D7.9 Retrofitting toolkit

Funding scheme	EU-H2020-Grean Deal, H2020-LC-GD-2020-3		
Project	ECF4CLIM, European Competence Framework for a Low Carbon Economy and Sustainability through Education		
Project number	101036505		
Project Coordinator	CIEMAT, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas		
Start Date of the Project	01.10.2021	Duration of project	48 months
Contributing WP	WP7 - DIGITAL PLATFORM TO PROMOTE ACTIVE LEARNING AND CITIZEN INVOLVEMENT		
Tasks	Task 7.3 Simulation Tools		
Dissemination Level	Public		
Due date	2023 October 30		
Submission date	2023 November 30		
Responsible partner	JYU		
Contributing organizations	CIEMAT, ENLITIA (previously SMARTWATT), ISQ		
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Version	2.0		

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036505

WHO WE ARE

The ECF consortium consists of ten partners. The project is coordinated by Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas-CIEMAT.

Name	Country	Logo
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CIEMAT	ES	
Instituto Superior Técnico. University of Lisbon. IST	PT	
Universidad de Sevilla USE	ES	
University of Jyväskylä JYU	FI	
Universitat Autònoma de Barcelona UAB	ES	
Meda Research Ltd MedaResearch	RO	
Instituto de Soldadura e Qualidade ISQ	PT	
Trebag Szellemi Tulajdon Es Projektmenedzser Korlatolt Felelossegu Tarsasag TREBAG	HU	
Smartwatt Energy Services SA Smartwatt	PT	
ENLITIA SA ENLITIA	PT	
Que Technologies Kefalaiouchiki Etaireia QUE	GR	

ABOUT THE PROJECT

Through a multidisciplinary, transdisciplinary and participatory process, ECF4CLIM develops tests and validates a European Competence Framework (ECF) for transformational change, which will empower the educational community to take action against climate change and towards sustainable development.

Applying a novel hybrid participatory approach, rooted in participatory action research and citizen science, ECF4CLIM co-designs the ECF in selected schools and universities, by: 1) elaborating an initial ECF, supported by crowdsourcing of ideas and analysis of existing ECFs; 2) establishing the baseline of individual and collective competences, as well as environmental performance indicators; 3) implementing practical, replicable and context adapted technical, behavioural, and organisational interventions that foster the acquisition of competences; 4) evaluating the ability of the interventions to strengthen sustainability competences and environmental performance; and 5) validating the ECF.

The proposed ECF is unique in that it encompasses the interacting STEM-related, digital and social competences, and systematically explores individual, organisational and institutional factors that enable or constrain the desired change. The novel hybrid participatory approach provides the broad educational community with an ECF adaptable to a range of settings; new ways of collaboration between public, private and third-sector bodies; and innovative organisational models of engagement and action for sustainability (Sustainability Competence Teams and Committees).

To encourage learning-by-doing, several novel tools will be co-designed with and made available to citizens, including a digital platform for crowdsourcing, IoT solutions for real-time monitoring of selected parameters, and a digital learning space. Participation of various SMEs in the consortium maximises the broad adoption and applicability of the ECF for the required transformational change towards sustainability.

LEGAL NOTICE

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1. EXECUTIVE SUMMARY

This document is the deliverable D7.9 belonging to task 7.3 of ECF4CLIM project, contains a description of the retrofitting toolkit integrated into the Simulators space of the ECF4CLIM's digital platform. This is an updated version produced after the interim review of project's deliverables.

ECF4CLIM Project has been funded by the European Commission under the H2020-European Green Deal Call, under the grant agreement no. 101036505.

2. RETROFITTING TOOLKIT

The design of a building under energy efficiency and sustainability criteria depends on different factors: climatology, urban layout, volume, construction variables, windows, dimensions and materials of shading elements, typology and use of buildings. The final objective is to achieve high levels of comfort inside these buildings through greater or lesser exposure to solar radiation, the rational use of winds or the modulation of temperature and humidity. One of the elements used to facilitate the efficient and sustainable design of buildings is through surface maps of climatic and energy characteristics. These maps are graphical representations of environmental properties and heating and cooling requirements, allowing the quantification of indoor thermal comfort levels.

The giant steps that society and the world are taking in terms of digitization are leading us to a new panorama in all sectors, including education. Therefore, the digital transformation in schools is something that is present today throughout our society and this could not be less for the education sector. The availability of resources is mainly use of computers, tablets, digital equipment and high-speed internet. Large number of innovative initiatives and projects, and many entities in the world of education and training promote e-Learning and digital development.

This toolkit aims to strengthen energy efficiency awareness among teachers, students or schools' manager and personnel and promote the engagement of the entire educational community in action towards behavioural changes towards efficiency and sustainability. This tool is also presented as an opportunity to make educational community aware of the potential of digital technologies in traditional education and new ways to use it. It is therefore vital to raise awareness among stakeholders and even offer training. They must feel that they are part of the change and that the tools will not replace them but will help them.

Main functionalities of the Retrofitting toolkit are described in this section. This digital platform is developed in two new tools:

- Maps for building energy retrofitting proposals
- Dynamic building energy performance.

The toolkit will select the input data for each school and analyse the climatic characteristics of the area, identify different measures to improve thermal comfort inside schools, estimate the heating and cooling needs based on the established set points, and quantify the thermal needs of a classroom based on the proposed energy efficiency measures.

The methodology applied to develop this retrofitting toolkit is outlined in Figure 1.

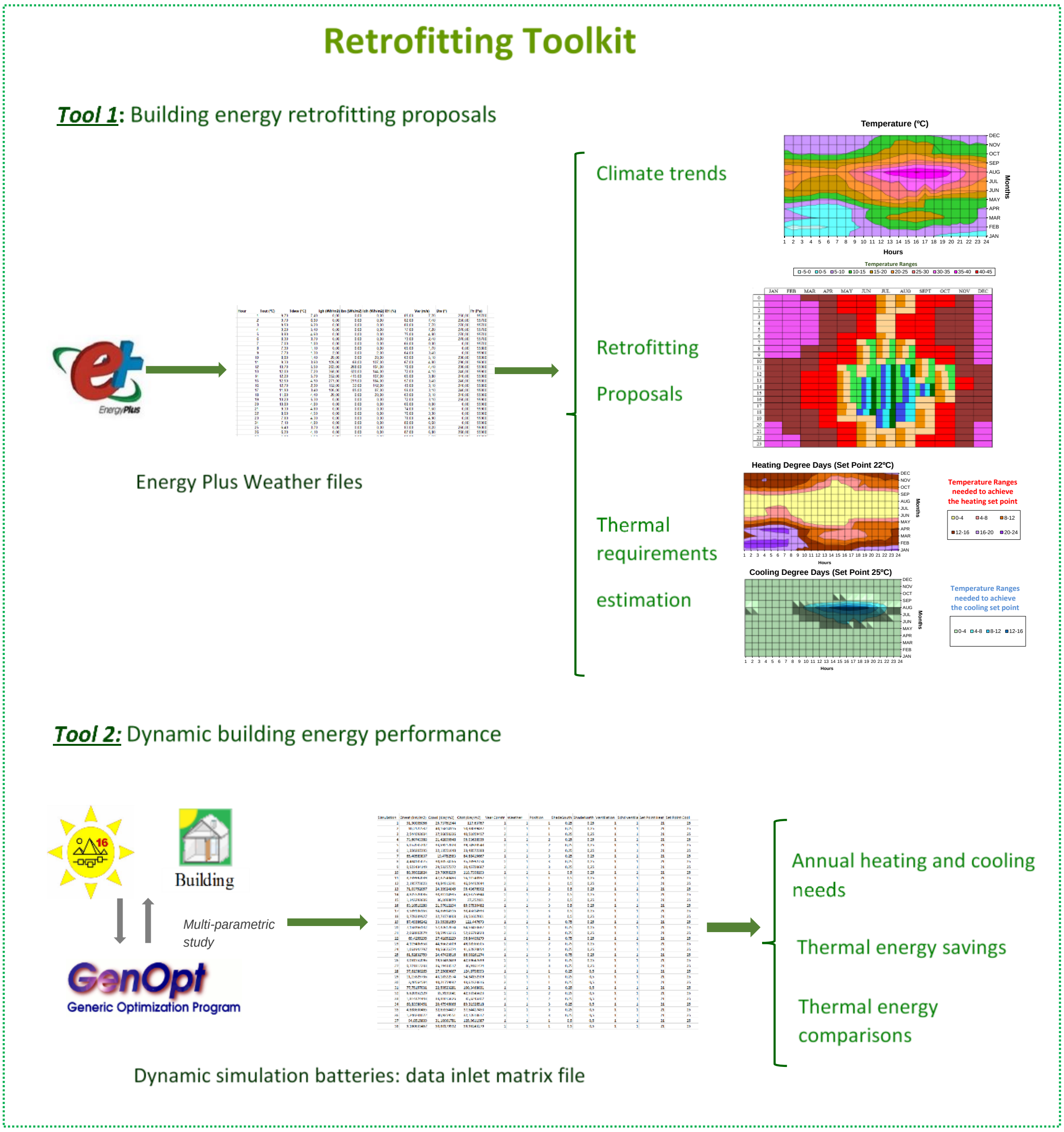

Figure 1– Overview of the Retrofitting Toolkit

To adapt the Retrofitting toolkit to different educational levels, both tools offer a variety of graphs to visualise the information according to the age groups of the students: primary school, secondary school or university. These graphs are tailored to the specific requirements of each level. Furthermore, the level of the information detail presented through these graphs, together with the explanatory texts and images, is adjusted in such a way as to suit the comprehension and learning needs of each educational group.

