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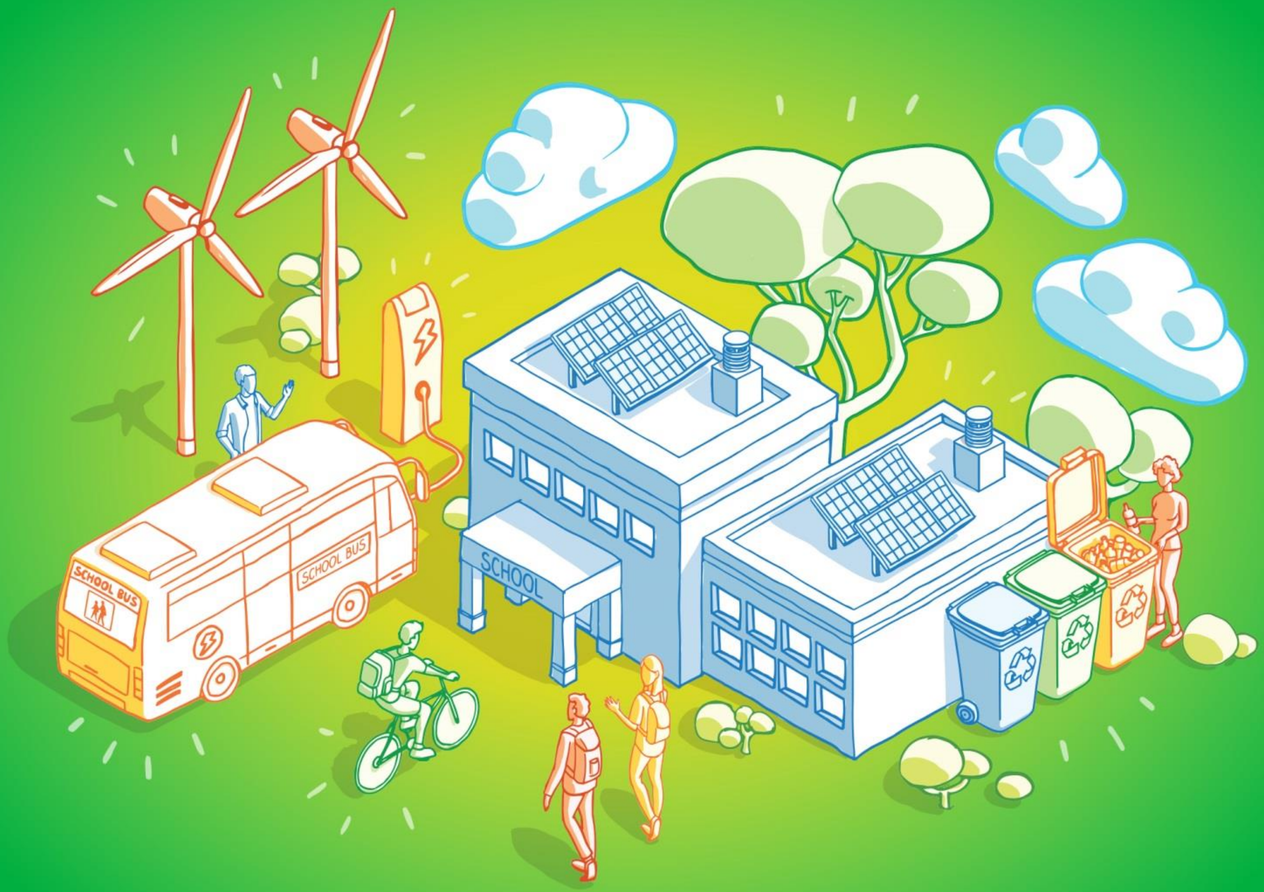


CLIMACT - ACTING FOR THE TRANSITION TO A LOW CARBON ECONOMY IN SCHOOLS – DEVELOPMENT OF SUPPORT TOOLS

E2.4.1 Building Scenario Module

September 2017

WWW.CLIMACT.NET

Executive Summary

This deliverable 2.4.1 is part of the **Activity 2.4 – Building Scenario Module**, and it contributes towards the objectives of the products of the **WP2 - Development of tools to support the transition to a low-carbon economy in schools**.

The aim of the Building Scenario Module (BSM) is to support the decision-making process in schools on the road to an efficient low-carbon economy transition. BSM consists of a simulation tool, which will be used to report the performance of the initial state of schools and the estimated performance after the simulation of proposed low-carbon retrofit solutions. BSM will generate two reports: an ***ENVIRONMENTAL SCHOOL PERFORMANCE REPORT*** of the initial school performance and an ***ACTION PLAN REPORT***, which will be the reference documents for the ClimACT schools (WP2-WP3).

Glossary

Acronym	Full name
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
DH	Percentage of discomfort hours (%)
DHW	Domestic Hot Water
ED	Annual energy demand (kWh/m^2 a)
EER	Energy Efficiency Ratio
FEC	Final energy consumption (kWh/m^2 a)
HVAC&R	Heating, Ventilation, Air Conditioning and Refrigeration
IAQ	Indoor Air Quality
KPI	Key Performance Indicator
LCE	Low Carbon Economy
PEC	Primary energy consumption (kWh/m^2 a)
RH	Relative Humidity
T	Temperature
O&M	Operation and Maintenance

Introduction

The objective of the present document is to define the structure and methodology of the Building Scenario Module (BSM). Once the structure and methodology are defined with the agreement of all ClimACT members, it will be applied into an excel file to check its reliability and accuracy.

The BSM structure is divided into 4 stages:

- **Stage 1. Initial performance assessment of schools**. BSM allows us to define the "reference baseline" of each school. It generates an ***ENVIRONMENTAL SCHOOL PERFORMANCE REPORT*** of the initial performance of schools, according to results obtained in technical pre-audits and audits. The data collected from audits are assessed according to specific methodologies to report environmental low-carbon economy impact of schools.

- **Stage 2. Selection of low-carbon retrofit solutions**. According to the initial performance results of the school and its specific needs and requirements, different low-carbon retrofit solutions will be selected in this stage, from a portfolio of solutions. All this information will be compiled in **ACTION PLAN REPORT.**

- **Stage 3. Simulation of selected low-carbon retrofit solutions.** For specific environmental areas, simulation methodologies are defined to predict the performance of solutions after their implementation. Thus, the performance of schools with the proposed low-carbon retrofit solutions can be simulated and predicted. Environmental and economic performance of solutions will be obtained. All this information will be compiled in **ACTION PLAN REPORT.**

Thus, the BSM tool allows us to generate two report of school evaluation.

-***REPORT 1. ENVIRONMENTAL SCHOOL PERFORMANCE REPORT*** will show the initial performance of the school, which will be the reference to the deliverable **E 3.2.2. INITIAL BASELINE OF THE PILOT SCHOOL –** (30/06/2017).

-REPORT 2. ACTION PLAN REPORT will show the portfolio of low-carbon economy solutions and the results of simulation of selected low-carbon retrofit solutions. BSM report allows us to identify the best available low-carbon retrofit solutions to be applied at schools. These reports will be the reference to the deliverable **E 3.3.2 BEST AVAILABLE ACTIONS AND SMART CONTROL STRATEGIES** and **E. 3.4.1 REPORT OF THE IMPLEMENTATION OF ACTION PLANS.**

The methodology of BSM is defined according to the criteria of leaders and participants of all environmental sectors, which are defined in Table 1.

Table 1 – Environmental sectors, leaders and participants

Sector	Leader	Participants
Energy	ISQ	EDGR, USE
Water	ISQ	IST
Waste	ISQ	IST
Transport	IST	UniGib
IAQ	ULR	IST
Green Space	IST	VLR
Green Procurement	IST	UniGib

Following sections define the structure and methodology for each environmental sector.

1 BSM - Assessment methodologies

1.1 BSM definition

In BSM Stage 1, the initial performance of schools will be assessed according to a Simplified Assessment Methodology. The leaders and participants of each environmental sector (table 1 - energy, water, waste, mobility, IAQ, green spaces and green procurement) are responsible to define the input/output variables (Task 2.2. - E.2.2.1) and the Simplified assessment methodology (Task 2.4 – E.2.4.1) for each environmental area.

In this stage, BSM allow us to define the "reference baseline" of each school. Figure 1 shows a scheme of the calculation method that will be applied for each environmental sector.

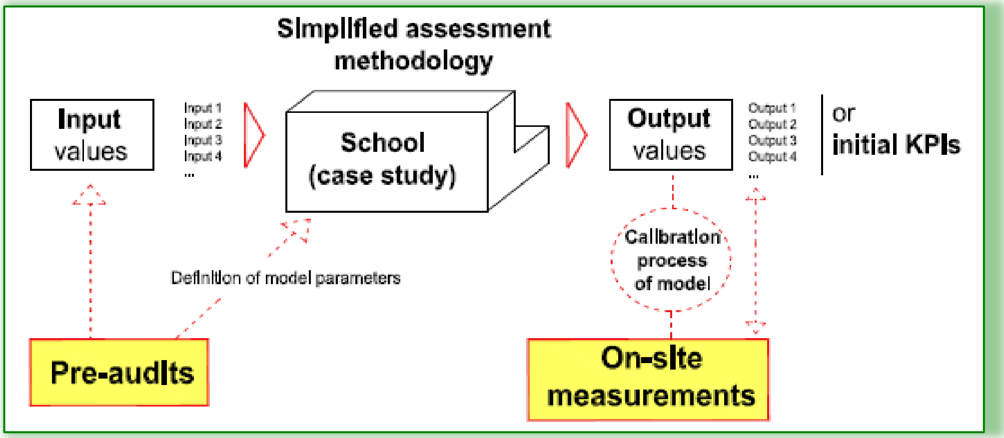


Figure 1 – Scheme. Definition of calculation method of BSM Stage 1.

The "reference baseline" of schools will be defined by means of different KPIs as a function of:

- **The information and inputs collected in pre-audits**, through the pre-audit check-list (short- and long-version): building characteristics, location, equipment, activities, behaviours, occupation profiles, etc.);
- **And the information collected in audits**, through the on-site measurement campaign with regard to IAQ, Energy, water, waste, etc. On-site measurements will be used to **calibrate the matematical models** of each environmental sector, and also **to add more information about the initial performance of schools.**

The results of the initial performance (initial KPIs) will be divided into following environmental areas: Waste, mobility, green spaces, green procurement; IAQ, Energy, Thermal comfort and Water.

The results of the initial performance of schools will be showed following the diagram showed in Figure 2.

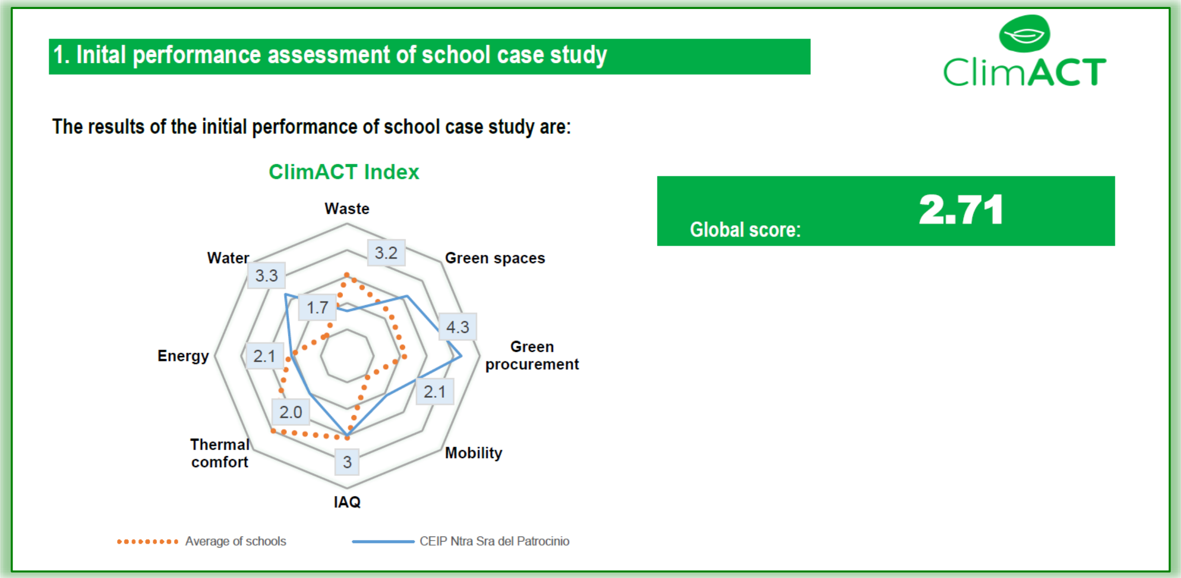


Figure 2 – Methodology to show the initial performance results.

This diagram has been defined using a similar criteria of those used in SDEWES Index [1], which was developed to benchmark cities based on 7 dimensions, 35 indicators, and close to 20 sub-indicators. Based on this wide-ranging scope, it allows ranking schools that have well-rounded and above average performances in many environmental dimensions.

Following sections define the methodology to assess the performance of schools in each environmental sector.

