CoolLIFE Tool & Knowledge Hub: User Manual and Guidelines

Cool LIFE

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List of Acronyms

CM	Calculation Module
NUTS	Nomenclature of Territorial Units for Statistics

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Keywords

- CoolLIFE Tool
- Knowledge Hub
- Space Cooling Demand
- Energy Efficiency
- Cooling Technologies
- District Cooling
- Calculation Modules (CMs)
- Economic Feasibility
- User Behavior & Comfort
- Demand Response
- Renewable Energy Sources (RES)
- Regulatory Frameworks
- Financing Instruments
- GIS-based Energy Planning
- NUTS Classification
- Building Stock Decarbonization
- Energy Communities
- Climate Adaptation
- Energy Poverty Reduction
- Decision Support Tool
- Strategic Planning
- Open Source Platform
- Thermal Expectations
- Behavioral Change in Cooling
- Summer Comfort Strategies
- Cooling Interventions
- Learning Materials

Disclaimer

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Executive summary

The **CoolLIFE project** addresses the increasing demand for space cooling in the EU by promoting sustainable cooling solutions. The project has developed two main resources to support public and private decision-making, planning, and implementation processes for efficient cooling strategies: the **CoolLIFE Analysis Tool** (in brief, CoolLIFE Tool) and the **CoolLIFE Knowledge Hub**.

The **CoolLIFE Tool** is an open-source platform that allows mapping space cooling demand across the EU. Beyond mapping, it offers a range of calculation models and data on building stock distribution, climate, technologies and renewable potentials, providing insights at local, regional, and continent levels. With this tool, users can assess current and future cooling needs, assess innovative cooling technologies options, and analyse demand-side management options, while being presented with overviews of the relevant economic, policy, and regulatory frameworks.

The **CoolLIFE Knowledge Hub** is a comprehensive online repository of curated data and resources aligned with the FAIR principle (Findable, Accessible, Interoperable, and Reusable). It provides access to quality-controlled datasets, research, and information on energy consumption, the influence of occupant behaviour, and funding opportunities, among others. The hub helps bridge data gaps in space cooling and supports informed decision-making for sustainable cooling solutions.

This **user manual** provides detailed guidance on how to effectively use the **CoolLIFE Tool and Knowledge Hub** to assess, draft and optimize cooling strategies, explore use cases, and enhance decision-making processes for energy-efficient cooling in various contexts. Practical applications for municipalities, energy planners, and building designers, have been tested in case study areas of different climatic zones, demonstrating how the **CoolLIFE Tool and Knowledge Hub** can help users harness data, implement best practices, and address regulatory and lifestyle factors in space cooling.

1. Getting Started

1.1. CoolLIFE Project

For decades, building space cooling (SC) demand has increased steadily in Europe (EU27) and is expected to rise even more in the coming years (2030/2050). This increasing cooling demand pattern highlights the need to prioritize cooling on an equal footing with heating in energy planning.

The CoolLIFE project addresses the increasing demand for space cooling in the EU by developing and promoting two main resources that will support public and private decision-making, planning, and implementation processes for efficient cooling strategies:

- the CoolLIFE Analysis Tool (in brief, CoolLIFE Tool)
- the CoolLIFE Knowledge Hub.

Check out the website by clicking here (https://coollife.revolve.media/) and discover your city's climate-neutral energy future.

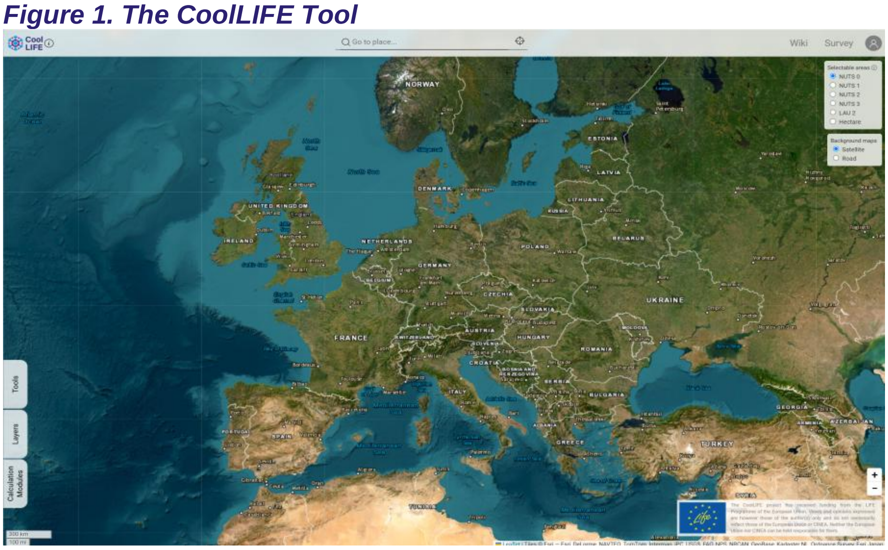
1.2. CoolLIFE Tool

The CoolLIFE Tool is an open-source online software that maps space cooling (SC) demand across the EU-27, from the hectare to the continental level (Figure 1). It guides users in addressing current and future cooling needs by promoting innovative, efficient SC solutions and integrating local renewable energy sources (RES). The tool also provides insights into comfort, lifestyle, and user behaviour across regions, along with demand-side management strategies, demand response (DR) measures, and considerations of economic feasibility, policy frameworks, and regulatory conditions to support optimal decision-making.

To learn more about the tool, jump to this section.

Click here(https://tool.coollifeproject.eu/map) and start assessing the space cooling demand of your municipality!

Figure 1. The CoolLIFE Tool



1.3. CoolLIFE Knowledge Hub

The CoolLIFE Knowledge Hub is a comprehensive online repository of curated data and resources aligned with the FAIR principle (Findable, Accessible, Interoperable, and Reusable). It provides access to quality-controlled datasets, research, and information on energy consumption, the influence of occupant behaviour, and funding opportunities, among others.

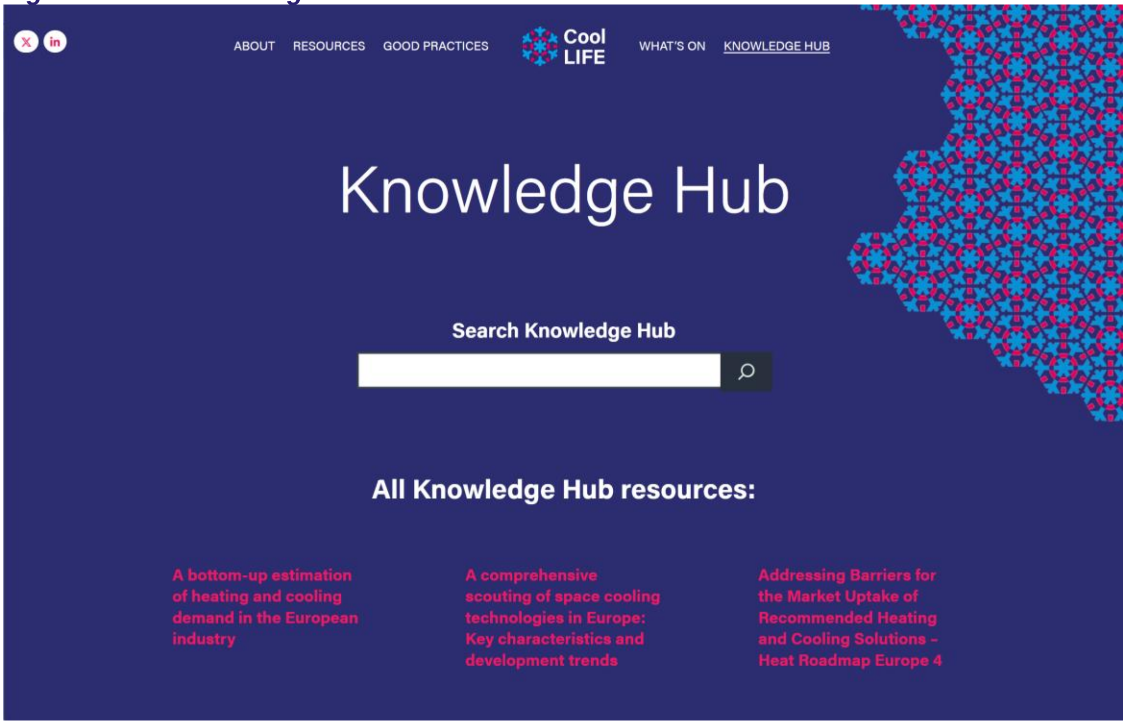
The Knowledge Hub contains:

- Scientific papers, datasets, and project deliverables with a focus on EU-wide and multinational European coverage
- Additional resources like conference briefs, sourced through scientific and grey literature analysis

Data and information sources made available on the CoolLIFE Knowledge Hub can be easily identifiable by a simple keyword search (Figure 2). Each resource page displays the most pertinent metadata. Finally, when available, data can be downloaded directly from the Knowledge Hub in widely used and reusable formats, such as Excel and CSV for datasets or PDF for reports.

Go on the project website or click directly here to access the online repository and all the other publicly available CoolLIFE deliverables.

Figure 2. The Knowledge Hub



1.4. CoolLIFE Wiki

The CoolLIFE Wiki hosts the documentation, guidance and manual of the CoolLIFE toolbox. It consists of the following main parts:

2. CoolLIFE Tool Overview and User Guide (page 14)
3. Calculation Modules (CMs) (page 27)

4. How to Apply the CoolLIFE Tool (Use Cases) (page 69)
5. Learning Center (page 83)

These sections are accessible on all Wiki pages in the sidebar.

CoolLIFE Tool Overview and User Guide walks the user through the interface of the toolbox, covering all general aspects related to the user experience, such as navigating different sections, layer selection, retrieving indicators, and using data upload and export functionalities.

Calculation Modules of the CoolLIFE Tool offer an in-depth explanation of the concepts and methodologies behind the calculation processes. Alongside methodological explanations, examples and test runs for each module help users understand the input parameters and interpret the output results.

How to Apply the CoolLIFE Tool showcases use cases for different target groups and serves as a guideline for performing cooling analyses and planning, including Comprehensive Assessments, NECPs, and local strategies.

Learning Center introduces the user to the full training material of the project.

2. CoolLIFE Tool Overview and User Guide

2.1. Key Capabilities

2.1.1. Introduction

This page outlines the key capabilities of the CoolLIFE Tool, a platform designed to assess space cooling (SC) demand and support decision-making for energy-efficient cooling solutions across EU-27 countries.

2.1.2. Capabilities of the CoolLIFE Tool

With the CoolLIFE Tool, users can:

1. Map Space Cooling (SC) Demand Across EU-27

Analyse SC demand at multiple spatial levels, from 100 × 100 m grids to NUTS0 (continental level), based on:

- Energy intensity levels (specific energy demand in kWh/m²·year).
- Total energy needs at different administrative levels (LAU2, NUTS3, NUTS2, NUTS1, NUTS0).

2. Gain Insights on:

a) *Utilizing Local Renewable Energy Sources (RES)*

- Assess the feasibility of meeting SC demand with local RES.
- Apply innovative, integrated solutions and the best available technologies.

b) *The Role of Comfort, Lifestyle, and User Behavior*

The tool considers regional variations in SC demand by analysing:

- Energy needs and air-conditioning patterns.
- Culturally influenced comfort expectations.
- Regional differences in work schedules and adaptive routines.

c) *Economic Feasibility Through Cost-Benefit Analysis (CBA)*

Evaluate the financial viability of selected technologies and interventions.

d) *Regulatory and Legal Considerations*

Understand relevant legal frameworks for implementing SC interventions.

3. Develop Strategies for Demand Response (DR)

- Load shifting from peak to off-peak hours.
- Maximizing PV self-consumption through SC devices.

2.2. User Interface & Navigation

2.2.1. Introduction

This page provides instructions on how to access the CoolLIFE Tool and introduces its GIS-based interface. It guides users through the initial disclaimer page and offers an overview of the tool's navigation structure, including key components like the Map Viewer, Toolbars, and interactive features.

2.2.2. Accessing the Tool

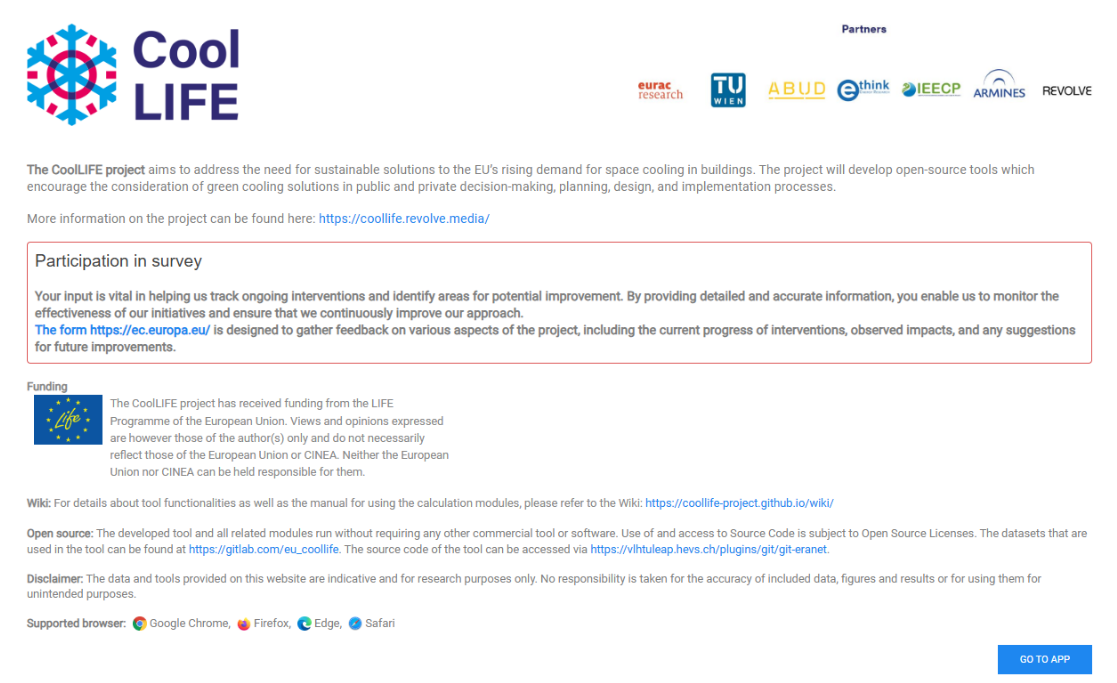
You can access the CoolLIFE Tool via the following link: ☞ https://tool.coollifeproject.eu

The CoolLIFE GUI features a GIS-based interface designed for intuitive interaction. Upon opening the toolbox, you'll first encounter the disclaimer page (see Figure 3), which provides:

- A disclaimer message
- Information on supported browsers
- An overview of the CoolLIFE project objectives
- Links to the CoolLIFE project website and relevant data repositories
- Links to CoolLIFE Participation Survey.

To proceed, simply press the 'GO TO APP' icon.

Figure 3. Initial Disclaimer page of the CoolLIFE Tool



2.2.3. Interface Layout and Navigation

Once the disclaimer is closed, the main map interface appears, displaying:

- The satellite map of EU-27 countries
- Boundaries for regional reference (with NUTS0 being the default selection).

This map serves as the starting point for all analyses. You can zoom, pan, and explore different regions to visualize SC demand at various spatial levels.

The user interface is immediately divided into three distinct sections:

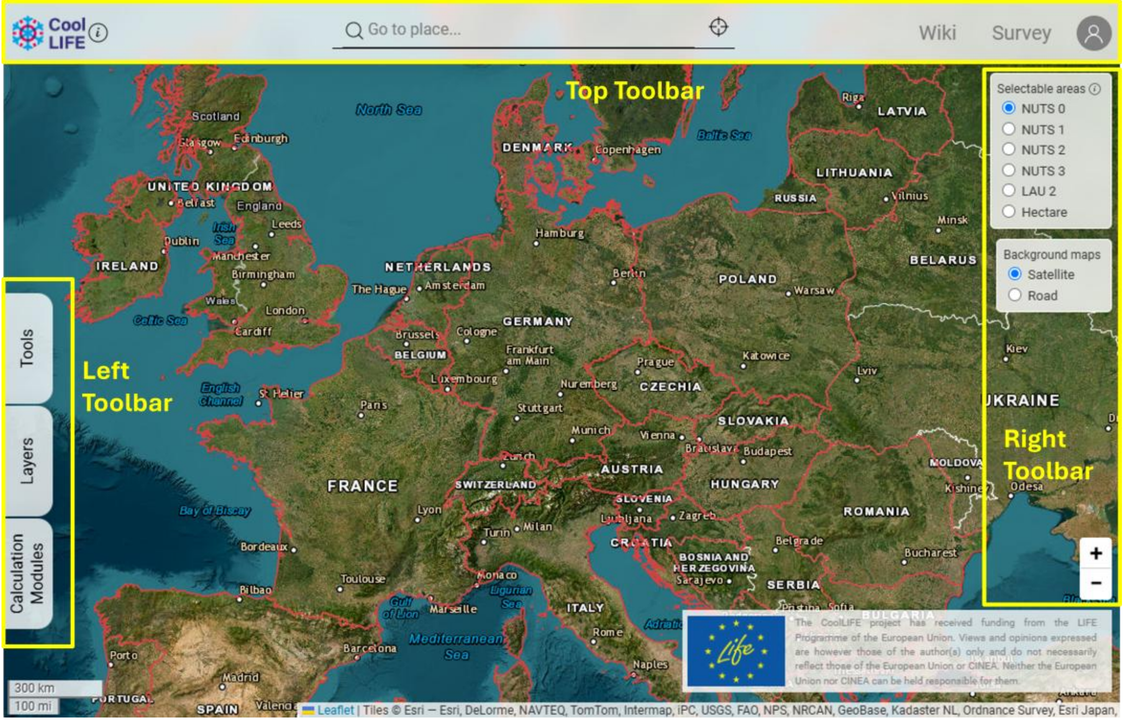
1. Map Viewer and Right Toolbar

- **Map Viewer** a GIS-based interface for visualizing spatial data, overlaying data layers, and performing interactive analyses.
- **Right Toolbar** provides tools for selecting spatial areas, switching base map styles, and controlling zoom levels for interactive map navigation.

2. **Left Toolbar**: contains the main operations of the tool, including layer selection, retrieving indicators, and running calculations.
3. **Top Toolbar**: features tools for searching locations, recentering the map, accessing relevant resources, and managing user profiles with login options.

Figure 4 below shows the user interface and the toolbars of the CoolLIFE Tool.

Figure 4. User interface and layout of the toolbars



2.2.3.1. RIGHT TOOLBAR

The following features are included here:

- **Selectable areas**: Choose spatial levels such as NUTS 0–3, LAU2, or hectare grids.
- **Background maps**: Switch between satellite imagery and road maps for different visualization styles.
- **Zoom Controls**: Easily zoom in and out to explore regions at various scales.

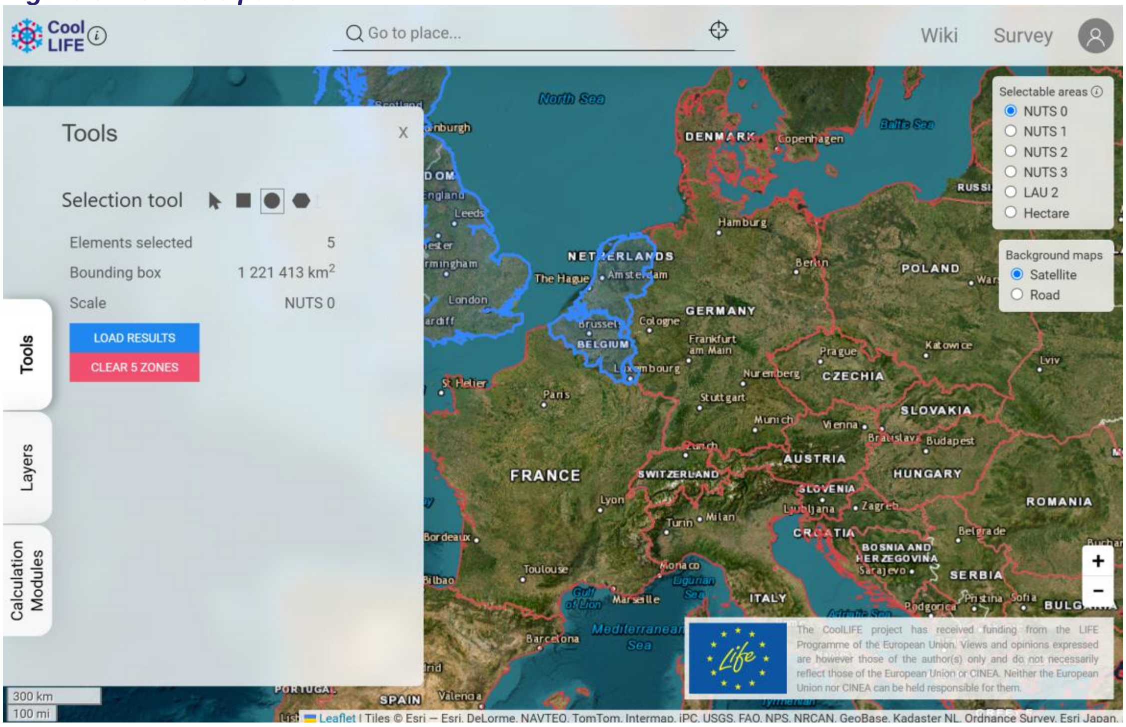
2.2.3.2. LEFT TOOLBAR

1. **Tools**: tools for selecting a region.
2. **Layers**: include various indicators for selected areas.

3. **Calculation Modules:** tools for specific calculations in selected areas.

Upon selecting a respective icon on the Left Toolbar, a side panel appears on the left side, enabling users to adjust parameters or interact with tool-specific features (see Figure 5).

Figure 5. Left side panel



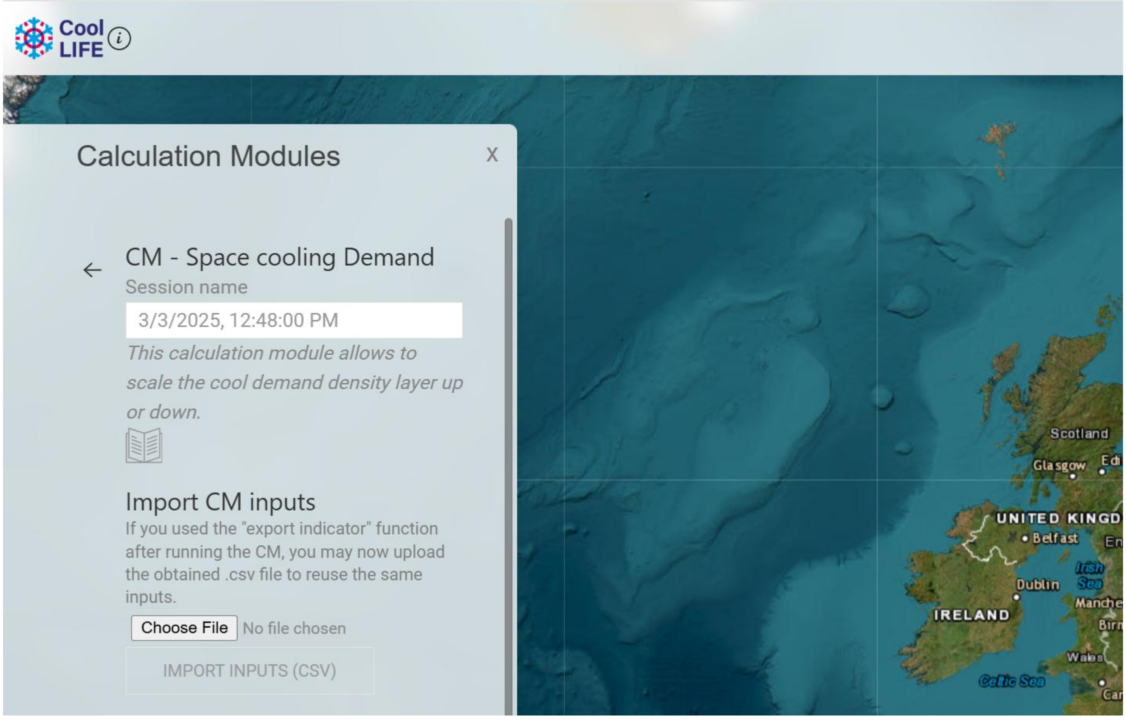
Under **Tools**, two additional functions are available:

- ***Load Results***: Shows the Results from the selected Layers and CMs run.
- ***Remove Selection***: clears the selection of the region.

Under **Layers** tab, the user can select the indicator of interest. The results for the selected area will be visualized on the map and the legend is available under each Layer. The numerical values are also available under Load Results (Tools tab).

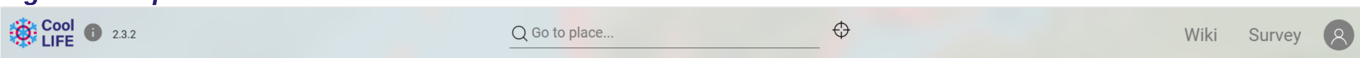
Under each **Calculation Module**, the user can access the relevant Wiki-page to learn about how to use the CM by clicking on the “book logo” (?) (see Figure 6).

Figure 6. Wiki-link within Calculation Modules (CMs)



2.2.3.3. TOP TOOLBAR

Figure 7: Top Toolbar



- **Project logo**: Link to the CoolLIFE website.
- **Go to Place**: Zoom in to a specific region by typing the name.
- **Wiki**: Link to this Wiki.
- **Survey**: Link to a survey regarding the tool.
- **User Account Functionalities**: Register and sign in to the web application.

The following **User Account Functionalities** are available in the Tool:

- **Register**: You can create an account for the CoolLIFE website. After submitting the form, shown in Figure 8, you will receive an email to activate your account.
- **Sign In**: After registering and activating your account you should be able to sign in with your email and password (see Figure 9 below).
- **Recover**: If you ever forget your password you can recover it, as illustrated in Figure 10. You will receive an email in Figure 11. Please be aware of setting a new password afterwards.

