October 2012. This analysis synthetizes the different costs given by the design team and is realised on 30 years and 60 years.

The lowest discounted LCC solutions identified in the LCC analysis were :

- 3 levels in basement,
- heat pumps using ground water.

These solutions have been implemented

#### → Methodologies, evaluation tools and/or standards used

Methodology used	Evaluation tools used	Standards used	Project concerned
Life cycle cost analysis	-	ISO 15686-Part5	CBKII ZENORA

<sup>17</sup> Gross Floor Area - total floor area inside the building envelope, including the external walls, and excluding the roof

<sup>18</sup> Gross Floor Area - total floor area inside the building envelope, including the external walls, and excluding the roof

Methodology used	Evaluation tools used	Standards used	Project concerned
Calculation of net value	-	DGNB Manual and data	CBKII

→ **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Life cycle cost analysis	Appraisal	Environmental consultant Economist	Architect Engineers Client
Calculation of net value	Conception	Environmental consultant Economist	Architect Engineers

#### 4.6.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

*Potential indicators identified:*

- Net present value [normalized per m<sup>2</sup>]

*Supporting indicators:*

- Building element and component life spans

#### 4.6.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

The *BREEAM criterion* was used in France for an analysis of the three buildings at the design phase. The indicators and the associated methodology required were not found to be accessible to all the project's actors for a number of reasons:

- The client did not plan for the LCC studies in the contracts;
- The environmental consultant had difficulties to guide the design team in the completion of studies;
- The design team had not carried out an LCC before in the context of a design;
- There was a lack of national databases or common guidelines to support LCC analyses in France.

In practice, the design teams did have the competence to conduct the LCC analyses. For instance, the cost consultants were familiar with cost data and could draw on their experience, while the engineers already possessed data on maintenance costs. The main knowledge gaps identified were linked to the end of life of the building and for all the categories of building elements (structure, envelope, services or finishing).

Regarding *DGNB*, the necessary expertise was not really available within the design team but the methodology was explained in detail. Default values for maintenance and end of life of the building were proposed in the manual. As a result, consultants was able to compile data and finalise the study. In the case of CBK II, these default values were effectively used.

In both cases, the scheme provided limited support. *DGNB* was at its pilot version and no tool was available for this criterion. *BREEAM* did not provide any tool or data to carry out LCC studies.

Having a standard LCC tool and supporting cost data available in each country may ensure a possible comparison between projects. Although it is appreciated that this may be difficult because there may be many differences from one Member State to another.

#### **4.7 REFERENCES**

BBC EFFINERGIE RT 2005

Energy label BBC Effinergie (RT 2012)

HQE v2008 Offices

HQE International v2011 Offices

BREEAM International SD 50660A : ISSUE 1.1 Europe Commercial v2009 Issue 1.1

DGNB (2012), DGNB international pilot version NOA10 : Office and administrative buildings – new build

LEED v3 2009 / Level Gold

## 5 FS 3. CLUSTER ALTO OFFICES, RENOVATION

### 5.1 FACT SHEET

#### 5.1.1 GENERAL INFORMATION

<b>Description</b>	The EULER project consists of the major refurbishment of a large office building. It was built in 1957 / 1959. Refurbishment works consist of: - Renovating the building fabric: new roof, new windows, new glazed wall; - Renovating the building systems: all HVAC, plumbing and security systems
<b>Involved parties</b>	OPCI EULER HERMES REAL ESTATE – Client EUROSIC GESTION – Developer Bouchaud Architects – Architect SNC Lavalin – Building services Engineers and Mechanical Engineers VP&Green engineering – Curtains wall Engineers ALTO INGENIERIE – BREEAM HQE LEED Consultant MAIN CONTRACTOR - DUMEZ
<b>Year</b>	2015

<b>Description</b>	The MEDERIC project consists of the major refurbishment of a large office building of 6'619sqm. Refurbishment works consist of: - Renovating the building fabric: new roof, new windows, new glazed wall; - Renovating the building systems: all HVAC, plumbing and security systems The building is located in France, in Paris (12-14 rue Méderic, 75017 Paris) The existing building occupies the site entirely.
<b>Involved parties</b>	OFI REIM – Client 234 Architecture - Architect CAP INGELEC – Mechanical Engineers ALTO INGENIERIE – BREEAM HQE LEED Consultant DUMEZ - Main contractor
<b>Year</b>	2013

<b>Description</b>	The LAFFITE LAFAYETTE project consists of the major refurbishment of a building with 1 level underground and 7 floors of office spaces. It is located in France, in the centre of Paris (75009).
<b>Involved parties</b>	EUROSIC – Developer DTACC – Architect MBE – HVAC Engineers SCEDATEC – Electrical Engineers ARCORA – Curtains wall Engineers SCYNA4 - Mechanical Engineers ALTO INGENIERIE – HQE Consultant SRC - GCC
<b>Year</b>	2015

#### 5.1.2 GEOGRAPHICAL AND BUILDING CHARACTERISTICS

##### Geographical and building characteristics

Building	Climate zone, Location	Typology	Type	Scale	Stage
Euler	Central-Europe, Paris (FR)	Office: medium-rise	Refurbishment	9 storeys; net area 13.300 m <sup>2</sup>	In-use
Mederick	Central-Europe, Paris (FR)	Office: medium-rise	Refurbishment	10 storeys; net area 6 619m <sup>2</sup>	In-use
Laffite Lafayette	Central-Europe, Paris (FR)	Office: medium-rise	Refurbishment	8 storeys; net area 5 589 m <sup>2</sup>	In-use

### 5.1.3 RELEVANT PROFESSIONAL CONTEXT

Assessment according to specific criteria in a building scheme/tool

Project	Certification Manual / Level Achieved	Energy Label Or Other environmental aspect
EULER	HQE Renovation v2010 BREEAM International v2009 Issue 1.1 / Level Very Good LEED v3 2009 / Level Gold	BBC Effinergie renovation (RT 2005 existant)
LAFFITE LAFAYETTE	HQE Renovation v2010	BBC Effinergie renovation (RT 2005 existant)
MEDERIC	HQE Renovation v2010 BREEAM International v2009 Issue 1.1 / Level Very Good BREEAM In-Use International v2015 / Level Excellent	BBC Effinergie renovation (RT 2005 existant)

## 5.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

### 5.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

→ Aspects covered of the macro-objective

- Operational carbon emissions
- Embodied carbon emissions

→ Improvement option(s)

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> Optimisation of the thermal envelop to reduce building energy needs.		
<b>HQE-cible 4.1.1 :</b> To improve building capacity to reduce energetical needs  <b>RT Existant globale :</b> building envelope performance	Ubât < Ubât max <b>EULER</b> Ubât max = 1,520 W/m <sup>2</sup> .K <b>MEDERICK</b> Ubât max = 0,92 W/m <sup>2</sup> .K <b>LAFFITE LAFAYETTE</b> Ubât max = 1,122 W/m <sup>2</sup> .K	ALL
<b>Improvement option:</b> To reduce energy consumption		
<b>RT Existant globale :</b> consumption considered by local regulation	Cep < Cep reference <b>EULER</b>	ALL



Evaluation criteria	Performance target	Project concerned
	Cep reference = 160 kWh/m <sup>2</sup> a <b>MEDERICK</b> Cep reference = 122 kWh/m <sup>2</sup> a <b>LAFFITE LAFAYETTE</b> Cep reference = 104 kWh/m <sup>2</sup> a	
Energy labelling " <b>BBC Effinergie Rénovation</b> "	Cep < Cref - 40%	ALL
<b>BREEAM, ENE 1 10 credits</b> : Reduce building primary energy consumption compared to regulation	Reduction of 37% as minimum compared to Cep reference to get 10 credits <b>EULER</b> Cep reference = 160 kWh/m <sup>2</sup> a <b>MEDERICK</b> Cep reference = 122 kWh/m <sup>2</sup> a	EULER
<b>HQE, cible 4.2.1</b> : Reduce building primary energy consumption	Reduction of 40% compared to HQE reference project <b>EULER</b> Cep reference = 160 kWh/m <sup>2</sup> a <b>MEDERICK</b> Cep reference = 122 kWh/m <sup>2</sup> a <b>LAFFITE LAFAYETTE</b> Cep reference = 104 kWh/m <sup>2</sup> a	ALL
<b>LEED EAP2 EAC1</b> : Minimum Energy Performance Option 1	5% improvement as minimum in the proposed building performance rating compared with the baseline building performance rating	EULER
<b>Improvement option: To reduce CO2 emissions</b>		
<b>HQE, cible 4.3.1</b> : Reduce CO2 emissions generated by energy use	Calculation of CO2 emissions linked to energy consumption	ALL
<b>Improvement option: To reduce SO2 emissions</b>		
<b>HQE, cible 4.3.1</b> : Reduce SO2 emissions generated by energy use	Calculation of SO2 emissions linked to energy consumption	ALL
<b>Improvement option: L2C energy sources</b> To reduce carbon emissions and atmospheric pollution by encouraging local energy generation from renewable sources to supply a significant proportion of the energy demand.		
<b>HQE 4.2.4</b> : Reduce building regular energy consumption by using L2C energy	Building energy needs must be covered by 10 to 40 % of L2C energy sources compared with global consumption	EULER
<b>BREEAM, ENE 5</b> : Low or zero carbon technologies	A local L2C energy technology must be installed in line with recommendations of a feasibility study led by an energy specialist and this method of supply results in more than 15% reduction in the building's CO2 emissions (not achieved on the project but the study has been led)	EULER

Detailed discussion:

$$U_{\text{bat}} \text{ max} = U_{\text{bat}} \text{ réf} + 25\%$$

$U_{\text{bat}}$ : Heat loss of a building by transmission through the walls (including thermal bridges) and windows expressed in W/m<sup>2</sup>/K. The lower  $U_{\text{bat}}$  is, the better the building envelope is performing.

Cep: Conventional energy consumption of a building for heating, cooling, domestic hot water, electricity for pumps and fans, and lighting facilities are expressed in kWh/m<sup>2</sup> /year in primary energy.

BBC Label EFFINERGIE The energy target is not given in absolute value. This label requires designing buildings twice as efficient as conventional buildings. New buildings: The target for maximum primary energy consumption is 40% of the baseline fixed by the thermal regulation.

- ☒ Embodied carbon emissions

Evaluation criteria	Performance target
<b>Improvement option:</b> To recognise and encourage the use of construction materials with a low environmental impact over the full life cycle of the building.	
<b>BREEAM MAT 1:</b> Materials specification (Major building elements)	A+ Rating for building components linked to roof, external walls, windows and upper floors

Detailed discussion:

A technical study has been prepared in design stage and provides a summary of the MAT 1 calculator, framed by GREEN GUIDE rating.

<https://www.bre.co.uk/greenguide/podpage.jsp?id=2126>

The Green Guide is part of BREEAM (BRE Environmental Assessment Method) an accredited environmental rating scheme for buildings. The environmental rankings are based on Life Cycle Assessments (LCA), using BRE's Environmental Profiles Methodology 2008.

Materials and components are arranged on an elemental basis so that designers and specifiers can compare and select from comparable systems or materials as they compile their specification.

The Green Guide rating, which is a measure of overall environmental impacts covering the following issues: Climate change, Water extraction, Mineral resource extraction, Stratospheric ozone depletion, Human toxicity, Ecotoxicity to Freshwater, Nuclear waste (higher level), Ecotoxicity to land, Waste disposal, Fossil fuel depletion, Eutrophication, Photochemical ozone creation, Acidification

About EULER, it should be noted that all existing / retained elements, e.g. external walls have been allocated an A+ rating. (Rate from A+ to E in Green Guide to specification)

→ **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Regulation calculation tool	Climawin 4.2 1.0.3	RT 2005 Existant (refurbishment)	ALL
Dynamic thermal simulation: Feasibility and comparison study with DTS as decision support tools	Virtual Environment" software: edited by IES Software Ltd, with APACHE calculation code	ASHRAE 90,1-2007 Appendix G methodology	EULER

Methodology used	Evaluation tools used	Standards used	Project concerned
LCA	Green Guide	<a href="https://www.bre.co.uk/filelibrary/greenguide/PDF/The-Green-Guide-Explained_March2015.pdf">https://www.bre.co.uk/filelibrary/greenguide/PDF/The-Green-Guide-Explained_March2015.pdf</a>	

Detailed discussion:

Energy demand is primarily calculated in design phase and updated during construction. Regulatory calculation is based on French *Règlementation Thermique 2005* regulation by using Climawin software (but it is not compulsory, over software are validated to realise this calculation). Furthermore, in order to meet the energy requirement for Leed certification scheme, the energy demand is also calculated by using ASHRAE 90,1-2007 Appendix G methodology and Virtual Environment” software: edited by IES Software Ltd, with APACHE calculation code .

→ **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Regulation calculation tool	Preliminary design, Technical design and building specifications and Construction	Contractors Mechanical Engineers	Architect / environmental consultant in preliminary/technical design phase and contractor in construction
Dynamic thermal simulation : Feasibility and comparison study with DTS as decision support tools	Preliminary design, Technical design and building specifications and Construction	Environmental consultant	Architect/engineer in preliminary/technical design phase and contractor in construction
LCA	Preliminary design, Technical design and building specifications Check of respect of specifications during Construction	Environmental consultant	Architect/engineer in preliminary/technical design phase and contractor in construction

Detailed discussion:

In the building design phase, energy demand is calculated by taking into account the local regulation and energy label requirement. Energy experts take the lead and have supports from architects. When an environmental consultant is associated to the projects, it could be lay stress on the fact that a complete control of values specified in prescriptions is done and checked in the case of certification process.

In the construction phase, the regular inspection of the quality of the construction works by the architect and responsible contractor is a very important task considering that some modifications could occur during works phase.

The execution of quality assurance tests (by a third party as for example the environmental consultant) is useful to indicate during the course of the construction works whether the final targets are realisable or to which specific issues extra attention should be paid.

Calculation of energy demand is required to get an energy label as BBC renovation.

It is often done by the general contractor or HVAC contractor.

Those data are updated in the final energy demand calculations of our cluster:

- in use ventilation rates verified via measurements by inspections
- results from duct air leakage tests according to NBN EN 12237
- performance of envelope's insulation and glazing

Commissioning of the building systems after work completion is an important part of the completion and operational lifetime of building project and a valuable contribution to its overall performance assessment. It has been done for EULER project.

## 5.2.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(s)

### → Overview

Indicator		Unit of measurement	Scope
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>			
Key	Primary Energy Consumption (Cep)	kWh/m <sup>2</sup> year	Operational Energy Average of all U value of facade element: wall, roof, windows...
Key	Specification of low or zero carbon technologies	% reduction in the building's CO2 emissions	Operational Energy
Key	Specification of construction materials with a low environmental impact over the full life cycle	% of surface	Operational Energy
Supporting	Envelope capacity to restrict losses (U <sub>bât</sub> )	W/m <sup>2</sup> .K	Operational Energy Average of all U value of facade element: wall, roof, windows...
Supporting	CO2 emissions	kg eq. CO2 /m <sup>2</sup> SHON/year	Operational Energy due to heating, cooling, lighting, hot water, ventilation & auxiliary, and relative to thermal surface
Supporting	SO2 emissions	g éq. SO2/m <sup>2</sup> SHON/year	

### → Key Indicator #1: Primary Energy Consumption (Cep)

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions

#### Technical specifications

- **Unit of measurement** : kWh/m<sup>2</sup>year

- **Scope of indicator:** the net energy consumption includes all energy use for space heating, space cooling, domestic hot water, auxiliary energy and the energy use for collective functions such as elevators and outdoor lighting in the entire neighbourhood, and the household electricity is not taken into account for the theoretical calculation, however can be measured by metering data.
- Associated data requirements:
  - o Thermal zoning
  - o Opaque constructions
  - o Glazed constructions
  - o Occupancy
  - o Lighting
  - o Fresh air rates
  - o Heating and cooling systems description
  - o Temperature set points
  - o Air Tightness
  - o Meteorological data
- Associated timeframe, conditions and requirements for measurement: manufacturers data and calculation from design team/contractor to specify systems
- Supporting tools required to quantify/estimate performance : specific software
- Source of indicator/metric and its scientific and market acceptance: ASHRAE 90,1-2007 Appendix G methodology has to be followed to achieve LEED requirements

#### Results

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
Primary Energy Consumption (Cep)	<b>EULER</b> Cep = 93,20 kWh/m <sup>2</sup> y (improvement of 42,11%) <b>MEDERICK</b> Cep reference = 69 kWh/m <sup>2</sup> y (improvement of 43,44%) <b>LAFFITE LAFAYETTE</b> Cep = 59,47 kWh/m <sup>2</sup> y (improvement of 40,97%)

#### → Key Indicator #2: Specification of low or zero carbon technologies

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions, embodied carbon emission

#### Technical specifications

- **Unit of measurement :** % of improvement against a reference
- **Scope of indicator:** the percentage of improvement is calculated from the energy consumption calculation
- Associated data requirements: energy study to compare different production proposals with or without LZC study
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	

Indicator	Results (As built)
SPECIFICATION OF LOW OR ZERO CARBON TECHNOLOGIES	<b>EULER</b> <10% of reduction of CO2 emissions Credit not achieved but solar water heating system has been implemented.

→ **Key Indicator #3: Specification of construction materials with a low environmental impact over the full life cycle**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Embodied carbon emission

**Technical specifications**

- **Unit of measurement** : % of building components with A+ rating
- **Scope of indicator:** % of building components with A+ rating entered into the BREEAM assessor's MAT 1 calculator on external walls, windows, roof and upper floor slabs could imply the achievement of 3 BREEAM credits
- Associated data requirements: materials/elements should have a rate under Green guide. It is still possible to ask for a specific rate by proforma to the BRE with supporting information like manufacturer's literature
- Associated timeframe, conditions and requirements for measurement: materials/elements should have a rate under Green guide. It is still possible to ask for a specific rate by proforma to the BRE with supporting information like manufacturer's literature
- Supporting tools required to quantify/estimate performance : MAT 01 Calculator from BRE
- Source of indicator/metric and its scientific and market acceptance: Green Guide

**Results**

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
Specification of construction materials with a low environmental impact over the full life cycle	<b>EULER</b> The technical study, which has been prepared in design stage, provides a summary of the MAT 1 calculator as well as the following additional details: <ul style="list-style-type: none"> <li>- the location of the element;</li> <li>- the area of the element;</li> <li>- its constituent materials;</li> <li>- its Green Guide rating (it should be noted that all existing / retained elements, e.g. external walls have been allocated an A+ rating)</li> </ul> The document provides information on the following elements: Roofs, External walls, Windows and Upper floors Rates go from C to A+ and it enables to get 4 credits under BREEAM SCHEME.

→ **Supporting Indicator #1: Envelope capacity to restrict losses ( $U_{bat}$ )**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

#### Technical specifications

- **Unit of measurement** : W/m<sup>2</sup>.K
- **Scope of indicator**: envelop performance compared to a reference supervised by regulation calculation methodology (Average of all U value of facade element: wall, roof, windows...)
- Associated data requirements
  - o U value of façade, floor slabs, roof element
  - o Volumetrics of the building
- Associated timeframe, conditions and requirements for measurement: manufacturers data
- Supporting tools required to quantify/estimate performance: specific software
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
Envelope capacity to restrict losses ( $U_{bat}$ )	<b>EULER</b> $U_{bat} \text{ max} = 779 \text{ W/m}^2.K$ <b>MEDERICK</b> $U_{bat} = 0,92 \text{ W/m}^2.K$ <b>LAFFITE LAFAYETTE</b> $U_{bat} = 0,810 \text{ W/m}^2.K$

#### → Supporting Indicator #2: CO2 emissions

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Operational carbon emissions, embodied carbon emission

#### Technical specifications

- **Unit of measurement** : kg. CO<sub>2</sub>eq /m<sup>2</sup> GIFA.year
- **Scope of indicator**: the CO<sub>2</sub> emission is calculated from the energy consumption calculation
- Associated data requirements: CO<sub>2</sub> emission of the hot and cold production
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance: not concerned

#### Results

Indicator	Results (As built)
<b>B1: Greenhouse gas emissions from building life cycle energy use</b>	
CO2 emissions	<b>EULER</b> Ref = 4,45 kg. CO <sub>2</sub> eq /m <sup>2</sup> GIFA.year <b>MEDERICK</b> Ref = 7,575 kg. CO <sub>2</sub> eq /m <sup>2</sup> GIFA.year <b>LAFFITE LAFAYETTE</b> Ref = 5,3 kg. CO <sub>2</sub> eq /m <sup>2</sup> GIFA.year

#### 5.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

1. *How accessible and easy to use was the indicator and the associated methodology?*
  - *Was the expertise already available within the design team/other project actors?*

Indicators and associated methodologies except the ones associated with LEED certification were accessible, easy to use for each member of the team, as most of the energy performance requirements directly related to the local regulation.

LEED is not well known by French designers but methodologies and tools are available and explained. Main challenge of the refurbishment project was to make a compromise between the conservation of the architectural value (which was a mandatory aspect in some case) and achieving a high energy performance.

2. *How readily available were the tools, data, test facilities etc... required to use the indicator?  
How reliable and/or comparable was the data and/or test methods used?  
What was the experience using calculation tools?*

Data used was derived from the as-built documents, as a result they are reliable and readily available. The building has been certified for HQE, LEED and BREEAM for Post Construction Phase and the energy labels BBC Effinergie has been validated for all the projects.

Conventional energy performance calculation tools (according to local regulation) have been used.

3. *How useful was the indicator by the design team, contractor and/or in communication with clients (as applicable) in order to improve performance?*

#### EULER

The client gave priority to indoor air quality instead of high energy performance (which resulted in higher ventilation rates). Nevertheless, the related energy label has been achieved even with this decision.

#### LAFFITE LAFAYETTE

The certification ambitions have been decided relatively late in the process. As a result, associated indicators and methodologies were not well known by the client but he was aware of the fact that this would provide a great value to sell the building. During construction, the destination of a number of spaces that were originally initially designed as offices were changed to sports areas, cafeterias and conference rooms, which implied a risk in achieving the energy performance values. Cooperate with the investor as soon as possible in the design process is really beneficial to maintain the energy performance by considering the tenant needs.

4. *How time and cost intensive was use of the indicator?*

Performance has been followed-up during design stage as a result of the certification process and has been checked at post construction stage. Conventional energy performance calculation tools (according to local regulation) have been used.

LEED requirements required dynamic thermal modelling and new knowledge of the team (for instance, as a result of the American standards and methodologies).

#### LAFFITE LAFAYETTE

Considering modification of uses in the building during works, design team contracts have been modified to integrate evaluation of tenants works.

#### MEDERIC



After completion of the construction works, the building was not entirely occupied, as a result, the client has begun a BREEAM In-Use certification.

5. *Based on their experience, would you make any suggestions for improvement? These could be in relation to any aspect of its use*

The three projects tried to reach medium environmental performance on one to three certification schemes. According to ALTO's experience, achieving those goals are often linked to having a high score on energy performance. Moreover when the client does not reach an outstanding or excellent level, efforts are often concentrated on energy use.

As for new construction, having several contractors on a building site represent a risk not to obtain a certification. Design team appointed to follow the certification during construction works must be totally involved and having knowledge on the environmental subjects.

### 5.3 MACRO-OBJECTIVE B3: EFFICIENT USE OF WATER RESOURCES

#### 5.3.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Water consumption

##### → Improvement option(s)

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce the consumption of potable water for sanitary use in buildings from all sources through the use of water efficient components and water recycling systems		
<b>HQE-cible 5.1:</b> Réduction de la consommation d'eau distribuée	Improvement against referenced consumption specific for each project	ALL
<b>BREEAM-WAT1:</b> Water consumption	<4,4 m <sup>3</sup> /person.year	EULER
<b>LEED WEp1:</b> Water efficiency	Reduction of 20% of the water consumption	EULER
<b>BREEAM-MAN 3</b> Construction site impacts	Monitor, report and set targets for water consumption arising from site activities	EULER MEDERIC
<b>HQE-cible3:</b> Construction with low site impact	Development of strategies to reuse and limit water on construction site (planning for irrigation of roads, reuse of rainwater to wash equipment on site, efficient equipment in the lockers...)	ALL

Detailed discussion:

#### HQE

An assessment of the efficiency of the building's domestic water consuming components is undertaken using the HQE target 5 calculator.

The consumption (L/person/day) of the assessed building is compared against a baseline performance and performance is achieved depending on a % of improvement.

#### **BREEAM**

An assessment of the efficiency of the building's domestic water consuming components is undertaken using the BREEAM WAT 01 calculator.

The consumption (m<sup>3</sup>/person/day) of the assessed building is compared against a baseline performance and BREEAM credits are awarded if consumption value is less than 5,5m<sup>3</sup> per person per year.

Maximum credits value is achieved with a consumption lower than 1,5m<sup>3</sup>/p/y

#### **LEED**

An assessment of the efficiency of the building's domestic water consuming components is undertaken using the LEED calculator.

The consumption (L/person/day) of the assessed building is compared against a baseline performance.

Concerning efforts during works,

#### → **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Calculation based on technical data et occupation assumptions compared to a reference fixed by certification scheme	HQE tool sheet	Certification scheme	ALL
	BREEAM tool sheet - Linked to 3 precipitation zones		EULER
	LEED tool sheet		EULER

Detailed discussion:

#### **HQE**

HQE's Water Calculation Tool is used to estimate water consumption (L per person per year) for the building based on the installed sanitary fittings.

Default values used to calculate improvement are those ones

- Regular taps for wash hand basins (10 litres/minute) – it is considered that 1 use lasts 15s
- High flow shower (14 litres/minute) – it is considered that 1 use lasts 10min
- WC (6 litre cistern)
- Urinal = 3,8 litres per use (flush)

Gender, visitors, number of permanent workers in the building, frequency of sanitary water use can be modified in the tool.

Different level of improvement performance enable the achievement of higher scores (CC is conventional consumption):

BASE : CC common sanitary blocks  $\leq$  CC<sub>ref</sub> common sanitary blocks

PERFORMANT : CC common sanitary blocks  $\leq$  0,70 CC<sub>ref</sub> common sanitary blocks

HIGH PERFORMANCE (3 POINTS) : CC common sanitary blocks  $\leq$  0,60 CC<sub>ref</sub> common sanitary blocks

HIGH PERFORMANCE (6 POINTS) : CC common sanitary blocks  $\leq$  0,50 CC<sub>ref</sub> common sanitary blocks

HIGH PERFORMANCE (12 POINTS) : CC common sanitary blocks  $\leq$  0,40 CC<sub>ref</sub> common sanitary blocks

To integrate a provision of rainwater which may cover % of sanitary water needs, design team has to justify by a separate calculation this %.

Then, it is integrated to the HQE tool.

Greywater recycling is not considered.

Reduction of water consumption linked to irrigation can add a value by achieving more point if it represents 40% when CC common sanitary blocks  $\leq 0,60$  CC<sub>ref</sub> common sanitary blocks and 20% when CC common sanitary blocks  $> 0,60$  CC<sub>ref</sub> common sanitary blocks.

Please note that water consumption tool is modified at each certification scheme's evolution.

### **BREEAM**

BREEAM's Water Calculation Tool is used to estimate water consumption (m<sup>3</sup> per person per year) for the building based on the installed sanitary fittings.

When entering flow rates for wash hand basin taps into the Water Calculation Tool, the flow rate is taken as 2/3 of the maximum flow rate quoted by the manufacturer. The maximum flow rate can be the flow rate achieved with a flow restrictor i.e. where flow restrictors are specified, 2/3 of the flow rate with the restrictor installed should be taken.

Where specified taps have a 'break-point' at the mid-range of the flow (often referred to as 'click taps' or two stage mixer taps), the flow rate should be taken as the maximum flow rate quoted by the manufacturer for the lower range before the water break. This is typically 50 per cent of the maximum flow rate for the total range, however this should not be assumed and manufacturer's information must always be used.

The water calculator determines water consumption for the assessed building using a default occupancy figure of 1 person per 10m<sup>2</sup> of nett lettable area. Even for instances where building occupancy is known, the default occupancy figure must be used to ensure a consistent assessment. The tool allows the assessor to account for any rainwater or greywater collection by offsetting the contribution from these sources from the total estimated water consumption figure.

Calculation tool only requires flow rate for plumbing equipment.

Default values used to calculate improvement are those ones

- Regular taps for wash hand basins (12 litres/minute)
- High flow shower (14 litres/minute)
- WC (6 litre cistern)
- Cistern serving single urinal = 10 litres per use (flush).
- Cistern serving two or more urinals = 7.5 litres per use (flush).
- Urinals with manual flush on each stall or automatic pressure flushing valves = 1.5 litres per use.

Those information have to be justified by the design team but are not requirement in the tool in case of reuse of rainwater and/or greywater recycling:

- a. Annual rainfall for the site location (mm)
- b. Rainwater catchment area (m<sup>2</sup>)
- c. Catchment type e.g. pitched roof, flat roof
- d. Rainwater filter co-efficient
- e. Rainwater collection tank capacity
- f. Percentage of tap and shower water collected and used for WC/urinal flushing.
- g. Percentage of building's WC/urinals using greywater to meet flushing demand.

Please note that water consumption tool is modified at each certification scheme's evolution.

Different level of improvement performance enables the achievement of higher scores thanks to efficiency of equipment, reuse of rainwater and/or greywater recycling:

- One credit where consumption is 4.5 - 5.5m<sup>3</sup> per person per year
- Two credits where consumption is 1.5 - 4.4 m<sup>3</sup> per person per year
- Three credits where consumption is <1.5 m<sup>3</sup> per person per year

#### LEED

Calculations are based on estimated occupant usage and includes only the following fixtures and fixture fittings (as applicable to the project scope): water closets, urinals, lavatory faucets, showers, kitchen sink faucets and pre-rinse spray valves.

Different level of improvement performance enables the achievement of higher scores thanks to efficiency of equipment, reuse of rainwater and/or greywater recycling:

Please note that water consumption tool is modified at each certification scheme's evolution.

#### → Project processes

Methodology	Stage	Lead actor	Supporting actor
Calculation based on technical data et occupation assumptions compared to a reference fixed by certification scheme	Preliminary design, Technical design and building specifications Check of respect of specifications during Construction	Environmental consultant	Architect, Plumbers, Engineers and Contractors
Construction with low site impact	Construction	Contractors	Environmental consultant

#### Detailed discussion:

In the case of project which follow a certified assessment process, environmental requirements and recommendations are provided to design team.

From those, plumbing equipment are specified ensuring consistency with environmental goals and in order to reach a water consumption as low as possible.

In this case, the environmental consultant takes the lead to recommend best performance but the team will also consider esthetical indicator, cost and efficiency of the equipment.

Grey water recycling or Rain water reuse are not necessary to respect HQE water criteria but to get the maximum environmental value under BREEAM and LEED projects have to specified those systems.

During works, performance of plumbing equipment are checked from manufacturer's data collected by the contractor.

Calculation could be updated in case of variation.

Concerning the goal of having low construction site impacts, those requirements have to be respected and checked by a third party:

- Monthly measurements of water consumption will be recorded and displayed on site.

- Appropriate target levels of water consumption will be set and displayed (targets could be annual, monthly or project targets). These should be based on the actual consumption figures from previous projects and should be appropriate to each construction stage.
- As a minimum, monitoring will/did include checking the meters and displaying some form of graphical analysis in the site office to show consumption over the project duration and how actual consumption compares to targets set.
- The design/site management team will/did nominate an individual responsible for the monitoring and collection of data.

Targets for water consumption during the construction process should be set using Constructing Excellence' Environmental KPI benchmarks. These documents do not specify targets but facilitate projects in setting appropriate targets.

[www.constructingexcellence.org.uk/zones/kpizone/default.jsp](http://www.constructingexcellence.org.uk/zones/kpizone/default.jsp) or

[http://www.ccinw.com/sites/kpi\\_pages.html?site\\_id=5&section\\_id=171](http://www.ccinw.com/sites/kpi_pages.html?site_id=5&section_id=171)

BREEAM does not require targets to be met but is encouraging the process of setting, monitoring and reporting targets.

### 5.3.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

#### → Overview

Indicator		Unit of measurement	Scope
<b>B3: Water Use</b>			
Key	Water consumption reduction	% (L/person/day)	Use
Key	Works water consumption	m <sup>3</sup> and Dispositions on site construction	Construction on site

#### → Key Indicator #4: Water consumption reduction

- *Macro-objective:* B3: Water Use
- *Specific aspect(s):* Water consumption

#### Technical specifications

- **Unit of measurement** : % of improvement
  - o **HQE** max defined by a reference which has to be calculated for each project
  - o **BREEAM** max 5,5m<sup>3</sup>/pers.year
  - o **LEED** max defined by a reference which has to be calculated for each project
- **Scope of indicator:**
  - o **HQE** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to plumbing equipment
  - o **BREEAM** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to plumbing equipment

- **LEED** calculation are done from assumptions on the building occupation (permanent and visitors, % of male and female, etc.) and linked to manufacturers data linked to plumbing equipment. The consumption (L/person/day) of the assessed building is compared against a baseline performance.
- Associated data requirements: In case of reuse of rainwater, water demand for irrigation or some other use is required
- Associated timeframe, conditions and requirements for measurement: not concerned
- Supporting tools required to quantify/estimate performance : specific calculator updated for each specification scheme
- Source of indicator/metric and its scientific and market acceptance: not concerned

### Results

Indicator	Results (As built)
<b>B3: Water Use</b>	
Water consumption reduction	<p><i>HQE requirements</i></p> <p><b>EULER</b> 61,7% - CC common sanitary blocks = 11m<sup>3</sup> per day ≤ CC<sub>ref</sub> common sanitary blocks = 26 m3 per day 12m<sup>3</sup> for reuse of rainwater for sanitary use, irrigation and washing parking area.</p> <p><b>MEDERICK</b> 36% - CC common sanitary blocks = 3,79m<sup>3</sup> per day ≤ CC<sub>ref</sub> common sanitary blocks = 10,47 m3 per day</p> <p><b>LAFFITE LAFAYETTE</b> 35% - CC common sanitary blocks = 11m<sup>3</sup> per day ≤ CC<sub>ref</sub> common sanitary blocks = 26 m<sup>3</sup> per day</p>
	<p><i>BREEAM requirements</i></p> <p><b>EULER</b> 2,98 m<sup>3</sup>/person.year</p> <p><b>MEDERICK</b> 4,09 m3 per person per year</p>
	<p><i>LEED requirements</i></p> <p><b>EULER</b> 32,39% from a calculated baseline design CC common sanitary blocks = 3,96m<sup>3</sup> per day ≤ CC<sub>ref</sub> common sanitary blocks = 5,86 m3 per day</p>

### → Key Indicator #5: Works water consumption

- *Macro-objective*: B3: Water Use
- *Specific aspect(s)*: Water consumption

### Technical specifications

- **Unit of measurement** : m3 and dispositions on site
  - **HQE / BREEAM** Development of strategies to reuse and limit water on construction site (planning for irrigation of roads, reuse of rainwater to wash equipment on site, efficient equipment in the lockers...)
  - **BREEAM** Monitor, report and set targets for water consumption arising from site activities
- **Scope of indicator**: To reduce the environmental impact of the construction

- Associated data requirements: water meter reporting
- Associated timeframe, conditions and requirements for measurement: monthly report and checked by a third part
- Supporting tools required to quantify/estimate performance : not concerned
- Source of indicator/metric and its scientific and market acceptance:  
[www.constructingexcellence.org.uk/zones/kpizone/default.jsp](http://www.constructingexcellence.org.uk/zones/kpizone/default.jsp) or  
[http://www.ccinw.com/sites/kpi\\_pages.html?site\\_id=5&section\\_id=171](http://www.ccinw.com/sites/kpi_pages.html?site_id=5&section_id=171)

### Results

Indicator	Results (As built)
<b>B3: Water Use</b>	
Water consumption during construction	<b>EULER</b> 1 653 m <sup>3</sup> – initial target 1017m <sup>3</sup> <b>MEDERICK</b> 952 m <sup>3</sup> – initial target 770m <sup>3</sup> <b>LAFFITE LAFAYETTE</b> 952 m <sup>3</sup> – no initial target specified

## 5.4 MACRO-OBJECTIVE B4A: HEALTHY AND COMFORTABLE SPACES

### 5.4.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Ventilation strategy
- Hazardous substances

#### → Improvement option(s)

- Ventilation strategy

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To reduce the risk to health associated with poor indoor air quality		
<b>HQE 11.1/13.1:</b> ensuring an efficient ventilation	25 m <sup>3</sup> /h.pers in offices spaces	ALL
<b>BREEAM HEA 8:</b> Indoor Air quality	29 m <sup>3</sup> /h.pers in Restaurant, Hall, Auditorium, Assembly room, Nursery 36 m <sup>3</sup> /h.pers in offices spaces	EULER
<b>BREEAM HEA 8:</b> Indoor Air quality	CO <sub>2</sub> sensors in assembly rooms, auditorium	EULER

#### Detailed discussion:

Clients laid stress on energy performance more than health and comfort.

As a result, efforts have not been done on the projects with low general score under BREEAM.

- Hazardous substances

Evaluation criteria	Performance target	Project concerned
<b>Improvement option:</b> To recognise and encourage a healthy internal environment through the specification of internal finishes and fittings with emissions of VOCs and formaldehyde known as much as possible		
<b>HQE 2.4/13,2 : choosing building components to limit the sanitary impact of the construction/control of internal pollution level</b>	Knowing VOC and formaldehyde emissions for 100% of the surface in contact with internal air (occupied spaces)	ALL
<b>BREEAM HEA 9: Volatile organic Compounds</b>	Respect of criteria for paintings, wood panels, timber structures, wood flooring, resilient textile and laminated floor coverings, suspended ceiling tiles, flooring adhesives, and wall covering for 100% of the surface in contact with internal air (occupied spaces)	EULER

Detailed discussion:

HQE certification's goal is to encourage the provision of environmental data more than consistency of value: FDES (French *fiches de données environnementales et sanitaires*) which follow the same norm as EPD (environmental product declaration - NF P 01-010) are not always checked.

BREEAM certification (2009 scheme) required a test certificate for each product supervised by European testing methodology.

Please note that at present time, BRE accepts eco labels which does not always means that a test supervised by European methods has been led.

→ **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used	Project concerned
Calculation of fresh air rates	-	French regulation	ALL
	-	EN 13779	EULER

Detailed discussion:

About CO2 sensors, areas of the building subject to large and unpredictable or variable occupancy patterns have CO2 sensors linked to the mechanical ventilation system and provide demand-controlled ventilation to the space. There is no specific methodology used.

→ **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Calculation of fresh air rates	Preliminary design, Technical design and building specifications Check of respect of specifications during Construction	Mechanical Engineer and Contractors	Architect and Environmental consultant



#### Detailed discussion:

Data of calculations are updated along the design process and construction of the building. This is certification's requirement to get the credits and to respect the assessment method.

The role of engineers is to design the installation in a first part but they also have to check the updated calculation made by contractors during Construction.

#### **5.4.2 INDICATORS AND ASSOCIATED QUANTIFICATION METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(s)**

##### → Overview

Indicator		Unit of measurement	Scope
<b>B4: Healthy and comfortable spaces</b>			
Key	Fresh Air rate	m3/h.pers	Use
Key	Low emissions of VOCs	% of surface which respect HQE requirement about VOCs emissions (obligation of 80%)	Use
Supporting	Design of unpredictable or variable occupancy patterns	Providing CO2 sensors linked to mechanical ventilation	Use

##### → Key Indicator: Fresh Air rate

- *Macro-objective:* B4: Healthy and comfortable spaces
- *Specific aspect(s):* Ventilation strategy

##### **Technical specifications**

- **Unit of measurement :** m3/h.pers
- **Scope of indicator:** The aim is to reduce the risk to health associated with poor indoor air quality. The building has been designed to provide fresh air rates to dilute pollutants in accordance with local regulation for HQE, EN 13779 for BREEAM
- Associated data requirements: calculation from mechanical engineer in design stage and contractor in post construction stage
- Associated timeframe, conditions and requirements for measurement: Fresh air rates are checked by measure after work completion.
- Supporting tools required to quantify/estimate performance
- Source of indicator/metric and its scientific and market acceptance: not concerned

##### **Results**

Indicator	Results (As built)
<b>B4: Healthy and comfortable spaces</b>	
Fresh Air rate	<b>EULER</b> 36 m3/h.pers <b>MEDERICK</b> 25 m3/h.pers <b>LAFFITE LAFAYETTE</b> 25 m3/h.pers

→ **Key Indicator: Low emissions of VOCs**

- *Macro-objective*: B4: Healthy and comfortable spaces
- *Specific aspect(s)*: Hazardous substances

**Technical specifications**

- **Unit of measurement** : % of surface
- **Scope of indicator**: The goal is to recognise and encourage a healthy internal environment through the specification of internal finishes and fittings with emissions of VOCs and formaldehyde known as much as possible
- Associated data requirements: manufacturer's literature to know the VOCs emissions of component
- Associated timeframe, conditions and requirements for measurement
- Supporting tools required to quantify/estimate performance ELODIE (not an obligation)
- Source of indicator/metric and its scientific and market acceptance not concerned

**Results**

Indicator	Results (As built)
<b>B4: Healthy and comfortable spaces</b>	
Low emissions of VOCs	<i>% of surface which respect HQE requirement about VOCs emissions (obligation of 80%)</i> <b>EULER</b> 76% <b>MEDERICK</b> 76% <b>LAFFITE LAFAYETTE</b> <75%
	<i>% of surface which respect BREEAM requirement about VOCs emissions (obligation of 100%)</i> <b>EULER</b> 100 % <b>MEDERICK</b> <100% - criterion not respected

→ **Supporting Indicator: Design of unpredictable or variable occupancy patterns**

- *Macro-objective*: B4: Healthy and comfortable spaces
- *Specific aspect(s)*: Ventilation strategy

**Technical specifications**

- **Unit of measurement** : Providing CO2 sensors linked to mechanical ventilation
- **Scope of indicator**: In mechanically ventilated spaces, the sensors are linked to the mechanical ventilation system and provide demand-controlled ventilation to the space to ensure indoor air quality and reduce the risk to health

**Results**

Indicator	Results (As built)
<b>B4: Healthy and comfortable spaces</b>	

Indicator	Results (As built)
Design of unpredictable or variable occupancy patterns	CO2 sensors installed in meeting rooms dedicated spaces.

## 5.5 REFERENCES

HQE Renovation v2010

BREEAM International v2009 Issue 1.1

BREEAM In-Use International v2015

LEED v3 2009

BBC Effinergie renovation (RT 2005 existant)

## 6 FS 4. ENSLIC

### 6.1 FACT SHEET

7 General information					
Description	The ENSLIC project (ENergy Saving through promotion of Life Cycle assessment in buildings) seeks to promote the use of Life Cycle Assessment (LCA) techniques in design for new buildings and for refurbishment, in order to achieve an energy saving in the construction and operation of buildings. ENSLIC is focusing on primary energy use and climate change potential indicators.				
Involved parties	IFZ (AU); ARMINES (FR); CalCon (DE); EMI (HU); Ecofys (NL); SINTEF (NO); KTH (SE)				
Year	01/10/2007 to 31/03/2010				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
CIR CS1	South Europe - Zaragoza, Spain	Apartment block	Existing	5 floors - 7641 m <sup>2</sup>	In use
CIR CS2	South Europe - Zaragoza, Spain	Apartment block	Existing	7 floors - 8607 m <sup>2</sup>	In use
CIR CS3	South Europe - Zaragoza, Spain	Offices	Renovation	2 floors - 1700 m <sup>2</sup>	-
ARM CS1	South Europe - Formerie, France	Semi-detached houses	Existing	2 floors - 132 m <sup>2</sup>	In use
ARM CS2	South Europe - Montreuil, France	Apartment block	Existing	6 floors - 5124 m <sup>2</sup>	In use
ARM CS3	South Europe - France	Apartment block	Design	6 floors - 6600 m <sup>2</sup>	Design phase
IFZ CS1	Central Europe - Weiz, Austria	Semi-detached houses	Existing	2 floors - 113,7 m <sup>2</sup>	In use
IFZ CS2	Central Europe - Weiz, Austria	Offices	Existing	4 floors - 3068 m <sup>2</sup>	In use
IFZ CS3	Central Europe - Gutenberg, Austria	Semi-detached houses	Existing	3 floors - 202,4 m <sup>2</sup>	In use
EMI CS1	Central Europe - Budapest, Hungary	Apartment block	Existing	11 floors - 25138 m <sup>2</sup>	In use
KTH CS1;	North Europe - Gävle, Sweden	Offices	Design	4 floors - 3314 m <sup>2</sup>	Design phase
KTH CS2;	North Europe - Sollentuna, Sweden	Offices	Design	4_6 floors - 10000 m <sup>2</sup>	Design phase
CAL CS1	Central Europe - Frankfurt a. M., Germany	Apartment block	Existing	9 floors - 2353 m <sup>2</sup>	In use
CAL CS2	Central Europe - Frankfurt a. M., Germany	Apartment block	Existing	3 floors - 2662 m <sup>2</sup>	In use
CAL CS3	Central Europe - Frankfurt a. M., Germany	Apartment block	Existing	4 floors - 1482 m <sup>2</sup>	In use
ECO CS1	Central Europe - Kollum, Netherlands	Detached house	Existing	3 floors - 170 m <sup>2</sup>	In use
ECO CS2	Central Europe - Nieuwegein, Netherlands	Offices	Design	92 floors - 16278m <sup>2</sup>	Design, tendering
Relevant professional context					
ENSLIC (ENergy Saving through promotion of Life Cycle assessment in buildings) is an Intelligent Energy Europe (IEE) project. Nine partners from as many countries (Austria, Netherlands, France, Spain, Germany, Hungary, Norway, Sweden, Bulgaria) were involved. Coordinator was Fundación CIRCE - Centro de Investigación de Recursos y Consumos Energéticos – Spain. The aim of the project was to promote the use of Life Cycle Assessment (LCA) techniques in design for new buildings and for refurbishment, in order to achieve an energy saving in the construction and operation of buildings. It started in 01/10/2007 and ended in 31/03/2010.					

## 6.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

### 6.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Operational carbon emissions
- Embodied carbon emissions

#### → Improvement option(s)

Improvement option	Evaluation criteria	Performance target	Related case studies
Application of materials with low environmental impact	-	-	CIR CS1-2; IFZ CS2
Individual improvement measures related to: <ul style="list-style-type: none"><li>- Building envelope</li><li>- Heating installation</li></ul>	-	-	ARM CS2-3; KTH CS1-2 CAL CS1-3
Increased energy efficiency of building envelope	RT2005 (French thermal regulation); Austrian energy certificate A++); PassivHaus standard	-	ARM CS1; IFZ CS1; EMI CS1
(nearly) zero energy and/or zero emission buildings	-	-	CIR CS3; ECO CS1-2
Application of renewable energy sources	-	-	CIR CS3; KTH CS1-2; ECO CS1-2
Simplified LCA-assessment by reducing life cycle stages	-	-	CIR CS3; CAL CS1-3

#### Discussion

ENSLIC focussed on primary energy use and climate change potential indicators. The cases covered in ENSLIC are assessments of existing designs or buildings. Different purposes of LCA were tested. Performance improvements assessed were:

- environmental impact as a result of material choices;
- reduction of carbon emissions from life cycle perspective as a result of highly ambitious energy performance (passive building);
- comparison of different design choices for building components.

#### → Methodologies, evaluation tools and/or standards used

Methodology used	Evaluation tools used	Standards used	Project / case study
Life Cycle Analysis (LCA)	SimaPro v7.1.8. ecoinvent v2.0 (2007)	ISO 14040-14043	CIR CS1-CS3
	EQUER v1,9,6 ecoinvent v2,0		ARM CS1-3

	ECOSOFT 3,4,1 IBO database		IFZ CS1-3
	Excel sheets ecoinvent v1.3		EMI CS1
	ENSLIC Excel tool ecoinvent v2.0		KTH CS1-2
	GaBi 4 Ökobau.dat (2009)		CAL CS1-3
	Greencalc+, V2.2.0.		ECO CS1-2
Energy performance calculation	CALENER VYP	EPBD, Spain	CIR CS1-CS3
	COMFIE	EPBD, France	ARM CS1-3
	Information not available	Information not available	IFZ CS1-3
	Information not available	Hungarian regulation (7/2006 v.24 TNM decree)	EMI CS1
	ENSLIC Excel tool	Information not available	KTH CS1-2
	Information not available	Information not available	CAL CS1-3
	NEN EPW NPR 5129 (NL) V2.1	NEN EPW NPR 5129 (NL) V2.1	ECO CS1
	NEN EPU NPR 2917:2006 V2.02	NEN EPU NPR 2917:2006 V2.02	ECO CS1

#### Discussion

ENSLIC explored how to simplify LCA with the purpose of increasing the use of LCA in the building practice. Proposed simplifications are: limiting the number of life cycle stages to production (A1-A3) and operation (B1-B7); limiting the number of impact categories (for instance, only global warming potential); making use of BIM and CAD-software. ENSLIC developed an own methodology, more specifically a simplified excel-sheet, based on ISO 14040-14043. Full list of proposed simplifications:

- Simplify the acquisition of building data by focusing on larger building elements, omit transport, etc.
- Simplify the inventory analysis by focusing on the most important substances that contribute to a certain impact category, omit the end of life of the building, only use generic emission data, etc.
- Simplify calculations by focusing on only a few impact categories.
- Reduce the time of building data acquisition by improved CAD applications.