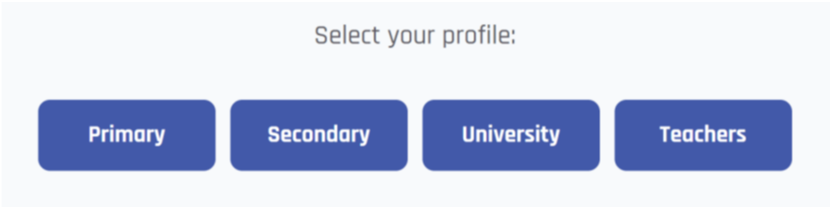

Figure 2– Overview of the initial profile selection screen of Tool1

This Retrofitting Toolkit has been programed within a Simulation Space (Figure 3) designed to inform, enhance knowledge and provide sustainable and efficient measures in the educational centres for both students and teachers. These three tools are:

- Environmental footprint calculator
- Retrofitting toolkit
- Sustainability Interventions Evaluation

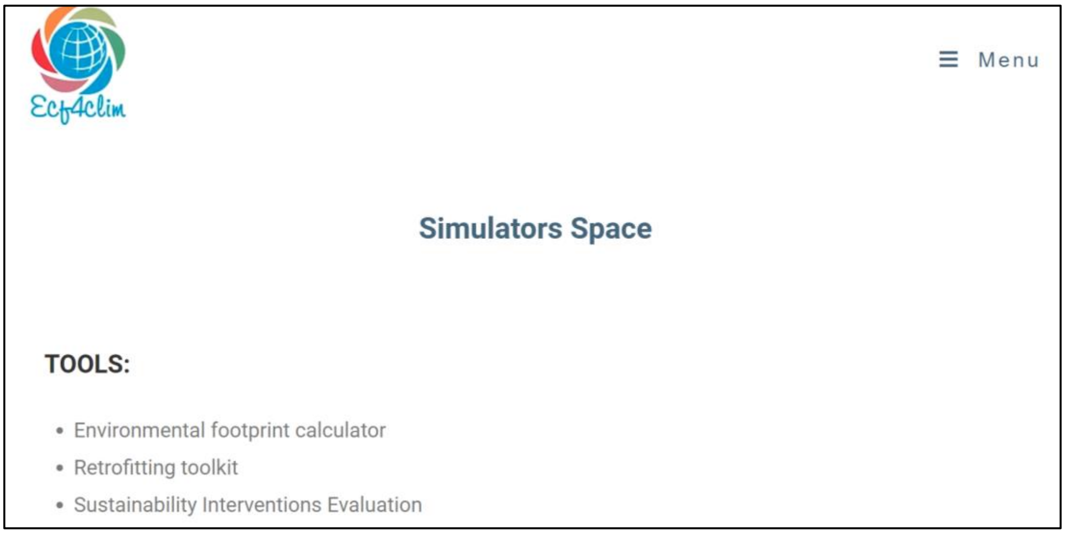

Figure 3– Overview of the Simulation Space

The Simulator Space includes all the tools developed in ECF4CLIM project. The access to the Retrofitting toolkits is available in the next links:

https://ecf4clim-app.smartwatt.net/app/retrofitting-tool-1,

https://ecf4clim-app.smartwatt.net/app/retrofitting-tool-2

The results obtained from these tools are very useful in the decision-making process to plan effective policies that take into account the climate impact on the built environment of the selected schools and universities.

3. TOOLS OF THE RETROFITTING TOOLKIT

The operation of this toolkit is developed through two tools, which allows analysing the improvement of energy efficiency in a sequential way: climate trends, passive and active measures proposed for each school, estimation of the thermal requirements and quantification of the thermal needs.

3.1 Tool1: Maps for building energy retrofitting proposals

This first tool is developed to provide climate and bioclimatic information of each school's location based on the weather files used. The tool is carried out considering three type of outputs:

- *Climate maps*, showing static results for each climate input.
- *Bioclimatic strategies* adapted to the climate zone of the school, showing static results for each climate input.
- *Heating and cooling estimation*, showing dynamic results for each climate.

The visualization of the results of this tool displays different diagrams to highlight climate trends, indoor thermal comfort and the thermal estimation required to reach temperature set points. The use of these charts allows quantifying the climate severity and predicting whether passive heating or cooling measures are likely to improve thermal comfort inside the schools.

Users

This tool is designed with the educational level of its users in mind by differentiating between educational profiles (Figure 2):

- Primary.
- Secondary.
- University.
- Teachers.

Outputs are shown in a different way depending on the educational level. These results are adapted to the knowledge and age of each level. Diagrams shown at university and teacher level are the same.

Input information

The climate of a locality is obtained from the treatment of meteorological variables recorded over a long period. This treatment generates a long-term meteorological model that characterizes the climatic patterns of the area, represented by a Typical Meteorological Year (TMY). The most representative variables representing the climatology of a location include mainly temperature, solar radiation and relative humidity, although it can also include wind direction and speed. In the development of the Retrofitting toolkit, TMY files of the schools' locations are used as input information to calculate the surface maps and the thermal energy needs of each school.

There are several climatic databases, but one of the most widely used when assessing the energy performance of a building is developed by ASHRAE and provided by EnergyPlus (E+). These climate files, defined in EPW format (see Figure 4), are created based on measurement campaigns provided from the World Meteorological Organization, and are used as input file in this tool.

F	G	H	I	J	K	L	M	N	O
lour	Tout (ºC)	Tdew (ºC)	Igh (Wh/m2)	Ibn (Wh/m2)	Idh (Wh/m2)	RH (%)	Vw (m/s)	Dw (º)	Pr (Pa)
1	9,70	7,40	0,00	0,00	0,00	85,00	7,20	250,00	95700
2	9,70	6,90	0,00	0,00	0,00	82,00	7,40	250,00	95700
3	9,50	6,20	0,00	0,00	0,00	80,00	7,70	270,00	95700
4	9,20	5,40	0,00	0,00	0,00	77,00	7,20	270,00	95700
5	8,80	4,60	0,00	0,00	0,00	75,00	4,80	270,00	95700
6	8,30	3,70	0,00	0,00	0,00	73,00	2,40	270,00	95700
7	7,00	1,00	0,00	0,00	0,00	66,00	0,00	0,00	95700
8	7,30	1,10	0,00	0,00	0,00	65,00	1,70	0,00	95800
9	7,70	1,30	2,00	0,00	2,00	64,00	3,40	0,00	95900
10	8,00	1,40	20,00	0,00	20,00	63,00	5,10	290,00	96000
11	9,30	3,60	126,00	68,00	107,00	67,00	4,80	290,00	96000
12	10,70	5,50	263,00	268,00	164,00	70,00	4,40	290,00	95900
13	12,00	7,20	368,00	520,00	144,00	72,00	4,10	240,00	95900
14	12,20	5,70	352,00	415,00	167,00	65,00	3,80	240,00	95900
15	12,50	4,10	271,00	211,00	184,00	57,00	3,40	240,00	95800
16	12,70	2,30	152,00	32,00	142,00	49,00	3,10	240,00	95800
17	11,90	3,40	105,00	85,00	87,00	56,00	3,10	240,00	95800
18	11,00	4,40	20,00	0,00	20,00	63,00	3,10	240,00	95900
19	10,20	5,30	0,00	0,00	0,00	72,00	3,10	250,00	95900
20	10,00	4,00	0,00	0,00	0,00	66,00	0,00	0,00	95900
21	9,30	4,80	0,00	0,00	0,00	74,00	1,60	0,00	95900
22	8,60	4,50	0,00	0,00	0,00	76,00	3,30	0,00	95900
23	7,80	4,30	0,00	0,00	0,00	78,00	4,90	0,00	95900
24	7,10	4,00	0,00	0,00	0,00	80,00	6,60	0,00	95900
25	6,40	3,70	0,00	0,00	0,00	83,00	8,20	260,00	96000
26	6,20	4,10	0,00	0,00	0,00	87,00	6,80	260,00	95900
27	6,00	4,50	0,00	0,00	0,00	90,00	5,50	260,00	95900
28	5,80	4,90	0,00	0,00	0,00	94,00	4,10	160,00	95900
29	6,00	5,00	0,00	0,00	0,00	93,00	3,10	170,00	95900
30	5,70	5,00	0,00	0,00	0,00	95,00	2,60	170,00	95900
31	5,40	5,00	0,00	0,00	0,00	97,00	2,10	190,00	95800
32	5,90	5,60	0,00	0,00	0,00	98,00	2,10	190,00	95800
33	6,50	6,20	1,00	0,00	1,00	98,00	2,10	190,00	95800
34	7,00	6,70	20,00	0,00	20,00	98,00	2,10	190,00	95800
35	8,10	7,00	62,00	0,00	62,00	93,00	2,80	190,00	95800
36	9,30	7,30	98,00	0,00	98,00	87,00	3,40	190,00	95800
37	10,40	7,50	120,00	0,00	120,00	82,00	4,10	240,00	95700
38	10,90	7,40	125,00	0,00	125,00	79,00	4,10	240,00	95700
39	11,30	7,20	113,00	0,00	113,00	76,00	4,10	240,00	95600
40	11,80	7,00	84,00	0,00	84,00	72,00	4,10	240,00	95500
41	11,10	7,10	44,00	0,00	44,00	76,00	4,80	240,00	95500
42	10,50	7,20	7,00	0,00	7,00	80,00	5,50	240,00	95500

Figure 4– Example of EPW input climate file

Results

The visualization of this tool allows users to select different maps that help to understand the improvement of the energy performance of buildings, through the evaluation of climate trends, the identification of the most appropriate bioclimatic measures and the estimation of their heating and cooling requirements. This tool provides different analyses adapted to the schools' profiles.