Figure 8. Registration form

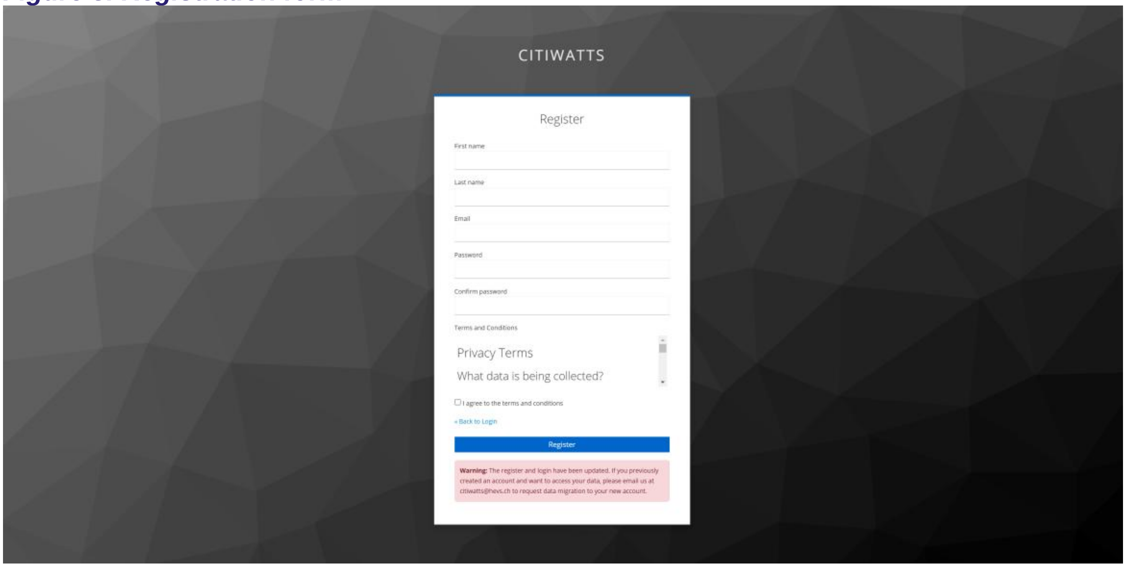


Figure 9. Sign in page

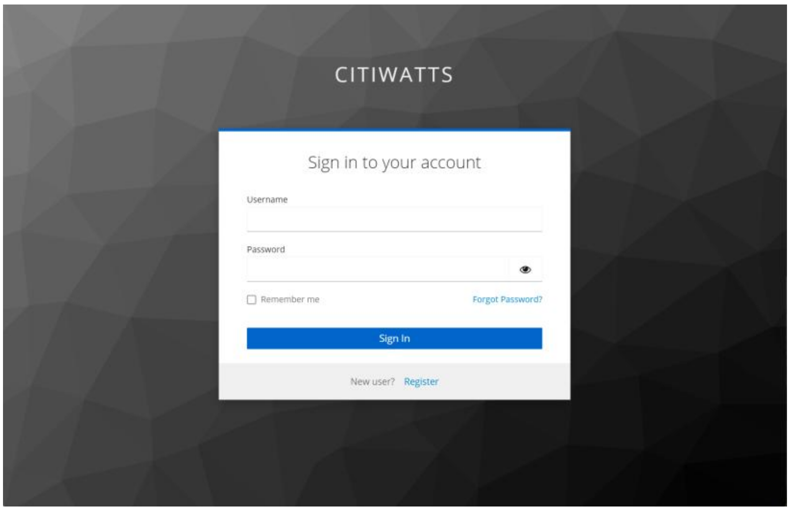


Figure 10. Reset password

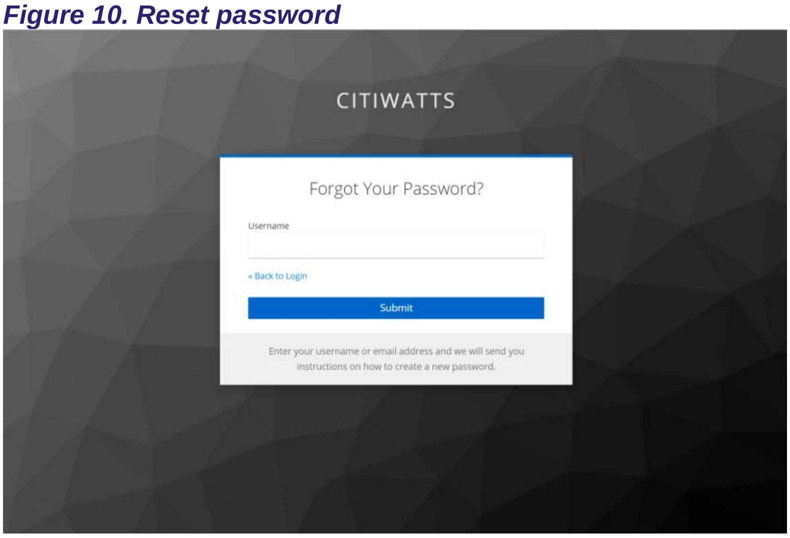
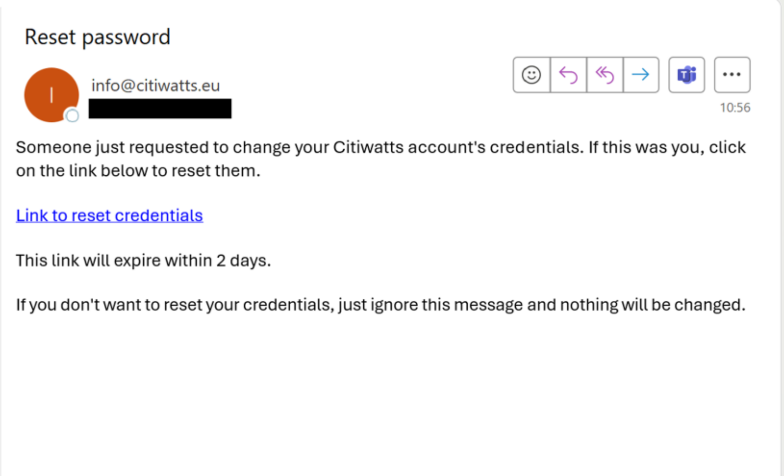


Figure 11. Reset password email



2.3. Core Functions

2.3.1. Introduction

This page introduces the core tools and functionalities of the CoolLIFE Tool for region selection, layer management, calculation and data visualization. It explains how to select territories at different scales, upload custom regions, and manage spatial data through raster and vector layers. Additionally, it covers the tools for downloading datasets, viewing symbology, and accessing detailed information about each data layer.

2.3.2. (Selection) Tools

You can choose the territorial scale that you want to analyze (NUTS regions or hectare level) or select a custom region (i.e. Hectare level). There are the following configurations for selection:

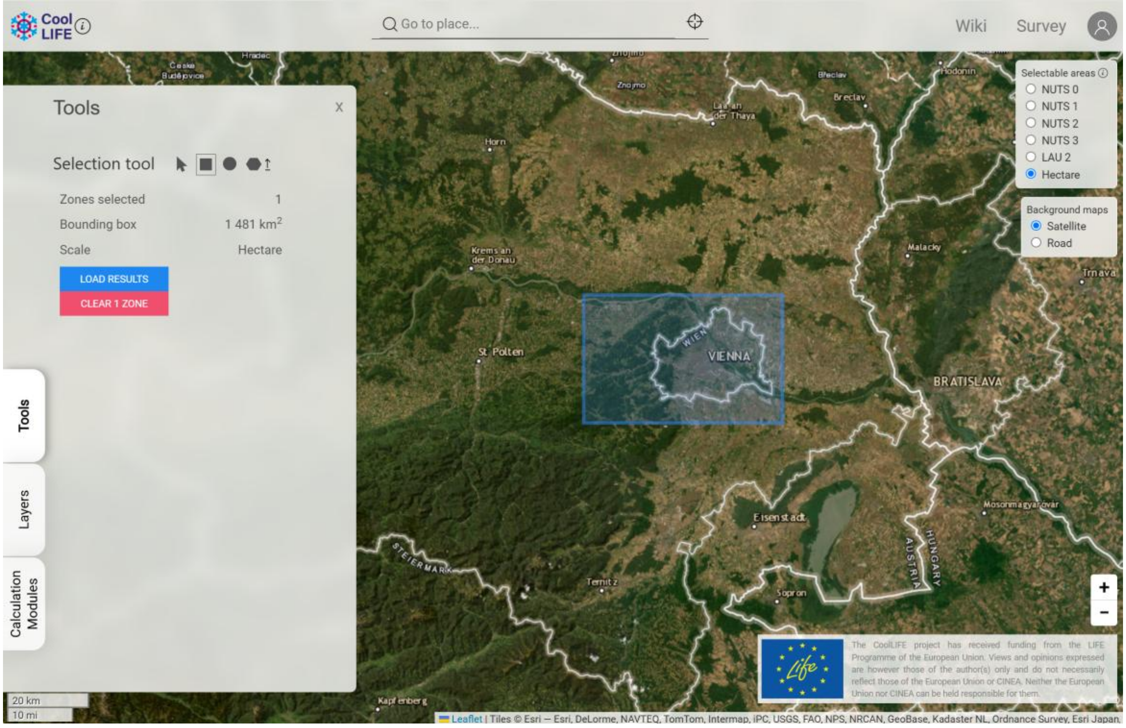
- Create a custom square region
- Create a custom circle region
- Create a custom polygon region
- Upload a GeoJSON object to use a custom area selection (Hectare only)

Figure 12 shows the example of selecting a region by hectare using a square selection tool. After selecting a working area, the information about it is demonstrated on a sidebar at the left of your screen.

Two further functions are available on the left sidebar after selecting the working area:

- **Load Results**: shows further information on a sidebar to the right of your screen.
- **Clear Zone**: deselects the previously selected regions.

Figure 12. Selection tool - example of using square selection tool by hectare



2.3.3. Layers

By pressing the Layers button, a sidebar appears on the left side of the screen, displaying various types of layers available in the CoolLIFE Tool.

There are two main categories of layers:

1. **Raster Layers** (Figure 15.

Figure 13) represent continuous data across a grid, including the data about:

- Buildings
- Renewable Energy Systems (RES) potential
- Climate

2. **Calculation Module Layers** (Figure 14) appear after running a calculation (in the Calculation Module) and contain continuous data.

More information about each Layer type can be accessed under a respective Layer, as shown in Figure 15.

Figure 13. Raster layers

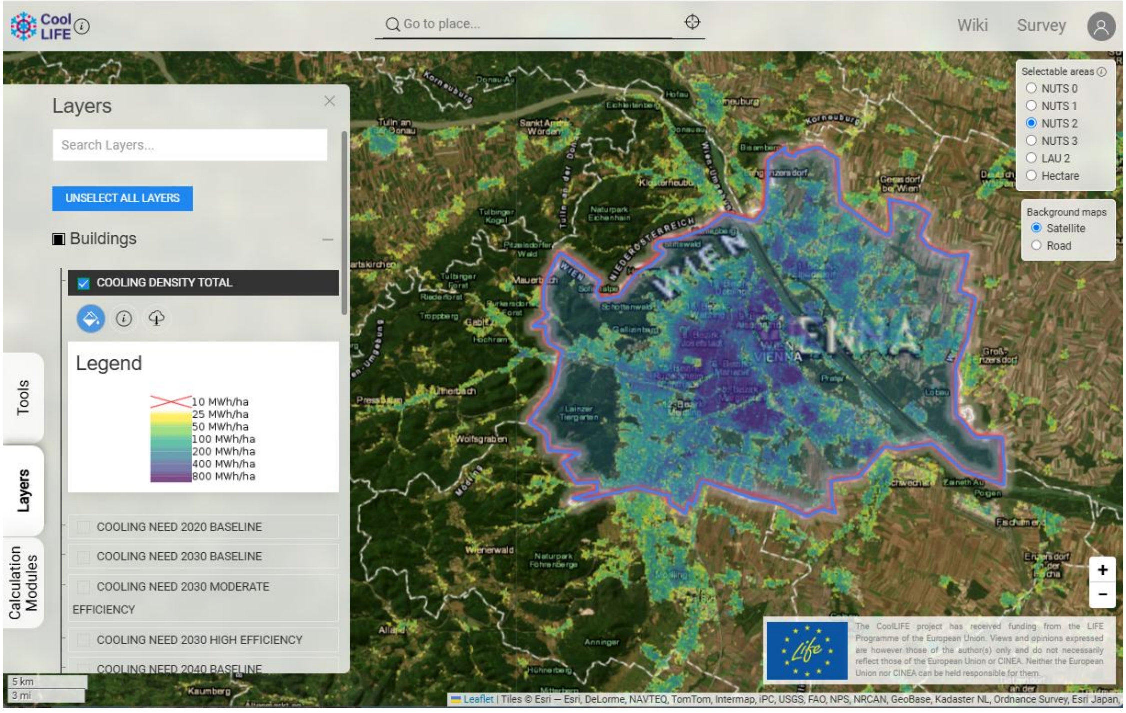


Figure 14. Calculation layers

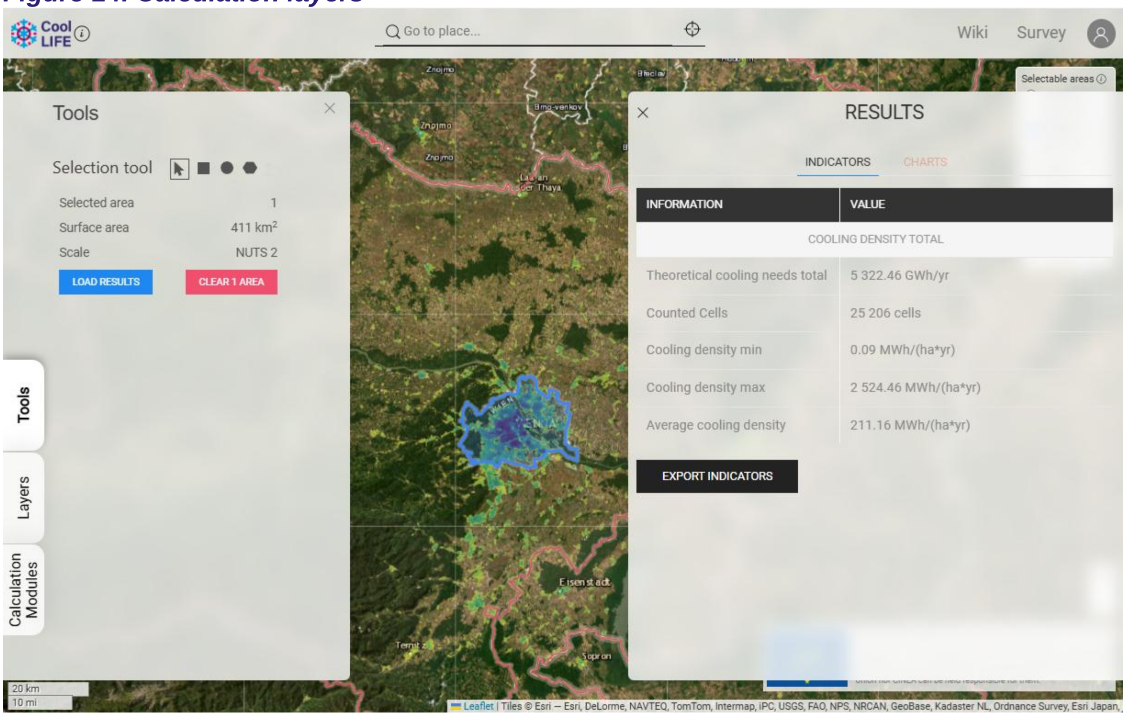
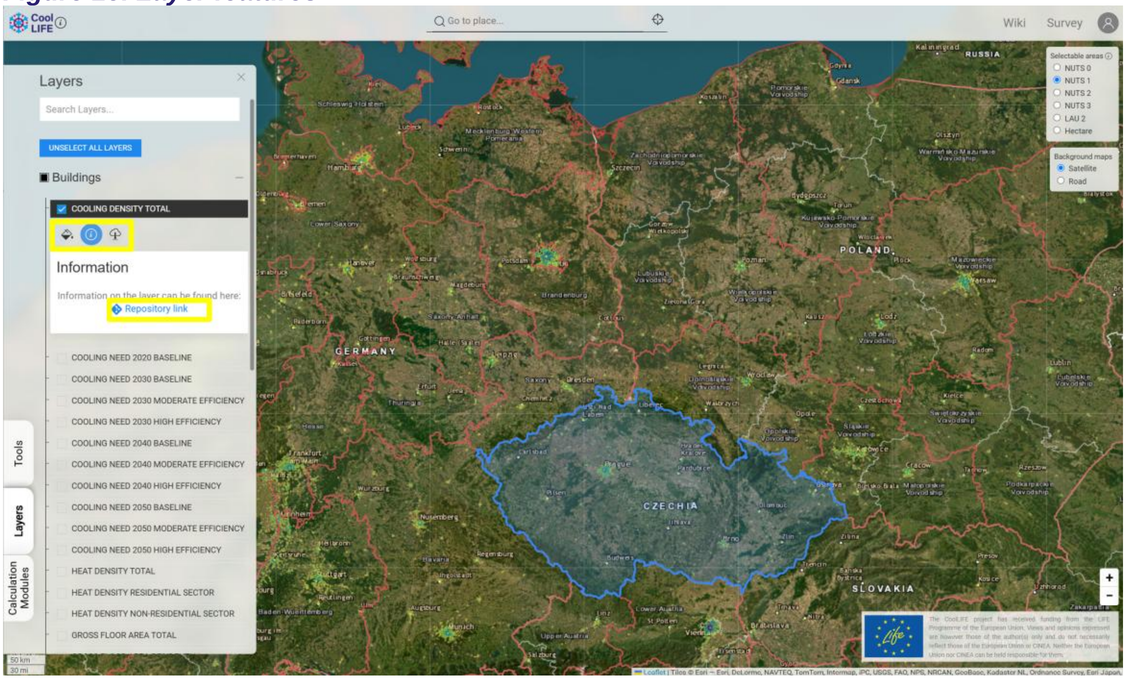


Figure 15. Layer features



Each layer comes with the following features (Figure 15):

- **Layer legend**: Displays the legend of the layer.
- **Information**: Provides a link to the GitLab repository with more detailed information about the data.
- **Download Dataset**: Allows downloading the default dataset for the layer.
- **Download Layer**: Enables downloading the specific data of the selected layer.

2.3.3.1. BUILDINGS

The following data layers related to Buildings are available in the CoolLIFE Tool:

- Heat density total
- Heat density residential sector
- Heat density non-residential sector
- Cooling density total
- Gross floor area total
- Gross floor area residential
- Gross floor area non-residential
- Building volumes total
- Building volumes residential
- Building volumes non-residential
- Share of gross floor area - constructions before 1975
- Share of gross floor area - constructions between 1975 and 1990
- Share of gross floor area - constructions between 1990 and 2000
- Share of gross floor area - constructions between 2000 and 2014

2.3.3.2. R.E.S. POTENTIAL

The following data layers related to RES Potential are available in the CoolLIFE Tool:

- Geothermal potential Heat Conductivity

2.3.3.3. CLIMATE

The following climate data layers are available in the CoolLIFE Tool:

- Average temperature
- Cooling degree days
- Heating degree days
- Solar radiation
- Wind speed

2.3.4. Calculation Modules

One of the core functions of this Tool is to calculate and visualize different indicators important for cooling planning. The calculation modules are structured into four main thematic categories:

1. Cooling
2. District Heating and Cooling
3. Policy
4. Finance

The CMs that are currently available for use are listed below (See Figure 16). Each module is available at a certain “Selectable area” (i.e. administrative boundary level). For example, CM Demand management works only at the NUTS1 level, thus, it is not selectable (in red) when the NUTS2 level is active. The level at which each CM operates is indicated in the “Introduction” section of each CM description.

The detailed CM descriptions are provided in the respective sections, accessible by clicking on the CM names.

1. **Cooling**

    3.1. CM: Space Cooling Demand **(page 27)**

    3.2**.** CM: Technologies And Measures **(page 30)**

    3.3. CM: Comfort, Lifestyle, And User Behaviour **(page 35)**

    3.5. CM: Demand-side Management/Demand Response **(page 52)**

2. **District Cooling**

    3.6. CM: District Cooling **(page 54)**

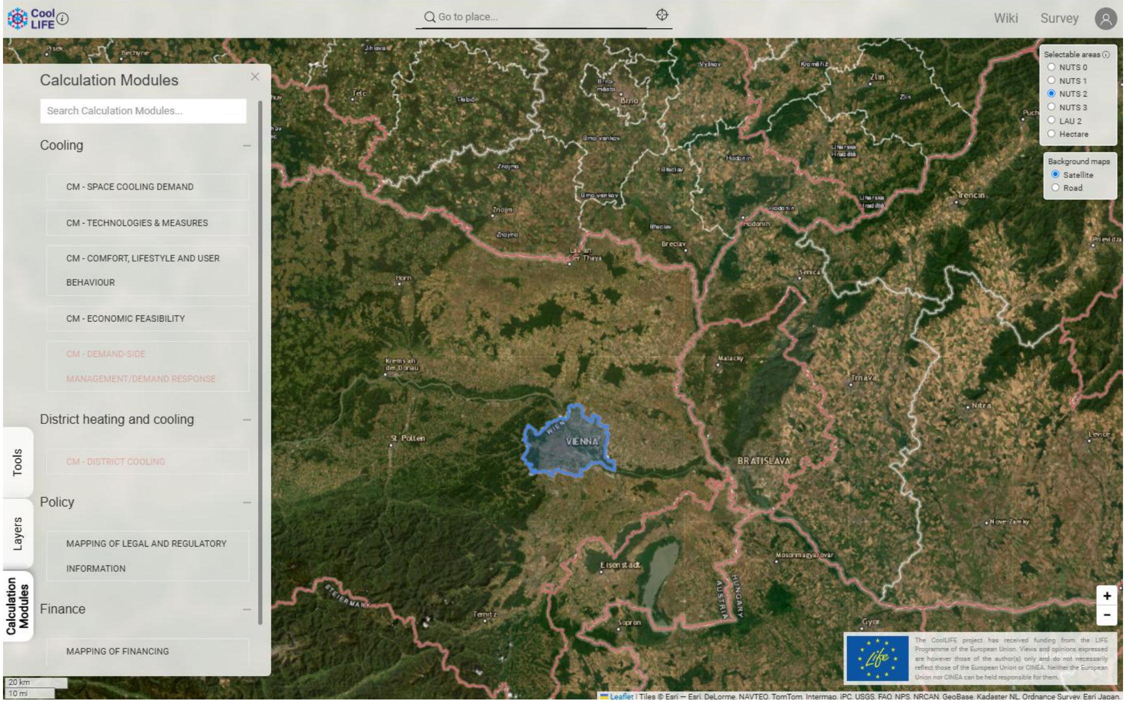
3. **Policy**

    3.7. Mapping of Legal and Regulatory Information **(page 61)**

4. **Finance**

    3.8. Mapping of Financing Instruments **(page 65)**

Figure 16. Calculation Modules



2.4. General Workflow

2.4.1. Introduction

This section provides a general workflow to guide users through the essential steps of using the tool, from selecting regions and enabling data layers to running calculations and viewing results. Whether you're conducting regional energy planning, performing cost-benefit analyses, or exploring cooling demand patterns, this workflow will help streamline your process.

2.4.2. Workflow

Follow these steps to effectively use the CoolLIFE Tool:

1. **Define a Territorial Scale**: Begin by selecting the territorial scale that best fits your analysis. Options include:

- NUTS regions (NUTS0–NUTS3) for broader administrative levels.
- LAU2 for more localized areas.
- Hectare-level grids for custom, high-resolution spatial analysis.

The first two options will select a working area that corresponds to administrative boundaries, while the hectare level will allow the selection of custom areas not bound by administrative regions.

2. **Select a Region**: Use the selection tools to choose your target region. Draw a custom square, circle, or polygon or upload a GeoJSON file for custom area selection. While with square, circle, or polygon shapes several administrative regions are selected.

3. **Enable the Layers Section**: Go to Layers to visualize the relevant data. Choose from raster layers (e.g., cooling density, climate data). Check out the legend, view metadata, or download datasets for deeper

analysis. Go back to the Tools tab and Load Results to view the numerical data. On the right side, you will see the Results panel with the information. You can export the indicators in Excel file format.

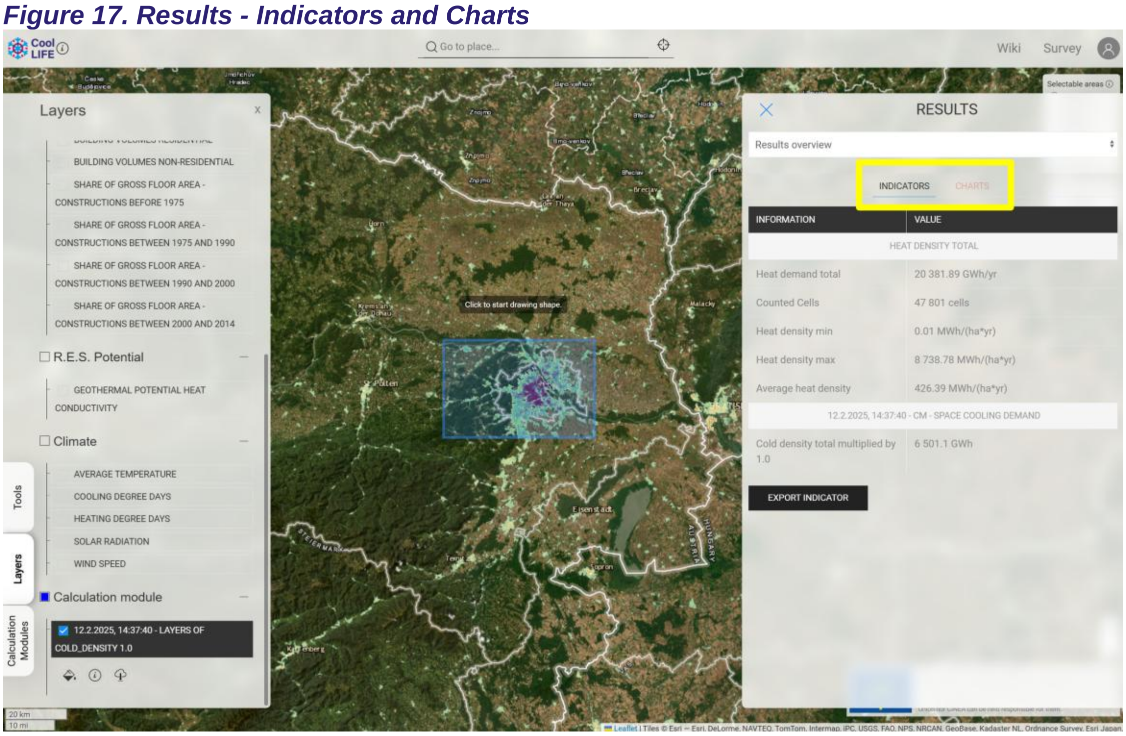
4. **Go to the Calculation Modules Tab**: Navigate to the Calculation Modules to access the tool's analytical capabilities. Select from available modules and proceed to the detailed instructions on each CM documented in the respective page:

    - Space Cooling Demand
    - Economic Feasibility
    - Comfort Lifestyle and User Behaviour
    - Technologies and Measures
    - Demand-side management/demand-response
    - District Cooling
    - Policy
    - Finance

In general, you should insert the 'Session name', define the input parameters (i.e. INPUTS) and input layers, and 'RUN CM'.

View Results on the map interface and in the Results pane on the right. The results consist of two parts: Indicators and Charts (See Figure 17). You can further analyze, export, or share the results as needed.

Figure 17. Results - Indicators and Charts



The user should refer to the section How to Apply the CoolLIFE Tool to learn more about the different ways in which this CoolLIFE Tool could be used.

3. Calculation Modules (CMs)

3.1. CM: Space Cooling Demand

3.1.1. Introduction

This Calculation Module (CM) enables the visualization of space cooling (SC) demand across the EU-27 at a high spatial resolution of 100 x 100 meters. It provides demand estimates for both the base year and future scenarios up to 2050, leveraging data on building stock distribution and climate conditions. By using this module, users can analyze and scale demand, identifying cold spots in urban areas that could be prioritized for cooling planning.

The module allows users to adjust cooling demand estimates by applying a scaling factor to the default cooling density maps. Since cooling demand is often reported in aggregated energy balances, this module helps spatially disaggregate such values by refining demand estimates at a granular level. The tool multiplies each cell in the input raster by the user-defined scaling factor, generating an updated cooling density map that reflects adjusted demand scenarios.

This functionality supports urban planners, policymakers, and researchers in developing localized cooling strategies, optimizing energy planning, and ensuring efficient resource allocation for future cooling infrastructure.

The module operates at **NUTS1, NUTS2, NUTS3, LAU2** and **Hectare levels**.

3.1.2. Method

Each cell's value of the input raster is multiplied by the multiplication factor.

3.1.3. Input

The following **input parameters** should be defined prior to the run:

- Multiplication factor [-]: a real value between 0 and 1000
- if the multiplication factor is > 1, the output raster is greater than the input.
- if the multiplication factor is < 1, the output raster is smaller than the input.

An **input layer** has to be selected from a dropdown menu. This input layer will be scaled up or down, depending on the multiplication factor. It is a map in raster format (*.tif). The following input layers are available at the moment:

- Cooling density total
- Cooling needs baseline 2020
- Cooling needs baseline 2030
- Cooling needs 2030 moderate efficiency
- Cooling needs 2030 high efficiency
- Cooling needs baseline 2040
- Cooling needs 2040 moderate efficiency
- Cooling needs 2040 high efficiency
- Cooling needs baseline 2050

- Cooling needs 2050 moderate efficiency
- Cooling needs 2050 high efficiency

It is possible to scale up or down personal heating and cooling density maps.

3.1.4. Output

The output of this CM consists of the following:

- An output raster (*.tif), corresponding to the input scaled by the multiplication factor.

3.1.5. Sample Run

This example demonstrates how to run the Space Cooling Demand Calculation Module (CM) using Vienna, Austria as a case study.

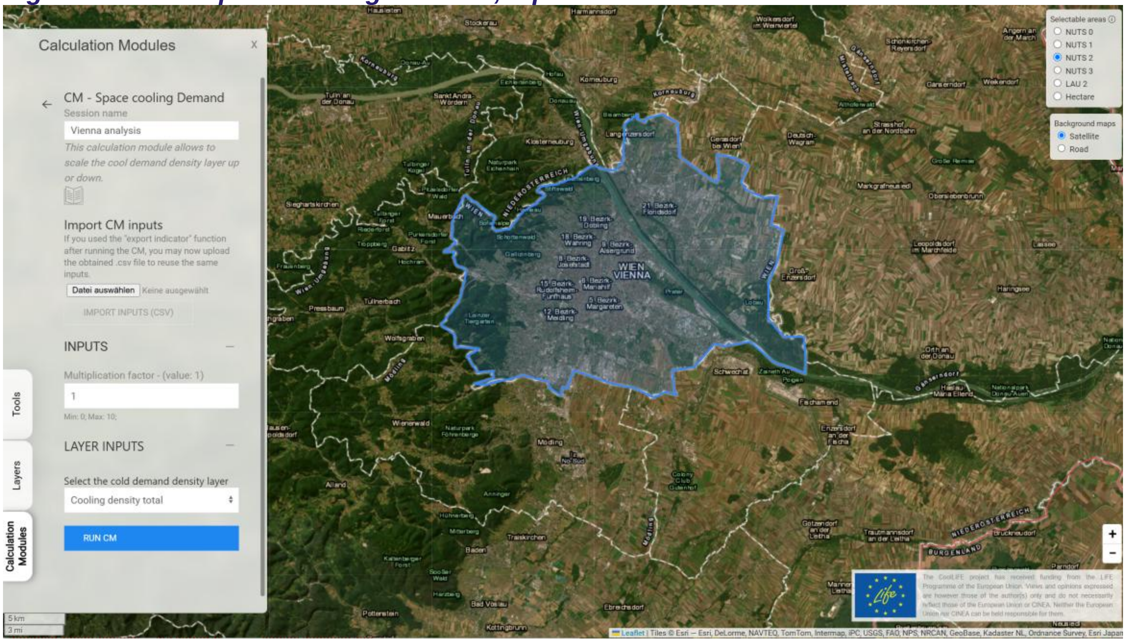
Step 1: Choose the appropriate 'Selectable area'

On the Right Toolbar, choose NUTS2 (Vienna as a province) or NUTS3 (Vienna as a city). In this case, it is the same area, as Vienna is both a city and a province.