ENSLIC distinguished three categories of LCA-tools, depending on the complexity:

- Basic: Basic calculations in Excel sheets with simple input and output only covering one or a few environmental impacts. Little or no experience is needed.
- Medium: LCA calculations made with help of building tools such as Ecosoft, EcoEffect, Equer, Legep, Envest, Beat, etc. Some experience and training are required to use these tools.
- Advanced: General and comprehensive LCA tools such as SimaPro, Gabi, etc. Much experience is needed to handle these software applications on a building level. These tools demand much training and profound understanding of LCA models and they might not even be suitable for application in early design phases.

The goal for the simplified tool developed in ENSLIC is to support the two lower levels, i.e. getting inexperienced people to first carry out simple LCAs and then try the buildings tools. Advanced LCA calculations are therefore not discussed further in this paper.

## 6.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Indicator	Unit of measurement	Life cycle stage	Macro-objective
Global Warming Potential	[tons CO <sub>2</sub> eq.]	Production & use	B1: GHG emissions
Primary energy consumption	[GJ]	Production & use	B1: GHG emissions
Energy demand	[kWh/m <sup>2</sup> .y]	Use	B1: GHG emissions

### → Indicator #1: Global Warming Potential

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions & Embodied carbon emissions

#### Technical specifications

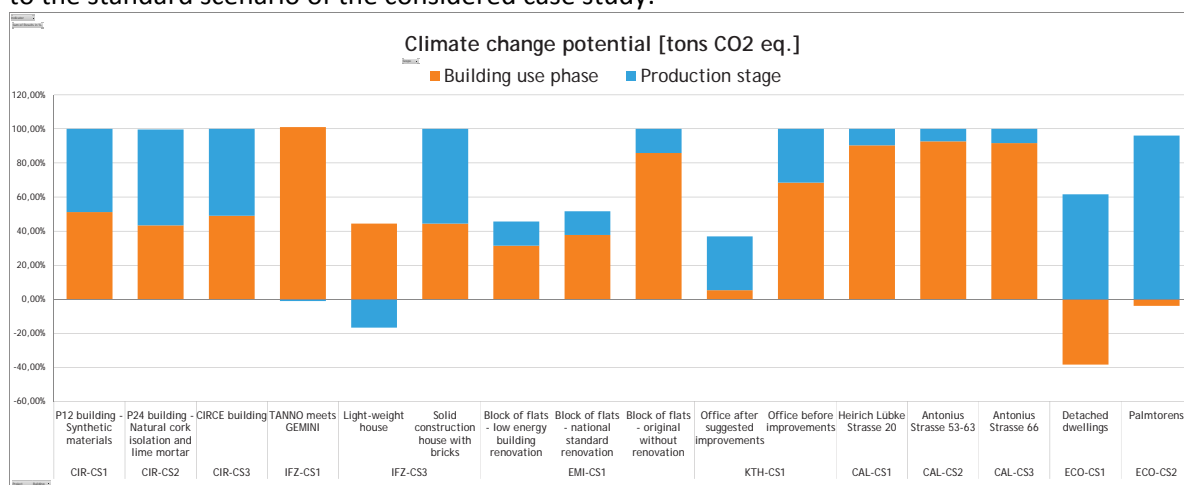
- Unit of measurement: tons CO<sub>2</sub> equivalent, tons CO<sub>2</sub> eq.
- Life cycle stage (with reference to EN 15643): Production stage (A1 to A3) and use stage (B1 to B7); Building construction phase (A4-A5) and building end of life (C1 to C4) can be considered thanks to the provision of default data based on assumptions, but most of ENSLIC case studies do not focus of these stages.  
Case studies with only production stage and building use phase: CAL CS1-3, CIR CS1-3, ECO CS1-2, IFZ CS1-3, KTH CS1-2. The goal of these case studies was to focus on collected data on real case. To claim a study to be a Life Cycle Analysis of a building, at least 2 Life Cycles Stages must be considered. The requirement is then met.
- Scope of indicator: GHG emissions during production stage: manufacturing of building structure and building envelope materials.  
GHG emissions during building use phase :emissions related to energy use for heating, cooling, Domestic Hot Water (DHW) and lighting. Ventilation and other energy consuming equipment may be included.  
For case studies ARM CS1-3 and EMI CS1: GHG emissions due to transport from manufacturer to installation site, and installation  
GHG emissions related to End of Life  
(GHG emissions during the considered life cycle stages may be aggregated.)
- The scope boundaries are defined according to study's commissioner wish (eg. choice between cradle to gate and cradle to grave study)
- Midpoint(s) and/or parameters: Climate change potential
- Functional unit: Whole building (office or residential) during its life span (35, 50, 75 or 80 years depending on case study)  
The study commissioner is free to choose any life span. Nevertheless, it is common to assume a 50-year life span for a building (cf building elements life span in References).
- Associated data requirements: Collected data to be linked to LCA database, see section "Methodologies, tools and standards".  
LCA databases contains dataset to model materials and energy used in building. These datasets have flows which are characterised for the IPCC method of CO<sub>2</sub> footprinting (e.g. 1 ton of bricks emits x kg of CO<sub>2</sub>eq during its production stage).
- Supporting tools required to quantify/estimate performance: Life Cycle Assessment tool with LCA database in which CO<sub>2</sub> characterisation factors are available, see section "Methodologies, tools and standards".

- Source of indicator/metric and its scientific and market acceptance: Intergovernmental Panel on Climate Change (IPCC) method, which is widely recognised and used in all LCA calculations.

## Results

### Overview and results:

Buildings in the case studies have different sizes and lifespans (i.e. different functional unit). Comparing buildings is therefore difficult. One possible solution is to use the same functional unit for the calculations. In addition, the result of this indicator in each case study is not easily compared as a result of different assessment methodologies, scope. Building location (climate zones) and building typology also make the comparison between two different buildings difficult. The majority of case studies only consider the production and in-use stages. The graph below shows the relative contribution of production and use phase of each case study scenario compared to the standard scenario of the considered case study.



### Detailed discussion:

Improvement options focusing on building use can reduce the impacts of this life cycle stage by more than 50% (e.g. EMI-CS1 and KTH-CS1, in which insulation thickness, design, material or equipment have been improved). To reduce the impacts of building use phase, the use of renewable energies are often recalled (e.g. negative impacts of building use phase for ECO-CS1 and ECO-CS2). For buildings constructed before 1985 (e.g. CAL-CS1, CAL-CS2 and CAL-CS3), the use phase is the main contributor to climate change in comparison with the production stage. Impact on climate change of these buildings is high due to concrete structure production process, poor insulation and heat losses from local gas heating system. Production stage can have negative impacts thanks to the use of bio-based materials (eg. IFZ-CS1 and CS9).

When using synthetic materials, building use phase contributes to climate change most; while the use of natural material increases the impact of production stage regarding climate change indicator. However, the use of natural materials does not significantly change the overall climate change potential of a building compared to the use of synthetic materials (eg. CIR-CS1 and CS2). When natural materials are used, a small shift of CO<sub>2</sub> emissions occurs from building use phase to production stage.

### Cross-links and trade-offs between other macro-objectives

Diminishing building use CO<sub>2</sub> emissions through the choice of specific material may increase the CO<sub>2</sub> emissions of the production stage (cf. CIR CS1 and CIR CS2). Such improvement measures shall be taken if only improvement of performance is effective for the whole life cycle.



Life Cycle Assessment not only addresses climate change concerns. As collected data are linked to LCA database, other indicators such as resource depletion or water depletion can be assessed depending on the selected evaluation method. These two mentioned indicators can address the macro-objectives B2 and B3 respectively. For instance, ARM CS1, ARM CS2 and ARM CS3 assess the environmental performance of buildings based on 12 indicators.

→ **Indicator #2: Primary energy consumption**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

**Technical specifications**

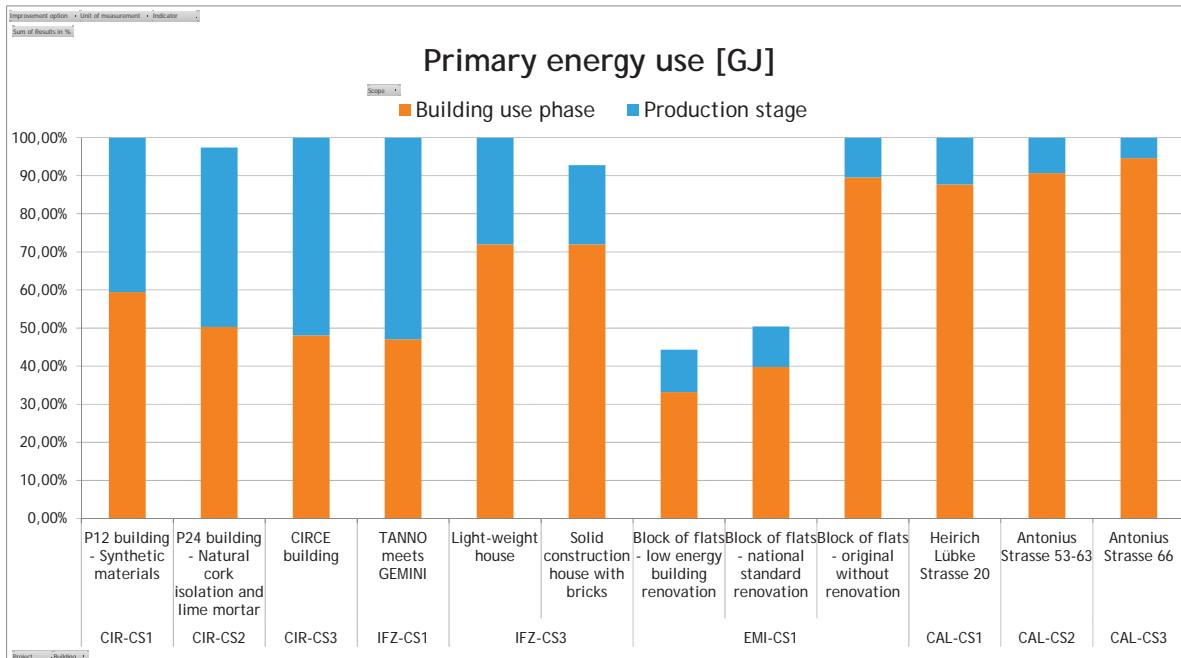
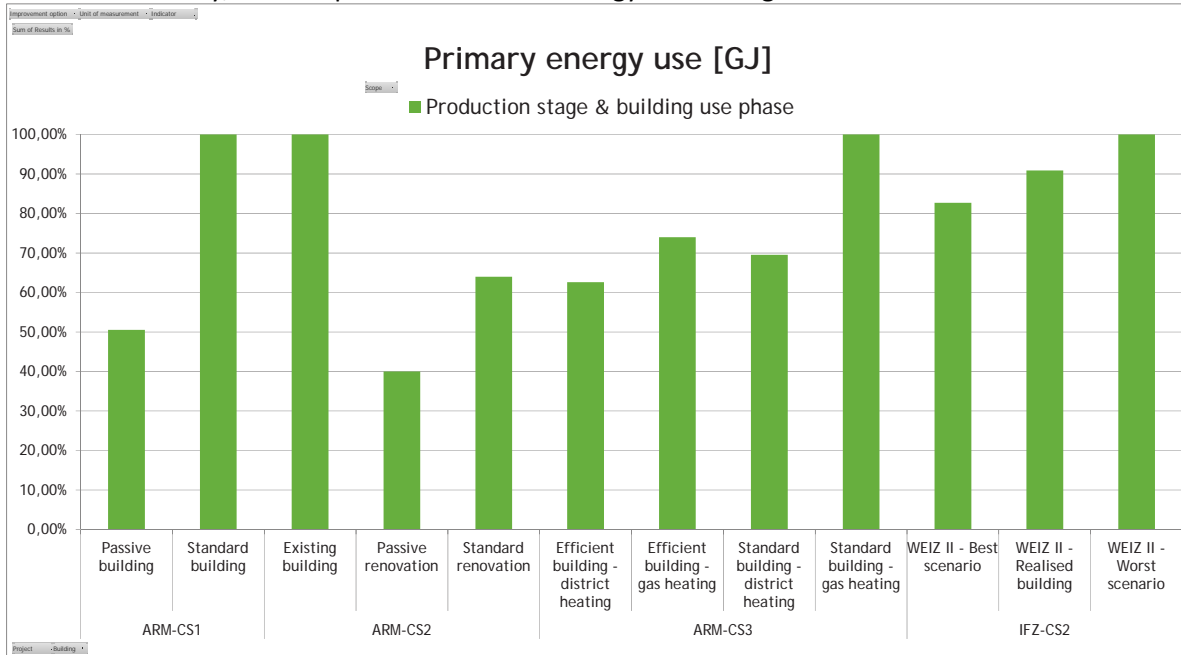
- Unit of measurement: MJ
- Life cycle stage (with reference to EN 15643):  
 Production stage (A1 to A3) and use stage (B1 to B7)  
 Building construction phase (A4-A5) and building end of life (C1 to C4) can be considered thanks to the provision of default data based on assumptions, but most of ENSLIC case studies do not focus of these stages.  
 Case studies with only production stage and building use phase: CAL CS1-3, CIR CS1-3, ECO CS1-2, IFZ CS1-3, KTH CS1-2.  
 The goal of these case studies was to focus on collected data on real case. To claim a study to be a Life Cycle Analysis of a building, at least 2 Life Cycles Stages must be considered. The requirement is then met.
- Scope of indicator: *Primary energy use during production stage: manufacturing of building structure and building envelope materials.*  
*Primary energy use during building use phase : energy use for heating, cooling, Domestic Hot Water (DHW) and lighting. Ventilation and other energy consuming equipment may be included.*  
*For case studies ARM CS1-3 and EMI CS1: primary energy use due to transport from manufacturer to installation site and installation*  
*Primary energy use related to End of Life*  
*(Primary energy use during the considered life cycle stages may be aggregated.)*  
*The scope boundaries are defined according to study's commissioner wish (eg. choice between cradle to gate and cradle to grave study)*
- Functional unit: Whole building (office or residential) during its life span (35, 50, 75 or 80 years depending on case study)  
 The study commissioner is free to choose any life span. Nevertheless, it is common to assume a 50-year life span for a building (cf building elements life span in References).
- Associated data requirements: Collected data to be linked to LCA database, see section "Methodologies, tools and standards".  
 LCA databases contains dataset to model materials and energy used in building.
- Collected data linked with software database in which flows have Lower Heating Values (LHV) predefined for each kind of used combustibles during production stage and use phase. (e.g. 1 ton of bricks uses x kg of fuel with LHV=y kg/MJ during its production stage)
- These datasets have flows which are characterised for the IPCC method of CO<sub>2</sub> footprinting(e.g. 1 kg of bricks emits x kg of CO<sub>2</sub>eq during its production stage).
- Supporting tools required to quantify/estimate performance: Life Cycle Assessment tool with LCA database in which LHV of combustible are available, see section "Methodologies, tools and standards".

- Source of indicator/metric and its scientific and market acceptance: Primary energy use is measured in MJ, unit to measure energy.

## Results

### Overview and results:

In each case study, 100% represents the most energy consuming scenario.



### Discussion:

Primary energy use of production stage and building use phase can be influenced by:

- The design of a building (standard vs passive design, e.g. ARM-CS1);
- The type of renovation (e.g. ARM-CS2 with different insulation thicknesses);
- The heating equipment (e.g. ARM-CS3 with district heating vs gas heating)

- District heating involves a lower primary energy use;
- The choice of materials (e.g. IFZ-CS2).

Improvement options focusing on building use can reduce the impacts of this life cycle stage by more than 50% (e.g. EMI-CS1, in which insulation thickness, design, material or equipment have been improved). For buildings constructed before 1985 (e.g. CAL-CS1, CAL-CS2 and CAL-CS3), the use phase is the main primary energy consumer in comparison with the production stage. Primary energy consumption of the use phase of these buildings is high due to concrete structure production process, poor insulation and heat losses from local gas heating system. Production stage of bio-based materials can require more primary energy than standard materials (e.g. wood vs bricks in IFZ-CS3).

When using synthetic materials, building use phase consumes primary energy mostly; while production stage requires more primary energy due to the use of natural material. However, the use of natural materials does not significantly change the overall primary energy use of a building compared to the use of synthetic materials (e.g. CIR-CS1 and CS2). When natural materials are used, a small shift of primary energy use occurs from building use phase to production stage.

#### ***Cross-links and trade-offs between other macro-objectives***

Diminishing building use primary energy consumption through the choice of specific material may increase this consumption at the production stage. Such improvement measures shall be taken if only improvement of performance is effective for the whole life cycle. Less primary energy use does not necessarily mean less CO<sub>2</sub> emissions (cf. AMR-CS3, in which district heating requires less primary energy while emitting more CO<sub>2</sub>). While the use of renewable energies allows credits regarding climate change impact category, the primary energy use indicator does not show the impacts or benefits of renewable energies (cf. IFZ-CS1 and IFZ-CS3). Data regarding prices of different primary energies used can be collected simultaneously with technical information of these energies (such as Lower Heating Values of used fuels), so that LCC calculation can be performed.

#### **→ Indicator #3: Energy demand**

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspects:* Operational carbon emissions

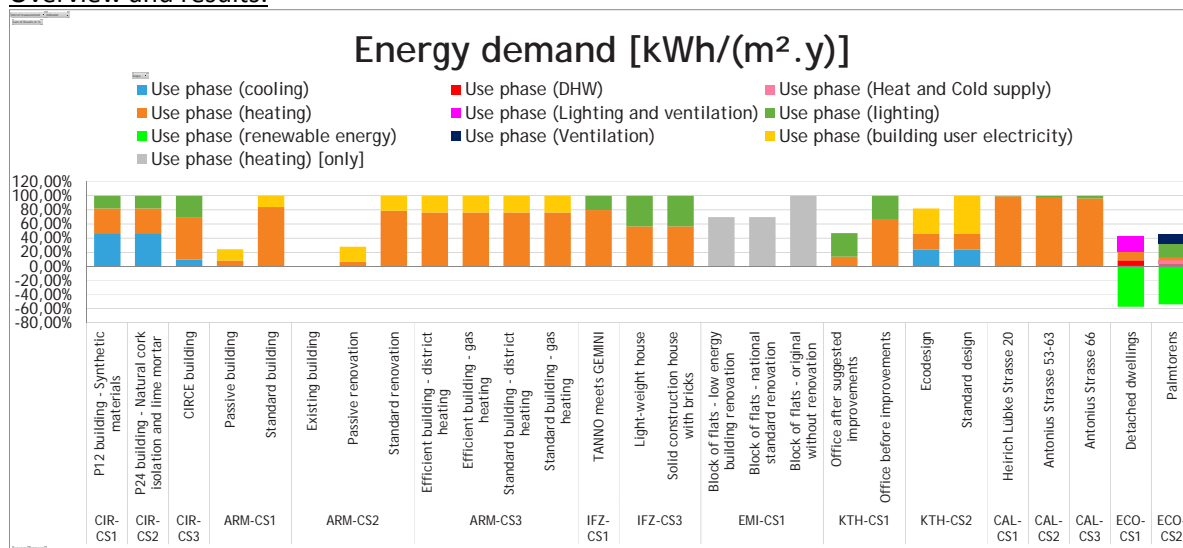
#### ***Technical specifications***

- Unit of measurement: [kWh/(m<sup>2</sup>.y)]
- Life cycle stage (with reference to EN 15643): Use stage, more specifically B6 Operational energy use
- Scope of indicator: *Energy use for heating, cooling, Domestic Hot Water (DHW) and lighting. Ventilation and other energy consuming equipment may be included. Energy demand during building use phase: emissions related to energy use for heating, cooling, Domestic Hot Water (DHW) and lighting. Ventilation and other energy consuming equipment may be included. Renewable energies can also be reported in this indicator (cf ECO-CS1 and ECO-CS2) even though renewable energies are not a consumption item of energy.*
- Functional unit: 1 m<sup>2</sup> of a building during 1 year  
Depending on the case study, the building is either residential or office building
- Associated data requirements:

- Supporting tools required to quantify/estimate performance: Energy simulation tools (cf. Methodologies)
- Source of indicator/metric and its scientific and market acceptance: kWh/(m<sup>2</sup>.y)], unit to measure energy.

## Results

### Overview and results:



## Discussion

The figure above clearly indicates the large variety of energy uses considered in the different cases.

Measures to reduce energy use during the building use phase both in design and renovation (cf. AMR-CS1, AMR-CS2 and KTH-CS1) allow significant reduction of energy demand for heating. The thermal performance of a material does not depend on its source: bio-based materials have same performance as synthetic materials in CIR-CS1 and CIR-CS2. Buildings located in South Europe climate zone (cf. CIR-CS1, CIR-CS2 and CIR-CS3) have a contribution of cooling in their energy demand. For buildings constructed before 1985 (e.g. CAL-CS1, CAL-CS2 and CAL-CS3), most of energy demand is involved by heating. These buildings required considerable heating because of poor insulation and heat losses from local gas heating system. Building user electricity, lighting and ventilation are important items for the energy demand indicator in numerous buildings (e.g. CIR-CS1-3, ARM-CS1-3, IFZ-CS1-3, KTH-CS1-2). It is possible to reduce the building user electricity demand through the eco-design of a building (cf. KTH-CS2). The use of renewable energies can compensate the energy demand of all other energy consuming pillar (e.g. ECO-CS1 and ECO-CS2).

### 6.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

#### → Project processes

Table below lists the different stages where actors are involved and where different methodologies are used.

Methodology	Project stage	Lead actor	Supporting actor
LCA	In use (assessment study)	LCA consultants	Municipalities or private owners of buildings that
Energy performance calculation	In use (assessment study)		
LCA	Renovation stage		

Energy performance calculation	Renovation stage		accepted to participate in ENSLIC assessment studies
LCA	Design		
Energy performance calculation	Design		

#### Detailed discussion:

The aim of ENSLIC European project is to create a simplified methodology of LCA to assess environmental performances of buildings. With this simplified LCA methodology, decision-making process would be eased. Most of ENSLIC case studies are assessment studies, without the aim to use LCA as a decision-making tool. However, the table below gives an overview on how is envisioned the use of LCA and ENSLIC tool at different project stages.

Type of user	Stage of the process	Purpose of LCA use
Consultants advising municipalities, urban designers	Preliminary phases	Setting targets at municipal level. Defining zones where residential/office building is encouraged or prohibited. Setting targets for development areas.
Property developers and clients.	Preliminary phases	Choosing a building site. Sizing a project. Setting environmental targets in a programme.
Architects	Early design (sketch) and detailed design in collaboration with engineers. Design of a renovation project.	Comparing design options (geometry / orientation, technical choices).
Engineers / Consultants	Early design in collaboration with architects, and detailed design. Design of a renovation project.	Comparing design options (geometry, technical choices).

#### → **Evaluation of project experience using the indicator(s)**

A wide range of buildings were assessed, using local tools and databases. While lessons can be derived regarding the proportion of embodied/operational energy or carbon and the division among building aspects, the results are rather difficult to compare, as each assessor has their own purposes, tools, boundary conditions and assumptions for the LCA. The results are thus very much dependent on the party who conducted the calculations. This highlights the need for additional guidelines to further complement common methodology.

The ENSLIC guidelines are directed at professionals working in the early design phases of building development or refurbishment projects who want to achieve energy savings and environmental improvements with regard to the entire lifetime of the building.

Architects and other consultants are the main target group, since they are the professionals involved who can perform an LCA assessment. Clients such as property developers and urban planners are also targeted, since these groups can demand better buildings and associated assessments to prove this.

While the goal of the project was to facilitate the use of LCA in practice, it is still unclear if the project succeeded in this objective, as all the cases were hypothetical exercises. No real-life pilot from the building practice was included. This is an aspect that should be taken into account when interpreting the findings of the ENSLIC study.

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## 7 FS 5. SKANSKA FIELD STUDY CLUSTER

### 7.1 FACT SHEET

General information					
Description	Skanska is a private project development and construction group. Skanska is active in North America and Europe (in particular Northern Europe, Eastern Europe and the UK). The SKANSKA Group developed a strategic framework to define its environmental ambitions on energy, carbon, materials and water: the Skanska Colour Palette. In particular with regards to using carbon footprinting in the building practice, the Skanska Group have extensive experience in several EU Member States. The field study analysis draws upon Skanska’s public database of pilot projects. Key actors of Skanska’s Business Units have been contacted for their learning experiences.				
Involved parties	SKANSKA Group				
Year	2015				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Skanska Finland HQ	Northern Europe, Helsinki (FI)	Office: medium-rise	New-build	8 storeys, 9.100 m²	In-use
Cold Harbour Lane	Central Europe, London (UK)	Residential: apartment block	New-build	2 buildings, 6 to 9 stories, 9.747 m² per building, 108 apartments	In-use
Sollallén townhouses	Northern-Europe, Växjö (SE)	Residential: terraced, semi-detached	New-build	21 dwellings (ranging from 79 m² to 91 m²)	In-use
Väla Gård	Northern Europe, Helsingborg (DK)	Office, medium rise	New-build	1.777 m²	In-use
Bassängkajen	Northern Europe, Malmö (SE)	Office, medium-rise	New-build	8.500 m² (phase 1) 7.800 m² (phase 2)	In-use
Powerhouse Kjørbo	Northern Europe, Sandvika (NO)	Office, low- and medium-rise	Renovation	5.180 m² (total); 2 buildings	In-use
Atrium 1	Central Europe, Warsaw (PL)	Office, high-rise	New-build	15 stories, 16.300 m² (office space)	In-use
Corso Court	Central Europe, Prague (CZ)	Office, medium-rise	New-build	7 stories, 17.202 m² (office space)	In-use
Riverview	Central Europe, Prague (CZ)	Office, medium-rise	New-build	7 stories, 7.037 m² (office space)	In-use
City Green Court	Central Europe, Prague (CZ)	Office	New-build	8 stories, 16.300 m² (office space)	In-use
Open Garden	Central Europe, Brno (CZ)	Office	New-build, renovation	1.454 m² (re-furbished);2.900 m² (new-build)	In-use
Green House	Central Europe, Budapest (HU)	Office medium-rise	New-build	8 stories, 17.900 m² (office space)	In-use
Relevant professional context					
<p>Carbon footprint assessments are an important component of Skanska’s environmental strategy. The Skanska Group has defined a Green Strategic Indicator related to carbon emissions for its Business Units (BUs), i.e. the number of projects that have been submitted to a Preliminary Carbon Footprint. Skanska conducted 113 carbon footprints in 2015 to benchmark project carbon emissions and to help identify low-carbon project options, which can result in project carbon and financial savings.</p> <p>Skanska has been a major contributor to two key initiatives regarding carbon footprinting: In 2010/2011 Skanska took part in pilot testing the Common Carbon Metric &amp; Protocol. It is an initiative of UNEP Sustainable Building &amp; Climate Initiative (SBCI) and is developed to provide globally applicable measurements and reporting of energy use in and greenhouse gas emissions</p>					

from existing portfolios of buildings. Furthermore, Skanska is a member of ENCORDER (European Network of Construction Companies for Research and Development) which has developed the ENCORDER CO<sub>2</sub> Measurement Protocol.

## 7.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

The Skanska Group developed a strategic framework to define its environmental ambitions, the Skanska Color Palette<sup>19</sup>. Projects must realize at least three of the following zeros to achieve Skanska's definition of Deep Green. In this field study analysis, the main focus is on energy and carbon, two of the four key components of the Color Palette.

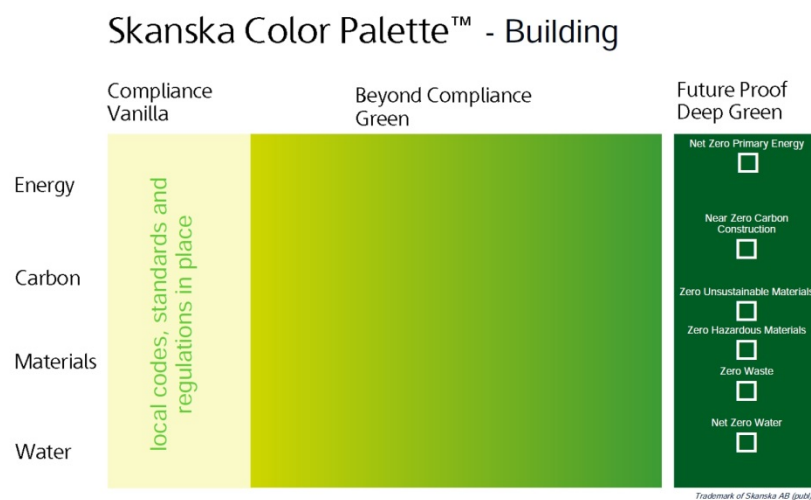


Figure 4: Skanska color palette (source: Skanska)

The starting point is *Vanilla*: compliance with current regulation, codes and standards. End ambition is *Deep Green*: Near zero carbon in construction, in the case of carbon. In between are three intermediate targets (the Skanska group uses the term *stepping stones*). The Color Palette serves as an overall framework but has to be specified by each business unit. It does allow each business unit some flexibility in the sense that they can adapt its (both intermediate and end) targets according to the local and regional context.

### 7.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

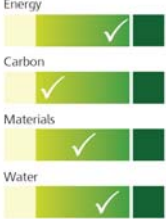
#### → Aspects covered of the macro-objective

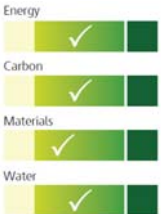
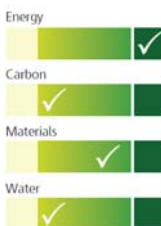
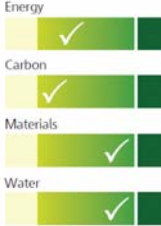
- Operational carbon emissions
- Embodied carbon emissions

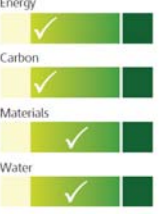
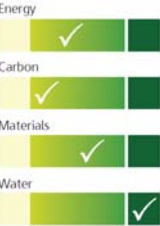
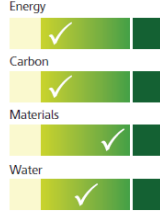
<sup>19</sup> Skanska (2016) *How we define green* [online], available at <http://group.skanska.com/sustainability/our-journey-to-deep-green/how-we-define-green/> [20/5/2016]



→ Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
<b>Open Garden</b>	<ul style="list-style-type: none"> <li>Geothermal heating systems</li> <li>Triple glazed windows</li> <li>Passive solar heating</li> <li>Passive cooling</li> <li>Natural ventilation</li> <li>Fluorescent light fittings and sensors</li> <li>Natural lighting</li> <li>New façade</li> <li>Wall and roof insulation</li> </ul>	<p>Czech building code</p> <p>Czech passive house standards</p> <p>Skanska color palette</p>	<p><b>New build</b></p> <ul style="list-style-type: none"> <li>Energy use: 23.3 kWh/m<sup>2</sup>a (87% less than Czech building code)</li> <li>Space heating demand (11 kWh/m<sup>2</sup>a) ≤ Passive house standards 15 kWh/m<sup>2</sup>a;</li> <li>Space cooling demand (3.6 kWh/m<sup>2</sup>a) ≤ Passive house standards 30 kWh/m<sup>2</sup>a;</li> <li>Primary energy demand ≤ 120 kWh/m<sup>2</sup>a;</li> </ul> <p><b>Renovation</b></p> <ul style="list-style-type: none"> <li>Energy use: 44.7 kWh/m<sup>2</sup>a (28% less than Czech building code)</li> </ul> <p>End goal: Deep Green on Energy and Carbon</p> <p>Skanska Color Palette™</p> 
<b>Väla Gård</b>	<ul style="list-style-type: none"> <li>PV panels</li> <li>Ground-source heating and cooling system</li> <li>Well-insulated envelope</li> <li>VAV system with heat recovery</li> <li>Natural daylighting with LED and solar shading</li> <li>Energy monitoring and control system (Temperature and CO<sub>2</sub> sensors, meters)</li> <li>Passive house window</li> <li>Heat recovery</li> </ul>	<p>Swedish building code</p> <p>Swedish passive house standards</p> <p>LEED</p> <p>Skanska color palette</p>	<ul style="list-style-type: none"> <li>Energy use: 16 kWh/m<sup>2</sup>a (over 80% less than Swedish building code)</li> <li>LEED Platinum</li> <li>End goal: Deep Green on Energy and Carbon</li> </ul> <p>Skanska Color Palette™</p> 
<b>Green House</b>	<ul style="list-style-type: none"> <li>Ground source heating and cooling system</li> <li>Solar hot water heating system</li> <li>Glazing and building orientation</li> <li>Low-speed ventilation system and double rotating heat exchangers</li> <li>Envelope insulation</li> <li>Occupancy sensors activate/deactivate the valves on the radiators</li> </ul>	<p>Hungarian building code</p> <p>LEED</p> <p>Skanska color palette</p>	<ul style="list-style-type: none"> <li>Energy use: 72.5 kWh/m<sup>2</sup>a (45% less than Hungarian building code)</li> <li>LEED Platinum</li> <li>End goal: Deep Green on Energy and Carbon</li> </ul> <p>Skanska Color Palette™</p> 

	<ul style="list-style-type: none"> <li>Chilled beams</li> <li>Natural daylighting</li> </ul>		
<b>Coldharbour Lane</b>	<ul style="list-style-type: none"> <li>Central biomass heating system</li> <li>Graphite-enhanced expandable polystyrene insulation sandwiched between two layers of reinforced concrete</li> <li>Triple glazed aluminium clad timber windows</li> <li>Low air permeability</li> <li>Energy efficient kitchen appliances and light fittings</li> </ul>	<p>UK building code</p> <p>Skanska color palette</p>	<ul style="list-style-type: none"> <li>Energy use: 48 kWh/m<sup>2</sup>a (heating) (47% less energy than UK building code)</li> <li>UK building code Sustainable Homes level 4</li> <li>End goal: Deep Green on Energy and Carbon</li> </ul> 
<b>Powerhouse</b>	<ul style="list-style-type: none"> <li>PV panels</li> <li>Ground source heat pumps</li> <li>Envelope insulation</li> <li>Solar shading</li> <li>Energy efficient displacement ventilation systems</li> <li>Natural daylighting via windows</li> <li>Low energy lighting system</li> </ul>	<p>Norwegian building code</p> <p>Norwegian passive house standards for commercial buildings (NS 3701)</p> <p>BREEAM-NOR</p> <p>Skanska color palette</p>	<ul style="list-style-type: none"> <li>Energy use: 32 kWh/m<sup>2</sup>a (80% less energy than Norwegian building code without taking into account PV electricity, over 100 percent with PV electricity)</li> <li>BREEAM-NOR "Outstanding"</li> <li>100% Energy savings and Energy plus buildings</li> <li>"Zero Carbon" (Powerhouse definition) by around 2070</li> <li>End goal: Deep Green on Energy and Carbon</li> </ul> 
<b>Skanska House</b>	<ul style="list-style-type: none"> <li>Demand based ventilation system, with occupancy sensors and low-speed air handling units</li> <li>District heating and cooling</li> <li>High degree of air tightness</li> <li>Natural daylighting with occupancy sensors</li> <li>Sunshades</li> </ul>	<p>Finish building code</p> <p>LEED</p> <p>EU GreenBuilding certification</p> <p>Skanska color palette</p>	<ul style="list-style-type: none"> <li>Energy use: 75 kWh/m<sup>2</sup>a (35% less than Finnish building code)</li> <li>LEED Platinum</li> <li>EU GreenBuilding certification</li> <li>End goal: Deep Green on Energy and Carbon</li> </ul> 
<b>Bassängka</b>	<ul style="list-style-type: none"> <li>CAV and VAV optimal</li> </ul>	Swedish	<ul style="list-style-type: none"> <li>Energy use: 76 kWh/m<sup>2</sup>a (36% less than</li> </ul>

jen	<ul style="list-style-type: none"> <li>operation</li> <li>• Energy efficient lighting</li> <li>• Chilled beams</li> <li>• Energy monitoring and measurement with meters</li> </ul>	building code  LEED  EU GreenBuilding  ASHRAE 90.1-2007  Skanska color palette	Swedish building code that demands commercial buildings use no more than 119 kWh/m <sup>2</sup> a)  <ul style="list-style-type: none"> <li>• LEED Platinum</li> <li>• EU GreenBuilding certification</li> <li>• End goal: Deep Green on Energy and Carbon</li> </ul> 
Atrium 1	<ul style="list-style-type: none"> <li>• Well-insulated envelope</li> <li>• Triple glazed windows</li> <li>• Ground source heating and cooling system</li> <li>• Building management system (BMS) with sensors/meters</li> <li>• Heat recovery</li> <li>• Daylight control systems, natural daylight</li> <li>• LED occupancy sensors</li> <li>• Regenerative drives in elevators</li> <li>• PV system on the roof</li> </ul>	Polish building code  LEED  GreenBuilding Programme  Skanska color palette	<ul style="list-style-type: none"> <li>• Energy use: 221 kWh/m<sup>2</sup>a (electricity) 64 kWh/m<sup>2</sup>a (district heating) (40% less than Polish building code)</li> <li>• LEED Platinum</li> <li>• EU GreenBuilding certification</li> <li>• End goal: Deep Green on Energy and Carbon</li> </ul> 
Corso Court	<ul style="list-style-type: none"> <li>• Well-insulated envelope</li> <li>• Triple glazed windows</li> <li>• Chilled beams</li> <li>• Low-speed air-handling units</li> <li>• Lighting system with daylight control, motion sensors and LED</li> <li>• Regenerative drives in elevators</li> <li>• Building management system (BMS) with sensors/meters</li> <li>• Bought electricity certified according to EKOenergy ecolabel</li> </ul>	Czech building code  LEED  Skanska color palette	<ul style="list-style-type: none"> <li>• Energy use: 124 kWh/m<sup>2</sup>a (36% less energy than Czech building code)</li> <li>• LEED Platinum</li> <li>• End goal: Deep Green on Energy and Carbon</li> </ul> 
Green Court	<ul style="list-style-type: none"> <li>• Natural ventilation</li> <li>• Low-pressure ventilation system</li> <li>• AHU with pre-cooling and heat recovery</li> <li>• Chilled beams</li> <li>• External shading fins</li> </ul>	Czech building code  LEED  Skanska color palette	<ul style="list-style-type: none"> <li>• Energy use: 79 kWh/m<sup>2</sup>a (56% less energy than Czech building code)</li> <li>• LEED platinum</li> <li>• End goal: Deep Green on Energy and Carbon</li> </ul>

	<ul style="list-style-type: none"> <li>• LED and automatic central lighting shutdown function</li> <li>• District heating from local cogeneration power plant</li> </ul>		
<b>Riverview</b>	<ul style="list-style-type: none"> <li>• Well-insulated envelope</li> <li>• Chilled beams</li> <li>• Reflective façade</li> <li>• LED lighting and occupancy sensors and daylight sensors</li> <li>• BMS with sensors and meters</li> </ul>	Czech building code  LEED  Skanska color palette	<ul style="list-style-type: none"> <li>• Energy use: 89.8 kWh/m<sup>2</sup>a (50% less energy than Czech building code)</li> <li>• LEED Gold</li> <li>• End goal: Deep Green on Energy and Carbon</li> </ul>

#### Detailed discussion:

Different improvement options are implemented in different projects to achieve this macro-objective, and these measures are mainly targeting at insulation and energy systems. Energy consumption is primarily calculated at design stage then compared with the regulated requirements from local building codes. Furthermore, green building certificates, such as LEED, BREEAM, are voluntarily used for more ambitious projects to set more ambitious energy performance targets, in addition to Skanska's Deep Green concept.

How the Deep Green concept translates into practice, is illustrated for the topics "Energy" and "Carbon" in the case of Skanska's BU in Sweden, see the table below.

*Table 2: Skanska's Colour Palette illustrated for Energy and Carbon in the case of the BU in Sweden*

Colour palette	Energy	Carbon
First stepping stone ("Vanilla")	comply with local EPBD requirements	perform a preliminary carbon footprint calculation
Second stepping stone	25% better than local EPBD regulation	25% CO <sub>2</sub> -reduction
Third stepping stone	50% better than local EPBD regulation	50% CO <sub>2</sub> reduction
End target ("Deep Green")	Zero energy	Zero carbon

A good example of a real-life building project in this sense is the project Powerhouse in Norway<sup>20</sup>. Powerhouse Kjørbo is a pilot building within the Research Centre on Zero Emission Buildings (ZEB). The balance indicator used for Zero Emission Buildings is measured in carbon dioxide equivalents (CO<sub>2</sub>e). The specific targets for this building are 100% energy savings and energy plus buildings and "Zero Carbon" by around 2070. The main definition of a Powerhouse is a building that shall

<sup>20</sup> Fjeldheim, H., Kristjansdottir, T., Sørnes, K., (2015), *Establishing the life cycle primary energy balance for Powerhouse Kjørbo*, Sustainable cities and buildings, Copenhagen 20-21 August 2015

produce at least the same amount of energy from on-site renewables as the energy used for production and transport of materials, the construction installation process, maintenance and replacement, demolition and operation (excluding plug-loads), demolition and end-of-life treatment. A zero emission building produces enough renewable energy to compensate for the building's greenhouse gas emissions over its life span. The ZEB research centre has defined different levels of zero emission buildings depending on how many phases of a building's lifespan that are counted in<sup>21</sup>.

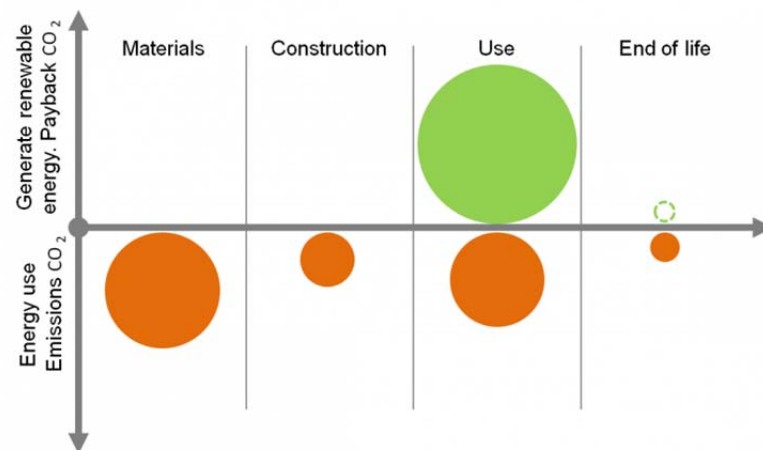


Figure 5: The building's renewable energy production compensate for greenhouse gas emissions from the entire lifespan of the building. (source: Research Centre on Zero Emission Buildings (ZEB), 2016)

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
<b>Open Garden</b>	Theoretical calculation (Energy, Carbon)  Monitoring (Energy)	Energy: EPBD calculation tool Carbon: Skanska AB carbon footprinting tool with data from: <ul style="list-style-type: none"> <li>Inventory of Carbon &amp; Energy (ICE) Version 1.6</li> <li>Defra(2007) and GHG 2009 Protocol Tool</li> <li>ecoinvent 1.3 databases</li> <li>World resources Institute (2009) GHG Protocol Tool for Stationary Combustion - v4.0</li> </ul>	<ul style="list-style-type: none"> <li>Czech building code</li> <li>Czech passive house standards</li> </ul>
<b>Väla Gård</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: ECO <sub>2</sub> carbon tool	<ul style="list-style-type: none"> <li>Swedish building code</li> <li>Swedish passive house standards</li> <li>LEED</li> </ul>

<sup>21</sup> The Research Centre on Zero Emission Buildings (2016), *ZEB definitions*, available at: <http://www.zeb.no/index.php/about-zeb/zeb-definitions> [1/8/2016]

<b>Green House</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: Skanska's carbon footprinting tool	<ul style="list-style-type: none"> <li>• Hungarian building code</li> <li>• LEED</li> </ul>
<b>Coldharbour Lane</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool	<ul style="list-style-type: none"> <li>• UK building code</li> </ul>
<b>Powerhouse</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: www.klimagassregnskap.no Footprinting tool Calculations in excel based on data from EPDs, Ecoinvent and scientific articles.	<ul style="list-style-type: none"> <li>• Norwegian building code</li> <li>• Norwegian passive house standards for commercial buildings (NS 3701)</li> <li>• BREEAM-NOR</li> </ul>
<b>Skanska House</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: BIM carbon calculation	<ul style="list-style-type: none"> <li>• Finish building code</li> <li>• LEED</li> <li>• EU GreenBuilding certification</li> </ul>
<b>Bassängkajen</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: ECO <sub>2</sub> carbon tool	<ul style="list-style-type: none"> <li>• Swedish building code</li> <li>• LEED</li> <li>• EU GreenBuilding</li> <li>• ASHRAE 90.1-2007</li> </ul>
<b>Atrium 1</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: Skanska's footprinting tool	<ul style="list-style-type: none"> <li>• Polish building code</li> <li>• LEED</li> <li>• GreenBuilding Programme</li> </ul>
<b>Corso Court</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: Skanska's footprinting tool	<ul style="list-style-type: none"> <li>• Czech building code</li> <li>• LEED</li> <li>• Skanska color palette</li> </ul>
<b>Green Court</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: Skanska AB carbon footprinting tool with data from: <ul style="list-style-type: none"> <li>• Inventory of Carbon &amp; Energy (ICE) Version 1.6</li> <li>• Defra(2007) and GHG 2009 Protocol Tool</li> <li>• ecoinvent 1.3 databases</li> <li>• World resources Institute (2009) GHG Protocol Tool for Stationary Combustion - v4.0</li> </ul>	<ul style="list-style-type: none"> <li>• Czech building code</li> <li>• LEED</li> </ul>
<b>Riverview</b>	Theoretical calculation (Energy, Carbon)	Energy: EPBD calculation tool Carbon: Skanska's footprinting tool	<ul style="list-style-type: none"> <li>• Czech building code</li> <li>• LEED</li> </ul>

#### Detailed discussion:

For building energy calculation, regulatory methodology is usually the very first step by taking into account local EPBD legislations. For instance, additional tools, such as Energie 2015, ProTech, and NKN, are used in Czech Republic in order to assist the regulatory calculation. Dynamic simulation is required for specific projects targeting on green building certifications, and the corresponding tools as required by the LEED certification scheme include HAP and DOE2. Besides, for certain projects, meters and sensors are also used for monitoring the energy system and its optimization.

The tools and methodologies used to perform the carbon footprint calculations, very much depend on the national or regional context. Skanska's BUs make use of other methodologies or databases for the carbon footprint calculations when available<sup>22</sup>. For instance:

- Skanska Norway uses the Norwegian government's carbon calculation tool (Klimagassregnskap<sup>23</sup>, (v1 was launched in 2007, current version is v5));
- Skanska Finland trialed the use of BIM (Building Information Modeling);
- The Swedish BU uses the ECO<sub>2</sub>-tool, which is based on the LCA/LCC tool Anavitor, developed by the Swedish Environmental Research Institute (IVL)<sup>24</sup>.

Furthermore, in the case that Skanska operates as the contractor, the targets, tools, databases and boundary conditions (scope, assumptions) regarding carbon footprinting depend on the client's ambitions, and the nature of the building. If there are no specific requirements, Skanska uses their own developed, group-wide project carbon footprinting tool, which is a standardized, simplified tool linked to other tools such as cost estimation programs.

Regarding data requirements, a distinction can be made between (carbon) emission data and material quantities. Carbon emission data is obtained from generic or local databases. Skanska's group-wide tool uses the "Inventory of Carbon & Energy (ICE) Version 1.6", "Defra(2007), GHG 2009 Protocol Tool", "ecoinvent 1.3" databases, and World resources Institute (2009) GHG Protocol Tool. Calibration with local conditions might be necessary. This can differ depending on the client's wishes and the regional or national context: ranging from generic LCI data available in LCA-software such as SimaPro (e.g. ecoinvent) or specific data from Environmental Product Declarations (EPDs) or local databases (for instance, emission data provided by the Swedish Environmental Research Institute IVL in Sweden or the national web based tool klimagassregnskap in Norway). Material quantities are obtained from cost estimations, bill of materials, BIM, discussions with designers and contractors, or literature sources. In practice, a combination of these sources is most often used. For the as-built situation, BIM-models are usually a reliable source. Quality assurance and data verification are, however, highlighted as a point of attention. This relates primarily to differences of the design compared to the as-built situation.