- *Primary level*.

For the primary level, the selection buttons correspond the city where the school is located and the variable that the student want to display. The graphs of these climatic variables are displayed by clicking on their icon: temperature, relative humidity, global solar radiation and wind speed (Figure 5).

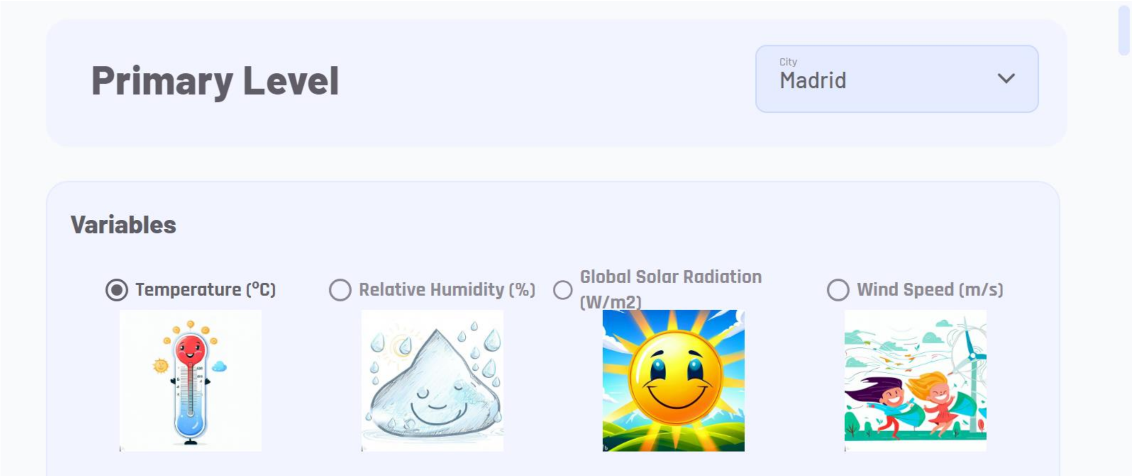

Figure 5– Selection buttons for primary students

The climate evolution of the meteorological variables is displayed in two hourly diagrams: annual and seasonal. The annual diagram (Figure 6) shows annual and seasonal values (summer, spring, autumn and winter) of the selected variable along the 24 hours of the day. The seasonal diagrams (Figure 7) show the selected variable along the 24 h of a representative day of the month. The months corresponding to each season are:

- Winter: January, February and December.
- Spring: March, April and May.
- Summer: June, July and August.
- Autumn: September, October and November.

In both hourly diagrams, four daily periods (X-axis) and three thermal sensation periods (Y-axis) are marked. The four daily periods are: early morning, morning, afternoon and early night while the three thermal sensation periods are: hot (coloured in red), comfort (coloured in pink) and cold (coloured in blue).

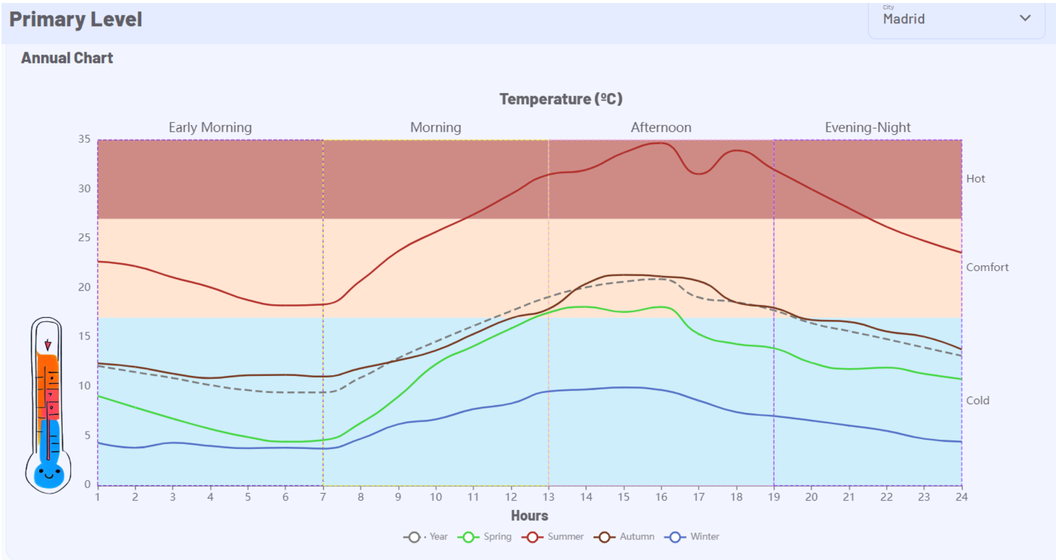

Figure 6– Annual hourly temperature diagram for primary students

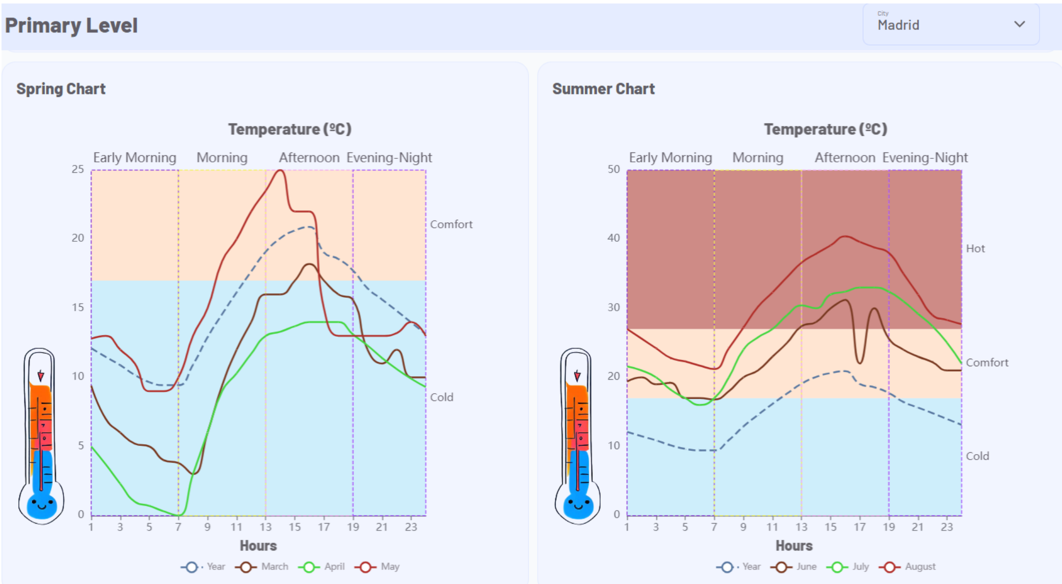

Figure 7– Spring and summer hourly temperature diagrams for primary students

Finally, a bioclimatic diagram is displayed representing the annual heating degree-days (HDD coloured in red) and the annual cooling degree-days (CDD coloured in blue) for each of the twelve months of the year.

- *Heating degree-days* is a measure of how much (in degrees) and for how long (in days) the outdoor air temperature was lower than a specific base temperature, (heating set point temperature is fixed to 22°C).
- *Cooling degree-days* is a measure of how much (in degrees) and for how long (in days) the outside air temperature was higher than a specific base temperature, (cooling set point temperature is fixed to 25°C).