Step 2: Navigate to the Study Area

Use the "Go To Place" search bar to locate Vienna and select the city.

Figure 18. CM - Space cooling Demand, Input



Step 3: Access the Calculation Module

Click on the "Calculation Module" tab. In the list of calculation modules, select "CM - Space Cooling Demand".

Step 4: Configure and Run the Calculation

In the CM interface, write a session name. Then enter the Multiplication Factor to scale up or down the cooling demand. By default, the scaling factor is set to 1 (no change). Adjust this value as needed. Select the Layer input, e.g. Cooling density total. Then press “RUN CM”. See Figure 18.

Step 5: View and Download Results

Once the calculation is complete, the scaled demand density map will be displayed on the map. The newly calculated demand values will be available in the Results section (See Figure 19). To download the generated layer:

- Open the “Layers” tab.
- Scroll down to the “Calculation Module” section.
- Locate the generated layer under “Layers of Cold_density” and download it (See Figure 20).

Once you are in the CM, select the value by the amount you want to scale up or down in the Multiplication Factor input. By default, the scaling factor is 1. Press “RUN CM”. Once the calculation is completed, the scaled-up demand density map will be visible on the map, and the newly calculated demand will be available in the result section. If you want to download this layer, go to the “Layers” tab, scroll to the bottom under the “Calculation module” section, and you will find the layer generated from the CM run as “Layers of Cold_density”.

Figure 19. CM - Space cooling demand, Results

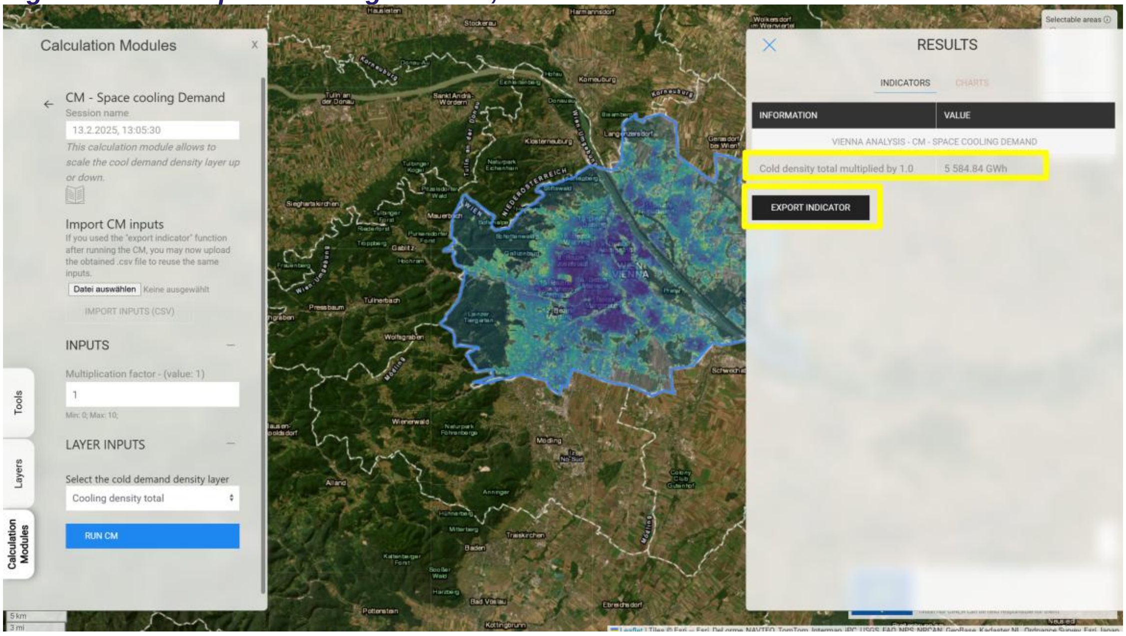
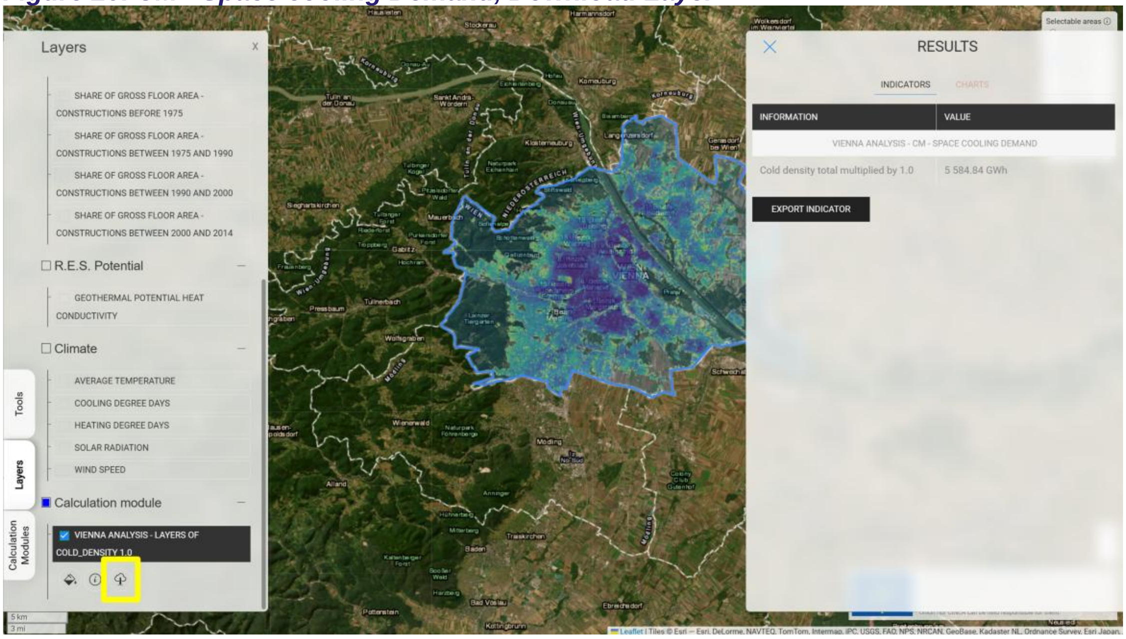


Figure 20. CM - Space cooling Demand, Download Layer



3.2. CM: Technologies And Measures

3.2.1. Introduction

This page provides an overview of the methodology, inputs, and outputs of the Space Cooling Demand Calculation Module. The module estimates the electricity consumption of air conditioning technologies required to meet space cooling (SC) needs across the EU-27. It allows users to analyze cooling demand for both the residential and non-residential sectors and evaluate the impact of energy efficiency measures in mitigating cooling needs.

The calculation is based on Cooling Degree Days (CDD) and predefined SC demand relationships, enabling users to explore different diffusion rates, technology efficiencies, and mitigation strategies. The module also supports scenario-based assessments, helping policymakers, planners, and researchers understand the effects of cooling adoption and efficiency improvements on overall energy demand.

The module works at **NUTS1, NUTS2, NUTS2, LAU2** as well as **hectare level**.

3.2.2. Method

The calculation principle is based on an assessment of the space cooling needs (SC needs) from the cooling degree-days (CDD) data in the selected area. The relations between CDD and SC needs (in kWh/(m²)) are derived from the works done by Dittmann et al., 2017 for:

- **the residential sector**: SC needs = $-3E^{-8} \times CDD^2 + 0.053 \times CDD + 6.105$
- **the non-residential sector**: SC needs = $-9E^{-9} \times CDD^2 + 0.142 \times CDD + 40.12$

The user can also obtain an **evaluation of the cooling capacity (kW/m²)** needed to supply the estimated cooling needs, based on Dittmann et al., 2017 for:

- **the residential sector**: SC capacity = $-2E^{-7} \times CDD^2 + 0.0713 \times CDD + 79.625$
- **the non-residential sector**: SC capacity = $-5E^{-9} \times CDD^2 + 0.1416 \times CDD + 159.19$

The calculation module also offers the possibility to observe the impacts of measures uptake to mitigate the cooling needs in both sectors. Based on the findings of the deliverable 2.1 (Duplessis et al., 2023), the following mitigation measures have been considered :

- the window opening, allowing natural free cooling during the night, the evening and the early morning,
- the solar shading, reducing solar direct radiations during the day,
- the use of fans use, especially ceiling fans, which increase the air circulation in rooms and then the summer comfort.

The user must bear in mind that the implementation of these measures does not provide the same service as SC technologies, but does ensure summer comfort at an acceptable level for buildings occupants, and therefore avoids the use of SC technologies. In the simplified approach presented here, we consider that these measures, when implemented, are taken together and make it possible to reduce the space cooling needs by up to 50%.

3.2.3. Input

3.2.3.1. INPUT PARAMETERS

The user shall define the following inputs (default value are also suggested):

- Building sector selection
- Space cooling diffusion rate
- Average Seasonal Energy Efficiency Ratio (SEER) of SC Technologies
- Measures uptake scenario.

Building sector selection indicates the building sector selected in the current calculation. There are 3 options: residential, non-residential and both sectors. The residential sector comprises single-family houses, multifamily houses and apartment blocks. The non-residential sector comprises buildings of offices, trades, education, health, hotels and restaurants sectors as well as other non-residential buildings. Default value: *residential*.

Space cooling diffusion rate [%] indicates the share (in %) of the cooled area among the total floor area of the selected sector. **Default value**: *7,5 %* in the residential sector and *23,5 %* in the non-residential sector (average values of cooled area in EU27).

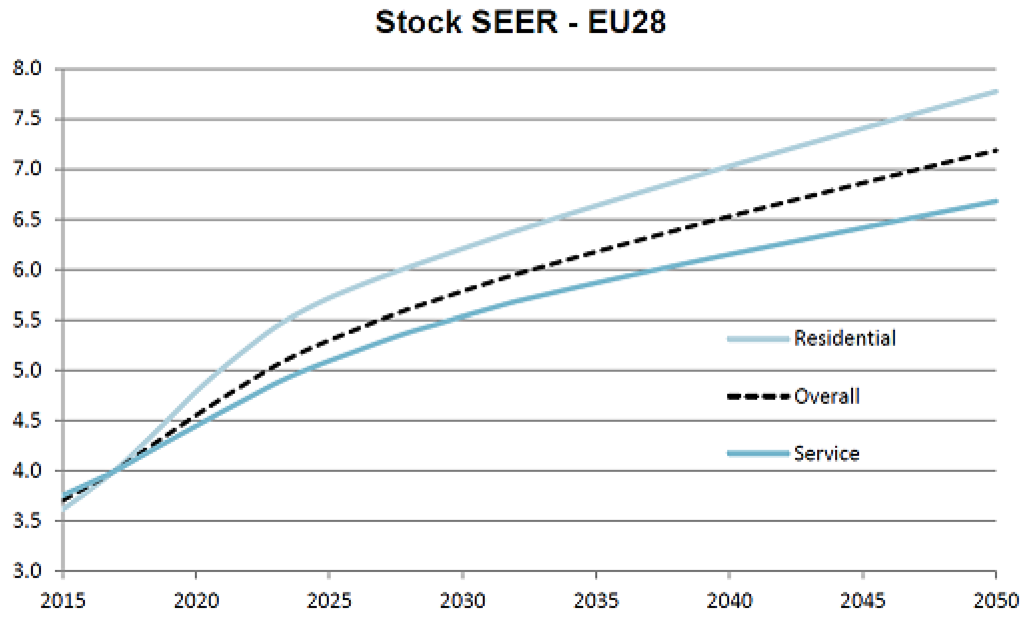
There are considerable differences in equipment levels within the EU residential sector. The southernmost countries (Cyprus, Malta) have SC diffusion rates in excess of 60%, while the countries around the Mediterranean (Spain, Italy, Greece, South of France) know SC diffusion rates of 20 to 30%. Continental countries currently have SC diffusion rates of around 10% and this rate falls to a few percent for other countries, mainly in Northern Europe (Dittmann et al., 2017).

In the non-residential sector, similar differences can be observed. The Mediterranean countries have SC diffusion rates of 70% to 85% in services sector. Most continental countries currently have SC diffusion rates of around 20%-30% in the service sector while in Northern Europe the SC diffusion rate in around 10-15 % (Dittmann et al., 2017).

Average SEER of SC technologies [-], indicates the average (in installed capacity) Seasonal Energy Efficiency Ratio of the space cooling technologies stock. Default value: *4,7* in the residential sector and *4,4* in the non-residential sector (average values of installed cooling capacities in EU27)

The average SEER of SC technologies stock is estimated around 4.7 in the residential sector and around 4.4 in the service sector (Dittmann et al., 2017). Nevertheless, this efficiency is expected to increase in the coming years as shown in Figure 21.

Figure 21. CM - Technologies and Measures, Average performance of the space cooling technologies stock



Measures uptake scenario, represents the level of adoption by the buildings' occupants of measures that reduce the space cooling needs. Default value: *no measure*.

- *No measure*: the buildings' occupants take no action to reduce the cooling needs
- *Low adoption*: the buildings' occupants moderatly use a mix of measures to reduce the cooling needs. 40% of occupants use systematically windows opening strategies for reducing cooling needs, and 20% among them also use both fans and shading.
- *High adoption*: the buildings' occupants widely use a mix of measures to reduce the cooling needs. 80% of occupants use systematically windows opening strategies for reducing cooling needs, and 40% among them also use both fans and shading.

3.2.3.2. INPUT LAYERS

The calculation module relies on the 3 following layers:

1. **Cooling degree days** shows the Cooling Degree Days for the reference period 2002-2012 in EU28 on hectare (ha) level. Information on the layer can be found here.
2. **Gross floor area residential** shows the residential gross floor area in EU28 on hectare (ha) level. Information on the layer can be found here.
3. **Gross floor area non-residential** shows the residential gross floor area in EU28 on hectare (ha) level. Information on the layer can be found here.

3.2.4. Output

The calculation module shows the following indicators:

- **Residential** or **non-residential cooled area [m^2]**: gives the residential and/or non-residential sectors area which is equipped with space cooling technologies.
- **Cooling demand [MWh/year]**: gives the cooling demand of the selected cooled area (ie. of the residential and/or non-residential cooled area).
- **Cooling demand with measures [MWh/year]**: gives the cooling demand reduced by the impact of mitigation measures implemented by the occupants.
- **Space cooling final energy consumption [MWh/year]**: gives the electricity consumption of SC technologies.
- **Cooling capacity [MW]**: gives the cooling capacity installed in the selected cooled area.
- **Cooling power capacity [MW]**: based on the cooling capacity, the power capacity of the installed SC technologies is based on an average SEER of SC technologies stock.

3.2.5. Sample Run

Step 1: Area selection

Select the scale of the study: the CM works at NUTS1, NUTS2, NUTS2, LAU2 as well as hectare level.

Select the area of the study: the selection tool available in the "Tools" section on the left enables you to select specific study areas. Let's select Slovenia for this analysis.

Step 2: Open the CM tab

Go to Calculation Module Tab and select "CM - Technologies & Measures"

Step 3: Building sector selection

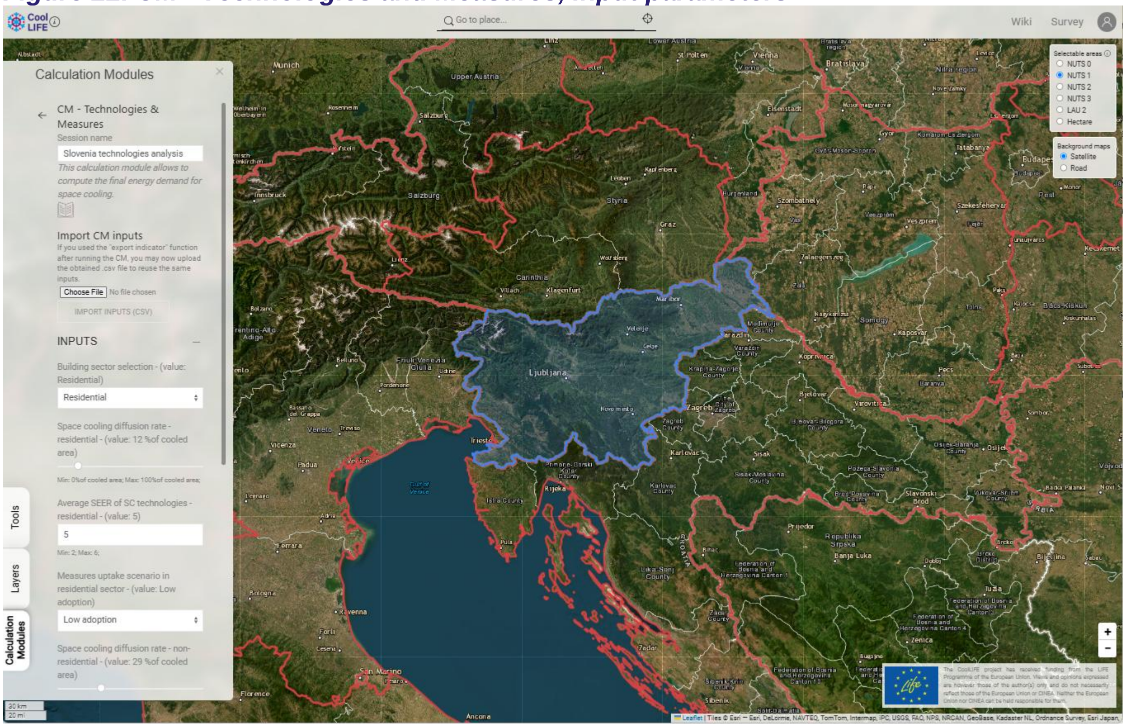
Select the sector you want to cover : residential, non-residential or both sectors. By default, the residential sector is selected. If you choose "residential", enter only the parameters relevant to "residential" (the paramters of non-residential will not be considered in such a case) and vice versa.

Step 4: Input data information

For each sector you want to cover in the study, you must enter the following parameters (Figure 22):

- Set the diffusion rate of the floor area which is equiped by space cooling technologies. By default, the EU-27 average value is taken. For this example, select 12 %.
- Set the Seasonal Energy Efficiency Ratio (SEER) of the space cooling technologies stock. By default, the EU-27 average value is taken. Enter the value of 5.
- Set the scenario of active and passive measures uptake by the buildings occupants: no measure, low adoption or high adoption (see Method and Input parameters sections above. By default, "no measure" scenario is considered. For this example, select Low adoption.

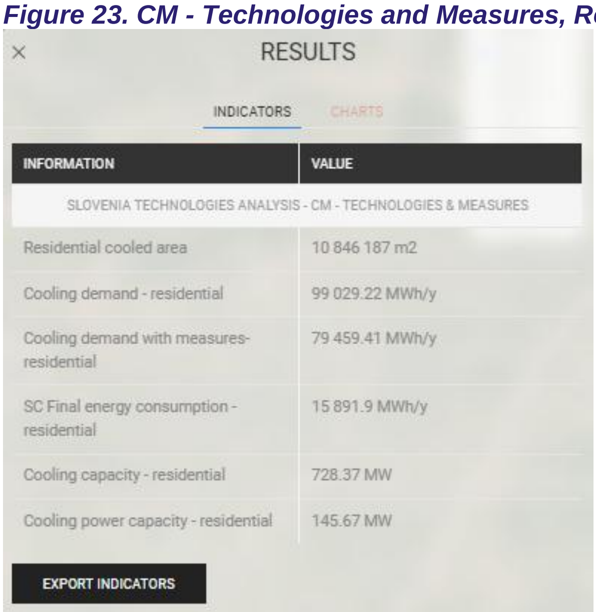
Figure 22. CM - Technologies and Measures, Input parameters



Step 5: Run the CM

The outputs are displayed in the “Results” section which shows all the outputs described in the section [Outputs](#) above. See Figure 23for the results of this example. If both building sectors are covered in the same run, the outputs are displayed together in the same results section.

Figure 23. CM - Technologies and Measures, Results



INFORMATION	VALUE
SLOVENIA TECHNOLOGIES ANALYSIS - CM - TECHNOLOGIES & MEASURES	
Residential cooled area	10 846 187 m2
Cooling demand - residential	99 029.22 MWh/y
Cooling demand with measures-residential	79 459.41 MWh/y
SC Final energy consumption - residential	15 891.9 MWh/y
Cooling capacity - residential	728.37 MW
Cooling power capacity - residential	145.67 MW

3.3. CM: Comfort, Lifestyle, And User Behaviour

3.3.1. Introduction

This calculation module provides information for the user on typical summer thermal comfort requirements and expectations, typical lifestyle and user behavioural patterns that influence space cooling (SC) demand within buildings through the member states of the EU27 area. Additionally, active behavioural SC interventions and adaptive routine practices that have proven to be successful in reducing SC demand in Europe and globally are displayed.

As part of human adaptation to hot temperatures (mainly in regions in a warmer climatic zone), traditional practices passed down through generations have been mainly focused on features of the building design that helped people to live comfortably in the hot periods of the year. In the context of climate change, learning from other countries that have already adopted successful strategies can help face the new challenges in sustainable space cooling.

The information displayed in the calculation module supports sustainable space cooling strategies through the following:

- **raise awareness** of the passive and occupant behavioural measures which are applied successfully in a particular location,
- **provide examples** of successful behavioural interventions that can be implemented on a wider scale,
- **provide a comparison** of thermal comfort expectations in different regions.

By learning from the CM results, policymakers can make more informed decisions when setting up new strategies and programs.

The module can be accessed on multiple scales: **NUTS1 - NUTS3, LAU and Hectare levels**. The user can select one or more territorial areas from the map using the selection tool. Regardless of the selected scale, the information returned corresponds to the Member State level.

3.3.2. Method

After selecting a location, the tool filters and displays the following types of information:

- Traditional behavioural patterns and lifestyle choices that are adopted in the country-specific climatic context, confirmed by empirical studies,
- Summer thermal comfort expectations of the building occupants, demonstrated through legislative and standard-based setpoints or overheating limits,
- Summer thermal comfort expectations reported in empirical studies,
- Successful intervention strategies that have proven to lead to increased acceptance of the thermal environment or reduction of space cooling demand.

When selecting locations in multiple countries, the tool will display results for all of these. The user can compare different country-specific lifestyles and user behaviour approaches towards the provision of a comfortable thermal environment in summer, which helps policymakers in finding appropriate strategies.

The passive and lifestyle measures for coping with summer weather and high temperatures have been compiled during the CoolLIFE project. The geographical distribution of traditional behavioural practices and passive solutions is incorporated into this module from the literature. Please see D3.1 section 4.4 in more detail.

The data used for thermal expectations on the national level was collected and summarized during the CoolLIFE project, published in deliverables D3.1 and D3.2 and D4.1. Where relevant, EN standard values are displayed in lack of country-specific data.

Behavioural interventions collected and presented in the D3.2 deliverable can be displayed, filtered and presented in the results field as indicators.

3.3.3. Input

3.3.3.1. TRADITIONAL BEHAVIOURAL PATTERNS AND LIFESTYLE CHOICES

The user can select whether these should be displayed or not.

3.3.3.2. THERMAL EXPECTATIONS

The user can select whether these should be displayed or not.

3.3.3.3. BEHAVIOURAL INTERVENTIONS

The *type of behaviour* explains what the intervention was. This can be selected from the following list:

- thermostat setpoints,
- shading and lighting,
- adaptation,
- electricity-powered space cooling appliances,
- electricity use,
- space use.

The *building type* categories have been aligned with the available case studies, and can be selected from:

- residential,
- office,
- public,
- educational,
- unspecified non-residential,
- unspecified.

The *intervention type* categories have been aligned with the literature review done within the project, and can be selected from:

- feedback and information,
- monetary incentives,
- nudges,
- policy.

3.3.3.4. OUTPUT

Output is provided in the Results tab, as *Indicators* and *Charts*. *Layer* results are not provided.

Information for thermal expectations represented by legislative and standard values are displayed as indicators. Custom indicators are displayed for each country, aligned with the country-specific legislative environment, for example, legislative setpoints values for areas with space cooling, or overheating limits for specific building types. Indicator values are stored and retrieved from the database on the NUTS0 level.

Additionally, preferred indoor temperatures in summer for residential buildings, where available, are displayed in the Charts tab. The current version of the tool includes these values for Germany, France, Spain and Hungary, aligned with the availability of results from representative surveys.

For the interventions, the displayed data contains a more detailed description of the intervention, displayed as four rows in the indicator tab:

- more detailed description of the successful intervention strategy,
- details on the results of the behavioural change,
- the geographical context of the case studies,
- and a link to the scientific publication of the case study results.

3.3.4. Sample Run

A sample run for Germany can be done as the following:

Step 1: Select a region in Germany.

Step 2: Go to the Calculation Module Tab and select “CM: Comfort, Lifestyle, And User Behaviour”.

Step 3: Select the types of outputs you would like to see.

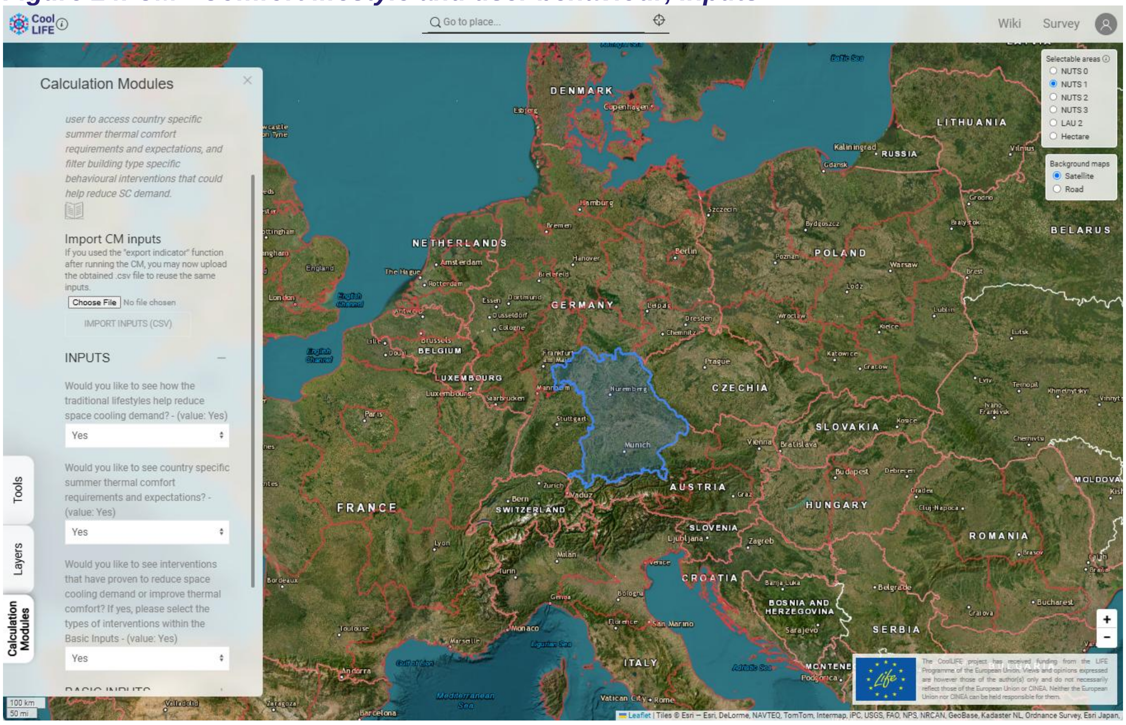
The user can select the types of outputs to be displayed. If yes is selected, further inputs are needed under the ’**BASIC INPUTS**’ section.

In the sample run the inputs are set to show all types of outputs available (Figure 24):

- Would you like to see how traditional lifestyles help reduce space cooling demand? **Yes**
- Would you like to see country-specific summer thermal comfort requirements and expectations? **Yes**
- Would you like to see interventions that have proven to reduce space cooling demand or improve thermal comfort? If yes, please select the types of interventions within the Basic Inputs. **Yes**

Since the interventions that have proven to reduce space cooling demand or improve thermal comfort within Germany have also been selected, the BASIC INPUTS menu needs to be opened to add specific search requirements. The user in this case wants to display intervention case studies in Germany, where monetary incentives were provided to reduce electricity use in the residential building sector.

Figure 24. CM - Comfort lifestyle and user behaviour, Inputs



Step 4: Select the detailed inputs for the intervention types.