#### → Project processes

Methodology	Project stage	Lead actor	Supporting actor
Preliminary (embodied) carbon footprint calculation	Concept design	Building client	Architect, engineers
Final (embodied) carbon footprint calculation	Technical design, construction, hand-over and close-out	Main contractor	Subcontractors

#### Detailed discussion:

The main value of the carbon footprint tool in practice is for optimisation purposes. A carbon footprint is typically conducted in two stages, depending on the stage of entry: Ideally, in a first

<sup>22</sup> Skanska (2012) *Carbon footprint in construction – examples from Finland, Sweden, Norway, UK and US* [online], available at <http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/140-carbon-footprinting-in-construction> [20/05/2016]

<sup>23</sup> Klimagassregnskap (2016) *Klimagassregnskap*, Available at <http://www.klimagassregnskap.no/> [20/5/2016]

<sup>24</sup> Anavitor (2016) *Anavitor* [online], available at <http://www.anavitor.se/> [20/5/2016]

step, a preliminary carbon footprint is made, based on the information provided from the client (in practice, for the major building components: steel and concrete structure; windows). Then, in a second step, the final carbon footprint is calculated in or at the end of the construction phase.

Selected BUs make more advanced use of carbon footprint to really support the decision-making in design phase, starting with identifying opportunities for improvement (“hot spots”) after the first step, which leads to the optimization of building components and/or construction process, for instance leaner design of the load bearing structures (in terms of form and dimensions of elements) as they have significant impact<sup>25</sup>. However, several BUs remarked that the reduction of carbon emissions is rarely the main driver. Cost-saving measures or construction process optimisation tend to be more decisive.

## 7.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Embodied carbon footprint/emissions	tCO <sub>2</sub> e or normalized kgCO <sub>2</sub> e/m <sup>2</sup>	Production stage (A1 to A3) and use stage (B1 to B7) excluding operational energy use; Building construction phase (A4-A5) and building end of life (C1 to C4)	B1: Greenhouse gas emissions from building life cycle energy use
Operational carbon	kgCO <sub>2</sub> e/m <sup>2</sup> .y	Use phase	B1: Greenhouse gas emissions from building life cycle energy use
Carbon footprint	tCO <sub>2</sub> e or normalized kgCO <sub>2</sub> e/m <sup>2</sup>	Embodied and operational carbon emissions	B1: Greenhouse gas emissions from building life cycle energy use

As there was a clear focus identified on embodied carbon emissions in Skanska’s practice, the analysis is limited to the first indicator.

### → Indicator #1: Embodied carbon emissions

- *Macro-objective*: B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s)*: Embodied carbon emissions

#### Technical specifications

- Unit of measurement: tons CO<sub>2</sub> equivalent, tons CO<sub>2</sub> eq
- Life cycle stage (with reference to EN 15643): Production stage (A1 to A3) and use stage (B1 to B7) excluding operational energy use; Building construction phase (A4-A5) and building end of life (C1 to C4), however this varies case-per-case (depending on building client’s brief)
- Scope of indicator: Varies case-per-case (depending on building client’s brief), but typically including superstructure, substructure, façade and in some cases also fit-out, technical installations (e.g. PV panels)

<sup>25</sup> Van de Vyver I. and Larsson G. (2016). *Use of carbon footprint in Skanska SE*



- Midpoint(s) and/or parameters: Climate change potential
- Functional unit: Whole building (office or residential) during its life span (35, 50, 75 or 80 years depending on case study)  
The study commissioner is free to choose any life span. Nevertheless, it is common to assume a 50-year life span for a building (cf building elements life span in References).
- Associated data requirements: Carbon emission data and material quantities, see section “Methodologies, tools and standards”.  
Supporting tools required to quantify/estimate performance: see section “Methodologies, tools and standards”
- Source of indicator/metric and its scientific and market acceptance: Intergovernmental Panel on Climate Change (IPCC) method, which is widely recognised and used in all LCA calculations.

### Results

Project / case study	Embodied carbon emission [tCO <sub>2</sub> e]
Open Garden	1195
Väla Gård	725
Green House	8212
Coldharbour Lane	2140
Powerhouse	-
Skanska House	7481
Bassängkajen	6900
Atrium 1	10537
Corso Court	5631
Green Court	11034
Riverview	3517

These figures are derived from publicly available fact sheets of individual Skanska projects. However, caution is required when trying to compare these figures to one another for the reasons described below.

Functional units can differ, more specifically the assumed lifespan. For instance, Skanska Norway reported a common lifespan of 60 years but this can be customized, according to the building program (for instance: museums). Skanska Sweden reported a default standard economic life span of 50 years for a building, but this can vary for each project.

Likewise, the life cycle stages and scope covered in a building’s carbon footprint can differ as well, depending on the objectives of the study and data limitations. For instance, carbon related to operation and demolition may be excluded when Skanska has a limited ability to influence these phases. Skanska Norway reported that this largely depend on the project and/or client. Skanska Sweden reported that production and construction are always considered but that Use phase and End of Life stages are included depending on the project and the client’s requirements. Benefits and loads beyond the project boundaries are not considered in the case of Skanska Sweden.

Finally, Skanska Hungary and Skanska Poland reported that their carbon footprint calculations prioritise the building components with the most significant contribution to the (embodied) carbon emissions: superstructure, substructure, fit-out, façade (in particular windows) (including transport and energy use during construction). This also relates to data availability (for instance, data on common building components such as steel and concrete structures are more easy to obtain).

Regarding data requirements, a distinction can be made between (carbon) emission data and material quantities. This has already been discussed in the section “tools, methodologies and standards”.

### 7.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

Skanska Sweden reported that the (intermediate) targets of carbon footprint as specified in Skanska’s Colour Palette are very difficult to achieve. As a matter of fact, none of the Skanska’s building projects to date have been able to achieve the 25% CO<sub>2</sub>-reduction, although it has been achieved with infrastructure projects. Furthermore, cost-saving and process optimization happen to be the main drivers for the construction and construction process instead of the reduction of carbon emissions, although a carbon footprint calculation supports the identification of hot spots.

The Skanska group mainly uses the carbon footprint calculations for benchmarking purposes, in the sense that each BUs possesses key reference projects to make comparisons with, as an addition to a group-wide database. However, it remains difficult to compare and benchmark among different projects since there are a lot of assumptions and system boundaries that may differ, depending on the context and client’s requirements [interview with Skanska Sweden]. As some countries lack common guidelines or regulation concerning (embodied) carbon footprinting, carbon footprints calculated by different companies are very difficult to compare [interview with Skanska Czech Republic].

Finally, interviews with the different BUs point out that carbon footprint calculations can be time consuming and skill-intensive. Coupled it with existing tools (especially Bill of Materials (BoM), BIM, REVIT to obtain material quantities) and further optimising this interaction has the most potential to reduce the skills and efforts needed.

## 7.3 REFERENCES

Skanska (2016) *How we define green* [online], available at <http://group.skanska.com/sustainability/our-journey-to-deep-green/how-we-define-green/> [20/5/2016]

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## 8 FS 6. GBCF'S BUILDING PERFORMANCE INDICATORS PILOTS

### 8.1 FACT SHEET

General information					
Description	The Building Performance Indicators are an initiative of the Green Building Council Finland , in cooperation with actors in the real estate and construction industries. The indicators are based on the European CEN/TC 350 family of standards. The indicators are suitable for anyone working in the industry. Furthermore, they are open-source and publicly available on the website of GBCF. Currently, the GBCF’s database contains 20 to 25 buildings (with the majority office buildings).				
Involved parties	Green Building Council Finland				
Year	2012				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
The Ministry of Environment	Northern-Europe, Finland	Office	Renovated	8.436 m² (GFA <sup>26</sup> )	design 2013/use 2015
Peab, Ultimate Business Park	Northern-Europe, Finland	Office	New-build	12.490 m² (GFA) / 550 persons	design 2014
Wood City, SRV	Northern-Europe, Finland	Office	New-build	12.800 m² (GFA)	Design 2015
The Ministry of Environment	Northern-Europe, Finland	Office	New-build	58.296 m² (GFA)	In-use 2013
Nokia-House 4	Northern-Europe, Finland	Office	New-build	6.407 m² (GFA)	In-use 2013
Quartetto	Northern-Europe, Finland	Office	New-build	8.040 m² (GFA)	In-use 2013
Säterinkatu	Northern-Europe, Finland	Office	New-build	30.270 m² (GFA)	In-use 2013
Pöyrytalo	Northern-Europe, Finland	Office	New-build	8.735 m² (GFA)	In-use 2013
Kathy / Skanska	Northern-Europe, Finland	Office	New-build	58.296 m² (GFA)	In-use 2013

The GBCF's eight Building Performance Indicators cover three of the six macro-objectives, more particular: Reduction of carbon emissions (B1), healthy and comfortable spaces (B4) and life cycle cost and value (B6).

### 8.2 MACRO-OBJECTIVE B1: GREENHOUSE GAS EMISSIONS FROM BUILDING LIFE CYCLE ENERGY USE

#### 8.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Operational carbon emissions
- Embodied carbon emissions

Five indicators correspond to macro-objective B1:

- *Life-Cycle Carbon Footprint Indicator*: Carbon emissions of a building's life cycle, calculated according to the LCA standards EN-15978 and EN-15804

<sup>26</sup> GFA: Gross Surface Area

- *Operational Carbon Footprint Indicator*: Carbon Footprint calculated according to the Green House Gas (GHG) Protocol
- *E-Value Indicator*: Primary energy consumption, according to national regulation
- *Baseload Demand Indicator*: Building's energy demand when it is not producing services for its occupants
- *Measured Energy Consumption Indicator*: Measured consumption of purchased energy in a property

The life cycle carbon footprint indicator covers both embodied and operational carbon emissions, whereas the others are limited to operational carbon emissions.

#### → Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
The Ministry of Environment; Peab, Ultimate Business Park; Wood City, SRV; Liipola, Lahti; Nokia-House 4; Quartetto; Säterinkatu; Pöyrytalo; Kathy / Skanska	Carbon emissions; Energy consumption	-	-

#### Detailed discussion:

- The GBCF did not define specific targets for the Building Performance Indicators, but did provide publicly available background information on its website, including a comprehensive calculation guide and web-tool for each indicator.
- The same building can have several E-values, if the building has several purposes (e.g. office – business premises) and if these different operations cover more than 10% of the heated net interior area. However, in the Building Passport only one E-value is presented, according to the principal purpose of the building.

#### → Methodologies, evaluation tools and/or standards used

Project / case study	Methodology used	Evaluation tools used	Standards used
The Ministry of Environment	<ul style="list-style-type: none"> <li>• EN 15978 Assessment of Environmental Performance of Buildings – Calculation Method</li> <li>• Cut-off rule for the carbon footprint assessment</li> <li>• National Building Code of Finland section D5's or the SFS-ISO 13790's calculation methods</li> </ul>	<ul style="list-style-type: none"> <li>• Tools follow the D5's or the SFS-ISO 13790's calculation methods</li> <li>• Dynamic calculation tool validated according to EN, CIBSE or ASHRAE standards, or corresponding IEA BESTEST test cases</li> <li>• Cross Sector Tools</li> <li>• Sector Specific Tools</li> <li>• Additional Guidance Documents</li> <li>• Customized Calculation Tools</li> </ul>	<ul style="list-style-type: none"> <li>• LCA standards EN-15978 and EN-15804</li> <li>• National Building Code of Finland, section D3 (2012) "Energy management in buildings"</li> <li>• Greenhouse Gas Protocol (GHG Protocol Corporate Standard, Revised)</li> </ul>
Peab, Ultimate Business Park; Wood City, SRV;	<ul style="list-style-type: none"> <li>• EN 15978 Assessment of Environmental Performance of Buildings – Calculation Method</li> </ul>	<ul style="list-style-type: none"> <li>• Tools follow the D5's or the SFS-ISO 13790's calculation methods</li> <li>• Dynamic calculation tool</li> </ul>	<ul style="list-style-type: none"> <li>• LCA standards EN-15978 and EN-15804</li> <li>• National Building Code of Finland, section D3</li> </ul>

Project / case study	Methodology used	Evaluation tools used	Standards used
Liipola, Lahti	<ul style="list-style-type: none"> <li>Cut-off rule for the carbon footprint assessment</li> <li>National Building Code of Finland section D5's or the SFS-ISO 13790's calculation methods</li> </ul>	validated according to EN, CIBSE or ASHRAE standards, or corresponding IEA BESTEST test cases	(2012) "Energy management in buildings"
Nokia-House 4; Quartetto; Säterinkatu; Pöyrytalo; Kathy / Skanska	<ul style="list-style-type: none"> <li>Allocation method presented in the Värkki final report section 6.4.</li> <li>Calculation method based on a duration curve</li> </ul>	<ul style="list-style-type: none"> <li>Cross Sector Tools</li> <li>Sector Specific Tools</li> <li>Additional Guidance Documents</li> <li>Customized Calculation Tools</li> <li>Electrical system that can measure at least the hourly electricity consumption</li> <li>Duration curve</li> </ul>	<ul style="list-style-type: none"> <li>Greenhouse Gas Protocol (GHG Protocol Corporate Standard, Revised)</li> <li>National Building Code of Finland, section D5 2012</li> </ul>

#### Detailed discussion:

- Cut-off rule or the carbon footprint assessment:  
To make the assessment easier, a general cut-off rule is applied to the assessment. This rule allows the omission of insignificant emissions from the assessment, according to the assessors judgement and if information on these emissions is not available. The cut-off rule should not be applied to disclose information or used if information on any emissions is available. The cut-off rule can be applied if detailed information is not available and if the portion of the omitted section is less than 1% of the building's total mass or total energy demand. The mass of all omitted sections cannot exceed 5% of the building's total mass or total energy demand. All omitted emission sources can be found in section 10.2. of the Värkki final report (in Finnish).
- Embedded carbon emissions are not included in the carbon footprint assessment, but the effects of wood materials can be reported as supplementary information.
- According to the standard, the principle for all waste flows is that the direct emissions generated by waste management are included in the carbon footprint assessment until the waste has been processed to the end-of-waste state, when it is no longer waste, but reusable material.
- If materials that origin from demolition sites or reusable waste flows are used in the construction of the building, the emissions generated by the original production no longer need to be included in the carbon footprint assessment. In this case, the emissions generated by the use of the materials, after the end-of-waste state, are included. To avoid double counting of the same values in the assessment, the emissions generated by the production of the reusable waste material are not included.
- A building continues its life after the demolition phase as raw materials, from which new products or energy can be produced to be used for the needs of the building sector or other industries. Also, a building can interact with the electric power system and can sell any surplus energy it produces to the electrical grid. These effects that take place outside the building's life-cycle are allocated into a separate section in this assessment. For the management of this information, the so-called module D is included.
- The GHG Protocol enables the assessment of activity in three different scopes (Scope 1, 2, and 3). According to GHG Protocol requirements, Scope 1 and 2 are mandatory. The contents of Scope 3 is chosen based on the type of activity of the company performing the assessment and the reporting.

- In each area of the Measured Energy Consumption assessment, only purchased energy is included in the calculations. Energy produced on the property (geothermal, solar, wind power) is not included.
- The formula for calculating energy consumption is:  
 Energy consumption = energy use, property + electricity use, user  
 If the electricity use of the user has not been measured separately or if it's value is zero, then energy consumption = energy use, property. The energy use of the property is calculated by adding up the different forms of purchased energy as kilowatt hours:  
 Energy consumption, property = district heating + district cooling + electricity use, property
- The baseload demand can vary significantly depending on the season. Maintaining the conditions of a property always consumes energy, even if there is not activity taking place (night time heating and ventilation, cooling of special-purpose spaces, appliances etc.). When assessing the baseload demand, these varying electrical loads that occur throughout the year (thawing and heating vehicles, outdoor lighting, night time ventilation, cooling etc.). To see the effect of the different seasons on the result of the assessment, measurements should be conducted in every season. With the help of the Baseload Demand indicator, the vacant electricity consumption or baseload consumption can be calculated, accordingly to annual, measured vacancy hours. A building's baseload consumption can be calculated by multiplying the baseload demand with 8760. The vacant electricity consumption is calculated by multiplying the baseload demand with the year's vacancy hours.

## 8.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
E-Value	[kWh/m <sup>2</sup> , a]	Design phase	B1: Greenhouse gas emissions from building life cycle energy use
Life-cycle Carbon Footprint	[kg CO <sub>2</sub> e / netto-m <sup>2</sup> / evaluating period]	Design phase	B1: Greenhouse gas emissions from building life cycle energy use
Operational Carbon Footprint	[kg CO <sub>2</sub> e/heated cross-m <sup>2</sup> ]	Use phase	B1: Greenhouse gas emissions from building life cycle energy use
Measured Energy Consumption	[kWh /heated brm <sup>2</sup> ]	Use phase	B1: Greenhouse gas emissions from building life cycle energy use
Baseload Demand	[kW]	Use phase	B1: Greenhouse gas emissions from building life cycle energy use

### → Indicator #1: E-Value

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

#### Technical specifications

- Unit of measurement: kWh/m<sup>2</sup>, a
- Scope of indicator: design phase
- Associated data requirements: heated net interior area, building's weighted, purchased energy forms, energy source-specific coefficients.
- Supporting tools required to quantify/estimate performance: there are several different tools that assess a building's E-value. In order to be compatible with this calculation guide,

the tools need to follow the National Building Code of Finland section D5's or the SFS-ISO 13790's calculation methods (monthly calculation methods for buildings without cooling). Also, any dynamic calculation tool for other types of buildings has to be validated according to EN, CIBSE or ASHRAE standards, or corresponding IEA BESTEST test cases (in the case of test cases, energy used for heating and cooling).

- Source of indicator/metric and its scientific and market acceptance: the E-value is needed for building permits and statutory energy performance certificates. It can be used to optimize design solutions and it can be used in the retail and the renting of buildings. The purpose of the E-value is not to describe true energy consumption. The E-value is defined by the annual consumption of purchased energy of a building in its intended use.

## Results

### Overview and results:

Project / case study	E-value [kWh/m <sup>2</sup> .y]
The Ministry of Environment	129
Peab, Ultimate Business Park	143
Wood City, SRV	131
Liipola, Lahti	108

### → Indicator #2: Life-cycle Carbon Footprint

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions; Embodied carbon emissions

### Technical specifications

- Unit of measurement: kg CO<sub>2</sub>e / netto-m<sup>2</sup> / evaluating period
- Scope of indicator: design phase
- Life cycle stage (with reference to EN 15643): A1-A3 Production phase, A4 Transport, A5 Construction, B1 Use, B2 Maintenance, B3 Repair, B4 Replacement, B5 Refurbishment, B6 Operational energy use, B7 Operational water use, C1 Demolition, C2 Transport, C3 Waste processing, C4 Waste disposal, D Benefits and loads beyond the system boundary.
- Associated data requirements:

The environmental information used in the assessment should be chosen according to the given order of the following list. If higher quality information is available, lower quality information should not be used.

1. Environmental product declaration for a product used in the building, compatible with the EN15804 standard.
2. Environmental product declaration for a general product group or similar product, compatible with the EN15804 standard.
3. Building-specific information that fulfils the requirements stated below.
4. Other environmental information, that fulfils the requirements stated below (e.g. an ISO 14025 type 3 environmental declaration or a life-cycle -based study concerning the item).

In the initial phase of the project (concept or design phase), building-specific or building section-specific or general information can be used instead of product-specific information.

Requirements of quality for environmental information beyond the EN 15804 standard:

- The environmental effects should cover the life-cycle phases required by the standard.



- Information concerning environmental effects or the product should not be older than 10 years.
  - The environmental information should be based on an annual average (exceptions need to be justified).
  - The emissions generated by waste management should be calculated for a period of at least 100 years.
  - Emissions generated over 100 years from now should be reported as separate, long-term emissions.
  - The environmental information should be based on technology actually used in the present.
  - The environmental information should be geographically relevant to the products purchased and used.
- Source of indicator/metric and its scientific and market acceptance: by assessing the carbon footprints of different options for the construction of a building in the design phase, it is possible to find the ideal option that produces the smallest carbon footprint possible during its life-cycle, in relation to the resources available. The building's carbon footprint can efficiently be managed and reduced by measuring the building's emissions during its life-cycle and as a whole. The Life-Cycle Carbon Footprint indicator can also be used as a design goal, as the basis for scoring in competitions, in comparing different options, or in identifying opportunities for improvement. For the developer, the most important requirements are life-cycle efficiency, improving design goals, and setting a building service life requirement.

## Results

### Overview and results:

Project / case study	Life-cycle carbon footprint [CO <sub>2</sub> e]
The Ministry of Environment	32 kg CO <sub>2</sub> e/m <sup>2</sup> /a
Peab, Ultimate Business Park	1.079.000
Wood City, SRV	9.377.947
Liipola, Lahti	8.495.030

### → Indicator #3: Operational Carbon Footprint

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

### Technical specifications

- Unit of measurement: kg CO<sub>2</sub>e/heated cross-m<sup>2</sup>
- Scope of indicator: use phase
- Midpoint(s) and/or parameters: district heating; district cooling; fuels, heating; electricity use, property; electricity use, user; waste management; refrigerants; fuels, own vehicles; fuels, other vehicles; maintenance.
- Associated data requirements: because all the values used in the assessment are based on calculated values only values based on measurements or on billing should be used in the assessment. If some values have been estimated, for example, because of insufficient measuring, the basis of this estimation needs to be clearly presented. If values need to be allocated (for example) between several properties or tenants, the allocation should be applied accordingly to the type of operations of those properties or tenants. For example, the net floor area used is a suitable allocation basis for similar tenants. If the different

parties practice very different types of operations, the allocation shares should be solved accordingly to the type of operations present. The basis for the solution should be presented as a part of the report.

- Supporting tools required to quantify/estimate performance:

Cross Sector Tools
Emission Factors from Cross-Sector Tools
Allocation of Emissions from a Combined Heat and Power (CHP) Plant
GHG emissions from purchased electricity
GHG emissions from stationary combustion (English)
GHG emissions from stationary combustion (Chinese)
GHG emissions from transport or mobile sources
GHG Protocol Tool for Energy Consumption in China (Chinese)
Global Warming Potential Values
Measurement and Estimation Uncertainty of GHG Emissions
Uncertainty Calculation Tool
Sector Specific Tools
CO <sub>2</sub> emissions from the production of ammonia
CO <sub>2</sub> emissions from the production of cement (CSI) - English
CO <sub>2</sub> emissions from the production of cement (US EPA)
CO <sub>2</sub> emissions from the production of iron and steel
CO <sub>2</sub> emissions from the production of lime
GHG emissions from pulp and paper mills
GHG emissions from the production of aluminum
HFC-23 emissions from the production of HCFC-22
N <sub>2</sub> O emissions from the production of adipic acid
N <sub>2</sub> O emissions from the production of nitric acid
Additional Guidance Documents
A Corporate Accounting and Reporting Standard (Corporate Standard)
Base Year Adjustments
Categorizing GHG Emissions Associated with Leased Assets
Hot Climate, Cool Commerce: A Service Sector Guide to Greenhouse Gas Management
Sample Corporate Standard GHG Inventory Reporting Template
Sample Product Standard GHG Inventory Reporting Template
Sample Scope 3 GHG Inventory Reporting Template
Supplier Engagement Guidance
Working 9 to 5 on Climate Change (for use by small office-based organizations only)
Customized Calculation Tools
Chinese Coal Fired Power Plants Tool
CO <sub>2</sub> emissions from the production of cement (CSI) – Chinese version
CO <sub>2</sub> emissions from the production of cement (US EPA) - customized tool for India
Pulp and Paper Tool - customized for Mexico (English version)
Pulp and Paper Tool - customized for Mexico (Spanish version)

- Source of indicator/metric and its scientific and market acceptance: the Operational Carbon Footprint indicator offers an efficient tool to evaluate the carbon footprint of the use of a property and all the building-related activities taking place in it. It measures actual carbon emissions based on the energy company's emissions profile instead of using values based on standardized coefficients. This indicator supports the development of your property portfolio and other sites, helps recognizing improvement opportunities, and also measures the effects of the operational model, use, maintenance, and the energy solution on the carbon footprint. The Operational Carbon Footprint indicator evaluates the user's activity in a building and therefore it can also be applied to measuring and managing emissions caused by the user. The carbon footprint of the building stock is usually

calculated for Global Reporting Initiative (GRI) reports, using the Greenhouse Gas Protocol (GHG Protocol Corporate Standard, Revised) as a guideline.

## Results

### Overview and results:

Project / case study	Operational carbon footprint[kg CO <sub>2</sub> e/GFA.y]
The Ministry of Environment	25,98 kg
Peab, Ultimate Business Park	-
Wood City, SRV	-
Liipola, Lahti	-
Nokia-House 4	23,4
Quartetto	21,6
Säterinkatu	60,7
Pöyrytalo	60,1
Kathy / Skanska	14,1

### → Indicator #4: Measured Energy Consumption

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

### Technical specifications

- Unit of measurement: kWh /heated brm<sup>2</sup>
- Scope of indicator: use phase
- Midpoint(s) and/or parameters: district heating; district cooling; fuels; electricity use, user; electricity use, property.
- Associated data requirements: the basis of calculation for each area of the assessment is presented in the table below. In each area of assessment, only purchased energy is included in the calculations. Energy produced on the property (geothermal, solar, wind power) is not included.

Area of assessment	Basis of calculation
District heating	Measured heating delivered to location. Small, neighborhood heating plants that serve several properties are also included in district heating.
District cooling	Measured cooling delivered to location.
Fuels	Fuels used on location. The energy values of different fuels can be found in Motiva's publication (in Finnish) Polttoaineiden lämpöarvot, hyötysuhteet ja hiilidioksin ominaispäästökertoimet sekä energian hinnat (19.4.2010). If the amount of fuels used cannot directly be measured, it can also be calculated by using the property's heating demand and the thermal efficiency of the fuels used, or by using the average of purchased fuel amounts of at least 3 years. Thermal efficiency tables can be found in the National Building Code of Finland, section D5 2012, tables 6.6. and 6.7.
Electricity use, user	Includes the purchased electricity used for the activity of users, divided into separate apartments or workspaces, if necessary. Depending on the type of property, this category can also include electricity used for lighting in apartments or personal saunas. This should also include the energy used for the charging of electric cars, if used.
Electricity use, property	All purchased electricity used in the building and on the plot. HVAC, lighting, property saunas and elevators, also outdoor lighting, and electricity used for heating and by heating appliances. Does not include electricity consumed by users (according to the definition given here).

- Source of indicator/metric and its scientific and market acceptance: the Measured Energy Consumption indicator measures the true consumption of purchased energy. In practice, the value given by the indicator is the total energy consumption according to the electrical bills. With the Measured Energy Consumption indicator you can:
  - set goals for energy efficiency and verify their fulfilment
  - monitor, plan, manage, and develop the energy consumption, economy, and efficiency of a property
  - share the costs of energy between different occupants

## Results

### Overview and results:

Project / case study	Measured Energy Consumption [kWh/m <sup>2</sup> .y]
Nokia-House 4	316
Quartetto	209
Säterinkatu	349
Pöyrytalo	255
Kathy / Skanska	195

### → Indicator #5: Baseload Demand

- *Macro-objective:* B1: Greenhouse gas emissions from building life cycle energy use
- *Specific aspect(s):* Operational carbon emissions

### Technical specifications

- Unit of measurement: kW
- Scope of indicator: use phase
- Midpoint(s) and/or parameters: hourly electricity consumption of the building; a year's hourly electricity consumption data (starting from the highest hourly consumption continuing to the lowest), using as the baseload the average hourly consumption of the lowest 20% (1752 hours).
- Associated data requirements: the baseload demand can be assessed for the electricity used by the property, the user, or the total electricity consumption, according to the needs of the assessment. In some cities, like Helsinki, consumers of large amounts of electricity can access information on their district heating system's hourly capacity. However, energy used for heating is not included in this assessment.
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): in order to assess the baseload demand, the building needs to be equipped with an electrical system that can measure at least the hourly electricity consumption. The baseload demand should be assessed based on a study period of at least one week. In the case of properties that are completely empty part of the time, the baseload demand should be measured during vacant hours when it is not performing set building systems. Weekends should also be included in the study period. The indicator uses the average mean power of the study period. If the property is constantly in use, the Baseload Demand indicator uses the moments of the least electrical load during the study period.
- Supporting tools required to quantify/estimate performance: electrical system that can measure at least the hourly electricity consumption; a duration curve composed of a year's hourly electricity consumption data (starting from the highest hourly consumption continuing to the lowest), using as the baseload the average hourly consumption of the

lowest 20% (1752 hours). The electricity consumption duration curve reveals how many hours a year the area's electricity need exceeds a certain electrical power.

- Source of indicator/metric and its scientific and market acceptance: identifying and separating the energy consumed during vacant hours helps removing unnecessary consumption that does not produce services for the building or falsely set building systems. The Baseload Demand indicator describes the building's energy demand when it is not producing services for its occupants. The baseload demand should be taken into consideration also when planning new buildings. With this indicator, you can manage and control electricity consumption that does not produce services for a property's occupants. With the Baseload Demand indicator you can:
  - set goals for the design of building systems
  - identify unnecessary energy consumption and falsely set building systems
  - raise a property's use rate and improve its economical and environmental performance

## Results

Overview and results:

Project / case study	Baseload Demand [kW/y]
Nokia-House 4	753
Quartetto	28
Säterinkatu	0
Pöyrytalo	240
Kathy / Skanska	23

### 8.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

In general, the guides for conducting calculations for different indicators are very well-written and available online and calculation tools on website are also well-developed. Users without technical background can also follow the instruction and conduct the calculation. However, calculation of some indicators can be time-consuming, and it is also difficult to find paying customers for the calculation of these indicators. Practical experience of conducting calculation on selected indicators are provided below.

E-value is mandatory according to Finnish building code. The same building can have several E-values, if the building has several purposes (e.g. office – business premises) and if these different operations cover more than 10% of the heated net interior area. However, in the Building Passport only one E-value is presented, according to the principal purpose of the building. The GBCF explicitly notes in its guidelines that, due to the weighted coefficients of different energy sources, the E-value indicator is not comparable with the measured energy consumption indicator. Also, the E-value indicator is weather-normalized according to the climate conditions in southern Finland, while the other indicators assess a building's performance in the climate conditions of the region it is located in.

To calculate measured energy consumption, it can be difficult to obtain the correct floor area, therefore in some cases, only part of the building area is used in the calculation. The building measurement system is key. It is more suitable for building owners and investors. It is relatively easier to acquire this data, but it is also difficult to contact the right person and to have them circulate the correct data but in some specific cases. This indicator is calculated in excel and the spreadsheet is provided by GBCF, which is straightforward to enter information in online tool once the required data is available. The most time-consuming part is to get the needed data in a proper and usable format.

Operational carbon footprint is very much aligned with measured energy consumption, it requires not that much “extra work” from a practical perspective. In Finland, embodied carbon footprint is not very well recognized and widely accepted compared to energy consumption. People do not really understand why they should calculate it, how to calculate it and how to interpret the results. People are only interested in short-term indicators. EN 15978, part of BREEAM and LEED certificates, is the only motivation. To conclude, it is hard to motivate people to be interested in this abstract concept.

### 8.3 MACRO-OBJECTIVE B4: HEALTHY AND COMFORTABLE SPACES

#### 8.3.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Exposure to hazardous substances – ventilation intake air
- Exposure to hazardous substances – materials emissions

Two indicators correspond to macro-objective B4a.

- *Indoor Air Class Indicator*: indicates the indoor air quality on a general level using four possible categories, according to a Finnish classification method
- *User Satisfaction Indicator*: Review of the work environment as experienced by the building user, using a survey. Following themes are addressed: Thermal comfort (both cooling and heating season), Indoor air quality (odours, stuffiness/staleness), Lighting, Acoustics (noise, acoustic privacy)

##### → Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target			
The Ministry of Environment; Peab, Ultimate Business Park; Wood City, SRV; Liipola, Lahti	Ventilation intake air; Materials emissions	The Finnish Classification of Indoor Environment and Material Emissions		S1	S2	S3
			Carbon dioxide concentration [ppm]	<750	<900	<1200
			Radon concentration [Bq/m <sup>3</sup> ]	<100	<100	<200
			Stability of environment [% of operating time]			
			office and school spaces	95%	90%	
			residential spaces	90%	80%	
Quartetto; Säterinkatu; Pöyrytalo	Thermal comfort (both cooling and heating season); Indoor air quality (odors, stuffiness / staleness); Lighting; Acoustics (noise, acoustic privacy)	-	At least 75% of satisfaction among users			

##### Detailed discussion:

- The Indoor Air Class indicator follows the Finnish Society of Indoor Air Quality and Climate's (Sisäilmayhdistys ry) guideline in the property's indoor environment classifications, which has four possible categories:

S1: Individual indoor environment  
 S2: Comfortable indoor environment  
 S3: Satisfactory indoor environment  
 – : No classification granted

It is possible that all of the classifications above can be found in the same building. In this calculation guide, the indoor environment classification of the assessed property is the best classification that at least 80% of the property's indoor spaces that serve the building's main purpose reach. For example, if 10% of a property's indoor spaces reach the S1 classification and 75% reach the S2 classification, then the property as a whole has a combined classification of S2. However, if 79% of the property's spaces have a classification of S2 but no other spaces of other classifications, then this indicator does not grant the property any classification.

- The User Satisfaction survey studies the quality of the work environment as experienced by the user, based on experiences during a longer duration, not just an individual moment. It covers five different areas:
  1. Thermal comfort, cooling season (summer)
  2. Thermal comfort, heating season (winter)
  3. Indoor air quality (odours, stuffiness/staleness)
  4. Lighting
  5. Acoustics (noise, acoustic privacy)

The results are calculated by first determining the percentage of unsatisfied users (answers -1...-3) for each area in the indoor environment. If the rate of dissatisfaction in any area exceeds 25%, the reasons should be investigated, and if necessary, conduct an indoor air quality evaluation. The final result is determined by calculating the average of satisfaction in all the areas in the survey. The percentage of satisfied users is 100% subtracted by the percentage of unsatisfied users. The objective is at least 75% of satisfaction among users.

#### → Methodologies, evaluation tools and/or standards used

Project / case study	Methodology used	Evaluation tools used	Standards used
The Ministry of Environment; Peab, Ultimate Business Park; Wood City, SRV; Liipola, Lahti	<ul style="list-style-type: none"> <li>• Finnish classification method "Finnish Classification of Indoor Environment 2008"</li> </ul>	<ul style="list-style-type: none"> <li>• User satisfaction survey</li> </ul>	<ul style="list-style-type: none"> <li>• Finnish Society of Indoor Air Quality and Climate (Sisäilmayhdistys ry) publication "Finnish Classification of Indoor Environment 2008"</li> </ul>
Quartetto; Säterinkatu; Pöyrytalo	<ul style="list-style-type: none"> <li>• Review of the work environment as experienced by the building user with a user satisfaction survey that covers five different areas</li> <li>• Final result determined by calculating the average of satisfied users in all the areas in the survey</li> </ul>	<ul style="list-style-type: none"> <li>• User satisfaction survey</li> </ul>	-

#### Detailed discussion:

The User Satisfaction survey examines the user's satisfaction rate in every area. The user can give seven different scores: +3 very satisfied, +2 satisfied, +1 partly satisfied, 0 neutral, -1 partly unsatisfied, -2 unsatisfied, -3 very unsatisfied. The survey can explore the reasons for dissatisfaction (scores -1...-3) with more specific supplement questions. The questions can be pre-formulated, or the respondent can freely write about the problem. For example, if the respondent is not satisfied with the thermal conditions during winter, a supplement question can inquire if the

reason is that the indoor temperature is too high or too low, or that the surfaces are too hot or cold, or if the reason is a draft in the workspace. It is also useful to ask the respondent to clarify in which part of the property he is working, so that possible problems can be pinpointed correctly inside the building.

If it is known that the property's users are showing health symptoms typically related to the indoor environment, a section concerning symptoms can be added to the survey. In this case, the users can be asked about the type and frequency of the symptoms. With the information gathered by this section, further possible problems can be identified.

### 8.3.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

#### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Indoor Air Class	Class 1-3	Design phase	B4: Healthy and comfortable spaces
User Satisfaction	[%]	Use phase	B4: Healthy and comfortable spaces

#### → Indicator #1: Indoor Air Class

- *Macro-objective:* B4: Healthy and comfortable spaces
- *Specific aspect(s):* Operational carbon emissions

#### Technical specifications

- Unit of measurement: Class 1-3
- Scope of indicator: design phase
- Midpoint(s) and/or parameters:

	S1	S2	S3
Carbon dioxide concentration [ppm]	<750	<900	<1200
Radon concentration [Bq/m <sup>3</sup> ]	<100	<100	<200
Stability of environment [% of operating time]			
office and school spaces	95%	90%	
residential spaces	90%	80%	

- Associated data requirements: carbon dioxide concentration, radon concentration, stability of environment (office and school spaces, residential spaces).
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): the quality of the indoor environment should be confirmed during the first year of use by measuring physical variables and by conducting a user satisfaction survey.
- Supporting tools required to quantify/estimate performance: user satisfaction survey.
- Source of indicator/metric and its scientific and market acceptance: the Indoor Air Class indicator sets goals for the indoor environment in new buildings and renovation projects. It is principally designed to help the developer, the designer, and the construction company to set common goals. It also informs the property's owner and users of the building's capacity to produce indoor environmental conditions of good quality. With the Indoor Air Class indicator, you can define the required levels of indoor air quality and cleanliness, operative temperature, thermal comfort, along with lighting and acoustics. By obtaining an Indoor Air Class classification, you can ensure the users' health and wellbeing in the



building. With the help of this indicator, you can confirm the fulfilment of set goals when the building has been taken into use.

### Results

#### Overview and results:

Project / case study	Indoor Class
The Ministry of Environment	S2
Peab, Ultimate Business Park	S2
Wood City, SRV	S2
Liipola, Lahti	S2

#### Cross-links and trade-offs between other macro-objectives

- Which aspect of performance does the trade-off relate to?
  - Trade-off between energy performance and thermal comfort;
  - Trade-off between energy performance and indoor air quality (ventilation).

#### → Indicator #2: User Satisfaction

- *Macro-objective: B4: Healthy and comfortable spaces*
- *Specific aspect(s): Operational carbon emissions*

#### Technical specifications

- Unit of measurement: %
- Scope of indicator: use phase
- Midpoint(s) and/or parameters: thermal comfort (both cooling and heating season); indoor air quality (odours, stuffiness / staleness); lighting; acoustics (noise, acoustic privacy).
- Associated data requirements: scores given by users in each area in the survey.
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): the quality of the indoor environment should be assessed with the User Satisfaction survey every 1-3 years.
- Supporting tools required to quantify/estimate performance: user satisfaction survey.
- Source of indicator/metric and its scientific and market acceptance: the User Satisfaction survey helps identifying possible problems in a property's technical systems. When the problems are identified, they can be solved before they cause negative effects, such as sickness among users or structural damage to the property. With the User Satisfaction indicator, you can:
  - assess and set goals for the indoor environment between the owner, tenant, and maintenance
  - assess the suitability of the work environment for your company or the quality of offered services

The User Satisfaction indicator can be applied to assessing the quality of the indoor environment and be used to set and achieve goals for the owner and the maintenance company, as well as communication between the owner and the tenant. The indicator shows the percentage of satisfied users in the different areas of the indoor environment.

### Results

#### Overview and results:

Project / case study	User Satisfaction
Nokia-House 4	-

Quartetto	69%
Säterinkatu	69%
Pöyrytalo	70%
Kathy / Skanska	-

#### ***Cross-links and trade-offs between other macro-objectives***

- Which aspect of performance does the trade-off relate to?
  - Trade-off between energy performance and thermal comfort;
  - Trade-off between energy performance and indoor air quality (ventilation).
- What is the quantifiable impact on performance?
  - The energy use is constrained through requirements for comfort and indoor climate.
  - Energy performance and insulation level are usually inherently linked together, and it is common to see that well insulated buildings theoretically usually perform better from energy perspective. Insulation level and airtightness are also usually linked together. Better insulation means less air leakage. Higher airtightness requires a good ventilation strategy but ventilation usually means high air exchange rate.

#### **8.3.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

Not available

### **8.4 MACRO-OBJECTIVE B6: OPTIMISED LIFE CYCLE COST AND VALUE**

#### **8.4.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL**

##### **→ Aspects covered of the macro-objective**

- Life cycle cost

The last indicator relates to macro-objective B6:

- *Life-Cycle Cost Indicator*: The indicator is based on EN 16627 and the EN 15643-4 framework of standards for life-cycle costs, belonging to the European CEN / TC 350 – Sustainability of Construction Works family of standards. The life-cycle cost assessment is performed on the same principles as the life-cycle carbon footprint indicator.

##### **→ Improvement option(s)**

Project / case study	Improvement option	Evaluation criteria	Performance target
The Ministry of Environment; Peab, Ultimate Business Park; Wood City, SRV; Liipola, Lahti	Life cycle cost and value	EN 15643-4 and the work-in-progress WI 017	EN 15643-4 -compatible “lowest life cycle cost”

#### Detailed discussion:

The basic principles (the EN 15643-4 and the work-in-progress WI 017) of the life-cycle cost assessment are:

- The Life-Cycle Cost indicator measures costs, not revenue (EN 15643-4 -compatible “lowest life cycle cost”).

- Costs are taken into account and divided into phases for the building's entire life-cycle.
- Costs generated at different times are made compatible with the net present value with a discount rate.
- The effects of general inflation on prices are not taken into account in this assessment.
- The life-cycle cost assessment is made with a minimum of one discount rate, that is presented with the results of the assessment. The person performing the calculation chooses the interest rate to be used based on the requirements of the client, the suitability to type of operations, the general practices in the sector, or the suitability to the project. The assessment can be done with several, parallel interest rates, in which case they are all presented with the results of the assessment.
- The VAT is taken into account accordingly if the operator using the property is able to deduct the VAT or not. The inclusion or exclusion of the VAT should be done systematically and consistently in all the phases and should be stated in the final report.
- Financing costs are included in the discount rate.
- The assessment boundaries should be set according to the same principles as in the Life-Cycle Carbon Footprint indicator (see section 5).

The goal of the Life-Cycle Cost indicator is to show how much a property owner will actually pay for a property during its entire life-cycle.

#### → Methodologies, evaluation tools and/or standards used

Project / case study	Methodology used	Evaluation tools used	Standards used
The Ministry of Environment; Peab, Ultimate Business Park; Wood City, SRV; Liipola, Lahti	Net present value with a discount rate	-	<ul style="list-style-type: none"> <li>European CEN/TC 350 family of standards - EN 16627 and the EN 15643-4 framework of standards for life-cycle costs</li> </ul>

#### Detailed discussion:

The discount rate used is the most significant single variable in terms of the result of the life-cycle cost assessment. The choice of discount rate should be based on principle that it will serve the decision-making of the operator in need of the results, and that it takes into account, among other things, the project type's typical risks that might emerge from demand or the introduction of new technological innovations, for example.

The cost level of goods to be used in this assessment is the current pricing. Rises in prices or the effects of inflation that take place during the time period of the building's life-cycle are not taken into account. An exception to this rule are energy prices, in which case the values given in the table of "1.3.4 Indicator #3: Life-cycle Cost- Midpoint(s) and/or parameters" of this document should be used. In the table are listed the minimum prices for the most volatile energy products, so that they can be included in the assessment. In other cases, the actual market price can be used in the assessment.

The assessment can include the additional cost coefficients, for example, for extra work or modifications that the operator finds likely to be needed, considering the quality of the design and taking other factors into consideration.

The costs generated by the building-related activities of the users are not included. Costs that are connected with inspections of the property are included in the costs concerning the building's condition and its production of services. Actual revenue is not included, but discounts, benefits,

and returns that lower purchase prices (e.g. material compensations in the demolition phase) are noted as deductions from net costs, if they are known. Subsidies are also not included in the life-cycle cost assessment. The possible sale of the building during its life-cycle and any mapping, marketing, or transaction fees are not included, as they are not a part of the building's life-cycle, but represent commercial processes beyond the life-cycle.

In the case of taxes and government payments, the basis of the assessment is the current legislation. Predicted changes to legislation and taxation and their effects on the building's life-cycle costs can be included, if the effects can be considered substantial. This decision is up to the person performing the life-cycle cost assessment, based on the objectives of the assessment.

#### 8.4.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Life-cycle Cost	[€/a/m <sup>2</sup> ]	Design phase	B6: Optimised life cycle cost and value

##### → Indicator #1: Life-cycle Cost

- *Macro-objective:* B6: Optimised life cycle cost and value
- *Specific aspect(s):* Operational carbon emissions

##### Technical specifications

- Unit of measurement: €/a/m<sup>2</sup>
- Scope of indicator: design phase
- Life cycle stage (with reference to EN 15643): A0 Before construction, A1-A5 Before the use phase, B1 Use, B2 Maintenance, B3 Repair, B4 Replacement, B5 Refurbishment, B6 Operational energy use, B7 Operational water use, C1-C4 End-of-life phase, D Benefits and loads beyond the system boundary.
- Midpoint(s) and/or parameters: the following parameters are used in the life-cycle cost assessment. As the price of electricity and oil fluctuate with time, they have been given minimum prices. Values under these fixed prices should not be used. Using higher prices, however, is acceptable. Concerning electricity, the transmission costs and current electricity taxes should always be included in the values used. Values of other energy forms should always include the excise tax. For energy, the VAT is taken into account with the same principles as for the assessment as a whole. In the case that the assessment is done for a user without the right to deduct VAT, the current VAT should be added to the minimum prices listed below, if they are used.

Parameter	Value	Source
Electricity, minimum price (VAT 0%)	5,2 cnt/kWh	The Finnish Energy Authority, price of electricity without taxes, user type L1, average price based on the period 1.11.2007 – 1.11.2012.
Light fuel oil, minimum price (VAT 0%)	65 cnt/liter	Statistics Finland, Energy prices, the average of consumer prices from 2007-2011 with taxes, with the VAT removed.
Annual rise in energy prices	4,60 %	Calculated, inflation-adjusted average of the development of prices for 2025-2030, based on the EU Energy Trends to 2030: Reference Scenario.

- Associated data requirements:

The information on project costs should be based on existing technologies and solutions found in the market, or other solutions that can reasonably implemented. The price level consists of the current market prices.

The information on project costs is chosen in the following order of importance. That is to say, information is reported in the given order and the following options are used only when the earlier option is unavailable.

1. Project-related prices based of received offers.
2. Project-related prices based on the cost assessment.
3. The average prices for corresponding services in corresponding building types. These average prices include accrued interest (e.g. cleaning € / m<sup>2</sup> / month in corresponding property) and are based empirical data or the current prices.
4. The additional cost coefficients for corresponding services in corresponding building types (e.g. the percent of the share of parts replacement in the building costs per year after the first ten years of use). These coefficients are based on empirical data or are generally in use.

The life-cycle cost assessment is a design phase tool. To serve its user well, it needs to anticipate the realization of costs as precisely as possible. However, the calculated result will unavoidably differ from the final, actual costs that will take place during the project. So that the Life-cycle Cost indicator can be calibrated to correspond to actual costs, the use of actual values based on empirical data from corresponding projects and buildings in the calculation is justifiable.

- Source of indicator/metric and its scientific and market acceptance: the Life-Cycle Cost indicator makes it possible to compare the entire life-cycle costs of different solutions for executing a construction project and to develop the building's cost structure during the life-cycle.

## Results

### Overview and results:

Project / case study	Life-cycle cost
The Ministry of Environment	90 €/brm <sup>2</sup> /a
Peab, Ultimate Business Park	102 €/m <sup>2</sup> /a
Wood City, SRV	82 €/m <sup>2</sup> /a
Liipola, Lahti	116 €/m <sup>2</sup> /a

### Detailed discussion:

After approval of the organizations involved, the GBCF shared access to a selection of projects in their database. Furthermore, the GBCF contacted key actors for each study who are able to provide project experience using these indicators in practice.

