D7.9 Retrofitting toolkit

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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	
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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	
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

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

This document is the deliverable D7.9 belonging to task 7.3 of ECF4CLIM project, contains a description about the retrofitting toolkit integrated into the Simulators space of the ECF4CLIM's digital platform. Future steps are also defined in this deliverable.

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. So, the digital transformation in schools is something that is very 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 also 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.

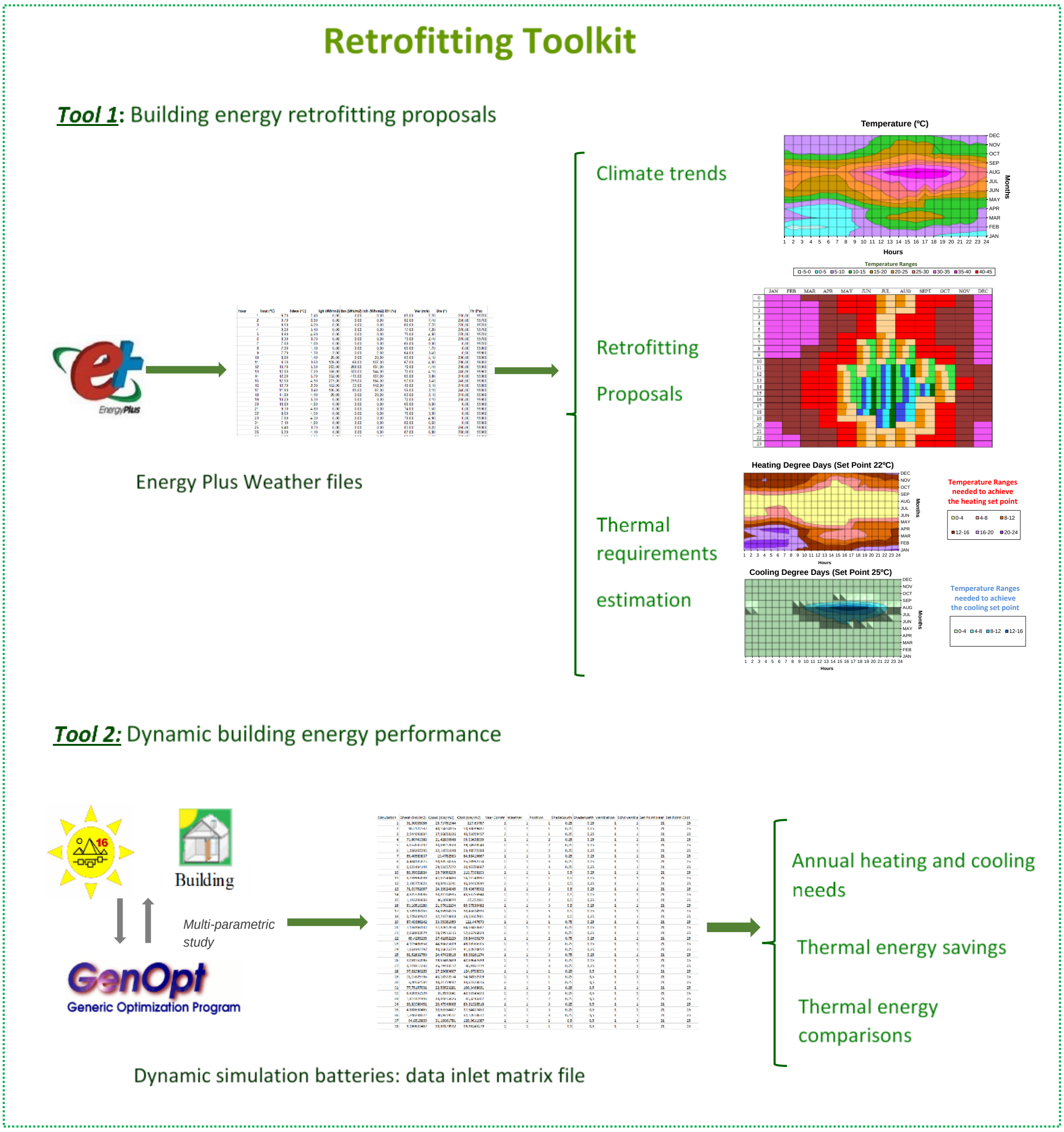

Figure 1– Overview of the Retrofitting Toolkit

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 BENEFITS

The operation of this toolkit has been developed through two tools, which will allow to analyse 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 Maps for building energy retrofitting proposals

This first tool is developed to provide climate and bioclimatic information of each school location based on the weather files used. The tool is carried out in three sections:

- *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 will display different surface maps 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 available with the same level of access for all types of users:

- School managers, personnel, and staff
- School users: students, teachers, etc.

Input information

The climate of a locality is obtained from the treatment of meteorological variables recorded over a long period of time. 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, have been 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
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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
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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 2– Example of EPW input climate file

The first step for the correct operation of this tool is the selection of the school location by the users, which will allow the identification of the climatic characteristics of the area. This selection is applied to the three tool sections (climate maps, bioclimatic strategies and thermal estimation). The second step is the selection of the heating and cooling set point temperatures. This input will be requested in the 'Heating and cooling estimation' section. Choosing this value will allow estimating the heating and cooling requirements of the school.

Results

The visualization of this tool will allow 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' locations.

- Section Climate maps.

Evaluate the hourly distribution of the main climatic variables, surface mappings have to be developed. Three main variables are analysed: temperature, relative humidity and solar global radiation.