This diagram also displays possible strategies to help achieve thermal comfort sensation inside the building:

- Radiator icon: turn on the heating.
- Window icon: take advantage of direct solar radiation.
- Fan icon: increase ventilation.
- House with shading devices: reduce direct solar gains.
- House with coat icon: increase insulation

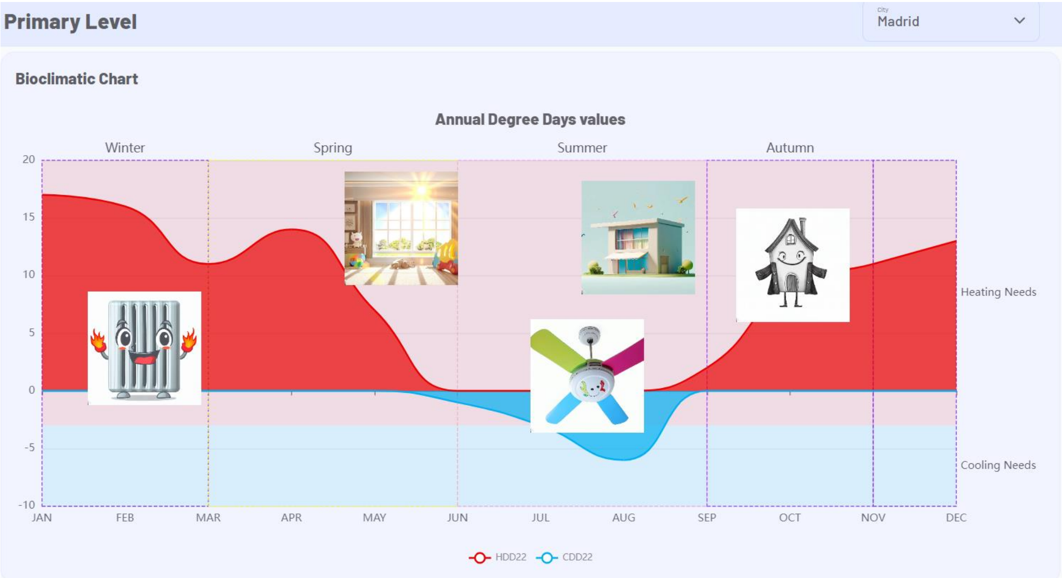

Figure 8– Bioclimatic chart for primary students

In all the diagrams, users can hover the mouse over the graph and the hourly value is displayed.

- *<u>Secondary level</u>*.

For the secondary level, the available selection buttons are the city where the school is located and the variable that the student want to display.

The climate evolution of the meteorological variables is displayed in two hourly bar charts: annual and seasonal. The values are displayed over the 24 hours of the day, separated into four daily periods on the X-axis (early morning, morning, afternoon and early night) and three thermal sensation periods on the Y-axis (hot: coloured in red, comfort: coloured in pink, and cold: coloured in blue).

The annual diagram (Figure 9) represents the hourly evolution of the seasonal variable (bars) and the annual hourly evolution (dotted line).

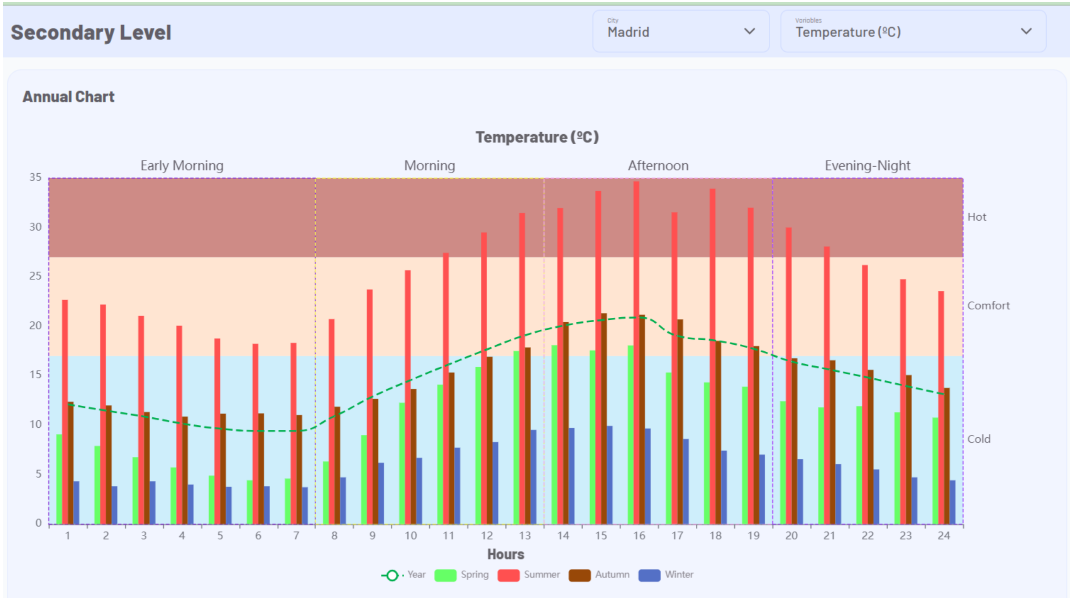

Figure 9– Annual hourly temperature diagram for secondary students

The seasonal diagrams (Figure 10) display similarly the selected variable along the 24 h of a representative day of the month. These representative days represent the most frequent average behaviour for each month. The months of the year are regrouped into four seasons:

- Winter: January, February and December.
- Spring: March, April and May.
- Summer: June, July and August.
- Autumn: September, October and November.

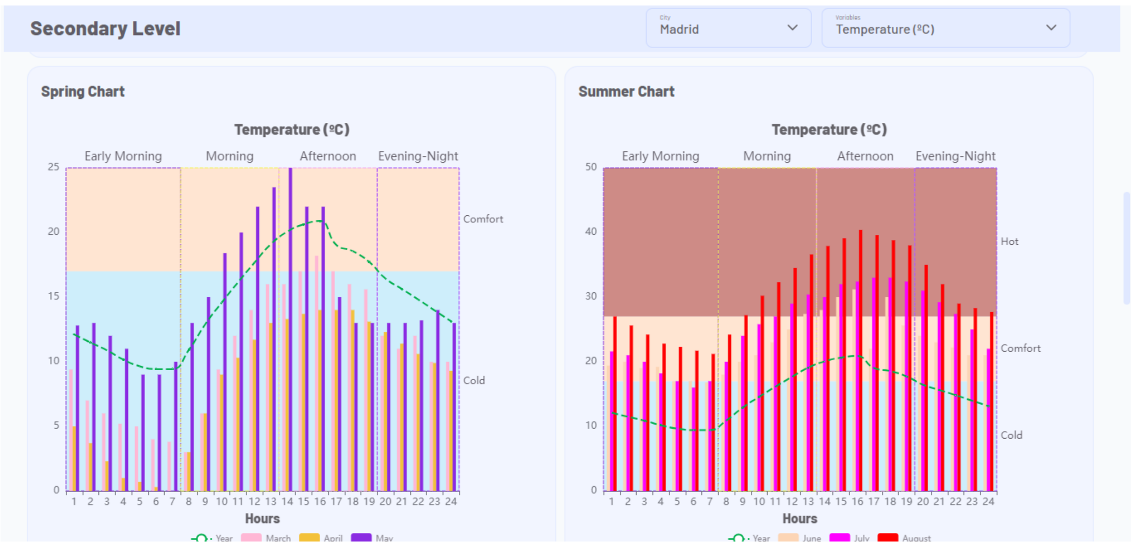

Figure 10 – Seasonal temperature diagrams for secondary students

Building heating and cooling needs are estimated based on the climatic severity using the degree-days methodology. This method calculates the effect of the outdoor temperature on the building thermal needs by setting temperature setpoints. Two indices are obtained: heating degree-days or the energy required heating the building (HDD), and cooling degree-days or the energy required cooling the building (CDD). The setpoints are set according the period of the year: 22°C for winter and 25°C for summer. Annual and seasonal degree-days are showing in Figure 11, differentiating four possible times of day on the X-axis.

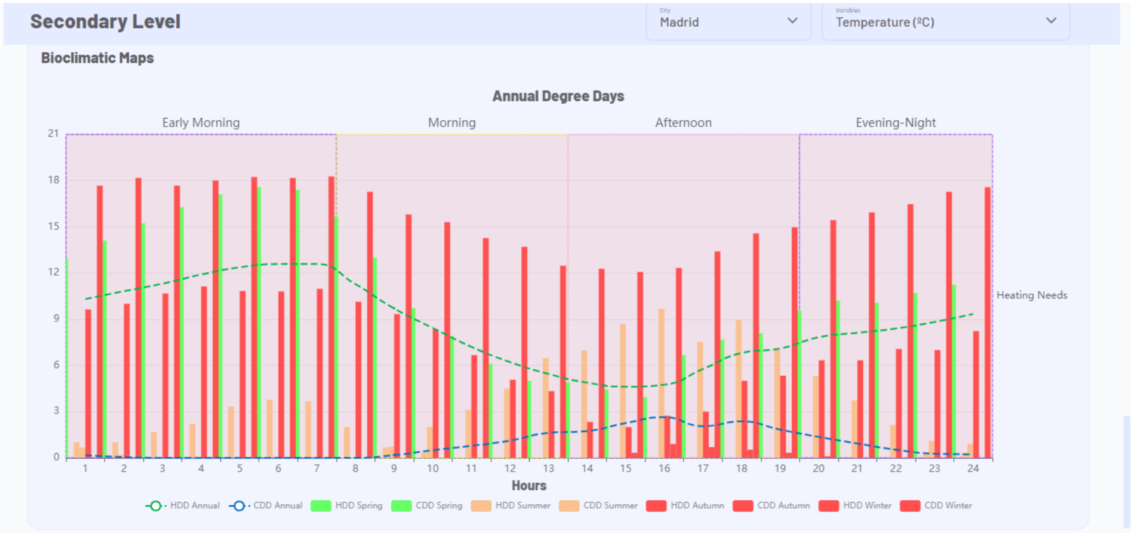

Figure 11– Annual degree-days diagram for secondary students

- *University level*.