### Cross-links and trade-offs between other macro-objectives

Not available

### 8.4.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

Not available

## 8.5 REFERENCES

Finnish Society of Indoor Air Quality and Climate (Sisäilmäyhdistys ry) publication "Finnish Classification of Indoor Environment 2008": <http://figbc.fi/wp-content/uploads/2015/05/Sateri-Finnish-classification-on-indoor-environment-2008.pdf>

Green Building Council Finland. <http://figbc.fi/en/building-performance-indicators/>

## 9 FS 7. IRCOW

### 9.1 FACT SHEET

General information	
<b>Description</b>	<p>IRCOW (Innovative Strategies for High-Grade Material Recovery from Construction and Demolition Waste) developed and validated upgraded technological solutions to achieve an efficient material recovery from Construction and Demolition (C&amp;D) waste by considering a life cycle perspective. The project developed new management schemes, separation technologies and products that are needed to significantly increase the reuse and recycling rates of C&amp;W waste in the EU. These methodologies were assessed and validated from an economic, environmental and toxicological point of view, by using both Life Cycle Assessment tools and case studies throughout Europe.</p> <p>The technological solutions were tested in five in-field case studies: selective demolition of an industrial/service building in Spain, selective demolition of a school with wooden building components in Sweden, selective dismantling and on-site treatment of fibrous materials in Poland, demolition of office buildings related with construction of non-residential buildings in Spain and Belgium.</p>
<b>Involved parties</b>	13 partners, consisting of industrial companies and associations from the construction and recycling sector. Other partners are research institutes, including Tecnia (coordinator) and VITO.
<b>Year</b>	From 2011-01-17 to 2014-01-16 (duration of 36 months)

Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale (m <sup>2</sup> )	Stage
CS1A	Southern Europe, Bilbao (ES)	Industrial building	Demolition	3,510	Demolition
CS1B	Southern Europe, Bilbao (ES)	Residential: Apartment block (student housing)	Demolition	2,540	Demolition
CS 4	Southern Europe, Teruel (ES)	Office: low-rise	Demolition, new-build	-	Demolition, construction
CS 5	Central-Europe, Antwerp (BE)	Office: low-rise	Demolition, new-build	-	Demolition, construction

Relevant professional context
<p><b>Field studies carried out by collaborative EU projects</b></p> <p>IRCOW is a European project funded by the FP7 programme for the call ENV.2010.3.1.3-1 - Innovative technologies and eco design recommendations for reuse and recycling of Construction and Demolition (C&amp;D) waste, with a special focus on technologies for onsite solutions.</p> <p>Thirteen partners from seven countries were involved (Belgium, Sweden, Poland, Spain, Italy, Germany and Finland), among which Tecnia (coordinator) and VITO.</p>

## 9.2 MACRO-OBJECTIVE B2: RESOURCE EFFICIENT MATERIAL LIFE CYCLES

### 9.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

##### - Circular flows:

- The use of re-used structural elements (or other hot spot building elements) within a new building
- The substitution of virgin materials with recycled or secondary/by-product materials
- The minimisation of waste along the supply chain e.g. during fabrication, on the construction site

#### → Improvement option(s)

In general the scope of the project was a higher circular material use, lowering primary material use and landfilled material. This was done during the demolition phase by a higher sorting at the source (selective demolition) and the production phase of new building products by the development of high-grade products with recycled materials.

Project / case study	Improvement option	Evaluation criteria	Performance target
CS 1	Selective demolition	Material recovery ratio	Maximised reuse and on-site recycling
CS 4	Selective demolition, new materials with recycled resources	Material recovery ratio, fraction of recycled material in new products	Wood-polymer composites (100 % recycled materials) Thermal insulation multilayer element with recycled material
CS 5	Selective demolition, new materials with recycled resources	Material recovery ratio, fraction of recycled material in new products	Recycled concrete (>20% of the coarse aggregate fraction replaced by recycled concrete aggregates). Demonstration of recycling options for autoclaved aerated concrete.

#### Discussion:

During the IRCOW case studies, the technologies that were developed during the project were demonstrated. To reach the objective (resource efficient material life cycles), the project aimed at a recovery rate of materials from demolition works in high-grade products (e.g. reuse or high-grade recovery). Therefore, the quality of the recovered materials was crucial. The materials from the demolition activities were reused if possible.

This quality, which was assessed by (time-consuming) manual classification techniques, is dependent on the demolition practices and/or subsequent sorting techniques. A selective demolition allows to obtain pure material fractions at the source. If necessary, mixed material fractions were treated by sorting techniques (e.g. UV-VIS sorting) to obtain a high-quality material fraction.

In CS1A, an industrial building was selectively demolished with a focus on the on-site recycling of the stony fraction. In CS1B, a student residence (13 levels) was selectively demolished. The reuse of materials was maximised.



In CS4, an old office building was demolished after an inventory of elements to be reused was performed. Afterwards, a penitentiary centre was built using recycled materials from the demolished office building. The concrete slab foundation contained recycled concrete aggregates. Non-mineral fractions (e.g. plastics, wood, and gypsum) were used for the manufacturing of wood-polymer composites and multilayer insulation components.

In CS5, an office building in the Port of Antwerp was demolished with maximal attention for reuse and recycling (selective demolition). Afterwards, a waste collection centre was built using concrete with recycled aggregates (20-30 % of the coarse aggregate fraction) and floor screed with recycled autoclaved aerated concrete (AAC).

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
CS 1, CS 4, CS 5	Recovery rates of material during demolition	Mass measurements of produced waste streams	/
CS 4, CS 5	Composition of the produced recycled aggregates	Manual classification method	EN 933-11
CS 4, CS 5	Amount of recycled materials in the developed products	Used product recipes	/

Discussion:

The IRCOW project aimed at an optimal recovery of construction and demolition waste (C&DW). In order to achieve this, the project partners aimed at products with a maximal amount of recycled materials that still complied with technical, environmental and durability standards.

A good separation of the different material fractions in a demolition project is crucial for an efficient recycling of the materials. In the demolition case studies, the project partners investigated the destination of the different material fractions and determined which amount was recovered. The Waste Framework Directive (2008/98/EC), article 11.2 states that "Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery".

To be sure that the products complied with all technical and environmental standards, the composition of the used recycled aggregates was determined. Some materials can be detrimental for the quality of the product if present in too high amounts. They can give the material a lower strength, cause chemical reactions or cause esthetical problems.

The amount of recycled materials in a product can be documented in the beginning of the production process, where all resources are added. Because the product manufacturers were part of the project, this could be easily done. The determination of the amount of recycled materials will be much more difficult after the production process.

## 9.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
<b>Material recovery ratio</b>	m%	End of life (C1-C4)	B2: Resource efficient material life cycles
<b>Fraction of recycled material</b>	m%	Product stage: manufacturing (A3)	B2: Resource efficient material life cycles
<b>Amount of unwanted constituents in the recovered fractions</b>	m%	End-of-life stage: Deconstruction/demolition (C1) waste processing (C3)	B2: Resource efficient material life cycles

### → Indicator #1: Material recovery ratio

- *Macro-objective: B2: Resource efficient material life cycles*
- *Specific aspect(s): Increase of amount of materials that are reused or recycled*

#### Technical specifications

- Unit of measurement: m%
- Life cycle stage (with reference to EN 15643): End of life (C1-C4)
- Scope of indicator: The whole building + infrastructure (excluding excavated soil). Recovery= reuse, recycling, energy recovery.
- Midpoint(s) and/or parameters: mineral resources depletion, land occupation, fossil resources depletion
- Functional unit: Building level
- Associated data requirements: processing certificates, delivered by the recycling plants
- Source of indicator/metric and its scientific and market acceptance: Waste Framework Directive (2008/98/EC), article 11.2

#### Results

##### Overview and results:

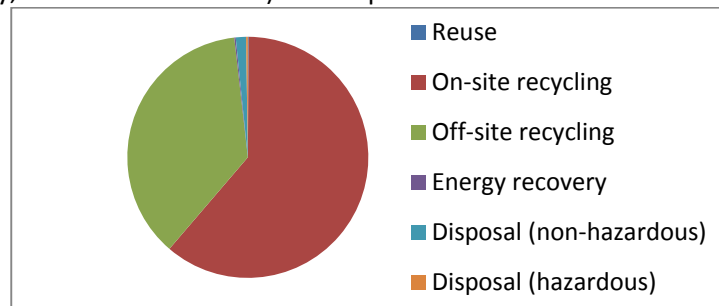
Project / case study	Reuse	Recycling	Energy recovery	Total recovery	Total recovery of the non-hazardous fraction
<b>CS 1A</b>	0.1 m%	98 m%	0.2 m%	98 m%	99 m%
<b>CS 1B</b>	0.2 m%	98 m%	1 m%	99 m%	99.9 m%
<b>CS 4</b>		97 m%		97 m%	97 m%
<b>CS 5</b>	0.5 m%	98 m%		98 m%	99 m%
<b>BAU* Flanders (A)</b>		99 m%	0.2 m%	99.6 m%	99.6 m%
<b>BAU* Flanders (B)</b>	1 m%	98 m%		99 m%	99 m%

\*BAU: business-as-usual

#### Discussion:

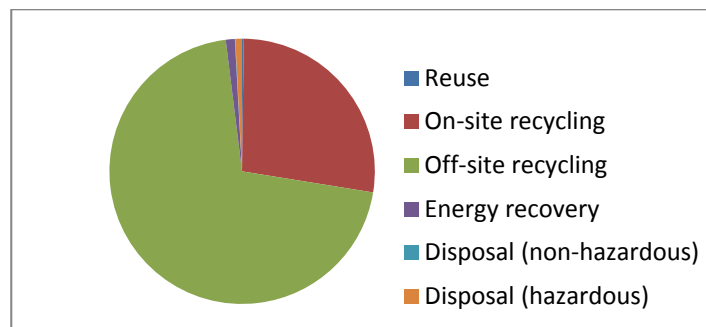
In CS 1A, the stony fraction was partly recycled on-site and partly off-site (Graphic 1). Also cardboard and metal fractions and part of the wood waste were recycled off-site. The contractor found some wood pallets on the site, these pallets were reused. A small fraction (0.2 m%) of the waste (mainly wood) was used for energy recovery. A small non-hazardous waste fraction

(e.g. gypsum, thermal insulation) was disposed. Also the hazardous waste (asbestos, fluorescence tubes with mercury, bituminous material) was disposed.



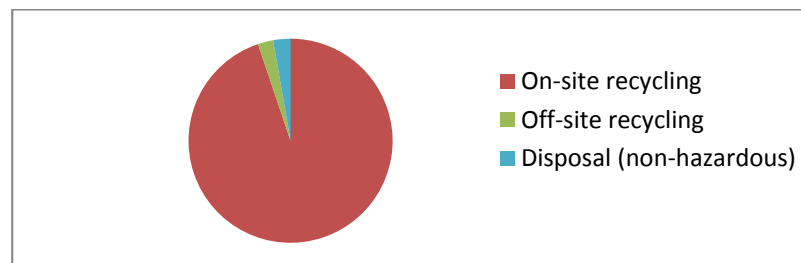
*Graphic 1: Recovery ratios for CS 1A.*

In CS 1B, 97 m% of the produced waste materials was recovered (Graphic 2). Reuse was the biggest attention point. However, only 0.2 m% of the total available material was reused (e.g. radiators, toilets, washing basins). The main part of the building (reinforced concrete elements, brick walls) was recycled. Recycled concrete aggregates were produced on-site, while a mixed stony fraction and the steel reinforcement bars were recycled off-site. Wood waste that could not be reused/recycled was used for energy recovery. The material that was disposed, was mainly hazardous waste (oil-contaminated waste, asbestos).



*Graphic 2: Recovery ratios for CS 1B.*

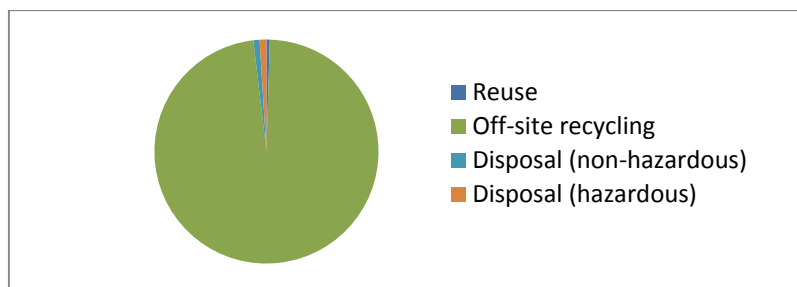
In CS 4, the emphasis was on the recycling of the stony fraction (95 m%) (Graphic 3). This fraction was completely recycled on-site. Metal, mineral wool and gypsum fractions were recycled off-site (respectively as metals, in wood-polymer composites and in new gypsum boards). A small fraction (3 m%) was disposed, this fraction was composed of non-hazardous waste (mainly wood and plastics).



*Graphic 3: Recovery ratios for CS 4.*

In CS 5, a smaller building was demolished (Graphic 4). Because of the smaller scale, on-site recycling was not economically viable. The stony fraction, the metal fraction and part of the wood

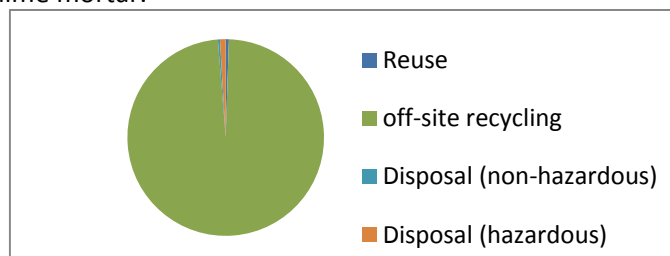
waste was recycled in off-site recycling plants. Some elements (windows, radiators, fire protection doors, lamps) were reused. A small non-hazardous waste fraction (e.g. gypsum, thermal insulation) was disposed. Also the hazardous waste (asbestos) was disposed.



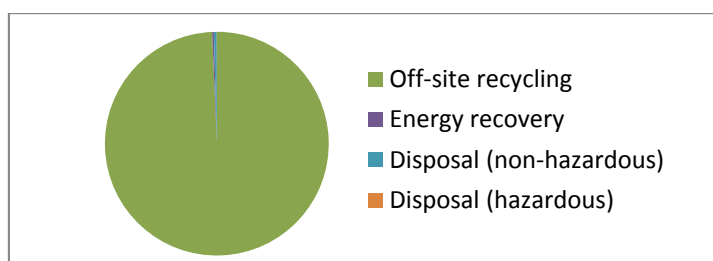
*Graphic 4: Recovery ratios for CS 5.*

As a comparison, we include 2 business-as-usual case studies in Flanders (Graphic 5, Graphic 6). Flanders has the highest recovery ratio of C&DW in Europe. Typically, the stony fraction and the metal fraction are recovered almost completely. Wood waste is recycled or used for energy recovery, depending on the quality. These 2 case studies are representative for bigger demolition works in Flanders. While some other European countries currently do not reach the 2008/98/EC recovery objective of 70% by weight, Flanders C&DW is on average recycled for more than 95 wt.%. However, recycling rates in Flanders can be lower for smaller demolition works or demolition works with space limitations.

Hazardous waste (e.g. asbestos) and mixed non-hazardous waste (e.g. plastics) is disposed. Flanders has a landfill ban for recyclable C&DW fractions. This also includes autoclaved aerated concrete, since there are recycling options available (demonstrated in CS 5). The reuse market in Flanders is not well established. A material that is often reused, are old bricks (good quality) with an easily removable lime mortar.



*Graphic 5: Recovery ratios for Flemish business-as-usual case study (industrial building).*



*Graphic 6: Recovery ratios for Flemish business-as-usual case study (apartment building).*

A general recovery ratio does not completely indicate the selectivity of the demolition process or the optimal recovery of the produced waste materials. No distinction is made between high-grade recovery (e.g. reuse, recycling in high-grade products) or low-grade recovery (e.g. energy production, backfilling). Based on the processing certificates, a distinction cannot always be made, because these certificates do not give information on the final recycling application.

It is possible to recover almost all of the produced materials. However, the numbers above do not reflect the quality of the produced material streams. For instance, while in CS 4 gypsum waste was recycled in new gypsum boards, in the Flemish BAU case study (B), the gypsum was not collected separately and ended up in the stony fraction. For both cases, recovery ratios would be the same. In Flanders, a supply chain tracking system is currently being developed, aiming to give a quality assurance to the recycling plants. This will be done by a follow-up of the demolition process via the demolition material inventory and control mechanisms. Tracimat currently aims at a quality improvement of the stony fraction, by a selective removal of hazardous materials (e.g. asbestos) and low-strength materials (e.g. gypsum). The system is voluntarily, but there will be a price differentiation in the gate fees of the recycling plants (low risk = lower gate fee).

The selective disposal of non-recyclable hazardous waste is crucial for a viable circular economy. Non-recyclable hazardous waste could be excluded from the recovery ratios. The Waste Framework Directive (2008/98/EC) also excludes hazardous waste.

A mass-based indicator favours high-density waste streams. This means that waste streams with a very low density will be insignificant to reach the target. High-density waste streams (e.g. stony fraction) are currently recovered more than low-density waste streams (e.g. insulation materials, plastics). Lower recovery rates are obtained if the results are reported on a volume base (Table 3).

Project / case study	Reuse	Recycling	Energy recovery	Total recovery	Total recovery of the non-hazardous fraction
CS 1A	1 V%	92 V%	1 V%	93 V%	94 V%
CS 1B	3 V%	89 V%	5 V%	98 V%	99.7 V%
CS 4		91 V%		91 V%	91 V%
CS 5	1 V%	95 V%		96 V%	97 V%
BAU* Flanders (A)		98 V%	1 V%	99 V%	99 V%
BAU* Flanders (B)	1 V%	96 V%		96 V%	97 V%

\*BAU: business-as-usual

Table 3: Estimated recovery ratios on a volume base.

The case studies above were demolition works. Construction waste will be less mixed than demolition waste, since pure fractions can be obtained during construction. This will make recovery easier.

#### **Cross-links and trade-offs between other macro-objectives**

A selective demolition can differ from a non-selective demolition in several aspects (e.g. energy use of used equipment, the use of water in dust measures). The impact of an increased selectivity in demolition practices on these aspects is currently being investigated in LCA studies for the H2020 project HISER ([www.hiserproject.eu](http://www.hiserproject.eu)).

On-site recycling limits the need of transport. However, on-site recycling is only possible for larger-scale demolition projects.

→ **Indicator #2: Fraction of recycled material**

- *Macro-objective: B2: Resource efficient material life cycles*
- *Specific aspect(s): Amount of materials that are reused or recycled*

**Technical specifications**

- Unit of measurement: m%
- Life cycle stage (with reference to EN 15643): Product stage, manufacturing (A3)
- Scope of indicator: Recycled materials in new products. Not in the scope: secondary fuels.
- Midpoint(s) and/or parameters: mineral resources depletion, land occupation, fossil resources depletion
- Functional unit: Product level
- Associated data requirements: product formulations
- Source of indicator/metric and its scientific and market acceptance: Amount of recycled material in recipes. Important: the recycled material cannot cause quality problems.

**Results**

Overview and results:

Project / case study	Product	Amount of recycled materials	Used recycled materials
CS 1	Concrete A	35 m%	Concrete aggregates
	Concrete B	43 m%	Concrete aggregates
CS 4	Embankment material	100 m%	Mixed aggregates
	Wood-polymer composites	96 m%	Wood & gypsum C&DW Mineral wool rejects HDPE plastic film Wood plastic composites
	Non-structural concrete	33 m%	Concrete aggregates
	Structural concrete	6-13 m%	Concrete aggregates
	Gypsum boards	10 m%	Gypsum C&DW
	Thermal insulation layer	5 m%	EPS beads
CS 5	Subfoundation	100 m%	Mixed aggregates
	Foundation concrete	29 m%	Mixed aggregates
	Indoor flooring concrete	11-15 m%	Concrete aggregates
	Outdoor flooring concrete	9-14 m%	Concrete aggregates
	Floor screed	14 m%	Autoclaved aerated concrete

Discussion:

In CS 1, concrete was produced with a total replacement of the coarse aggregate fraction by recycled aggregates (concrete A). This coarse aggregate fraction forms 35 m% of the concrete, other resources are a fine aggregate fraction and cement. As cement, ordinary Portland cement was used. Possible recycled materials in the cement were not included. In concrete B, also 10% of the fine aggregate fraction (traditionally limestone) was replaced by ceramic fines.

In CS 4, several products were produced with recycled material. A mixed stony fraction was used an embankment material. Furthermore, recycled concrete aggregates were used to replace part of the coarse aggregates in concrete products. The replacement ratio depended on the type of concrete (e.g. non-structural or structural). A wood-polymer composite (WPC) was produced with several recycled materials (wood and gypsum C&DW, mineral wool rejects, recycled HDPE film, used WPCs). Furthermore, gypsum plaster boards were produced with recycled gypsum (10 m%) and an insulating mortar was produced using recycled EPS beads.

In CS 5, all the concrete products for the construction of a waste collection centre contained recycled aggregates. Foundation concrete was produced with 60% replacement of the coarse aggregate fraction with mixed recycled aggregates. For flooring concrete (higher quality) this replacement was 20-30 m%. The indoor flooring concrete contained a bit more recycled material because coal fly ash was used to replace a fraction of the cement. Recycled autoclaved aerated concrete (AAC), a waste stream that's still often landfilled, was used to replace part of the sand fraction in a floor screed. The sub-foundation of the construction site completely existed of mixed recycled aggregates.

Several products were developed with recycled materials. Some of these materials are currently often landfilled (e.g. AAC, gypsum), other materials have an established market (e.g. coal fly ash). This difference is not taken into account with a general amount of recycled material as an indicator.

#### ***Cross-links and trade-offs between other macro-objectives***

Recycling activities often occur close to the construction and demolition sites, in densely populated areas (for economic reasons). Since natural resources may need to travel long distances, transport decreases.

Since cement production is responsible for a significant part of the CO<sub>2</sub> production, LCAs show a big difference in impact for products where the ordinary Portland cement is (partly) replaced (e.g. with coal fly ash or steel slag).

It is highly important that the replacement of primary material with recycled materials does not lower the durability of the produced products. The durability of the products described above was similar to the durability of the traditional products.

#### **→ Indicator #3: Amount of contaminants in the recovered fractions**

- *Macro-objective: B2: Resource efficient material life cycles*
- *Specific aspect(s): Facilitate high-grade recycling*

#### ***Technical specifications***

- Unit of measurement: m%
- Life cycle stage (with reference to EN 15643): Deconstruction/demolition (C1) and waste processing (C3)
- Scope of indicator: Processed waste streams (e.g. after sorting)
- Midpoint(s) and/or parameters: ecotoxicity, soil salinisation
- Functional unit: Waste stream level
- Associated data requirements: classification results (e.g. EN 933-11)
- Source of indicator/metric and its scientific and market acceptance: Depending on waste stream. For recycled aggregates EN 933-11 is used in regional and European standards.

#### ***Results***

Overview and results:

Project / case study	Material stream	Amount of unwanted constituents	Type of contaminants
CS 4	Mixed recycled aggregates	0.1 m%	Mainly organics
CS 5	Autoclaved aerated concrete	2 m%	Gypsum

### Discussion:

In order to achieve high-grade recycled material, the amount of unwanted constituents needs to be limited. This can be achieved by a selective demolition process or by a sorting process after the demolition.

In order to demonstrate an automatic sorting process based on near infrared detection, a mixed recycled aggregates sample with a significant amount of unwanted (organic) constituents (3-4 m%) was treated. After treatment, this amount lowered to 0.1 m% (Vegas, et al., 2015). This allows the use of high amounts of mixed recycled aggregates in concrete. The amount of unwanted constituents (X-fraction) was analysed by manual classification (EN 933-11).

The IRCOW project showed that autoclaved aerated concrete (AAC) C&DW could be recycled in floor screed applications. In order to achieve durable and sustainable products, gypsum contamination of the AAC waste should be limited (Bergmans, et al., 2016). Based on sulphur concentration analyses, gypsum contamination of the used samples (originating from selective demolition) was estimated 2 m%.

### **9.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

#### **→ Evaluation of project experience using the indicator(s)**

The indicators above are measurable if the necessary information is available. For the material recovery ratio of demolition works, the processing certificates of the involved recycling plants or landfills are necessary. However, these do not always give enough information and don't allow to differentiate between different recycling practices (details can differ between different countries). The fraction of recycled material in a new product requires the product recipe and can only be controlled in the beginning of the production process. The determination of the amount of contaminants in a material fraction is often a time-consuming manual work. Currently, other less time-consuming techniques are being developed (e.g. quality assessment by laser-induced breakdown spectroscopy (LIBS)).

The measurement of recovery ratios indicates that the WFD target (70 m% recycling of the non-hazardous fraction) can easily be reached for larger buildings that are mainly composed of stony material if a (semi-)selective demolition is performed. In the Flemish region, a recovery ratio of >90 m% is currently reached. The demolition of wood-based buildings can lead to lower recovery rates, since recovery routes for wood are not always well established and other fractions (e.g. insulation materials) can become more significant. Furthermore, small-scale demolition works or the lack of space can hamper selective demolition processes (e.g. the amount of container that can be placed). A general recovery ratio does not make a distinction between high-grade or low-grade recovery.

For a research project that is focused on recycling, the amount of recycled material in a new product is a very useful indicator. Of course, this has to be completed with data on the quality and performance of the developed products (as was done in the IRCOW project) since the product has to be usable in the relevant conditions. The impact of a replacement with recyclable materials on sustainability depends on several factors (e.g. primary material that is replaced, type of recycled material, transport distances). To include these factors, LCA studies are necessary.



For product manufacturers, the quality of the recycled material is crucial. At the moment, quality is often assessed visually. This visual assessment is either time-consuming or inaccurate. Automated detection systems could facilitate this quality assessment.

### **9.3 REFERENCES**

Bergmans, J., Nielsen, P., Snellings, R. & Broos, K., 2016. Sulfate leaching from recycled autoclaved aerated concrete in floor screeds is controlled by ettringite solubility. *Construction and Building Materials* 111, pp. 9-14.

Vegas, I., Broos, K., et al., 2015. Upgrading the quality of mixed recycled aggregates from construction and demolition waste by using near-infrared sorting technology. *Construction and Building Materials* 75, pp. 121-128.

## 10 FS 8. OFFICAIR

### 10.1 FACT SHEET

General information							
Description	The European FP7 research project Officair was organised to identify key indoor air pollutants in modern offices and to assess their occurrence in European modern office buildings. Fieldwork consisted of a general survey based on questionnaires (in 167 buildings) and an indoor air quality (IAQ) assessment in 32 office buildings. By means of targetted intervention studies in 9 office buildings, knowledge on the impact of specific interventions for a cleaner indoor air were demonstrated. Based on these IAQ data, sophisticated air modelling tools have led to a health risk assessment that is representative for European modern office buildings.						
Involved parties	Fifteen partners from ten countries (Belgium, Netherlands, France, United Kingdom, Denmark, Spain, Italy, Greece, Portugal, Hungary) were involved, among which University of Western Macedonia (coordinator) and VITO <sup>27</sup> .						
Year	November 1st 2010 - January 31st 2014						
Geographical and building characteristics							
Building	Climate zone, Location		Typology		Type	Scale	Stage
16 Office buildings	Southern Europe: Spain, Greece, Italy and Portugal		Offices: low-rise, medium-rise, high-rise	New-build and renovated, existing ('modern offices'	Up to 5 stories; 4 units in each building	In use	
13 Office buildings	Central-Europe: France, the Netherlands		Offices: low-rise, medium-rise, high-rise	New-build and renovated, existing ('modern offices'	Up to 5 stories; 4 units in each building	In use	
3 Office buildings	Northern Europe: Finland		Offices: low-rise, medium-rise, high-rise	New-build and renovated, existing ('modern offices'	Up to 5 stories; 4 units in each building	In use	
5 Office buildings	Eastern Europe		Offices: low-rise, medium-rise, high-rise	New-build and renovated, existing ('modern offices'	Up to 5 stories; 4 units in each building	In use	

Relevant professional context
<b>Field studies carried out by collaborative EU projects</b> Officair is a European project funded by the FP7 programme for the call ENV.2010.1.2.2-1 - Indoor air pollution and health risks of modern office buildings with a total budget of EUR 4 026 174.63.

### 10.2 MACRO-OBJECTIVE B4A: HEALTHY AND COMFORTABLE SPACES

#### 10.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Exposure to hazardous substances – ventilation intake air
- Exposure to hazardous substances – materials emissions

<sup>27</sup> [http://cordis.europa.eu/project/rcn/96704\\_en.html](http://cordis.europa.eu/project/rcn/96704_en.html)

→ Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target

Discussion:

→ Methodologies, evaluation tools and/or standards used

**Table 3.1** Overview of IAQ monitoring performed in the Detailed study (Source: Officair - Mandin et al., 2013).

<i>Pollutants / parameters</i>	<i>Method</i>	<i>References and suppliers</i>
Aldehydes (7): Formaldehyde; Acetaldehyde; Acroleine; Propionaldehyde, Benzaldehyde; Hexanal; Glutaraldehyde	Sampling: DNPH passive sampler Radiello®: blue diffusive body code 120-1 + cartridge code 165	Analysis: LC, ISO 16000-4 By: CNR-IIA
VOCs (12): Benzene, Toluene, Xylenes, Ethylbenzene, N-hexane, Trichloroethylene, Tetrachloroéthylène, α-Pinene, Limonene, 2-Butoxyethanol, 2-Ethylhexanol, Styrene	Sampling: Passive sampler Radiello®: diffusive body code 120-2 + cartridgecode 145	Analysis: Thermal desorption, GC, ISO 16017-2 By: CNR-IIA
Nitrogen dioxide (NO <sub>2</sub> )	Sampling: HDPE circular diffusive sampler Gradko	Analysis: Spectrophotometry By Gradko,UK
Ozone (O <sub>3</sub> )	Sampling: Passive sampler Radiello®: diffusive body code 120-1+ cartridge code 172	Analysis: Spectrophotometry By ELTE
PM <sub>2.5</sub>	Gravimetric, low-volume aerosol sampler, quartzfiberfilters	Weighted By ELTE
Temperature and relative humidity	Continuous monitoring equipment connected to a data logger (1-10 minutes)	
Airflow rate	Flow finderor equivalent material + PFT passive method (optional)	

Discussion:

Officair focussed on exposure of hazardous substances, either from ventilation intake air or from materials emissions. The IAQ of offices was assessed via a measurement campaign on European scale. The measurement campaign consisted of three complementary phases: a “general survey” based on questionnaires (167 buildings); a “detailed study” with measurements carried out both in summer and in winter (32 buildings); and an “intervention study” with deeper measurements (e.g. active sampling and on-line monitoring) carried out before and after an intervention related to IAQ (9 buildings). The indoor air monitoring was carried out before and after four weeks of use, and at two locations: the intervention room and the control room.

The measurement methods applied are illustrated in the case of Greece (Sakellaris et al., 2013)<sup>28</sup>:

*“measurements were conducted in five modern office buildings located in urban and suburban area of Athens. Specifically, in each building, sampling took place at four indoor (office rooms) and one outdoor site. Each sampling period lasted for five weekdays (Monday to Friday). In particular, measurements included passive sampling of VOC (Volatile Organic Compounds), Aldehydes, O<sub>3</sub> and NO<sub>2</sub>.*

*Additionally, PM<sub>2.5</sub> samples were collected with low volume samplers on quartz fiber filters. Physical parameters (temperature, relative humidity, visible and UVA radiation, wind speed, ultra-fine particles) were also monitored. Finally, ventilation was estimated by the passive PerFluorocarbon Tracer (PFT) technique as well as the mechanical flow rate was measured actively using flow meters.”*

The intervention study also included emission testing of materials typically present in modern office rooms (flooring, desks, computer screens, printers, office chairs, simulation of cleaning activities).

#### 10.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

###### Key indicators:

- VOCs, TVOC, aldehydes [ $\mu\text{g}/\text{m}^3$ ]
- particulate matter (PM<sub>2.5</sub>, PM<sub>10</sub>) [ $\mu\text{g}/\text{m}^3$ ]
- O<sub>3</sub> [ $\mu\text{g}/\text{m}^3$ ]
- NO<sub>2</sub> [ $\mu\text{g}/\text{m}^3$ ]
- Indoor/outdoor (I/O) ratios of pollutants
- Flow rate [l/s/per; l/s/m<sup>2</sup>; m<sup>3</sup>/h]
- Air Change rate per hour (ACH) [h<sup>-1</sup>]

###### Supporting indicators

- Temperature [°C]
- Relative Humidity [RH]

###### Discussion:

###### Detailed study

A comparison with the existing IAQ guidelines (e.g. from the World Health Organization) showed that indoor concentrations in office buildings could exceed the reference values for *benzene* and PM<sub>2.5</sub>.

IAQ measurements were performed in Winter and in Summer. Results were compared to each other, and findings indicated that higher indoor concentrations were observed in winter for *benzene*, *limonene*,  *$\alpha$ -pinene* and *nitrogen dioxide*. Conversely higher indoor concentrations were observed in summer for *formaldehyde* and *ozone*. This indicated that a one week sampling strategy is not enough to approach a “long term” concentration.

In addition to this temporal or seasonal variability, the in-situ measurements indicated a spatial variability (for instance, higher concentration of outdoor pollutants in the indoor air of office spaces on ground floor versus office spaces on higher level) and an indoor/outdoor relationship (for instance, high Input/Output ratios for selected VOCs and aldehydes indicate that these are

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<sup>28</sup> I.A. Sakellaris, D.E. Saraga, K.K. Kalimeri, E.M. Kouglioumtzidis, V.G. Mihucz, R. Mabilia and J.G. Bartzis (2013) *Air Quality measurements in indoor environment of modern offices in Athens, Greece (Officair Project)*

more prominent in the indoor air, while low Input/Output ratios for O<sub>3</sub> and NO<sub>2</sub> indicate the contrary).

#### *Intervention study*

The emissions monitored from a typical office configuration with randomly selected materials, show a myriad of emitted compounds, including SVOC's.

A first observation is that for the continuous emitting products, especially the wall board has by far the largest amount of total emissions followed by an office desk, PC and chair. Printer and projector have relatively low emissions. The discontinuous emitting products all-purpose cleaner and screen cleaner have the highest emissions, but these are clearly at the moment of their use and therefore dependent on the use scenario. Overall they will have a lower impact on the longer term exposure, but are more important for short term exposure. Since a wall board and office desk panel have in an office environment typically several m<sup>2</sup>, these two are the most important polluters in offices.

A second observation is that VOC's and Carbonyl compounds are the most abundant group of compounds emitted and there are substantial differences between the products, ranging up to a factor of 100. Particles are emitted by the cleaning products and the printer. For the cleaning products these are in fact mostly aerosols due the spraying of the products. In case of a printer, the amount of particles is the highest of all product emissions (PM 10 = 15.7 µg/m<sup>3</sup> in the test chamber) and also UFP (peak concentration 1800 particles/cm<sup>3</sup> and range 14.1-333 nm) is emitted. When printing, the printer creates 5 ppb of ozone level in the 1 m<sup>3</sup> test chamber.

A set of 27 pollutants are identified as key compounds, overall there are over 100 compounds emitted. From these 27 key compounds, the top 10 pollutants can be calculated, assuming all 8 products are simultaneously present in the test chamber one would obtain the concentrations of Figure 4. The top 10 of emitted compounds are : 1-methoxy-2 propanol, acetonitrile, glutaraldehyde, acetaldehyde, dihydromyrcenol, hexanal, α-pinene, formaldehyde, eucalyptol, propanal. This observation is from the point of view of product emissions.

#### **10.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

Officair formulated three key recommendations for an improved IAQ. These key recommendations are in-line with the findings of the EnVIE<sup>29</sup> and HealthVent initiatives and follow the precautionary principle that prevention is better than remediation. This is translated as follows: the first two recommendations focus on 'source control', the third focusses on 'exposure control'.

##### *1st recommendation: Limit entrance of pollutants from outdoor*

A clean outdoor air quality is a prerequisite. This does not only relate to regionally high outdoor pollutant levels, but can also relate to local sources, for instance motor vehicle exhaust from nearby roadways. When this is not the case, ventilation air should be treated, by being filtered or even washed. Otherwise outdoor becomes a pollution source indoors. In the case of pre-construction and building design phase, the building location should be treated as a first component of the source control strategy.

##### *2nd recommendation: Limit pollutants from indoor sources by choosing low emission cleaning products, building materials and furniture*

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<sup>29</sup> EnVIE (2009) *Objectives and approach of EnVIE* [online], available at: <http://paginas.fe.up.pt/~envie/> [20/5/2016]

This recommendation does not only relate to the building project team, who can choose low emitting tested and approved materials and products, but also addresses the policy level: policy can lead manufacturers to decrease the pollutants that are emitted from the construction, furniture and cleaning products.

The results of the Officair field studies highlighted also a very important issue: IAQ assessment techniques focus on assessment of individual indoor air compounds, but in reality, indoor air compounds chemically react with each other. One possible way to assess the real impact of cleaning products as well building materials, would be emission testing in natural conditions, rather than in artificial clean air conditions. In addition, elimination or reduction of the main reactants would be possible by advanced labelling systems on which designers can base material selection.

Another factor that has to be taken into account, is the fact that emission rates vary significantly over time: for a given product, emissions of some chemicals decay rapidly (within hours or days), while others as carpet and vinyl tiles may release pollutants less volatile at nearly constant rates for many months. The acute or long-term impacts of materials can thus be dramatically different and need to be factored into product assessment.

Finally, in the evaluation of emissions impacts, materials need to be considered as parts of systems whenever possible. For instance, carpeting is not independent of cushions, adhesives or subfloors. Emissions from a system may be markedly different than those from its individual constituents.

*3rd recommendation: Limit exposure by using a ventilation strategy based on health criteria*

The use of ventilation should be understood as an „exposure control“ tool after source control measures have been adopted. It should be based on health criteria instead of relying heavily on comfort criteria. Bearing in mind the meaning of „exposure“, there are ways of limiting it by other means that do not imply changing the ventilation rate, for instance, the ventilation rate can be variable along the occupational period, according to the scheduled activities.

### **10.3 REFERENCES**

Goelen, E. et al., 2013, *Officair Deliverable D3.2 - Report on primary product emissions, factors influencing product emissions and novel method technique development*

de Oliveira Fernandes, E., Ventura Silva, G. et al., 2014, *Officair - Deliverable D8.4 Recommendations and prioritization of IAQ policies related to office buildings*

OFFICAIR, 2014, *Officair - DeliverableD 4.2 / D7.2 Report on results from detailed investigation/ Report on results from detailed investigations of health effects*

## 11 FS 9. CLEAN AIR, LOW ENERGY

### 11.1 FACT SHEET

General information					
Description		The aim of this exploratory study was to assess the indoor air quality (IAQ) in energy-efficient and passive (n50<0.6/h; annual energy demand <15kWh/m²) buildings (EEBs), including homes and schools. Physical, chemical and biological parameters have been measured in order to determine whether indoor environment in such buildings differs from traditional, non-energy- efficient buildings. A particular focus was put on how the outdoor environment, building airtightness and ventilation systems affect these indoor parameters. In total 51 indoor (and corresponding outdoor) sites in low-energy buildings, equipped with a mechanical ventilation system (controlled supply and exhaust air as well as trickle ventilators with controlled exhaust air) in Flanders (Belgium) were studied (of which 25 houses and 26 classrooms).			
Involved parties		VITO (Belgium), National Institute for Health and Welfare THL (Finland) Architecture and Urban Planning, Ghent University (Belgium) Technological Advice centre Acoustics, BBRI			
Year		15/02/2011- 15/07/2012			
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
22 houses	Central-Europe, BE	Residential:single -family house	new-build	1-2 stories	In use
3 flats	Central-Europe, BE	Residential: multi-family house	new-build		In use
27 schools (*)	Central-Europe, BE	school building	newbuild	-	use
(*): The field study analysis will not focus on the schools, as this building type is not within the scope of this study.					

### Relevant professional context

#### Private or public sector buildings and portfolios

Clean Air Low Energy is an exploratory study in the Flemish region (Belgium), commissioned by the Environment, Nature and Energy Department (Departement Leefmilieu, Natuur en Energie, LNE) and the Flemish Energy Agency (Vlaams Energieagentschap, VEA) and carried out by a consortium consisting of Belgian organizations (VITO, BBRI and University of Ghent) and the Finnish institute THL.

### 11.2 MACRO-OBJECTIVE B4A: HEALTHY AND COMFORTABLE SPACES

#### 11.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Exposure to hazardous substances – ventilation intake air

- Exposure to hazardous substances – materials emissions
- Moisture and mould

Clean Air Low Energy aims for the assessment of the indoor air quality in sustainable, energy-efficient buildings (houses and schools), typically equipped with mechanical ventilation systems. The main focus is the determination of the influence of outdoor air, of the ventilation system (type, usage, maintenance) on the indoor environment. Therefore, this study is relevant for macro-objective B4 Healthy and comfortable spaces, with a primary focus on the aspect “Exposure to hazardous substances as a result of ventilation intake air”. The aspects of moisture and mould and the exposure to hazardous substances as a result of materials emissions are covered as well, but in less detail.

→ **Improvement option(s)**

Improvement option	Evaluation criteria	Performance target
building ventilation rate	<p>comply with Belgian residential ventilation standard, the European ventilation standard as well as the guidelines for indoor noise.</p> <p>Assess total air exchange rate of a building: determine airflow rates, perform pressurisation tests and assess installation and environmental noise.</p>	<p>- operation flow rate equals design flow rate</p> <p>- recommendations of airtightness: leakage limited to 3 ACH @ 50 Pa for mechanical ventilation and 1 ACH @ 50 Pa for heat recovery ventilation</p> <p>- noise nuisance (installation noise &lt; 35 dB)</p>
indoor air quality (chemical)	<p>comply with Flemish Indoor Environment Guidelines (Royal Decree of 11<sup>th</sup> of June 2004), WHO Indoor Air Quality Guidelines and aim for an indoor environment that is ‘better’ than Flemish ‘average house’.</p> <p>Assess IAQ using reference methods for air sampling and analysis</p> <p>selection of low-VOC emitting building materials</p>	<p>- IAQ guideline values</p> <p>- WHO Indoor Guidelines</p> <p>- Reference IAQ of Flemish ‘average house’</p>
indoor air quality (biological parameters)	<p>comply with Flemish Indoor Environment Guidelines (Royal Decree of 11<sup>th</sup> of June 2004)</p> <p>Assess IAQ, no reference methods for air sampling and analysis available</p>	<p>- IAQ guideline values</p>

Discussion:

Clean air, low energy is a post-occupation evaluation study. While the comparison of different performance improvements options were not a specific part of the research, the measurements performed in the study do provide insight on the relation between the IAQ on the one hand and



building characteristics on the other hand. More particular, the study indicates to which extent the choice and design of the ventilation system and the performance of the building envelope regarding airtightness could influence the IAQ.

→ **Methodologies, evaluation tools and/or standards used**

Methodology used	Evaluation tools used	Standards used
Assess total air exchange rate of a building: determine airflow rates, perform pressurisation tests	<ul style="list-style-type: none"> <li>- comparison operation flow rate and design flow rate</li> <li>- evaluate air tightness</li> <li>- assess installation and environmental noise</li> </ul>	NBN D 50-001 EN 13779 NBN EN 13829 NBN EN ISO 140-5:1998 NBN EN ISO/TR 140-13:1997 NBN EN 12354-2:2000 NBN EN ISO 3382:2000 NBN EN ISO 10 052:2005 NBN 01-400-1:2008
Low-emitting material selection  Air sampling of indoor air quality parameters included in the Flemish Indoor Environment Decree and the WHO Indoor Guidelines	Mandatory or voluntary building materials labelling (low VOC-emitting) or include emissions in product policy  comply with <ul style="list-style-type: none"> <li>- Flemish Indoor Environment Guidelines,</li> <li>- WHO Indoor Air Quality Guidelines</li> </ul> aim for an indoor environment that is 'better' than Flemish 'average house'.	Royal Decree of 18-08-2014 on floor coverage materials and glues.  Royal Decree of 11 <sup>th</sup> of June 2004 WHO Indoor Environment Guidelines  Surveillance of health complaint-free houses in Flanders (2012, Agency of Care and Health, Flemish Government, Belgium)  ISO standards for air sampling of chemical parameters, for indoor air sampling in general and for chemical analysis ISO 16000-01 amongst others: ISO 16000-4 ISO 16000-5 ISO 16000-15 EN 14626:2005 EN 14412 and EN 13528-3 EN 14907:2005
Air sampling of biological indoor environment parameters from Flemish Indoor Environment Decree	comply with <ul style="list-style-type: none"> <li>- Flemish Indoor Environment Guidelines</li> </ul>	ISO 21527-1 ISO 4833 ISO 16000-01

#### Discussion:

Monitoring data was collected using diffusive passive samplers to monitor TVOC, VOC and aldehydes; air samplers to monitor particulate matter; measurement units to record CO<sub>2</sub>, Relative Humidity (RH) and temperature; pressurization tests to measure the airtightness; and samplers for biological parameters (fungi, yeast, bacteria). The user satisfaction concerning the indoor environment, the thermal comfort and noise nuisance was assessed via questionnaires. Table 4 gives an overview of the methods, applied in the field in order to assess the scheduled chemical parameters. The settings of the mechanical ventilation system were kept under normal operating conditions during the measurements.

*Table 4 overview of the applied methods to assess chemical parameters in houses and schools (source: Cleanair, lowenergy 2012)*

Compound	Measurement technique	Sampling time	Sampling site
TVOC	Radiello passive sampler	Houses: 7 days Schools: 5 days	Houses: living room Schools: classroom Parallel outdoor
VOC (MTBE, benzene, trichloroethene, toluene, tetrachloroethene, ethylbenzene, m-+p-xylene, styrene, o-xylene, 1,2,4-trimethylbenzene, 1,4-dichlorobenzene, hexane, heptane, cyclohexane, n-butylacetate, $\alpha$ -pinene, 3-carene, d-limonene, and TVOC)	Radiello passive sampler	Houses: 7 days Schools: 5 days	Houses: living room Schools: classroom Parallel outdoor
Aldehydes (total aldehydes, formaldehyde and acetaldehyde)	Umex passive sampler	Houses: 7 days Schools: 5 days	Houses: living room Schools: classroom Parallel outdoor
PM <sub>2.5</sub> (mass concentration)	MS&T Harvard type impactor	Houses: 7 days–24h Schools: 5 days – teaching hours	Houses: living room Schools: classroom Parallel outdoor
PM <sub>x</sub> (time evolution)	Grimm optical PM monitoring	Houses: 7 days Schools: 5 days	
CO <sub>2</sub>	Catec Klimabox (schools and living rooms) + CO <sub>2</sub> meter K33-ELG (bedrooms)	Houses: 7 days Schools: 5 days	Houses: living room + bedroom(s) Schools: classroom

*Table 5 Overview of the applied methods to assess biological parameters in houses and schools*

Compound	Measurement technique	Sampling time	Sampling site
Bioaerosol samples – fungi and yeast	Andersen 6-stage impactor	5 minutes total volume ~150L 28.3 L/min flow rate	15 Houses: living room, bedroom 15 classrooms Parallel outdoor
Bioaerosol samples – total bacteria	Andersen 6-stage impactor	5 minutes total volume ~150L 28.3 L/min flow rate	15 Houses: living room 15 classrooms Parallel outdoor
Settled dust sampling – fungi and yeast	Swap sampling	Not applicable - height of 1.5 to 2 m	Houses: living room, bedroom

			15 classrooms
Settled dust sampling – total bacteria	Swap sampling	Not applicable - height of 1.5 to 2 m	Houses: living room, bedroom 15 classrooms

Biological agents were assessed by using air samples and surface samples of settled dust. The microbial pollutants addressed were bacteria, fungi and yeast.

Regarding the air samples, sampling was performed in the living room, the bedroom as well as in the garden. All samples were collected during the same house visit. Samples were collected in the middle of the room, at a height of 1-1.5m. The analysis of the samples were conducted according to ISO 21527-1<sup>30</sup> in case of the total fungi and yeasts, and ISO 4833<sup>31</sup> in case of the total bacteria.

Regarding the surface samples of settled dust, houses received a post package, containing (1) two Petri dishes with a surface of 15 cm for houses; (2) a letter with instructions and explanations (see Annex); (3) a questionnaire for biological measurements. The participants were instructed to open the Petri dishes and to install two halves in the living room and two halves in the bedroom for residences. The Petri dish should be installed at a height of 1.5 m, be out of reach of children and pets (the inside of the dish should not be touched), and should not be closer than 1 meter to a window or door opening. When the dishes were installed, a printed document saying '*Please don't touch or move*', was installed next to it. Any incident should be reported on the questionnaire for biological measurements. The samples were exposed for one week (7 days). The sampling analysis of the yeast and fungi and the total bacteria was performed in agreement with ISO 21527-1<sup>30</sup> and ISO 4833<sup>31</sup> respectively.