1.2 Waste

The waste sector will be evaluated through the accounting of waste produced, recycled and reused. So, the group "waste" is characterized by 3 KPIs:

- **KPI-W1 – Annual production of urban solid waste (USW) per student (m^3)**
- **KPI-W2 – Annual production of recyclables per student (m^3)**
- **KPI-W3 – Annual production of reusables per student (m^3)**

The final score for the waste is based on the scores calculated for each one of the groups.

1.2.1 Waste produced

The score for the group "waste produced" includes the **KPI-W1 – Annual production of urban solid waste (USW) per student (m^3/student)**.

$$\mathrm{KPI_{R1}} = \frac{\text{Weekly production of USW } (m^3)}{\text{Nº of students}}$$

The "waste produced" score is expressed by the following equation:

$$Score_{Waste\ produced} = \frac{(\max(\mathrm{KPI_{R1}}) - \mathrm{KPI_{R1}}) \times 5}{\max(\mathrm{KPI_{R1}}) - \min(\mathrm{KPI_{R1}}) \times 0.95}$$

1.2.2 Waste recycled

The score for the group "waste recycled" includes the **KPI-W2 – Annual production of recyclables per student (m^3)**.

$$\mathrm{KPI_{R2}} = \frac{\text{Weekly production of recyclable waste } (m^3)}{\text{Nº of students}}$$

The "waste recycled" score is expressed by the following equation:

$$Score_{Waste\ recycled} = \frac{\mathrm{KPI}_{R2} \times 5}{\max(\mathrm{KPI}_{R2}) \times 1.05}$$

1.2.3 Waste reused

The score for the group "waste reused" includes the **KPI-W3– Annual production of reusables per student (m^3)**.

$$\mathrm{KPI_{R3}} = \frac{\text{Weekly production of reusable waste } (m^3)}{\text{Nº of students}}$$

The "waste reused" score is expressed by the following equation:

$$Score_{Waste\ reused} = \frac{\mathrm{KPI}_{R3} \times 5}{\max(\mathrm{KPI}_{R3}) \times 1.05}$$

1.2.4 Final score for waste

The final score to evaluate the schools' performance regarding the waste sector is calculated according to the following equation:

$$Score_{Waste} = \frac{2 \times Score_{Waste\ produced} + Score_{Waste\ recycled} + Score_{Waste\ reused}}{4}$$

1.3 Transports

The transport sector is characterized by three main groups: “parking” (including KPI-T1, KPI-T2), “public transports networking” (including KPI-T3) and “CO_2 emissions from transports” (including KPI-T4). So, the group “transport” is characterized by 4 KPIs:

- **KPI-T1. Nº of parking spaces for electric cars** at school or periphery (up to a 100m radius) per student.
- **KPI-T2. Nº of parking spaces for bicycles** at school or periphery (up to a 100m radius) per student.
- **KPI-T3. Nº of public transports passing daily per hour per student** (1000 m radius).
- **KPI-T4. CO_2 emitted per student.** The final score for the transports is based on the scores calculated for each one of the groups.

1.3.1 Parking

The group “parking” is characterized by 2 KPIs:

- **KPI-T1** - **No. of parking spaces for electric cars** at school or periphery (up to a 100m radius) per student.
-

$$\mathrm{KPI_{T1}} = \frac{\text{Nº of charging stations for eletric cars}}{\text{Nº of students}}$$

- **KPI-T2** - **No. of parking spaces for bicycles** at school or periphery (up to a 100m radius) per student.

$$\mathrm{KPI_{T2}} = \frac{\text{Nº of parking places for bicycle}}{\text{Nº of students}}$$

All of them contribute for the “parking” score, expressed by the following equation:

$$Score_{parking} = \left[\frac{\mathrm{KPI_{T1}} \times 5}{1.05 \times \max(\mathrm{KPI_{T1}})} + \frac{\mathrm{KPI_{T2}} \times 5}{1.05 \times \max(\mathrm{KPI_{T2}})}\right] / 2$$

1.3.2 Public transports networking

The score for the group “Public transports networking” considers the **KPI-T3 - No. of public transports** passing daily per hour per student (1000 m radius).

$$\mathrm{KPI_{T3}} = \frac{\text{Nº of public transports per hour within a 1000m radius}}{\text{Nº of students}}$$

The “Public transports networking” score is expressed by the following equation:

$$Score_{public\ transports} = \frac{\mathrm{KPI_{T3}} \times 5}{1.05 \times \max(\mathrm{KPI_{T3}})}$$

1.3.3 CO_2 Emissions from transports

The score for the group "CO_2 Emissions from transports" considers the **KPI-T4 - CO_2 emitted per student.** It is calculated based on information from the behavior questionnaires, according the following methodology:

1) Calculation of people equivalent for each transport considering the total no. of answers, the total no. of students and the number of answers *Never* (0%), *Sometimes* (40%), *Almost always* (80%), *Always* (100%) .

$$PE_i = \frac{\left(\#_{\text{never}} \times 0 + \#_{\text{almost never}} \times 1/3 + \#_{\text{almost always}} \times 2/3 + \#_{\text{always}} \times 1\right) \times \text{ nr of persons of the school}}{\text{Mº of persons that answered to the questionnaire}}$$

Where:
i = transport mean (motorbike; car; boat; tram; train; subway; bus; bicycle; on foot);
PE_i = person equivalent of the transport mean *i*.

2) Calculation of the CO_2 emissions per transport mean

$$CO_{2\,i}\text{Emissions} = \sum_i (FE_i \times PE_i) \times \text{daily average distance} \times 22 \times 10$$

Where:
$CO_{2\,i}$ Emissions = Annual emissions associated to the transport mean *i.*
FE_i = emission factor of the transport mean *i* .

Table 2 presents the CO_2 Emission Factors for each transport mean:

Table 2 – CO_2 emission factors for each transport mean

CO_2 Emission Factor (kgCO_2 per passenger per km)				
Transport	**Spain**	**France**	**Gibraltar**	**Portugal**
Foot	0.000000	0.000000	0.000000	0.000000
Bicycle	0.000000	0.000000	0.000000	0.000000
Bus	0.015440	0.015440	0.015440	0.015440
Subway	0.028242	0.004445	0.072487	0.030415
Train	0.027648	0.011163	0.058298	0.029153
Tram	0.050757	0.008271	0.129522	0.054545
Boat	0.115000	0.115000	0.115000	0.115000
Car	0.146170	0.146170	0.146170	0.146170
Motorcycle	0.093010	0.093010	0.093010	0.093010

3) Calculation of the Total CO_2 emission per student

$$\mathrm{KPI}_{\mathrm{T4}} = \frac{\sum_i \mathrm{CO}_{2\,i} \text{ Emissions}}{\text{Nº of students}}$$

The total “CO_2 emissions” score per student is calculated considering maximum emission 100% students travelling by car:

$$Score_{CO2\ emisisons} = = 5 - \frac{\text{School emissions} \times 5}{\text{Emissions of 100\% of students going by car}}$$

1.3.4 Final Score for transports

The final score to evaluate the schools performance regarding the transport sector is calculated according to the following equation:

Final $score_{transports}$ = (2 x Score parking + Score Public transports networking + 2 x Score CO_2 emissions)/5

1.4 Green spaces

The green spaces sector is characterized by four groups: "green areas" (including KPI-GS1, KPI-GS3), "use of chemists in green areas maintenance" (including KPI-GS5), "CO_2 sequestration" (including KPI-GS6), and "CO_2 emissions" (including KPI-GS7). So, the group "green spaces" is characterized by 7 KPIs:

- **KPI-GS1. Nº of trees per non-covered area**
- **KPI-GS2. Nº of trees per student**
- **KPI-GS3. Green area per non-covered area**
- **KPI-GS4. Green area per student**
- **KPI-GS5. Annual usage of chemicals per green area**
- **KPI-GS6. Annual CO2 sequestration per non-covered area**
- **KPI-GS7. Annual CO2 emissions per green area**

The final score for the green spaces is based on the scores calculated for each one of the groups.

1.4.1 Green areas

The group "Green Areas" is characterized by 4 KPIs:

- **KPI-GS1 - No. of trees per non-covered area** (nº/m^2)

$$\mathrm{KPI_{GS1}} = \frac{\text{Nº of trees}}{\text{Non} - \text{covered area } (\mathrm{m}^2)}$$

KPI-GS2 – No. of trees per student (nº/student)

$$\mathrm{KPI_{GS2}} = \frac{\text{Nº of trees}}{\text{Nº of students}}$$

- **KPI-GS3 - Green area per non-covered area** (%)

$$\mathrm{KPI_{GS3}} = \frac{\text{Green area } (\mathrm{m}^2)}{\text{Non} - \text{covered area } (\mathrm{m}^2)} \text{ x } 100$$

- **KPI-GS4 -Green area per student** (m^2/ student)

$$\mathrm{KPI_{GS4}} = \frac{\text{Green area } (\mathrm{m}^2)}{\text{Nº of students}}$$

The KPI-GS1 and KPI-GS3 contribute for the "Green Areas" score, expressed by the following equation:

$$Score_{green\ areas} = \left[\frac{\mathrm{KPI}_{GS1} \times 5}{1.05 \times \max\,(\mathrm{KPI}_{GS1})} + \frac{\mathrm{KPI}_{GS3} \times 5}{1.05 \times \max\,(\mathrm{KPI}_{GS3})}\right]/2$$

1.4.2 Use of chemists in green areas maintenance

The score for the group "use of chemists in green areas maintenance" includes the **KPI-GS5** - **Annual usage of chemicals per green area** (Kg/m^2).

$$\mathrm{KPI}_{\mathrm{GS5}} = \frac{\text{Quantity of fertilizers and pesticides (kg)}}{\text{Green area } (\mathrm{m}^2)}$$

The "use of chemists in green areas maintenance" score is expressed by the following equation:

$$Score_{use\ of\ chemists} = 5 - \frac{\mathrm{KPI}_{GS4} \times 5}{\max\left(\mathrm{KPI}_{GS4}\right)}$$

1.4.3 CO_2 sequestration

The score for the group "CO_2 sequestration" includes the **KPI-GS6 - CO_2 sequestration per non-covered area** per year (kgCO_2/ m^2 a).

$$\mathrm{KPI}_{\mathrm{GS6}} = \frac{\text{nº of trees } \times \mathrm{SR}_{\text{dominant species}} + \text{lawn area} \times \mathrm{SR}_{\text{lawn}}}{\text{non} - \text{covered area}}$$

Where: SR = sequestration rate [2].

The "CO_2 sequestration" score is expressed by the following equation:

$$Score_{CO2\ sequestration} = \frac{\mathrm{KPI}_{GS5} \times 5}{1.05 \times \max\left(\mathrm{KPI}_{GS5}\right)}$$

Table 3 presents the CO_2 sequestration rate attributed to each specie.

Table 3: CO_2 sequestration rate attributed to each specie

CO2 sequestration rate per specie							
Turfgrass/lawn [1]	0.78	Citrus limon	1.77	Quercus suber	3.71	Sambucus nigra	6.60
Butia capitata	0.02	Quercus coccifera	1.87	Maclura pomifera	3.71	Erica arborea	6.67
Cordyline sp,	0.02	Ulmus glabra	1.90	Prunus cerasifera	3.87	Laurus nobilis	6.67
Musa paradisiaca	0.02	Thuja occidentalis	1.97	Citrus aurantium	3.90	Rhamnus alaternus	6.67
Yucca aloifolia	0.09	Koelreuteria paniculata	2.07	Euonymus japonica	3.90	Robinia pseudoacacia	6.67
Chamaerops humilis	0.10	Tilia euchlora	2.15	Parkinsonia aculeata	3.97	Jacaranda mimosifolia	6.90
Phoenix reclinata	0.18	Cistus albidus	2.20	Calocedrus decurrens	4.20	Melia azedarach	7.01
Phoenix canariensis	0.19	Arbutus unedo	2.23	Acacia retinodes	4.21	Tipuana tipu	7.43
Washingtonia robusta	0.23	Prunus domestica	2.25	Catalpa bignonioides	4.23	Tilia europaea	7.67
Washingtonia filifera	0.28	Prunus dulcis	2.34	Yucca guatemalensis	4.35	Quercus cerrioides	7.81
Bupleurum fruticosum	0.39	Quercus ilex	2.40	Cedrus deodara	4.58	Casuarina sp,	7.93
Magnolia macrophylla	0.50	Alnus glutinosa	2.43	Eriobotrya japonica	4.58	Acacia saligna	8.23
Juniperus communis	0.56	Olea europaea	2.46	Pinus pinaster	4.61	Gleditsia triacanthos	8.65
Crataegus monogyna	0.58	Taxus baccata	2.49	Cedrus atlantica	4.72	Acer platanoides	8.72
Juniperus oxycedrus	0.60	Ginkgo biloba	2.51	Fraxinus ornus	4.77	Tilia platyphyllos	8.85