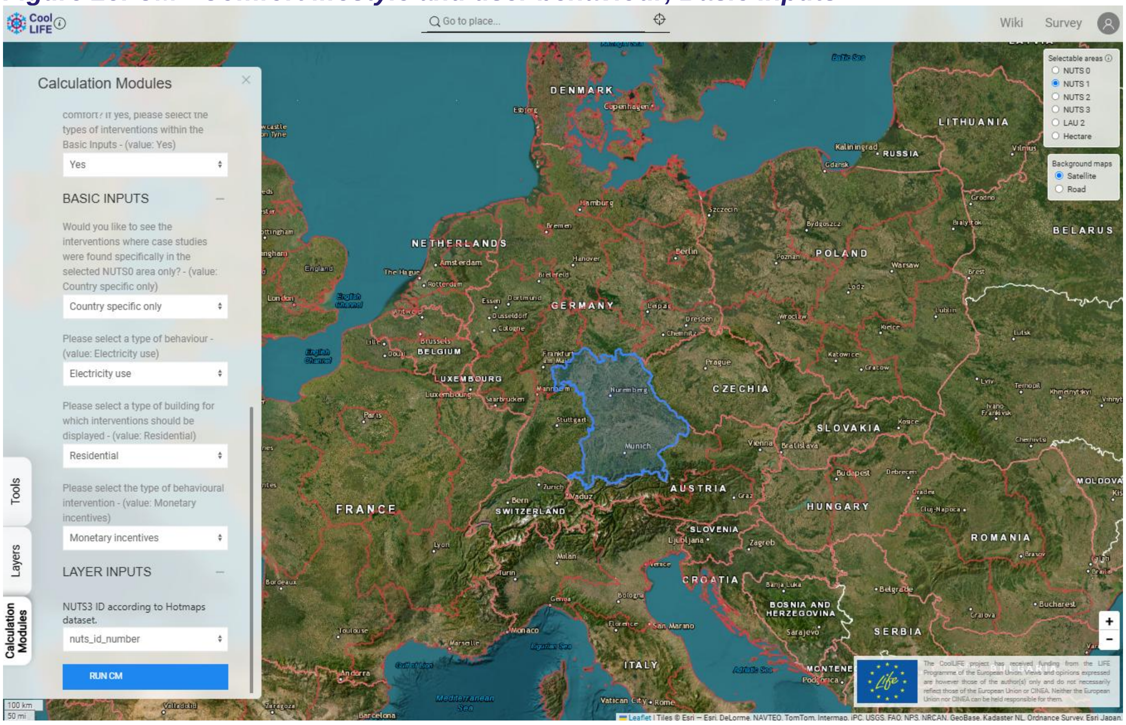
Open the *BASIC INPUTS* field (Figure 25). First, the users can determine whether they would like to restrain the search for interventions that have been proven to be successful in published case studies within the country of interest, or they would like to see all case studies regardless of the geographical context.

Then, the user can filter the interventions based on the *type of behaviour*, the *type of building* and the *type of intervention*. Users can select a specific option from the dropdown menu or can select to display all of the interventions. In the sample run, the following inputs are selected:

- Would you like to see the interventions where case studies were found specifically in the selected NUTS0 area only?: **Country-specific only**
- Please select a type of behaviour: **Electricity use**
- Please select a type of building for which interventions should be displayed: **Residential**
- Please select the type of behavioural intervention: **Monetary incentives**

Finally, the layer used for relating the NUTS ID of a particular location to the database is displayed.

Figure 25. CM - Comfort lifestyle and user behaviour, Basic Inputs



Based on the selected combination, information regarding the successful interventions will be displayed on the indicator tab.

Step 5: Run the CM

CM is run with these inputs.

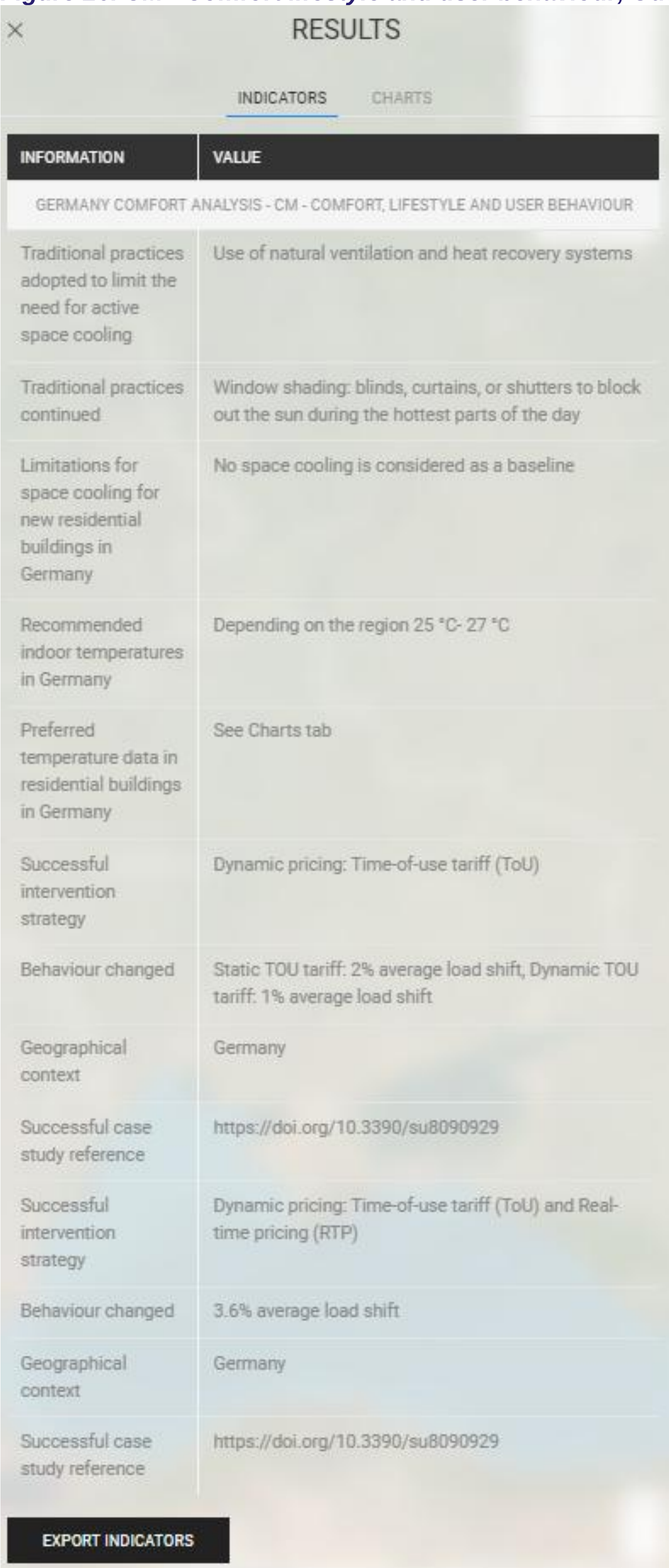
Step 6: Check the results

Indicators are shown in the Indicators tab (Figure 26).

For the traditional practices two types of practices were found.

For the country specific thermal expectations the user can see, that in new residential buildings, no space cooling is considered as a baseline. The recommended indoor temperatures are between 25 °C-27 °C.

Figure 26. CM - Comfort lifestyle and user behaviour, Output indicators



RESULTS

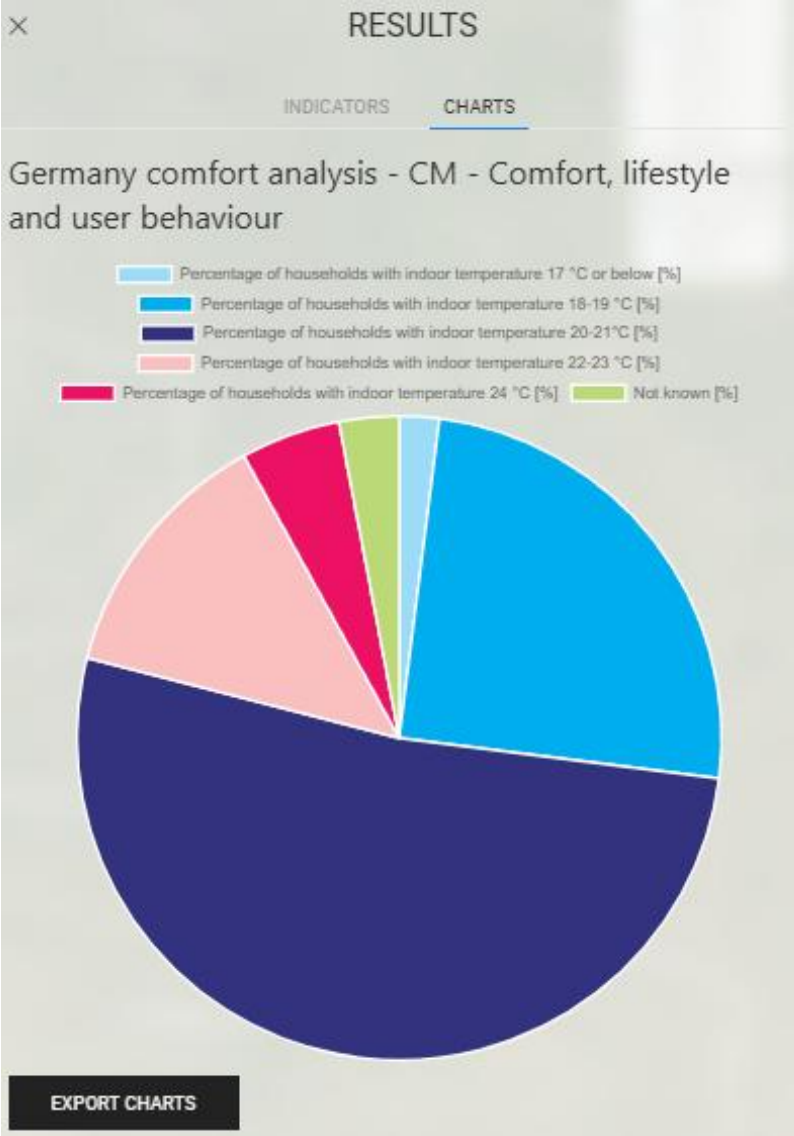
INDICATORS CHARTS

INFORMATION	VALUE
GERMANY COMFORT ANALYSIS - CM - COMFORT, LIFESTYLE AND USER BEHAVIOUR	
Traditional practices adopted to limit the need for active space cooling	Use of natural ventilation and heat recovery systems
Traditional practices continued	Window shading: blinds, curtains, or shutters to block out the sun during the hottest parts of the day
Limitations for space cooling for new residential buildings in Germany	No space cooling is considered as a baseline
Recommended indoor temperatures in Germany	Depending on the region 25 °C- 27 °C
Preferred temperature data in residential buildings in Germany	See Charts tab
Successful intervention strategy	Dynamic pricing: Time-of-use tariff (ToU)
Behaviour changed	Static TOU tariff: 2% average load shift, Dynamic TOU tariff: 1% average load shift
Geographical context	Germany
Successful case study reference	https://doi.org/10.3390/su8090929
Successful intervention strategy	Dynamic pricing: Time-of-use tariff (ToU) and Real-time pricing (RTP)
Behaviour changed	3.6% average load shift
Geographical context	Germany
Successful case study reference	https://doi.org/10.3390/su8090929

EXPORT INDICATORS

The preferred temperatures within the dwellings are provided in the Charts tab (Figure 27). The pie chart shows the percentage of households within the residential sector of the selected country, who prefer a certain indoor temperature within their home.

Figure 27. CM - Comfort lifestyle and user behaviour, Outputs: Charts - Thermal expectations - empirical, pie chart

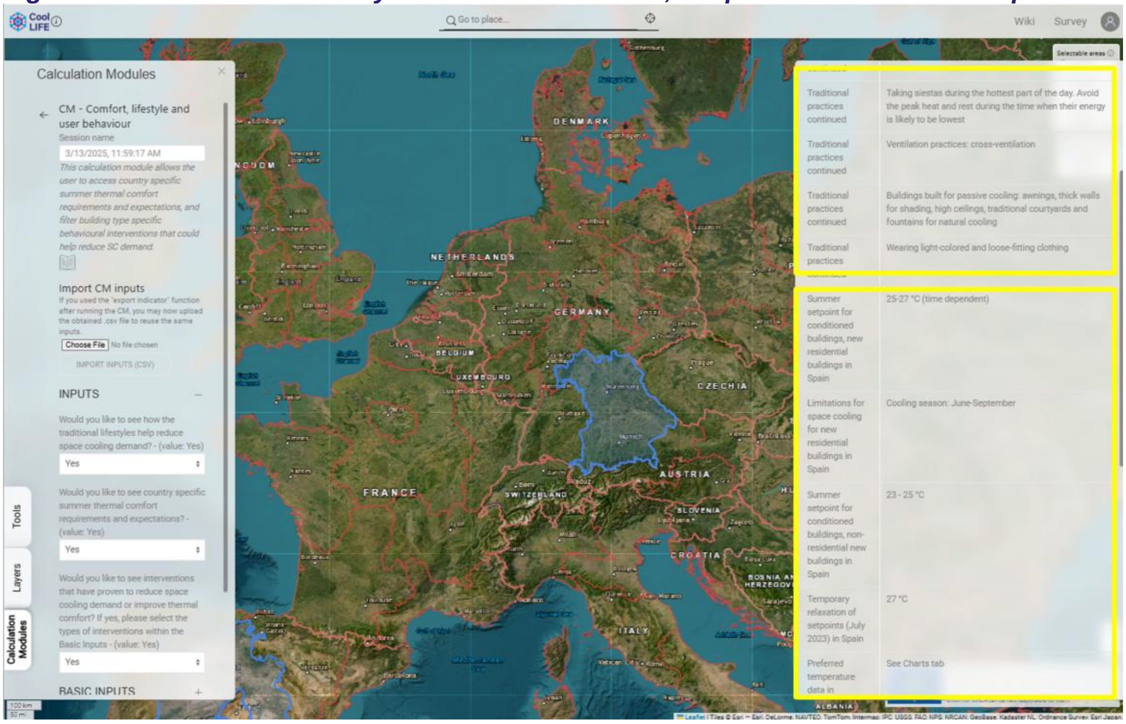


Two behavioural interventions are displayed within the Indicators tab for the given inputs, each with four rows.

3.3.4.1. MULTIPLE COUNTRIES

When multiple countries are selected, the results are displayed in a consecutive way. For example, the results for Germany and Spain will look like below (Figure 28):

Figure 28. CM - Comfort lifestyle and user behaviour, Outputs: Indicators - Multiple countries



3.4. CM: Economic Feasibility

3.4.1. Introduction

This Calculation Module (CM) enables users to conduct an economic and financial assessment of investments in space cooling (SC) facilities, considering various financing options. Users can either rely on default data on typical investment costs (€/kW) for different cooling technologies or input specific project data for a more tailored analysis. The module provides key financial insights based on cost-benefit analysis (CBA), evaluating projects under different financing support schemes.

This module offers two types of assessments:

- **National-level assessment**: for policymakers and energy planners to analyze policy scenarios and investment strategies, focusing on the evolution of cooling demand and associated costs.
- **Building-level assessment**: for property owners to evaluate cooling demand reductions and associated costs at an individual building scale.

The module works at **NUTS1**, **NUTS2**, **NUTS3** and **LAU2**. However, it is to be noted that irrespective of the geographical selection, results are presented as national-level averages. The analysis can be done either to acquire **National level** for aggregated results or on **Building levels** for specific building types.

3.4.2. Method

The approach allows the quantification of the effects of passive measures and technological advancements on space cooling demands, integrating environmental, economic, and societal impacts. The methodology is structured to utilize open-source data sets for evaluating EU-wide cooling demand trends, starting with a bottom-up estimation based on national building stock distribution. The process involves calibrating building physics parameters to reflect passive cooling measures, leading to estimates of Theoretical Useful Energy Demand (TUED) and Practical Useful Energy Demand (PUED). Specifically, the following parameters are estimated:

- **Theoretical Useful Energy Demand (TUED)**: This step models the potential cooling demand if all built floor areas had space cooling technologies, serving as a baseline to assess energy savings from passive measures. This is taken as input from results generated by the Invert EE-lab model.
- **Diffusion Rates of Technology**: The adoption rates of active cooling technologies are analyzed to translate theoretical potential into practical application, reflecting realistic market penetration. The diffusion rates are used to scale the TUED to **practical useful energy demand**.
- **Final Energy Demand**: After considering the adoption of passive and active technologies, the actual energy consumption (Final Energy Demand) is estimated, accounting for different rates of technological advancement and the mix of technologies employed.
- **Impact of Passive Measures**: The methodology rigorously accounts for the potential energy savings achievable through various scenarios of passive measure uptake, allowing for detailed projections of energy demand reductions across different EU regions and timeframes.
- **Economic Parameters**: Based on the impact of the predefined scenarios of the active and passive measures, the module calculates costs for implementing such scenarios in terms of the cooling provided as well as the costs per unit of energy savings. The overall costs of the scenarios are categorized into three components:
- *Active CAPEX*: The investment in new technology for each year is annualized over its lifetime.
- *Active OPEX*: The operation costs of the technologies
- *Passive CAPEX*: The investment costs on passive cooling measures

Based on these costs, the calculation module provides the economic indicators for the scenario in terms of the levelized cost of cooling supply and the levelized costs of savings in terms of the useful energy demand.

This approach not only provides insights into the direct impacts of cooling technologies but also highlights their broader implications for energy efficiency and social well-being within the EU-27 context.

3.4.3. Input

The following **input parameters** must be selected:

- **Assessment type**: The user can perform the assessment either on a national level (covers the overall cooling sector of the selected country) or a building level (provides financial indicators to a homeowner).
- **National-level assessments**: allow users to compare demand trajectories under current policy frameworks with scenarios that envision both high and low uptake of active cooling technologies. It also examines how advancements in technology efficiency impact overall demand over time. For financial assessments, the tool evaluates the costs associated with energy savings and investments in active cooling technologies. Key parameters used in our analysis include the Levelized Cost of Cooling (LCOC) for cooling supply and the Levelized Cost of Energy Savings (LCES). By comparing these costs at a national scale, the tool helps determine the economic viability of investing in both passive and active cooling measures, guiding strategic decision-making in energy policy development.
- **Building-level assessment**: enables users to select a specific building type within their region and define its size in square meters (m^2). Based on these inputs, the module calculates the overall costs of cooling supply with the active measures, estimates the potential for energy savings, and provides an overview of the costs required to implement various passive cooling measures. This assessment supports informed decision-making by offering a first-level evaluation of economic feasibility, helping building owners explore cost-effective solutions for improving energy efficiency in their buildings. The module utilizes similar parameters as the national-level assessment, allowing for a consistent evaluation framework across different scales.

- **Passive measure efficiency**: Based on literature and existing market shares of different passive cooling measures, options on pre-defined passive measures packages at different levels of efficiency can be selected (See Table 1). The future possibility of user-defined packages is foreseen.
- **Diffusion rates of Active Measures**: The parameter indicates the rate of diffusion of cooling technologies. Scenarios can be developed based on different rates of diffusion of the technology.
- **Active measure efficiency**: This parameter indicates the SEER values of the individual supply technology, allowing the user to define the development of cooling technologies.

Table 1. Efficiency Levels of Passive Cooling Strategies

Category	Baseline	Moderate	High
Shading	No additional shading	Manual shading	Automated shading
Shading Technology	Internal Venetian Blind	Highly reflective inner screen	External Venetian Blind
Window Glazing	Single glazing window	Double glazing low emissivity window	Solar controlled window glazing
Night Ventilation	No night ventilation	Low level of night ventilation	High level of night ventilation
Indoor Temperature	Average indoor temperature	Indoor temperature increase by 2°C	Indoor temperature increased by 4°C

The user needs to select the **input layer**, i.e. the region where the analysis is to be performed. In case of an error regarding the size of the region, the user can select a sub-region (e.g. NUTS1) within the same country, which will still give results on the national level. The user needs to avoid selecting multiple regions at the same time.

3.4.4. Output

The following outputs will be obtained from this analysis.

- Indicators:
- Total Final Energy demand from the scenario
- Useful Energy saving potential from the selected scenario in the year 2050
- Percentage Final Energy demand savings
- Description of the Scenario
- Charts:
- Total Useful Energy demand of the scenario vs. Baseline for years 2030,2040 and 2050
- Total Final Energy demand of the scenario vs. Baseline for years 2030,2040 and 2050
- Break down of total investment in active and passive measures (scenario vs. Baseline)
- Comparison of levelized cost of cooling (Passive - Euros per MWh of saved useful energy demand; Active - Euros per MWh of supplied useful energy demand)

3.4.5. Sample Run

3.4.5.1. NATIONAL LEVEL

Here, the sample run of the calculation module for Czech Republic (Czechia) is performed on a national level.

Step 1: Area Type Selection

Select the NUTS1 on the top right area selection option.

Step 2: Region Selection Option

Select the NUTS1 region Czechia.

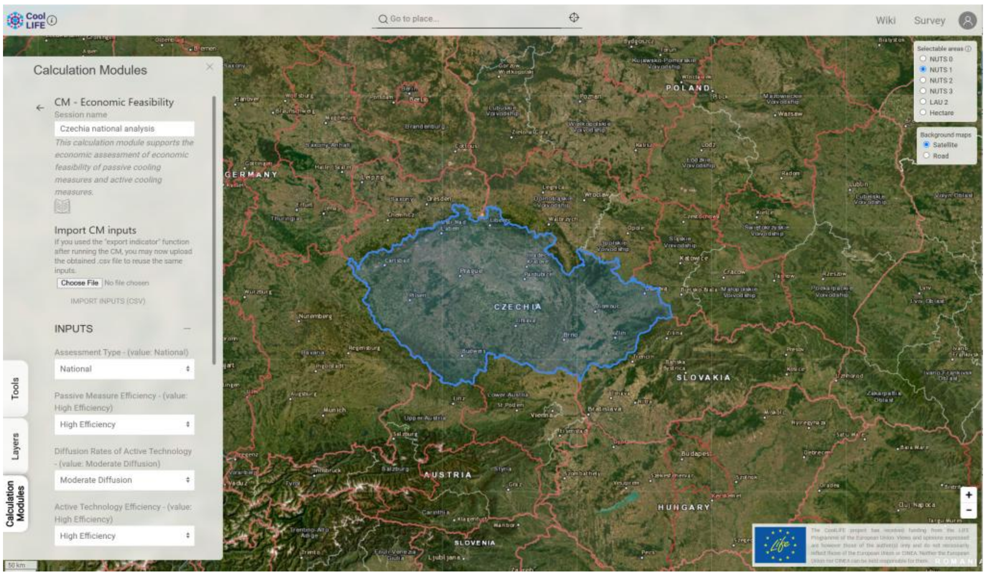
Step 3: Go to the Calculation Module Tab and Select the CM Economic Feasibility.

Step 4: Provide Input Parameters

Now, we provide the **input parameters** to the CM (see ***Figure 29*** and Figure 30). Here, we have simplified the user input requirements with a set of pre-defined combinations of technology and measures based on literature.

- Enter the **Session name**, e.g. “Czechia national analysis”.
- Select the **Assessment Type** as National as we are performing a National level assessment. The results from the CM could be an input to the National Comprehensive Assessment Report.
- Select the **passive measure efficiency**. Choose ‘High Efficiency’. This means that we are assessing a scenario where we see a widespread application of passive measures with high efficiency (energy savings potential) in Austria up to 2050. The underlying assumptions and passive measure combination details are in the method section above.
- Select **Diffusion Rates of Active Measures**. Choose ‘Moderate Diffusion’. This means we are assessing a scenario where there is a moderate increase in the diffusion of technology until 2050. The underlying assumptions and rates of active measure uptakes are available in the method section above.

Figure 29. CM - Economic feasibility, National-level assessment, Input parameters, part 1



- Select **Active Measure Efficiency**. Choose ‘High Efficiency’. This means we are assessing a scenario where there is considerable improvement in the efficiency of the active cooling technology. The underlying assumptions and rates of active measure efficiency improvements are available in the method section above.
- Select the **Building type** in [m^2]. For National-level assessment, this parameter doesn’t play a role.
- Enter the **Building Floor Area**. This parameter is irrelevant to the National-level assessment
- Define the **discount rate**. For this example, we assume 5%.
- **The lifetime of the technology and measures** can be adjusted, based on literature and average value define this as 10 years for this example.

Figure 30. CM - Economic feasibility, National-level assessment, Input parameters, part 2

Step 5: Run the CM

Step 6: View and Download Results

See Figure 31 and Figure 32. The following output types are available:

1. **Indicators:**

- Country name
- Scenario Description
- Baseline Seasonal Energy Efficiency Ratio (SEER): Based on literature the current SEER value for the Czech Republic. Future scenarios are based on this.
- Base year Useful energy demand for Base Scenario: Base Scenario refers to the no-change scenario. This is the comparison scenario where no passive and active measure uptake and no efficiency measures are assumed for the entire study horizon.
- 2050 Useful energy demand for Base Scenario: This is the projected 2050 demand for the base scenario.
- 2050 Useful energy demand for Selected Scenario: This is the projected 2050 demand for the scenario we have defined based on the input parameters.
- Final Energy Demand (FED) savings estimated in the scenario 2050: Compared to the baseline, here are the savings in the final energy demand with the defined uptake and development of active and passive cooling measures.

2. **Charts:**

- *Chart 1*: Comparison of Baseline and selected scenario over the time horizon (Figure 32).

- *Chart 2*: Break down of the total investment required for the selected scenario vs the baseline (Figure 32).
- *Chart 3*: Comparison of levelized cost of cooling on useful energy demand of the two scenarios (Figure 32). In this example, it is evident that the passive measures are more appealing, and hence, it could be argued to orient the policy framework toward promoting its uptake.

Figure 31. CM - Economic feasibility, National-level assessment, Example Results, Indicators

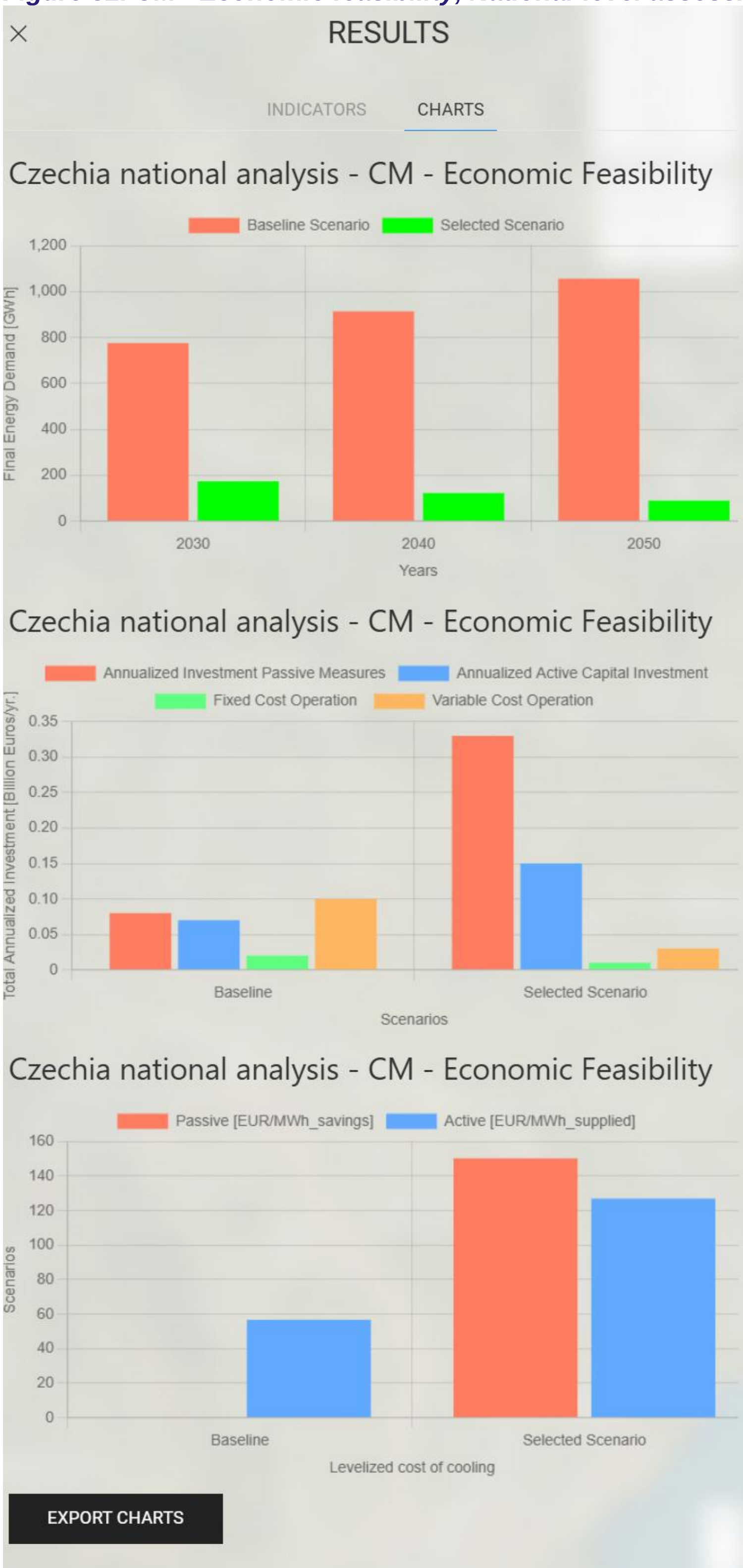
RESULTS

INDICATORS CHARTS

INFORMATION	VALUE
CZECHIA NATIONAL ANALYSIS - CM - ECONOMIC FEASIBILITY	
country	CZE
Scenario Description:	In this scenario uptake of high efficiency packages of passive measure along with moderate diffusion levels of supply technology and high efficiency level of active technology improvement rates are expected for Czech Republic
Baseline Seasonal Energy Efficiency Ratio (SEER)	3.88
Improved Seasonal Energy Efficiency Ratio (SEER) in the Scenario	7.88
Base year Useful energy demand for Base Scenario	2 580.54 GWh
2050 Useful energy demand for Base Scenario	4 344.19 GWh
2050 Useful Energy Demand for Selected Scenario	884.51 GWh
Savings in the Useful Energy Demand by 2050	79.64 %
2050 Final Energy Demand for Base Scenario	1 120.47 GWh
2050 Final Energy Demand for Selected Scenario	89.55 GWh
Final Energy Demand savings estimated in this scenario by 2050	92.01 %
Levelized Cost of Energy Saving from selected passive measure per unit useful energy saved	150.29 EUR/MWh
Levelized Cost of Energy of the scenario measure per unit useful energy supplied	126.97 EUR/MWh

EXPORT INDICATORS

Figure 32. CM - Economic feasibility, National-level assessment, Example Results, Charts



3.4.5.2. BUILDING LEVEL

Step 1: Area Type Selection

Select the NUTS1 on the top right area selection option.