#### → Project processes

Methodology	Stage	Lead actor	Supporting actor
determine airflow rates, perform pressurisation tests	use phase	Engineering office	Architect
Low-emitting material selection	design phase	Architect	Manufacturer, building client
IAQ assessment	use phase (6 months after delivery)	Architect	energy expert

<sup>30</sup> ISO 21527-1 (2008) Microbiology of food and animal feeding stuffs -- Horizontal method for the enumeration of yeasts and moulds -- Part 1: Colony count technique in products with water activity greater than 0,95

<sup>31</sup> ISO 4833 (2013) Microbiology of the food chain -- Horizontal method for the enumeration of microorganisms

## 11.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

#### Key indicators:

- Indoor air pollutant concentrations (VOCs, TVOCs, aldehydes, particulate matter PM<sub>2.5</sub>, PM<sub>10.0</sub>) [ $\mu\text{g}/\text{m}^3$ ]
- Flow rate [ $\text{m}^3/\text{h}$ ]
- Air Change Rate or Air Changes per Hour (ACH) [ $\text{m}^3/\text{m}^3/\text{hr}$  @50Pa]
- Airtightness n50 [ $\text{m}^3/\text{m}^3/\text{hr}$  @50Pa]
- Concentration of biological agents (fungi, yeast and total bacteria) [Colony Forming Units (CFU)/ $\text{m}^3$ ]

#### Supporting indicators:

- Temperature [K]
- Relative Humidity (RH) [%]
- Indoor CO<sub>2</sub> concentration [ppm]

### → Indicator: Indoor air pollutant concentrations

- *Macro-objective: B4a Healthy and comfortable spaces*
- *Specific aspect(s): Exposure to hazardous substances – material emissions*

#### Technical specifications

- Unit of measurement:  $\mu\text{g}/\text{m}^3$
- Scope of indicator: indoor air concentrations of VOCs, TVOCs, aldehydes, particulate matter PM<sub>2.5</sub>, PM<sub>10.0</sub>
- Life cycle stage (with reference to EN 15643): B1-7 use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit:  $\text{m}^3$  of a representative space in the building
- Associated data requirements
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): See “methodologies, tools and standards”, with key reference the ISO 16000 series.
- Supporting tools required to quantify/estimate performance: See “methodologies, tools and standards”, with key reference the ISO 16000 series.
- Source of indicator/metric and its scientific and market acceptance: WHO iaq guidelines

#### Results

Regarding hazardous substances, of all identified VOCs in Clean Air Low Energy, formaldehyde, d-limonene,  $\alpha$ -pinene, and toluene were most abundant in indoor air.

### → Indicator: Flow rate and Air change rate

- *Macro-objective: B4a Healthy and Comfortable spaces*
- *Specific aspect(s): Ventilation rate / ventilation intake air*

### Technical specifications

- Unit of measurement:
  - o Flow rate:  $\text{m}^3/\text{h}$
  - o Air change rate: Air Change per Hour (ACH),  $\text{h}^{-1}$
- Scope of indicator: fresh air rate
- Life cycle stage (with reference to EN 15643): B1-7 use stage
- Midpoint(s) and/or parameters : not applicable
- Functional unit: room or building level
- Associated data requirements: see “methodologies, tools and standards”
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): see “methodologies, tools and standards”
- Supporting tools required to quantify/estimate performance: see “methodologies, tools and standards”
- Source of indicator/metric and its scientific and market acceptance: see “methodologies, tools and standards”

### Results

Regarding flow rate and air change rates, the measurement results as illustrated in Figure 6 and Figure 7 show that the occupants operated their ventilation system at a much lower rate (median=0.24 ACH, average=0.24 ACH) than the design flow rate specified in the Belgian residential ventilation standard<sup>32</sup> (about 1 ACH).

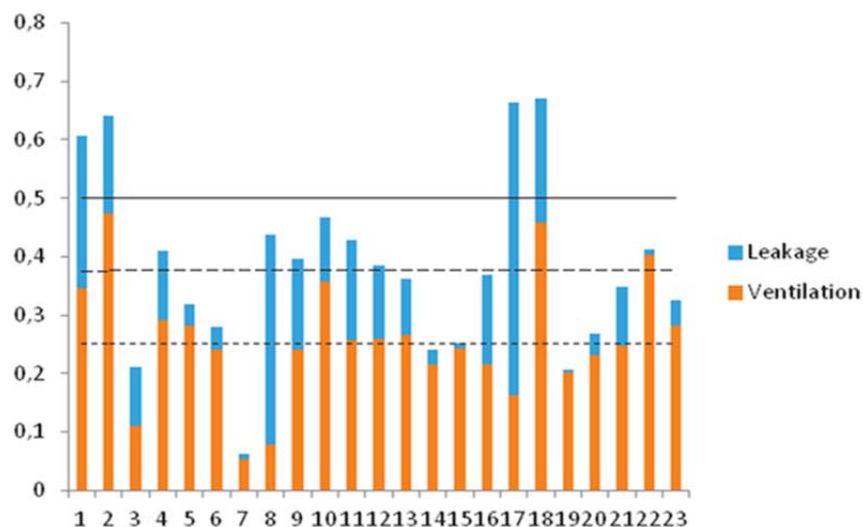


Figure 6: Total air change rate (ACH) in the residences, subdivided by leakage and ventilation

<sup>32</sup> BIN, Ventilatievoorzieningen in woongebouwen, in, Brussels, 1991

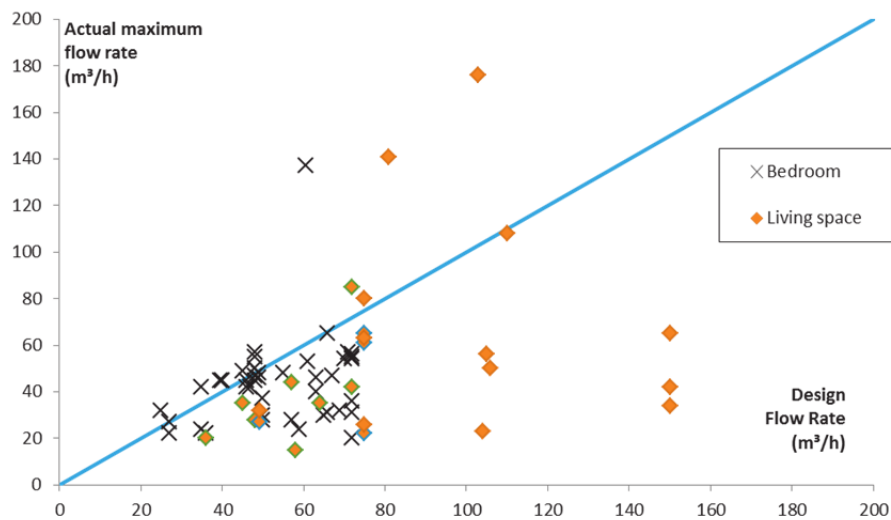


Figure 7: Actual maximum mechanical flow rate and design flow rate for all living spaces and bedrooms in the residences with heat recovery ventilation

Source: Clean Air, Low Energy (2012)

#### → Indicator: Airtightness

- Macro-objective: B4a Healthy and comfortable spaces
- Specific aspect(s): Ventilation

#### Technical specifications

- Unit of measurement: n50: m³/m³.h
- Scope of indicator: airtightness of the (volume of the) building
- Life cycle stage (with reference to EN 15643): B1-7 in-use
- Midpoint(s) and/or parameters : not applicable
- Functional unit: building
- Associated data requirements: volume of the building
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): see “methodologies, tools and standards”
- Supporting tools required to quantify/estimate performance: see “methodologies, tools and standards”
- Source of indicator/metric and its scientific and market acceptance: see “methodologies, tools and standards”

#### Results

To investigate the relation between airtightness and the indoor air quality, three airtightness classes were identified for the residences:

- Airtightness group 1:  $n50 \leq 0.6$  (very airtight)
- Airtightness group 2:  $0.6 < n50 \leq 2.5$  (airtight)
- Airtightness group 3:  $2.5 < n50$  (moderately airtight)

The airtightness criterion n50 is derived from the Passivhaus standard. It is the proportion of the buildings internal volume of air that is changed per hour at 50 pascals of air pressure *i.e. 0.6 would equate to 60% of the internal volume*.

One of the main findings was the fact that more airtight residences were characterized by a lower air change rate. However, the residential indoor CO<sub>2</sub> level appeared to be independent of the airtightness. This finding indicates that a high building airtightness does not necessarily prevent an effective building aeration.

The presence of all chemical compounds monitored, as well as temperature and relative humidity, appeared to be independent of the level of airtightness of residences. No clear trends could be identified for viable fungi and bacteria in residential indoor air in buildings of different levels of airtightness. A classification of the dwellings in relation to a minimal total air change rate of 0.5 ACH was used.

In general, it can be concluded that a lower ACH class (higher total air change rate) in residences does not imply distinct differences between the occurrence of chemical components in the living rooms. There is only an indication of a minor improvement for TVOC, formaldehyde and CO<sub>2</sub> in the lowest ACH class, compared to the other classes. Viable fungi and bacteria however, seemed again to increase in lower ACH classes.

However, following conditions should be taken into account:

- Residences are characterised by a much wider variety of different indoor sources (such as cooking, household products, furniture, etc...) than other building typologies, for instance schools.
- The residences are categorized in 4 classes, not taking into account the amount of occupants (since this is variable from day-to-day and within one day).
- Total air change rate and the airtightness are monitored and calculated at building level. The IAQ of residences is determined in the living room.

#### → Indicator: Concentrations of biological agents

- *Macro-objective: B4a Healthy and comfortable spaces*
- *Specific aspect(s): Mould and moisture*

#### **Technical specifications**

- Unit of measurement: CFU/m<sup>3</sup> (CFU: Colony Forming Units)
- Scope of indicator: fungi, bacteria and yeast
- Life cycle stage (with reference to EN 15643): use stage
- Midpoint(s) and/or parameters: Not Applicable
- Functional unit: 1 m<sup>3</sup> of a representative space in the building
- Associated data requirements
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*): see "methodologies, tools and standards"
- Supporting tools required to quantify/estimate performance: see "methodologies, tools and standards"
- Source of indicator/metric and its scientific and market acceptance: WHO IAQ guidelines

#### **Results**

Regarding biological agents, the average levels of total viable fungi indoors were comparable or slightly lower compared to the outdoor average concentrations ( $1.5 \times 10^2$  and  $4.2 \times 10^2$  CFU/m<sup>3</sup>, respectively).

## → Cross-links and trade-offs between other macro-objectives

B1 Operational energy use, more in particular to which extent the choice and design of the ventilation system and the performance of the building envelope regarding airtightness could influence the IAQ.

### 11.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

The IAQ in energy-efficient, mechanically ventilated houses and schools was found to be moderately improved or equal to the IAQ monitored in traditional buildings. There is no indication that the trend towards energy efficient buildings will cause detrimental effects on IAQ and human health.

In energy-efficient, mechanically ventilated buildings (trickle ventilators with controlled exhaust as well as controlled supply and exhaust air), most chemical compounds occur at similar or somewhat lower concentration levels compared to traditional buildings. Mechanically ventilated buildings are clearly more effectively ventilated than traditional buildings. This finding indicates that sufficiently ventilated buildings could be characterised by even more reduced indoor concentration levels if an efficient source reduction strategy would be implied. More guidance on the usage of low-emitting building materials and consumer products; labelling of products, or regulations on material emissions would be of considerable value to achieve this goal.

Greater awareness and information on use and maintenance of the ventilation system is needed (generally the ventilation system is used at a low set point), since most of the users do not seem to be aware of the impact or functionality of their ventilation system. Quality assurance for ventilation systems would imply an added value to the quality of the indoor environment: commissioning is necessary since this study, in accordance with others, demonstrates that the design flow rates specified in the standards are not met in a majority of cases.

There is a lack of baseline information of viable fungi and bacteria in Belgium, Flanders, in complaint-free, traditional houses and schools. Also the interrelation between chemical/physical/biological characteristics and their behaviour in traditional, in newly built and in renovated buildings should be studied more in detail.

### 11.3 REFERENCES

Stranger, M. et al., 2009, *Cleanair, Lowenergy - Exploratory research on the quality of the indoor environment in energy-efficient buildings: the influence of outdoor environment and ventilation*, VITO

## → Flemish Indoor Environment Decree 11th of June 2004

Chemical parameters

Compound / factor	Guideline value	Intervention value
acetaldehyde	$\leq 4.600 \mu\text{g}/\text{m}^3$	
other aldehydes (total)	$\leq 20 \mu\text{g}/\text{m}^3$	
asbestos		0.1 fibre / $\text{cm}^3$
benzene	$\leq 2 \mu\text{g}/\text{m}^3$	10 $\mu\text{g}/\text{m}^3$
formaldehyde	$\leq 10 \mu\text{g}/\text{m}^3$	100 $\mu\text{g}/\text{m}^3$
carbon monoxide	$\leq 5.7 \mu\text{g}/\text{m}^3$	30 $\text{mg}/\text{m}^3$
carbon dioxide	$\leq 900 \text{mg}/\text{m}^3$	
ozone	$\leq 110 \mu\text{g}/\text{m}^3$	
nitrogen dioxide	$\leq 135 \mu\text{g}/\text{m}^3$	200 $\mu\text{g}/\text{m}^3$
tetrachloroethylene	$\leq 100 \mu\text{g}/\text{m}^3$	
toluene	$\leq 260 \mu\text{g}/\text{m}^3$	
trichloroethylene	$\leq 200 \mu\text{g}/\text{m}^3$	



<b>TVOC (total organic compounds)</b>	≤ 200 µg/m <sup>3</sup>
<b>PM<sub>2.5</sub></b>	≤ 15 µg/m <sup>3</sup>
<b>PM<sub>10</sub></b>	≤ 40 µg/m <sup>3</sup>

#### Physical parameters

Compound / factor	Guideline value	Intervention value
<b>extremely low frequency (ELF) electric and magnetic fields (EMF)</b>	≤ 0.2 µT	10 µT
<b>temperature</b>		
- Winter	20°C ≤ T ≤ 24°C	
- Summer	22°C ≤ T ≤ 26°C	
<b>draught</b>		
- Winter	< 0.10 m/s	
- Summer	< 0.25 m/s	
<b>ventilation rate</b>	≥ 1/h	
<b>relative humidity</b>		<sup>3</sup>
- Winter	30% ≤ RH < 55%	
- Summer	30% ≤ RH < 80%	

#### Biological parameters

Compound / factor	Guideline value	Intervention value
<b>house dust mite</b>	≤ 0.2 mg guanine/g dust	
<b>cockroach</b>	< 1 per building	
<b>micro-organisms</b>	≤ 500 CFU/m <sup>3</sup>	
<b>mites</b>		
- In floor covering	≤ 10/g dust	
- In bed / furniture	≤ 100/g dust	
<b>rat / mouse</b>	< 1 per building	<sup>3</sup>
<b>fungi</b>	≤ 200 CFU/m <sup>3</sup>	

Note that an update of the Flemish Indoor Environment Decree will be published by the end of 2016.

#### → WHO Indoor Air Guidelines

Compound / factor	Guideline value
<b>benzene</b>	as low as possible
<b>carbon monoxide</b>	100 mg/m <sup>3</sup> 15 minutes 35 mg/m <sup>3</sup> 1 hour 10 mg/m <sup>3</sup> 8 hours 7 mg/m <sup>3</sup> 24 hours
<b>formaldehyde</b>	0.1 mg/m <sup>3</sup> 30 minutes
<b>naphthalene</b>	0.01 mg/m <sup>3</sup>
<b>nitrogen dioxide</b>	200 µg/m <sup>3</sup> 1 hour
<b>PAH (polycyclic aromatic hydrocarbons)</b> - Benzo(a)pyrene	1.2 ng/m <sup>3</sup> excess lifetime cancer risk 1/10 000, 0.12 ng/m <sup>3</sup> excess lifetime cancer risk 1/100 000 0.012 ng/m <sup>3</sup> excess lifetime cancer risk 1/1 000 000
<b>radon</b>	for current smokers: 67 Bq/m <sup>3</sup> excess lifetime cancer risk 1/100 6.7 Bq/m <sup>3</sup> excess lifetime cancer risk 1/1000  for lifelong nonsmokers 1670 Bq/m <sup>3</sup> excess lifetime cancer risk 1/100 167 Bq/m <sup>3</sup> excess lifetime cancer risk 1/100

→ Establishment of the indoor environment of the 'average' Belgian (Flemish) residential house

In the project 'Surveillance of health complaint-free houses in Flanders (2012, Agency of Care and Health, Flemish Government, Belgium), in which the indoor environment of the Flemish 'average residential house' was determined based on an IAQ assessment in a representative set of 450 Flemish houses without health-complaints of inhabitants related to the indoor environment, equally distributed over cities, provinces, environments and building typologies.

Compound / factor	Indoor concentrations in the 'average Belgian (Flemish) residential house'			
	average ± stdev	min-max	P25	P75
MTBE [ $\mu\text{g}/\text{m}^3$ ]	1.84 ± 7.1	0.1 - 93	0.1	0.65
Benzene [ $\mu\text{g}/\text{m}^3$ ]	1.54 ± 2.09	0.1 – 24.3	0.56	1.6
Trichloroethene [ $\mu\text{g}/\text{m}^3$ ]	0.34 ± 1.19	0.1 – 12.0	0.1	0.1
Toluene [ $\mu\text{g}/\text{m}^3$ ]	35 ± 409	0.92 – 7700	3.1	11.3
Tetrachloroethene [ $\mu\text{g}/\text{m}^3$ ]	1.43 ± 11.2	0.1 – 195	0.1	0.232
Ethylbenzene [ $\mu\text{g}/\text{m}^3$ ]	1.34 ± 2.38	1.34 – 30.0	0.4	1.23
m- + p-Xylene [ $\mu\text{g}/\text{m}^3$ ]	3.8 ± 7.4	0.212 – 78.0	0.97	3.3
Styrene [ $\mu\text{g}/\text{m}^3$ ]	0.26 ± 1.53	0.1 – 28.0	0.1	0.1
o-Xylene [ $\mu\text{g}/\text{m}^3$ ]	1.3 ± 2.09	0.1 – 14.5	0.35	1.21
1,2,4-Trimethylbenzene [ $\mu\text{g}/\text{m}^3$ ]	3.7 ± 9.5	3.7 – 138	0.64	3.1
1,4-Dichlorobenzene [ $\mu\text{g}/\text{m}^3$ ]	0.19 ± 0.53	0.1 – 6.9	0.1	0.1
tVOC [ $\mu\text{g}/\text{m}^3$ ]	443 ± 604	39 - 7520	242	458
Hexane [ $\mu\text{g}/\text{m}^3$ ]	2,01 ± 3,2*	0,10 - 31	0,64	1,75
Heptane [ $\mu\text{g}/\text{m}^3$ ]	2,76 ± 6,7*	0,10 - 54	0,53	2,18
Cyclohexane [ $\mu\text{g}/\text{m}^3$ ]	2,41 ± 5,7*	0,10 - 58	0,45	1,92
n-Butylacetate [ $\mu\text{g}/\text{m}^3$ ]	2,82 ± 3,9*	0,22 - 28,7	0,80	2,76
alfa-Pinene [ $\mu\text{g}/\text{m}^3$ ]	10,8 ± 23,9*	0,34 - 164	2,11	9,0
3-Carene [ $\mu\text{g}/\text{m}^3$ ]	3,3 ± 7,0*	0,10 - 60	0,71	3,1
d10-Limonene [ $\mu\text{g}/\text{m}^3$ ]	31 ± 61*	1,37 - 500	7,1	26,8
CO <sub>2</sub> (24h) [ppm]	722 ± 185	416 – 1645	591	834
Formaldehyde [ $\mu\text{g}/\text{m}^3$ ]	26.6 ± 17.4	2.23- 180	16.3	31.0
Acetaldehyde [ $\mu\text{g}/\text{m}^3$ ]	8.7 ± 17.7	0.74 – 264	4.1	8.7
Total other aldehydes [ $\mu\text{g}/\text{m}^3$ ]	14.2 ± 9.7	3.6 – 252	8.5	17.6
PM <sub>2.5</sub> [ $\mu\text{g}/\text{m}^3$ ]				
Temperature [°C]	21.1 ± 2.2	15.2 – 27.6	19.7	22.5
Relative humidity [%]	51 ± 9.3	27.7 – 74	45	58
Draught [m/s]	0.08 ± 0.08	0.001 – 0.71	0.04	0.09

\* measured in 180 residential houses

## 12 FS 10. RENOVAIR

### 12.1 FACT SHEET

General information						
Description		Explorative field study, for the generation of representative data for Flanders on indoor environments pre and post energy-efficient renovations, in order to explore the impact of specific renovations on the indoor environment. To generate data on indoor environments post energy-efficient renovations, in order to create a database of renovated buildings that can then be evaluated against indoor environments of newly built energy-efficient buildings (the Clean Air Low Energy Study, LNE 2013) as well as the average Flemisch indoor environment in a dwelling (Surveillance of health complaint-free houses, AZG 2012). Data on the impact of time on the decay of indoor pollutants after the use of new building materials, will be used to formulate recommendations. Specific attention is also put on the impact of air filtration in the air intake on the occurrence of traffic-related air pollutants in indoor air. Results and conclusions of this exploratory research on the impact of energy-efficient renovations on the indoor environment, are intended to lead to targetted policy recommendations on energy-efficient renovations and air filtration.				
Involved parties		VITO (Belgium), National Institute for Health and Welfare THL (Finland) Architecture and Urban Planning, Ghent University Faculty of Applied Engineering Sciences, University of Antwerp PROVIKMO vzw, Study and documentation service				
Year		19/12/2013 – 19/04/2016				
Geographical and building characteristics						
Building		Climate zone, Location	Typology	Type	Scale	Stage
16 dwellings	private	West-Europe	private houses	constructed before 2006, recent or on- going energy- efficient renovations	representative: detached, terraced houses as well as apartments	In use Fieldwork before and after renovations in 9 dwellings

Relevant professional context	
<b>Private or public sector buildings and portfolios</b> Renovair is an exploratory study in the Flemish region (Belgium), commissioned by the Environment, Nature and Energy Department (Departement Leefmilieu, Natuur en Energie, LNE) and the Flanders Environment Agency (Vlaamse Milieumaatschappij (VMM) and carried out by a consortium consisting of Belgian organizations (VITO, University of Ghent, Faculty of Applied Engineering Sciences, University of Antwerp, PROVIKMO vzw) and the Finnish institute THL.	

## 12.2 MACRO-OBJECTIVE B4A: HEALTHY AND COMFORTABLE SPACES

### 12.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Exposure to hazardous substances – ventilation intake air
- Exposure to hazardous substances – materials emissions
- Moisture and mould

#### → Improvement option(s)

The Renovair study is a follow-up of the Clean Air Low Energy study. The objectives, methodology and used references are similar for both projects. Key difference is the fact that Renovair investigates renovated dwellings instead of newly build dwellings. Furthermore, not only the relationship between indoor air quality and overall energy performance of the whole building is assessed, but also the relationship between indoor air quality and individual (or a combination of) renovation measures.

Renovation measure
Upgrade of windows (to high efficiency glass)
Façade insulation (cavity or outside façade)
Wall insulation (inside)
Floor insulation
Roof and ceiling insulation
Wall treatment against rising damp
Combination projects (combines 2 to 3 initiatives)
Thorough energetic renovations
Installation of a mechanical ventilation system
Duct cleaning and cleaning of the heat recovery system
Filter replacements in a mechanical ventilation system

Table 6: Overview of renovation measures evaluated in Renovair (source: Renovair)

#### → Methodologies, evaluation tools and/or standards used

As the Renovair study is similar to the Clean Air Low Energy study, we refer to this field study for the description of measurement methods, indicators and used references.

However, adaptation of the methodology was required owing to the nature of the building projects. Because not all renovation activities impacted on the same indoor characteristic, it was not relevant to quantify each parameter before as well as after the renovation. If for instance IAQ was not expected to be a motivation to initiate a specific renovation measure, a comparison of the quantified indoor environment after the renovation activity with existing datasets on IAQ in Flemish houses, generated more added value than a comparison to the situation prior to the renovation.

In order to define such a specific measuring for each renovation, the relevance of quantifying the different parameters prior or after the execution of the renovations is indicated in the study (by specifying a cause or specific consequence of the renovation). This is illustrated for two renovation measures in Table 7.

<i>Renovation measure</i>	<i>Category/indicator/method</i>	<i>Before the renovation</i>	<i>Less than 6 months after the renovation</i>	<i>More than 6 months after the renovation</i>
Thorough renovations	Upgrade of windows (to high efficiency glass)	-	-	Product emissions, humidity
	Microbials indoors	Moisture damage; change of occupant behaviour	-	Moisture damage; change of occupant behaviour
	Moisture in walls	Moisture damage	-	Moisture damage
	Thermography	Cold bridge	-	Cold bridge
	Air tightness	Openings and cracks	-	Openings and cracks
	Ventilation rate	-	-	-
	Indoor comfort	Comfort and well-being	-	Comfort and well-being
	Indoor air quality	IAQ without direct sources	Product emissions	Product emissions, humidity
	Microbials indoors	Change in air infiltration and occupant behaviour	-	Change in air infiltration and occupant behaviour
	Moisture in walls	Moisture damage	-	Moisture damage
Minor renovations	Thermography	Thermal comfort	-	Thermal comfort
	Air tightness	Air infiltration	-	Air infiltration
	Ventilation rate	Openings and cracks	-	Openings and cracks
	Indoor comfort	Comfort and well-being	-	Comfort and well-being

Table 7: Relevance of quantifying the different parameters prior or after the execution of the renovations (source: Renovair)

Test methods applied are listed in the table below. As already remarked, these methods are similar to the Cleanair, Lowenergy study.

*Table 8 Monitored parameters, sampling methods and durations in the renovation study (source: Renovair, 2016)*

<i>Parameters</i>	<i>Sampling method</i>	<i>Sampling duration</i>	<i>Location</i>
TVOC	Radiello sampler	passive	House: 7 days School: 5 days
			House: renovated room School: renovated classroom Outdoor: representative site
VOC (MTBE, benzene, trichloroethene, toluene, tetrachloroethene, ethylbenzene, m- + p-xylene, styrene, o-xylene, 1,2,4-trimethylbenzene, 1,4-dichloro-benzene, hexane, heptane, cyclohexane, n-butyl-acetate, alfa-pinene, carene, d10-limonene)	Radiello sampler	passive	House: 7 days School: 5 days
			House: renovated room School: renovated classroom Outdoor: representative site
Aldehydes (total aldehydes, formaldehyde and acetaldehyde)	Umex passive sampler		House: 7 days School: 5 days
			House: renovated room School: renovated classroom Outdoor: representative site

<i><b>Parameters</b></i>	<i><b>Sampling method</b></i>	<i><b>Sampling duration</b></i>	<i><b>Location</b></i>
PM <sub>2.5</sub> (mass concentration)	MS&T Harvard type impactor	House: 7 days–24h School: 5 days – teaching hours	House: renovated room School: renovated classroom Outdoor: representative site
SVOCs or other specific chemicals	Active sampling on PDMS-Tenax (SVOCs) or Tenax (VOCs), or other, depending on the target compounds	To be specified	House: renovated room School: renovated classroom Outdoor: representative site
CO <sub>2</sub>	Catec Klimabox	House: 7 days School: 5 days	House: renovated room School: renovated classroom Outdoor: representative site
Bacteria (Gram positive/negative bacteria) and fungi	Settled dust analysis by means of swap sampling	1-week collection period	House: renovated room School: renovated classroom Outdoor: representative site
Visual inspection of fungi and moisture problems	Walk-through survey, based on the HITEA checklist for building inspection	n.a.	House: renovated room School: renovated classroom
Subjective evaluation of the indoor environment	Questionnaire-based	House: (before and) after the intervention School: (before and) after the intervention	House: inhabitants School: pupils and teacher
Temperature	Catec Klimabox	House: 7 days School: 5 days	House: renovated room School: renovated classroom Outdoor: representative outdoor site
Relative humidity	Catec Klimabox	House: 7 days School: 5 days	House: renovated room School: renovated classroom Outdoor: representative site
Draught		House: 1h School: 1h	House: renovated room School: renovated classroom Outdoor: representative site
Ventilation rate	Flowbox measurements	instantaneous measurement	House: all vents School: all vents
Air leakage (air tightness)	Pressurization tests	- (instantaneous measurement, total time +- 1h)	House: front door (intervention in rest of dwelling) Schools: classroom door
Surface temperature	Infrared imaging	instantaneous measurement	House: renovated room School: renovated classroom

## → Project processes

See “Cleanair, lowenergy”

## 12.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Key indicators identified:

- indoor/outdoor ratios of indoor air pollutants (I/O-ratio): PM<sub>2.5</sub>, CO<sub>2</sub>, TVOC, aldehydes
- other indicators: see Clean Air, Low Energy

### → Indicator: Indoor air pollutant concentrations

- *Macro-objective: B4a Healthy and comfortable spaces*
- *Specific aspect(s): Exposure to hazardous substances – material emissions*

### Technical specifications

- See “Cleanair, Lowenergy”

### Results

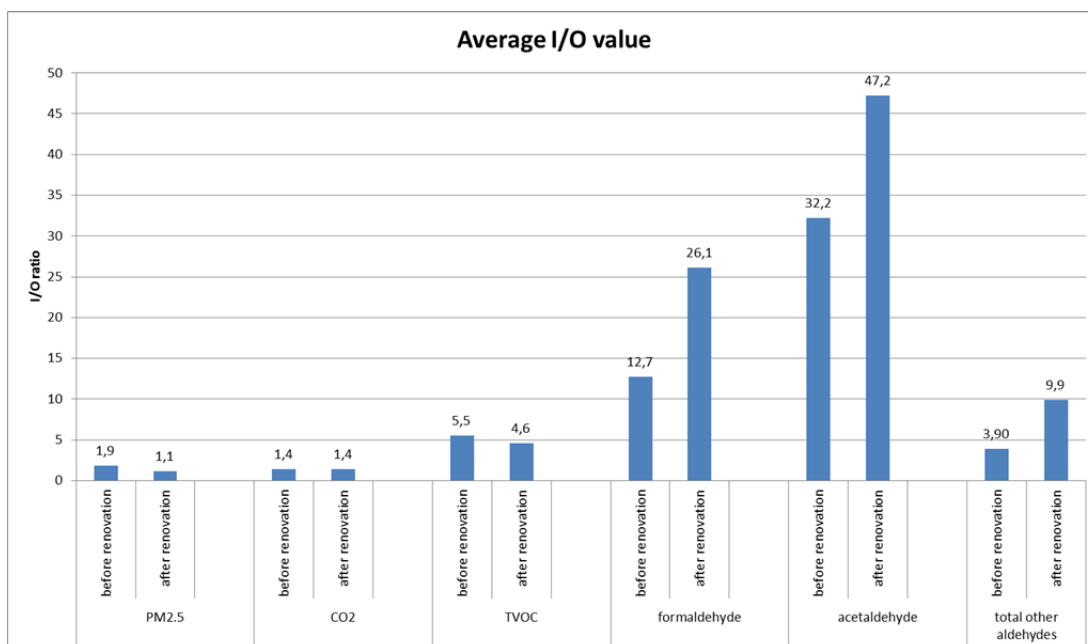


Figure 6.8 Indoor/Outdoor ratios (I/O-ratio) prior to and 6 months after the renovations for selected hazardous substances (source: Renovair)

### General evaluation of the impact of renovations on indoor environmental parameters

Indoor aldehydes (formaldehyde, acetaldehydes and to a lesser extent the sum parameter other aldehydes) were found at increased indoor levels more than six months after the renovation activity took place. This finding indicates that more than 6 months after the renovation activity took place, certain emissions originating from the indoor use of building materials may still be present indoors.

The selection of low VOC emitting building materials lead to a direct improvement of the IAQ in terms of indoor TVOC and formaldehyde, according to a small qualitative study of four of the Renovair cases.

### Evaluation of the effectiveness and impact of specific renovations on the indoor environment

For most of the studied cases, a relation between IAQ and ventilation characteristics (air tightness and ventilation rate) can be noticed in the Renovair dataset.

- Outdoor levels of volatile organic compounds (VOCs) and PM<sub>2.5</sub> are reflected in the corresponding indoor concentration.
- The installation of more insulated windows did not affect the IAQ, or the building air tightness, and a ventilation system type A (natural ventilation) did not lead to reduced indoor CO<sub>2</sub> levels compared to a non-mechanically (naturally) ventilated house.
- The installation of floor insulation led to increased TVOC and formaldehyde levels post renovation, but also raised the floor temperature with 3°C. Within a week after installing the PUR floor insulations, traces of dimethylbenzylamine, a catalyst for foam formation, were detected in the living room.
- Wall treatment against rising damp was found to affect indoor VOCs (increased TVOC level, traces of epoxy silanes) at differing levels less than a week after the installation and was found at reduced indoor levels again 6 months after the installation.

In one house, TVOC concentration levels reached a level that is ranked according to the German Indoor Air Quality guide values as *'should not be exceeded in rooms for long-term residence'* (1-3 mg/m<sup>3</sup>). Six months after the renovation the concentration levels had decreased to levels classified by the same institution as *'ideal conditions'*.

Only in one of the two studied cases, moisture in walls was found to decrease. It was found in some cases that some cold spots present before the renovation, were still present after the thorough renovation and that unfinished renovations (finishing works) also affected the air tightness of the building.

### **12.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

According to the Renovair data, cold bridges present before the renovation are in some cases found to be more pronounced post renovation. The air tightness around the joinery in the façades was a point of particular interest in the thorough renovation cases. Older front doors and garages clearly showed heat losses around the frames.

The awareness for this phenomenon could be raised (e.g. by incorporating it in subsidies, or by mandatory follow-up of renovation planning by an expert). A similar finding was reported in the Finland 'Moisture and Mould programme'. In a new Decree (REF) set by the Social Affairs and Health Ministry in Finland, the government offers the possibility for a professional house inspection (person with qualifications according to requirements set by the government) in houses with health hazards, who formulates recommendations for a suitable renovation of the private dwelling.

Thorough initiatives for selecting low VOC emission materials lead to a direct improvement of the IAQ in terms of indoor TVOC and formaldehyde. There is a need for guidelines and tools for building professionals and citizens for selecting low VOC-emitting building materials. The table for building material selection in the guide 'Bouw Gezond' for building professionals, is a very useful tool in this context<sup>33</sup>.

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<sup>33</sup> Environment, Nature and Energy Department (2016) *Fiches Bouw Gezond (Dutch)* [online], available at <http://www.lne.be/campagnes/bouw-gezond/bouw-gezond/meer-informatie/fiches-map-bouw-gezond/fiches-bouw-gezond> [20/5/2016]



### **12.3 REFERENCES**

Stranger, M. et al., 2016, *Renovair – Explorative study on the quality of the indoor environment in buildings after (energy-efficient) renovations*, VITO

## 13 FS 11. INSULATE

### 13.1 FACT SHEET

General information						
Description		INSULAtE aims to demonstrate how energy improvements impact indoor environmental parameters, and to develop a protocol for assessment of the impacts. In the first phase, case study measurements were performed in Finland and Lithuania, including about 20 multi-family buildings per country (about 200 apartments). In the second phase, the assessment was extended in a total of 43 multi-family buildings in Finland. Specific objectives include: <ul style="list-style-type: none"><li>- To develop a common protocol for assessing the impacts of a building's energy performance on indoor environmental quality and health and to establish an integrated approach for the assessment of environmental and health information, including demonstrating the use of relevant environmental and health indicators;</li><li>- To demonstrate the effects (both positive and negative) of energy efficiency on Indoor Environment Quality (IEQ) and health in two-to-three different European countries;</li><li>- To develop guidelines to support the implementation of related policies; and</li></ul> To facilitate transnational networking and the dissemination of information.				
Involved parties		THL (Finland), TUT, KTU				
Year		1.9.2010 - 31.12.2015.				
Geographical and building characteristics						
Building		Climate zone, Location	Typology	Type	Scale	Stage
46	apartment buildings	Northern Europe	residential: multi-family house	renovation	241 flats (5 flats per building)	In use Fieldwork before and after renovation in 39 apartment buildings
20	apartment buildings	Eastern Europe	residential: multi-family house	renovation	96 flats (5 flats per building)	In use Fieldwork before and after renovation in 15 apartment buildings

Relevant professional context	
<b>Field study carried out by collaborative EU projects</b> INSULAtE is a European project, co-financed by EU Life+ programme (project Life number: LIFE09 ENV/FI/000573) <sup>34</sup> . Project coordinator is THL (The National Institute for Health and Welfare), other project partners are the Tampere University of Technology-Dept. of Civil Engineering (Finland), the Kaunas University of Technology-Dept. of Environmental Engineering, (Lithuania) and the World Health Organization-European Centre for Environment and Health (Bonn Office, Germany)	

<sup>34</sup>[http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n\\_proj\\_id=3725](http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=search.dspPage&n_proj_id=3725)

## 13.2 MACRO-OBJECTIVE B4A: HEALTHY AND COMFORTABLE SPACES

### 13.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Exposure to hazardous substances – ventilation intake air
- Exposure to hazardous substances – materials emissions
- Moisture and mould

#### → Improvement option(s)

Table 9: International and national guideline values for selected indoor air quality indicators in Finland and Lithuania (source: Haverinen et al., 2016)

Parameter	Unit	WHO	EU	National guidelines	
				Finland	Lithuania
T	°C	-	-	18-26 <sup>a</sup>	18-22
RH	%	-	-	20-60	35-60 <sup>b</sup>
CO <sub>2</sub>	ppm	-	-	1150 > outdoor	1200
CO <sup>c</sup>	ppm	8.6 (8h); 25 (1h)	10 (8h)	7	2.43 (24 hr)
PM <sub>2.5</sub>	µg/m <sup>3</sup>	25 (24 hr)	25 (yr)	-	40 (24hr)
PM <sub>10</sub>	µg/m <sup>3</sup>	50 (24 hr)	50 (24 hr); 40 (yr)	-	50 (24hr)
NO <sub>2</sub>	µg/m <sup>3</sup>	40 (yr); 200 (hr)	200 (hr); 40 (yr)	-	40 (24 hr)
CH <sub>2</sub> O	µg/m <sup>3</sup>	100 (30 min)	-	50 (yr)	100 (30 min) 10 (24 hr)
Radon	Bq/m <sup>3</sup>	100 (yr)	-	100/200/400 <sup>d</sup>	400
TVOCs	µg/m <sup>3</sup>	-	-	400	100 <sup>e</sup>

<sup>a</sup> 'Good' level of room temperature is 21 °C ('adequate' level is 18 °C), and should not be above 26 °C, unless the high temperature is due to outdoor temperature. During the heating seasons, indoor temperature should not exceed +23...24 °C.

<sup>b</sup> In Lithuania, the values for RH only refers to heating season.

<sup>c</sup> Values refer to maximum daily 8-hour mean.

<sup>d</sup> Guideline values in Finland: 100 Bq m<sup>-3</sup> (new buildings); 200 Bq m<sup>-3</sup> (built after 1992).

<sup>e</sup> Lithuanian guideline is for aliphatic hydrocarbons of C1-C10 structure (100 mg/m<sup>3</sup>).

#### → Methodologies, evaluation tools and/or standards used

The methodologies applied and indicators assessed in INSULAtE are similar to the ones covered in Renovair, but while Renovair focusses on the relation of energy efficient renovations in the Belgian (Central-European) context, INSULAtE focusses on this relation in the Scandinavian (Northern-European) context. Furthermore, the buildings studied in INSULAtE are mostly multi-family houses or apartment buildings (built in the period 1960-1980), in contrast to the single family houses covered in Renovair.

Assessments were performed in a total of 46 Finnish and 20 Lithuanian apartment buildings (about 5 apartments per building) on two occasions: 1st assessment at the baseline (before retrofits in the case buildings) and 2nd (follow-up) assessment (after retrofits in the case buildings). Assessments were performed mainly during the heating seasons.

In addition, information was gathered from the occupants by using self-administered housing and health questionnaires and diaries. The questionnaire included 49 questions, mainly related to the dwelling and its surroundings, hygiene, indoor environmental issues, and health and wellbeing. The questionnaire was based on a formerly developed Housing and Health questionnaire, which has been used to collect comparative data from random samples of Finnish dwellings in 2007 and 2011 [1, 2]. The diary was filled once a day for a two-week period, and it included questions about time spent in the home and undertaking activities (such as opening windows for ventilation).

The assessment protocol is explained in detail in the project website ([www.insulateproject.eu](http://www.insulateproject.eu)).

#### → Project processes

Similar to “Cleanair, Lowenergy” and “Renovair”

### 13.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

#### → Overview

Assessment included the following measurements of indoor environmental quality indicators that may impact the health and wellbeing of residents<sup>35</sup>:

- Indoor temperature (T) and relative humidity (RH)
- Air change rate (ACR)
- Carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO)
- Particulate matter (PM<sub>2.5</sub>, PM<sub>10</sub>)
- Nitrogen dioxide (NO<sub>2</sub>)
- Volatile organic compounds (VOC)
- Formaldehyde (CH<sub>2</sub>O)
- Radon
- Microbes and fibres in settled dust.

### 13.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

A selection of key findings that emerged in the study:

- A majority of the apartments fulfilled the national guideline values for IEQ parameters, but after the retrofits some indoor pollution sources emerged. This indicates that special attention should be paid to pollution source control
- Finnish buildings exceeded the maximum recommended indoor temperature during heating seasons (23 °C) for about 40% of the time both before and after retrofits, while

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<sup>35</sup> Haverinen-Shaughnessy U., Turunen M., Du L., Leivo V., Kiviste M., Aaltonen A., Prasauskas T., Martuzevicius D. (2016) *Improving energy efficiency of multi-family buildings, impacts on indoor environmental quality and health*, THL

relative humidity was often below recommended (RH <20%). Lowering high indoor temperatures could help to save energy and maintain more acceptable RH

### **13.3 REFERENCES**

Haverinen, U. et al., 2016, *Improving energy efficiency of multi-family buildings, impacts on indoor environmental quality and health*, THI

## 14 FS 12. GREEN BUILDING COUNCIL SPAIN (GBCS) FIELD STUDY CLUSTER - IDOM

### 14.1 FACT SHEET

General information						
Description		The Green Building Council Spain (GBCS) provided two field studies in Spain that take into account future projections for climate change and related potential influence of the urban heat island effect when modelling a building's thermal performance and comfort levels. IDOM is an international engineering, architecture and consulting firm. It originates from Spain but currently has branches in sixteen countries across five continents. IDOM Spain uses future case scenarios when making energy simulations. Two case studies selected for detailed analysis are the IDOM headquarters in Bilbao (finished in 2011) and the IDOM headquarters in Madrid (finished in 2010).				
Involved parties		IDOM				
Year		2010, 2011				
Geographical and building characteristics						
Building		Climate zone, Location	Typology	Type	Scale	Stage
IDOM Headquarters	Madrid	Southern-Europe, Madrid, Spain	Office: medium-rise	New-build	5 stories, 15300 m <sup>2</sup>	In use
IDOM Headquarters	Bilbao	Southern-Europe, Bilbao, Spain	Office: medium-rise	New-build	5 stories, 14400 m <sup>2</sup>	In use

Relevant professional context	
<p>Possible adaptation measures are demonstrated in two buildings of IDOM. Their new Headquarters building in Bilbao (finished in 2011) is the first building in Spain that has its Study of Climate Change Adaptation according to IDOM. UKCIP 2003 Methodology has been used to identify the climate change risks, in this case: sea/river level increase and precipitation increase. Hydrometeorology models have been simulated using with the IHACRES software (e.g. IHACRES) to assess adaptation measures. The second IDOM case, the headquarters in Madrid (finished in 2010) is the first office building of its size in the Mediterranean climate that incorporates Thermally Activation of the Building Structure (TABS) according to IDOM. The building and the TABS-system are closely monitored and adapted during the use phase.</p>	

### 14.2 MACRO-OBJECTIVE B5: RESILIENCE TO CLIMATE CHANGE

#### 14.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Thermal tolerance

##### → Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
IDOM Madrid	Thermally Active Building System(TABS);	TABS ISO	LEED;

Headquarters	Integrated strategies with envelope, thermal mass, solar shading, etc. Green roof and green areas;	11855-1; LEED;	Thermal comfort zone in Fanger or ASHRAE 55.2004
IDOM Bilbao Headquarters	Integrated strategies with envelope, thermal mass, solar shading, etc. Green roof and green areas;	LEED;	LEED; Thermal comfort zone in Fanger or ASHRAE 55.2004

Detailed discussion:

IDOM Madrid Headquarters (finished in 2010) is the first office building of its size in the Mediterranean climate that incorporates Thermally Active Building System (TABS). TABS is based on the thermal storage capacity of parts of a building. The “Active” element of a combined heating and/or cooling system is achieved by embedding pipes in the structural concrete slabs of the building. TABS operate at temperatures close to ambient which facilitates the integration of renewable energy and cooling sources that are free of cost. Most of the IDOM projects have an thermal active building system and/or any other systems integrating all the specialities. IDOM’s knowledge of the real performance of the system, its energy consumption and its comfort analysis has reached in this moment a level much over the level of the simulation systems.

In general, thermal comfort in IDOM projects do not only rely on the HVAC system. The rational design of envelope, the thermal mass, the solar shading and any other integrated strategies let the building take advantage of the environmental conditions such as geothermal, aerothermal, etc. This kind of integrated technologies lets IDOM design resilient buildings because the influence of a variation of the climate in the comfort is much less than in any system only based on the use of air.

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
IDOM Madrid Headquarters	Dynamic simulation with future and historical weather profile;	Design Builder; EnergyPlus; Autodesk tools; JEPlus; METEONORM software and "future" weather profile;	LEED; Comfort standards (usually Fanger or ASHRAE 55.2004);
IDOM Bilbao Headquarters	Dynamic simulation with future weather profile; Hydrometeorology modelling;	IHACRES software; Design Builder; EnergyPlus; Autodesk tools; JEPlus; METEONORM software and "future" weather profile;	UKCIP 2003; LEED; Comfort standards (usually Fanger or ASHRAE 55.2004);

Detailed discussion:

Design temperature is usually considered to be slightly higher than the current one to have into account a probable increment in the next (few) years, during the life of the building. In Spain the values in the regulations are barely used while the values from clients always indicate a more ambitious level of efficiency and sustainability.

EnergyPlus and Design Builder are used for dynamic simulation in IDOM. Future case scenarios are analysed in energy simulations. For this purpose, IDOM uses METEONORM software and its "future" weather profile feature, and the building is usually simulated with two weather profiles: the one from the historical data and one for 50 years ahead.

When simulating buildings in Design Builder and EnergyPlus, IDOM conducts both of active (with all HVAC equipment) and passive (free-running building) simulation. IDOM analyses the energy demand, energy consumption and user comfort of the buildings. IDOM designs the buildings in order to reduce the energy demands and energy consumptions while maintaining the comfort standards (usually Fanger or ASHRAE 55.2010) with the historic and future weather data (with priority in the historic weather file). Recently IDOM has started using JEPlus and parametric simulations. A simulation variable matrix is generated and the economic aspects are added to simulation results as another dimension for further optimization.

That is the generic methodology, however each project is analysed in its own context. For instance, IDOM Bilbao Headquarters (finished in 2011) is the first building in Spain that conducted the study of climate change adaptation. IDOM uses UKCIP 2003 Methodology to identify the possible climate change risks, e.g. sea/river level increase and precipitation increase, thereafter hydrometeorology model is built and simulated by using IHACRES software.

#### 14.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

No specific indicators are explicitly identified for IDOM. However, generic EnergyPlus output parameters on thermal comfort can be considered as the useful indicators, such as temperature and relative humidity. Therefore results are also not available.

#### 14.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

##### → Project processes

Methodology	Stage	Lead actor	Supporting actor
Simulation	Design stage	Architects	physicists, biologists, chemists, geologists

#### Evaluation of project experience using the indicator(s)

Design temperature are usually considered to be slightly higher than the current one to have into account a probable increment in the next years, during the life of the building. The practice in Spain is that the values in the regulations are barely used while the targeted building energy performance values from clients always indicate a more ambitious level of efficiency and sustainability.

Apart from temperature and solar radiation projections, IDOM also uses UKCIP 2003 Methodology to identify the possible climate change risks, e.g. sea level increase and precipitation increase, thereafter hydrometeorology model is built and simulated by using IHACRES software.

IDOM has started to use JEPlus on parametric simulations, and a simulation variable matrix is generated and the economic aspects are added to simulation results as another dimension for further optimization. All of these quantification tools are fairly important, and they are used as tools to improve the design in order to get a better building performance and thermal comfort.