Juglans nigra	0.78	Punica granatum	2.52	Schinus molle	4.98	Tilia tomentosa	9.49
Bougainvillea glabra	0.81	Pistacia lentiscus	2.61	Coriaria myrtifolia	5.02	Morus alba	9.64
Juniperus phoenica	0.81	Ficus carica	2.69	Pinus pinea	5.03	Populus canadensis	9.90
Schinus polygamus	0.81	Pyracantha angustifolia	2.71	Acer negundo	5.18	Salix alba	9.93
Ligustrum japonicum	0.84	Pinus halepensis	2.74	Quercus pubescens	5.29	Platanus acerifolia	10.82
Albizia julibrissin	0.87	Mespilus germanica	2.86	Bauhinia forficata	5.37	Casuarina cunninghamiana	11.07
Viburnum tinus	0.92	Nerium oleander	2.98	Magnolia grandiflora	5.41	Broussonetia papyrifera	11.38
Spartium junceum	0.97	Pittosporum tobira	3.01	Ulmus pumila	5.42	Phytolacca dioica	12.59
Prunus americana	0.98	Ficus elastica	3.04	Casuarina equisetifolia	5.55	Aloe arborescens	12.81
Rosmarinus officinalis	1.15	Phillyrea latifolia	3.06	Populus simonii	5.59	Cocculus laurifolius	13.11
Rhamnus sp,	1.31	Ligustrum vulgare	3.07	Erythrina crista-galli	5.61	Phoenix dactylifera	15.72
Buxus sempervirens	1.36	Ceratonia siliqua	3.10	Sophora japonica	5.65	Populus alba	21.81
Ligustrum ovalifolium	1.43	Abies alba	3.18	Ulmus minor	5.72	Populus alba	21.81
Ficus benjamina	1.44	Wisteria sinensis	3.18	Corynocarpus laevigatus	5.73	Celtis australis	33.06
Pyrus communis	1.46	Brugmansia Spp,	3.35	Acer pseudoplatanus	5.75	Pinus radiata	36.43
Crataegus laevigata	1.52	Acacia dealbata	3.42	Brachychiton populneum	5.76	Eucalyptus camaldulensis	52.89
Ailanthus altissima	1.53	Ligustrum lucidum	3.42	Prunus cerasifera	5.80	Eucalyptus globulus	71.89
Prunus avium	1.57	Cercis siliquastrum	3.46	Celtis occidentalis	5.99	Values in kg CO_2/tree and year	
Cupressus macrocarpa	1.60	Fraxinus angustifolia	3.50	Fraxinus excelsior	6.01	except	
Elaeagnus angustifolia	1.69	Firmiana simplex	3.57	Tamarix gallica	6.14	[1] kg CO_2 seq/m^2 and year	

1.4.4 CO_2 emissions from green spaces maintenance

The score for the group "CO_2 emissions from green spaces maintenance" includes the **KPI-GS7 - Annual CO_2 emissions per green area** (kgCO_2/ m^2 a).

$$\mathrm{KPI}_{GS7} = \frac{\text{Combustível} \times \mathrm{FE}_{\text{fuel}} + \text{water} \times \mathrm{FE}_{\text{water}} + \text{electicity} \times \mathrm{FE}_{\text{electricity}}}{\text{Non} - \text{covered area } (\mathrm{m}^2)}$$

Where: FE = factor emission [1].

The "CO_2 emissions CO_2 emissions from green spaces maintenance" score is expressed by the following equation:

$$Score_{CO2\ emissions} = 5 - \frac{\mathrm{KPI}_{GS6} \times 5}{\max(\mathrm{KPI}_{GS6})}$$

Table 4 presents the CO_2 emission factors associated with petrol, water and energy consumption for green spaces maintenance.

Table 4: CO_2 emission factors associated with petrol, water and energy consumption for green spaces maintenance

Country	Water (kgCO_2/l)			Energy (kg CO_2/kWh)	Petrol (kgCO_2/l)
	Tap water	Rain water	Well water		
Portugal	1.74E-04	7.28E-06	1.76E-04	4.20E-01	2.87
Spain	1.64E-04		1.46E-04	3.96E-01	
France	4.94E-05		2.89E-05	5.95E-02	
Gilbraltar	6.35E-03			1.00E+00	

1.4.5 Final Score for green spaces

The final score to evaluate the school performance regarding the green spaces sector is calculated according to the following equation:

$$\textbf{Final score}_{\textbf{green spaces}} = \frac{(\textbf{Score green areas} + \textbf{Score use chemists} + \textbf{Score CO2 sequestration} + \textbf{Score CO2 emissions})}{\textbf{4}}$$

1.5 Green procurement

The green procurement sector is characterized by six groups: “equipment efficiency” (including KPI-GP1), “paper used” (including KPI-GP2), “biological food” (including KPI-GP3), “eco-driving certification” (including KPI-GP4), “training in green procurement” (including KPI-GP5), and “suppliers” (including KPI-GP6). So, the group “green procurement” is characterized by 6 KPIs:

- **KPI-GP1. Equipment efficiency. Equipment with A+ or higher Energy Label in school**
- **KPI-GP2. Quantity of recycled paper used in school**
- **KPI-GP5. Food with biological certificate**
- **KPI-GP4. Eco-driving certification**
- **KPI-GP3. Training in green procurement**
- **KPI-GP6. Local suppliers**

The final score for the green procurement is based on the scores calculated for each one of the groups.

1.5.1 Equipment efficiency

The score for the group “equipment efficiency” includes the **KPI-GP1 - Equipment efficiency. Equipment with A+ or higher Energy Label in school**.

$$\mathrm{KPI_{GP1}} = \frac{\text{Nº of equipment A+ or higher EU energy label}}{\text{Total nº of equipments}}$$

The “equipment efficiency” score is expressed by the following equation:

$$Score_{equipment\ efficiency} = \mathrm{KPI_{GP1}} \times 5$$

1.5.2 Paper used

The score for the group “paper used” includes the **KPI-GP2 - Quantity of recycled paper used in school**.

$$\mathrm{KPI_{GP2}} = \frac{\text{Quantity of recycled paper (kg)}}{\text{Total quantity of paper (kg)}}$$

The “paper used” score is expressed by the following equation:

$$Score_{paper\ used} = \mathrm{KPI_{GP2}} \times 5$$

1.5.3 Biological food

The score for the group "biological food" includes the **KPI-GP5 - Food with biological certificate**.

$$\mathrm{KPI_{GP3}} = \frac{\text{Quantity of food with biological certificate (kg)}}{\text{Total quantity of food (kg)}}$$

The "biological food" score is expressed by the following equation:

$$Score_{biological\ food} = \mathrm{KPI_{GP3}} \times 5$$

1.5.4 Eco-driving certification

The score for the group "eco-driving certification" includes the **KPI-GP4** - **Eco-driving certification per staff**.

$$\mathrm{KPI_{GP4}} = \frac{\text{Nº of employees with eco} - \text{driving certificates}}{\text{Total nº of employees}}$$

The "eco-driving certification" score is expressed by the following equation:

$$Score_{eco-driving} = \mathrm{KPI_{GP4}} \times 5$$

1.5.5 Training in green procurement

The score for the group "training in green procurement" includes the **KPI-GP3** - **Training in green procurement per staff**.

$$\mathrm{KPI_{GP5}} = \frac{\text{Nº of employees with training in green procurement}}{\text{Total nº of employees}}$$

The "training in green procurement" score is expressed by the following equation:

$$Score_{training\ green\ procurement} = \mathrm{KPI_{GP5}} \times 5$$

1.5.6 Suppliers

The score for the group "suppliers" includes the **KPI-GP6 – local suppliers**.

$$\mathrm{KPI_{GP6}} = \frac{\text{Nº of local suppliers}}{\text{Total nº of suppliers}}$$

The "suppliers" score is expressed by the following equation:

$$Score_{suppliers} = \mathrm{KPI_{GP6}} \times 5$$

1.5.7 Final Score for green procurement

The final score to evaluate the schools performance regarding the green procurement sector is calculated according to the following equation:

$\text{Final score}_{\text{green procurement}}$ = 1 x Score equipment quantification + 0.75 x Score paper use + 1 x Score biological food + 0.5 x Score eco-driving certification + 0.75 x Score training in green procurement + 1 x Score suppliers

1.6 IAQ

Indoor Air Quality sector is characterized by three groups: “ventilation” (KPI-E2 and KPI-E3), “thermal comfort” (KPI-E4) and “air pollutants” (KPI-E5). It will be assessed through the IAQ audits. So, the group “IAQ” is characterized by 5 KPIs:

- **KPI-IAQ1. Class 0: Percentage of CO2 during occupancy period < 1000 ppm (%)**
- **KPI-IAQ2. Class 1: Percentage of CO2 during occupancy period ranging between 1000 - 1700 ppm (%)**
- **KPI-IAQ3. Class 2: Percentage of CO2 during occupancy period ranging > 1700 ppm (%)**
- **KPI-IAQ4. Percentage of temperature between 20°C and 26°C during the occupancy period (%)**
- **KPI- IAQ5. Percentage of number of air pollutants exceeding the guideline (%)**

The final score for the IAQ is based on the scores calculated for each one of the groups.

1.6.1 Ventilation

Ventilation will be assessed following the criteria developed by the French National Observatory of IAQ to assess IAQ (actually stuffiness) in schools: The ICONE index.

The ICONE index for “IAQ” is characterized by 3 KPIs:

- **KPI-IAQ1. Class 0: Percentage of CO_2 concentration during the occupancy period ranging < 1000 ppm.**
- **KPI-IAQ2. Class 1: Percentage of CO_2 concentration during the occupancy period ranging between 1000 - 1700 ppm**
- **KPI-IAQ3. Class 2: Percentage of CO_2 concentration during the occupancy period ranging > 1700 ppm.**

The ICONE index first considers 3 classes of IAQ, namely, CO_2 < 1000 ppm (class 0), 1000 < CO_2 <1700 ppm (class 1) and CO_2 > 1700 ppm (class 2). CO_2 was originally used as a marker of perceived air quality (odors). Therefore, the ICONE index considers a Fechner-type law expressing that the perceived odor intensity doesn’t vary linearly with concentration but in a logarithmic way:

$$N = \alpha \log_{10}\left(c_0 f_0 + c_1 f_1 + c_2 f_2\right) \quad (1)$$

With f0, f1 and f2 being the percentage of measurements where the CO2 concentrations are in class 0, 1 and 2 during the occupancy period, respectively. Therefore:

$$f_0 + f_1 + f_2 = 1 \quad (2)$$

Then, by defining a scale ranging from 0 to 5 for IAQ (N = ICONE index), and making the following assumptions:

ICONE = 0 if all concentrations are in class 0 (below 1000 ppm);

ICONE = 5 if all concentrations are in class 2 (above 1700 ppm);

An ICONE value of 2.5 either corresponds to 100% of values in class1 or 1/3 of concentrations in class 2 and 2/3 in class 1 (which means that class 2 weights 3 times more than class 1). Thus, Equation (1) and Equation (2) return the following final expression of the ICONE index:

$$Score_{Ventilation} = \left(\frac{2.5}{log_{10}(2)}\right) log_{10}(1 + f_1 + 3f_2) \quad (3)$$

That way the ICONE index ranges from 0 (best air quality, all concentrations are below 1000 ppm) to 5 (worst indoor air quality; all measured concentrations are over 1700 ppm during the occupancy period).

1.6.2 Thermal comfort

Thermal comfort sector is characterized by **KPI-IAQ4. Percentage of temperature between 20°C and 26°C during the occupancy period (%).** It shows the percentage of comfort period related to the dry bulb temperature evolution along the evaluated period. It is defined as the percentage of time in which temperatures lie in the range from 20°C to 26°C during the occupancy period, corresponding to a class-2 comfort according to the EN 15251 standard.

$$\mathrm{KPI}_{\mathrm{IAQ4}} = \text{Percentage of temperature in comfort zone along occupancy period } (\%)$$

The final score for the thermal comfort is based as follows: the percentage is multiplied by 5 in order that the index range from 0 (worst performance, all temperatures are below 20°C or above 26°C during occupancy) to 5 (best performance, all temperatures are between 20°C and 26°C). Therefore, $Score_{comfort}$ is given by:

$$Score_{thermal\ comfort} = \mathrm{KPI}_{\mathrm{IAQ4}}\ x\ 5$$

1.6.3 Air pollutants

Air pollutans is characterized by **KPI-IAQ5. Percentage of number of air pollutants exceeding the guideline (%).**

$$\mathrm{KPI}_{\mathrm{IAQ5}} = \frac{\text{Number of air pollutants exceeding the guideline}}{Total\ number\ of\ air\ pollutants\ evaluated}$$

The “air pollutants” score is expressed by the following equation:

$$Score_{Air\ pollutants} = 5 - (\mathrm{KPI}_{\mathrm{IAQ5}}\ x\ 5\ )$$

1.6.4 Final Score for IAQ

The final score for IAQ sector of a school building will be obtained from the result of all groups: ventilation, thermal comfort and air pollutants. It is calculated according to the following equation:

$$\textbf{Final score}_{\textbf{IAQ}} = \frac{(\textbf{Score in Ventilation} + \textbf{Score in Thermal comfort} + \boldsymbol{Score\ in\ Air\ Pollutants})}{\mathbf{3}}$$

1.7 Energy

Energy consumption sector is characterized by four groups: "energy consumption" (KPI-E1 and KPI-E2), "renewable energy" (KPI-E3), "energy cost" (KPE-E4 and KPI-E5) and CO_2 emissions associated to energy consumption (KPI-E6). It will be assessed through the annual energy consumption of the schools [kWh/a]. So, the group "energy" is characterized by 7 KPIs:

- **KPI-E1. Annual final energy consumption per useful area (kWh/m²)**
- **KPI-E2. Annual final energy consumption per student (kWh/student)**
- **KPI-E3. Percentage of renewable energy production (%)**
- **KPI-E4. Annual energy cost per useful area (€/m²)**
- **KPI-E5. Annual energy cost per student (€/student)**
- **KPI-E6. Annual CO_2 emissions per students (associated to energy consumption) ($kgCO_2$/student)**

The final score for the energy is based on the scores calculated for each one of the groups.