Step 2: Region Selection Option

Select the NUTS1 region Czech Republic.

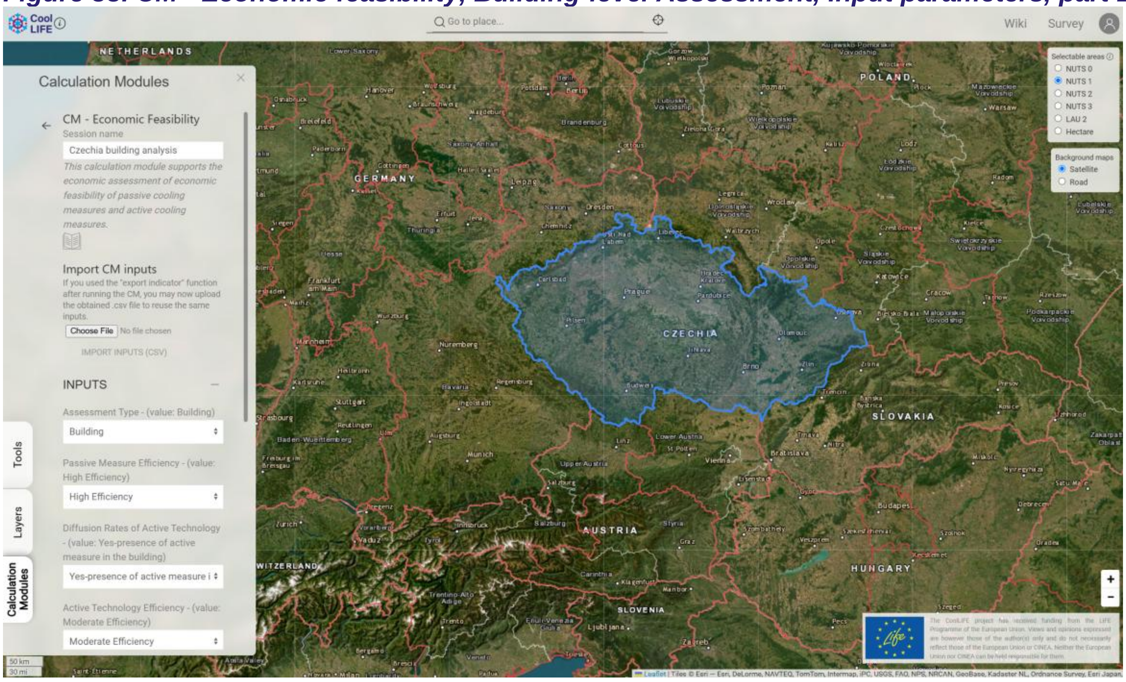
Step 3: Go To the Calculation Module Tab And Select The Cm-Economic Feasibility

Step 4: Provide Input Parameters

Now, we provide the **input parameters** to the CM (see Figure 33 and Figure 34). Here, we have simplified the user input requirements with a set of pre-defined combinations of technology and measures based on literature.

- Enter the **Session name**, e.g. "Czechia building analysis".
- Select the **Assessment Type** as Building level as we are performing a building level assessment.
- Select the **passive measure efficiency.** Choose 'High Efficiency'. This means that we are assessing a scenario where we see a widespread application of passive measures with high efficiency (energy savings potential) in the Czech Republic. The underlying assumptions and passive measure combination details are in the method section above.
- Select **Diffusion Rates of Active Measures**: Here, for building level assessment, we just select "Yes- the presence of active cooling measure," indicating that the building under consideration has the existence of a cooling supply technology.

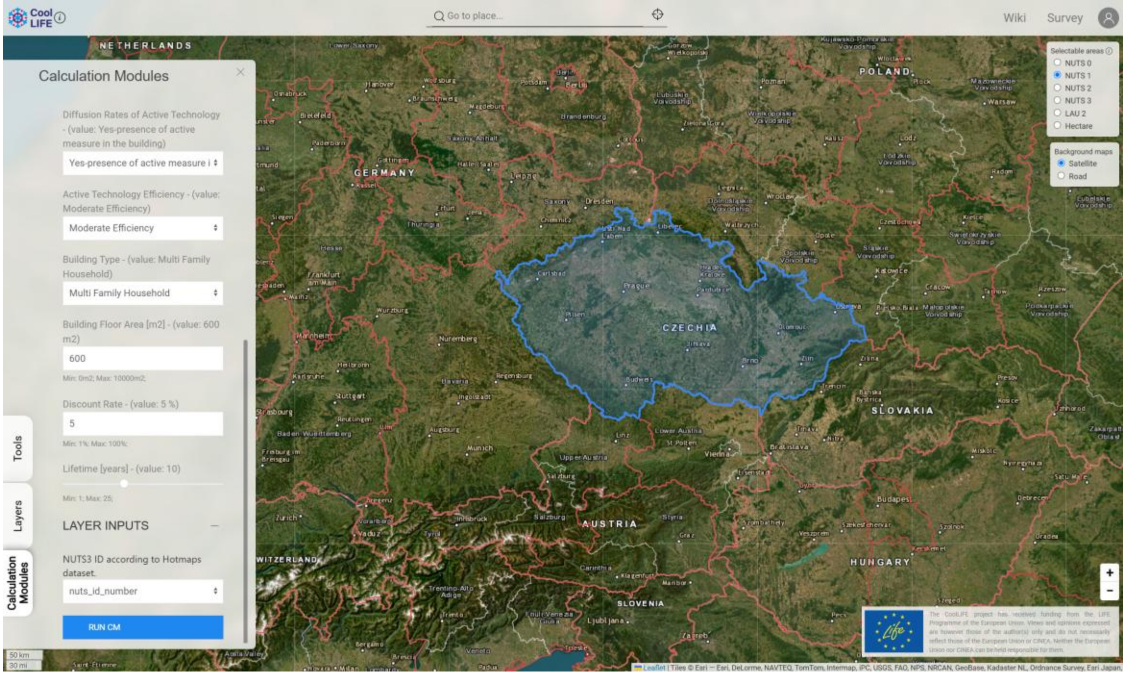
Figure 33. CM - Economic feasibility, Building-level Assessment, Input parameters, part 1



- Select **Efficiency of Active Measure**: Here, you need to select the type of active measure, which is defined by the efficiency of the technology. A high level of efficiency indicates higher upfront investment but lower operation costs. Choose "Moderate Efficiency" for this sample run.
- Select the **building type**: Here, you can choose the type of building based on which the space cooling demand for the building is calculated. Multiple residential and non-residential options of building archetypes can be selected. Choose "Multi Family Household".
- Enter the **gross floor area of the building**: Here, you need to enter the total gross floor area of your building. Enter 600 square meters here.
- Define the **discount rate**. For this example, we assume 5%.
- **The lifetime of the technology and measures** can be adjusted, based on literature and average value define this as 10 years for this example.

Note: If in case you encounter an error in the Building level run of the CM, this is because the building stock data for this building type is missing in the database. This will updated when improved data is acquired. For now, we suggest using other similar building types to obtain tentative results.

Figure 34. CM - Economic feasibility, Building-level Assessment, Input parameters, part 2



Step 5: Run The CM

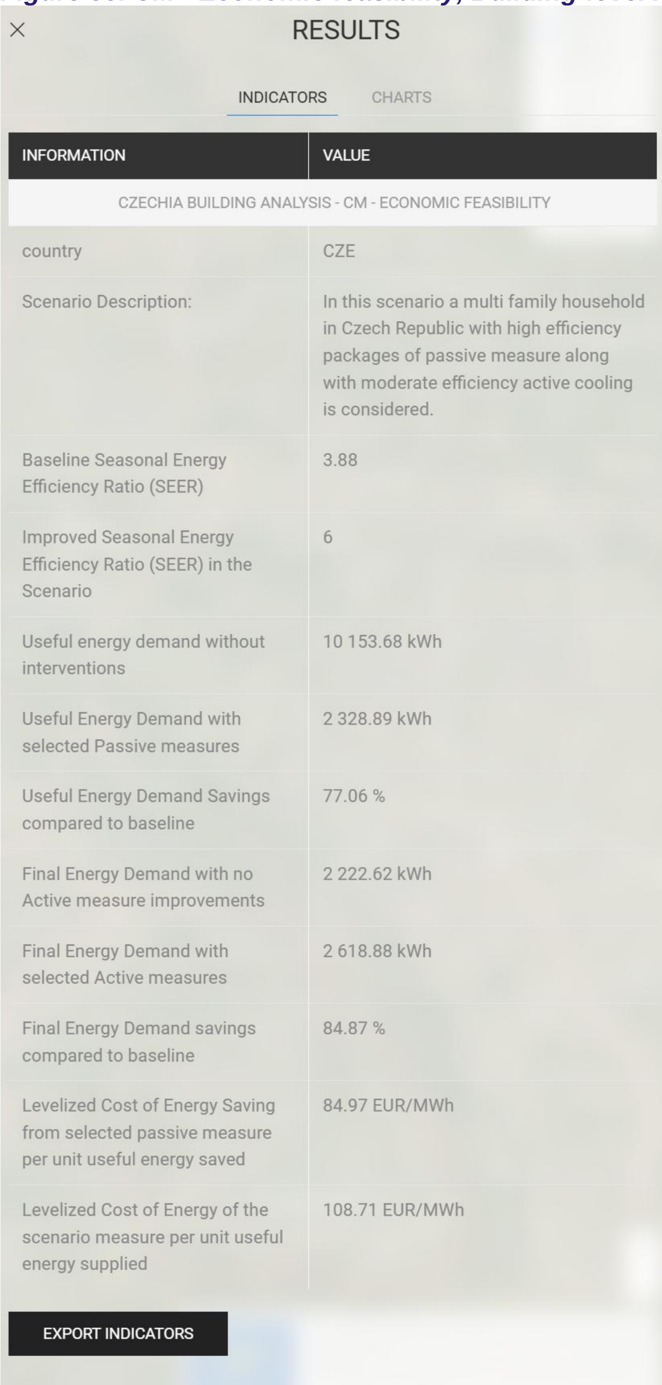
Step 6: Example Results

See Figure 35 and Figure 36. The results include:

1. **Indicators:**

- Country name
- Scenario Description
- Baseline Seasonal Energy Efficiency (SEER) Ratio: The value is based on literature (the current average SEER value for the Czech Republic.) Future scenarios are based on the scaling of these average SEER values.
- *Useful Energy Demand without interventions*: This is the comparison scenario where no passive and active measure uptake and no efficiency measures are assumed for the entire study horizon.
- *Useful energy demand with selected active and passive measures*: This is the calculated demand if there is the uptake of defined passive measures and technology improvement.
- *Useful Energy Demand Savings compared to Baseline*: Percentage useful energy savings from the intervention of the measures.
- *FED Savings Compared to Baseline*: Percentage of final energy savings from the intervention of the measures.

Figure 35. CM - Economic feasibility, Building-level Assessment, Example Results, Indicators



RESULTS

INDICATORS CHARTS

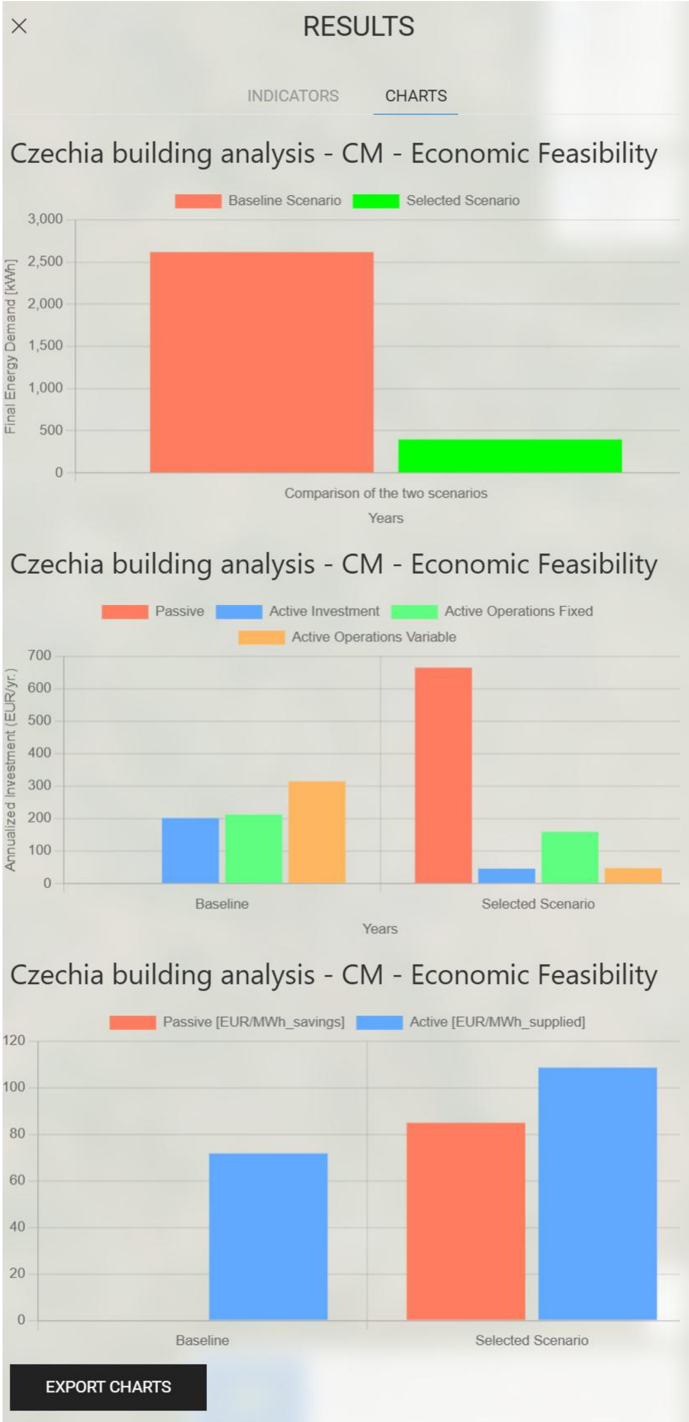
INFORMATION	VALUE
CZECHIA BUILDING ANALYSIS - CM - ECONOMIC FEASIBILITY	
country	CZE
Scenario Description:	In this scenario a multi family household in Czech Republic with high efficiency packages of passive measure along with moderate efficiency active cooling is considered.
Baseline Seasonal Energy Efficiency Ratio (SEER)	3.88
Improved Seasonal Energy Efficiency Ratio (SEER) in the Scenario	6
Useful energy demand without interventions	10 153.68 kWh
Useful Energy Demand with selected Passive measures	2 328.89 kWh
Useful Energy Demand Savings compared to baseline	77.06 %
Final Energy Demand with no Active measure improvements	2 222.62 kWh
Final Energy Demand with selected Active measures	2 618.88 kWh
Final Energy Demand savings compared to baseline	84.87 %
Levelized Cost of Energy Saving from selected passive measure per unit useful energy saved	84.97 EUR/MWh
Levelized Cost of Energy of the scenario measure per unit useful energy supplied	108.71 EUR/MWh

EXPORT INDICATORS

2. Charts:

- *Chart 1*: Comparison of Baseline and selected scenario.
- *Chart 2*: Break down of the total investment required for the selected scenario compared against the baseline.
- *Chart 3*: Comparison of levelized cost of cooling on useful energy demand of the two scenarios.

Figure 36. CM - Economic feasibility, Building-level Assessment, Example Results, Charts



3.5. CM: Demand-side Management/Demand Response

3.5.1. Introduction

The CoolLife Demand-side Management/Demand Response calculation module provides users with an impression of cooling demand response potential. The CM is designed to assess the DR potential of cooling demand for a user-defined region by utilizing pre-cooling strategies and the thermal properties of the region's building stock to provide an analysis of PV self-consumption, where DR is used to shift cooling demand to match PV supply. Archetype data are used to provide a reference building that is considered a new construction (construction period later than 2010), a single-family home, which utilizes the floor area and U-values typical of such buildings for each country. A reference day in the summer period (August 2020) was used to assess cooling demand (please note that results will be impacted based on the conditions of the reference day for each country).

The module operates at the **NUTS0 level**.

3.5.2. Method

The CM utilizes a 5R1C model to calculate building cooling demand based on a new construction archetype - both for the BAU simulation as described in ISO 13790 (International Organization for Standardization, 2008) and for the optimization model described by Wilczynski et al. 2023 - utilizing climate data from PVGIS (European Commission, 2017). The suggested PV system nominal power is computed at NUTS0 resolution based on pre-processed optimization results as described by Dallapiccola et al, 2022. Finally, a linear optimization model matches cooling demand with PV supply utilizing the flexibility of the building envelope.

3.5.3. Input

As input, the user simply selects the country (NUTS0) where they would like to evaluate PV matching load shifting.

3.5.4. Output

Three KPIs related to daily energy consumption on a reference summer day are calculated and displayed as outputs, including:

1. the total daily business as usual (BAU) cooling demand using non-PV load, which assumes no PV system is present
2. the total daily cooling demand using non-PV load, which assumes a PV system is present but demand is not optimized to match PV supply
3. the total daily cooling demand using non-PV load that utilizes demand response load shifting, which assumes a PV system is present and demand is optimized to match PV supply

3.5.5. Sample Run

Step 1: Select a country at NUTS0 level

Select Germany.

Step 2: Go to the “Calculation Modules” tab

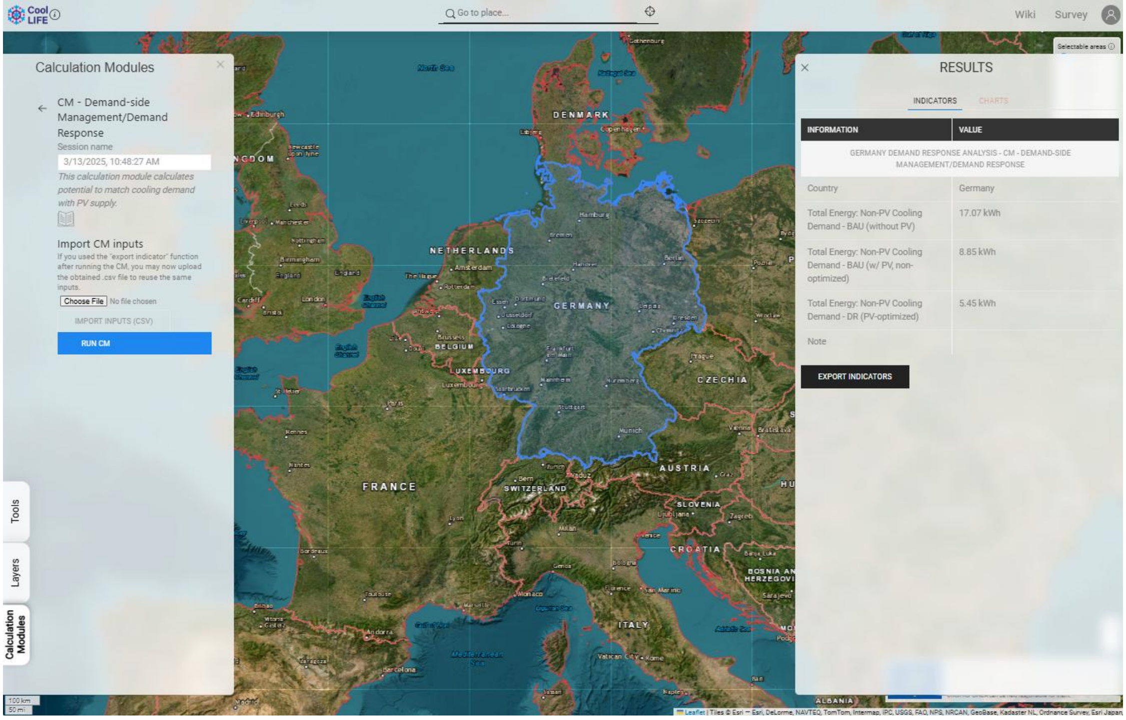
Select “CM - Demand-side Management/Demand Response”.

Step 3: Run the CM

Step 4: View and Download Results

The output provided is described in the Output section of this wiki. Note that lower demand (kW) implies that more cooling load is being consumed by PV supply as the output values are displaying only cooling load that is NOT supplied by a PV system. The user can use these values to demonstrate the potential for a PV system in reducing the cooling load for a new SFH in the selected country (Figure 37).

Figure 37. CM - Demand Response, Input and Results



3.6. CM: District Cooling

3.6.1. Introduction

This calculation module assesses the feasibility of **district cooling (DC) networks** by identifying areas where DC implementation is economically viable. Designed as a **planning tool**, the module helps policymakers and energy planners determine where DC could be a cost-effective alternative to conventional cooling methods.

By integrating techno-economic analysis with spatial planning, the module provides insights into potential DC zones, supporting preliminary design and investment decisions. It considers **economic factors, cooling demand distribution**, and **infrastructure requirements** while maintaining a simplified approach that does not delve into detailed engineering design.

This module is particularly valuable for high-demand zones—such as hospitals, office buildings, and grocery stores—where DC networks can leverage economies of scale. By comparing levelized cooling costs between DC grids and individual cooling systems, the module **identifies areas where DC can offer financial and operational advantages**.

Additionally, the module incorporates pipe sizing estimates, network cost assessments, and feasibility evaluations, offering a comprehensive yet streamlined approach to DC planning. The tool is open-source and accessible via GitHub, encouraging transparency and community involvement in cooling infrastructure development.

The module operates at the **Hectare level**.

3.6.2. Method

The module operates at a 100 × 100-meter resolution, allowing for a detailed spatial analysis of DC feasibility across a selected region. The analysis focuses on economic viability while avoiding in-depth design specifics, ensuring it remains a practical tool for early-stage planning and policy guidance.

The key features of the model are:

- **Techno-economic Feasibility**: Identifies potential DC zones based on cost-effectiveness.
- **Pipe Sizing**: Estimates necessary pipe diameters using simplified physical calculations adapted to specific cell layouts.
- **Open Source**: Available on GitHub to promote transparency and community collaboration.

The analysis is based on several simplifying assumptions to maintain computational efficiency:

- **Cooling Supply Options**: The module considers a limited selection of cooling sources for DC supply.
- **Infrastructure Exclusion**: Existing infrastructure is not factored in to simplify cost estimates.
- **DC Connection Rate**: Assumed to be equal to the cooling technology diffusion rate in the region.
- **Standardized Economic Assumptions**: DC is treated as a single technology, with uniform cost assumptions for different network components.

Granularity and technical details of the model include:

- **Fine Spatial Resolution**: The module evaluates feasibility at a high geographic granularity to enhance planning accuracy.
- **Annual Peak Demand Consideration**: The module only considers annual peak cooling demand, simplifying the overall energy demand profile.

The following cost and network design considerations are included in the module:

- **Pipe Diameter Estimation**: Uses a combination of empirical data and theoretical calculations to determine appropriate pipe sizes.
- **Network Costing**: Estimates costs based on average pipe diameter and total projected network length within each cell.
- **Feasibility Assessment**: Uses the levelized cost of cooling (LCOC) to determine economically viable areas for DC implementation.

Further methodological details are available in Malla and Kranzl, 2024.

3.6.3. Input

3.6.3.1. INPUTS

- Average Electricity Price: This refers to the typical retail electricity prices, which are essential for estimating the operational costs of individual cooling systems. For district cooling (DC), these prices are adjusted downward to reflect the more favourable rates often available to larger-scale, industrial operations.
- Estimated Cooling Days in a year: Enter the average number of days in your region that require cooling. Based on this, the model calculates the peak load from the annual total space cooling demand.
- COP District Cooling Supply Technology: The average coefficient of performance of large-scale district cooling supply units. The default value is based on literature that represents the average values of such large systems

- COP Individual Cooling Supply Technology: The average coefficient of performance of individual/conventional space cooling units like air-conditioners.
- Discount Rate: Based on present market values
- Lifetime-District Cooling: Total average lifetime of the overall district cooling system.
- Lifetime-Individual Supply Technology: Total average lifetime of the individual supply system.
- Select the cold demand density layer: Select default layers or external layers if available.
- Select the gross floor area density layer: Select default layers or external layers if available.
- Select the gross floor area density layer non-residential: Select default layers or external layers if available.

3.6.3.2. ADVANCED INPUTS

- Network Delta T: The difference in the supply and return temperatures of the district cooling grid.
- Threshold of Non-Residential GFA Ratio: This parameter sets the threshold for identifying anchor points. Only cells with a non-residential floor area equal to or exceeding this threshold will be classified as anchor cells.
- Unit CAPEX for Individual Supply System: The investment costs of the individual supply system are used to calculate the threshold LCOC of individual supply systems for a given electricity price. The average investment costs for different countries are in [Table - Individual System Costs].
- Unit OPEX for Individual Supply System (Euros/MW/Year): The fixed operational costs of the individual supply system are used to calculate the threshold LCOC of individual supply systems for a given electricity price. The average investment costs for different countries are in [Table - Individual System Costs]
- Unit CAPEX for District Cooling Supply System: The input is used to calculate the supply costs for the district cooling supply technologies. Average values are provided as default. Only change if more reliable local-level values are available.
- Unit OPEX for Individual Supply System (Euros/MW/Year) - The input is used to calculate the supply costs for the district cooling supply technologies. Average values are provided as default. Only change if more reliable local-level values are available. Literature shows values ranging from (3,200-16,000 EUR/MWh)

Table 2. Individual System Costs (Mitterrutzner et al, 2023)

Country	CAPEX (1000€/MW)	OPEX (€/MW/Year)
Cyprus	284.55	11382.02
Austria	285.52	11420.67
Denmark	290.57	11622.72
Estonia	291.24	11649.50
France	286.51	11460.47
Germany	287.30	11491.90
Italy	285.52	11420.69
Poland	285.52	11420.67
Romania	285.90	11436.19

Spain	283.30	11332.18
Sweden	290.56	11622.26

3.6.4. Output

Indicators

- Were feasible locations for District Cooling identified?: Shows if feasible locations for District Cooling were identified by the CM. If no, other indicators will not be shown.
- Total theoretical cooling demand in GWh within the selected zone: Total demand in the region under evaluation.
- Estimated actual cooling demand in GWh within the selected zone: Considering the diffusion of space cooling technologies, the total demand that is actually ready to be connected to the district cooling network.
- DC cooling potential in GWh within the selected zone: Based on the model results, the total demand in locations that are techno-economically feasible for further assessment of district cooling under pre-defined assumptions.
- Total Peak Covered by District Cooling: Total peak covered by the identified feasible locations.
- Potential share of district cooling from total actual demand in the selected zone: Percentage of the total demand in the region that has the potential of DC supply.
- Number of Clusters Identified: Total number of identified locations feasible for district cooling under given assumptions.
- Annualized Total Costs: Estimates on the total required investment for the development of the identified areas into district cooling networks. This is the sum of grid, pumping, and supply costs.
- Annualized Total Grid Costs: Estimates on the grid investment required for the development of the identified areas into district cooling networks.
- Total Annual Pumping Costs: Estimates on the investment in pumps required for the development of the identified areas into district cooling networks.
- Total Supply Costs: Estimates on the supply investment required for the development of the identified areas into district cooling networks.
- Average levelized cost of cooling for Individual Supply: Average levelized cost of cooling for supply via individual solutions. This is used as the threshold for the identification of the district cooling potential area. (It is to be noted that this value is used as a threshold to identify potential district cooling feasible areas. Areas where the cost for construction of the grid is cheaper than individual supply are characterized as potentially feasible. However, since supply and pumping costs are further added to the grid costs of the identified areas, there may be cases where the overall levelized cost of district cooling supply could be higher than the individual costs)
- Average levelized cost of distribution grid in the potential feasible area: Average costs for the distribution network.
- Average levelized cost of district cooling supply in the potential feasible area (network + pumping + simplified supply): Overall average levelized cost of district cooling grid for all identified potential areas.
- Total pipe trench length: Total trench length to be dug, if all identified potential areas, are to be realized as a district cooling grid.