#### 14.3 REFERENCES

IDOM. <http://www.idom.com/en/>



## 15 FS 13. GREEN BUILDING COUNCIL SPAIN (GBCS) FIELD STUDY CLUSTER – NEW4OLD

### 15.1 FACT SHEET

General information						
Description		The main goal of the cofounded by the European Commission LIFE Project, New4Old (LIFE10 ENV/ES/439), is to define the most appropriate method and the best available practice in social housing rehabilitation with energy and environmental sustainability criteria, as well as to apply innovative technologies in the fight against climate change through an efficient use of resources and energy. The demonstrator project consists in the energy rehabilitation of a rental social housing building located in Zaragoza’s historic quarter, according to the conclusions and strategies developed for the LIFE project. In actions taken in households of this nature passive design strategies are essential due to the limited income of owners, who often cannot afford energy bills. Therefore, the proposed actions will help improve the building’s passive performance and reach a higher thermal comfort, without increasing the economic cost linked to energy consumption.				
Involved parties		Technological Centre AITEMIN, Madrid Polytechnic University (UPM), Portugal Technological Centre for Ceramics and Glass (CTCV) and the Zaragoza City Housing Society (SMZV)				
Year		2013				
Geographical and building characteristics						
Building		Climate zone, Location	Typology	Type	Scale	Stage
Rental social housing building		Southern-Europe, Zaragoza, Spain	Residential: apartment block	Renovation	4 stories, # units, # m²	In use

Relevant professional context
<p>The LIFE Project New4Old intends to prove that it is possible to design an energy retrofitting methodology for the most energy inefficient dwellings in order to reduce the effects of climate change. The case study is a building block owned by Zaragoza City Housing Society, built in the early 90's. It is a block between two buildings located in Zaragoza's historic quarter, with two façades. The main one faces north and the south façade is oriented to a large courtyard, which separates this block from another of the same development set, and it has three light wells of around 3 x 4 m. It is a four storey building, with dwellings in the upper three floors and commercial spaces in the ground floor. The dwellings face north or south with many rooms opening up to the light wells.</p>

### 15.2 MACRO-OBJECTIVE B5: RESILIENCE TO CLIMATE CHANGE

#### 15.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Thermal tolerance

→ Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
<b>Rental social housing building</b>	<ul style="list-style-type: none"> <li>Improvements on building's envelope;</li> <li>Solar shading in south façade with tilted blades;</li> <li>Courtyard environmental conditioning;</li> <li>Passive heating prototype device: flat steel plate recruiter placed horizontally under the blades</li> </ul>	CT-79 building thermal regulations	Requirements in CT-79 building thermal regulations

Detailed discussion:

Projections of temperature changes expected for Zaragoza until 2050 show a tendency in the increase of maximum temperatures in most months. This means that ventilation needs and moisture contribution will increase, reaching extreme situations during the warmest times. Those months entering comfort areas in their central hours will expand and solar radiation contribution will still be necessary during the coldest months. Household users answered a survey created together with SMZV social services, in order to evaluate their comfort conditions throughout the year, as well as to get to know which improvement measures they considered as priority. In general, it is found that getting warmer in winter and cooler in summer are the most important for the residents from the survey. The improvement measures were proposed to reach the targets.

→ Methodologies, evaluation tools and/or standards used

Project / case study	Methodology used	Evaluation tools used	Standards used
<b>Rental social housing building</b>	<ul style="list-style-type: none"> <li>Calculation and simulation;</li> <li>Zaragoza climatic study and 2050 projection climograms;</li> </ul>	<ul style="list-style-type: none"> <li>Energy performance certificate;</li> <li>CE3 software;</li> </ul>	Spanish building code

Detailed discussion:

Differences in today's climate conditions and those expected for 2050 for Zaragoza may be observed in the following climograms.

Figure 4. Comparative Olgay bioclimatic chart for Zaragoza. Period 1971-2050

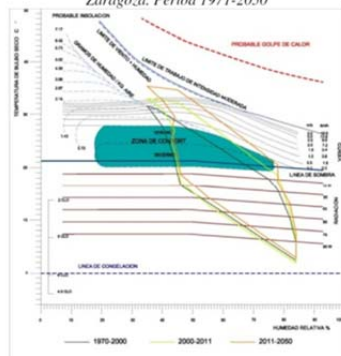
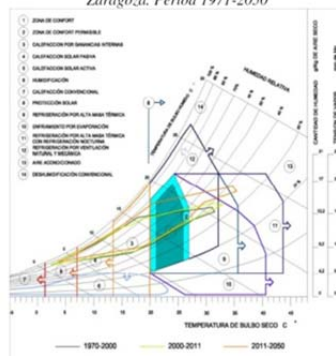


Figure 5. Comparative Givoni bioclimatic chart for Zaragoza. Period 1971-2050



Annual areas have been represented in these charts with average temperature and humidity data of maximum and minimum records. The blue line represents 1971 data and the orange one corresponds with expectations for 2050.

## 15.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

No specific indicators are explicitly identified for New4Old. However, generic output parameters from simulation software on thermal comfort can be considered as the useful indicators, such as temperature and relative humidity. Results are not available either.

## 15.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

### → Project processes

Methodology	Stage	Lead actor	Supporting actor
Simulation and calculation	Design	Architects	physicists, biologists, chemists, geologists

### → Evaluation of project experience using the indicator(s)

In addition to the climate change phenomenon, urban heat island phenomenon should also be considered. In the case of Zaragoza, it is particularly worth highlighting the importance of considering adjustment actions to overheating conditions, not only because of climate forecast evolution, but also heat island phenomenon. In this case study, due to the location of the building (in the high density historic quarter), the increase of the temperatures will be even higher than in other less dense areas. In summer, the situation will get even worse.

## 15.3 REFERENCES

Energy rehabilitation of social housing for rent, as demonstrator in the LIFE “New4Old” Project. See [wsb14barcelona.org/programme/pdf\\_poster/P-010.pdf](http://wsb14barcelona.org/programme/pdf_poster/P-010.pdf)

## 16 FS 14. DESIGN FOR FUTURE CLIMATE (D4FC)

### 16.1 FACT SHEET

General information	
<b>Description</b>	The Design for Future Climate competition was launched by the Technology Strategy Board (TSB, now Innovate UK) in 2010 to provide funding for the development of adaptation strategies for new build and refurbishment projects. Innovate UK invited proposals from design teams to develop adaptation strategies for two types of existing large building project: Either planned low impact new buildings (at the design stage), or large non-domestic buildings about to be refurbished to low impact standards. In total, 45 projects received funding through the project. These projects developed adaptation strategies for a range of new build and refurbishment projects, and identified many effective measures for adapting to the effects of climate change.
<b>Involved parties</b>	Innovate UK, Buro Happold, ARUP, Glenn Howell
<b>Year</b>	2010

Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Co-operative HQ, Buro Happold	Central Europe, Manchester (UK)	Office, medium-rise	New-build	30000 m <sup>2</sup>	In-use
100 City Road, ARUP	Central Europe, London (UK)	Office, high-rise	New-build	16000 m <sup>2</sup>	In-use
Admiral HQ, Glen Howell	Central Europe, Cardiff (UK)	Office, medium-rise	New-build	18580 m <sup>2</sup>	In-use

Relevant professional context
<p><b>Private or public sector buildings and portfolios</b></p> <p>The Design for Future Climate (D4FC) competition was launched by Innovate UK to enable built environment projects to look at Climate Change in the design of £4.2Bn of construction and building refurbishment in the UK. It ran over two phases between 2010-2014 and granted £5M to 45 projects. The 240 companies working on this programme were challenged with developing adaptation strategies for their building projects over the course of the 21st century. The design teams were challenged to consider the following:</p> <ol style="list-style-type: none"> <li>1. What is the risk exposure to future climate?</li> <li>2. How to adapt the building now &amp; the future?</li> <li>3. When to implement adaptation measures?</li> </ol> <p>Innovate UK is the UK's innovation agency. It is an executive non-departmental public body, sponsored by the Department for Business, Innovation &amp; Skills.</p> <p>(source: <a href="https://connect.innovateuk.org/web/design-for-future-climate">https://connect.innovateuk.org/web/design-for-future-climate</a>)</p>

### 15.2 MACRO-OBJECTIVE B5: RESILIENCE TO CLIMATE CHANGE

#### 15.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Thermal tolerance

→ Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
Co-operative HQ, Buro Happold	<ul style="list-style-type: none"> <li>• Double-skin façade</li> <li>• Earth duct (air supplied via buried duct to benefit from stable ground temperatures)</li> <li>• Management and operational measures (flexible working)</li> <li>• Improved staff awareness and preparedness</li> <li>• Increased flood attenuation tank</li> </ul>	CIBSE Guide (2006) comfort criteria; EN 15251 A	no more than 5% of occupied hours exceeding 25°C, no more than 1% of occupied hours exceeding 28°C.
100 City Road, ARUP	<ul style="list-style-type: none"> <li>• Relaxing thermal comfort criteria</li> <li>• Limiting solar gains – shading</li> <li>• Limiting lighting load heat gain</li> <li>• Limiting computer equipment heat gain</li> <li>• Modifying/optimising building fabric</li> <li>• Adjusting thermal mass</li> <li>• Adjusting room height, air distribution system</li> <li>• Night time cooling</li> <li>• Mixed mode ventilation</li> <li>• Increased natural ventilation potential</li> </ul>	CIBSE Guide (2006) A	no more than 5% of occupied hours exceeding 25°C, no more than 1% of occupied hours exceeding 28°C.
Admiral HQ, Glen Howell	<ul style="list-style-type: none"> <li>• Low-energy ICT equipment</li> <li>• Adaptive comfort strategy</li> <li>• Reduction of the occupancy density</li> <li>• Development of future adaptation strategies early in the design stage</li> </ul>	CIBSE Guide (2006) A	no more than 5% of occupied hours exceeding 25°C, no more than 1% of occupied hours exceeding 28°C.

Discussion:

The methodological framework used in the D4FC projects is based on the four stage approach of Modern Built Environment – Knowledge Transfer Network:

1. Identify risks to core business, supply chain and wider network
2. Classify climate-related risks
3. Identify climate change adaptation strategies
4. Assess the value of adaptation options

Key resource for the D4FC projects are the UK Climate Projections published in 2009 (UKCP09). UKCP09 provides future climate projections for land and marine regions as well as observed (past) climate data for the UK. Initially, three case studies from the D4FC database are selected, based on the level of documentation of these case studies. In what follows, the main improvement options, data sources, tools and indicators are screened.

*Case 1: Co-operative headquarters by Buro Happold:*

Climate Change risk assessment was carried out using UKCP09 climate projections for 2030s and 2050s. Dynamic thermal modelling was used to predict the energy use and internal comfort for these future scenarios. Adaptation measures suggested in this project are:

- Double-skin façade
- Earth duct (air supplied via buried duct to benefit from stable ground temperatures)
- Management and operational measures (flexible working)
- Improved staff awareness and preparedness

- Increased flood attenuation tank

*Case 2: 100 City Road, London by ARUP:*

Dynamic Thermal Modelling was used to make comparisons between 2005 Test Reference Year (TRY) and UKCP09 climate projections for 2020, 2050 and 2080. The adaptation measures implemented are an increased maximum summer temperature from 26°C to 28°C, night time cooling and anticipation to integrate shading devices in the building construction at a later date.

*Case 3: Admiral Insurance HQ, Cardiff by Glen Howell:*

Detailed energy modelling was carried out upon the building according to an accurate specification of its current design and use profile. This was completed under a base case (present) climatic scenario and for three future scenarios; 2030, 2050 and 2080, using climate files created by Exeter University, from the UKCP09 datasets. It emerged that the overall strategy should focus upon creating a more efficient building use profile rather than implementing physical building changes. Building Information Modelling (BIM) approach is suggested to simplify the process and to allow modelling of future adaptations to be more readily completed using up-to-date climate data. Adaptation measures considered are:

- Low-energy ICT equipment in line with existing replacement schedule
- Application of adaptive comfort strategy, allowing the cooling set point to be raised
- Reduction of the occupancy density as working patterns change
- The development of future adaptation strategies early in the design stage, allowing physical alterations to be made to the design that would not be cost-effective to implement as part of a retrofit strategy.

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
Co-operative HQ, Buro Happold	Dynamic simulation	<ul style="list-style-type: none"> <li>• UK Adaptation Wizard</li> <li>• IES Virtual Environment</li> <li>• CFD</li> <li>• CIBSE adaptive thermal comfort</li> </ul>	CIBSE Guide A (2006); EN 15251
100 City Road, ARUP	Dynamic simulation	<ul style="list-style-type: none"> <li>• IES Virtual Environment</li> <li>• Oasys BEANS Suite</li> <li>• Ansys CFX</li> </ul>	CIBSE Guide A (2006)
Admiral HQ, Glen Howell	Dynamic simulation	<ul style="list-style-type: none"> <li>• IES Virtual Environment</li> <li>• Climate datasets from PROMETHEUS research project</li> </ul>	CIBSE Guide A (2006)

Discussion:

*Case 1: Co-operative headquarters by Buro Happold:*

Climate Change risk assessment was carried out using UKCP09 climate projections for 2030s and 2050s. Dynamic thermal modelling was used to predict the energy use and internal comfort for these future scenarios. Test Reference Year (TRY) and Design Summer Year (DSY) weather tapes are both used in this case for comparison.

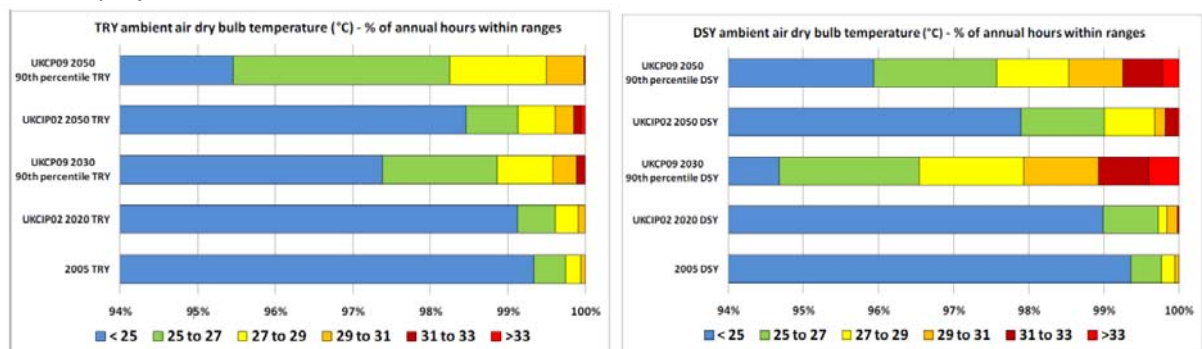
*Case 2: 100 City Road, London by ARUP:*

Dynamic Thermal Modelling was used to make comparisons between 2005 Test Reference Year and UKCP09 climate projections for 2020, 2050 and 2080.

*Case 3: Admiral Insurance HQ, Cardiff by Glen Howell:*

Detailed energy modelling was carried out upon the building according to an accurate specification of its current design and use profile. This was completed under a base case (present) climatic scenario and for three future scenarios; 2030, 2050 and 2080, using climate files created by Exeter University, from the UKCP09 datasets. It emerged that the overall strategy should focus upon creating a more efficient building use profile rather than implementing physical building changes.

In terms of the weather data used in the case studies, CIBSE Test Reference Year data series are commonly regarded as a year with “average” temperatures and are intended primarily for use in determining average annual energy consumption. TRY is a year of weather data that is a composite of twelve typical months, not necessarily from the same year. Design Summer Year data series were created primarily for assessing summer overheating risk. Temperature comparisons of climate projections on TRYs and DSYs as below:



Additionally, following CIBSE Guide A (2006), there are two different approaches to indoor thermal comfort, and it is necessary to point out the difference between static approach and adaptive approach. In static approach, any set point temperature is constant throughout the whole year. Adaptive method assumes that people make adjustments to themselves, for instance in terms of clothing, activity and posture, to adapt to different circumstances; in this approach therefore assumptions regarding indoor comfort temperature thresholds will change with the daily or monthly outdoor temperatures. Adaptive thermal comfort can be exploited by designers to make buildings more resilient towards climate change by providing opportunities for occupants to make adjustments to suit the changing environment.

#### 15.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Temperature	[°C]	Use stage <ul style="list-style-type: none"> <li>Operative temperature               <ul style="list-style-type: none"> <li>Mean radiant temperature</li> <li>Ambient air temperature</li> </ul> </li> <li>Upper limit temperature               <ul style="list-style-type: none"> <li>Neutral temperature                   <ul style="list-style-type: none"> <li>Running mean outdoor temperature</li> </ul> </li> </ul> </li> </ul>	B5: Resilience to climate change



		<ul style="list-style-type: none"> <li>○ Discomfort temperature</li> </ul>	
<b>Overheating hours / Overheating risks (rate)</b>	[h] or [%]	Use stage Summation of the number of hours that the operative temperature ( $T_o$ ) is above the upper limit ( $T_{upper}$ )	B5: Resilience to climate change

### → Indicator #1: Temperature

- *Macro-objective: B5: Resilience to climate change*
- *Specific aspect(s): Thermal tolerance*

#### Technical specifications

- Unit of measurement: [°C]
- Scope of indicator: Building use stage, and different values are defined and used to assess the thermal comfort.
- Life cycle stage (with reference to EN 15643): B1 in use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit: for office buildings, temperatures are usually simulated at floor level, and the simulation is whole year simulation with time step of 1 hour.
- Associated data requirements: operative temperature is defined as the average of the mean radiant temperature and ambient air temperature, weighted by the heat transfer coefficients for radiation and convection. The temperature limits are defined and calculated based on neutral temperature (the temperature at which a human feels comfortable, and it differs for each residential typology). It is a function of the running mean outdoor temperature. The running mean outdoor temperature is the weighted average of the outdoor temperature of the preceding days;
- Supporting tools required to quantify/estimate performance: IES Virtual Environment
- Source of indicator/metric and its scientific and market acceptance: widely used in scientific research (ASHRAE Standard 55, CIBSE and EN 15251);

#### Results

##### Overview and results:

Project / case study	Improvement option	Results
Co-operative HQ, Buro Happold	Raising staff awareness	

##### Detailed discussion:

##### Case 1: Co-operative headquarters by Buro Happold:

CIBSE adaptive comfort model has been applied in the assessment of indoor comfort conditions for 2005 and 2050 data projections to indicate the future overheating risk. The green band of comfort zone indicates temperature range in which occupants will likely feel comfortable if they have measures to adapt to the environment. It is interesting to note that the comfort temperature

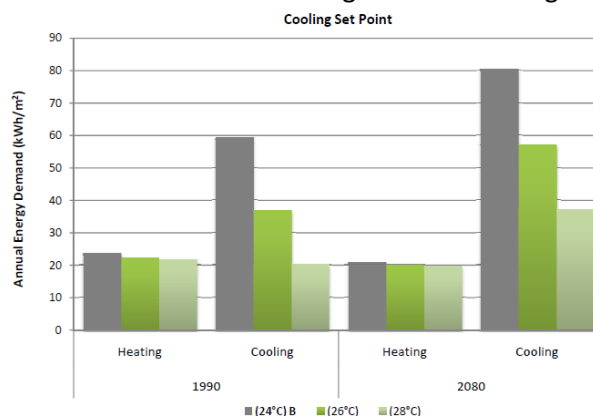


threshold is 26.7°C in 2050s near extreme case, that is, with the warming outside temperatures, as long as the indoor temperature is below 26.7°C, the indoor condition is deemed comfortable for the occupants who have adaptive capacity. As can be seen, under the near extreme warm conditions projected by UKCP09 2050s 90th percentile, indoor temperatures of the Head Office are within the comfort band as indicated in “green” band of the figures. As part of climate change awareness raising, occupants should be ready to adopt adaptive thermal comfort in the future, for instance, by 2030s to 2050s, likely adapt themselves to the rising temperatures and this is the most cost effective operation adaptation measure.

#### ***Cross-links and trade-offs between other macro-objectives***

The trade-off between thermal comfort and energy consumption for cooling is clearly reflected in this field study, which relates to macro objective B1. In order to keep the temperature below the upper limit during summer, energy consumption for cooling may increase. This is analysed in *case study 3: Admiral HQ, Glen Howell*.

Adjusting the cooling set point was by far the most influential method that could be used to reduce building’s space conditioning demand. However, increasing the set point may have a considerable impact upon the comfort levels within the building. Thus, in making this adaptation care must be taken to find the optimum, tolerable level, balanced against the productive output of the workforce. On this point, It was noted that as external temperatures are expected to rise, it is possible that people’s tolerance to higher temperatures may increase, making such a change more acceptable. Increasing the maximum summer temperature from 26°C to 28°C as users are likely to adapt to higher temperatures as the climate warms. This is a low-cost adaptation that delivers significant energy savings. The approach suggested for use on this building was to increase this set point from 24°C to 25°C by 2030, to 26°C by 2050 and to 27°C by 2080. It is also interesting that Admiral has a ‘relaxed’ attitude to dress code, which research shows should be conducive to increased thermal comfort and a wider tolerable range in both heating and cooling set points.



#### **→ Indicator #2: Overheating hours**

- *Macro-objective: B5: Resilience to climate change*
- *Specific aspect(s): Thermal tolerance*

#### ***Technical specifications***

- Unit of measurement: [h]
- Scope of indicator: Building use stage; when the operative temperature  $T_o$  exceeds the threshold temperature an overheating hour is registered, and it is the summation of the number of hours that the operative temperature ( $T_o$ ) is above the upper limit ( $T_{upper}$ ).

- Life cycle stage (with reference to EN 15643): B1 in use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit: for office buildings in this field study, overheating hours can be simulated either at building average level or at floor level; the time scale is usually one simulation year, and it can also be the extreme period during summer.
- Associated data requirements: operative temperature and temperature upper limits, also see the details in the previous section.
- Supporting tools required to quantify/estimate performance: IES Virtual Environment
- Source of indicator/metric and its scientific and market acceptance: overheating hour is used in the scientific world to evaluate the thermal performance (ASHRAE Standard 55, EN 15251). From market perspective, the similar concept is also used in some local passive house requirements (e.g. Belgian PHP).

## Results

### Overview and results:

Project / case study	Improvement option	Results
Co-operative HQ, Buro Happold	Double skin façade	
	Management and operation measures	
100 City Road, ARUP	Night cooling	

### Detailed discussion:

#### Case 1: Co-operative headquarters by Buro Happold:

The building double skin façade has been modelled against different weather types. The future climate presents generally warmer ambient temperatures and greater solar radiation as shown in the table. The double skin cavity will be warmer as expected. This may cause overheating of the adjacent offices. As can be seen from the results, based on UKCIP02 projections which represent median climatic conditions, the indoor temperatures will still meet CIBSE criteria and the temperature exceeding 25°C is less than 5%. However, for near extreme case of 90th percentile at 2030s and 2050s, the indoor temperature will exceed 5% criteria, meaning that occupant will feel warm. CIBSE recommends to use DSY for overheating assessment. Based on the DSY data that by 2050s, at either median or near extreme conditions, occupant will feel warm with temperatures above 25°C occurring more than 5%. As shown in the results, the indoor temperature would not exceed 28°C in any cases. Even at 2050 90th percentile case, the overheating threshold of 28°C is

never exceeded. Double skin façade is an effective shelter for indoor environment. With the currently designed chiller capacity and double skin façade, the indoor temperatures will unlikely exceed 28°C, the overheating threshold. However, with warmer climate projected for 2050s and for near extreme case, the indoor temperatures will exceed 25°C for more than 5%, meaning that occupants will likely feel “warm”.

The impact of management and operation measures are also analysed. As part of management and operation measures, staff can be encouraged to change seats from the south to the north facing space, using hot desks or work at home as well as coming to office and finishing work early; such flexible working style could be one of the adaptation measures during heat wave and near extreme warm summer period. By implementing so, the exceedance of 25°C is less than 5% of occupied hours in 2050s based on the median scenario. However, under the near extreme case with 90th percentile projection for 2050s represented by UKCP09 data, the number of hours above 25°C will be more than 5% of occupied hours.

*Case 2: 100 City Road, London by ARUP:*

The results indicate that it may be feasible to passively cool the office spaces for much of the year using only night ventilation and thermal mass. It shows the percentage of the year that the space operative temperature is predicted to be above 26°C. For the TRY data, the chilled ceiling would only be needed for around 6% of the year, increasing to around 32% of the year by the 2050s. Also shown are results for the CIBSE DSY data, which is the weather data normally used in the assessment of overheating in naturally ventilated buildings. Even for the DSY data, the results indicate that the offices could perform well with only passive cooling for much of the year.

***Cross-links and trade-offs between other macro-objectives***

This is again linked with macro objective B1. To keep low rate of overheating hours/risks, the energy consumption for cooling may increase for this compensation. The similar trade-off is already discussed in previous section.

**15.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

→ **Project processes**

Methodology	Stage	Lead actor	Supporting actor
Dynamic simulation	Design stage	Dynamic simulation modellers	Architects, Engineers

Detailed discussion:

Dynamic simulations with different future climate profiles are conducted for large scale office buildings in this field study.

→ **Evaluation of project experience using the indicator(s)**

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?  
The indicators are easy to use in this field study. Dynamic thermal simulation is widely used to assess the indicators.
- Was the expertise already available within the design team/other project actors?  
Yes

- How clear/informative was the associated guidance material?  
CIBSE is the main guidance for assessing the thermal comfort in UK, and the criteria is clear.
- o How readily available were the tools, data, test facilities etc.. required to use the indicator?
  - How reliable and/or comparable was the data and/or test methods used?  
CIBSE Adaptive thermal comfort has been published in Guide A as a guidance criteria/tool. This has not been well applied in the UK, for instance, British Councils for Offices have not used this criteria as guidance for a Grade A commercial environment. This is the limitation of its wide use.  
CIBSE Adaptation comfort criteria are based on EN15251 published in EU. Based on the limited research findings, adaptive thermal comfort proves to work well and can offer great energy savings. Another limitation is the lack of large amount of data of user feedback.
  - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*  
The simulation software, IES-VE, does not accurately reflect the implications of exposing thermal mass, given the complexity of actually implementing this adaptation work in practice. In this sense, the software appears to be somewhat rudimentary in assessing more passive design principles involving thermal mass and hence it may not be suitable for use on such buildings.  
IES has a wide range of modules that can carry out steady state and dynamic thermal calculations, bulk air flow analysis, Building Regulations compliance and solar shading assessments. Analysis of building services systems can also be carried out using the ApacheHVAC module. The software's ability to perform a multitude of analyses within a single model allows for efficient early concept and detailed calculations. The software has a simple graphical user interface to allow the building geometry to be developed quickly.  
Each software tool has its own strength and limitation. Compared to other tools used in the United States, IES maybe more focussed on building fabric and dynamic performance evaluation. It has some limits on modelling complex HVAC systems and control strategies. For the purpose of this adaptation study, IES is a perfectly capable tool for assessing indoor environment.
- o How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?
  - Was it suitable for the buildings evaluated? *If no, what issues arose?*
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*  
It is suitable for the office buildings, and the temperature limits and the overheating hours are usually combined for assessing the thermal comfort. However the "thresholds" are different.

Thermal discomfort	'Warm' temperature threshold	'Hot' temperature threshold
Offices, schools and living areas in homes	25°C	28°C
Bedrooms in homes	21°C	25°C
Building has 'overheated' if it is over 'hot' temperature for more than 1% of occupied hours		
Heat stress risk	Indoor temperature above 35°C (for healthy adults at 50% relative humidity)	

- o How time and cost intensive was use of the indicator?
  - How easy was it for the auditor/assessor to verify performance?

No information

Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*

Occupants should raise the awareness and adapt themselves to the rising temperatures, which is the most cost effective operation adaptation measure. Flexible working style could be one of the adaptation measures during heat wave and near extreme warm summer period.

Buro Happold have experience of many tools of this kind and all have their strengths and weaknesses. Buro Happold used CFX tool for assessing the detailed airflow patterns and temperature stratification within the double skin cavity for this building. The most important aspect in choosing the tools is to have a good understanding of the purpose of the simulation study, i.e. define a problem and then match the modelling methodology with the strength of a tool that can offer. Of course, learning curve of using a tool is also an important aspect to consider. The complexities of such a comprehensive study mean that it would be very easy to dive into detailed modelling with thousands of data files, which could be prone to mistakes. Dynamic simulation modellers have many levels of inputs and having an in-depth understanding of the inputs, how to change them and the effects of doing so is invaluable. Buro Happold has developed an excel post processor for processing all the raw data. This post processor has been checked and validated using a number of simulation runs. Once Buro Happold achieved the confidence of this data processor, the data became more manageable. Overall, all these tools are recommended, however, due to the complexity of the study, some degree of modelling competence is necessary to ensure the good quality and standard of the study.

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MBE, KTN, Guidance for making the case for climate change adaptation in the built environment, 2013

## 17 FS 15. KNOWLEDGE FOR CLIMATE

### 17.1 FACT SHEET

General information					
Description		The present study focuses on the effectiveness of climate change adaptation measures applied at the level of building components for three generic residential buildings as commonly built in - among others - the Netherlands: (1) detached house; (2) terraced house; (3) apartment. The numerical study involves both residential buildings that are built according to the building regulations and common practice in 2012, and residential buildings that were constructed in the seventies of last century, and which have a lower thermal resistance of the opaque and transparent parts of the building envelope.			
Involved parties		Eindhoven University of Technology; University of Leuven			
Year		2014			
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Detached house	Central-Europe, Netherlands (NL)	Residential, detached	Existing	-	Simulation
Terraced house	Central Europe, Netherlands (NL)	Residential, terraced	Existing	-	Simulation
Apartment	Central Europe, Netherlands (NL)	Residential, apartment	Existing	-	Simulation

Relevant professional context
<p><b>Private or public sector buildings and portfolios</b></p> <p>The research presented in this field study has been funded by the Dutch Knowledge for Climate Research Program and was carried out by partners within the Climate Proof Cities research consortium. The research is conducted within the Climate Proof Cities (CPC) research consortium, which is one of the research consortia investigating the climate vulnerability of urban areas and the development and effectiveness of climate change adaptation measures. CPC is a mainly Dutch consortium, which groups several universities, research institutes, policy makers and city officials to perform an integrated and thorough analysis on climate change adaptation focused on several locations in the Netherlands.</p>

### 17.2 MACRO-OBJECTIVE B5: RESILIENCE TO CLIMATE CHANGE

#### 17.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

##### → Aspects covered of the macro-objective

- Thermal tolerance

##### → Improvement option(s)

Project / case study	Improvement option	Evaluation criteria	Performance target
Detached	<ul style="list-style-type: none"> <li>Increased thermal resistance (<math>R=5.0 \text{ m}^2\text{K/W}</math>)</li> </ul>	ASHRAE	Comfort zone

house, Terraced house, Apartment	and $R=6.5 \text{ m}^2\text{K/W}$ ; <ul style="list-style-type: none"> <li>• Lowered thermal capacity;</li> <li>• Increased short-wave reflectivity (albedo from 0.3 to 0.6 and 0.8);</li> <li>• Vegetation roofs (Leaf Area Density Index of 5);</li> <li>• Exterior solar shading (east, south and west side of the facades);</li> <li>• Additional natural ventilation;</li> </ul>	Standard 55	with the temperature upper limit
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Detailed discussion:

The study considers three types of residential buildings are considered: 1) detached house; (2) terraced house; (3) apartment. For every type, construction characteristics of the 1970s and in the 2012 are used. The building geometries are based on the example residential buildings as defined by Agentschap NL in the Netherlands. The base case is a heavy-weight building, i.e. the floors are made of concrete and stone materials are used for both sides of the cavity walls. Two different insulation values have been used for the envelope of the base case buildings; a base case building built in the 1970s with low values for the thermal resistance, and a base case building according to the building regulations in the Netherlands in 2012 with high thermal resistance values.

The climate change adaptation measures investigated are: increased thermal resistance of the building envelope, changed thermal capacity, increased short-wave reflectivity (albedo value), vegetation roofs, solar shading and additional natural ventilation. To assess the performance of the six different adaptation measures, dynamic thermal simulations are conducted using EnergyPlus, an open-source energy simulation tool used for thermal calculations.

→ **Methodologies, evaluation tools and/or standards used**

Project / case study	Methodology used	Evaluation tools used	Standards used
Detached house, Terraced house, Apartment	<ul style="list-style-type: none"> <li>• Dynamic simulation with adaptive comfort method;</li> <li>• Climate profile measurement;</li> </ul>	<ul style="list-style-type: none"> <li>• EnergyPlus</li> </ul>	ASHRAE Standard 55

Detailed discussion:

To assess the performance of the six different adaptation measures, dynamic thermal simulations are conducted using EnergyPlus. This program was developed by the US Department of Energy and is widely used by engineers and scientists. EnergyPlus has been validated extensively for thermal calculations. The airflow network model present in EnergyPlus has been - among others - successfully validated for natural ventilation flow using on-site measurements (in case the vents are automatically controlled in the building where the measurement took place), furthermore, the results obtained in EnergyPlus showed a very good agreement with analytical solutions and results obtained with other airflow network models.

The weather data that has been used is what was measured in De Bilt, the Netherlands, during 2006. This year is known for the occurrence of several heat waves, and can therefore be seen as an example of a year with summer temperatures that will probably occur more often in the future as a result of climate change.

## 17.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

The accessed indicators are: overheating hours, degree hours, neutral temperature, operative temperature and upper limit (threshold for thermal comfort) temperature.

Indicator	Unit of measurement	Scope	Macro-objective
<b>Temperature</b>	[°C]	Use stage <ul style="list-style-type: none"> <li>Operative temperature <ul style="list-style-type: none"> <li>Mean radiant temperature</li> <li>Ambient air temperature</li> </ul> </li> <li>Upper limit temperature <ul style="list-style-type: none"> <li>Neutral temperature <ul style="list-style-type: none"> <li>Running mean outdoor temperature</li> </ul> </li> <li>Discomfort temperature</li> <li>Extreme temperature</li> </ul> </li> </ul>	B5: Resilience to climate change
<b>Overheating hours / Overheating risks (rate)</b>	[h] or [%]	Use stage Summation of the number of hours that the operative temperature ( $T_o$ ) is above the upper limit ( $T_{upper}$ )	B5: Resilience to climate change
<b>Degree hour</b>	[°C*h]	Use stage Degree hour obtained by multiplying an overheating hour with the exceedance	B5: Resilience to climate change

### → Indicator #1: Temperature

- *Macro-objective: B5: Resilience to climate change*
- *Specific aspect(s): Thermal tolerance*

#### Technical specifications

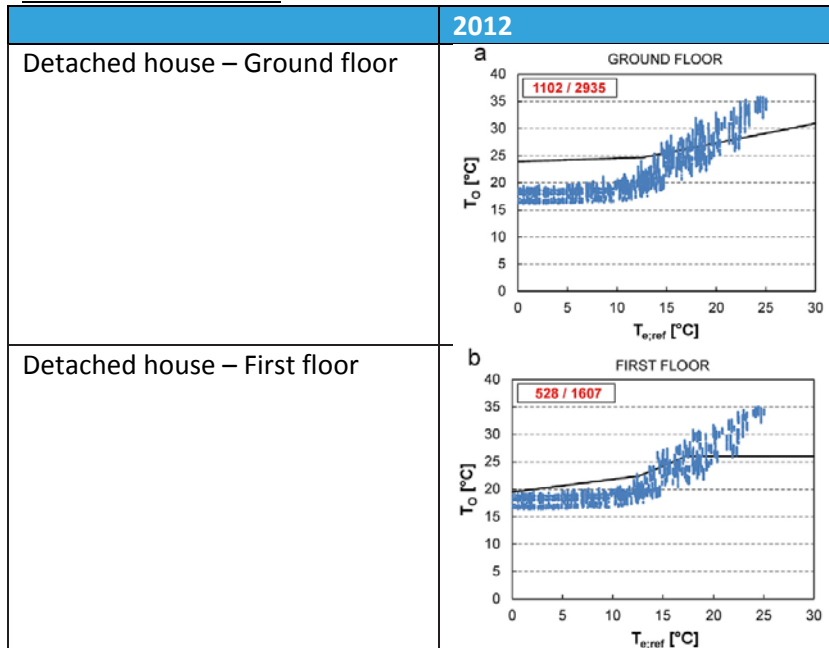
- Unit of measurement: [°C]
- Scope of indicator: Building use stage, and different values are defined and used to assess the thermal comfort.
- Life cycle stage (with reference to EN 15643): B1 in use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit: for houses, temperatures are simulated for each floor, ground floor and first floor; for apartment, temperatures are simulated at room level, living room and bedroom. The simulation is whole year simulation with time step of 1 hour.
- Associated data requirements: operative temperature is defined as the average of the mean radiant temperature and ambient air temperature, weighted by the heat transfer coefficients for radiation and convection. The temperature limits are defined and calculated based on neutral temperature (the temperature at which a human feels comfortable, and it differs for each residential typology). It is a function of the running mean outdoor temperature. The running mean outdoor temperature is the weighted average of the outdoor temperature of the preceding days;
- Supporting tools required to quantify/estimate performance: EnergyPlus



- Source of indicator/metric and its scientific and market acceptance: widely used in scientific research (ASHRAE Standard 55 and EN 15251);

## Results

### Overview and results:



Detailed temperature results for detached house from 1970, terraced house and apartment are not available in the publication.

### Detailed discussion:

The black line indicates the temperature upper limit for thermal comfort, which differs for the ground floor from the first floor due to the different neutral temperatures. Every dot represents one hour of the year while the value of the dot is the operative temperature at that specific hour. The dots above the black line (threshold value) are overheating hours. The indicator of temperature is further used to as basis to define and calculate overheating hours. For the base case detached house built in 2012, the ground floor has 1102 overheating hours and 2935 degree hours, and the first floor has 528 overheating hours and 1607 degree hours.

### Cross-links and trade-offs between other macro-objectives

The trade-off between thermal comfort and energy consumption for cooling is clear in this study, which relates to macro objective B1. In order to keep the temperature below the upper limit during summer, energy consumption for cooling may increase.

### → Indicator #2: Overheating hours

- *Macro-objective: B5: Resilience to climate change*
- *Specific aspect(s): Thermal tolerance*

### Technical specifications

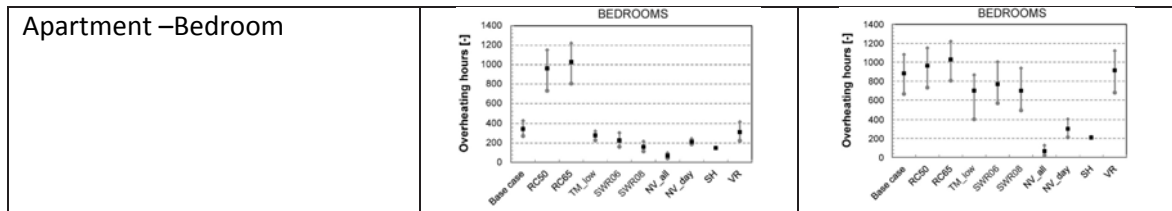
- Unit of measurement: [h]

- Scope of indicator: Building use stage; when the operative temperature  $T_o$  exceeds the threshold temperature an overheating hour is registered, and it is the summation of the number of hours that the operative temperature ( $T_o$ ) is above the upper limit ( $T_{upper}$ ).
- Life cycle stage (with reference to EN 15643): B1 in use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit: overheating hours are derived by comparing temperature levels, therefore the functional unit is similar. For houses, overheating hours are calculated for each floor, ground floor and first floor; for apartment, overheating hours are calculated at room level, living room and bedroom. In addition, the time scale is one simulation year.
- Associated data requirements: operative temperature and temperature upper limits, also see the details in the previous section.
- Supporting tools required to quantify/estimate performance: EnergyPlus
- Source of indicator/metric and its scientific and market acceptance: overheating hour is used in the scientific world to evaluate the thermal performance (ASHRAE Standard 55, EN 15251). From market perspective, the similar concept is also used in some local passive house requirements (e.g. Belgian PHP).

## Results

### Overview and results:

Typology	1970s	2012
Detached house – Ground floor		
Detached house – First floor		
Terraced house – Ground floor		
Terraced house – First floor		
Apartment – Living room		



#### Detailed discussion:

The table above depicts a summary of the simulation results for different typologies built in the 1970s and 2012. The results for the base case and the cases with the implemented adaptation measures are shown in the table above. The number of overheating hours for different levels and rooms are presented separately. The average, minimum and maximum number of overheating hours and degree hours are calculated for the four orientations of the building, and these values are also presented in the graphs.

The number of overheating hours and degree hours in residential buildings that are built according to the building regulations of 2012 is higher than for the buildings from the 1970s. This somewhat counter-intuitive finding can be explained by the higher thermal resistance of the former, which reduces the heat transport through the envelope once the air inside the building has been heated by solar radiation through the transparent parts of the building envelope.

Differences in the number of overheating hours occur between the three types of residential buildings. The number of overheating hours is significantly larger for the apartment building due to the heat transfer through the roof of both the living room and the bedrooms.

Increasing the thermal resistance of the building envelope increases the number of overheating hours, therefore, in well-insulated buildings shading or additional natural ventilation should be provided to limit the number of overheating hours.

Increasing the short-wave reflectivity results in less overheating hours and degree hours. The magnitude of this effect depends on the thermal resistance of the building envelope and on the type of building.

The application of a vegetated roof decreases the number of overheating hours and degree hours only to a limited extent for the cases studied.

The effect of increasing the short-wave reflectivity or of adding a vegetated roof is much larger for a poorly-insulated building than for a well-insulated building.

Additional natural ventilation by opening the windows above a certain indoor air temperature and when the indoor air temperature is higher than the outside air temperature significantly reduces the number of overheating hours and degree hours; they can be reduced to almost zero when natural ventilation is applied throughout the day.

Providing additional natural ventilation only during daytime (08:00-20:00) results in a smaller decrease of the number of overheating hours compared to the case in which additional natural ventilation is applied during the entire day, however, the reduction is still significant.

Adding operable exterior solar shading and lowering them when the solar radiation on the window is 150 W/m<sup>2</sup> or larger has a very large effect on the number of overheating hours and degree

hours. For the detached house and the terraced house the number can be decreased to almost zero, whereas for the apartment it can be reduced to around 200 in most cases.

#### ***Cross-links and trade-offs between other macro-objectives***

This is again linked with macro objective B1. To keep low rate of overheating hours/risks, the energy consumption for cooling may increase for this compensation.

#### **→ Indicator #3: Degree hours**

- *Macro-objective: B5: Resilience to climate change*
- *Specific aspect(s): Thermal tolerance*

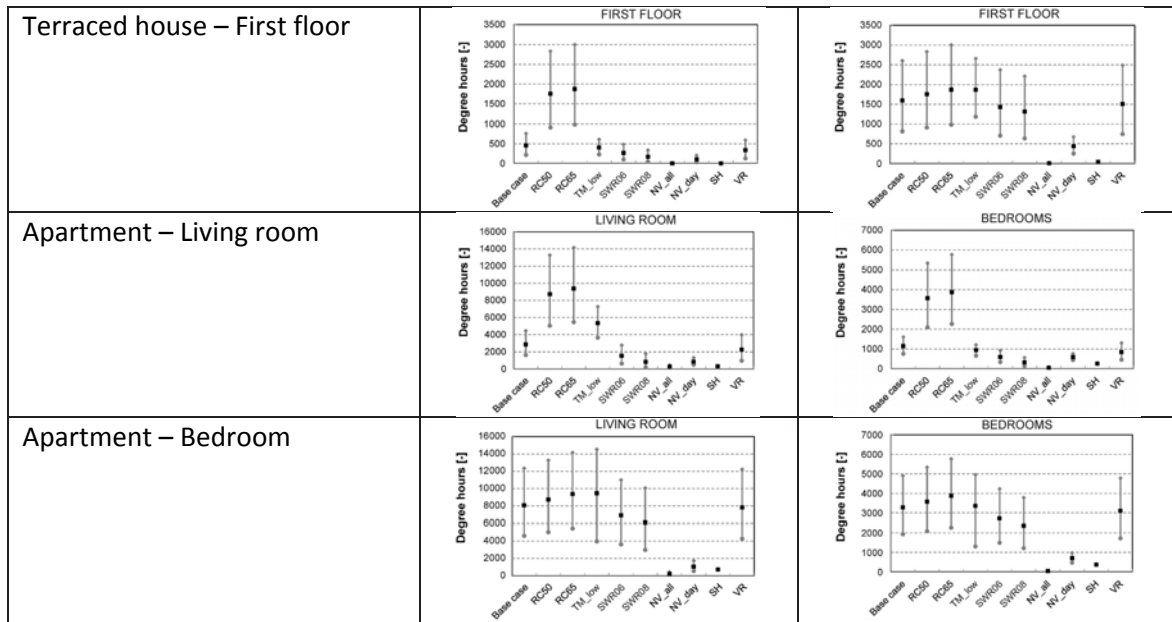
#### ***Technical specifications***

- Unit of measurement: [°C\*h]
- Scope of indicator: Building use stage; degree hour is obtained by multiplying an overheating hour with the exceedance.
- Life cycle stage (with reference to EN 15643): B1 in use stage
- Midpoint(s) and/or parameters: not applicable
- Functional unit: degree hours are derived by multiplying an overheating hour with the exceedance, therefore the functional unit is similar. For houses, overheating hours are calculated for each floor, ground floor and first floor; for apartment, overheating hours are calculated at room level, living room and bedroom. Again, the time scale is one simulation year.
- Associated data requirements: see the requirements for indicator 1 and indicator 2.
- Supporting tools required to quantify/estimate performance: EnergyPlus
- Source of indicator/metric and its scientific and market acceptance: degree hour is used in the scientific world to evaluate the thermal performance.

#### ***Results***

##### Overview and results:

Typology	1970s	2012
Detached house – Ground floor		
Detached house – First floor		
Terraced house – Ground floor		



#### Detailed discussion:

The table above depicts a summary of the simulation results for different typologies built in the 1970s and 2012. The results for the base case and the cases with the implemented adaptation measures are all combined in one single graph. Likewise, the number of degree hours for different levels and rooms are presented separately. The average, minimum and maximum number of overheating hours and degree hours are calculated for the four orientations of the building, and these values are also presented in the graphs. Degree hour has been analysed because of the similar meaning with overheating hour.

#### ***Cross-links and trade-offs between other macro-objectives***

Similarly, it is again linked with macro objective B1. To keep low rate of overheating hours/risks, the energy consumption for cooling may increase for this compensation.

#### **17.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

##### **→ Project processes**

Methodology	Stage	Lead actor	Supporting actor
Simulation and calculation	Simulation	Researcher	-

#### Detailed discussion:

The dynamic simulation is conducted by the researchers in this case study.

##### **→ Evaluation of project experience using the indicator(s)**

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?  
The indicators are easy to use in this field study. Dynamic thermal simulation is widely used to assess the indicators.
- Was the expertise already available within the design team/other project actors?

- Yes. The researchers conducted the dynamic simulation.
- How clear/informative was the associated guidance material?  
ASHRAE Standard 55 is the main material for the thermal comfort model and criteria used by the researchers, and the criteria is clear.
  - o How readily available were the tools, data, test facilities etc.. required to use the indicator?
    - How reliable and/or comparable was the data and/or test methods used?
    - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*  
To assess the performance of the six different adaptation measures, dynamic thermal simulations are conducted using EnergyPlus. This program was developed by the US Department of Energy and is widely used by engineers and scientists. EnergyPlus has been validated extensively for thermal calculations. The airflow network model present in EnergyPlus has been - among others - successfully validated for natural ventilation flow using on-site measurements (in case the vents are automatically controlled in the building where the measurement took place), furthermore, the results obtained in EnergyPlus showed a very good agreement with analytical solutions and results obtained with other airflow network models.
  - o How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?
    - Was it suitable for the buildings evaluated? *If no, what issues arose?*  
Yes, the indicators are suitable for the residential buildings.
    - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*  
The level of thermal comfort in office buildings differs from the level of thermal comfort that people experience in their homes is caused by several factors. Residents have different activity levels than people in an office situation and the activity level can more easily be adapted to the situation. At the same temperature people feel warmer in their homes than in an office situation; people tend to evaluate rooms as being warmer due to the presence of furnishing. Residents also accept a wider range of temperatures in their indoor environment because they have to pay for their own energy bill and they can more easily adjust to temperature differences (e.g. by changing clothing and adapting behaviours).
  - o How time and cost intensive was use of the indicator?
    - How easy was it for the auditor/assessor to verify performance?  
As mentioned, EnergyPlus has been validated extensively for thermal calculations. The airflow network model present in EnergyPlus has been - among others - successfully validated for natural ventilation flow using on-site measurements (in case the vents are automatically controlled in the building where the measurement took place).  
Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*

*If available, post occupancy evaluation findings and issues identified e.g. performance gaps*

### 17.3 REFERENCES

T. Van Hooff, B. Blocken, J.L.M. Hensen, H.J.P. Timmermans. Reprint of: On the predicted effectiveness of climate adaptation measures for residential buildings. Building and Environment 83 (2015) 142-158.