At this level, surface maps of each variable are developed to highlight the climatic severity and building thermal needs. This analysis is carried out by comparing the climate variables at two zones selected by users. This is done graphically displaying two climographs for one variable and both locations. The climograph represent the variable values for the 24 hours of the day on the X-axis and for the 12 months of the year on the Y-axis.

Variables to be selected:

- Temperature (Figure 12)
- Relative humidity,
- Global solar radiation
- Wind speed.
- Heating and cooling degree-days (Figure 13), allowing the user to select the temperature established as reference in the calculation of these building thermal needs (setpoints).

These values are available to download by the users in Excel sheets.

At this university level, the tool also provides a qualitative study to estimate how climate influence the requirements to thermal conditioning the schools using the Degree Days methodology for heating (HDD) and cooling (CDD). Heating and cooling degree-days are defined as a function of the thermal balance between outdoors and indoors, using set-point temperatures as references. These variables represent how external temperature fluctuations affect thermal needs in schools, giving the “hourly degrees” required to achieve a comfortable indoor environment. Users based on the school requirements can adapt setpoint temperatures but care must be taken into account to maintain an adequate level of thermal comfort inside the classrooms. Figure 12 shows the heating degree-days setting the setpoint at 22°C while Figure 13 shows the cooling degree-days setting the setpoint at 23°C.

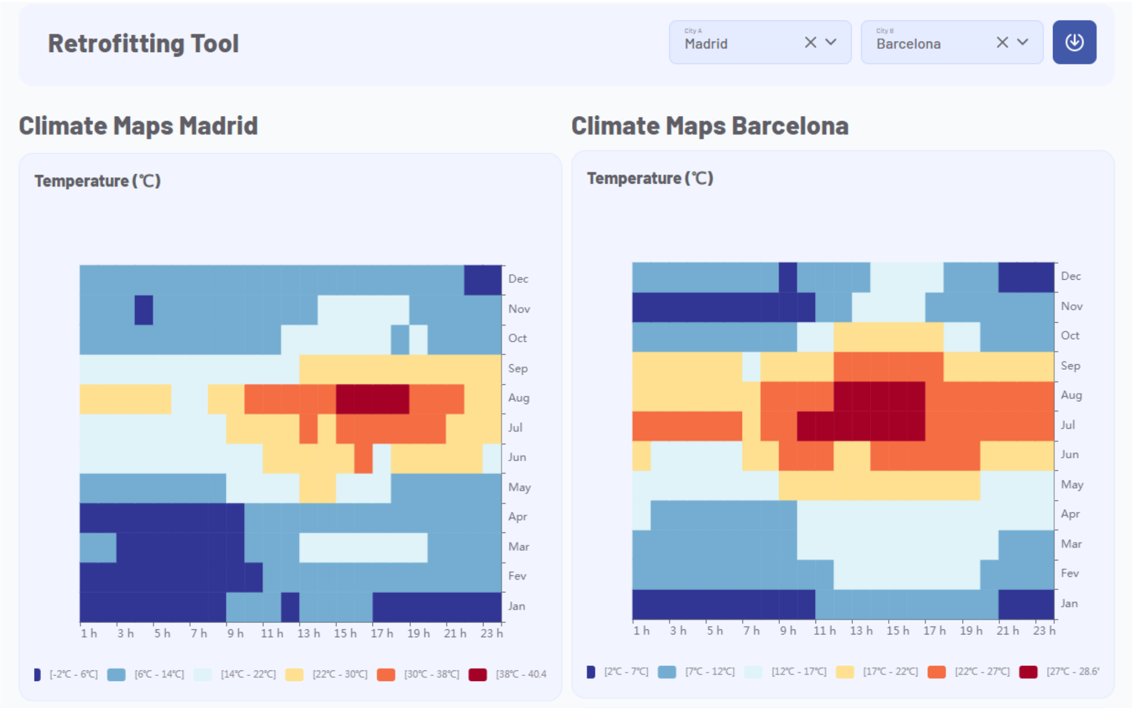

Figure 12– Climograph for the temperature in two different locations for University students

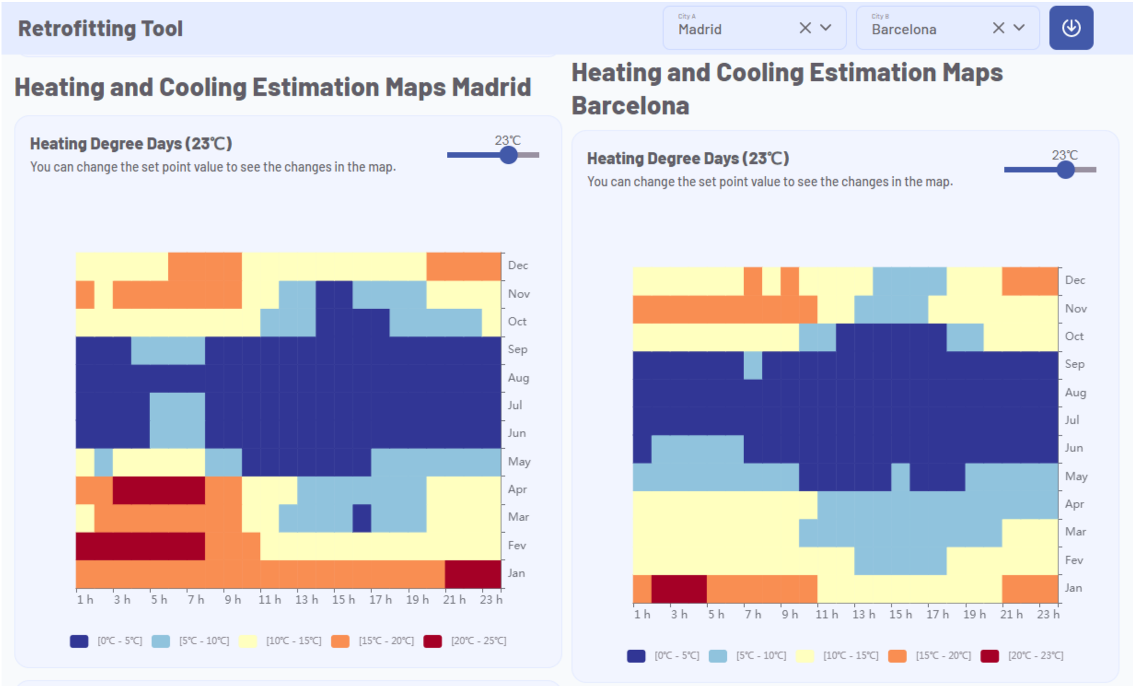

Figure 13– Climograph for the heating degree-days in two different locations, for a fixed reference value of 23ºC in both, intended for University students

The improvement of indoor comfort conditions in different climate zones is presented through the surface mapping of the bioclimatic strategies. These 2-D bioclimatic diagrams represent the recommended passive and active strategies to achieve thermal comfort inside buildings under these climates, employing a colour code. The X-axis indicates the hourly values and the Y-axis indicates the monthly values.

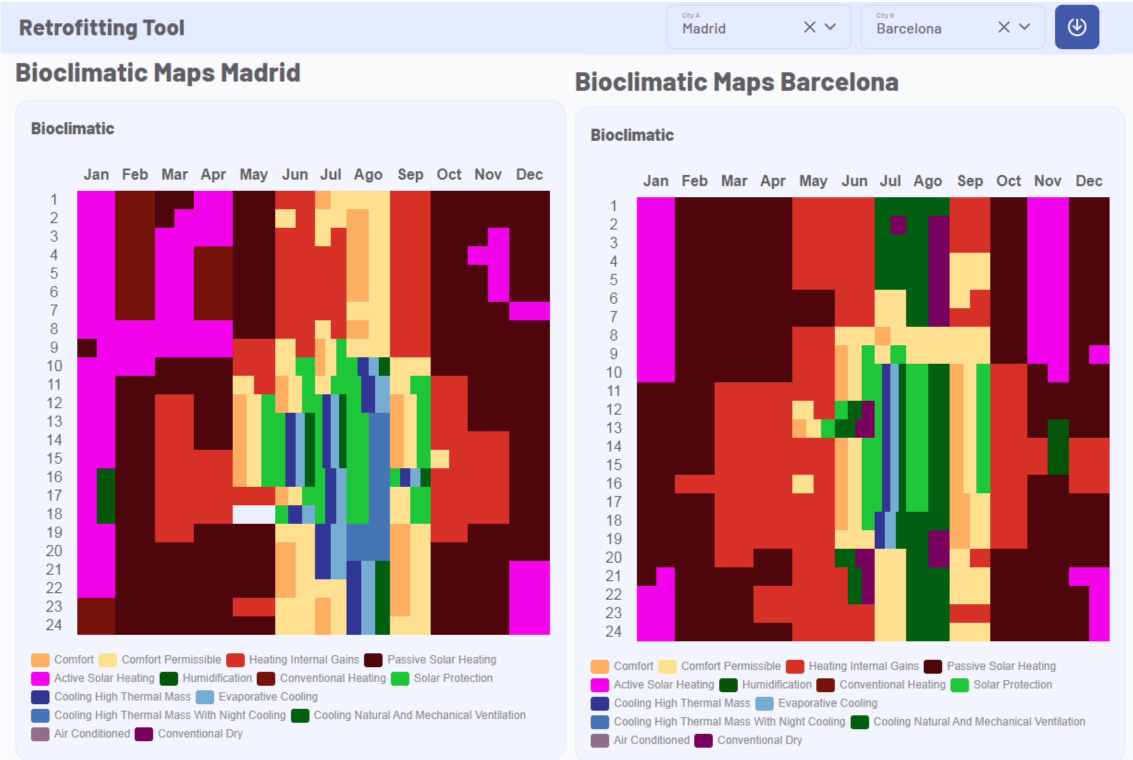

Figure 14– Bioclimatic strategies proposed for two different locations, for University students

These bioclimatic maps propose potential strategies to optimise building design based on human thermal requirements and local climatic conditions. These diagrams determine the comfort zone in relation to air temperature, humidity, solar radiation and wind speed. These maps show fourteen zones corresponding to twelve bioclimatic design strategies adapted to the climatology of the area, whose implementation allows reaching a thermal comfort sensation inside the schools.