Layers

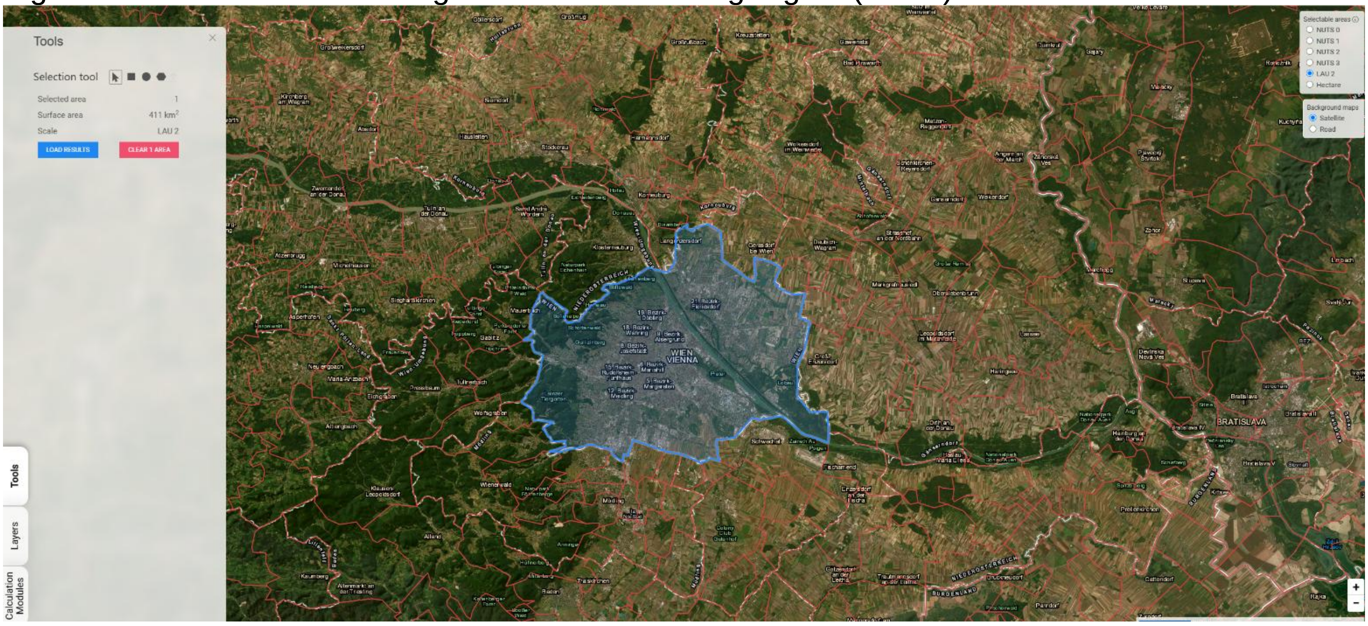
- District Cooling areas and their Potential -Shapefile: Identified areas with all aggregated above parameters per DC area.

3.6.5. Sample Run

Step 1: Select the region

The district cooling calculation module only works on the LAU2 region as this is a local energy supply system. Make sure you are on the correct level of area. Select Vienna for this sample run.

Figure 38. CM - District Cooling Selection of working region (LAU2)

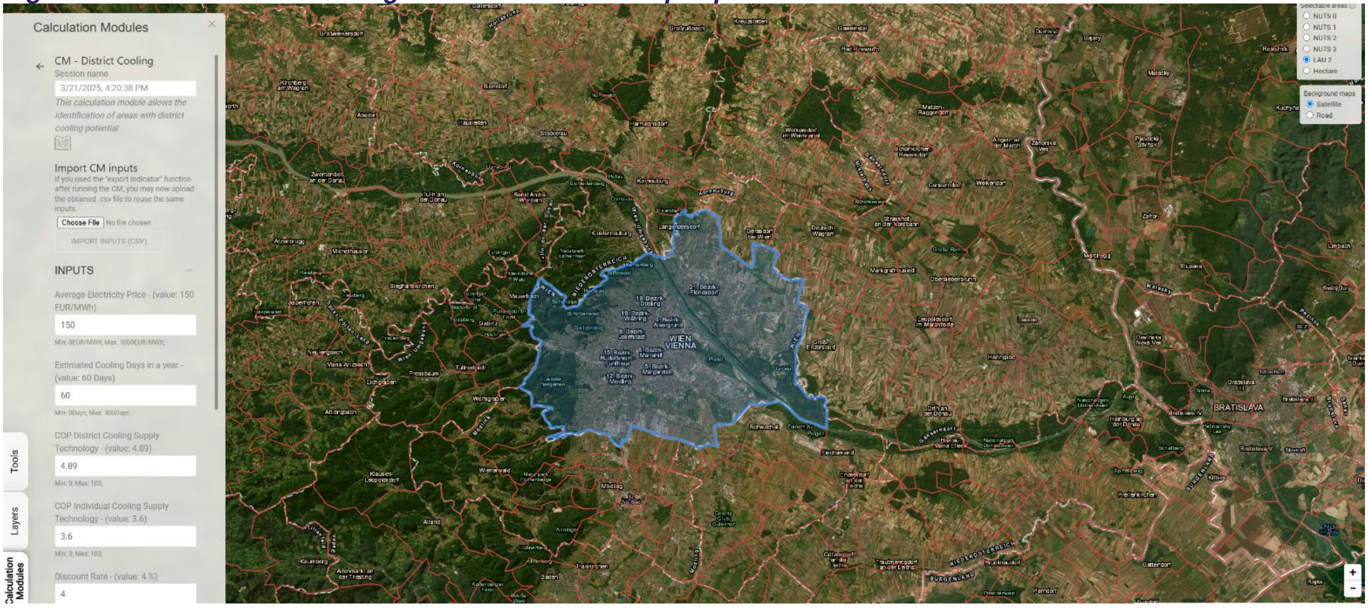


Step 2: Select the basic input parameters.

These include the following:

- Electricity Price: With this value, the CM calculates the cost of supply from individual systems and then uses it as a threshold to cut off cells where the development of a DC grid is more expensive than individual supply. Use the default value of 150 EUR/MWh.
- Estimated cooling days in the Year: With this value, the annual cooling need per cell is converted into peak cooling load. Use the default value of 60 days
- COP District Cooling Supply Technology: This is used in calculating the operational costs of the district cooling system. Use the default value as this is the average value for Austria.
- COP Individual Cooling Supply Technology: This is used in calculating the operational costs of the individual cooling system. Use the default value as this is the average value for Austria.
- For the sample run we take the default values for the discount rate, lifetime district cooling and lifetime individual supply technology

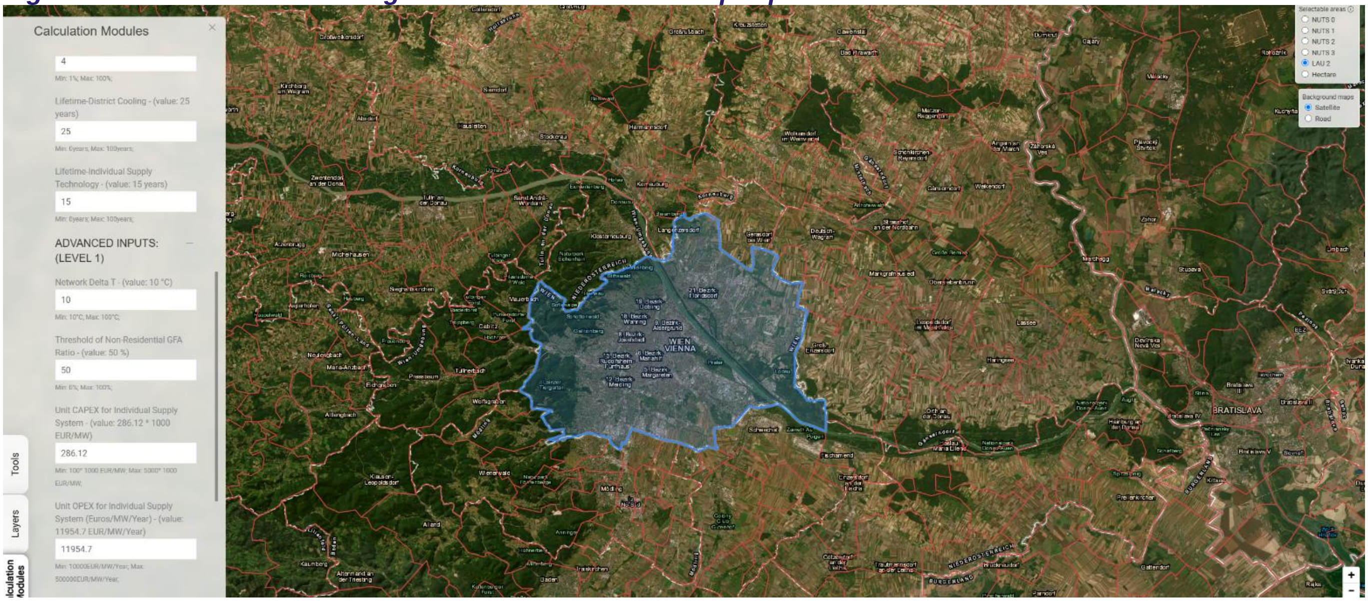
Figure 39. CM - District Cooling Selection of basic input parameters



Step 3: Enter the advanced set of parameters.

We use the default values here. The technical values of network delta T and Threshold of Non-residential GFA are standard values from the literature. The cost values represent the average values for Austria.

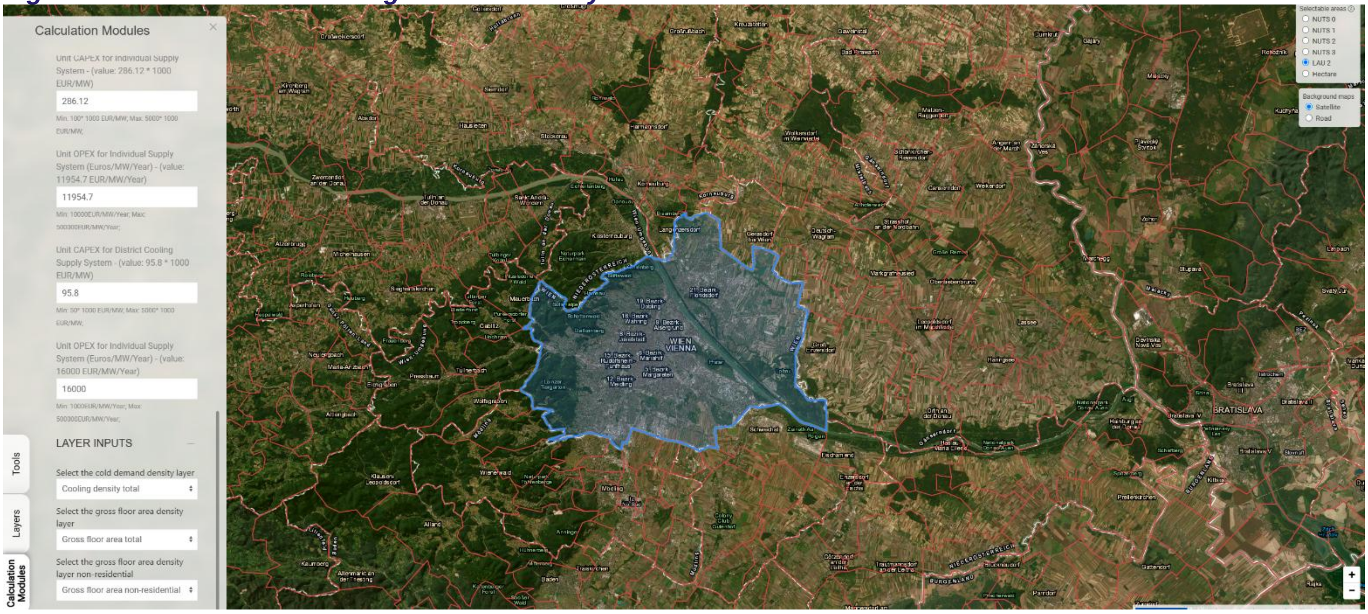
Figure 40. CM - District Cooling Selection of advanced input parameters



Step 4: Select the input layers.

The CM depends on 3 different raster layers as input. For the sample run we take default values.

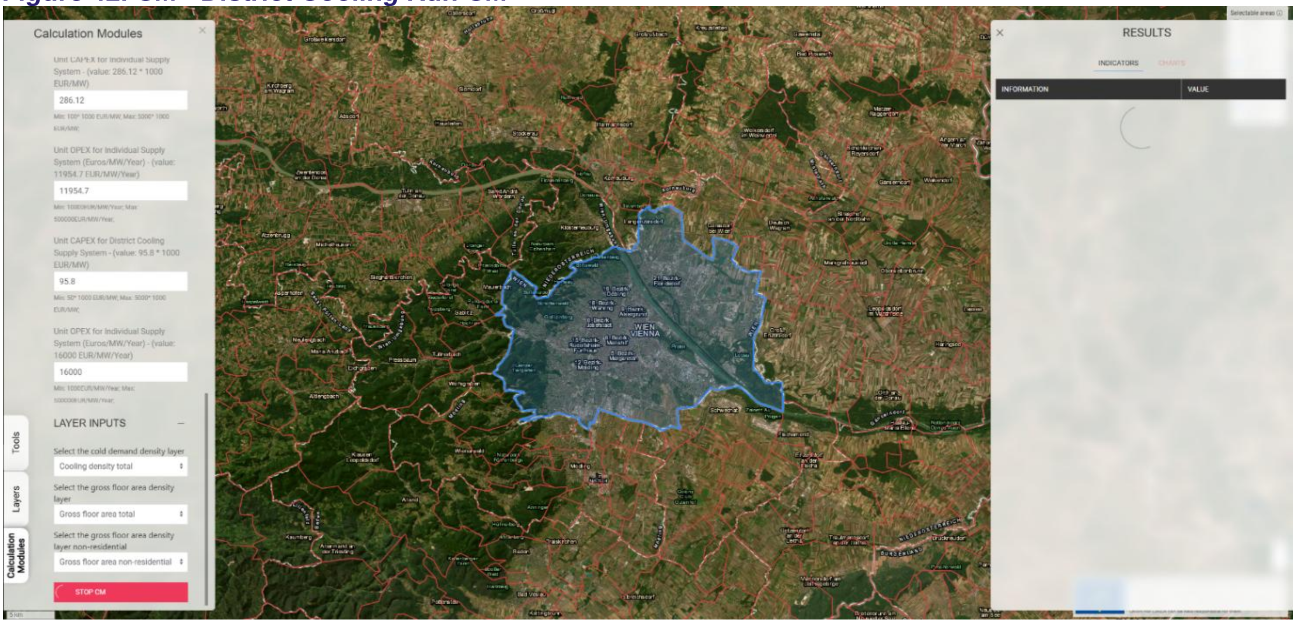
Figure 41. CM - District Cooling Selection of layers



Step 5: Run the CM

Since the calculation happens on a hectare level, the CM run may take some time depending on the size of the region as well as the defined scenario. Based on our sample Run Scenario the run should take about 15- 20 secs.

Figure 42. CM - District Cooling Run CM

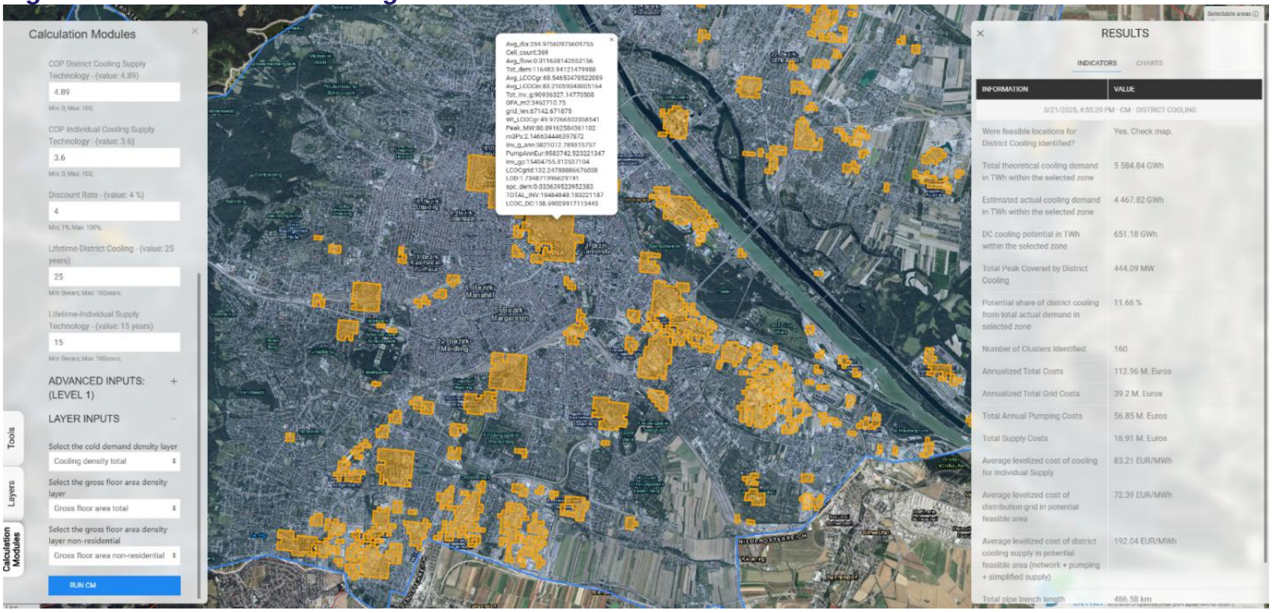


Step 6: View and Download the Results

Once the run is completed, you will be able to visualize the results on the map. In the results pane on the right, you will see the results on the total potential coverage, identified number of regions for district cooling as well as different cost components for implementation. Under the defined scenario for Vienna, almost 12% of the cooling need can be supplied from district cooling, fulfilling a peak load of over 440 MW at average supply costs of 192 EUR/MWh.

On clicking the regions in the map you can visualize the different parameters of the individual identified feasible area. For advanced-level users, you can go to the layers tab and scroll to the bottom to find a downloadable shape file with detailed results for each identified cluster of cells.

Figure 43. CM - District Cooling Results



3.7. Mapping of Legal and Regulatory Information

3.7.1. Introduction

This module provides access to policy-relevant data collected within the scope of the CoolLIFE project. The users can search for information about the current EU policy framework and national legislation, planning and strategies relevant to sustainable space cooling solutions.

The module summarizes information available in EU legislation, as well as in Member State's reporting to the European Commission about strategies, policies and regulations relevant to sustainable space cooling, complemented by targeted searches on national building regulations and financing schemes (public and private).

By now, information is included for the following EU Member States: Austria, Belgium, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Malta, Poland, Slovenia, and Spain.

The module can be accessed on multiple scales: **NUTS1 - NUTS3, LAU and Hectare levels**. The user can select one or more territorial areas from the map using the selection tool. Regardless of the selected scale, the information returned corresponds to the Member State level.

3.7.2. Method

The regulatory and legal aspects presented in the CoolLIFE Tool are based on the findings of [Deliverable D4.1: Review and mapping of legislations and regulations on sustainable space cooling at EU and national levels](). The review of the EU policy framework and national policies relevant to space cooling involved several steps.

1. **EU-Level Screening**: A comprehensive review of key EU legislation relevant to space cooling was conducted, focusing on the most recent versions adopted after the Fit-for-55 package. This included:
    - the Energy Efficiency Directive (EED),
    - Renewable Energy Directive (RED),
    - Energy Performance of Buildings Directive (EPBD),
    - the Ecodesign for Sustainable Products Regulation (ESPR)
    - European Commission communications, such as the 2016 Heating and Cooling Strategy and the Renovation Wave strategy.

2. **National Policy Review**: The analysis of Member States' policies and regulations included:
    - National Energy and Climate Plans (NECPs), screened using targeted keywords to identify relevant provisions on space cooling.
    - Comprehensive Assessments (CAs) for heating and cooling (2020 reporting), assessed for content related to space cooling.
    - Long-Term Renovation Strategies (LTRS), focusing on references to cooling, supported by previous literature.
    - National Adaptation Strategies (NAS) and National Adaptation Plans (NAP), reviewed through keyword-based content analysis and structured assessment of measures and best practices.
3. **In-Depth Country Analysis**: Ten countries were selected for a deeper review: Spain, France, Italy, Germany, Greece, Portugal, Austria, Hungary, Croatia, and Sweden. The selection criteria included the highest cooling energy consumption and climate diversity. National building regulations were analysed to understand how space cooling and summer comfort are addressed in terms of definitions, calculation methods, and performance requirements for both new and existing buildings.

4. **Supplementary Analysis**: The national policy review was complemented by literature searches and use of the MURE database on energy efficiency policies.

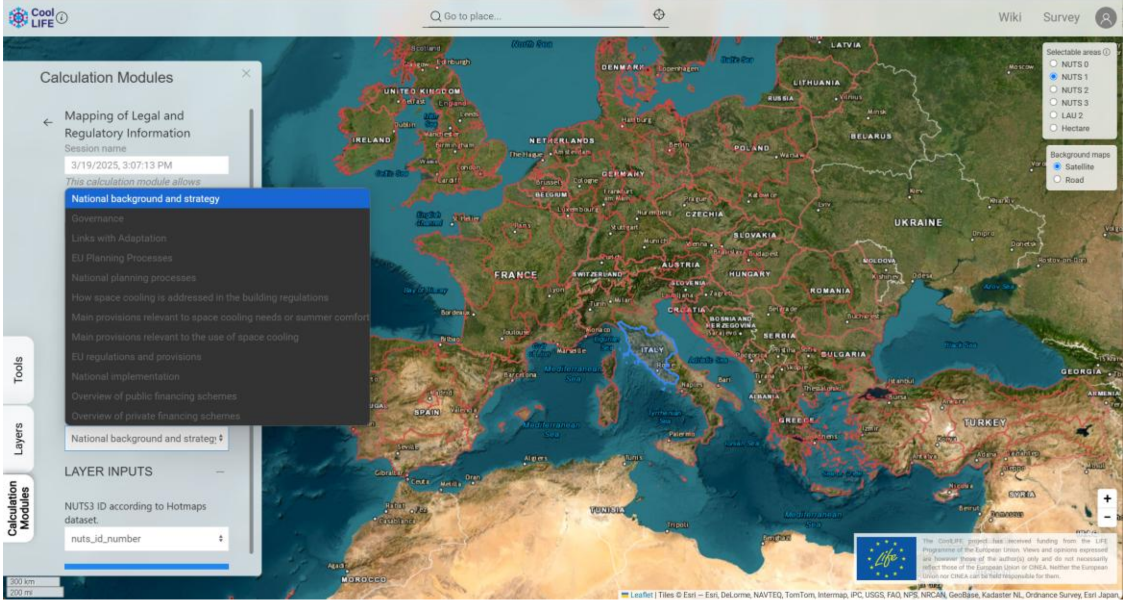
5. **Integration into the CoolLIFE Tool**: The results from these steps were compiled and structured into the regulatory and legal aspects module of the CoolLIFE Tool, providing an overview of current frameworks and governance structures influencing sustainable space cooling across the EU and selected Member States.

3.7.3. Input

The user can select an indicator of interest. The following indicators are available:

- **National background and strategy**: Based on the review of the draft NECP updates.
- **Governance**: Based on the review of the draft NECP updates.
- **Links with Adaptation**: Links between space cooling and national adaptation plans or strategies.
- **EU planning processes**: The approach and processes related to heating and cooling plans or assessments based on the review of the draft NECP updates.
- **National planning processes**: The approach and processes related to heating and cooling plans or assessments based on the review of the CAs reported by Member States in 2020.
- **How space cooling is addressed in the building regulations**
- **Main provisions relevant to space cooling needs or summer comfort**
- **Main provisions relevant to the use of space cooling**
- **EU regulations and provisions**: Relevant EU regulations and provisions.
- **National implementation**
- **Overview of public schemes**
- **Overview of private schemes**.

Figure 44. Regulatory Layer - Input



3.7.4. Output

Running the CM generates a **summary of background and policies** in the selected country, structured **according to "Indicators of Interest"** (see Figure 45):

- National background and strategy
- Governance
- Links with Adaptation
- EU planning processes
- National planning processes
- How space cooling is addressed in the building regulations
- Main provisions relevant to space cooling needs or summer comfort
- Main provisions relevant to the use of space cooling
- EU regulations and provisions
- National implementation
- Overview of public schemes
- Overview of private schemes

Figure 45. Regulatory Layer – Output

3.7.5. Sample Run

Step 1: Choose the appropriate 'Selectable area'

This can be done for all NUTS regions. For this module, you can select NUTS1 (in "Selectable areas" on the top right).

Step2: Navigate to the study area

Select any region in the country you are interested in.

- Note 1: If you receive an AREA SELECTION WARNING, we recommend choosing a lower NUTS level within the same country. This warning usually occurs when the selected area is too large. Opting for smaller regions within the country should resolve the issue, as the data you access are on a national level.
- Note 2: If you want to see the information about another country, first click again on the region previously selected (to de-select it), and then click on another region in the country you are interested in.

Step 3: Access the Calculation Module

Click on the "Calculation Module" tab. In the list of calculation modules, select "CM - Legal and Regulatory Layers" under "Policy".

Step 4: Configure and Run the Calculation

The user **selects the type of information** to be displayed in the tool.

This is done in "INPUTS", by selecting the "**Indicator of Interest**". See the above **Outputs indicators and layers** about the different indicators available.

Note: "Import CM inputs" appears in the panel of this CM, as for any CM. However, for this CM, it is not needed and not possible for users to import their own data.

The user runs the CM by clicking on "**RUN CM**" at the bottom of the CM panel.

Step 5: View and Download Results

The information about the selected indicator will appear in a new "RESULTS" window on the right. You can scroll down to see the whole information available about the selected indicator.

To see the information about another indicator, you can select this other indicator in "Indicator of Interest" and click again on "RUN CM".

3.8. Mapping of Financing Instruments

3.8.1. Introduction

This module allows accessing and filtering the CoolLIFE EU27 Mapping of Financing Instruments relevant to sustainable space-cooling solutions, available on the CoolLIFE Website.

Each scheme is classified and provided with details of country, level (European, National, Regional, Local), Name in English and local language, issuer (public or private), covered sectors (Y = directly ; (Y) = indirectly; blank = not covered), type of instrument, main and additional links, a short description and the last time the page was visited.

Concerning private financing, if no suitable instrument is currently available, it could still be worth exploring the credit and investment institutes listed in the mapping, as they provide green finance and could offer other options or be open to bilateral negotiations.

Through this module, the users can filter the dataset per country, including or not the EU-level schemes and per instrument source (public, private or all). The module can be accessed on multiple scales: **NUTS1 - NUTS3, LAU and Hectare levels**. The user can select one or more territorial areas from the map using the selection tool. Regardless of the selected scale, the information returned corresponds to the Member State level. To consider more than one country, we recommend downloading the whole CoolLIFE EU27 Mapping of Financing Instruments and filtering it manually.

3.8.2. Method

The CoolLIFE EU-27 dataset of financial instruments for sustainable space cooling is a subset of the whole EU-27 Country Mapping of Financing Schemes to decarbonize Buildings, Heating and Cooling. The methodology to create it followed these key steps:

1. **Scope Definition**: The study focused on financing schemes directly related to cooling or energy efficiency improvements for building envelopes to reduce cooling demand and enhance summer comfort. Schemes targeting space heating without direct cooling impact were excluded.

2. **Literature Review**: An extensive review of existing knowledge and previous studies on financing schemes for heating and cooling (H&C) and building decarbonization was conducted. Sources included policy reports, academic studies, and institutional publications from organizations such as EEFIG, DG Energy, OECD, and the European Investment Bank (EIB).

3. **Data Collection**: Relevant financing schemes were identified through desk research using multiple sources:

    - Odyssée-Mure Database
    - National policy documents such as National Energy and Climate Plans (NECPs), National Energy Efficiency Action Plans (NEEAPs), Long-Term Renovation Strategies (LTRSs), and Recovery and Resilience Plans (RRPs).
    - Comprehensive Assessments and existing databases, including ODYSSEE-MURE, EBRD, fi-compass, and OECD repositories.
    - Websites of national agencies responsible for climate action and funding distribution, including National Energy Agencies, Energy Efficiency Funds, and relevant Ministries.
4. **Structured Desk Research**: A systematic scanning of collected sources was performed, compiling a long list of financing schemes. To ensure completeness, keyword-based searches were conducted in national languages.