## 18 FS 16. DAVIS LANGDON CASE STUDIES

## 18.1 FACT SHEET

General information							
Description		<p>The thematic strategy on the urban environment outlined the need to develop a common methodology at European level for evaluating the overall sustainability performance of building and construction, including their life-cycle costing. It was felt that the construction sector and its clients (and, in particular, public procuring authorities) could help improve the sector's environmental performance and realise potential cost savings by concentrating on the early integration of environmental considerations in the construction cycle.</p> <p>It was recommended the development and adoption of a common European methodology for LCC in construction taking into account the work done under international standard ISO 15686.</p> <p>The scope of this study was therefore identified <i>as providing an analysis and evaluation of the different national approaches for LCC, as well as elaborating an approach for the estimation of Life Cycle Costs and related indicators for buildings and constructed assets which could be of added value at EU level.</i></p>					
Involved parties		David Langdon Management Consulting					
Year		Ended in 2007					
Geographical and building characteristics							
Building		Climate zone, Location	Typology	Type	Scale		Stage
Kuopio House	Taxation	Northern-Europe, Finland	Office: low-rise	Renovation	-		In-Use
Meaux Centre	Shopping	Central-Europe, France	Retail	New-build	GUA 70.000 m <sup>2</sup> . 42.000 m <sup>2</sup> of green/entertainment space		Design
Kempkensberg Project		Central-Europe, Netherlands	Office: high-rise	New-build	GA 46.850 m <sup>2</sup> . 12.000 m <sup>2</sup> garden		Design
	Rikshospitalet	Northern-Europe, Norway	Health, hospital	New-build	GA 100.000 m <sup>2</sup> subdivided in different functional areas		Design
New House	Opera	Northern-Europe, Norway	Culture	New-build	GA 40.000 m <sup>2</sup> subdivided in two parts audience and production.		Design
	Uppsala Entrance	Northern-Europe, Sweden	Residential	New-build	7 buildings, 90 apartments		Design
	Southampton City College	Central-Europe, UK	Education	Combination of refurbishment and new build	New build: hub building 3-storey block, block 2 3-storey teaching building and service single-storey building Refurbishment: block B theatre and block E 3-storey		Design
Wandsworth Bridge Primary Centre	Road Care	Central-Europe, UK	Health	Renovation	-		In-Use
	Steletova 8 Housing	Southern-Europe, Slovenia	Residential	Renovation	3.800 m <sup>2</sup> net floor area, 60 apartments		In-Use
<p>The selected case studies refer only to the buildings, not the infrastructure ones, such as the motorway in the Netherlands. The focus is on residential and offices however the methodology employed for the cultural and health buildings was also looked into in this collection of information.</p>							
Relevant professional context							
<b>Collaborative EU projects with a relevant focus</b> <p>It was recommended the development and adoption of a common European methodology for LCC</p>							

in construction taking into account the work done under international standard ISO 15686. In 2006 the European Commission appointed Davis Langdon from the UK to undertake a project to develop a common European methodology for Life Cycle Costing (LCC) in construction. A key objective of this Communication is to address the obstacles to the uptake of Green Public Procurement (GPP), of which one is lack of information on life cycle costing of products.

#### **Building permitting in member states**

The literature review done in this study can serve for a cross-check for this regulatory context (as it describes the policy context in member states). Attention to be paid to the eventual changes from the reviewed situation, due to evolutions in methodologies and legislation.

## **18.2 MACRO-OBJECTIVE B5: OPTIMISED LIFE CYCLE COST AND VALUE**

### **18.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL**

#### **→ Aspects covered of the macro-objective**

- Life cycle cost

#### **→ Improvement option(s)**

The LCC calculations can be performed with different objectives in mind:

1. Choice of materials, components or systems and assessment of their financial implications.
2. Inform strategic decisions such as new build or refurbishment.
3. Outline business cases
4. Procurement, environmental and assessment of future costs purposes. Likely maintenance, operation and management costs. Post competition evaluation to assess the proposed solutions.
5. Retrospective comparison of actual operational costs in relation with original LCC assessment

#### **→ Methodologies, evaluation tools and/or standards used**

Two briefing workshops were organized for the LCC specialist to, amongst other goals, agree in applying the common EU LCC Methodology.

Methodology used	Evaluation tools used	Standards used	Project / case study
Simplified EU LCC Methodology.	-	ISO 15686	Kuopio Taxation House, Finland
EU LCC Methodology	Excel base model	ISO 15686 Part 5	Meaux Shopping Centre, France
	RDG's DCF/LCC model.	Investment options assessed by the Discounted Cash Flow method and RGD used its own calculation methods and databases for service life/maintenance Costs breakdown structure NEN 2634 for construction and NEN 2748 for	Kempkensberg Project, Netherlands



EU LCC Methodology		operational costs	
	-	Norwegian national standard classification system NS3454 and three levels of LCC calculation defined	Rikshospitalet, Norway
	Currently being developed a web based tool from an excel based tool		New opera house, Norway
	-	ISO 15686 Part 5	Steletova 8 Social Housing, Slovenia
	<a href="http://www.edkalkyl.se">www.edkalkyl.se</a>	ISO 15686 Part 5	Uppsala Entrance, Sweden
	-	BCIS cost breakdown BS ISO15686-5	Southampton City College, UK Wandsworth Bridge Road Primary Care Centre, UK

#### Detailed discussion:

The EU LCC Methodology is the common methodology developed within the project. The diagram flow is shown in Figure 8. The methodology can be summarized in 15 steps represented in Figure 9. Steps 10, 12 and 13 are not compulsory.

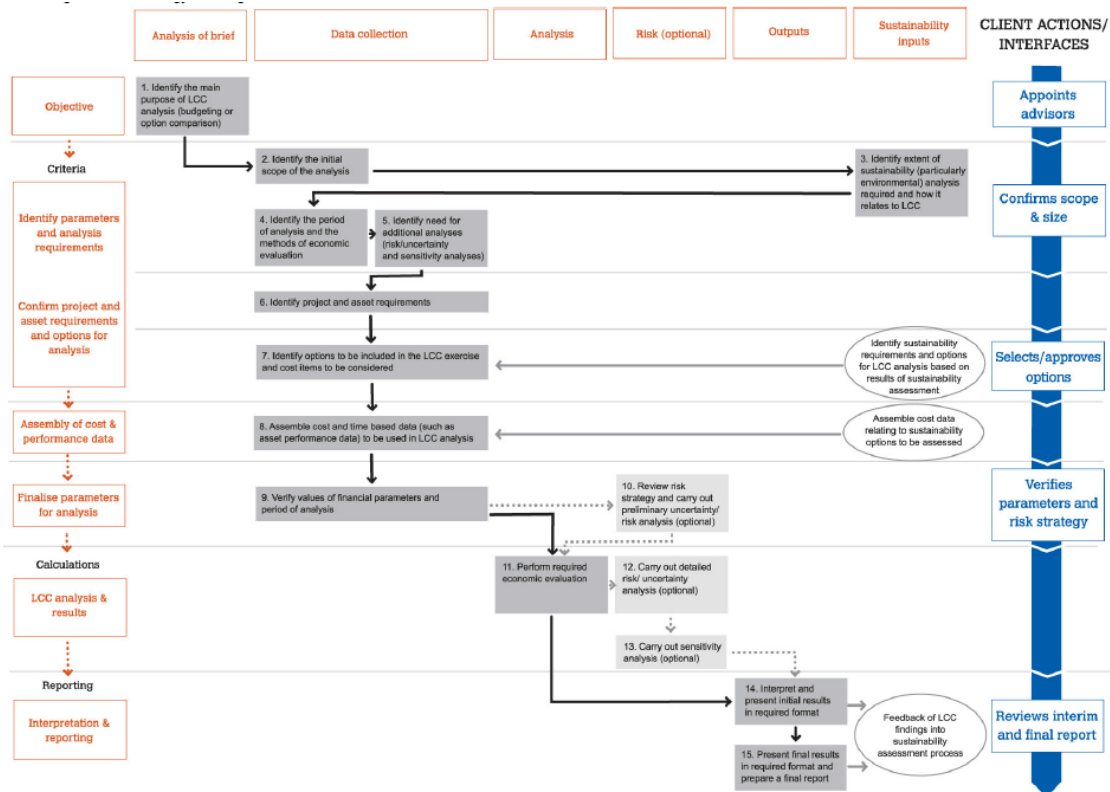


Figure 8: Methodology flow diagram

STEP	OUTCOME / ACHIEVEMENT
1 Identify the main purpose of the LCC analysis	Statement of purpose of analysis Understanding of appropriate application of LCC and related outcomes
2 Identify the initial scope of the analysis	Understanding of: Scale of application of the LCC exercise Stages over which it will be applied Issues and information likely to be relevant Specific client reporting requirements
3 Identify the extent to which sustainability analysis relates to LCC	Understanding of: Relationship between sustainability assessment and LCC Extent to which the outputs from a sustainability assessment will form inputs into the LCC process Extent to which the outputs of the LCC exercise will feed into a sustainability assessment
4 Identify the period of analysis and the methods of economic evaluation	Identification of the period of analysis and what governs its choice Identification of appropriate techniques for assessing investment options
5 Identify the need for additional analyses (risk/uncertainty and sensitivity analyses)	Completion of preliminary assessment of risks/uncertainties Assessment of whether a formal risk management plan and/or register is required Decision on which risk assessment procedures should be applied
6 Identify project and asset requirements -	Definition of the scope of the project and the key features of the asset Statement of project constraints Definitions of relevant performance and quality requirements Confirmation of project budget and timescales Incorporation of LCC timing into overall project plan
7 Identify options to be included in the LCC exercise and cost items to be considered	Identification of those elements of an asset that are to be subject to LCC analysis Selection of one or more options for each element to be analysed Identified which cost items are to be included
8 Assemble cost and time (asset performance and other) data to be used in the LCC analysis	Identification of: All costs relevant to the LCC exercise Values of each cost Any on-costs to be applied Time related data (e.g. service life/maintenance data)
9 Verify values of financial parameters and period of analysis	Period of analysis confirmed Appropriate values for the financial parameters confirmed Taxation issues considered Application of financial parameters within the cost breakdown structure decided
10 Review risk strategy and carry out preliminary uncertainty/risk analysis	Schedule of identified risks verified Qualitative risk analysis undertaken – risk register updated Scope and extent of quantitative risk assessment confirmed
11 Perform required economic evaluation	LCC analysis performed Results recorded for use at Step 14
12 Carry out detailed risk/uncertainty analysis (if required)	Quantitative risk assessments undertaken Results interpreted
13 Carry out sensitivity analyses (if required)	Sensitivity analyses undertaken Results interpreted
14 Interpret and present initial results in required format	Initial results reviewed and interpreted Results presented using appropriate formats Need for further iterations of LCC exercise identified
15 Present final results in required format and prepare a final report	Final report issued, to agreed scope and format Complete set of records prepared to ISO 15686 Part 3

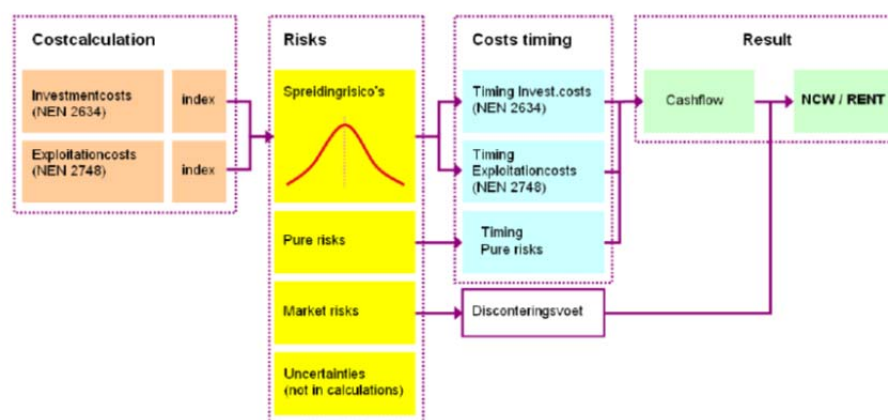
Figure 9: Summary of the methodology 15 Steps.

**Finland, Kuopio Taxation House:** The methodology was used on a simplified basis in order to ensure harmony in content. Generally, the challenges faced in applying LLC are the attitudes towards use of life cycle criteria and life cycle costing. The aim was to compare traditional and integrated HVAC systems. The data included investment costs of the HVAC systems, heating energy costs over 15 years, cooling energy costs over 15 years, electricity costs over 15 years, maintenance costs over 5 years because the owner wants to have a new tender after that time. The LCC analysis covered a period of 15 years which is both rental time and estimated removal time of HVAC systems.

**France, Meaux Shopping Centre:** This case study illustrates how the methodology can be adopted to inform the client of the impact of investment costs on maintenance costs by taking into account the environmental performance of materials. The EU LCC Methodology fits well with the LCC practice in France. Results were not available at the time of concluding the report. Information sourced through focused research and private databases.

**Netherlands, Kempkensberg:** Although the EU LCC methodology is not currently adopted by the NEN community, it did not cause any problems. The EU methodology fits with the Dutch methodology. The LCC assessment was used to inform the strategic decision making process and to achieve the economically most advantageous tender – value for money. The time scale for the LCC was 25 years and the analysis was applied over the contract period of the building (20 years). Periodical risk assessment, and Monte Carlo simulation of the alternative option were required as part of the tender process.

The LCC model was RDG's DCF/LCC model. See figure below:



**Norway, Rikshospitalet:** The EU LCC methodology was easy to use and it was used to show how the methodology can be applied retrospectively to compare actual operational costs in relation to the original LCC assessment (done using the Norwegian Standard NS 3454). The methodology fits well with the LCC process used in Norway.

**Norway, Opera House:** the EU LCC methodology was applied to establish the maintenance and repairs work for a public cultural building and then check this expenditure against actual costs. The goal for the LCC analysis was to produce costs estimates of likely Maintenance Operation and Management costs over 60 and 150 years taking into account the design choices made (e.g. differences between different external envelope of the building). The two life span showed little difference. The real discount rate was 6%. LCC calculations were carried out for all materials, elements, systems etc.

**Sweden, Uppsala Entrance:** the EU LCC methodology was applied to assess the financial implications of systems and components. The EU LCC methodology corresponds with the common LCC methodology in Sweden. The LCC was used at early design stage to identify the right actions to reduce the use of energy, choose the most efficient heating and cooling system, and to choose the windows that provided most sun protection. This study examined the available technologies to produce renewable energy in or on buildings located in urban environment. The key issue was to assess how the investment and operating costs of different systems and components impacted on the sale price of the residential units. The timescale for the LCC is 30 years to match that of the most common solution in Sweden for district heating. No risk/uncertainty or sensitivity analyses were performed. When the energy system considered had a shorter lifespan than the calculation period, an initial investment for the remaining time was added as a periodic maintenance cost.

**UK, Southampton City College:** The methodology is used to support an outline business case and become a key component in the design and construction decisions. The EU LCC methodology captures the same issues within the UK LCC analyses. The initial results for the LCC were benchmarked against an extensive database of similar projects, with appropriate analysis undertaken.

**UK, Wandsworth Bridge Road Primary Care:** EU LCC methodology was used to inform a new build or refurbish strategic decision. The LCC costs for a new build and a full refurbishment were examined in combination with the expected capital costs in order to determine the “whole life cost” of the two options. The LCC consisted of detailed life cycle replacement (LCR) models and outlined the potential costs of components and assets over time. The LCR models were based on a period of 25 years in order to benchmark the project costs in line with the current market and over 60 years in order to mirror the LCR over the assumed life of the facility. The cost plan was updated regularly along with the design information, resulting in accurate build-up of LCC models. LCC analysis incorporated life cycle replacement costs of the building, along with the energy consumption and water costs. It did not include sustainable options or sustainability assessment for the building. Energy and utility costs were based on the predicted annual consumption of the building and the costs per unit that the centre was paying.

**Slovenia, 8 Social Housing:** This case study illustrates how the EU LCC methodology could be used during post competition evaluation to assess the energy efficiency solutions used for a low carbon refurbishment project. The EU LCC methodology was easily applied however, the database for LCC costs for early stage of design was only partly available. The service life of components and information on maintenance costs are problematic to obtain. Two time periods were taken into account: 30 years due to the life time of most of building elements in the refurbishment project and 60 years due to life time requirements for residential building in regulations.

#### 18.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

##### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Net present value	NOK, €, Kr, £	Investment, operation and maintenance A1 - A5, B1 – B7	B6: Optimized life cycle cost and value

→ **Indicator #1: Net present value**

- *Macro-objective*: B6: Optimized life cycle cost and value
- *Specific aspect(s)*: Life Cycle Cost (LCC)

**Technical specifications**

- Unit of measurement: NOK, €, Kr, £
- Scope of indicator: Discounted annual costs
- Life cycle stage (with reference to EN 15643): A1-A5, B1-B7 use stage
- Midpoint(s) and/or parameters: Not applicable for LCC.
- Functional unit: Per building or buildings according to the case study.
- Associated data requirements: See methodology [table above](#).
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*)
- Supporting tools required to quantify/estimate performance: See methodology [table above](#).
- Source of indicator/metric and its scientific and market acceptance: Following ISO 15686-5 standard headlines.

**Results**

Overview and results:

Case study	Objective
Kuopio Taxation House, Finland	Two energy saving solutions investigated. Assessment of the best HVAC option
Meaux Shopping Centre, France	Inform the choice of materials during design process. No results available at the time of finalizing the report.
Kempkensberg Project, Netherlands	Used for procurement, environmental and assessment of future costs purposes.
Rikshospitalet, Norway	Retrospectively to compare actual operational costs in relation to the original LCC assessment
New Opera House, Norway	The goal was to produce costs estimates of likely Maintenance Operation and Management costs over 60 and 150 years taking into account the design choices made
Uppsala Entrance, Sweden	To assess the financial implications of systems and components.
Southampton City College, UK	Outline business case and become a key component in the design and construction decisions
Wandsworth Bridge Road Primary Care Centre, UK	To inform a new build or refurbish strategic decision.
Steletova 8 Social Housing, Slovenia	Post competition evaluation to assess the energy efficiency solutions used for a low carbon refurbishment project.

Detailed discussion:

**Finland, Kuopio Taxation House:** The figure below shows the input data and the results of the three LCC calculations. A key aim was to test the advantage by the two energy saving solutions investigated (integrated and traditional HVAC). Both investment and life cycle costs for the solution integrated B came up under by almost 10%.

**Kuopio Taxation house**

Company: Senate Properties

Contact person: Sakari Pulakka

Period: 15 years

Cost level: 7/2009

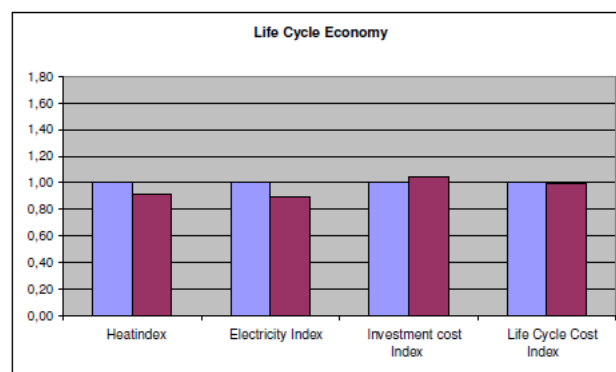
	Tradit: A	Integrated: B	Integrated: C
<b>ENERGY CONSUMPTIONS MWh</b>			
Electricity consumption	98	89	90
Heating energy	791	716	798
Facility electricity	233	217	218

**ECONOMICAL EFFECTS (VAT = 0)**

Investment cost	1 535 000	1 605 000	1 815 200
Maintenance cost (5 y)	147 500	135 000	136 800
Heating energy cost	391 500	354 400	394 000
Facility electricity cost	251 600	234 400	235 400
Lighting energy cost:	105 800	96 100	97 200
Resale value	0	0	0
<b>Life Cycle Cost</b>	<b>2 431 400</b>	<b>2 424 900</b>	<b>2 679 600</b>

**ECONOMY**

Heatindex	1,00	0,91	1,00
Electricity Index	1,00	0,89	0,99
Investment cost Index	1,00	1,05	1,15
Life Cycle Cost Index	1,00	1,00	1,10



**Netherlands, Kempkensberg:** The costs relevant to the LCC exercise were the investment costs (included building costs and supplementary costs), as well as the costs and profit during operational and possible reminder value.

The values of each costs were:

The values of each cost were:

- Investment costs: 130 million euros
- Operational costs: 50 million euros

	millions €	%
Investment	130	72
Operation	50	28
NPV	180	100
Excess value:		6%

The on-costs applied were:

- Costs for architects and advisors 18%
- Art 1%
- Development costs 4,6%
- Fees 2%
- Incidental outgoings / Risks 13%
- Interest for lot 0%
- Interest for building 3,86%

The initial results of the LCC indicated that DBFMO (Design Build Fund Maintain Operate) / PPP was very suitable (economically and qualitative).

**Norway, Rikshospitalet:** The analysis considered NPV in accordance with NS3454 for 60 year service life period. The LCC calculations are:

- Level 1: concept stage. LCC is a general assessment typically based on building costs multiplied by factors or based on key indicators of costs (per m2)
- Level 2: Key performance indicators. LCC is calculated based on defined quality and standard requirements for the building.
- Level 3: building component. LCC is used to evaluate different alternatives (elements, systems, components, materials etc)

Risk analyses were carried out on this project for frequencies of maintenance, real interest discount rates, service life periods etc

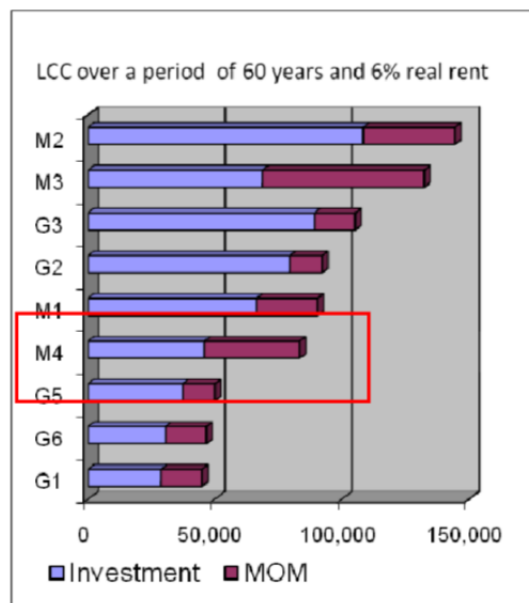
Results are shown in the table below:

	Estimate Level 1 jan 90	Estimate Level 2 jun 90	Detailed analysis of RH's accounts jul 90		Calculation June 3 1993		
			MC	MD	Project documented Level 3	Statsbygg estimate	corrected calculation
<b>2 Management</b>		<b>70</b>	<b>61</b>	<b>180</b>	<b>49</b>	<b>49</b>	<b>66</b>
21 Taxes etc.					49	49	49
22 Insurance							
23 Administration							9
<b>3 Operation</b>		<b>420</b>	<b>486</b>	<b>420</b>	<b>406</b>	<b>345</b>	<b>388</b>
31 Drift og ettersyn		90	129	12	102	41	54
32 Cleaning		180	245	268	184	145	184
33 Energy		150	112	112	122	160	150
<b>4 Maintenance</b>		<b>110</b>	<b>312</b>	<b>324</b>	<b>141</b>	<b>120</b>	<b>164</b>
41 Running					6		11
42 Periodic		55	143	155	51	60	69
43 Replacements		55	169	169	84	60	78
<b>Sum MOM</b>	<b>660</b>	<b>600</b>	<b>849</b>	<b>924</b>	<b>606</b>	<b>515</b>	<b>619</b>

The LCC exercise identified a difference in maintenance costs between the initial calculation and actual accounts. This was primarily due to the fact that the accounts costs for maintenance also included minor refurbishments. This work has led to a revision of NS 3454 in year 2000.

**Norway Opera House:** The following main costs were calculated: administration, operation, maintenance, consumption, cleaning. The LCC assessment included risk analysis to reflect the frequency of maintenance and repair solutions, real interest rates, service life periods etc. The LCC analysis estimated the cost consequences of the choices made over the two periods of time (60 and 150 years).

One of the LCC exercises involved a comparison between different stone alternatives of the external envelop of the building. The figure below shows that marble (M4) was chosen instead of granite (G5) although the MOM costs and total costs were higher than for granite. This decision was made because the architectural intention was to have a totally white opera house and in this case, this criterion was more important than the cost.



The following main costs were calculated: administration, operation, maintenance, consumption and cleaning.

**Sweden, Uppsala Entrance:** The LCC was used to evaluate systems options. A key issue was to assess how the investment and operating costs of different systems and components impacted the sale price of the residential units. The costs considered were investment costs, new investment costs (needed when the lifespan of the system was shorter than 30 years), maintenance, cost of energy bought and income of energy sold. NPV were calculated for the different sources of energy considered. The results are shown in the figure below:

	District Heating	Pellets (2 sup.)	Air thermal solar collect (1 lev.)	Flat therm. solar collect (1 lev.)	Combined solar collector/suncells (1 lev.)	HAWT (1 lev.)	VAWT (1 lev.)	Silicon Suncells (2 lev.)
Investment cost	150 000	1 050 000 (200 kW)	428 000 (41 kW)	462 000 (110 kvm)	630 000 (100 kvm)	665 000 (25 kW)	600 000 (25 kW)	540 000 (200 kvm)
Annual maintenance cost	5000	11 000	9100	9100	7000	10000	9000	9000
New investment cost	0	525 000 kr (20 år)	278 000 kr (12 år) 139 000 kr (24 år)	312 000 kr (15 år)	96 000 (25 år)	258 000 kr (20 år)	90 000 kr (25 år)	0
Technical lifespan/calculationperiod (year)	30	20/30	12/30	15/30	25/30	20/30	25/30	30
Produced heat (kWh/year)	0	361 000	61 000	49 000	24 300	0	0	0
Purch. värme (kWh/year)	361 000	0	300 000	312 000	336 700	361 000	361 000	361 000
Produced electricity for internal use (kWh/year)	0	0	0	0	6000	20 000	20 000	22 000
Produced electricity sold ext. (kWh/year)	0	0	0	0	0	10 000	5 000	0
Köpt el (kWh/år)	32 000	32 000	32 000	32 000	26 000	12 000	12 000	10 000
Total present cost (kr)	5 121 000	6 075 000	5 045 000	5 139 000	5 254 000	5 239 000	5 121 000	5 028 000
Energy cost per produced/bought kWh (kr/kWh)	0,63 (0,63)	2,34 (0,63)	0,57 (0,63)	0,65 (0,63)	0,83 (0,63)	0,75 (0,63)	0,63 (0,63)	0,53 (0,63)

The results showed that there are good opportunities to use these sources of energy.

**UK, Southampton City College:** As the results of the exercise were refined, more detailed interpretation of the results and their comparators were undertaken. The LCC analysis included a 30 year appraisal period for the business case and a 60 year appraisal period for the option appraisals and feasibility studies. Information on energy costs and efficiency of the renewable technologies was created using a dynamic modelling system by the contractor's engineers. The assessment of the suitable renewable technologies included the life cycle costs associated with the



technology as well as the energy efficiency and carbon saving to develop a 'whole life' picture and assess the most suitable sustainable option for the project. The LCC analysis was used for both the assessment of environmental options and the assessment of future costs in line with the overriding business case.

The BCIS cost breakdown consists of 6 categories:

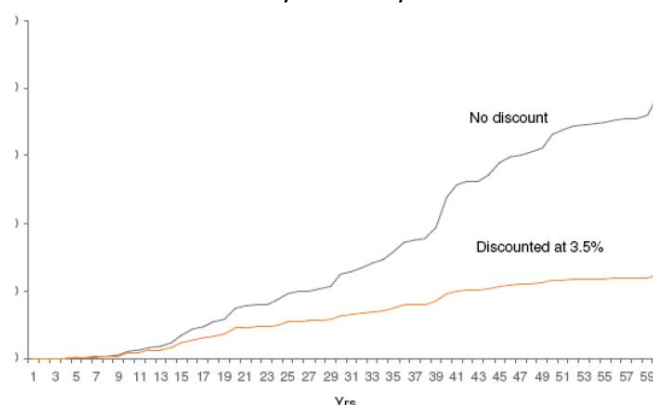
- substructure,
- superstructure,
- finishes,
- FF&E,
- services and external works.

Three phases of refurbishment and new build reconstruction were included in the LCC analysis. All the costs and elements included in the Bills of Quantities were included in the LCC. The costs relevant to this LCC exercise were the capital and renewal costs, based on a price per unit of measurement (i.e. £ / m<sup>2</sup>) and the utility costs, in the form of energy consumption data and unit costs. (i.e. £ / kWhr). The on – costs applied to the model included:

- Strip Out / Preparation allowance
- Existing Building / Out of Hours allowance
- Preliminaries allowance
- Overhead & Profit allowance
- Design Reserve allowance
- Contingency allowance

The predicted life expectancy of components and systems was used in order to generate the life cycle costs. Industry standard data, manufacturers' guidance / warranties and Davis Langdon's benchmarks / experience were used for these figures. The payback period for the renewable technologies included this data and the expected energy savings / consumption that were driven by the project engineers' energy models.

The graph below shows the cumulative 60 year life cycle cost in real and discounted terms.



**UK, Wandsworth Bridge Road Primary Care:** The costs of relevance to this LCC exercise were the capital and renewal costs, based on a price per unit of measurement (i.e. £ / m<sup>2</sup>) and the utility costs, in the form of energy consumption data and unit costs. (i.e. £ / kWhr). The on – costs applied to the model included:

- Strip Out / Preparation allowance
- Existing Building / Out of Hours allowance
- Preliminaries allowance
- Overhead & Profit allowance
- Design Reserve allowance

- Contingency allowance

The following costs were not considered within the model:

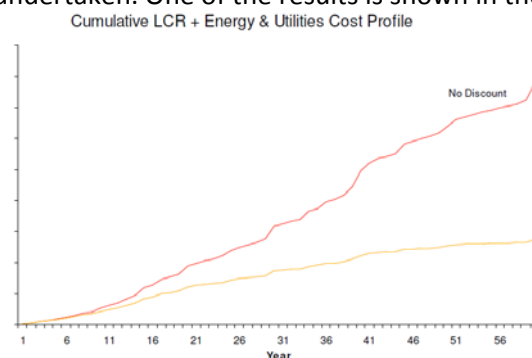
- VAT
- Taxation and Capital Allowances
- Works not currently in the model, due to future remodelling, extension etc
- Works due to future legislation coming into force after this model was prepared
- Professional fees
- Insurances and rates
- Ongoing costs including decommissioning of the building beyond the end of the

25 Year Life Cycle assessment

- Out of hours premium
- ICT Equipment unless specifically covered in the cost plan
- Loose furniture unless specifically covered within the cost plan
- The model does not take into consideration any allowances or costs for vandalism

The predicted life expectancy of components and systems was used in order to generate the life cycle costs. Industry standard data, manufacturers' guidance / warranties and Davis Langdon benchmarks / experience were used for these figures. The cost data was sourced from the capital costs contained within the cost plans.

The initial results for the LCC were benchmarked against an extensive database of similar projects, with appropriate analysis undertaken. One of the results is shown in the graph below:



**Slovenia, 8 Social Housing:** The LCC analysis took into consideration the following facts:

- Cost data available were based on estimated costs based on the designer's proforma refurbishment cost information
- Detailed information on the structure of investment costs was not available due to lump sum contract used (discussion for acquisition of detailed structure of actual costs for research purposes available from contractor are currently under way)
- In spite of the fact that energy consumption readings before and after refurbishment were available, the energy modelling and calculations were done without complete information on the actual users' profile.

The client required a comparison analysis of several refurbishment scenarios over 30 and 60 years life time, expressed in NPV. The costs for these alternatives had to be divided into operational costs (paid by tenants) and maintenance costs (paid by the Housing Fund).

Sensitivity analysis investigated the effect of: building life time (1-60 years), interest rate (2,5%-10%), inflation rate (0-5%) and increase energy price (6-10%).

Several scenarios were evaluated due to integrated planning of renovation. The scenario adopted for this project proved not to be the most economically viable one. See table below:

Scenarios	QNH (kWh/a)	CO2 emissions (kg CO2/a)
VAR 1	332.361	173.293
VAR 2	332.361	173.293
<b>VAR 2a*</b>	<b>244.990</b>	<b>127.738</b>
VAR 3	266.547	138.978
VAR 4	154.663	80.641
VAR 5	85.558	44.610
<b>VAR 5a**</b>	<b>181.150</b>	<b>94.452</b>
VAR 6	197.442	102.946

\*measured »before 2006/2007«

\*\* measured »after 2008/2009«

The LCC exercise was carried out after the investment was completed and was not therefore a parameter for decision making. Due to the type of the building contract used, detailed information on the structure of investment costs (per element of refurbishment) was not available. Consequently also the determination of maintenance and replacement costs was less reliable.

The following elements were evaluated: envelope insulation, exchange of windows, and installation of mechanical ventilation with heat recovery (scenarios were created based on these basic elements). Eight scenarios were analysed based on these elements of major refurbishment, including users' behaviour.

Life time of elements and frequency of regular maintenance were the time related data used. The performance data were obtained by energy simulation and by measured energy consumption, the energy costs were calculated based on that. Maintenance costs were determined according to the national regulation on maintenance of residential buildings (unfortunately this database is very general and does not cover new technologies) and based on the cost of particular building element. The cost of element was obtained based on the data base for Slovenian construction sector. The sources of information used were the design documentation, actual energy consumption, regulation on maintenance of residential buildings, EPBD regulation, statistical data on investment costs, database for investment assessment, EIE LCC DATA database, National energy plan, NEEAP 2008-2016 as well as direct contact with providers of building products, designers, energy expert and building owners.

The interest rate used was assumed as required for public investments and varied. The inflation rate was sourced from the national data. Energy prices were assumed according to national energy scenarios. The generalized prices were taken from data bases available at Construction chamber. Taxation was not considered. Capital cost was considered as instant cost and was thus not discounted.

The need for additional iterations was assessed based on periodic discussions about the several aspects of LCC results and influencing factors. Eight scenarios were analysed with up to 3 iterations in general in order to do the fine tuning of LCC model. An LCC model for system level (level 2) was used in this case study.

The LCC results were interpreted by NPV of the scenarios analysed over the life time of a project (in € and €/m2a). The tables below show the NPV of refurbishment scenarios in relation to the building lifetime.

Building life time	VAR1	VAR2	VAR2a	VAR3	VAR4	VAR5	VAR5a	VAR6
30	€ 475.485	€ 787.762	€ 676.847	€ 1.106.106	€ 636.299	€ 960.269	€ 1.071.713	€ 582.766
60	€ 1.024.328	€ 1.336.605	€ 1.110.974	€ 1.599.800	€ 896.762	€ 1.172.425	€ 1.427.608	€ 892.864

For the lifetime of 30 years the lowest NPV is obtained in renovation scenario VAR4 and VAR6 (envelope insulation, windows, but no mechanical ventilation with heat recovery, for both cases with minor differences). For the life time of 60 years the most economically viable scenarios do not differ, but it can be also seen, that the investment in VAR 4 and/or VAR 6 pays out with the energy savings in comparison with the initial scenario VAR1 in 48 years (replacement of elements is needed after 30 years). The actually implemented scenario VAR5 (also mechanical ventilation with heat recovery) that brings also better thermal comfort (not financially evaluated), has an average NPV value of € 1.172.425. If mechanical ventilation with heat recovery is not properly used and/or not installed in all parts of the building (as demonstrated by measured energy use in case VAR5a) than the NPV of renovation measures is increased to € 1.427.608.

This LCC case study covers the aspect of the investor and does not include the impact of external costs (CO2 costs, thermal comfort, and value of the existing building stock).

#### ***Cross-links and trade-offs between other macro-objectives***

- Which aspect of performance does the trade-off relate to? B1: Greenhouse gas emissions from building life cycle energy use,

What is the quantifiable impact on performance? See results of the **Slovenia, 8 Social Housing**

- To what extent can it be mitigated?

### **18.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

#### **→ Project processes**

Due to time constraints, the methodology could not be applied fully on all projects (from business case through to completion and in use). However, the case studies in their entirety cover all steps of the methodology.

The general feedback is that the methodology was very useful for the case studies and its steps fitted well within existing LCC practices in the countries analysed. No instances were found where the methodology could not be applied because of its unsuitability. The instances where the methodology could not be applied precisely were mainly in countries where LCC use is not sufficiently matured.

The methodology could be applied to all different types and sizes of projects. For smaller project or for projects where LCC is applied purely for systems or component evaluation, the methodology can be applied in a simplified way to reflect the lower level of complexity of the issue investigated.

The application of the methodology suggests that during the 'in use' phase, there appears to be a certain 'optimistic' approach in the way LCC is applied at initial stages of projects that leads to inaccurate assumptions for maintenance and operational costs. This is primarily due to lack of real data from operational assets to input into the LCC calculations but also relates to the way buildings or systems are used in real life. Initially, the application of the methodology at this stage was originally considered 'too mature' in relation to the level of use for LCC across Europe and it wasn't a key target.

Since some of the case studies could not disclose the full results of LCC analyses, it is difficult to generalise the financial impact that an LCC approach has on projects. However some case studies show that life cycle cost savings can be achieved. It is important to note that in order to get a true reflection of the impact of the LCC approach, a post completion evaluation needs to be carried out.

→ **Evaluation of project experience using the indicator(s)**

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?
  - . Detailed guidance documents are drafted.
  - Was the expertise already available within the design team/other project actors?
    - Case studies were performed by experts in the field from different countries.
  - How clear/informative was the associated guidance material?
    - Informative material was clear.
- How readily available were the tools, data, test facilities etc.. required to use the indicator?
  - Not always specified which tools were employed in each case study. Sometimes, data is not easy to find. This situation has been indicated in the specific cases' description
  - How reliable and/or comparable was the data and/or test methods used?
    - The methodology employed is the same one for all the case studies since it is the methodology developed within the project. However data and results are difficult to compare due to the sometimes confidentiality or the presentation in the report.
  - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*
    - Not applicable
- How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?
  - Was it suitable for the evaluated buildings? *If no, what issues arose?*
    - . The methodology was proven useful for the different objectives of the case studies. See [table above](#).
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*
- How time and cost intensive was the use of the indicator?
  - .Not mentioned.
  - How easy was it for the auditor/assessor to verify performance?
    - .Not applicable.

Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*  
*If available, post occupancy evaluation findings and issues identified e.g. performance gaps*

### 18.3 REFERENCES

Davis Langdom (2007), Life Cycle Costing (LCC) as a contribution to sustainable construction: a common methodology, final methodology.

Davis Langdom (2010), Development of a promotional campaign for life cycle costing in construction.

## 19 FS 17. LCC DATA

### 19.1 FACT SHEET

General information					
Description	The LCC-DATA project aimed at easing and extending the use of Life Cycle Costs Analysis (LCCA) in the construction industry and hence improve the decision-making process towards more sustainable buildings. In more practical terms, the project aimed at developing a <b>web-based database for benchmarking buildings' in-use costs</b> (operation, maintenance, management, energy, etc) in order to ease LCC calculations. Using benchmarking for performing LCCA can indeed be very valuable as usual LCC analysis are often too time-demanding or too complex for the market actors (e.g. architects, engineers, large property owners).				
Involved parties	SINTEF (Norway), <a href="#">Österreichische Energieagentur</a> (Austria), <a href="#">CITYPLAN spol. s.r.o.</a> (Czech Republic), <a href="#">Berliner Energieagentur GmbH</a> (Germany), <a href="#">Centre for Renewable Energy Sources</a> (Greece), <a href="#">Building and Civil Engineering Institute ZRMK</a> (Slovenia)				
Year	Ended in 05/2009				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Vestfold University College	Northern-Europe, Norway	Office: mid-rise	New-build	2 storeys, offices, auditoriums, library	Design
Sogn of Fjordane University College	Northern-Europe, Norway	Office: low-rise	New-build	3 storeys, offices, auditoriums, cafeteria	Design
Elementary school “Vrchlickeho”	Central-Europe, Czech Republic	Office: low-rise	Renovation	Gross area 5.185 m <sup>2</sup> . Main building and gym	In-Use
CRES main office	Southern-Europe, Greece	Office: low-rise	Renovation	2 storeys, offices, reception area, meeting rooms	In-Use
CRES bioclimatic office	Southern-Europe, Greece	Office: low-rise	Renovation	2 storeys. 529 m <sup>2</sup> gross area. office areas, library and small meeting room	In-Use
GSIS – Ministry of Finance and economics	Southern-Europe, Greece	Office: low-rise.	Renovation	4 storeys, 4.800 m <sup>2</sup> per floor. 30.000 m <sup>2</sup> gross area.	In-Use
Os Frana Albrehta and OS Toma Brejca in Kamnik	Southern-Europe, Slovenia	Office:	New-build	Two buildings one with 4.867 m <sup>2</sup> and other with 4.749 m <sup>2</sup> net floor area	Design
Apartment building	Southern-Europe, Slovenia	Residential: Apartment building	New-build	2 wings, 4 storeys and penthouse flat. Garages and wellness center with swimming pool and sauna in the ground floor	Design
Social housing Steletova	Southern-Europe, Slovenia	Residential: apartment building	Renovation	5 storeys, 3.800 m <sup>2</sup> net floor area, 60 flats	In-Use
TECHbase	Central-Europe, Austria	Office: low-rise	Renovation	Rentable floor area of 12.500 m <sup>2</sup> of which 7.500 m <sup>2</sup> is used as office area	In-Use
BRC	Central-Europe, Austria	Office: medium-rise	Renovation	7 storeys. Rentable floor area 5.110 m <sup>2</sup>	In-Use
Mariahilfer Strasse	Central-Europe, Austria	Office	Renovation	7 storeys. Rentable floor area 3.600 m <sup>2</sup> in 6 floors. Shopping mall	In-Use

				in the ground floor. Two parking floors underground..			
Justice_1	Central-Europe, Germany	Office	Renovation	7 buildings.	136.432 m <sup>2</sup> net	In-Use	
Culture_1	Central-Europe, Germany	Offices and museum	Renovation	15 properties.	79.165 m <sup>2</sup> net	In-Use	
School_1	Central-Europe, Germany	Schools	Renovation	9 properties.	School and gym buildings. 92.692 m <sup>2</sup> net	In-Use	

These specific cases are chosen to illustrate the life-cycle costs related to the main categories of buildings (e.g. offices, hospitals, schools, etc.) with focus on the installed systems (e.g. heating and cooling applications, ventilation, etc.). [ref: D16&D17 Energy & LCC calculations]

### Relevant professional context

#### Collaborative EU projects with a relevant focus

*Further specifications:*

IEE co-funded project, with international consortium of partners.

There are a certain number of market barriers regarding LCCA and costs benchmarking, e.g. the lack of maturity of the construction and property industries regarding the use of LCCA and costs benchmarking. In addition, building owners, as well as Facility Management organisations, are often reluctant to share their financial data.

LCC Data showed that reasonably accurate results can be obtained in early phase by using key numbers or "rules of thumb" for LCCA.

## 19.2 MACRO-OBJECTIVE B5: OPTIMISED LIFE CYCLE COST AND VALUE

### 19.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

- Life cycle cost

#### → Improvement option(s)

In general, it is mentioned in several study cases that for further reliable LCC calculations, it is important to enlarge the data amount in the databases and therefore obtain more reliable key-figures for future LCC level 1 calculations.

#### → Methodologies, evaluation tools and/or standards used

Methodology used	Evaluation tools used	Standards used	Project / case study
Level 1 LCC analysis by using statistic information (key-figures generated from the database built in the project)	LCProfit and national database for benchmarking	"NS 3454: 2000 Livssyklus-kostnader for byggverk. Prinsipper og struktur" describes the process for calculating LCC, the input/output, and the cost classification	<b>Norway</b> Vestfold University College and Sogn of Fjordane University College
	GEMIS	There is no directive for the calculation of costs in the Czech Republic	<b>Czech Republic</b> Elementary school "Vrchlickeho"
	LCProfit	There is no legislative framework on cost classification, no national system,	<b>Greece</b> CRES main office,

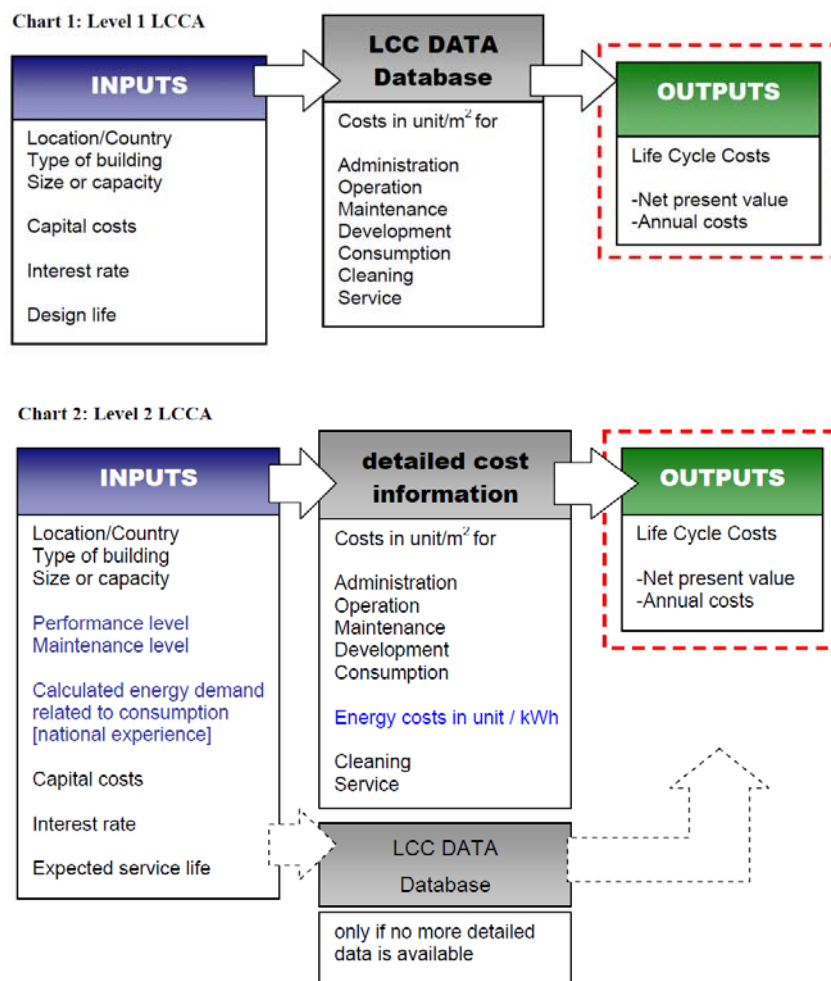
		and no legislation that imposes LCC calculations in Greece; however Public Private Partnership (PPP) and Energy Service Companies (ESCOs) approve that need and sets LCC as a principle parameter in the building industry.	CRES bioclimatic office, and GSIS – Ministry of Finance and Economics
	Not mentioned	LCC is voluntary	<b>Slovenia</b> Os Frana Albrehta and OS Toma Brejca in Kamnik  Apartment building  Social housing Steletova
	Not mentioned	Approach based on “ÖNORM B 1802” for the level 2 analysis of the case study buildings was used.	<b>Austria</b> TECHbase,  BRC, and  Mariahilfer Strasse
	Not mentioned	-	<b>Germany</b> Justice_1, Culture_1, and School_1
Level 2 LCC analysis by using project specific information.	LCProfit and national database for benchmarking	“NS 3454: 2000 Livssykluskostnader for byggverk. Prinsipper og struktur” describes the process for calculating LCC, the input/output, and the cost classification	<b>Norway</b> Vestfold University College and  Sogn of Fjordane University College
	GEMIS	There is no directive for the calculation of costs in the Czech Republic	<b>Czech Republic</b> Elementary school “Vrchlickeho”
	LC Profit	There is no legislative framework on cost classification, no national system, and no legislation that imposes LCC calculations in Greece; however Public Private Partnership (PPP) and Energy Service Companies (ESCOs) approve that need and sets LCC as a principle parameter in the building industry.	<b>Greece</b> CRES main office,  CRES bioclimatic office, and  GSIS – Ministry of Finance and Economics
	Not mentioned	LCC is voluntary	<b>Slovenia</b> Os Frana Albrehta and OS Toma Brejca in Kamnik  Apartment building  Social housing Steletova
	Not mentioned	Approach based on “ÖNORM B 1802” for the level 2 analysis of the case study buildings was used.	<b>Austria</b> TECHbase,  BRC, and  Mariahilfer Strasse
	Not mentioned	-	<b>Germany</b> Justice_1, Culture_1, and School_1



### Detailed discussion:

In this project two LCC calculations were performed. They are named as level 1 and level 2 LCC. For the level 1 LCC analysis, the created database within this project was used in the Czech Republic, Greece, Norway and Slovenia. In Austria the existing benchmark database (IBI-database) was used. In Germany an excel-file of refurbishment measures and costs for reducing the CO<sub>2</sub>-emissions of buildings was the basis for the analyses.

For the level 2 LCC analysis, the national rules were followed. The comparison with the level 2 analysis according to national rules will demonstrate the accuracy of its estimations and therefore the relevance of the used key-figures. The two charts below represent the difference between the level 1 and level 2 calculations.