The twelve design strategies shown in the bioclimatic maps correspond to following measures:

- *Sun protection by shading*. Reduction of incident solar gains on the school using solar protections.
- *Natural or forced ventilation*. Reduction of cooling loads using ventilation rates.
- *Heating by internal gains*. Increase of indoor temperatures due to the consideration of the internal loads inside the school (people, computers, electronic equipment, lighting...).
- *Passive use of solar energy*. Reduction of heating demands by taking advantage of the natural resources of the area (radiation and wind) in different building components: glazing, Trombe walls, greenhouses, etc.
- *Active use of solar energy*. Reduction of heating and electricity demands through the installation of solar thermal collectors and photovoltaic panels.

- *Conventional heating*. Use of conventional heating to meet the thermal demands of the school when outdoor temperatures are very low. In order to take advantage of the renewable resources of each area, the use of biomass boilers or geothermal heat pumps is recommended.
- *Cooling by high thermal mass*. Reduction of cooling demands for buildings with high inertia, delaying and damping the entry of the heat during the hours of maximum radiation.
- *Cooling by high thermal mass and night renewal*. Reduction of cooling demands taking advantage of the high thermal inertia and night ventilation. The use of night ventilation reduces the thermal loads of the building and delays the start-up of the cooling systems.
- Air-conditioning. Use of conventional air conditioning systems to reduce cooling demands when outdoor temperatures are very high. To minimize the use of conventional systems, absorption refrigeration systems powered by solar energy could be used.
- *Humidification*. Improvement of thermal comfort conditions in very dry environments by injecting water into the ambient air.
- *Evaporative systems*. Reduction of cooling demands by increasing the water content of the air and approaching the comfort zone. This process reduces the air temperature while increases the humidity ratio.
- *Dehumidification systems*. Reduction of cooling demands by reducing the water content of the air and bringing the values closer to the comfort band.

The bioclimatic strategy map shows these twelve strategies, one comfort zone and another permissible comfort zone, obtained from the requirements specified by Givoni in his bioclimatic chart. These strategies can appear alone or several can coexist together, although with different weight.

3.2 Tool 2: Dynamic building energy performance

A dynamic energy building performance tool is developed to evaluate the energy saving potentials achieve by the implementation of different retrofitting measures in schools. This tool gathers the initial building information, queries the simulation database available and quantifies the retrofitting percentage reached by the measure selected. The use of this tool allows estimating the energy response of a representative classroom when different retrofitting measures are implemented.

The methodology used to create this tool is divided in four phases. First, a representative classroom is modelled based on the climate information, the construction characteristics and operational variables. Secondly, different retrofit measures are proposed in order to create the inlet simulation database of the tool. Retrofitting measures such us modification of windows, ventilation rates or lighting typologies are studied. Thirdly, several batteries of simulations are executed to calculate the thermal loads of the representative classroom reached with the implementation of one measure. Finally, a post-processing of the outputs is done to calculate the annual thermal demands and the retrofitting savings achieve by each measure.

Users

This tool is designed with the educational level of its users in mind by differentiating between educational profiles:

- Primary.
- Secondary.
- University.

Outputs are shown in a different way depending on the educational level. These results are adapted to the knowledge and age of each level.

Input information

This tool seeks to quantify the annual thermal demands of a classroom as well as the retrofitting savings achieved based on the climatic characteristics of the school location, the position of the classroom in the building and the construction and use characteristics. These analyses are carried out through dynamic simulation tools, which allow the variation of parameters (climate, construction characteristics…), input variables (lighting typologies, ventilation rates...) and boundary conditions (classroom position, shades…)

The quantification of each proposed retrofitting measure is calculated through a parametric study, quantifying the influence on the annual thermal demands. With this aim, a dynamic simulation program is coupled with a parameterization program to generate a database used as input file in the form of data inlet matrix.

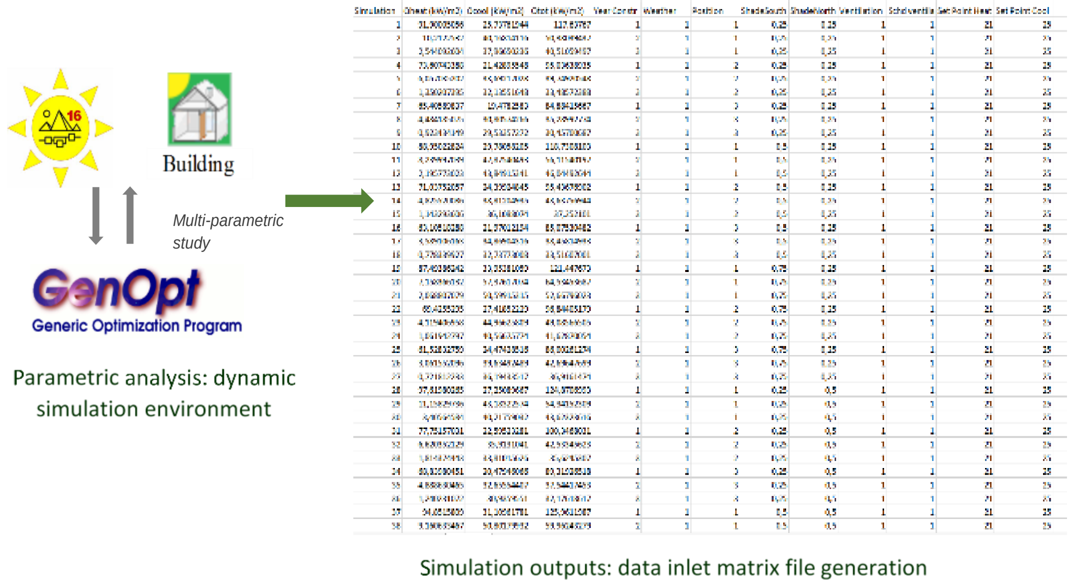

Figure 15– Methodology to create the data inlet matrix file

In the visualization of the tool, all users select the location of the school and the position of the classroom in the building. Other characteristics, such as orientation, should be available in secondary and university levels.

Results

The dynamic building energy performance tool is able to assess thermal performance of each studied classroom giving as results annual heating and cooling needs. The selected improvements to quantify the energy saving achieved in the building are:

- Walls improvements.
- Windows improvements.
- Walls and Windows improvements.
- Lighting typologies.
- Ventilation rates.
- Infiltration characteristics of the building.
- Shading on the windows.

This Tool 2 allows students to compare and appreciate the effect of the different parameters taken into account for the estimation of thermal demand, and at the same time to relate the results of this tool with the previously defined maps, where strategies to reduce demand are proposed.

- *Primary level*.

At the primary level, the analysis of energy savings due to the implementation of an improvement measure starts with the selection of the school of interest and the selection of the building floor to be studied (Figure 16).