5. **Shortlisting and Categorization**: Only currently active schemes were retained. Schemes were classified into public and private funding instruments. Key details recorded included scheme name, country, administrative level, target sectors (residential/non-residential), instrument type, duration, and links to relevant sources. For clarity, different financial instruments were grouped in a few overarching types (grants, loans, subsidies, guarantees, tax incentives, etc.).

Note: The mapping was last updated in August 2024. Some schemes might have been discontinued, and some new schemes might have been launched, which are not captured in this mapping. For more detail on the methodology and the outcome of the assessment, please consult the CoolLIFE D4.2 Review of Financing Schemes and the full dataset CoolLIFE EU27 Mapping of Financing Instruments which list details on the mapping process and references where new schemes are most likely to be found.

3.8.3. Input

The user can select whether the EU-level schemes should be included, and if the schemes should be filtered per public, private or all.

3.8.4. Output

Running the CM provides in the result box:

- The total number of schemes,
- The link to the CoolLIFE Website where the whole CoolLIFE EU27 Mapping of Financing Instruments overall mapping and
- The scheme titles for the filtered region/selection.
- Clicking on the **Export Extra Files** button, the filtered mapping is downloaded as a filtered CSV file together with a layer, also saved in the layer tab, as a zip file.

3.8.5. Sample Run

Step 1 - Select the NUTS1 area in the map. Search and click on Slovakia.

Step 2 - Go to Calculation Module Tab and select "Mapping of Financial Instruments".

Step 3 - Enter the input parameters.

Name the Session "Slovakia financial instruments". Do no include EU-27 support schemes by selecting 'No'. This way you will see only the national instruments. You can select the type of instruments - public or private. Select private for this example. If none of these are selected, both public and private financial schemes will be demonstrated.

Step 4 - Run the CM

The results window will pop up on the right. You can download the results as well.

Figure 46. Financial Instruments Layer - Input parameters

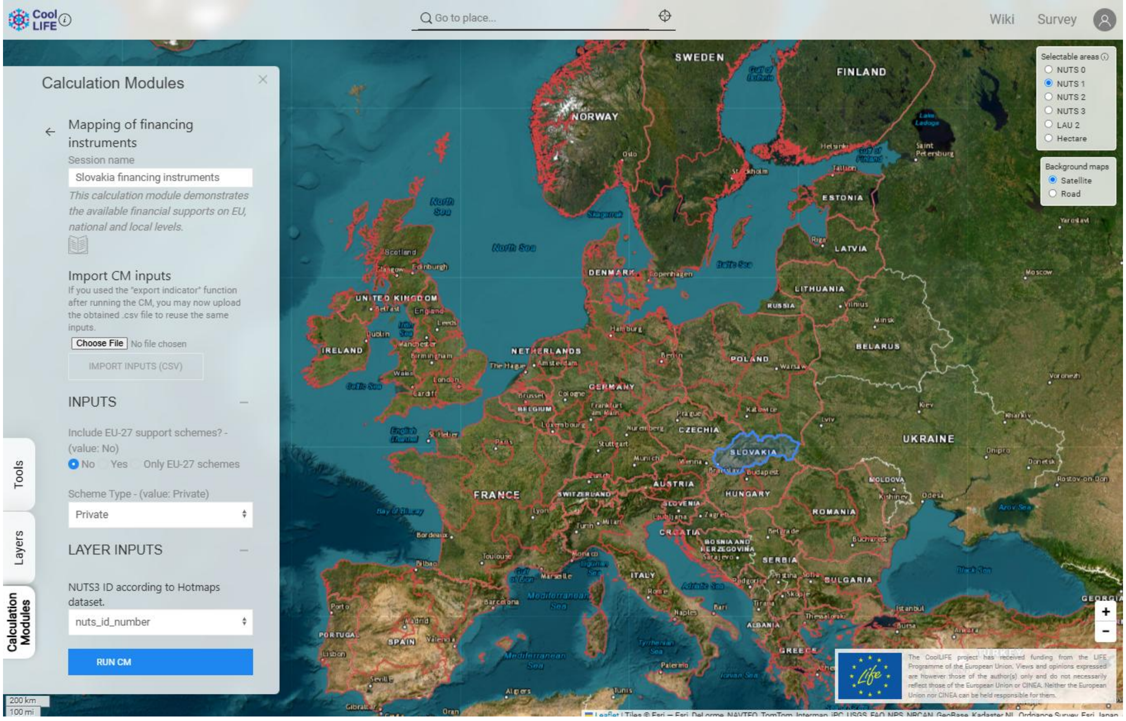
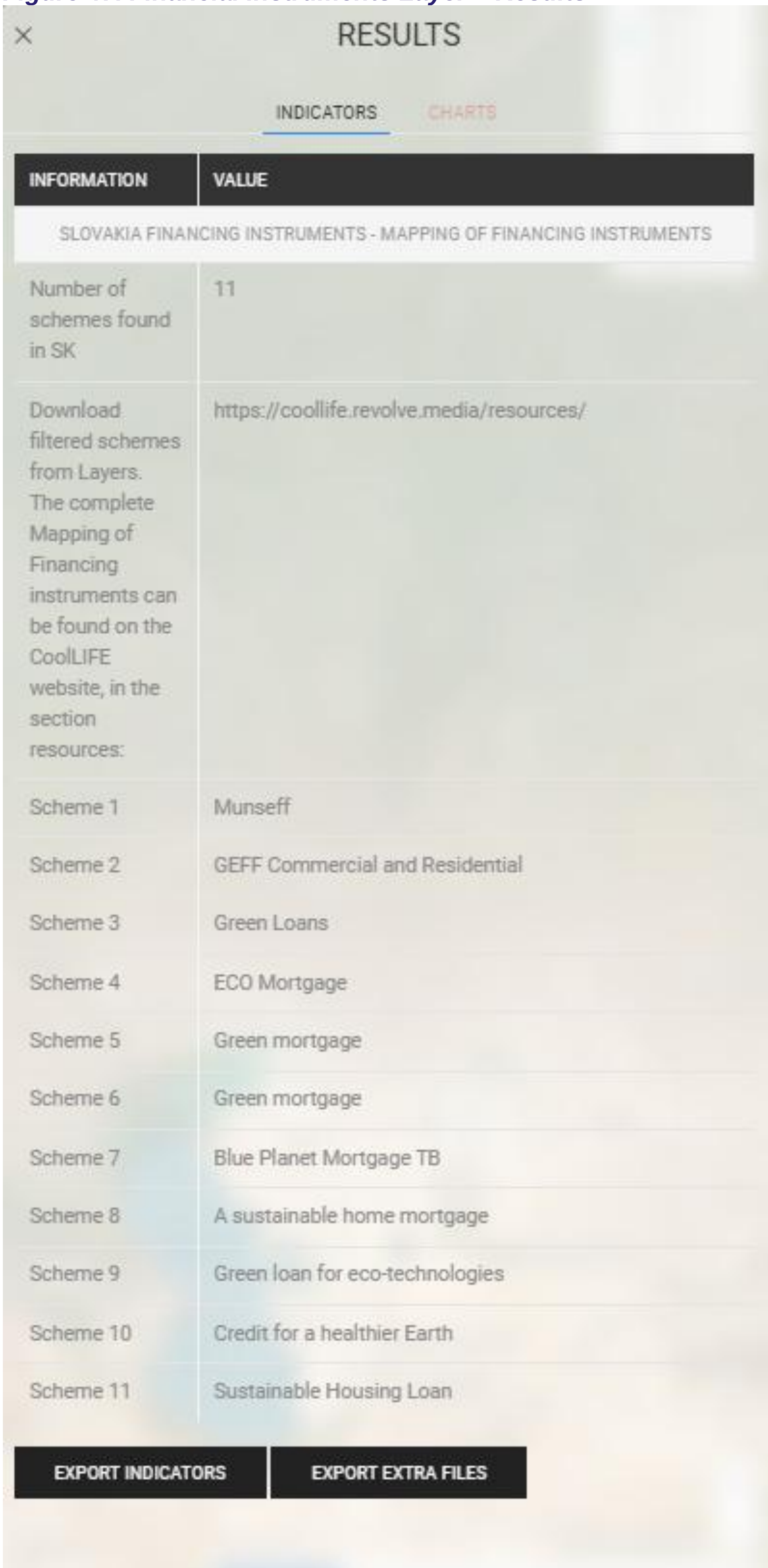


Figure 47. Financial Instruments Layer – Results



4. How to Apply the CoolLIFE Tool (Use Cases)

4.1. Use Case 1: Strategic Planning for Energy Efficiency and Renewable Energy Integration

4.1.1. Target Users

Civil society, energy cooperatives, technicians, planners, and policymakers.

4.1.2. Use Case Description

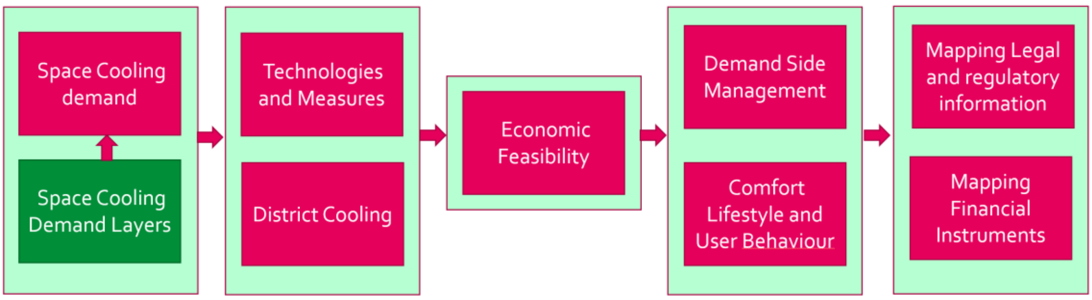
With the aim to intervene towards higher energy efficiency of residential buildings and a wider integration of RES plants, the story should address the integration of space cooling (SC) in the wider energy efficiency sector. This means increasing the knowledge of technicians and making strategic decisions in the SC sector at a regional scale.

4.1.3. Research Question

How can space cooling be integrated into the broader energy efficiency sector to improve strategic decision-making at a regional scale, ensuring higher energy efficiency in residential buildings and better integration of renewable energy sources?

4.1.4. Calculation Module Use and Order

Figure 48. Use Case 1 - CM Use Order



- Space Cooling Demand Layers: To begin the analysis, it is essential to establish a baseline understanding of cooling demand and the impact of energy efficiency measures. The default layers in the CoolLIFE platform provide existing layers representing different scenarios of passive measure uptake. These layers offer insights into cooling demand projections and the effect of energy efficiency measures on demand reduction. By selecting the appropriate layers for different forecast years, planners and policymakers can define the initial conditions for strategic decision-making.
- Space Cooling Demand: To integrate space cooling into energy efficiency planning, it is necessary to determine current and projected cooling demand. The Space Cooling Demand Calculation Module allows

users to select and adjust the default cooling demand layers based on different passive measure uptake scenarios and forecast years. By refining these layers to fit regional needs, planners and policymakers can establish an accurate baseline for assessing cooling interventions.

- Technology and Measures: Once the cooling demand baseline is set, it is important to evaluate how technology adoption and efficiency measures influence cooling electricity consumption. The Technology and Measures Calculation Module enables users to estimate the energy consumption of decentralized space cooling units, such as air conditioners, while considering cooling degree days and efficiency improvements. This module helps identify the impact of different technology deployment scenarios on overall energy demand.
- District Cooling: In areas with high cooling demand density, district cooling may be a more efficient and cost-effective alternative. The District Cooling Calculation Module helps users spatially identify locations where a district cooling grid could be implemented under different market and technology efficiency scenarios. This module ensures that centralized cooling options are considered alongside decentralized solutions, providing a holistic view of cooling interventions at the regional scale.
- Economic Feasibility: Assessing the financial viability of different cooling interventions is essential for effective decision-making in energy efficiency planning. The Economic Feasibility Calculation Module allows users to compare the costs of various cooling solutions at both the national and building archetype levels. This module enables a detailed economic analysis of different scenarios, including the adoption of passive cooling technologies and the development of active cooling systems. By evaluating these scenarios, planners and policymakers can identify the most cost-effective measures to improve energy efficiency—both at the individual building level and across the entire building stock—ensuring optimal investment in sustainable cooling solutions.
- Demand-Side Management: To maximize the integration of renewable energy sources into space cooling, the Demand-Side Management Calculation Module assesses the potential for demand response and PV self-consumption. This module provides insights into how cooling demand can be shifted to align with renewable generation, reducing peak loads and increasing energy efficiency.
- Comfort, Lifestyle, and User Behavior: Understanding how lifestyle patterns and behavioural trends affect space cooling demand is crucial for strategic decision-making. The Comfort, Lifestyle, and User Behavior Calculation Module provides information on thermal comfort requirements, typical cooling behaviours, and adaptive interventions that can reduce energy demand. This ensures that technological and economic analyses consider real-world user behaviour.
- Legal and Regulatory Layers: Integrating space cooling into the energy efficiency sector requires alignment with regulatory frameworks. The Legal and Regulatory Layers Calculation Module provides an overview of relevant EU policies, national legislation, and planning strategies related to space cooling. This module ensures that proposed interventions comply with existing laws and leverage available policy support.
- Financial Instruments: The final step in supporting the integration of space cooling into energy efficiency planning is identifying financial support for implementation. The Financial Instruments Calculation Module allows users to explore and filter funding mechanisms by country and type (public, private, or EU-level). This module helps policymakers and planners secure the necessary financial resources for deploying energy-efficient cooling solutions.

This structured use of calculation modules enables regional planners and policymakers to make informed decisions regarding the integration of space cooling into the energy efficiency sector. By sequentially assessing cooling demand, technology adoption, economic feasibility, demand management potential, behavioural factors, regulatory conditions, and financing opportunities, this approach ensures that cooling interventions are aligned with strategic energy efficiency and renewable energy goals.

4.2. Use Case 2: Reducing Energy Poverty and Ensuring Summer Comfort

4.2.1. Target Users

Engineers, researchers, municipalities, NGOs, and civil society.

4.2.2. User Story Description

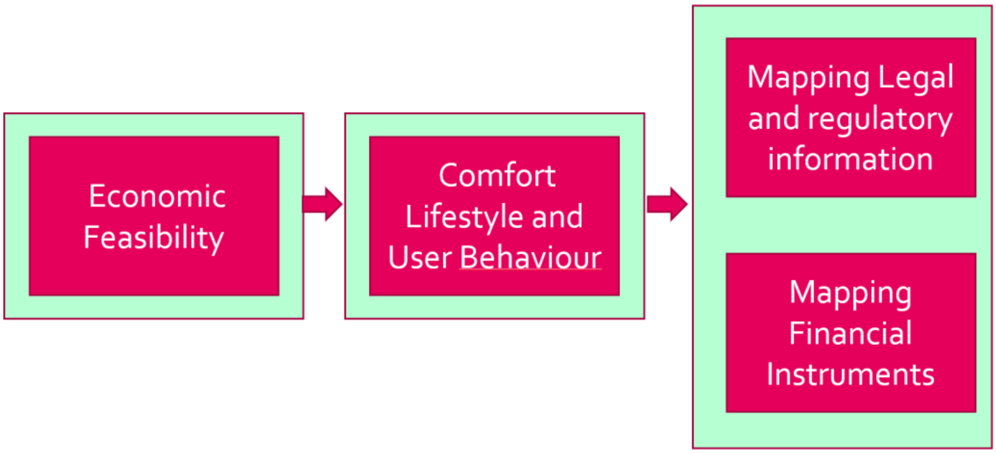
The transformation of the space cooling (SC) sector, its strategic planning, and more SC interventions can strongly contribute to reducing energy poverty, for example, by proposing strategies to provide all households with solutions to ensure decent summer comfort. There is also an increasing need for data to calculate energy needs, gaps, retrofit requirements, and other factors to reduce energy poverty.

4.2.3. Research Question

How can space cooling interventions be designed and implemented to reduce energy poverty while ensuring equitable access to summer comfort for all households, particularly in vulnerable communities?

4.2.4. Calculation Module Use and Order

Figure 49. Use Case 2 - CM Use Order



- Economic Feasibility: Addressing energy poverty requires a thorough understanding of the financial constraints households face in accessing cooling solutions. The Economic Feasibility Calculation Module enables users to assess the affordability of different cooling interventions at both the national and building archetype levels. By comparing the costs of passive and active cooling technologies across different scenarios, this module helps planners and policymakers identify the most cost-effective measures to improve energy efficiency while ensuring that cooling solutions remain accessible to low-income households. This analysis is critical in designing policies and financial support mechanisms that can enhance cooling affordability without exacerbating economic burdens.
- Comfort, Lifestyle, and User Behavior: Ensuring summer comfort for all households, particularly those at risk of energy poverty, requires an understanding of how people interact with cooling technologies and what

factors influence their cooling demand. The Comfort, Lifestyle, and User Behavior Calculation Module provides insights into typical summer thermal comfort requirements, household cooling behaviors, and adaptive practices that can reduce energy demand. This module helps users identify behavioral interventions and cooling strategies that can improve comfort without excessive energy consumption, such as the promotion of shading, natural ventilation, and efficient cooling habits. Understanding these behavioral patterns supports the design of targeted awareness programs and community-based cooling initiatives that empower households to manage their cooling needs effectively.

- Legal and Regulatory Layers: Policies and regulations play a critical role in shaping access to affordable cooling solutions, particularly for vulnerable populations. The Legal and Regulatory Layers Calculation Module provides an overview of EU and national legislation, building codes, and policies that impact space cooling affordability and access. By mapping out relevant policy frameworks, this module allows users to identify regulatory barriers and opportunities for improving cooling access. It also helps in assessing whether national and local policies provide adequate support for energy-poor households, ensuring that legal frameworks align with equitable cooling access objectives.
- Financial Instruments: Expanding access to cooling solutions for energy-poor households requires appropriate financial mechanisms. The Financial Instruments Calculation Module enables users to explore funding opportunities and financial support schemes that can facilitate the adoption of efficient cooling technologies. By filtering funding sources at the national and EU levels, users can identify grants, subsidies, or low-interest loans that can make energy-efficient cooling solutions more affordable for low-income households. This module ensures that financial barriers are addressed and that appropriate funding channels are leveraged to support vulnerable communities.

By systematically applying these calculation modules, policymakers, engineers, and social organizations can design effective space-cooling interventions that address energy poverty while ensuring equitable summer comfort. The combination of economic feasibility assessment, behavioural analysis, regulatory framework mapping, and financial instrument identification enables the development of targeted, cost-effective strategies that improve access to cooling without increasing financial burdens. This structured approach ensures that space cooling contributes to long-term energy equity and resilience in vulnerable communities.

4.3. Use Case 3: Strategic and Building-Level Planning for Low-Carbon and Energy-Efficient Space Cooling

4.4. Target Users

Public administrations, industry, policy makers, energy consultants, citizens, energy communities.

4.4.1. User Story Description

Transformations towards more strategic and effective space cooling (SC) solutions are needed. Currently, SC interventions are often implemented at the individual building or flat level, whereas a strategic planning approach could better align with low-carbon targets. Additionally, space cooling interventions at the building scale are increasingly required, and there is a strong need to reduce energy consumption in this sector. The CoolLIFE tool and knowledge hub can contribute by providing data-driven insights into cooling demand, efficiency measures, and financial viability at both the regional and building levels.

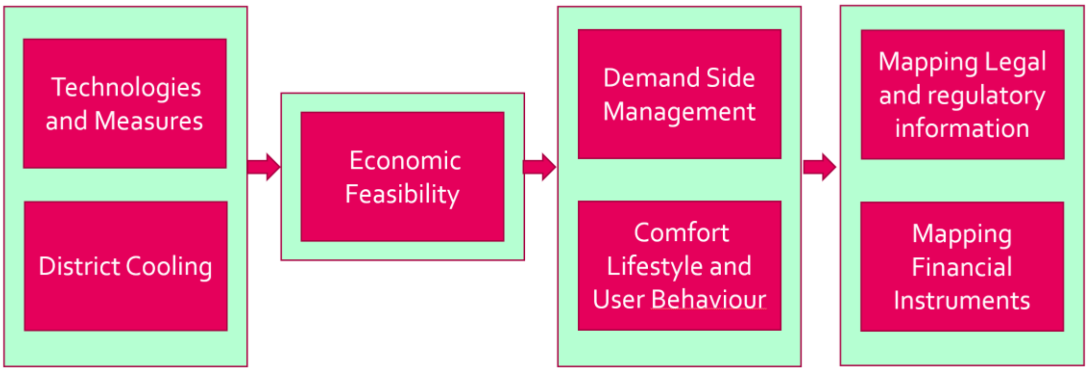
4.4.2. Research Questions

- How can space cooling interventions be scaled beyond individual buildings to a strategic, low-carbon planning approach that aligns with long-term energy and climate targets?

- How can space cooling interventions at the building scale be optimized to reduce energy consumption while ensuring economic feasibility and regulatory compliance?

4.4.3. Calculation Module Use and Order

Figure 50. Use Case 3 - CM Use Order



- Technology and Measures: The first step in shifting to large-scale SC planning and optimizing building-level cooling interventions is understanding the impact of different cooling technologies on overall energy demand. The Technology and Measures Calculation Module enables users to calculate electricity consumption for space cooling based on cooling degree days and technology efficiency. This module helps assess how different scenarios of technology adoption—such as the increased deployment of energy-efficient air conditioners or alternative cooling solutions—affect electricity demand. At the strategic level, it helps policymakers evaluate technology trends and their implications on regional energy consumption. At the sector level (residential/non-residential), it provides insights into cooling demand in different building types and the impact of efficiency improvements on electricity consumption for cooling supply.
- District Cooling: While decentralized cooling solutions such as air conditioners dominate current interventions, large-scale planning requires evaluating the feasibility of district cooling. The District Cooling Calculation Module allows users to spatially assess areas where centralized cooling solutions could be implemented based on cooling demand density. This module provides insights into the viability of network-based cooling, helping policymakers determine where district cooling grids can replace inefficient individual systems and contribute to long-term decarbonization. At the building level, it offers a means for building owners to assess whether their building or neighborhood falls within a potential district cooling zone and whether future connections may be available. This supports informed investment decisions and facilitates the transition towards centralized cooling solutions where feasible.
- Economic Feasibility: Large-scale strategic planning and building-level cooling interventions must also consider financial implications. The Economic Feasibility Calculation Module enables users to compare the costs of different cooling scenarios at both the national and building archetype levels. This includes evaluating the economic viability of various passive cooling measures and different development scenarios for active cooling technologies. At the strategic level, it helps policymakers identify the most cost-effective solutions to support large-scale, sustainable cooling strategies. At the building level, it allows users to assess the financial viability of different energy efficiency improvements and technology adoption pathways, ensuring that investments align with economic constraints and long-term cost savings.
- Demand-Side Management: An effective low-carbon cooling strategy should incorporate demand-side flexibility. The Demand-Side Management Calculation Module evaluates the potential for demand response and PV self-consumption in cooling demand. This module enables planners to assess how shifting cooling loads can help reduce peak demand, optimize energy use, and integrate higher shares of renewable energy. For large-scale planning, it ensures that increased cooling demand does not lead to grid instability or excessive reliance on fossil fuel-based electricity generation. At the building level, it allows users to analyze

opportunities for PV self-consumption and load shifting, helping to reduce energy costs while increasing grid stability and efficiency.

- Comfort, Lifestyle, and User Behavior: Moving beyond individual cooling interventions requires understanding how user behavior and thermal comfort expectations influence cooling demand. The Comfort, Lifestyle, and User Behavior Calculation Module provides data on thermal comfort requirements, typical cooling behaviors, and proven behavioral interventions. At the strategic level, it ensures that large-scale planning efforts align with real-world user needs and social acceptance while promoting energy-efficient behaviors. At the sector level (residential/non-residential), it helps users develop effective cooling interventions that balance efficiency with occupant comfort, integrating behavioral considerations into technology and policy decisions.
- Legal and Regulatory Layers: To transition from scattered, individual-level cooling interventions to a more coordinated approach, regulatory support is essential. The Legal and Regulatory Layers Calculation Module maps out existing EU and national policies, planning strategies, and building regulations that impact space cooling. At the strategic level, this module helps policymakers identify regulatory gaps, align planning efforts with climate policies, and ensure that legal frameworks support the adoption of large-scale, low-carbon cooling solutions. At the building level, it ensures that proposed cooling interventions comply with national and EU regulations, guiding stakeholders through regulatory constraints and opportunities.
- Financial Instruments: The successful implementation of strategic and building-level cooling interventions depends on securing appropriate funding sources. The Financial Instruments Calculation Module provides an overview of available financial mechanisms, including national and EU-level grants, subsidies, and investment schemes. At the strategic level, this module ensures that financial constraints do not hinder large-scale cooling transformation efforts. At the building level, it helps individual building owners and planners identify suitable financial instruments to support the deployment of energy-efficient cooling technologies.

By systematically applying these calculation modules, policymakers, energy consultants, and building owners can develop effective space cooling strategies at both the regional and building scales. This structured approach enables the assessment of cooling technology impacts, the feasibility of district cooling, economic viability, demand-side flexibility, behavioral influences, regulatory alignment, and financial support. The result is a comprehensive, data-driven strategy for transitioning to more sustainable, energy-efficient space cooling solutions while ensuring both large-scale and building-level optimization.

4.5. Use Case 4: Supporting Data-Driven Space Cooling Interventions for Technicians

4.5.1. Target Users

Renewable energy communities, engineers, energy consultants.

4.5.2. User Story Description

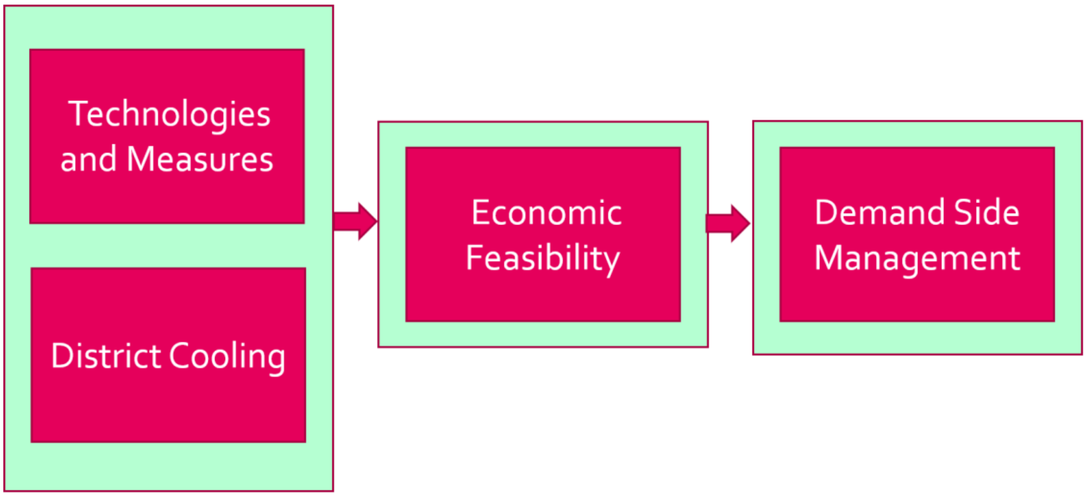
More and more technicians need data to measure buildings’ energy consumption and cooling needs to design effective interventions. The consortium should decide if the CoolLIFE tool will be able to provide this kind of data and therefore target the designers of interventions.

4.5.3. Research Question

How can space cooling data be utilized to support engineers and energy consultants in designing effective cooling interventions based on building energy consumption and demand patterns?

4.5.4. Calculation Module Use and Order

Figure 51. Use Case 4 - CM Use Order



- Technology and Measures: The first step in designing effective cooling interventions is quantifying the energy consumption associated with different cooling technologies. The Technology and Measures Calculation Module allows users to estimate electricity consumption for space cooling by considering cooling degree days and system efficiency. This module provides a scenario-based assessment of cooling demand under different technology adoption and efficiency improvement scenarios, helping engineers and energy consultants determine optimal cooling strategies for various building types.
- District Cooling: For certain buildings or areas with high cooling demand density, centralized district cooling may offer a more efficient solution than decentralized cooling units. The District Cooling Calculation Module enables users to assess the feasibility of district cooling grids by spatially identifying regions where district cooling networks could be implemented. This module supports engineers in evaluating whether district cooling is a viable option for specific locations, helping them design interventions that maximize system efficiency and minimize energy costs.
- Economic Feasibility: To ensure that proposed cooling interventions are financially viable, the Economic Feasibility Calculation Module allows users to compare different passive cooling measures and active cooling technology development scenarios. By analyzing the costs of various cooling solutions at the national and building archetype levels, engineers and energy consultants can identify the most cost-effective measures. This module supports decision-making by providing a financial comparison of different energy efficiency improvements, ensuring that interventions are both technically and economically feasible.
- Demand-Side Management: Integrating renewable energy sources into space cooling solutions requires understanding how cooling demand can be optimized through demand-side flexibility. The Demand-Side Management Calculation Module evaluates demand response potential and PV self-consumption for cooling. By shifting cooling demand to better align with renewable energy generation, this module helps engineers develop strategies that reduce reliance on grid electricity while improving energy efficiency. This is particularly valuable for designing interventions that incorporate on-site renewable energy sources.