In **Norway**, for the case of *Vestflod University College*. Project costs in 2003 and 2006 are used for level 1 calculations. The running costs used in level 1 are not adjusted for inflation so they are not comparable. Level 2 calculations are based on project costs from 2006. Further input are the energy and cleaning costs.

For the *Sogn of Fjordane University College*, level 1 calculation is done by using key data from the LCC tool, combined with the correct area for the buildings, number of employees and students and project costs. The project costs used are the ones of the tender. For the level 2 calculations, project costs are the same as used in level 1 with adjustments based on information from the pre-project material on cleaning, waste handling, energy costs, maintenance and development. Two level 2 calculations are done for constant ventilation and variable ventilation.

In the **Czech Republic**, for the Elementary school “Vrchlickeho”, the actual state of building costs and energy consumption is used for the level 1 calculation. In level 2, the state of costs and energy consumption after the reconstruction of the building is used. Reconstruction includes insulation of walls, changing windows and installation of thermo regulation valves for heaters.

In **Greece**, Level 1 calculations are derived with cost information from LCC-DATA database and level 2 calculations are derived using LCProfit software. Input data on the software is mainly from costs collected and average national statistic cost data. In the case of missing figures, average market costs and estimates are used.

For the **Slovenian case studies** of *Os Frana Albrehta* and *OS Toma Brejca in Kamnik*, for level 1, the data collected in the project was used. For energy costs the LCC database was expanded with existing data for benchmarking in municipalities collected in the year 2000. For level 2 calculations more detailed cost calculation was used based on regulation on maintenance standards for residential buildings and apartments and CENING database of costs for construction works. Investment costs were assumed according to the national database ([www.peg-online.net](http://www.peg-online.net)).

In the *Apartment building* case study four LCC cases were calculated. For LCC level 1 the data was taken from the LCC-DATA database. Due to the currently small sample of residential buildings in the database at this stage, the costs used for LCC may rather illustrate the method than be fully representative. Level 2 reflects frequent situation in practice.

In the *social housing Steletova* case study, the level 2 calculations were done for several scenarios of building energy renovation.

In the **Austrian case studies**, for the level 1 analysis the key-figures were generated from the IBI-database, which at the moment includes 40 Austrian buildings (18 offices).

### 19.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

Key performance indicators can be the costs in different categories, as well as total cost (for instance Net present value). Costs given in more detailed cost categories gives a better possibility to look into all steps in the supply chain, and more thoroughly analyse to identify and quantify costs in the different processes.

#### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
<b>Annual costs</b>	NOK/m <sup>2</sup> a, CZK/m <sup>2</sup> a, CZE/a, €/m <sup>2</sup> a, €/a, €	A1 - A5: For Norway case studies, Czech Republic level 2 calculation. Greek case studies 2 and 3 for level 1 calculation. Slovenian case studies 1 and 2 for level 1 calculations. Austrian case studies 1, 2 and 3 for level 2 calculations.	B6: Optimized life cycle cost and value

		B1 – B7: Use stage	
<b>Net present value</b>	€	A1 - A5: For Norway case studies, Czech Republic level 2 calculation. Greek case studies 2 and 3 for level 1 calculation. Slovenian case studies 1 and 2 for level 1 calculations. Austrian case studies 1, 2 and 3 for level 2 calculations. B1 – B7: Use stage	B6: Optimized life cycle cost and value

→ **Indicator #1: Annual costs**

- *Macro-objective:* B6: Optimized life cycle cost and value
- *Specific aspect(s):* Life Cycle Cost (LCC)

**Technical specifications**

- Unit of measurement: NOK/m<sup>2</sup> a, CZK/m<sup>2</sup> a, CZE/a, €/m<sup>2</sup> a, €/a or €
- Scope of indicator: Discounted annual costs
- Life cycle stage (with reference to EN 15643): (A5), B1-B7 use stage
- Midpoint(s) and/or parameters: Not applicable for LCC.
- Functional unit: Some case studies calculated it per square meter per year, others per year, and others the total costs.
- Associated data requirements: See methodology [table above](#).
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*)
- Supporting tools required to quantify/estimate performance: Calculations per level 1 and level 2 methodology as explained above, See methodology [table above](#).
- Source of indicator/metric and its scientific and market acceptance: annual costs is a standard financial calculation to estimate the future costs translated into the present year.

**Results**

Overview and results:

Country	Norway						Czech Republic			
Project	Versfold			Fjordane			Vrchlickeho			
Type of calculation	Level 1 project costs 2003	Level 1 project costs 2006	Level 2 project costs 2006	Level 1	Level 2 constant ventilation	Level 2 variable ventilation	Level 1	Level 1	Level 2	Level 2
Units	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	CZK/a	CZK/m <sup>2</sup> a	CZK/a	CZK/m <sup>2</sup> a
Capital costs										
Project costs	1498	2106	2106	1177	1177	1177			4220000	814
Remaining costs	0									
Running costs										
Units	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	NOK/m <sup>2</sup>	CZK/a	CZK/m <sup>2</sup> a	CZK/a	CZK/m <sup>2</sup> a
Administration	40	40	245	40	101	101	9243081	1783	9243081	1783
Operating	500	500	808	500	439	431	3217024	620	3217024	620
Maintenance	90	90	100	90	53	53	4093595	790	4093595	790
Development	20	20	2	20	24	24				
Cleaning	incl opera	incl opera	82	incl opera	46	46				
Consumption										
Service										
Energy costs	incl opera	incl operating		incl operating						
Total energy demand	incl opera	incl opera	162	incl opera	92	86	1371000	264	1064000	205
Heating	incl opera	incl opera	63	incl opera	35	31	1051000	203	744000	143
Cooling	incl opera	incl operating		0	0	0				
Electricity	incl opera	incl opera	99	incl opera	57	55	320000	62	320000	62

Country	Greece							
Project	CRES main office				CRES bioclimatic		Ministry	
Type of calculation	Owner data 2007-2008	Level 1 external wall insulation	Level 1 external shading system	Level 2	Level 1	Level 2	Level 1	Level 2
Units	€/a	€/a	€/a	€/a	€	€	€	€
Capital costs								
Project costs					429623	na	2640000	na
Remaining costs								
Running costs								
Units	€/a	€/a	€/a	€/a	€/a	€/a	€/a	€/a
Administration	2519	2519	2519	3160	7248	4068	na	63039
Operating	3500	3500	4500	40000	1900	15558	incl maint	102000
Maintenance	3395	3395	4800	9288	5329	3529	621000	96308
Development	1700	40736	29558				-	
Cleaning	13713	13713	14500	15886	5135	7098	384000	368225
Consumption	3864	3864	3864	2573	3324	1545	na	1545
Service	1892	1892	1892	na	942	na	240000	na
Energy costs								
Total energy demand	17672	16184	14871	31465	14871	31465	496030	741483
Heating	6467	4979	6467		6467		56250	
Cooling	incl electr	incl electr	incl electricity		incl electricity		incl electricity	
Electricity	11205	11205	8404		8404		439780	

Country	Slovenia											
Project	Kamnik		Ljubljana								Social housing Steletova	
Type of calculation	Level 1: avg energy standard	Level 1: very low energy standard	Level 1 case 0	Level 1 case 1	Level 1 case 2	Level 1 case 3	Level 2 case 0	Level 2 case 1	Level 2 case 2	Level 2 case 3		
Units	€	€	€	€	€	€	€	€	€	€		
Capital costs							17100000	18000000	18150000	18350000		
Project costs	8500000	9350000										
Remaining costs												
Running costs												
Units	€/a	€/a	€	€	€	€						
Administration	2695,48	2695,48	14030	14030	14030	14030						
Operating	7025,5	7025,5	2300	2300	2300	2300						
Maintenance	36305,9	36305,9	246939,5	259440	261523,4	264301,3						
Development												
Cleaning	9453,45	9453,45	9200	9200	9200	9200						
Consumption	7199,63	7199,63	56963,5	56963,5	56963,5	56963,5						
Service	14042,79	14042,79										
Energy costs												
Total energy demand	21946,56	8848,01					191083,5	142266,5	129043,5	185409,5		
Heating	12752,59	4251					108822	38065	8606	52916		
Cooling	incl electr	incl electricity					incl electr	incl electr	incl electr	incl electricity		
Electricity	9193,98	4597,01					82261,5	104201,5	120437,5	132493,5		

Country	Austria								Germany		
Project	TECHbase		BRC - 2005		BRC - 2010		Mariahilfer strasse		Justice 1	Culture 1	School 1
Type of calculation	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	--	--	--
Units	€	€	€	€	€	€	€	€			
Capital costs	na	17500000		7154000		7154000		2927500			
Project costs											
Remaining costs											
Running costs											
Units	€	€	€	€	€	€	€	€			
Administration	37762,5	18000	16325,75	9120	16325,75	9120	6600	7800			
Operating	26625	36000	11867,98	18240	8825,5	18240	5806,25	15600			
Maintenance	106950	192500	92146,93	78694	68524,13	78694	14725	32202,5			
Development											
Cleaning	82725	33750	26042,67	17100	26042,67	17100	9675	11250			
Consumption	110040	137045,3	43639,2	46586,22	41857	42620,35	29692,5	32359,37			
Service	24525	17250	11782,53	8740	11782,53	8740	3250	5750			
Energy costs											
Total energy demand											
Heating	incl opera	incl operating									
Cooling											
Electricity	incl opera	incl operating									

#### Detailed discussion:

For the **Norwegian** calculations, neither the discount rate nor the lifetime span calculation are specified in the report. It is the only country that uses square meters as a base unit. In the first case, the project costs increases considerably from data of 2003 and data of 2006. One reason is the more specific information available on the construction itself and the topics and qualities added during the process. In this case, the total costs per year increase considerable from level 1 to level 2 calculations. Nevertheless, in the second case study, the level 1 calculation seems to be suitable as decision support in the early project stage.

In the **Czech Republic** case, the discount rate used is 5% and the lifetime of capital costs is considered 30 years. In the level 1 calculation the actual state of building costs and energy consumption is used. In level 2 the state of costs and energy consumption after the reconstruction of the building is used. Thus, both calculations are not directly comparable.

**Greece** analysed three case studies. The LCC calculation aimed to predict the cost saving in the case study of buildings' lifetime, testing different alternatives, mostly on envelope upgrade. Level 1 and level 2 calculations have been carried out for all case studies. In the first case study, administration, consumption and cleaning costs are relatively similar. While operating costs differ significantly, the largest difference is found in the maintenance costs, which are doubled for the level 2 calculation. For the second case study, only the consumption costs are similar. Administration, maintenance and cleaning costs are higher than calculated in level 2. Operation costs differ similarly as in case 1. For the third case study, significant differences on operation, maintenance and energy costs are observed. Cleaning costs are very similar. In conclusion, the current disadvantage of the database is the limited number of building entries.

For **Slovenia**, three case studies were analysed although annual costs were only calculated for the first two ones. In the first case study, only level 1 calculations were done since the LCC database counts only with a limited number of entries for schools. In the second case study, due to the currently small sample of residential buildings in the database, the costs used are rather illustrative of the methodology than fully representative. Since the collection data is ongoing, the reliability of the data is expected to increase. As a conclusion, level 1 LCC is appropriate in the early design stage of the building.

For **Austria**, the figures are shown in € per square meter (net floor area). The calculations use an interest rate of 6% and a lifetime of 80 years for offices. They conclude that the most practicable way seems to be a combination of level 1 and level 2 analyses, to allow for an easy, more practicable and time-effective method in the calculation of LCC for buildings. The level 1 analysis is less time-consuming, especially according to the additional work of calculating the estimated rental income for the level 2 analysis. The differences between level 1 and level 2 calculations vary from 1% to almost 40%. The total difference is small, except for the case of the refurbished building. The main deviation in this building strives in the operation costs. In conclusion, the level 1 calculation is a practicable way to calculate the estimated costs for office buildings with the existing IBI database. Differences in the categorisation level are observed. On the other hand, to perform comparisons e.g. between heating options, it is more practical to use the level 2 calculations.

**Germany** did not present in the report LCC calculations for their three case studies.

### ***Cross-links and trade-offs between other macro-objectives***

- Which aspect of performance does the trade-off relate to? B1: Greenhouse gas emissions from building life cycle energy use,
- What is the quantifiable impact on performance? It can be measured by CO<sub>2</sub> emissions [kg of CO<sub>2</sub> per m<sup>2</sup>]. As it is not within the scope of this project, the CO<sub>2</sub> emissions are not calculated for all the case studies. As an example, the second Slovenian case study (Ljubljana); Case 2 reduces to the maximum the CO<sub>2</sub> emissions and the consumption costs but not the maintenance costs.

Table 23: Energy indicators of the Slovenian cs N°2

Related to the entire building complex per useful m<sup>2</sup> of flat area

	case 0	case 1	case 2	case 3
Energy (final / delivered) kWh	2,057,000	1,056,000	689,000	1,821,000
Heating (gas)	1,880,000	768,000	485,000	564,000
Electr & Cooling	177,000	288,000	204,000	1,257,000
Primary energy kWh	2,260,550	1,387,200	923,600	3,266,550
CO <sub>2</sub> emissions kg CO <sub>2</sub>	507,410	321,600	214,820	790,290
Primary energy kWh/m <sup>2</sup>	197	121	80	284
CO <sub>2</sub> emissions kg CO <sub>2</sub> /m <sup>2</sup>	44	28	19	69

In the second Austrian case study, the CO<sub>2</sub> emissions in 2010 are 4.82 kg/m<sup>2</sup> higher than those in 2005. This is due to a higher overall electricity demand caused by a higher cooling demand after the thermal gains.

- To what extent can it be mitigated? A balanced evaluation should be made (energy and economic) before making a decision on the renovation measures.

#### → Indicator #2: Net present value

- *Macro-objective:* B6: Optimized life cycle cost and value
- *Specific aspect(s):*

#### Technical specifications

- Unit of measurement: Net present value is a calculation that compares the amount invested today to the present value of the future cash receipts from the investment. In other words, the amount invested is compared to the future cash amounts after they are discounted by a specified rate of return.
- Scope of indicator: Used as [defined](#).
- Life cycle stage (with reference to EN 15643): (A5), B1-B7
- Midpoint(s) and/or parameters: Not applicable
- Functional unit: See discussion [below](#).
- Associated data requirements: See methodology [table above](#)
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*)
- Supporting tools required to quantify/estimate performance: none
- Source of indicator/metric and its scientific and market acceptance: commonly used economic parameter.

#### Results

Overview and results:

Country	Slovenia	
Project	Social housing Steletova, NPV 30 years (€)	Social housing Steletova, NPV 60 years (€)
var1	475.485	1.024.328
var2	787.762	1.336.605
var2a	676.847	1.110.974

<b>var3</b>	1.106.106	1.599.800
<b>var4</b>	636.299	896.762
<b>var5</b>	960.269	1.172.425
<b>var5a</b>	1.071.713	1.427.608
<b>var6</b>	582.766	892.864

	Austria							
	TECHbase		BRC - 2005		BRC -2010		Mariahilfer strasse	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
NPV (€)	6.194.887	7.177.839	2.943.223	2.948.144	2.863.529	2.882.636	1.056.205	1.733.765

#### Detailed discussion:

The Net Present Value calculations are only presented for a few case studies from the project; one case study from Slovenia and the case studies of Austria.

Slovenia calculated the NPV for two life spans of 30 and 60 years and several scenarios of building renovation (var1 – var6). Austria used a lifetime of 80 years and a discount rate of 6%.

#### ***Cross-links and trade-offs between other macro-objectives***

- Which aspect of performance does the trade-off relate to? B1: Greenhouse gas emissions from building life cycle energy use, B3: Efficient use of water resources
- What is the quantifiable impact on performance? The NPV calculation can be used to evaluate investments on improving the energy behaviour of the building. Although sometimes, the most economical viable investment may not be the one having the largest impact on CO<sub>2</sub> emissions and energy and water savings.

As an example, for the Slovenian case, the most viable solution is variable 3, when mechanical ventilation with heat recovery is installed without no thermal improvement. It is followed closely with variable 5: renovation of low-e windows and TI for walls and mechanical ventilation. The heat energy demand of the building is the lowest with variable 5 (85.558 kWh) while with variable 3, the heat demand of the building is more than double (266.547 kWh)

- To what extent can it be mitigated? Energy and economic analysis should be done when making a decision on renovation measures.

### **19.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)**

#### **→ Project processes**

The project concludes that for decisions on the kind of building and the size, the developer may rely on level 1 analysis as a tool for decision making. However, for more detailed decisions e.g. on the heating option the level 2 analysis is more practical. Level 2 LCC calculations of a building are tailored and depend on the detailed data on building elements, life time and maintenance needs/requirements. Nevertheless, often certain data about running costs are taken from level 1 LCC calculations, since there is no more reliable information available. See summary of the standards used below:

Project / case study	Methodology used	Evaluation tools used	Standards used
----------------------	------------------	-----------------------	----------------



<b>Norway</b> Vestfold University College and  Sogn of Fjordane University College	Level 1 and level 2 LCC analysis	LCProfit and national database for benchmarking	"NS 3454: 2000 Livssyklus kostnader for byggverk. Prinsipper og struktur" describes the process for calculating LCC, the input/output, and the cost classification
<b>Czech Republic</b> Elementary school "Vrchlickeho"	Level 1 and level 2 LCC analysis.	GEMIS	There is no directive for the calculation of costs in the Czech Republic
<b>Greece</b> CRES main office,  CRES bioclimatic office, and  GSIS – Ministry of Finance and Economics	Level 1 and level 2 LCC analysis.	LCProfit.	There is no legislative framework on cost classification, no national system, and no legislation that imposes LCC calculations in Greece; however Public Private Partnership (PPP) and Energy Service Companies (ESCOs) approve that need and sets LCC as a principle parameter in the building industry.
<b>Slovenia</b> Os Frana Albrehta and OS Toma Brejca in Kamnik  Apartment building  Social housing Steletova	Level 1 and level 2 LCC analysis.	Not mentioned	LCC is voluntary
<b>Austria</b> TECHbase,  BRC, and  Mariahilfer Strasse	Level 1 and level 2 LCC analysis.	Not mentioned	Approach based on "ÖNORM B 1802" for the level 2 analysis of the case study buildings was used.
<b>Germany</b> Justice_1, Culture_1, and School_1	Level 1 and level 2 LCC analysis	Not mentioned	

The aim of the database created is to generate key-figures to be used in the level 1 analysis in the early design stage, thus helping to prevent time-consuming activities, and to be comparable to the outcome of detailed level 2 analysis. In that case, only a little input data would be required and the calculation of running costs over the lifetime are also easy to perform.

The second level of analysis (level 2) is an effective tool which can be used in the planning phase. Available data at this stage is more detailed and project-specific. Hence, the accuracy of estimates improves and enables investors to choose between specific development activities.

#### → Evaluation of project experience using the indicator(s)

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?  
The indicator and methodology did not seem to induce any difficulty in the project.
- Was the expertise already available within the design team/other project actors?  
Calculations were performed by experts in the field.
- How clear/informative was the associated guidance material?

- How readily available were the tools, data, test facilities etc.. required to use the indicator?  
Partners are experienced with these types of calculations, therefore all necessary background tool or data was available
  - How reliable and/or comparable was the data and/or test methods used?  
Some information is missing in the report to make all the study cases fully comparable e.g. LCC standard used, building life span assumed...
  - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*  
Not indicated
- How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?
  - Was it suitable for the evaluated buildings? *If no, what issues arose?*  
The calculations strive to demonstrate the adequacy of the database compiled within the project for level 1 LCC calculations. As such, the study cases were appropriate since data was available for both level 1 and level 2 LCC calculations.
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*
- How time and cost intensive was the use of the indicator?  
Not indicated.
  - How easy was it for the auditor/assessor to verify performance?  
Not indicated.

Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*

*If available, post occupancy evaluation findings and issues identified e.g. performance gaps*

### 19.3 REFERENCES

Life-Cycle-Costs in the Planning Process. Constructing Energy Efficient Buildings taking running costs into account, LCC-DATA (2009) "Classification system for facility management information"

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Swarr Thomas E., Hunkeler David, Klopffer Walter, Pesonen Hanna-Leena, Ciroth Andreas, Brent Alan C., and Pagan Robert, (2011) "Environmental Life Cycle Costing: A Code of Practice"

## 20 FS 18. IMMOVALUE

### 20.1 FACT SHEET

General information					
Description	The project aimed at integrating energy efficiency and partly other sustainability aspects into property valuation standards. In a first step, the project team developed a solid “modified” valuation approaches. In a second step, the approaches have been checked through a comprehensive expert reviewing process with direct involvement of the relevant association for property valuation, the Royal Institute of Chartered Surveyors (RICS) or The European Group of Valuers Association (TEGoVA). In the third step, the newly developed standards for property valuation have been disseminated to the market.				
Involved parties	<ul style="list-style-type: none"><li>- KPMG Financial Advisory Services GmbH</li><li>- Dr. Leopoldsberger + Partner</li><li>- SINTEF Stiftelsen for industriell og teknisk forslning ved Norges tekniske høgskole</li><li>- e7 Energie Markt Analyse GmbH</li><li>- Technical University "Gheorghe Asachi" Iasi</li><li>- Fachhochschule Kufstein Tirol Forschungs GmbH</li></ul>				
Year	Ended in 04/2010				
Geographical and building characteristics					
Building	Climate zone, Location	Typology	Type	Scale	Stage
Modified Income approach					
Vienna Offices building	Central-Europe, Austria	Office: mid-rise	Renovation	finished in 1999, GFA of approx. 30,000 m² GLA of 21,421 m².	In-Use
Tenement in Graz	Central-Europe, Austria	Residential: apartment building	Renovation	Finished in 2006, GFA of approx. 3,000 m² GLA of 2,000 m².	In-Use
Condominium in Bad Häring/Kufstein	Central-Europe, Austria	Residential office	/ Renovation	Finished in 1970 (fictious), GLA of 92.53 m².	In-Use
Condominium in Feldkirch–Toster	Central-Europe, Austria	Residential: apartment building	Renovation	Finished in 1973, GLA of 94.58 m².	In-Use
Commercial Unit in Vienna – Freehold Interest	Central-Europe, Austria	Residential: apartment building	Renovation	Finished in 1995, GLA of 59.78 m².	In-Use
Community Center in the Ruhr Area	Central-Europe, Germany	Mix residential / office	Renovation	Finished in 2008, GFA of approx. 12,908 m² and GLA of 10,757 m².	In-Use
Multi-family Building in the Rhine-Main Area	Central-Europe, Germany	Residential: apartment building	Renovation	Finished in 2008, GFA of approx. 6,120 m² and GLA of 4,095 m².	In-Use
Office Building in the Oresund-Region	Northern-Europe, Sweden	Office	Renovation	Finished in 2006, GFA of approx. 23,014 m² and GLA of 16,440 m².	In-Use
Care Retirement	Central-Europe,	Residential	Renovation	Finished in 2009,	In-Use

Home in the Ruhr Area	Germany			GFA of approx. 5,750 m <sup>2</sup> and GLA of 4,286 m <sup>2</sup> .	
<b>Modified Sales Comparison Approach</b>					
Residential property in Iasi	Southern-Europe, Romania	Residential: apartment building	Renovation	Finished in 1974, GLA of 234.26 m <sup>2</sup> .	In-Use
<b>Modified Cost Approach</b>					
Single-family House in St. Christophen	Central-Europe, Austria	Residential: single-family house	Renovation	Finished in 1962, GFA main building 230 m <sup>2</sup> .	In-Use
Single-family House in Nußdorf am Attersee	Central-Europe, Austria	Residential: single-family house	Renovation	Finished in 1953, GFA main building 301.63 m <sup>2</sup> .	In-Use
Single-family House in St. Andrä i.L.	Central-Europe, Austria	Residential: single-family house	Renovation	Finished in 1955, GFA main building 235 m <sup>2</sup> .	In-Use
Condominium in Braunau	Central-Europe, Austria	Residential:	Renovation	Finished in 1996, GLA 90.08 m <sup>2</sup> .	In-Use

### Relevant professional context

#### Collaborative EU projects with a relevant focus

IEE co-funded project, with international consortium of partners.

The project's results and methods have interested the European Group of Valuers' Association (TeGoVA) which is the publisher of the European Valuation Standards (EVS). The project has then contributed to the preparation of a Guidance note for the integration of energy performance and LCC into EVS which should be published in autumn 2010. The project was able to gain high awareness among experts as well as among real estate market players such as valuers, developers and customers.

## 20.2 MACRO-OBJECTIVE B5: OPTIMISED LIFE CYCLE COST AND VALUE

### 20.2.1 TRANSLATION OF SPECIFIC MACRO-OBJECTIVES INTO ACTION AND IMPROVEMENT AT PROJECT LEVEL

#### → Aspects covered of the macro-objective

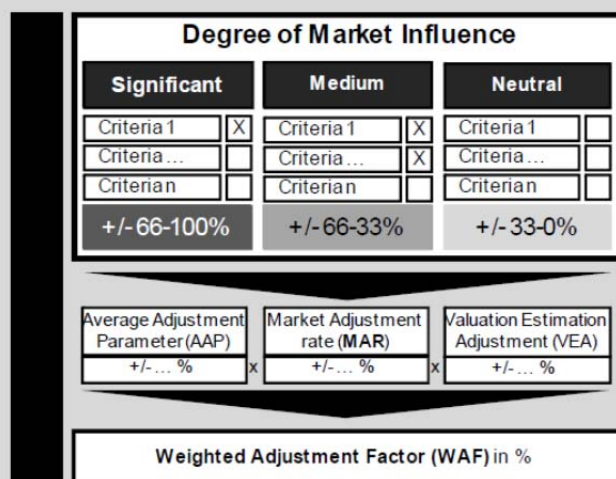
- Market value

#### → Improvement option(s)

This project addresses the gap of the integration of energy efficiency and LCCA into valuation practice. It focuses on the development of methodologies where energy efficient buildings would see that advantage reflected on the market value. LCC and LCCA data are an input for the developed methodologies.

→ **Methodologies, evaluation tools and/or standards used**

- An appropriate way to quantify the degree to which the property market seems to be already influenced by green or energy-efficient building developments could be provided by applying a newly developed scoring model – the so called WAPEC (Weighted Adjustment for Valuation Parameter Effecting Characteristics) as illustrated below:



- The result of the easy-to-handle scoring model is an adjustment factor in percent that a valuer can use to adjust the market data of comps for the subject property being valued. The WAPEC-model gives guidance for the valuer to process his thoughts regarding the integration of energy efficiency and other sustainability issues into his valuation in a structured and transparent way.

Project / case study	Methodology used	Evaluation tools used	Standards used
Vienna Offices building Tenement in Graz Condominium in Bad Häring/Kufstein Condominium in Feldkirch-Toster Commercial Unit in Vienna – Freehold Interest Community Center in the Ruhr Area Multi-family Building in the Rhine-Main Area Office Building in the Oresund-Region Care Retirement Home in the Ruhr Area	Modified Income approach – opaque markets	Not specified	RICS valuation guidance German market value (§194 BauGB), WertV and WertR Austrian valuation law (“Liegenschaftsbewertungsgesetz”) and standards (ONORM B1802-1)
Residential property in Iasi	Modified Sales Comparison Approach- multifamily residential buildings	Not specified	International Valuation Standards IVS1 and Romanian valuation procedures

Single-family House in St. Christophen Single-family House in Nußdorf am Attersee Single-family House in St. Andrä i.L Condominium in Braunau	Modified Cost Approach	Not specified	Austrian valuation law ("Liegenschaftsbewertungsgesetz") Austrian law – Upper Austria regional planning
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Detailed discussion:

The **income related approaches** are based on the expectation of future rental income, which implies that these approaches are used for offices or other commercial buildings. The appraiser uses the estimated rental value (ERV) based on market-data and currently available rental information to determine the gross potential income of the property being valued. The motivation for integrating the EPC at this point relies on the fact that the energy efficiency level might influence the tenants' willingness to pay in the long run.

The project developed different approaches for developed as well as opaque markets<sup>36</sup>. *For developed markets* it is recommended that national property valuation committees and associations who have access to energy efficiency and related data information should assure access to such analytic results for the specific property market and property type.

*For opaque markets*, the modified income approach consists of two parts:

1. The potential rent premium must be assessed by analyzing operational cost differences between the subject and comparables. This is based on the assumption that lower operational costs can be transferred to higher rents up to a certain degree.
2. The market conditions need to be assessed in order to derive the extent to which rents can be increased due to lower operational costs. The valuer can perform this in a structured and transparent way by applying the score-card developed within this project.

The developed score-card is the so-called WAPEC (Weighted Adjustment for Valuation Parameter Effecting Characteristics). The WAPEC-model gives guidance for the valuer to process his thoughts regarding the integration of energy efficiency and other sustainability issues into his valuation in a structured and transparent way. By isolating the importance of energy efficiency (and potentially other sustainability aspects) within a specific property market due to various predefined aspects and characteristics the appraiser can derive an indication to which degree energy efficiency and/or other related issues already affect the property markets. This indication is expressed through the so-called "Market Adjustment Rate" (MAR), which the valuer can use to describe the quantity of the markets' attention and willingness to pay for energy-efficient buildings.

Valuers must also quantify the maximum range of willingness to pay for energy performance or other sustainability issues. In a rational property market one can describe this using the "Average Adjustment Parameter" (AAP). If only energy efficiency is accounted for the AAP (given in percent of the evaluated parameter at market level), can be maximum as high as the annual "Energy Cost Saving Potential" (ECSP) in percent derived by applying the ratio of the gap between the expected cost for energy consumption of a reference building (comparable group of properties) and the property being valued (subject property), to the annual rental income. The reference building in this case refers to the mean of comparable buildings at the date of valuation.

<sup>36</sup> An opaque market can be a market where all comps are non-efficient or a market where sales and rental data is not fully available to the public

The approach can be expressed in the following equation:

$$ECSP = \frac{\sum_{i=1} (E_{ref,i} \times p_{e,i}) - \sum_{i=1} (E_{sub,i} \times p_{e,i})}{r_M \times 12}$$

Where

$E_{ref,i}$  – final energy consumption of specific energy carrier  $i$  of reference building [kWh/m<sup>2</sup>a]

$E_{sub,i}$  – final energy consumption of specific energy carrier  $i$  of the property being valued [kWh/m<sup>2</sup>a]

$p_{e,i}$  – average price for energy carrier  $i$  [€/kWh]

$r_M$  – observable market rent of the comparable properties [€/m<sup>2</sup> p.m.]

If valuers have estimated the MAR, AAP and the related VEA accordingly, the “Weighted Adjustment Factor” (WAF) - expressing the degree to which market rent for the subject property has to be adjusted (compared to the comparables) - can be quantified by simply multiplying these variables.

$$WAF = MAR \times AAP \times VEA$$

The valuer can then apply the calculated WAF to the key valuation parameters (in this case the observable market rent per m2 per month) in order to derive a numerical “Valuation Parameter Adjustment (VPA)”

Furthermore, if data availability allows, it is advisable to go beyond the pure energy cost and include the other relevant operating cost elements such as costs relating to cleaning, inspection, maintenance, replacement etc to determine the AAP. Using an LCC approach one can derive the “Operating Cost Saving Potential” (OCSP) expressed along the lines of the approach described above:

$$OCSP = \frac{\sum_{i=1} (OC_{ref,i}) - \sum_{i=1} (OC_{sub,i})}{r_M \times 12}$$

Where

$OC_{ref}$  – operating cost element of a reference building

$OC_{sub}$  – operating cost element of the subject property

$i$  – certain operation cost category

$r_M$  – observable market rent of comparable properties [€/m<sup>2</sup> p.m.]

The **sales comparison approach** is based on the idea that identical houses should have identical prices. It is highly recommended for valuation of condominiums, especially if they are owner-occupied. In the case of single family houses, it is recommended just for typical, standardized objects, such as semidetached houses. For the valuation of multifamily-houses it should have only a supportive role.

The proposed methodologies are based on the idea that the Energy Saving Potential of a building (ESP) represents a feature to be taken into consideration in valuation procedures. The ESP is the difference between the annual energy demand and the annual reference energy demand of the building. Both information can be extracted from the EPC.

Definitions of the reference energy demands, if any, are different for each country and procedures for calculating them depend on the type of building. Therefore, the proposed methodology must be adapted to each situation.



Rates of ESP must be calculated for each type “j” of energy demand/consumption (e.g. j=1 for gas, j=2 for electricity, j=3 for district heating, etc). For a specific energy demand/consumption “j”, the ESP of a building is

$$(ESP)_j = (E_{demand})_j - (E_{ref})_j$$

Where

ESP – energy saving potential of the building [kWh/m<sup>2</sup> year]

E<sub>demand</sub> – energy demand/consumption of the building [kWh/m<sup>2</sup> year]

E<sub>ref</sub> – reference energy demand [kWh/m<sup>2</sup> year]

The methodology presented here considers that the added value of a building generated by energy efficiency can be calculated with the Equation

$$V_{ESP} = MAR \sum_{j=1}^3 [(ESP)_j \cdot (P_E)_j] \left[ \frac{(1+i)^t - 1}{(1+i)^t \cdot i} \right]$$

Where

MAR – market adjustment coefficient

j – type of energy

P<sub>E</sub> – actual price for each type of energy [€/kWh]

i – discount rate

t – remaining economic lifetime of property [years]

In *developed markets*, by using statistical analysis tools, such as regression analysis, the valuer can analyse the influence of each factor and the estimate market value for subject properties. By considering V<sub>ESP</sub> a marketable feature, regression analysis can provide a coefficient reflecting its weight in the total value of the building. This coefficient can be theoretically applied for further valuation.

*Opaque markets* are characterized by a reduced number of comparables. The main problem in using the sales comparison approach is that it is very difficult to find comparables that have an EPC and/or are energy efficient. This represents a certain limit on the proposed methodology.

The proposed method depends on the markets’ transparency and available data including, data extracted from the EPC, which limit broader use.

The **cost approach** is the least frequently used because the cost approach is not able to reflect the market in most cases. Nevertheless, many countries still use it as an accepted valuation approach. This approach uses the replacement costs of the property being valued. In general, the cost approach is used for properties where the costs play the dominant role.

This approach is driven by two main effects: The technical effect and the market effect. These two effects represent the adjustments that are necessary in order to match construction costs and the actual value of the building.

When modifying the basic approach one should keep in mind that cost to upgrade does not necessarily equal value. This fact shows the need for the valuer to separately integrate the technical effect and the market effect. The modification must contain both effects to get the actual market value. A common solution for the cost approach for all countries or regions is impossible because of the different characteristics of the regional and national property markets.



The quantification of the technical effect is the same for developed and opaque markets. Therefore, it must be clear which type of construction leads to a good energy efficiency level. A higher quality usually leads to higher costs.

The market effect quantification is different for developed and opaque markets. For developed markets one must derive the ratio between the market value (real transaction price) and the calculated cost value from past transactions. If both values are known, there are two ways to calculate the adjustment; either by simple linear regression or by comparing same buildings.

For opaque markets, one might use a scoring model in order to quantify the market effect related to energy efficiency. The scoring model is a tool to get a feeling about how important energy efficiency is in that particular market. Furthermore the tool helps to quantify the effect. For that reason, the WAPEC, also used in a different way in the income approach, was established as a first indicator for property valuers.

The idea for this scoring model is based on the additional costs between reference buildings in the market and the valuated building. The remainder is the basis for the calculation. This value is referred to as AAP. This amount is then multiplied by the “market adjustment rate” (MAR), which can be seen as quantification for the markets’ attention and resulting from the willingness to pay for energy-efficient buildings. In other words the AAP is weighted by the MAR. Hence the adjustment is the product of MAR times AAP.

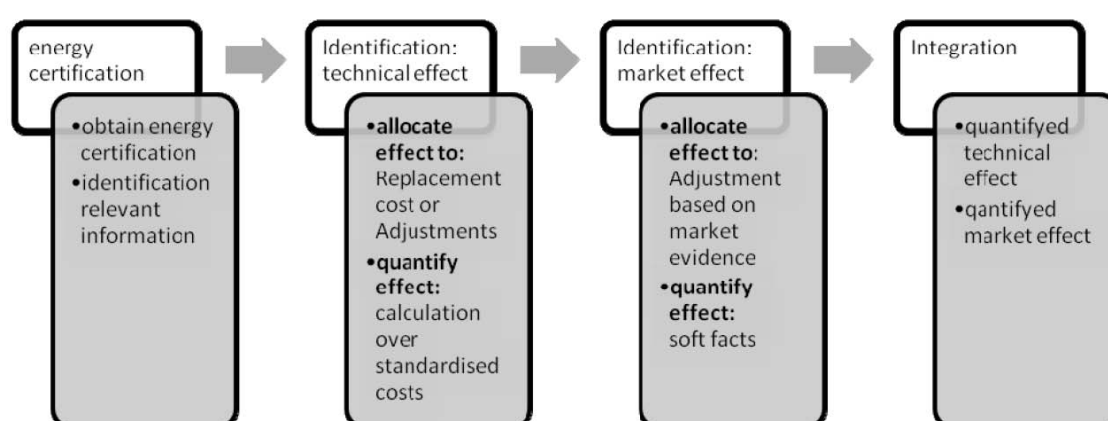


Figure 11: Process of integration in undeveloped markets

## 20.2.2 INDICATORS OR METRICS AND ASSOCIATED METHODOLOGY USED TO MEASURE PERFORMANCE IMPROVEMENT(S)

### → Overview

Indicator	Unit of measurement	Scope	Macro-objective
Market value	€, SEK	B1 – B7: Use stage	B6: Optimized life cycle cost and value

Supporting indicator	Unit of measurement	Scope	Macro-objective
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WAF	%, €	B1 – B7: Use stage	B6: Optimized life cycle cost and value
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→ **Indicator #1: Market value**

- *Macro-objective:* B6: Optimized life cycle cost and value
- *Specific aspect(s):* Comparison of ordinary valuation standards with the modified methodologies: income, sales and cost approaches

**Technical specifications**

- Unit of measurement: € or SEK
- Scope of indicator: Market valuation calculation with the adapted methodology. See methodology table above.
- Life cycle stage (with reference to EN 15643): B1-B7 use stage
- Midpoint(s) and/or parameters: Not applicable for LCC.
- Functional unit: Flat or building.
- Associated data requirements: See methodology [table above](#).
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*)
- Supporting tools required to quantify/estimate performance: See methodology [table above](#).
- Source of indicator/metric and its scientific and market acceptance: There exist some standards on market valuation as specified in the methodology [table above](#).

**Results**

Overview and results:

Case study	Standard Valuation (€)	Modified Valuation (€)	Value impact	LCC?	Developed market?
<b>Modified Income approach</b>					
Vienna Offices building - energy cost differences	52.320.000	52.530.000	0,4%	N	Y
Vienna Offices building - full life cycle cost assessment	Comparison to buildings with standard performance	17.150.000	5,0%	Y	Y
Tenement in Graz	3.314.000	3.349.000	1,1%	N	Y
Condominium in Bad Häring/Kufstein	83.185	83.809	0,8%	N	N
Condominium in Feldkirch-Toster	128.298	126.685	-1,3%	N	N
Commercial Unit in Vienna – Freehold Interest	141.079	141.982	0,6%	N	N
Community Center in the Ruhr Area	34.900.000	34.900.000	0,0%	N	N
Multi-family Building in the Rhine-Main Area	5.730.000	5.730.000	0,0%	N	N

Office Building in the Oresund-Region (SEK)	476.800.000	476.800.000	0,0%	N	N
Care Retirement Home in the Ruhr Area	11.940.000	11.940.000	0,0%	N	N
<b>Modified Sales Comparison Approach</b>					
Residential property in Iasi	51.484	54.392	5,6%	N	N
<b>Modified Cost Approach</b>					
Single-family House in St. Christophen	93.200	93.200	0,0%	N	N
Single-family House in Nußdorf am Attersee	208.200	207.500	-0,3%	N	N
Single-family House in St. Andrä i.L	83.450	81.325	-2,5%	N	N
Condominium in Braunau	120.400	119.300	-0,9%	N	N

#### Detailed discussion:

The proposed modified valuation approaches were tested by:

1. Calculating 10 pilot project valuations applying the **income approach** which can be seen as the standard approach prevailing for markets with complex and heterogeneous properties (office, retail, bigger residential buildings etc.): 6 pilot projects related to the Austrian market, 3 pilot projects were calculated for the German market and 1 case study dealt with the Swedish market. For the given building segments these entire markets can be interpreted as opaque markets with comparably little (reference) data available.
2. Testing of the **sales comparison approach** for one pilot project on the Romanian market: The sales comparison approach is suitable for homogenous property markets where a lot of data for similar comparables is available. It was therefore tested for multi-family residential buildings (panel buildings) on the real estate market of the city of Iasi.
3. Finally the modified **cost approach** was tested for 4 pilot projects. The cost approach is only applied for simple properties; therefore it was tested with the pilot valuation of three single family houses and of one condominium.

The main result of the testing is that all proposed modified valuation approaches work well and generate comprehensive results. There are, however, in practically all cases serious data problems relating to the lacking availability of EPC and LCCA for the subject and the comparables properties.

The value impact of the modified approach is for most of the cases very low; practically negligible in all cases except for two. The main reasons for that is that the "distance" between the subject property and standard buildings on the market with regard to energy efficiency is too low. Secondly, the sometimes incomplete data basis forces the valuers to take comparative assumptions.

For one pilot project where the LCCA was calculated, the value impact is around 5%. The reason is the reliable data basis of operational costs and the fact that the subject property is a very sustainable building with superior energy efficiency.

The pilot in Iasi applying the sales comparison approach results in a value impact of around 5% between a non-refurbished and a refurbished block of flats. The market value estimated by using thermal retrofitted comparables is higher than the value calculated meaning that the city of Iasi is willing to pay more than the value achieved by the energy savings or the costs of investment for the thermal retrofitting.

In general, only for very energy efficient and sustainable properties with sufficient data bases on energy and/or operational cost differences, the modified approaches would come up with a premium of 5-10%.

Sometimes finding reliable and adequate market information regarding buildings' energy efficiency or life-cycle-costs is still quite difficult because the market is not transparent enough. The study cases of Nußdorf am Attersee and Andrä i.L are situated in a rural area. In general, the market transparency in rural areas is lower than in urban areas so it is very difficult to identify comparable properties and it can be considered opaque. It is a problem to identify the value of the land but also a problem to identify properties, to get information about energy efficiency or LCC. However, for the case of Nußdorf am Attersee, it was possible to obtain market information from various sources such as local real estate agencies and the local municipality.

The EPC includes a lot of detailed information, therefore it is important that valuers are able to understand and use the right figures. Sometimes, the valuers had to estimate the AAP due to the lack of EPCs from comparable properties.

LCC data was sometimes impossible to find because LCCA are mostly not undertaken in real estate practice (e.g. LCC does not exist in Romania). Such analysis tools are too sophisticated and extensive that their application in property valuation property cannot be claimed.

### ***Cross-links and trade-offs between other macro-objectives***

- Which aspect of performance does the trade-off relate to? There are no really cross-links or trade-offs with other macro-objectives. The fact that the cost to upgrade does not necessarily equal value could generate a trade-off with the macro-objective B1. However, in this project, the valuation methodologies were adapted to include both technical and market aspects in the adapted valuation methodologies.
- What is the quantifiable impact on performance?
- To what extent can it be mitigated?

### **→ Supporting Indicator #1: WAF**

- *Macro-objective:* B6: Optimized life cycle cost and value
- *Specific aspect(s):* Comparison of ordinary valuation standards with the modified methodologies: income, sales and cost approaches

### ***Technical specifications***

- Unit of measurement: %, €
- Scope of indicator: It express the degree to which market rent for the subject property has to be adjusted (compared to the comparables).
- Life cycle stage (with reference to EN 15643): B1-B7 use stage
- Midpoint(s) and/or parameters: Not applicable for LCC.
- Functional unit: Flat or building.

- Associated data requirements: See methodology [table above](#).
- Associated timeframe, conditions and requirements for measurement (*if field/laboratory testing is required*)
- Supporting tools required to quantify/estimate performance: See methodology [table above](#).
- Source of indicator/metric and its scientific and market acceptance: This indicator is defined in the developed methodologies to adapt the market value of the property.

## Results

### Overview and results:

Case study	WAF (% or €)
Vienna Offices building - energy cost differences	0.43 %
Vienna Offices building - full life cycle cost assessment	3,74 %
Tenement in Graz	1,5 %
Condominium in Bad Häring/Kufstein	0,63 %
Condominium in Feldkirch-Toster	-0,94 %
Commercial Unit in Vienna – Freehold Interest	0,63 %
Community Center in the Ruhr Area	0,75 %
Multi-family Building in the Rhine-Main Area	1,03 %
Office Building in the Oresund-Region (SEK)	0,825 %
Care Retirement Home in the Ruhr Area	0,875 %
Residential property in Iasi	-
Single-family House in St. Christophen	0 %
Single-family House in Nußdorf am Attersee	-7.500 €
Single-family House in St. Andrä i.L	-2.125 €
Condominium in Braunau	-1.121 €

### Detailed discussion:

The weighted adjustment factor is defined in this project as explained in the [methodology section](#). As explained at the [market value indicator](#), the market values are not that greatly affected.

## 20.2.3 LESSONS LEARNED FROM THE EXPERIENCE OF MEASURING AND VERIFYING THE PERFORMANCE IMPROVEMENT(S)

### → Project processes

During the last years the interest of real estate industry in energy efficiency and other sustainability issues increased in general. Several recent studies in the US and Europe confirmed a certain willingness to pay for environmental features. However, there is a considerable gap between general acknowledgement of importance and practical integration of energy efficiency and LCCA into valuation practice. Practically all valuation reports deal with these issues only in a qualitative (descriptive) way and are not able to reflect the issue in quantitative terms.

1. The IMMOVALUE project contributes bridging the gap between theoretical importance and the practical application in integrating energy efficiency, LCCA and other sustainability issues into property valuation by offering modified methodologies which are based on standard valuation approaches but reflect energy efficiency and LCCA in a more transparent and quantitative way.

2. By means of 15 case studies (property valuations) IMMOVALUE demonstrated that the modified approaches work well and deliver reasonable results. In general the value impact, however, is limited. Only very energy efficient and sustainable properties would come up with a premium of 5-10 %. Higher value impacts depend on an increased market sensitivity towards energy efficiency and sustainability (i.e. if the markets do not only account for cost advantages but account also for better comfort levels, for better productivity etc. to be achieved in sustainable buildings).

3. In valuation practice it is the lack of data that sets limits for broad application of the modified valuation approaches. In most cases data on energy efficiency, LCCA and other sustainability aspects are very vague. Although prescribed by law EPC are still missing for many valuation processes, LCCA is practically not available at all. For a broad application valuers need reliable data bases on reference buildings (comparables) including not only data on building site, rent level and building equipment but also on energy efficiency and different operational cost categories. In addition valuers require training making them capable to interpret energy benchmarks, results of LCCA and other technical characteristics of the building in a correct way.

→ **Evaluation of project experience using the indicator(s)**

*indicative factors to address when interviewing project actors:*

- How accessible and easy to use was the indicator and the associated methodology?  
The calculation methodology was developed within the project, as such all the partners had enough information to use.
  - Was the expertise already available within the design team/other project actors?  
The partners were familiar with the market value calculation.
  - How clear/informative was the associated guidance material?  
Developed material explaining the methodology was clear enough.
- How readily available were the tools, data, test facilities etc.. required to use the indicator?  
The required tools are not mentioned. For some of the calculations LCC or EPC data was missing.
  - How reliable and/or comparable was the data and/or test methods used?  
Results seem to be very reliable.
  - What was the experience using any associated calculation tools *e.g. energy modelling, LCA software, water calculator*  
Not specified.
- How useful was the indicator by the design team, contractor and/or in communication with clients (*as applicable*) in order to improve performance?  
The methodology developed focuses on market value calculations.
  - Was it suitable for the evaluated buildings? *If no, what issues arose?*  
Some of the buildings were missing LCC or EPC data due to the type of market.
  - *Note here any experience relating to its used in the public sector e.g. as client, building permitting*  
The developed results and methods are reflected in the actual Guidance Note for the integration of energy performance and LCC into EVS which has been prepared by the European Group of Valuers' Association, the publisher of the European Valuation Standards.
- How time and cost intensive was the use of the indicator?
  - How easy was it for the auditor/assessor to verify performance?  
Not indicated.

Based on their experience, would they make any suggestions for improvement? *These could be in relation to any aspect of its use*

*If available, post occupancy evaluation findings and issues identified e.g. performance gaps*

**20.3 REFERENCES**

IMMOVALUE: Improving the market impact of energy certification by introducing energy efficiency and life-cycle cost into property valuation practice , (2010) "Report on Pilot-Project Valuations and Survey Results"

IMMOVALUE: Improving the market impact of energy certification by introducing energy efficiency and life-cycle cost into property valuation practice, (2010) "Integration of Energy Performance and Life-Cycle Costing into Property Valuation Practice"