1.7.1 Energy consumption

The score for the group "energy consumption" includes the **KPI-E1 Annual final energy consumption per useful area (kWh/m²)** and the **KPI-E2 Annual final energy consumption per student (kWh/student).**

$$\mathrm{KPI_{E1}} = \frac{\sum_i \text{Annual consumption of electricity}_i + \sum_j (\text{Annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}{\text{Useful area } (\mathrm{m}^2)}$$

Where:
i = type of electricity (provide by the grid; onsite produced);
j = type of fuel (diesel; LPG; natural gas);
FC_j = conversion factor to kWh of fuel j [9].

$$\mathrm{KPI_{E2}} = \frac{\sum_i \text{Annual consumption of electricity}_i + \sum_j (\text{Annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}{\text{Student}}$$

Where:
i = type of electricity (provide by the grid; onsite produced);
j = type of fuel (diesel; LPG; natural gas);
FC_j = conversion factor to kWh of fuel j [9].

The "energy consumption" score is expressed by the following equation:

$$Score_{Energy\ consumption} = \left[\frac{(\max(\mathrm{KPI_{E1}}) - \mathrm{KPI_{E1}}) \times 5}{\max(\mathrm{KPI_{E1}}) - \min(\mathrm{KPI_{E1}}) \times 0.95} + \frac{(\max(\mathrm{KPI_{E1}}) - \mathrm{KPI_{E1}}) \times 5}{\max(\mathrm{KPI_{E1}}) - \min(\mathrm{KPI_{E1}}) \times 0.95}\right]/2$$

1.7.2 Renewable energy

The score for the group "renewable energy" includes the **KPI-3 Percentage of renewable energy production (%).**

$$\mathrm{KPI_{E3}} = \frac{\text{Renewable energy produced for on} - \text{site comsumption} + \text{Renewable energy production sold to grid}}{\sum_i \text{Annual consumption of eletricity}_i \ + \sum_j (\text{Annual consumption of fuel}_j \times \text{density}_j \times \mathrm{FC}_j)}$$

Where:
i = type of electricity (provide by the grid; onsite produced);
j = type of fuel (diesel; LPG; natural gas);
FC_j = conversion factor to kWh of fuel *j* [9].

The "renewable energy" score is expressed by the following equation:

$$Score_{Renewable\ energy} = \mathrm{KPI_{E3}} \times 5$$

1.7.3 Energy cost

The score for the group "energy cost" includes the **Annual energy cost per useful area (€/m^2)** and the **KPI-E5. Annual energy cost per student (€/student).**

$$\mathrm{KPI_{E4}} = \frac{\text{Annual energy cost (€)}}{\text{Useful area } (\mathrm{m}^2)} \quad \text{and} \quad \mathrm{KPI_{E5}} = \frac{\text{Annual energy cost (€)}}{\text{Nº of studentss}}$$

The "energy cost" score is expressed by the following equation:

$$Score_{Energy\ cost} = \left[\frac{(\max(\mathrm{KPI_{E5}}) - \mathrm{KPI_{E5}}) \times 5}{\max(\mathrm{KPI_{E5}}) - \min(\mathrm{KPI_{E5}}) \times 0.95} + \frac{(\max(\mathrm{KPI_{E6}}) - \mathrm{KPI_{E6}}) \times 5}{\max(\mathrm{KPI_{E6}}) - \min(\mathrm{KPI_{E6}}) \times 0.95}\right]/2$$

1.7.4 CO_2 emissions

The score for the group "Carbon footprint" includes the **KPI-6 Annual CO_2 emissions per students (associated to energy consumption) (kgCO_2/student).**

$$\mathrm{KPI_{E6}} = \frac{(\text{Electricity consumption} - \mathrm{REP} \times \mathrm{GL}) \times \mathrm{FE}_e + \sum_i (\text{consumption of fuel}_{\,i} \times \text{density}_i \times \mathrm{FC}_i) \times \mathrm{FE}_i)}{\text{Nº of students}}$$

Where:
i = type of fuel (diesel; LPG; natural gas);
FC_i = conversion factor to kWh of fuel *i* [9]
FE_e = emission factor associated to electrical energy consumption [10].
FE_i = emission factor associated to fuel *I* [10].
REP = Renewable electrical production
GL = Grid losses

The "CO_2 emissions" score is expressed by the following equation:

$$Score_{CO2\ emissions} = \frac{(\max(\mathrm{KPI_{E7}}) - \mathrm{KPI_{E7}}) \times 5}{\max(\mathrm{KPI_{E7}}) - \min(\mathrm{KPI_{E7}}) \times 0.95}$$

Primary energy factors and CO_2 emission coefficients for each country and region are reported in Annexe 1.

1.7.5 Final Score for energy

The final score for the energy sector of a school building will be obtained from the result of all groups: energy consumption, renewable energy, energy cost and CO_2 emissions, derived from energy consumption of heating, cooling and lighting. It is calculated according to the following equation:

$$\text{Final score}_{energy} = \frac{(\text{Score in Energy consumption} + \text{Score in Renewable energy} + \text{Score in Energy cost} + \text{Score in CO2 emissions})}{4}$$

1.8 Water

The water sector will be evaluated through the water bills and the group "water" is characterized by 4 KPIs:

- **KPI-H_2O1 Water consumption per useful area (m^3/m^2)**
- **KPI-H_2O2 Water consumption per student (m^3/student)**
- **KPI-H_2O3 Water cost per useful area (€/m^2)**
- **KPI-H_2O4 Water cost per student (€/student)**

1.8.1 Water consumption

The score for the group "water consumption" includes the **KPI- H_2O1 Water consumption per useful area (m^3/m^2)** and the **KPI- H_2O2 Water consumption per student (m^3/student).**

$$\mathrm{KPI}_{\mathrm{H_2O1}} = \frac{\text{Annual water consumption}}{\text{Useful area}} \quad \text{and} \quad \mathrm{KPI}_{\mathrm{H_2O2}} = \frac{\text{Annual water consumption}}{\text{Nº of students}}$$

The "water consumption" score is expressed by the following equation:

$$Score_{Water\ consumption} = \left[\frac{(\max(\mathrm{KPI}_{\mathrm{H_2O1}}) - \mathrm{KPI}_{\mathrm{H_2O1}}) \times 5}{\max(\mathrm{KPI}_{\mathrm{H_2O1}}) - \min(\mathrm{KPI}_{\mathrm{H_2O1}}) \times 0.95} + \frac{(\max(\mathrm{KPI}_{\mathrm{H_2O2}}) - \mathrm{KPI}_{\mathrm{H_2O2}}) \times 5}{\max(\mathrm{KPI}_{\mathrm{H_2O2}}) - \min(\mathrm{KPI}_{\mathrm{H_2O2}}) \times 0.95}\right] / 2$$

1.8.2 Water cost

The score for the group "water cost" includes the **KPI-H_2O3 Water cost per useful area (€/m^2)** and the **KPI-H_2O4 Water cost per student (€/student).**

$$\mathrm{KPI}_{\mathrm{H_2O3}} = \frac{\text{Annual water costs}}{\text{Useful area}} \quad \text{and} \quad \mathrm{KPI}_{\mathrm{H_2O4}} = \frac{\text{Annual water costs}}{\text{Nº of students}}$$

The "water cost" score is expressed by the following equation:

$$Score_{Water\ cost} = \left[\frac{(\max(\mathrm{KPI}_{\mathrm{H_2O3}}) - \mathrm{KPI}_{\mathrm{H_2O3}}) \times 5}{\max(\mathrm{KPI}_{\mathrm{H_2O3}}) - \min(\mathrm{KPI}_{\mathrm{H_2O3}}) \times 0.95} + \frac{(\max(\mathrm{KPI}_{\mathrm{H_2O4}}) - \mathrm{KPI}_{\mathrm{H_2O4}}) \times 5}{\max(\mathrm{KPI}_{\mathrm{H_2O4}}) - \min(\mathrm{KPI}_{\mathrm{H_2O4}}) \times 0.95}\right] / 2$$

1.8.3 Final score for water

The final score to evaluate the schools' performance regarding the water sector is calculated according to the following equation:

$$Score_{Water} = \frac{Score_{Water\ consumption} + Score_{Water\ cost}}{2}$$

2 BSM - Low-carbon retrofit solutions

2.1 Selection of low-carbon retrofit solutions

In BSM stage 2, once we have the initial performance results of the school, following the specific needs and requirements of school, we will select different low-carbon retrofit solutions. The portfolio of low-carbon retrofit solutions is defined and characterised in task 3.3.

For each solution, it is defined a cost ratio and a target that should achieve schools.

2.2 Estimated performance of low-carbon solutions

The performance of schools with the proposed low-carbon retrofit solutions can be simulated and predicted for some specific environmental areas, following the methodologies defined in Annexe 1 for Energy simulation and Annexe 2 for IAQ simulation. Environmental performance of solutions can be obtained.

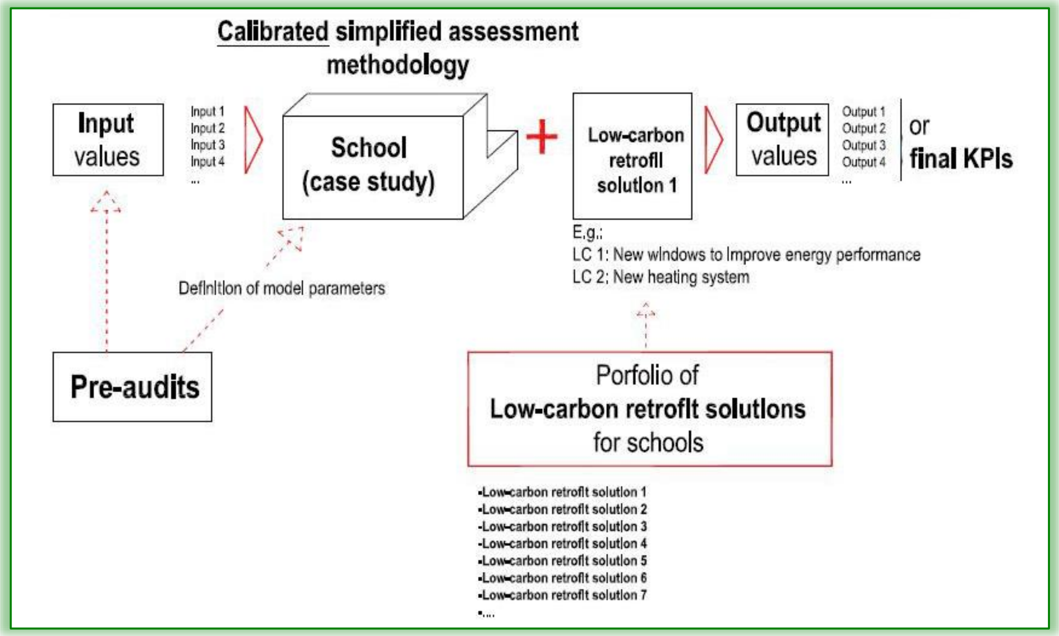


Figure 6 - Scheme. Definition of calculation method for low-carbon retrofit solutions.

In both methodologies, the results of initial school performance should be calibrated to ensure that estimated performance of low-carbon retrofit solutions is as accurate as possible. Calibration methods are detailed in next section.

2.2.1 Calibration process

The initial school performance is evaluated by means of an on-site measurement campaign in all schools, in which Indoor Air Quality and Energy consumption is measured.

This information will be implemented into the simulation tool with the aim of calibrating the mathematic models of calculation methodologies in specific environmental sectors. Following sections define the calibration process for selected environmental areas.

2.2.1.1 *Energy consumption for heating and cooling*

The calibration of energy consumption of a specific school will be developed by means of energy bills. Once the input data of school buildings have been introduced, uncertain operating conditions are modified to calibrate the energy model according to real energy bill values. Next figure shows an example of the calibration process for annaual energy consumption by source and montly electricity consumption in a case study.