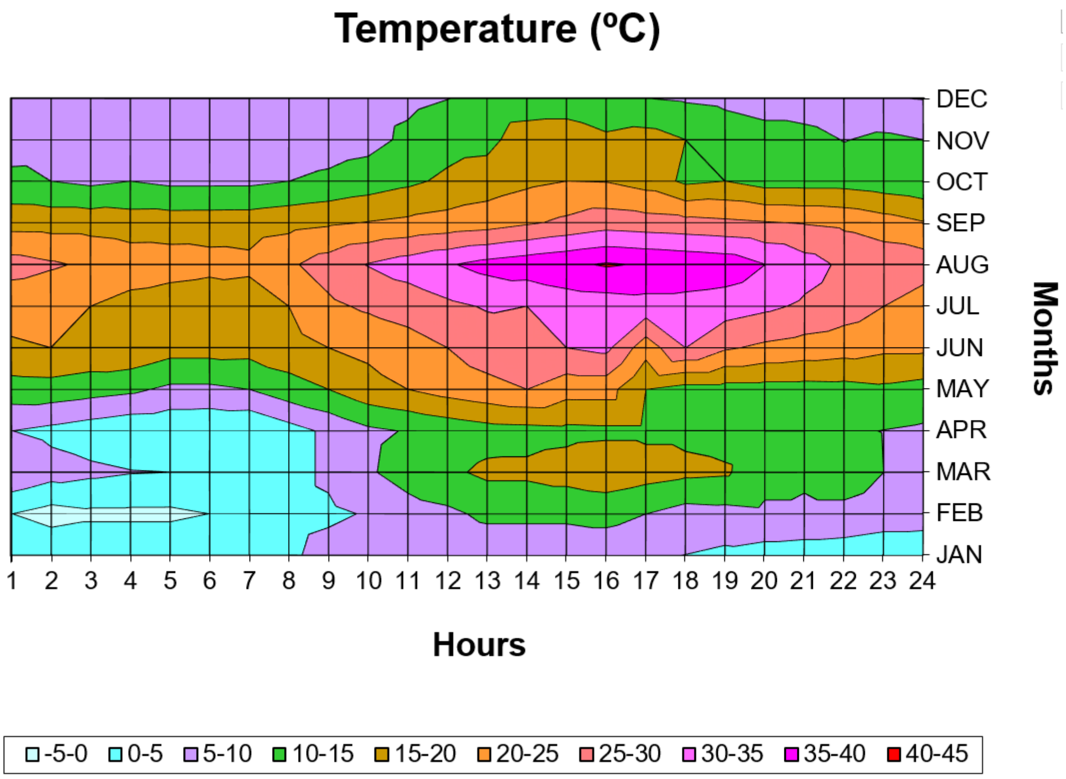

Figure 3– Example of Temperature map

- Section Bioclimatic strategies adapted to climate.

A quantification of different passive bioclimatic strategies will be done in order to improve the thermal comfort condition inside schools in different climate zones. Bioclimatic maps are defined to propose the potential strategies for an optimized thermal 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 through the use of solar protections.
- *Natural or forced ventilation*. Reduction of cooling loads through the use of 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. To represent these zones on the surface map, a colour code has been used for each area, as shown in figure 4. These strategies can appear alone or several can coexist together, although with different weight.