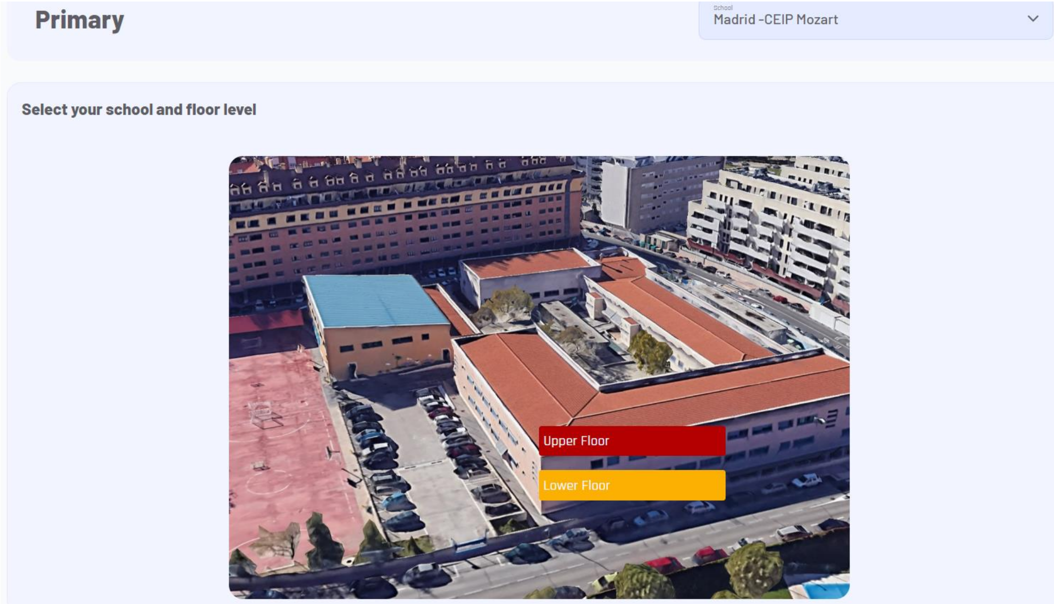

Figure 16– Selection of school and building floor of Tool 2 for primary students

Once the classroom floor is chosen, all the parameters of the base case are automatically configured to simplify the use of the tool:

- Classroom with one outdoor façade facing south and without shading devices.
- Classroom area of 50 m^2.
- Building poorly insulated.
- Basic glass on windows according to the current constructive normative in the year of the building construction.
- Classroom with fluorescent lighting.
- No ventilation rate is considered.

The classroom image provides the improvement measures that can be assessed: walls, windows, walls & windows, ventilation, lighting and shadows (Figure 17). The estimated heating and cooling needs for the base case are shown at the bottom of the classroom image.

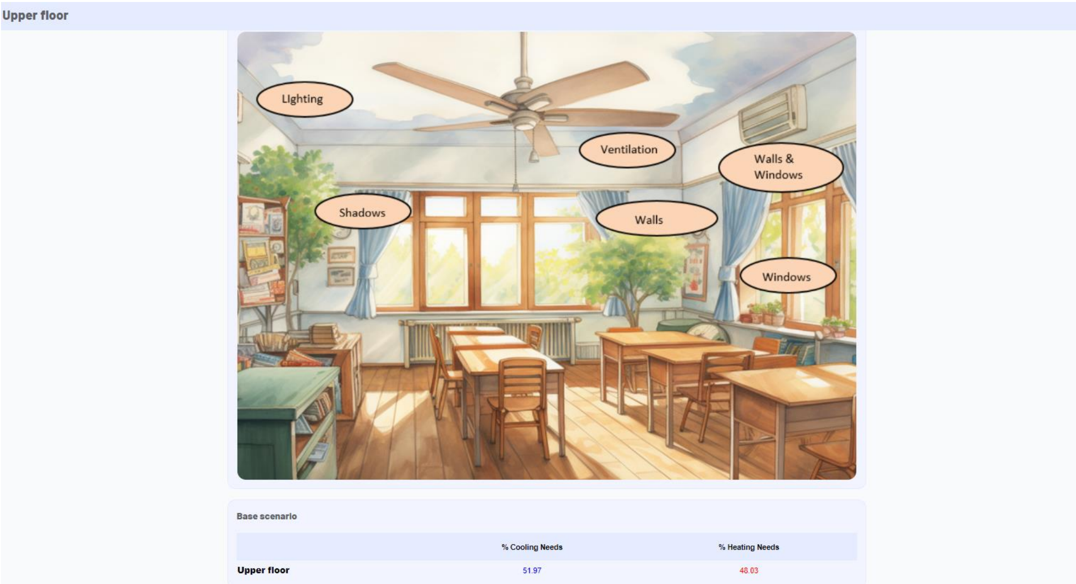

Figure 17– Improvement measures proposed to evaluate the classroom energy savings of Tool 2 for primary students

By clicking on the icons of the improvement measures, students have the option to analyse to analyse the energy savings foe heating and cooling generated by the selected measure with respect to the base case (Figure 18). The improvement option for each measure is automatically associated with the most optimal result from the battery of outputs generated in the simulation environment. These optimal results used as an improvement of each of the measures have the following values associated with them (Figure 19):

- Building well insulated.
- Materials of the building envelope enclosures updated to regulations after 2010.
- Low emissive double glass in windows.
- Classroom with LED lighting.
- Summer ventilation.
- 75% shade on the south façade during the summertime.

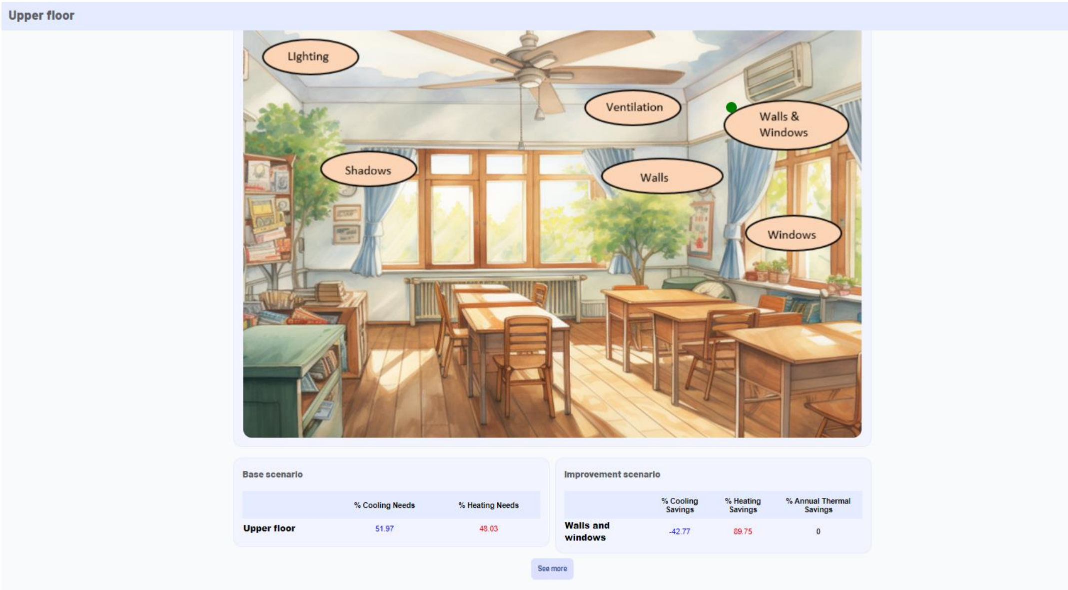

Figure 18– Savings in heating and cooling needs produced by the implementation of a measure with respect to the base case in Tool 2 for primary students

See less

Base scenarios by floor

Base case	Area	Building Insulation	Floor	Normative	Window	Illumination	Ventilation	% Heating Needs	% Cooling Needs
Upper floor	50.41	After 2006 Poorly insulated (Infiltration=0.67)	0	Between 2000-2010	Simple glass	Fluorescent lighting	No ventilation	48.03	51.97

Improvement scenario by measurements

Retrofitting measures	Area	Building Insulation	Normative	Window	Illumination	Ventilation	Shading 1F	% Heating Savings	% Cooling Savings	% Annual Thermal Savings
Illumination	50.41	After 2006 Poorly insulated (Infiltration=0.67)	Between 2000-2010	Simple glass	LED	No ventilation	0	26.37	-11.09	12.37
Shadows	50.41	After 2006 Poorly insulated (Infiltration=0.67)	Between 2000-2010	Simple glass	Fluorescent lighting	No ventilation	0.75	30.33	77.76	48.05
Ventilation	50.41	After 2006 Poorly insulated (Infiltration=0.67)	Between 2000-2010	Simple glass	Fluorescent lighting	Summertime	0	27.98	-21.87	9.35
Walls	50.41	After 2006 Poorly insulated (Infiltration=0.67)	After 2010	Simple glass	Fluorescent lighting	No ventilation	0	47.74	-19.42	22.65
Walls and windows	50.41	After 2006 Poorly insulated (Infiltration=0.67)	After 2010	Low emissive double glass	Fluorescent lighting	No ventilation	0	89.75	-42.77	40.23
Windows	50.41	After 2006 Poorly insulated (Infiltration=0.67)	Between 2000-2010	Low emissive double glass	Fluorescent lighting	No ventilation	0	81.73	-37.75	37.08

Figure 19– Parameter values used as optimized options for all the improvement measures of Tool 2 for primary students

- *Secondary level*.

The estimation of heating and cooling energy savings produced by the implementation of an improvement measure at secondary educational level starts with the selection of the study classroom. This location is determined by the selection of the school of interest, the building floor to be studied and the orientation of the external façade (Figure 20). This selection sets the parameters that are used to define the base case:

- Classroom with one outdoor façade without shading devices.
- Classroom area of 50 m^2.

- Building poorly insulated.
- Basic glass on windows according to the current constructive normative in the year of the building construction.
- Classroom with fluorescent lighting.
- No ventilation rate is considered.