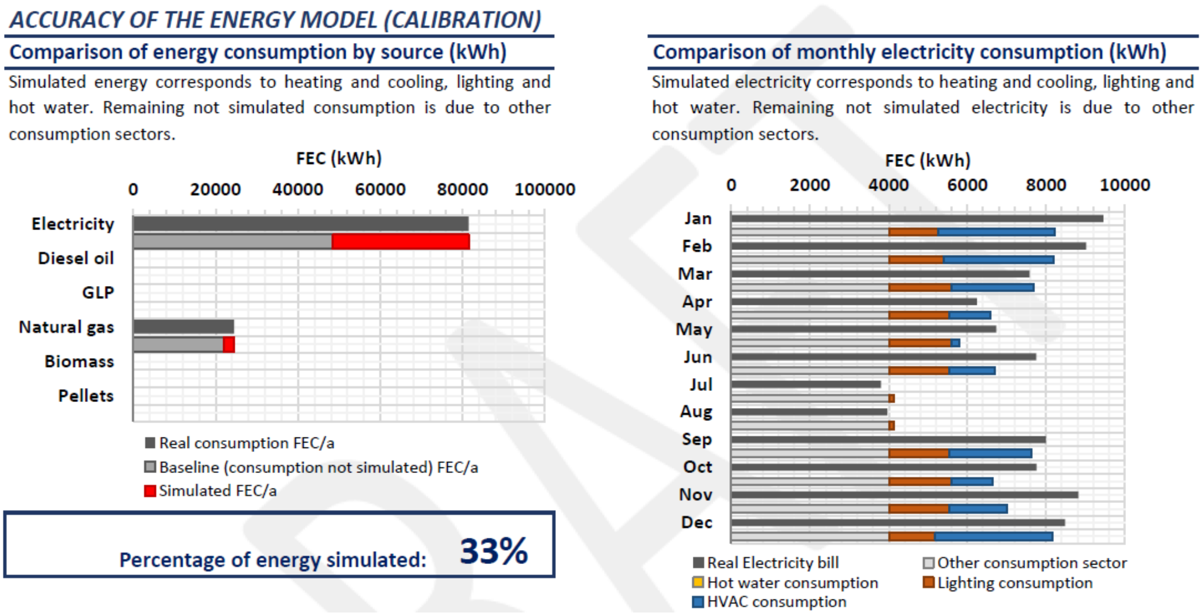


Figure 6 – Example of calibration process of energy consumption for a case study

In colours (red, orange, blue and yellow) are illustrated the results of simulated energy consumption for heating and cooling, lighitng and hot water. Remaing energy consumption not simulated is represented as baseline for other consumption sectors.

For the specific case of the comparison of monthly electricity consumption, June and August are months with a nearly zero occupation and April is considered as the reference month with nearly zero energy consumption related to heating and cooling due to the fact that April presents the minimum energy demand. So, to calibrate real FEC related to heating and cooling with simulated FEC results, a reference baseline is fixed at 4000 kWh, which discounts energy consumption derived from other uses (appliances and other).

From this fast calibration, the annual accuracy of the model predicting energy bill is situated around 80-85%. This value could be improved following an iterative self-learning procedure.

2.2.1.2 IAQ

The calibration of IAQ of a specific school will be developed by means of real monitoring data.

3 Annexes

3.1 Annexe 1 – Energy assessment methodology for simulation

Schools buildings can be defined with different geometries, sizes and levels of compactness, but they are commonly structured in the same modular basis and with similar conceptual design. Aiming to achieve an easier energy assessment of school buildings and involve technician as well as school communities in an effective low-carbon energy transition, a novel energy assessment methodology has been developed. It allows modelling and evaluating energy performance of school buildings with a reduced number of input data, and adjusted to the specific characteristics of schools. It is conceived as a user-friendly methodology. It allows calculating the indoor thermal comfort along the year, energy demand, final energy consumption, primary energy consumption and related CO_2 emissions. The methodology, which is illustrated in Fig. 1, is divided into three modules: building geometry modelling module, energy assessment module and energy rating module.

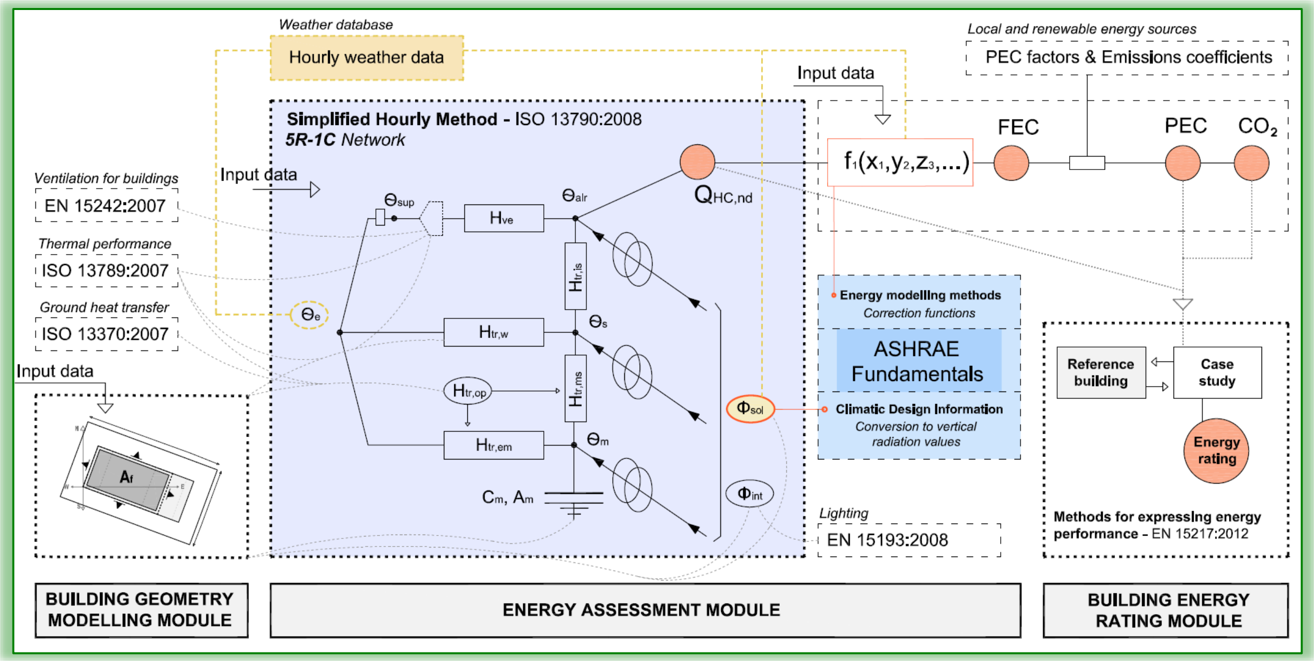


Figure 1. Assessment methodology structure

Mathematic model integrates International and European standards about thermal performance of buildings, ASHRAE procedures and simplified calculation models derived from school building configurations.

3.1.1 Building geometry modelling

A simplified methodology for school building geometry modelling is developed considering the configuration of pilot case studies. Mathematical model is divided into four steps which are illustrated in Figure 2.

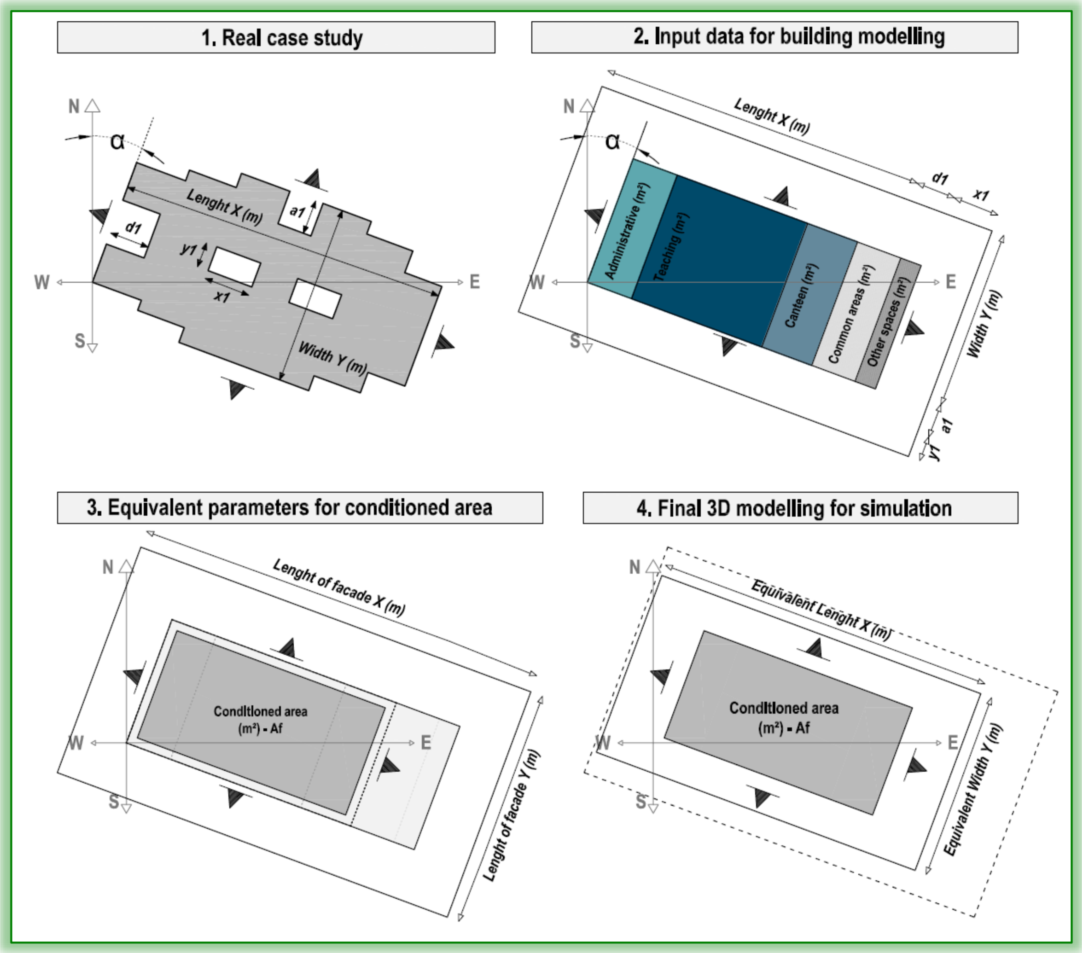


Figure 2. Mathematical model for building modelling

Input data, which are showed in step 1 and step 2, are: building orientation, gross area (m²) per sector (administrative, teaching, canteen, common spaces and other spaces), maximum external dimensions (length X, width Y and height Z), clearance height, and maximum dimensions of opened and closed courtyards (y_1, x_1, d_1 and a_1 values). Total façade length per orientation is calculated according to Eq. 1 and 2.

$$Façade\ X = Lenght\ X + x1 + d1 \quad (1)$$

$$Façade\ Y = Width\ Y + y1 + a1 \quad (2)$$

In step 3, as a function of conditioned sectors (for example: administrative, teaching and canteen), final conditioned usable area (A_f) is calculated, taking a relationship between gross and usable area of 0.825. This fixed value has been obtained as the average of the observed parameters in the 9 school buildings under study, which range from 0.80 to 0.85.

In step 4, an equivalent conditioned façade length (X_{eq} and Y_{eq}) per orientation for conditioned area is calculated according to Eq. 3 and 4. It applies the relationship between real perimeter and total gross area to the final A_f value.

$$X_{eq} = \sqrt{\left[A_f \cdot \frac{Facade\ \ X \cdot Facade\ Y}{Total\ gross\ area}\right] \cdot \left[\frac{Façade\ X}{Façade\ Y}\right]} \tag{3}$$

$$Y_{eq} = \sqrt{\frac{\left[A_f \cdot \frac{Facade\ \ X \cdot Facade\ Y}{Total\ gross\ area}\right]}{\left[\frac{Façade\ X}{Façade\ Y}\right]}} \tag{4}$$

Once envelope surfaces and conditioned usable area have been evaluated, an opening ratio is applied per façade orientation. This value should be defined by end-users.

This modelling method allows considering the compactness ratio of building (indoor volume/envelope surface), which highly affects the energy efficiency performance. From this modelling, all required geometric variables (linear and surface parameters) for energy assessment are obtained. However, it assumes direct heat exchange between conditioned area and outdoor space, without considering thermal damping due to adjoining unconditioned spaces.

3.1.2 Energy assessment methodology

Energy assessment model evaluates heating and cooling energy performance (demand and consumption). It is based on the “Simplified hourly method” detailed in ISO 13790:2008 [2]. This method consists of explicit hourly operating schedules and explicit hourly climate data. The model is a simplification of a dynamic simulation, with the following intention: same level of transparency, reproducibility and robustness; clearly specified, limited set of equations, enabling traceability of the calculation process; reduction of input data; unambiguous calculation procedure; and with main advantage that the hourly time-intervals enable direct input of hourly patterns.

The mathematic procedure is based on an equivalent resistance-capacitance (R-C) model, which is illustrated in Fig. 3.