This tool is applied to predict what strategies are needed to achieve the comfort sensation inside the school for each hour and each month.

Figure 4– Fourteen zones corresponding to different bioclimatic design strategies shown in the bioclimatic maps

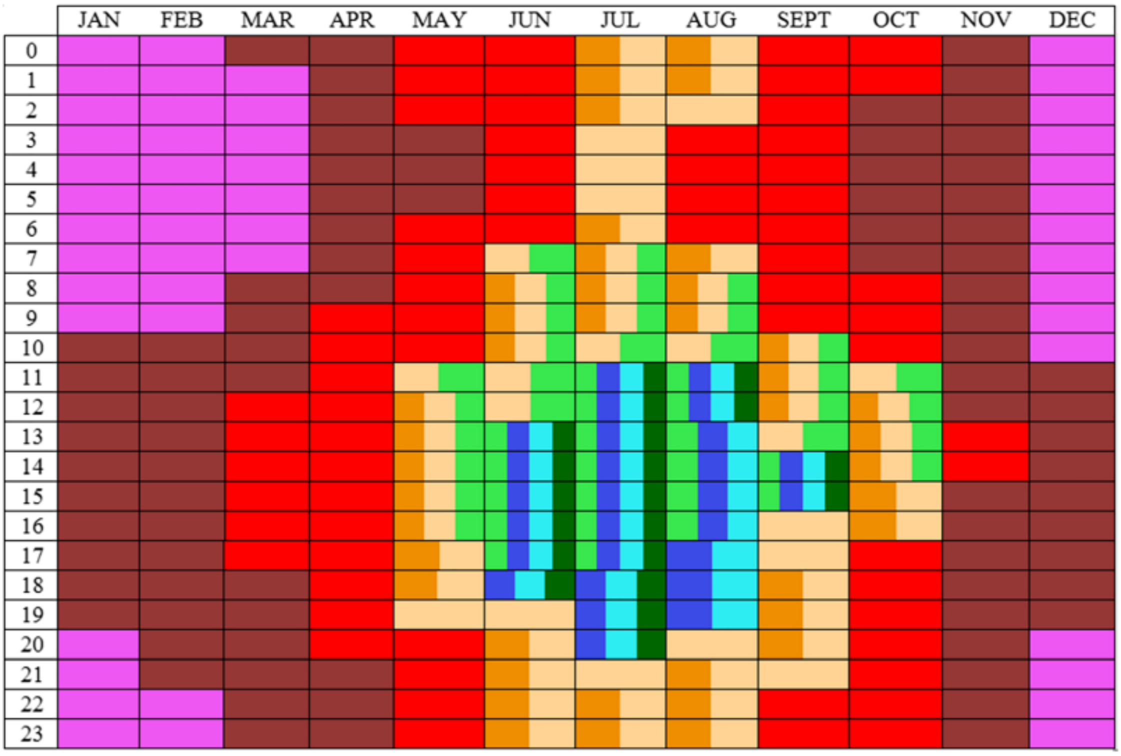

Figure 5– Example of bioclimatic strategies map

The use of these maps allow a visual assessment of the thermal severity of the area, and provide indications on the corrective measures that should be adopted to optimize the level of comfort inside the school: Increase or decrease humidity, consider natural or mechanical ventilation, solar or conventional heating, air conditioning, giving a particular importance to passive heating or cooling.