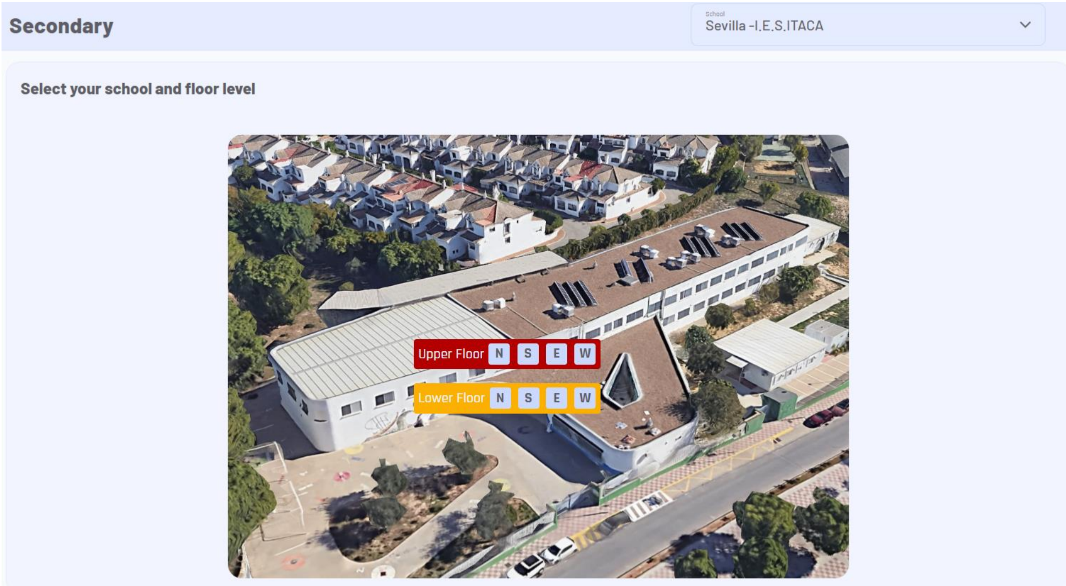

Figure 20– Selection of school and building floor of Tool 2 for secondary students

Once the classroom is selected, a set of improvement measures are available: walls, windows, walls & windows, ventilation, lighting and shadows (Figure 21). The estimated heating and cooling needs of the classroom selected as the base case are displayed in a bar figure at the bottom of the classroom image.

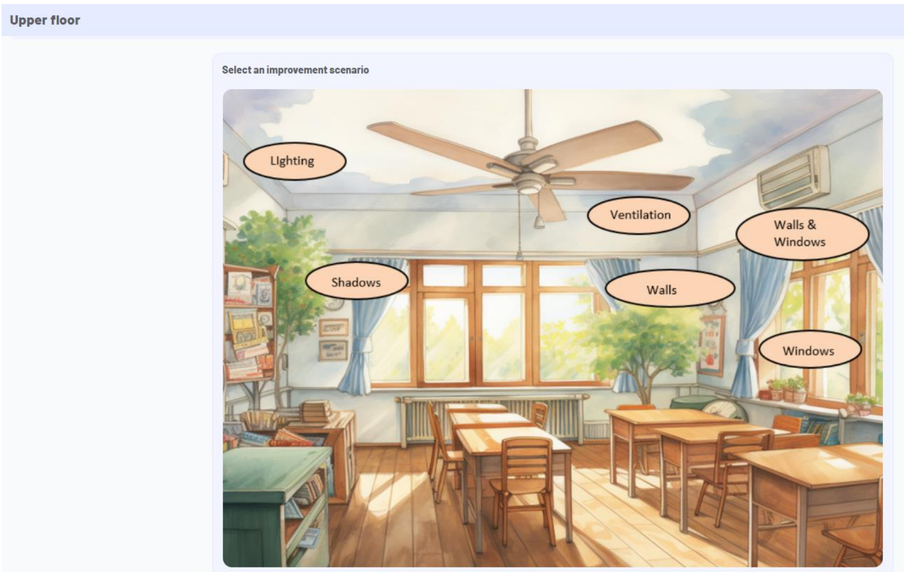

Figure 21– Improvement measures proposed to evaluate the classroom energy savings of Tool 2 for secondary students

Finally, the energy savings in heating and cooling needs produced by the implementation of an improvement measure are calculated with respect to the base case, resulting in the comparative graph of the two cases (Figure 22) and the percentages of savings obtained (upper table of Figure 23). The improvement parameters set for each measure are associated with the most optimal result generated in the simulation environment:

- Building well insulated.
- Materials of the building envelope enclosures updated to regulations after 2010.
- Low emissive double glass in windows.
- Classroom with LED lighting.
- Summer ventilation.
- 75% shade on the outdoor façade during the summertime.

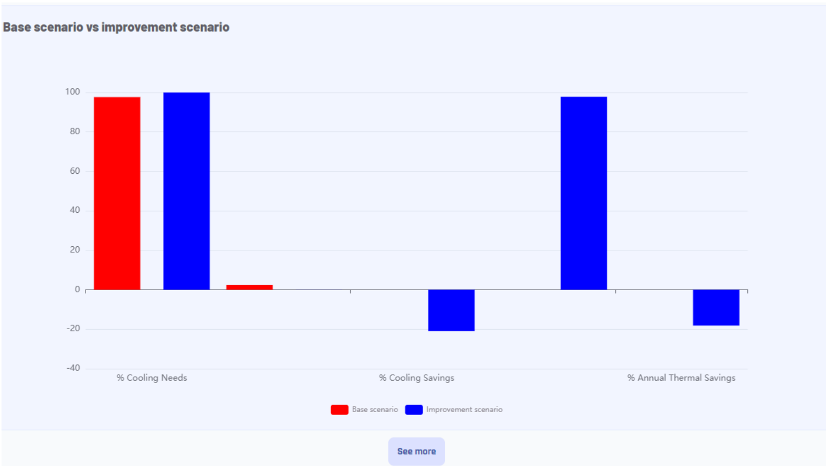

Figure 22– Energy savings for heating and cooling needs produced by the implementation of a measure with respect to the base case in Tool 2 for secondary students

Base scenarios by floor

Base case	Area	Building Insulation	Floor	Normative	Window	Illumination	Ventilation	% Heating Needs	% Cooling Needs
North	50.41	After 2006 Well insulated (Infiltration=0.1)	0	Between 2000-2010	Double glass	Fluorescent lighting	No ventilation	11.24	88.76
South	50.41	After 2006 Well insulated (Infiltration=0.1)	0	Between 2000-2010	Double glass	Fluorescent lighting	No ventilation	0.04	99.96
East	50.41	After 2006 Well insulated (Infiltration=0.1)	0	Between 2000-2010	Double glass	Fluorescent lighting	No ventilation	2.38	97.62
West	50.41	After 2006 Well insulated (Infiltration=0.1)	0	Between 2000-2010	Double glass	Fluorescent lighting	No ventilation	2.07	97.93

Improvement scenario by measurements

Retrofitting measures	Area	Building Insulation	Normative	Window	Illumination	Ventilation	Shading 1F	% Heating Savings	% Cooling Savings	% Annual Thermal Savings
Illumination	50.41	After 2006 Well insulated (Infiltration=0.1)	Between 2000-2010	Double glass	LED	No ventilation	0	0.06	9.44	9.44
Shadows	50.41	After 2006 Well insulated (Infiltration=0.1)	Between 2000-2010	Double glass	Fluorescent lighting	No ventilation	0.75	0	73.57	73.54
Ventilation	50.41	After 2006 Well insulated (Infiltration=0.1)	Between 2000-2010	Double glass	Fluorescent lighting	Summertime	0	0	2.71	2.71
Walls	50.41	After 2006 Well insulated (Infiltration=0.1)	After 2010	Double glass	Fluorescent lighting	No ventilation	0	99.67	-7.26	-7.22
Walls and windows	50.41	After 2006 Well insulated (Infiltration=0.1)	After 2010	Low emissive double glass	Fluorescent lighting	No ventilation	0	99.74	-21.58	-21.54
Windows	50.41	After 2006 Well insulated (Infiltration=0.1)	Between 2000-2010	Low emissive double glass	Fluorescent lighting	No ventilation	0	99.77	-11.1	-11.06

Figure 23– Tables of energy saving results (upper table) and the parameters set in each measurement (lower table) of Tool 2 for primary students

4. LEVEL OF DEVELOPMENT OF THE TOOLS

This section describes the main developments made in the two tools that make up the Retrofitting Toolkit as well as the task that remain pending completion.

Tool 1: maps for building energy retrofitting proposals

Tool 1 is fully developed, including both the initial theoretical databases, the calculation engine and the visualisation of the developed diagrams in the simulation space.

Tool 2: dynamic building energy performance.

The calculation engine for tool 2 is developed, although the visualisation of data at university level is still to be completed. The input variables and the proposed measures are identified and the simulation batteries are also developed to create the data input matrix. The results visualisation environment is currently being worked on.

5. FUTURE STEPS

Regarding the next steps, ENLITIA is finalising the visualisation of the results obtained in Tool 2 of the Retrofitting toolkit. These results are based on the information available in the databases differentiated by educational levels, automating all the necessary rules and calculations using Python.

Finally, ENLITIA is developing the verification and validation of the web-based tool in schools. These application tests can identify the level of difficulty and the degree of understanding achieved by users of the retrofitting toolkit. This verification will be important in the implementation of the tools, although it will be necessary that the toolkit is complete, robust, reliable and representative of the defined requirements.