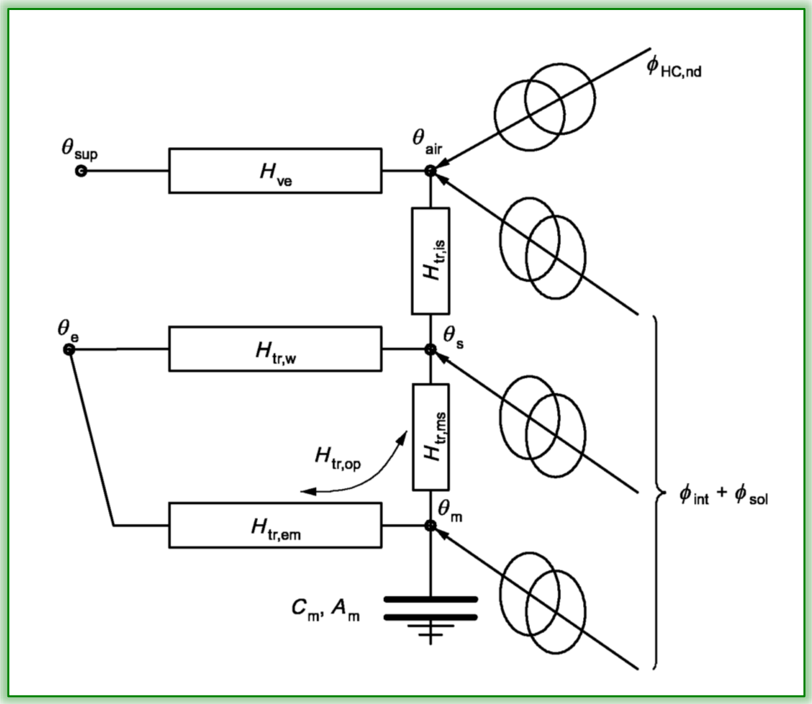


Figure 3. Mathematic model 5R1C (reprinted from [2]).

The heating and cooling demand is calculated by heating and cooling power needs per hour (ΦHC,nd, W/m^2), being positive for heating and negative for cooling. The model makes a distinction between the internal air temperature and mean internal surface temperature, and it includes heat capacities of building and air in the rooms. It enables its use for thermal comfort checks and it increases the accuracy by considering the radiative and convective parts of solar, lighting and internal heat gains. Furthermore, it uses an hourly time step and all building and system input data can be modified per hour.

Following sections define the mathematic model 5R1C (five resistances and one capacitance) and provide the fixed values and assumptions implemented for the specific case of school buildings.

3.1.2.1 Ventilation heat transfer model (ventilation and infiltration)

Heat transfer of ventilation (H_{ve}, W/m^2 K) is calculated according to Eq. 5. It is based on total air flow due to leakage and ventilation airflow (q_{ve}), and supply air temperature (Θ_{sup}).

$$H_{ve} = p_a\ c_a[\sum_k b_{ve}\ \ q_{ve}] = 0.33\ [\sum_k b_{ve,k}\ \ q_{ve,k}] \qquad (5)$$

where:

$p_a\ c_a$: *heat capacity of air per volume (0.33 W/m³ K)*
$b_{ve,k}$: *adjustment factor for supply air temperature different to outdoor conditions.*
$q_{ve,k}$: *airflow rate through the conditioned space (m³/s per hour).*

Airflow rate is obtained as the sum of fresh airflow derived of mechanical supply, infiltration and natural ventilation (window opening periods), following the procedure defined in EN 15242:2007 [3]. So, input data are: leakage airflow (Q_{4Pa}, m^3/h per m^2 at 4Pa), mechanical ventilation rate (m^3/h per m^2), and opening periods of windows (which take place when outdoor conditions are close to set-point temperatures). It allows considering natural ventilation procedures as the most efficient systems facing mechanical ventilation systems. As a reference, different values of building air leakage levels are provided in Table 1 according to Annex B of EN15242:2007 [3].

Table 1. Examples of leakages characteristics (reprinted from [3])

Building leakage level	m^3/h per floor area at 4Pa
low	0.6
average	1.1
high	2.2

3.1.2.2 Transmission heat transfer model

Heat transfers by transmission (H_{tr}, W/m^2 K) is calculated according to ISO 13789:2007 [4] and it is split into the opaque envelope area transmission ($H_{tr,op}$) and the window area transmission ($H_{tr,w}$). $H_{tr,op}$ is calculated according Eq. 6, containing the building thermal mass in the 5R-1C model, which is divided into two part ($H_{tr,em}$ and $H_{tr,ms}$).

$$H_{tr,op} = \frac{H_D + H_g + H_U + H_A}{A_f} \tag{6}$$

where:
H_D: heat transfer coefficient by transmission to external environment temperature
H_g: heat transfer coefficient by transmission to ground
H_U: heat transfer coefficient by unconditioned adjacent spaces
H_A: heat transfer coefficient by adjacent buildings

Heat transfer by transmission related to adjacent spaces (H_U) and buildings (H_A) is not considered due to the specific configuration of school buildings, which are commonly isolated. So, final procedure is obtained according to Eq. 7.

$$H_{tr,op} = \frac{H_D + H_g}{A_f} = \frac{b_{tr,x}[\sum_i A_i U_i + \sum_k I_k \psi_k] + b_{tr,y}[\sum_i A_i U_i + \sum_k I_k \psi_k]}{A_f} \tag{7}$$

where:
b_{tr}: correction factor, with a value of b_{tr}≠1 if temperature is different to external temperature
A_i: area of element i (m^2)
U_i: thermal transmittance of element i (W/m^2 K)
I_k: length of thermal bridge k (m)
ψ_k: heat transmission by linear thermal bridge k (W/m K)

$H_{tr,w}$ is calculated according Eq. 8, assuming zero thermal mass in the 5R-1C model.

$$H_{tr,w} = H_D = \frac{b_{tr,z}[\sum_i A_i U_i + \sum_k I_k \psi_k]}{A_f} \tag{8}$$

Correction factors (b_{tr}) are fixed at 1 for envelope, windows as well as ground floor due to the fact that ground floor thermal transmittance (U-value) is calculated according to ISO 13370:2007 [5], which take into account the thermal damping of ground according to the applied construction technique.

Overall linear thermal transmittance values of thermal bridges associated to school building typologies are used according to different technical manuals and standards [6]–[8]. They take places through a set of yes/no questions to end-users. Values are reported in Table 2.

Table 2. Common linear thermal transmittance values of thermal bridges

Linear thermal transmittance	ψ (W/m K)
Façade-ground	0.54
Façade-intermediate floor	0.6
Facade-roof	0.44
Windows (lintels, jambs and sills)	0.5
Shading devices (roller blinds)	0.8

3.1.2.3 Heat gains

Heat gains are split into internal heat gains (Φ_{int}) and solar gains (Φ_{sol}).

Internal heat gains take places according to the hourly and weekly schedules implemented, which are requested as input data. They are divided into occupation gains, lighting gains and appliances gains:

-Heat flow rate from occupants ($\Phi_{int,oc}$) depends on the metabolic activity, age and occupation density (m^2/person) of conditioned area. Metabolic rate of sitting tasks ranges from 1.0 to 1.2 met (from 58 to 70 W/m^2) according to ISO 7730:2005 [9]. As average value in school buildings, ISO 13790:2008 defines a heat flow rate from occupants of 70W/person, or 7.0 W/m^2 for an occupation density of 10m^2/person. With the aim of taking into account an average metabolic activity and the real occupant density of school buildings, final heat flow rate is implemented following Table 3, according to Annex G of ISO 13790:2008 [2]. Maximum occupation density values are fixed at 2 m^2/person and 1.5 m^2/person respectively, according to building design standards [10], with a simultaneity factor of 0.75 for administrative and teaching areas. This allows getting a heat flow rate result based on real building areas, considering an average metabolic rate for sitting activities.

Table 3. Heat flow rate from occupants (reprinted from [2]).

Occupation density	Occupancy (m^2/person)	Metabolic rate (W/m^2)
I	1	15
II	2.5	10
III	5.5	5
IV	14	3
V	20	2

-Heat flow rate from appliances ($\Phi_{int,ap}$) is fixed at 1W/m^2 for schools, according to Annex G of ISO 13790:2008 [2].

-Heat flow rate from lighting ($\Phi_{int,l}$) is calculated according to EN 15193:2008 [11], which depends on nominal lighting power (NP) and lighting control type (manual or auto). Average NP for school buildings is fixed at 20W/m^2, according to Annex F of EN 15193:2008.

Solar gains take places according to the hourly radiation climate data through building elements. Solar gains are divided into opaque envelope gains and windows gains:

-Solar heat gains through both building elements are calculated according to Eq. 9, reported in ISO 13790:2008 [2].

$$\Phi_{\mathrm{sol,k}} = F_{sh,ob,k} A_{sol,k} I_{sol,k} - F_{r,k} \Phi_{r,k} \tag{9}$$

where:
$\Phi_{\mathrm{sol,k}}$: solar heat gains through building element *k* (W)
$F_{sh,ob,k}$: shading reduction factor for external obstacles of surface *k*
$A_{sol,k}$: effective collecting area of surface k (m^2)
$I_{sol,k}$: global solar irradiance of collecting area k, with given orientation and tilt angle (W/m^2)
$F_{r,k}$: form factor between the element and the sky (roof:1; vertical façade: 0.5)
$\Phi_{r,k}$: extra heat flow due to thermal radiation to the sky (W), according to section 11.3.5 of 13790:2008 [2]

-As shading reduction factor (SRF), a factor for external obstacles ($F_{sh,ob,k}$) is fixed. It is obtained only for opaque vertical façade ($F_{sh,ob,v}$), and is considered according to Eq. 10. It takes into account the own building geometry obstacles. Other external obstacles are neglected.

$$F_{sh,ob,v} = \frac{Lenght\ X + \ Lenght\ Y}{Façade\ \ X + \ Façade\ \ Y} \tag{10}$$

-Effective collecting area involved in solar gains ($A_{sol,k}$) is obtained from Eq. 11 for glazed elements and Eq. 12 for opaque parts. For glazed elements, a seasonal shading factor for movable shading devices in windows ($F_{sh,gl}$) is requested to end-users.

$$\mathrm{A_{sol,w}} = F_{sh,gl} g_{gl} (1 - F_F) \mathrm{A}_{w,p} \tag{11}$$

where:
$\mathrm{A_{sol,w}}$: effective collecting area of the glazed element (m^2)
$F_{sh,gl}$: shading reduction factor for movable shading provisions
g_{gl}: total solar energy transmittance of the transparent part of the element
F_F: frame area fraction
$\mathrm{A}_{w,p}$: overall projected area of the glazed element (m^2)

$$\mathrm{A_{sol,op}} = \alpha_{S,c} R_{se} \mathrm{U}_c A_c \tag{12}$$

where:
$A_{sol,op}$: effective collecting area of the opaque part (m^2)
$\alpha_{S,c}$: dimensionless absorption coefficient for solar radiation of the opaque part (roof: 0.5; vertical façade; 0.7)
R_{se}: external surface heat resistance of the opaque part, according to ISO 6946.
U_c: thermal transmittance of the opaque part (W/m^2 K)
A_c: projected area of the opaque part (m^2)

-Conversion of global horizontal radiation values (W/m^2) per hour to vertical radiation values ($I_{sol,k}$) per orientation (N, NE, E, SE, S, SW, W, NW and N) is deployed through the mathematical model defined in ASHRAE Fundamentals (chapter 14) [12].

-Final ratio of solar gains (W/m^2) per hour is obtained according to Eq. 13.

$$\Phi_{sol} = \frac{\sum_w \Phi_{sol,w} + \sum_{op} \Phi_{sol,op}}{A_f} \tag{13}$$

Solar and internal heat gains are distributed between the three temperature nodes: air node (Θ_{air}), the central node (Θ_s) which is a mix of Θ_{air} and mean radiant temperature ($\Theta_{r,mn}$), and the node representing the mass of the building zone (Θ_m), according to the mathematic model defined in Annex C of ISO 13790:2008 [2].

3.1.2.4 Internal heat capacity of school building

The thermal mass or internal heat capacity of the building or building zone (C_m) is represented by a single thermal capacity in the 5R1C model, located between $H_{tr,ms}$ and $H_{tr,em}$. It can be calculated by summing the corrected heat capacities of all the building elements in direct thermal contact with the internal air of the zone under consideration. However, to reduce input data, 5 default values as a function of the type of construction have been implemented, according to Table 4 reported in ISO 13790:2008 [2].

Table 4. Default values of building heat capacity (reprinted from [2]).

Building Heat Capacity Class	A_m (m^2)	C_m (J/K)
Very Light	$2.5 \cdot A_f$	$80000 \cdot A_f$
Light	$2.5 \cdot A_f$	$110000 \cdot A_f$
Medium	$2.5 \cdot A_f$	$165000 \cdot A_f$
Heavy	$3.0 \cdot A_f$	$260000 \cdot A_f$
Very heavy	$3.5 \cdot A_f$	$370000 \cdot A_f$

C_m: internal heat capacity (J/K)
A_m: effective mass area (m^2)

3.1.2.5 Occupation conditions

Occupation conditions consists of: occupation profiles for weekdays, weekends and holidays; percentage of occupation (%); and set-point temperatures. They should be defined according to the real use patterns of schools:

-Hourly occupation profiles for weekdays are defined per every conditioned zone (administrative, teaching, canteen, common spaces and/or other spaces). Fixed annual and weekly schedules are defined for the academic course of schools.