- Section Heating and cooling estimation.

The tool carried out 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 have been 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.

- *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). HDD are used for calculations related to the energy consumption required to heat the classrooms.
- *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). CDD are used for calculations related to the energy consumption required to cool the classrooms.

Base indoor temperatures are initially set to 22°C and 25°C in HDD and CDD, respectively. This set points can be adapted by users for each school requirements but care must be taken into account to maintain an adequate level of thermal comfort inside the classrooms.

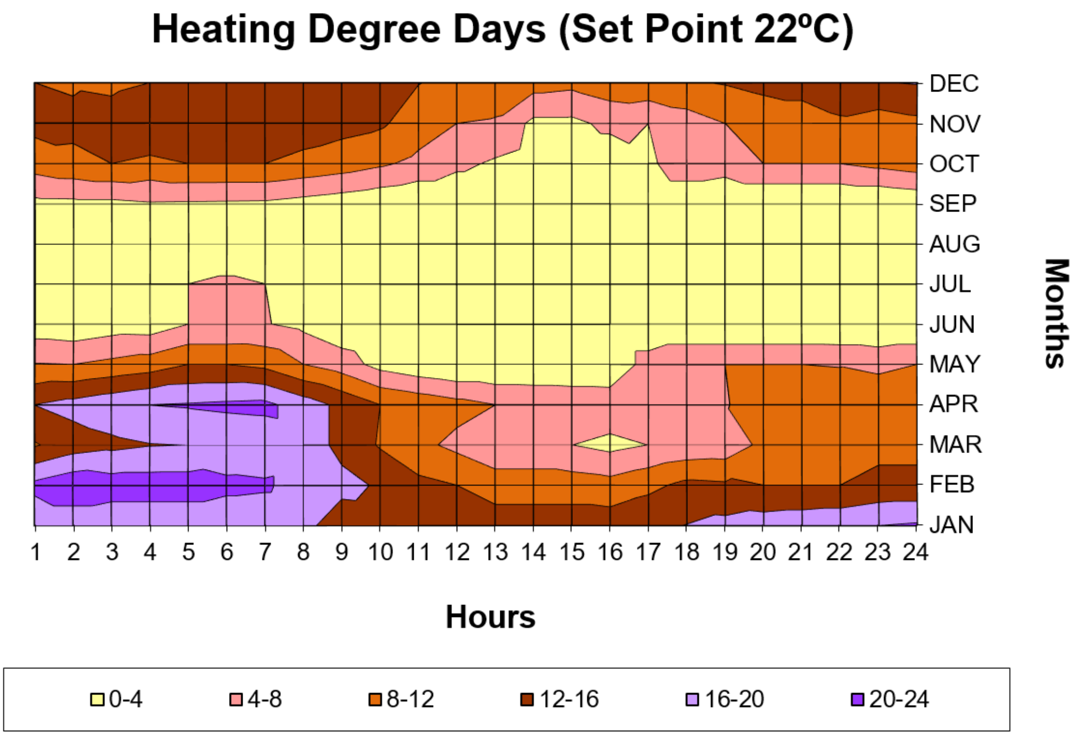

Figure 6– Example of Heating estimation map

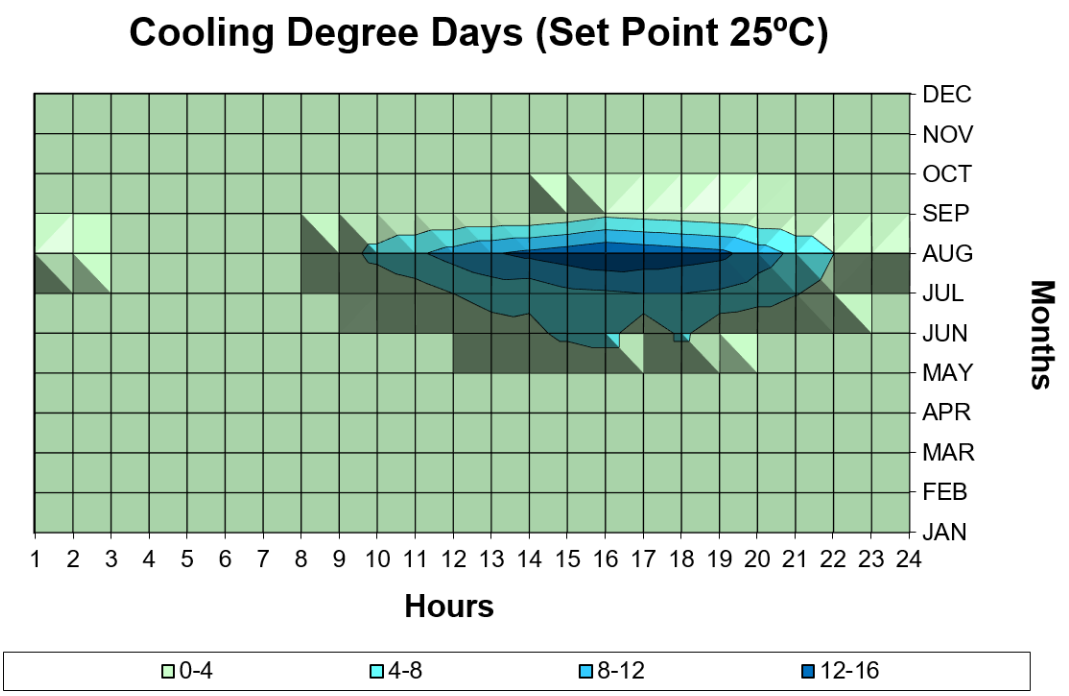

Figure 7– Example of Cooling estimation map

3.2 Dynamic building energy performance

A dynamic energy building performance tool will be 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 will be modelled based on the climate information, the construction characteristics and operational variables. Secondly, different retrofit measures will be proposed in order to create the inlet simulation database of the tool. Retrofitting measures such us modification of windows, variation of set-point temperatures or occupation patterns will be studied. Thirdly, several batteries of simulations will be executed to calculate the thermal loads of the representative classroom reached with the implementation of one measure. Finally, a post-processing of the outputs will be done to calculate the annual thermal demands and the retrofitting savings achieve by each measure.

Users

This tool is available with the same level of access for all types of users:

- School managers, personnel and staff
- School users: students, teachers, etc.

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 will be carried out through dynamic simulation tools, which allow the variation of parameters (climate, construction characteristics…), input variables (set point temperatures, ventilation rates...) and boundary conditions (classroom position, shades…)