-Percentage of occupation is obtained through the current building occupation (nº of users) and the maximum building capacity ($2m^2$/person for administrative and 1.5 m^2/person for teaching [10]).

-Set-point temperatures are fixed at 21 and 24ºC, for cooling and heating respectively.

Fig. 4 illustrates an example of the common operating profiles for a school building

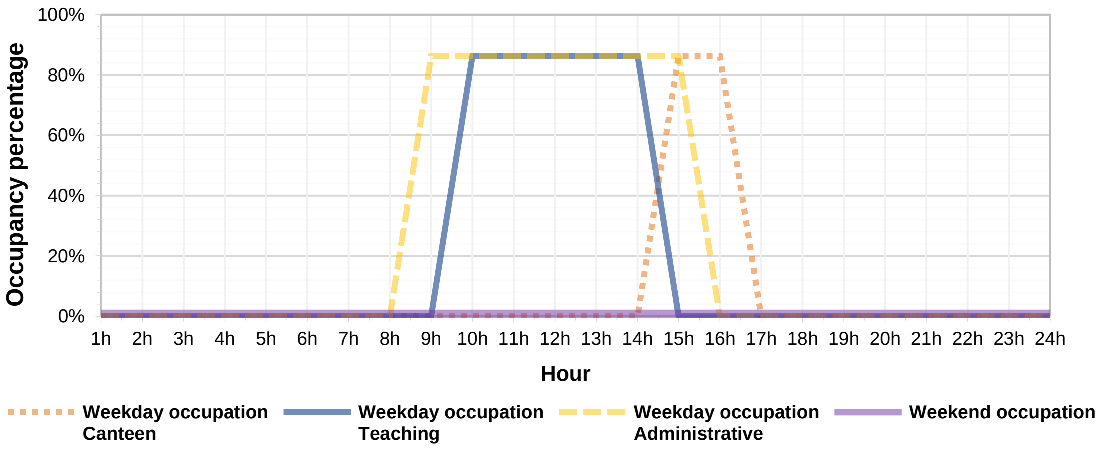


Fig. 4. Example of operating profiles of a school

The heat flow generated by occupants and appliances is applied according to the defined occupation profile. However, heat flow derived from lighting is applied according to a specific hourly operating profile due to its importance in the final energy performance.

3.1.2.6 Heating and cooling systems

A heating and/or cooling system has to be defined in each conditioned area in which end-users have to provide the following input data: system type, energy source, nº systems, nominal capacity per system, efficiency and average operating period (although energy demand lasts all occupied period, system could operate for a shorter time). In addition, a simultaneity factor and a minimum operation demand (kW) are considered for energy modelling, which allow calibrating the model according to real operating conditions (by means of energy bills).

Energy consumption characteristics of heating and cooling equipment depend generally on load conditions, environmental conditions, and equipment control strategies. These variables vary constantly and require calculations on an hourly basis. Therefore, energy consumption modelling of HVAC systems is calculated by simple equations developed by regression analysis of design data published by manufacturers', energy standards and manuals [13], [14]. The functional form of the regression equations and correction functions takes many forms: exponentials, Fourier series, and, most of the time, second- and third-order polynomials. Requested data of systems are for rated operating conditions, so correction functions are used to correct rated operation data at nominal conditions, such as Eurovent certification values, to building operating conditions.

Different operating patterns have been defined for a portfolio of heating and cooling systems:

-Electric heating consumption, such as electric radiators, depends mainly on the part-load ratio, relating part-load power to full-load power, and it is calculated through Eq. 14

$$\mathrm{P} = \mathrm{P}_{nom}\, f_{plr}(PLR) \tag{14}$$

where:
P: *equipment power (kW)*
P_{nom}: *equipment power (kW) under nominal conditions*
$f_{plr}(PLR)$: *fraction full-load power function, relating part-load power to full-load power*
PLR: *part-load ratio*

-Boiler operating consumption depends mainly on the part-load ratio [13], and it is determined through Eq. 15. $f_{plr}(PLR)$ value is fixed through a simple linear regression for each boiler typology (electric, conventional, condensing, low temperature, and biomass) as a function of part-load ratio (PLR).

$$\mathrm{P} = \frac{\mathrm{Load}}{\eta_{op}} = \frac{\mathrm{Load}}{\left[\mu_{\mathrm{nom}}\ \underbrace{f_t(t_a t_b, \dots)}_{\approx 1}\ f_{plr}(PLR)\right]} \tag{15}$$

where:
$Load$: *power delivery to load (kW)*
P: *equipment power (kW)*
η_{op}: *equipment efficiency under operating conditions*
μ_{nom}: *equipment efficiency under nominal full-load conditions*
$f_t(t_a t_b, \dots)$: *function relating full-load power at off-design conditions (t_a, t_b, ...) to design conditions*
$t_a t_b, \dots$: *operating temperatures that affect power*
$f_{plr}(PLR)$: *fraction full-load power function, relating part-load power to full-load power*
PLR: *part-load ratio*

-Heat pump operating consumption depends on part-load ratio and environmental operating conditions [13], and it is determined through Eq. 16. $f_t(t_a t_b, \dots)$ and $f_{plr}(PLR)$ are fixed through second- and third-order polynomials.

$$\mathrm{P} = \mathrm{P}_{nom}\, f_t(t_a t_b, \dots)\, f_{plr}(PLR) \tag{16}$$

where:
P: *equipment power (kW)*
P_{nom}: *equipment power (kW) under nominal conditions*
$f_t(t_a t_b, \dots)$: *function relating full-load power at off-design conditions (t_a, t_b, ...) to design conditions*
$t_a t_b, \dots$: *operating temperatures that affect power*
$f_{plr}(PLR)$: *fraction full-load power function, relating part-load power to full-load power*
PLR: *part-load ratio*

3.1.2.7 *Final procedure for calculation of building energy performance*

Final procedure for calculation of building energy performance is deployed by means of following steps:

-Building energy demand ratio is calculated according to Annex C of ISO 13790:2008 [2], where is obtained ΦH,nd and ΦC,nd (W/m^2) per hour along whole year.

-Final energy consumption (FEC) ratio (kWh/m^2 a) is calculated following mathematical procedure defined in section 3.2.6, according to the type of heating and cooling system and applied conditioned area.

-Non-renewable primary energy consumption (PEC_{nr}) ratio (kWh/m^2 a) is calculated according to the energy source applied to each conditioned area. Each energy source considers a primary energy factor, which is defined per region or country.

-CO_2 emissions ratio (Kg CO_2eq/m^2 a) is obtained according to the CO_2 emissions coefficient derived from consumed energy sources.

Primary energy factors and CO_2 emission coefficients for SUDOE school buildings are shown in Table 5.

Table 5. Primary energy factors and CO_2 emission coefficients for SUDOE area.

Location	Energy source		PEC factor	PEC_{nr} factor	CO_{2eq} emissions coefficient	References
			(kWh/FEC)	(kWh/FEC)	(Kg CO_2eq/FEC)	
Spain	Electricity from national grid		2.736	2.316	0.396	i
France	Electricity from national grid		3.605	3.358	0.059	i
Gibraltar	Electricity from national grid		3.868	3.863	1.002	i
Portugal	Electricity from national grid		2.250	1.553	0.420	i
All locations	Electricity in situ	Solar	1.070	0.0000099	0.0000023	i
		Wind	2.722	0.023	0.0066	i
		Diesel engine (generator)	1.282	1.280	0.310	i
		Gasoline engine (generator)	1.292	1.289	0.281	i
		LPG engine (generator)	1.221	1.219	0.285	i
	Heating (boiler>100 kW)	Diesel oil	1.273	1.268	0.311	i
		LPG	1.168	1.166	0.254	i
		Natural gas	1.161	1.159	0.239	i
		Biomass	1.037	0.034	0.018	ii
		Biomass (pellets)	1.542	0.082	0.044	i

i: Factors have been defined throught the Life Cycle Assessment. For electricity from National grids have been calculated using data from country electricity generation of electricity ([15], [16], [17], [18], [19], [20],[21]*) and electricity production process from Ecoinvent database*[22]*. Cumulative Energy Demand*[23] *has been the method use to calculate the PEC and PEC non renewable factors. CO2eq emissions coefficients have been obteined using IPCC method*[24].

ii Biomass factor are the same defined for Spanish energy performance certificates derived from the EPBD requirements and the CEN standards. They are reported in [25].

3.2 Annexe 2 – IAQ assessment methodology for simulation

A simple dynamic model assuming a perfect mixing of the air in the classrooms is developed to predict CO_2 concentrations. Assuming isothermal conditions, the mass balance of CO_2 in a classroom is given by the differential equation:

$$V\frac{dC(t)}{dt} = QC_{out}(t) - QC(t) + N(t)S \quad (1)$$

With V : Classroom volume (m^3)

C : Indoor CO_2 concentration (mg/m^3)

C_{out} : Outdoor CO_2 concentration (mg/m^3)

Q : Airflow rate (m^3/s)

S : Unit production rate of CO_2 (mg/s/person)

N : Number of occupants in the classroom

t : Time (s)

Eq. (1) can be reformulated as:

$$\frac{dC(t)}{dt} = \lambda[C_{out} - C(t)] + \frac{N(t)S}{V}, \quad (2)$$

Where λ is the air change rate, in units of s^{-1}:

$$\lambda = \frac{Q}{V} \quad (3)$$

The analytical solution of Eq (2) is:

$$\boxed{C(t) = C_0 e^{-\lambda t} + \left[C_{out} + \frac{N(t)S}{\lambda V}\right]\left(1 - e^{-\lambda t}\right)} \quad (4)$$

Where C_0 (mg/m^3) is the initial concentration in the classroom, that is to say $C_0 = C(t=0)$.

Eq (4) defines the IAQ model, which will be assessed through a time interval of 5 min.

Two days will be simulated having the same occupancy and airflow patterns. The first day will serve as the initialization period. Final score will be computed from the predicted concentrations during the occupancy period of the 2nd day. That way results will not depend upon the initial CO_2 concentration considered for the simulation.

In addition, simulations will be carried out in the more representative classroom for each pilot school.

3.2.1 IAQ model inputs

Parameters required for IAQ assessment model are:

- Classroom volume *V* (m^3).
- Outdoor CO_2 concentration can be assumed constant (*e.g.* 450 ppm or 500 ppm).
- Daily schedules of:
  - A representative daily occupancy schedule (specification of the number of occupants every 5 minute)
  - A representative daily schedule for window openings (0 if windows are closed, 1 if they are open, to specify with a 5 minute time step).
  - The daily schedule for mechanical ventilation, if the classroom is mechanically ventilated (1: fan on, 0: fan off, to specify with a 5 minute time step)

It will be required to obtain the number of occupants along the day and the periods when windows are opened.

Based on this information, the model will assign values for the air change rate (λ) and the internal CO_2 production rate (*N* x *S*) at each time step.

3.2.2 Production rate

The CO_2 exhaled rate (*S)* depends on the age, activity, height and weight. It can be determined from the equation:

$$S[m^3/h] = 0.0085 \text{ x } M \text{ x } A_{body}, \tag{5}$$

Where *M* (met) is metabolism, which is typically of 1.2 met (70 W/m^2) in schools, and A_D (m^2) is the surface area of the naked body. The latter can be estimated from Dubois' formula as a function of weight W (kg) and height H (cm):

$$A_{body} = 0.007184\, H^{0.725} W^{0.425} \tag{6}$$

The figure hereafter shows representative increases in weight and height of girls and boys as a function of age. From these graph, and considering that the number of boys and girls is the same in the class, the following mean height and weight can be considered as a function of the age of students:

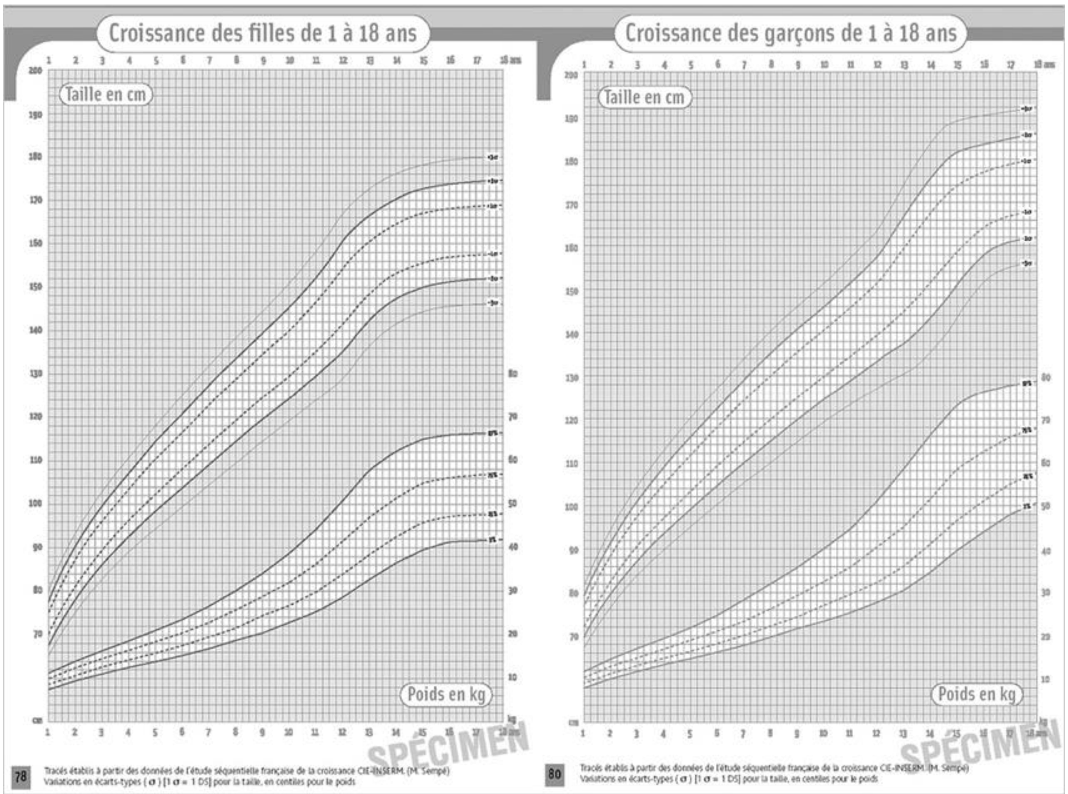
Table 1. Weight and height of girls and boys as a function of age

Age	Weight (kg)	Height (cm)
6	20.5	117.5
7	23	123.5
8	27	129.5
9	29.5	134.5
10	33	140
11	37	146
12	40.5	153
13	46.5	159
14	51.5	165.5
15	56.5	170
16	59	173
17	60	174
18 and over	61	175

After computing *S* from Eqs (5) and (6), it can then be converted from units of [m^3/h] to [mg/s] from the relation:

$$S\left[\mathrm{mg/s}\right]=\frac{1\mathrm{x}10^{6}}{3600}\rho_{CO2}S\left[\mathrm{m}^{3}/\mathrm{h}\right]$$

Where ρ_{CO2} (kg/m^3) is the CO_2 density. A representative value of 1.73 kg/m^3 can be taken considering that CO_2 is exhaled at 37°C and normal atmospheric pressure.



3.2.3 Air change rate

The daily air change rate schedule will be established based on:

- The window opening schedule
- The mechanical ventilation schedule, if the classroom is mechanically-ventilated
- Measured ventilation / infiltration rates when windows are closed or open (determined from the decay of CO_2 concentrations, see section 4.4.4 of guidelines for audits)

The following rules are suggested to build the air change schedule, depending whether the classroom is mechanically ventilated or not.

<u>If the classroom has a mechanical ventilation system:</u>

- During periods when the mechanical ventilation operates and windows are closed, the air change rate is the one measured in these conditions. If the air change rate couldn't be determined for these conditions, the default value is the mandatory air change rate in the country, according to the table below:

Table 2. Mandatory air change rate per country

Country	Mandatory air change rate
France	15 m^3/h/person in primary and secondary schools, i.e. students from 6 to 15 years old
	- 18 m^3/h/person in high schools and University, i.e. students over 15 years old
Portugal	

Spain	-12.5 l/s/student (or 45 m^3/h/student), according to current Spanish building standard, RITE 2007 [1].
Gibraltar	

- During periods when the mechanical ventilation operates and windows are open, the air change rate is the maximum between the measured air change rate in these conditions (from CO_2 decays during breaks if windows are open for instance) and the air change rate for mechanical ventilation (see previous point).
- During periods when the mechanical ventilation is off and windows are closed, the air change rate is the measured infiltration rate (determined from the CO_2 concentration decay, considering the period starting from the time occupants have left the classroom and the mechanical ventilation is shut down). In case the air change rate could not be estimated in this configuration, a default value will be assigned based on the results of other pilot schools.

If the classroom has a no mechanical ventilation system

- During periods when windows are closed, λ is the measured natural ventilation or infiltration rate. A default value will be assigned based on the results of other pilot schools if this air change rate is not available for these conditions.
- During periods when windows are open, the air change rate is the one measured in these conditions, from the CO_2 decay during breaks for instance. If the data is not available, a default value will be assigned based on the results in the other pilot schools.

3.2.4 Summary of parameters and variables

To sum, based on the methodology described previously, the following information would be needed for the IAQ methodology.

- Country $\rightarrow$ determines the mandatory air change rate to consider for mechanical ventilation
- Classroom volume (V)
- Mean age of students $\rightarrow$ determines the body height and weight to consider to calculate the unit CO_2 production rate.
- 24h occupancy schedule with a 5 minute time step
- 24h schedule for window openings with a 5 minute time step (0 = closed, 1 = open)
- 24h schedule for mechanical ventilation (0 = turned off, 1 = turned on; 0 for all timesteps means no mechanical ventilation)
- Measured natural ventilation or infiltration rate
- Measured air change rate when windows are open

3.3 Annexe 3. Summary of KPIs, partial scores and final scores

Sector	KPIs	Units	Scores	Final Scores
Water	KPI-W1. Annual production of urban solid waste (USW) per student	m^3/student	$Score_{Waste\ produced}$	$Score_{Waste}$
	KPI-W2. Annual production of recyclables per student	m^3/student	$Score_{Waste\ recycled}$	
	KPI-W3. Annual production of reusables per student	m^3/student	$Score_{Waste\ reused}$	
Transport	KPI-T1. Nº of parking spaces for electric cars at school or periphery (up to a 100m radius) per student.	nº/student	$Score_{parking}$	$Score_{Transport}$
	KPI-T2. Nº. of parking spaces for bicycles at school or periphery (up to a 100m radius) per student.	nº/student		
	KPI-T3. Nº of public transports passing daily per hour per student (1000 m radius)	nº/student	$Score_{public\ transports}$	
	KPI-T4. CO_2 emissions (associated to transports) emitted per student	kgCO_2/student	$Score_{CO2\ emissions}$	
Green spaces	KPI-GS1. Nº of trees per non-covered area	nº/m^2	$Score_{green\ areas}$	$Score_{Green\ spaces}$
	KPI-GS2. Nº of trees per student	nº/student		
	KPI-GS3. Green area per non-covered area	%		
	KPI-GS4. Green area per student	m^2/ student		
	KPI-GS5. Annual usage of chemicals per green area	Kg/m^2	$Score_{use\ of\ chemists}$	
	KPI-GS6. Annual CO2 sequestration per non-covered area	kgCO_2/m^2	$Score_{CO2\ sequestration}$	
	KPI-GS7. Annual CO2 emissions per green area	kgCO_2/m^2	$Score_{CO2\ emissions}$	
Green procurement	KPI-GP1. Equipment efficiency. Equipment with A+ or higher EU Energy Label in school	nº/total	$Score_{equipment\ efficiency}$	$Score_{Green\ procurement}$
	KPI-GP2. Quantity of recycled paper used in school	Kg recycled/kg used	$Score_{paper\ used}$	
	KPI-GP3. Food with biological certificate	Kg certificated food/total	$Score_{biological\ food}$	
	KPI-GP4. Eco-driving certification	nº eco-driving staff/total	$Score_{eco-driving}$	
	KPI-GP5. Training in green procurement	nº trained staff/total	$Score_{training\ green\ procurement}$	
	KPI-GP6. Local suppliers	Nº local suppliers/total	$Score_{suppliers}$	
IAQ	KPI-IAQ1. Class 0: Percentage of CO2 during occupancy period < 1000 ppm	%	$Score_{Ventilation}$	$Score_{IAQ}$
	KPI-IAQ2. Class 1: Percentage of CO2 during occupancy period ranging between 1000 - 1700 ppm	%		
	KPI-IAQ3. Class 2: Percentage of CO_2 during occupancy period ranging > 1700 ppm.	%		
	KPI-IAQ4. Percentage of temperature between 20°C and 26°C during the occupancy period	%	$Score_{thermal\ comfort}$	
	KPI- IAQ5. Percentage of number of air pollutants exceeding the guideline	%	$Score_{Air\ pollutants}$	
Energy	KPI-E1. Annual final energy consumption per useful area	kWh/m^2	$Score_{Energy\ consumption}$	$Score_{Energy}$
	KPI-E2. Annual final energy consumption per student	kWh/student		
	KPI-E3. Percentage of renewable energy production	%	$Score_{Renewable\ energy}$	
	KPI-E4. Annual energy cost per useful area	€/m^2	$Score_{Energy\ cost}$	
	KPI-E5. Annual energy cost per student	€/student		
	KPI-E6. Annual CO_2 emissions per students (associated to energy consumption)	kgCO_2/student	$Score_{CO2\ emissions}$	
Water	KPI-H_2O1. Water consumption per useful area	m^3/m^2	$Score_{Water\ consumption}$	$Score_{Water}$
	KPI-H_2O2. Water consumption per student	m^3/student		
	KPI-H_2O3. Water cost per useful area	€/m^2	$Score_{Water\ cost}$	
	KPI-H_2O4. Water cost per student	€/student		

3.4 Annexe 4 – Excel files

Excel file for stage 1: **ClimACT 3.2.1. Excel of inputs. Baseline report.xlsx**

Excel file for stage 2 and stage 3: **ClimACT 3.3.2. Tool for action plan report.xlsm**

4 References

[1] “SDEWES Index.” .

[2] “ISO 13790:2008. Energy performance of buildings. Calculation of energy use for space heating and cooling.” 2008.

[3] “EN 15242:2007. Ventilation for buildings. Calculation methods for the determination of air flow rates in buildings including infiltration.” 2007.

[4] “ISO 13789:2007. Thermal performance of buildings. Transmission and ventilation heat transfer coefficients. Calculation method.” 2010.

[5] “ISO 13370:2007. Thermal performance of buildings. Heat transfer via the ground. Calculation methods.” 2010.

[6] *Catálogo de elementos constructivos del Código Técnico de la Edificación.* Instituto de Ciencias de la Construcción Eduardo Torroja. Consejo Superior de Investigación Científica, 2010.

[7] *Manual de fundamentos técnicos de calificación energética de edificios existentes CE3*. Instituto para la Diversificación y Ahorro de la Energía (IDAE), 2012.

[8] *DA DB-HE-3. Documento de Apoyo al Documento Básico DB-HE Ahorro de energía. Código Técnico de la Edificación. Puentes térmicos*. España, España, 2013.

[9] “ISO 7730:2005. Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.” 2005.

[10] Ministerio de Vivienda, *Real Decreto 314/2006, del 17 de marzo, por el que se aprueba el Código Técnico de la Edificación.* España, 2006.

[11] “EN 15193:2008. Energy performance of buildings. Energy requirements for lighting.” 2010.

[12] ASHRAE, “Chapter 14. Climatic Design Information,” in *Ashrae Handbook: Fundamentals*, 2009.

[13] ASHRAE, “Chapter 19. Energy estimating and modeling methods,” in *Ashrae Handbook: Fundamentals*, 2009.

[14] *Condiciones de aceptación de Procedimientos alternativos a LIDER y CALENER*. Instituto para la Diversificación y Ahorro de la Energía (IDAE), 2009.

[15] Red Eléctrica, “El Sistema Eléctrico Español 2015,” 2016.

[16] MINETUR, “La Energía en España 2015,” 2016.

[17] Réseau de transport d’électricité, “Annual Electricity Report 2015,” 2016.

[18] Goverment of Gibraltar, “National Energy Efficiency Action Plan GIBRALTAR,” 2014.

[19] Government of Gibraltar, “Energy | Government of Gibraltar,” 2016. [Online]. Available: https://www.gibraltar.gov.gi/new/energy. [Accessed: 20-Feb-2017].

[20] Redes Energéticas Nacioanais, “DADOS TÉCNICOS - 2015,” 2015.

[21] Redes Energéticas Nacioanais, “DADOS TÉCNICOS,” 2016.

[22] B. Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E., and Weidema, "The ecoinvent database version 3 (part I): overview and methodology.," *Int. J. Life Cycle Assess.*, vol. 21(9), pp. 1218–1230, 2016.

[23] Y. Frischknecht, R.; Jungbluth, N.; Althaus, H.-J.; Hischier, R.; Doka, G.; Bauer, Ch.; Dones, R.; Nemecek, T.; Hellweg, S.; Humbert, S.; Margni, M.; Koellner, T.; Loerincik, "Implementation of life cycle impact assessment methods. Data v2.0 (2007). Ecoinvent report No. 3." 2007.

[24] V. B. and P. M. M. Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia and (eds.), "IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change," Cambridge, United Kingdom and New York, NY, USA, 2013.

[25] *Factores de emisión de CO2 y coeficientes de paso a energía primaria de diferentes fuentes de energía final consumidas en el sector de edificios en España*. Instituto para la Diversificación y Ahorro de la Energía (IDAE), 2014.