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

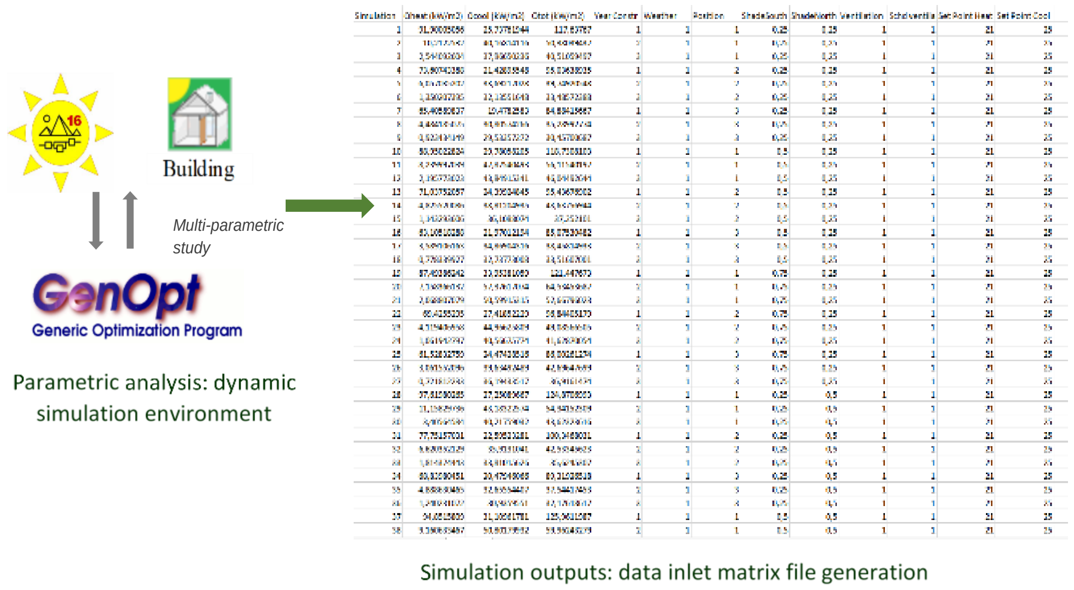

Figure 8– Methodology to create the data inlet matrix file

In the visualization of the tool, the user will select the characteristics of the studied classroom with respect to climate, position of the classroom in the building, construction values, building operational values and building use. This selection will identify the heating and cooling needs provided by the data inlet matrix.

Results

The dynamic building energy performance tool will be able to assess building performance of each studied classroom giving as results annual heating and cooling needs. It allows the users to compare and to appreciate the effect of different parameters taken into account for the energy demand estimation and at the same time link the results of Tool 2 to the ones of Tool 1, where strategies to reduce demand are proposed.

4. LEVEL OF DEVELOPMENT OF 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

The calculation engine of tool 1 is fully developed, however its visualization in the simulation environment of the project remains to be completed. The EPW climatic files corresponding to each climatic zone have been identified and the surface maps have been calculated for each school. Work is currently underway to implement such maps in the general simulation environment of the digital platform.

Tool 2: dynamic building energy performance.

The calculation engine of tool 2 is partially developed. The input variables and the proposed measures have been identified, but the simulation batteries are being carried out to create the data inlet matrix.

5. FUTURE STEPS

Regarding the next steps, CIEMAT will finish the simulation batteries that will allow creating the input database for tool 2. Smartwatt will include all the available information in the databases and proceed to automatize all the necessary rules and calculations using Python. CIEMAT and Smartwatt will work together to define the visualization of the results produce by this Retrofitting toolkit

Finally, Smartwatt will develop the verification and validation of the sustainability interventions evaluation web tool to be done. This application testing can lead to proactive resolution of functional and system-related problems before they affect end users, and allow the identification of bottlenecks and underutilized resources for re-implementation.

To ensure a successful implementation of the tools, the application of functional testing will be a crucial step. It is important that the tool is complete, robust, reliable and representative of the defined requirements. Testing will reveal areas that need improvement (e.g. slow performance), and it will be adopted performance and scalability best practices to ensure that the web tools provides valid results.

Furthermore, a comprehensive test plan involving subject matter and role experts, documented user workflows and documented system configuration will ensure successful testing with practical and effective results. Tests can be re-run in a controlled, repeatable approach starting with testing single user interactions and then escalating the test to a simulated load test. User transaction insertion, user think time, user task tracking as well as parameterization transaction entries will be assessed. Analyse, compare and correlate key metrics such as response times and system behaviour, will evaluate unexpected results caused by component or test case error, and evaluate capacity limitations and thresholds.