By systematically applying these calculation modules, engineers, energy consultants, and renewable energy communities can access the necessary data to design effective cooling interventions. This structured approach enables them to assess technology impacts, evaluate district cooling feasibility, ensure financial viability, and integrate demand-side flexibility into cooling strategies. The result is a data-driven methodology for optimizing space cooling solutions, improving energy efficiency, and supporting the transition to sustainable cooling technologies.

4.6. Use Case 5: Behavioral Change for Energy Savings in Space Cooling

4.6.1. Target Users

Public administrations, civil society.

4.6.2. User Story Description

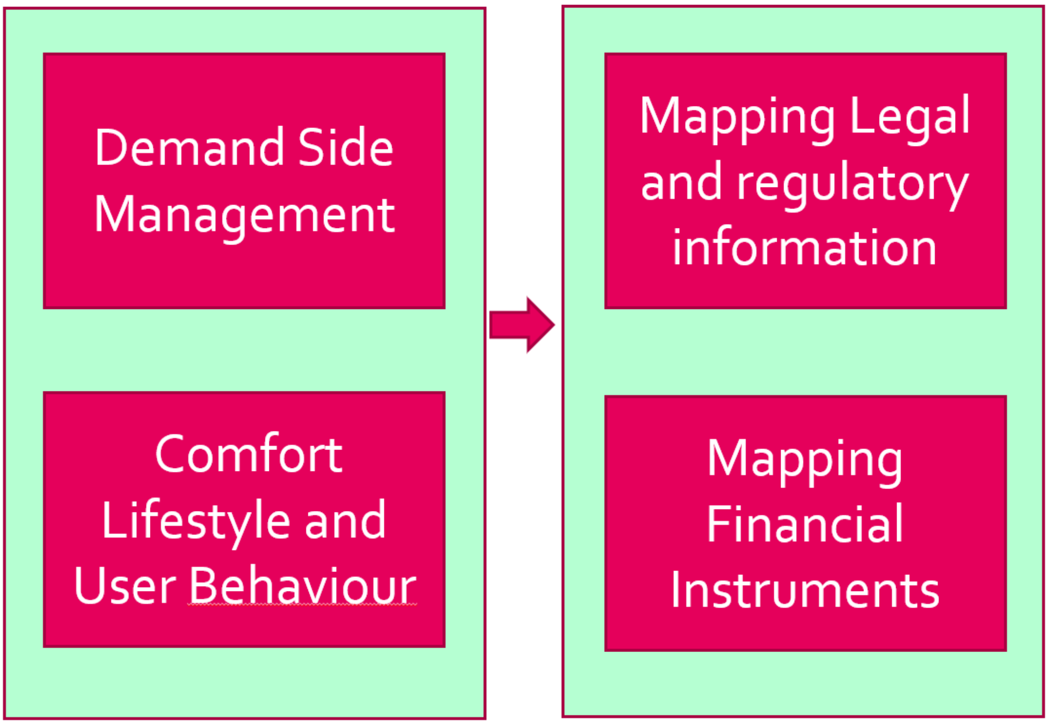
Changing energy behaviors to reduce consumption in public and private buildings is a crucial aspect of the transformation of the energy system, and space cooling (SC) is becoming an increasingly significant part of this transition.

4.6.3. Research Question

How can behavioral changes and adaptive cooling practices contribute to reducing energy consumption in public and private buildings, and how can they be effectively integrated into space cooling strategies?

4.6.4. Calculation Module Use and Order

Figure 52. Use Case 5 - CM Use Order



- Demand-Side Management: Encouraging behavioral change in cooling consumption requires a clear understanding of how demand-side measures can optimize energy use. The Demand-Side Management Calculation Module allows users to assess the impact of demand response strategies and PV self-consumption on cooling energy use. By shifting cooling demand to match renewable energy generation, this module provides a foundation for developing behavioral interventions that encourage energy-saving habits, such as pre-cooling buildings during peak solar hours or reducing cooling loads when demand is high.

- Comfort, Lifestyle, and User Behavior: Energy behavior and thermal comfort expectations significantly influence cooling demand. The Comfort, Lifestyle, and User Behavior Calculation Module provides insights into how typical cooling behaviors, adaptive interventions, and comfort preferences shape energy use. This module helps identify behavioral strategies that have been successful in reducing cooling energy demand, such as adjusting temperature setpoints, using natural ventilation, or adopting shading techniques. Understanding these factors allows policymakers and public administrators to design targeted awareness campaigns and encourage behavioral change in both residential and commercial buildings.
- Legal and Regulatory Layers: Behavioral change strategies are most effective when supported by regulations and policies that encourage energy-efficient cooling practices. The Legal and Regulatory Layers Calculation Module provides an overview of EU and national regulations that influence space cooling, including policies that promote energy efficiency and demand-side flexibility. This module helps public administrators identify legal mechanisms—such as building codes, energy efficiency mandates, or incentives for energy-conscious cooling practices—that can be used to reinforce behavioral change initiatives.
- Financial Instruments: To support behavioral change initiatives, financial mechanisms can be leveraged to encourage the adoption of energy-efficient cooling habits and technologies. The Financial Instruments Calculation Module allows users to identify relevant financial support schemes, such as subsidies for efficient cooling equipment, incentives for behavioral awareness programs, or grants for demand-side management interventions. By aligning financial incentives with behavioral change strategies, policymakers can ensure that energy-saving practices are widely adopted and sustained over time.

By applying these calculation modules, public administrations and civil society organizations can develop effective strategies for promoting behavioral change in space cooling. This structured approach allows for the assessment of demand-side flexibility, identification of energy-saving behavioral interventions, alignment with regulatory frameworks, and integration of financial incentives. As a result, cooling energy consumption in public and private buildings can be significantly reduced while ensuring long-term sustainability and efficiency.

4.7. Use Case 6: Integrating Space Cooling into Energy Communities

4.7.1. Target Users

Civil society, citizens, public administrations.

4.7.2. User Story Description

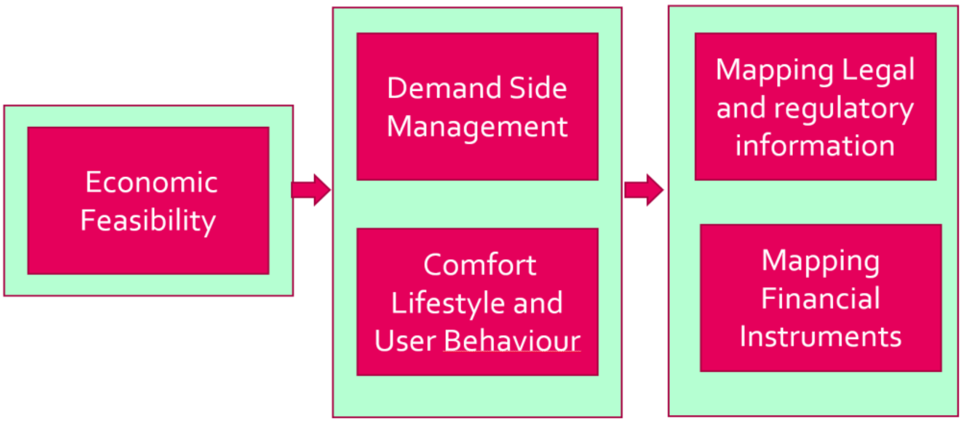
Energy communities build an idea of collective energy management that provides shared benefits to participants. There is an interest in understanding how, in the future, thermal and space cooling (SC) interventions could be integrated within energy communities.

4.7.3. Research Question

How can space cooling be integrated into energy communities to enhance collective energy management, improve energy efficiency, and ensure shared benefits for participants?

4.7.4. Calculation Module Use and Order

Figure 53. Use Case 6 - CM Use Order



- Economic Feasibility: To assess the viability of integrating space cooling into energy communities, it is necessary to evaluate the economic feasibility of different cooling interventions. The Economic Feasibility Calculation Module allows users to compare the costs of passive cooling measures and active cooling technology scenarios at both the national and building archetype levels. This module helps determine the most cost-effective approaches for incorporating cooling solutions into energy communities, ensuring that shared investments lead to long-term financial and energy efficiency benefits. The national and building stock averages can be used to estimate economic potentials in energy communities.
- Demand-Side Management: Efficient cooling integration within energy communities requires leveraging demand-side flexibility. The Demand-Side Management Calculation Module evaluates the potential for demand response and PV self-consumption in cooling demand. By analyzing how cooling loads can be shifted to align with renewable energy generation, this module supports the design of community-wide strategies that optimize cooling energy use. This includes load balancing techniques, peak demand reduction, and integrating solar-powered cooling, all of which contribute to increasing the energy efficiency of shared cooling resources.
- Comfort, Lifestyle, and User Behavior: Energy communities rely on collective engagement, and understanding cooling demand patterns within communities is essential for designing effective interventions. The Comfort, Lifestyle, and User Behavior Calculation Module provides insights into how thermal comfort expectations and behavioural patterns influence cooling demand. This module helps identify community-based behavioural interventions, such as shared cooling solutions, demand response programs, and adaptive practices that can optimize energy consumption while maintaining comfort.
- Legal and Regulatory Layers: Integrating space cooling into energy communities must align with existing regulatory frameworks. The Legal and Regulatory Layers Calculation Module maps out relevant EU and national policies, planning strategies, and regulations that impact space cooling and energy communities. This module helps identify legal opportunities and potential regulatory barriers to implementing shared cooling solutions, ensuring that initiatives are compliant with national and EU energy laws.
- Financial Instruments: Access to financial support is critical for deploying shared cooling solutions in energy communities. The Financial Instruments Calculation Module enables users to explore funding mechanisms, including subsidies, grants, and EU-level financing programs. This module helps identify financial opportunities that can support the integration of energy-efficient cooling systems into energy communities, ensuring that shared investments align with long-term sustainability goals.

By applying these calculation modules, public administrations, civil society, and citizens can explore pathways for integrating space cooling into energy communities. This structured approach allows for an assessment of economic feasibility, demand-side flexibility, behavioural factors, regulatory alignment, and financial support, ensuring that space cooling is effectively incorporated into community-based energy management systems. The result is an optimized approach that enhances collective energy efficiency while delivering shared benefits to participants.

4.8. Use Case 7: Provide inputs to the development of the National Comprehensive Assessment Report

4.8.1. Target Users

National Energy Agency, policy makers, national regulatory bodies, and consultants supporting policy implementation.

4.8.2. User Story Description

The revised Energy Efficiency Directive (EED) emphasizes the need for national-level assessments to identify and promote cost-effective energy efficiency measures, including space cooling. Member States are required to conduct comprehensive assessments of energy efficiency potentials, integrating cooling demand and supply into long-term energy planning. The directive mandates that space cooling be assessed alongside heating and district energy systems, ensuring alignment with decarbonization targets, energy security, and affordability considerations. This analysis supports the development of national energy efficiency action plans and strategic frameworks, ensuring compliance with EU climate goals.

4.8.3. Research Question

How can national-level assessments of space cooling, as required by the Energy Efficiency Directive (EED), support the identification of cost-effective efficiency measures, promote the integration of district cooling, and align with long-term decarbonization and energy security targets?

4.8.4. Comprehensive Assessment

The following sections outline how the capabilities of the CoolLIFE tool, combined with the resources available in the KnowledgeHub, can support member states in conducting comprehensive cooling analyses and developing strategic cooling plans. These efforts directly contribute to the preparation of national comprehensive assessment reports.

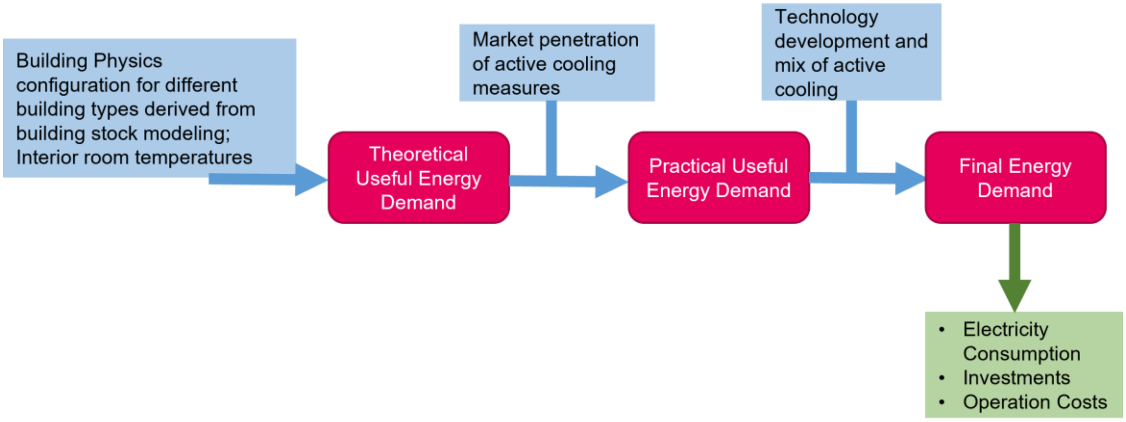
The Energy Efficiency Directive (EED) mandates that EU Member States conduct a Comprehensive Assessment to identify the most resource- and cost-efficient solutions for meeting heating and cooling demands. This assessment is crucial for promoting energy efficiency and integrating high-efficiency cogeneration and efficient district heating and cooling systems. The following sections outline how the capabilities of the CoolLIFE tool, combined with the resources available in the KnowledgeHub, can support member states in conducting comprehensive cooling analyses and developing strategic cooling plans. These efforts directly contribute to the preparation of national comprehensive assessment reports. Focusing on the cooling sector, the Comprehensive Assessment requires the following aspects to be covered:

- Data Collection: Map cooling demand and define system boundaries to accurately capture needs.
- Technical Potential: Assess the potential for efficient cooling, including district cooling and renewable sources.
- Scenarios: Develop a baseline (current demand) and alternative scenarios with efficient cooling measures.
- Cost-Benefit Analysis (CBA): Conduct a cooling-focused CBA, including environmental and health benefits.
- Optimal Solutions: Identify the most cost-effective cooling strategies, prioritizing efficient and renewable options.

The methodology/strategy used with the CoolLIFE toolbox allows a user to generate results that can be seen as first-level inputs to the Comprehensive Assessment report. This methodology can provide preliminary data and insights, supporting detailed assessments required by the EED and facilitating efficient planning of cooling strategies.

The following figure shows the sequence of methodological steps for evaluating the cooling energy scenarios for the cooling energy demand in CM:.Space Cooling Demand and CM: Economic Feasibility.

Figure 54. Methodology of the Economic Feasibility



To maintain user-friendliness, the toolbox minimizes user input requirements by offering a selection of pre-defined scenarios. This allows users to evaluate different combinations of active and passive measures for development.

For the distribution of the building stock, in the predefined scenarios, the building physics parameters are first configured to simulate the passive measures. In this way, the potential energy savings can be estimated under different scenarios for the implementation of passive measures. This is done based on the Invert/EE-Lab model (Müller, 2015). This serves as the basis for calculating the theoretical cooling demand (useful energy demand). This represents the cooling demand if it is assumed that 100 % of the built-up areas that have a certain cooling demand are conditioned with active cooling. The technology penetration rates of active cooling are then included again as predefined scenarios, taking into account the speed and extent of the introduction of active cooling technologies. This step is crucial as it translates the theoretical cooling demand into a practical cooling demand that can be met. This metric reflects the realistic energy demand for space cooling after taking into account the market penetration of active cooling technologies and measures.

In the subsequent phase of the assessment, the user can focus on the cooling energy demand (final energy demand), which indicates the actual energy consumption after the implementation of active cooling technologies. The user can select from a range of different rates of technological development and a mix of active technologies. In the course of this, it is assumed that technological progress leads to improved performance figures. For each of the resulting scenarios, electricity requirements and economic key figures are determined by the tool. This allows the user to compare, evaluate, and interpret these scenarios.

Table 3. Pre-defined scenario assumptions theoretical cooling requirement with region-specific values

Parameter	Region	Baseline	Moderate Efficiency (Manual Systems)	High Efficiency (Radiation-Controlled Systems)

Activation of sun protection systems (South)	Category Mediterranean	0.66	0.67	0.88
	Category Rest	0.66	0.67	0.79
Activation of sun protection systems (East-West)	Category Mediterranean	0.39	0.54	0.81
	Category Rest	0.24	0.36	0.7
Activation of sun protection systems (North)	Category Mediterranean	0	0.03	0.43
	Category Rest	0	0	0
Proportion of shading devices on window surfaces (South)	Category Mediterranean	0.5	0.67	1
	Category Rest	0.5	0.5	0.8
Proportion of shading devices on window surfaces (East-West)	Category Mediterranean	0.33	0.39	0.5
	Category Rest	0.33	0.33	0.5
Proportion of shading devices on window surfaces (North)	Category Mediterranean	0	0.03	0.43
	Category Rest	0	0	0
Reduction factor z for movable sun protection systems	Category Mediterranean	0.7	0.62	0.24
	Category Rest	1	0.8	0.24
g-value	Category Mediterranean	0.75	0.52	0.25
	Category Rest	0.65	0.35	0.25
Night ventilation (Air exchange rate during night ventilation)	Category Mediterranean	Baseline	Baseline	Baseline
	Category Rest	Baseline	Baseline * 1.5	Baseline * 2

Average indoor temperature of cooled building areas	Category Mediterranean	Baseline	Baseline + 1	Baseline + 2
	Category Rest	Baseline	Baseline + 2	Baseline + 4

Table 4. Pre-defined assumptions for practical and useful energy demand and need

Scenario Dimension	Name	Range of Scenario Design
Market Penetration of Active Cooling	High-Moderate-Low	High Market Penetration: +10% by 2050 compared to “moderate” Moderate Market Penetration: 2% increase by 2050 Low Market Penetration: No increase in market penetration compared to the base year
Annual Utilization Rate of Active Cooling	High-Moderate-Low	High Annual Utilization Rate: Average annual performance factors increase by a value of 6 by 2050. Moderate Annual Utilization Rate: Average annual performance factors increase by a value of 3 by 2050. Low Annual Utilization Rate: No increase in annual performance factors compared to the base year

For each run of the calculation module, the user can generate results in terms of the following parameters:

- Parameters
- Total Final Energy demand from the scenario
- Useful Energy saving potential from the selected scenario in the year 2050
- Percentage of Final Energy demand savings
- Description of the Scenario
- Charts
- Total Useful Energy demand of the scenario vs. Baseline for years 2030,2040 and 2050
- Total Final Energy demand of the scenario vs. Baseline for years 2030,2040 and 2050
- Breakdown of total investment in active and passive measures (scenario vs. Baseline)
- Comparison of levelized cost of cooling (Passive - Euros per MWh of saved useful energy demand; Active - Euros per MWh of supplied useful energy demand) For specific details on running the calculation module check CM: Economic Feasibility

The results for each run of the calculation module can be analyzed by the user, making it possible to compare different scenarios.

5. Learning Center

5.1. Learning Materials - CoolLIFE Tool and Knowledge Hub

This page provides an overview of the training materials and events designed to support the capacity-building objectives of the CoolLIFE project. It offers a structured approach for learning how to use the CoolLIFE Knowledge Hub and Tool, including the Calculation Modules (CMs), and guidelines to assist users in applying them to manage sustainable space cooling.

5.1.1. CoolLIFE Wiki

This Wiki is an online resource that provides detailed guidance on using the CoolLIFE Tool and Knowledge Hub. It is structured to offer information on data methodologies, instructions to use functionalities and guidelines for various use cases and target users.

5.1.2. CoolLIFE User Manual

The User Manual provides step-by-step instructions on using the CoolLIFE Tool and Knowledge Hub. It includes guidelines for applying the CoolLIFE Tool and Knowlege Hub in a toolchain, exercises for practical application, and best practices in sustainable space cooling management.

5.1.3. CoolLIFE Tutorials

A series of video tutorials introduce users to the main features of the CoolLIFE Tool and Knowledge Hub, Calculation Module (CM) and key functionality, making it easy for users to get hands-on guidance for specific applications. They can be watched on YouTube, as part of the CoolLIFE Playlist: YouTube CoolLIFE Playlist.

5.1.4. Training Events

CoolLIFE training events are designed with different time frames to suit various audiences and levels of detail:

- ***Short Training (10–20 minutes):*** *A brief introduction to the project, tools, and functionalities. Suitable for third-party webinars and conferences.*
- ***Long Training (60 minutes):*** *A more detailed walkthrough of each CM and functionality, applied to case studies or toolchains. Suitable for CoolLIFE's events.*
- ***In-depth Workshop (60–120 minutes):*** *A comprehensive workshop including practical exercises to apply CMs to real-case scenarios. Suitable for longer national stakeholder workshops.*

Table 5 lists all the events along with recordings and presentation links (when available).

Table 5. The list of all CoolLIFE Events (trainings, workshops, etc).

Date	Name and Place	Number of participants	Link to the presentation (if available)	Link to the recording (if available)

22nd August 2024	DHC+ Summer School, Linz, Austria	38	Download here	No recording
17th September 2024	Act!onHeat Webinar: How to finance sustainable solutions in district heating? (online)	28 excl. 6 speakers	Download here	Available here
29th October 2024	EHP-RHC Accelerator Webinar (online)	23	Download here	Available here
18th November 2024	Data Science Conference – Tech Tutorial (online)	26	Not available	Not available
31st March 2025	Stakeholder national event – Italy (high-level, no training)			
1st April 2025	Complete CoolLIFE Training (online)		Download here	Available here
28th April 2025	CoolLIFE Training for the Project Plan4Cold (online)			
29th April 2025	Spring lecture at TU Wien			
30th April 2025	Stakeholder national event - Greece			
	Stakeholder national event – Italy (users level, with training)			
May	Stakeholder national event - France			
6th May	Another international training - TDB (Adrian Joyce?)			
20th May 2025	C4E Central & Eastern European Energy Efficiency Forum, Cavtat, Croatia			
27th May 2025	EU Sustainable Energy Day (EUSEW)			

5.2. Other Materials - Beyond the Tool and the Hub

5.2.1. Introduction

Throughout the project, valuable knowledge has been generated beyond the development of the tool and hub, offering insights that can be applied for various purposes. This page provides a concise overview of these resources, each referring to relevant deliverables for further details. The topics covered include:

5.2.2. Overview of cooling technologies (page 85)
5.2.3. Overview of cooling measures (page 87)
5.2.4. Summary of current and projected cooling demand (page 87)
5.2.5. Overview of potential impact of different measures (page 88)
5.2.6. Analysis of space cooling-related comfort requirements (page 89)
5.2.7. Overview of user behaviour interventions (page 89)
5.2.8. Quantification of occupant behaviour effect on space cooling demand (page 90)
5.2.9. Summary of current EU-level legislation and Member States' policies relevant to sustainable space cooling (page 91)
5.2.10. Overview of current financing schemes for cooling (page 92)
5.2.11. Geoscientific datasets for investment decision support and strategic planning of 5GDHC (page 93)

The following sections present brief overviews of each topic, with links to relevant deliverables for a more comprehensive understanding.

5.2.2. Overview of cooling technologies

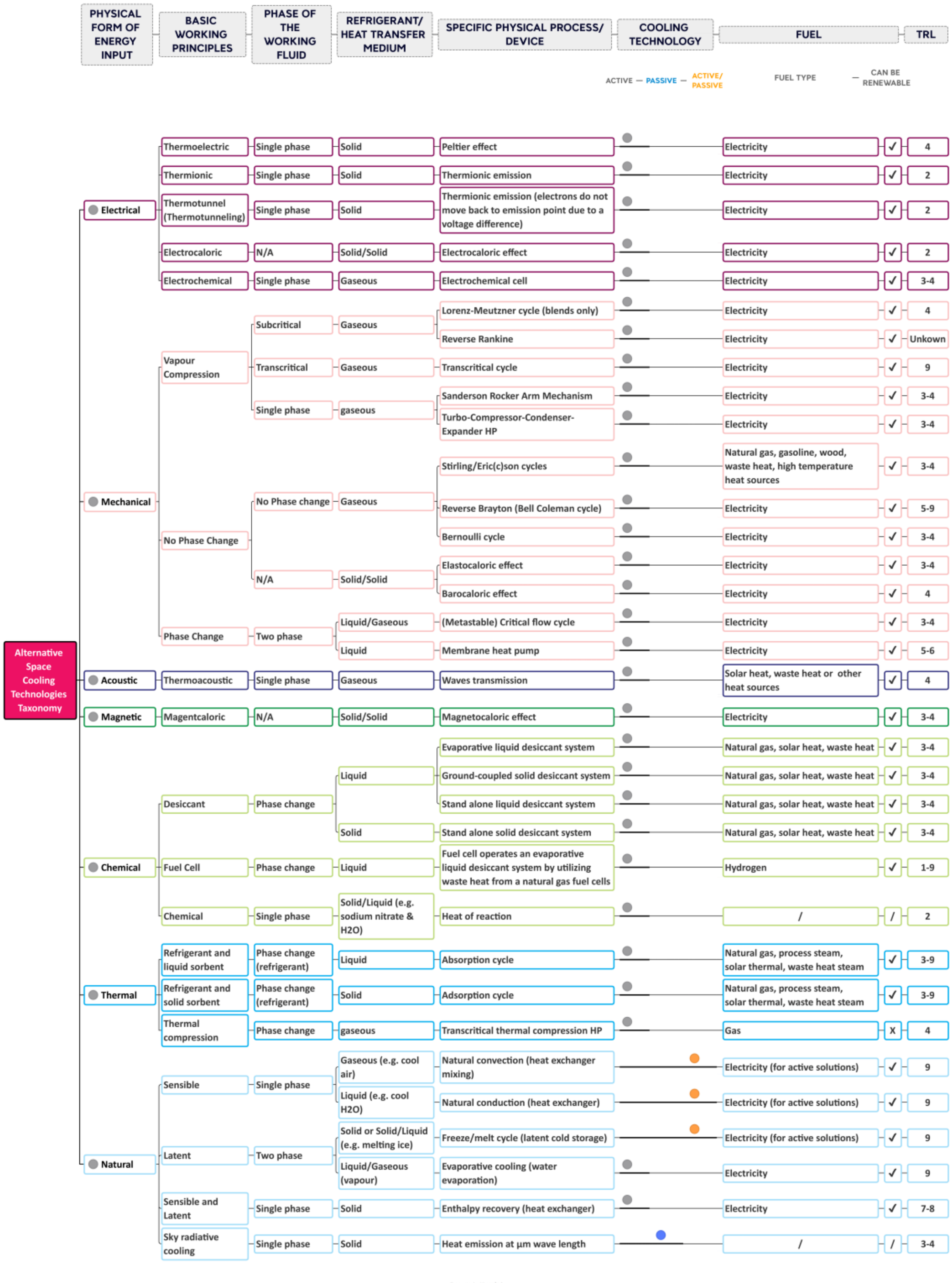
An overview of current and future space cooling (SC) technologies to address Europe's growing cooling needs was conducted. As a result, the taxonomy of SC technologies was created and can be viewed in Figure 55 below. The technologies were categorized using multiple parameters, including:

- physical energy form (electrical, mechanical, acoustic, magnetic, chemical, thermal, and natural)
- operating principle
- refrigerant/heat transfer medium, working fluid phase (single-phase, two-phase, or no phase change)
- technology type (active, passive, or both)
- fuel type (including renewable energy)
- Technology Readiness Level (TRL).

The review classified SC technologies into conventional vapour compression (VC) systems 35 alternative technologies, including magnetocaloric, thermoacoustic, thermoelastic, thermoelectric, desiccant cooling, and membrane heat pumps. Special consideration was given to technologies capable of integration with renewable energy sources, as well as their efficiency (seasonal energy efficiency ratio – SEER), lifecycle costs (CAPEX, OPEX), environmental impacts, and sector-specific applications.

The detailed overview can be accessed in deliverable D2.1 "Taxonomy of space cooling technologies and measures" (Duplessis et al, 2023). The report assesses various space cooling (SC) technologies currently available on the market, as well as emerging technologies with potential future applications.

Figure 55. Taxonomy of Space Cooling Technologies



The **key findings** about SC technologies are as follows.

- **Vapour Compression (VC) Systems**, including split systems, VRF systems, rooftop units, and chillers, meet nearly 99% of Europe's space cooling demand due to their scalability, efficiency, and mature technology (TRL 9).
- Thirty-five **Alternative technologies**, including thermoelectric, magnetocaloric, and desiccant cooling, offer higher energy efficiency but are limited by cost and scalability. Most are in early development stages (TRL 2-4), except transcritical CO2 cycles and absorption systems (TRL 4-9).

- **Cost-Benefit and Scalability Considerations**: VRF systems are preferred in dense urban areas due to lower noise and heat emissions, despite higher costs. District cooling networks offer long-term benefits in high-demand areas, while portable air conditioners are least efficient and noisiest.
- **Environmental and Regulatory Impact**: Climate conditions and regulations promoting low-GWP refrigerants favour advanced technologies like CO2 cycles and magnetocaloric cooling, improving their cost-effectiveness in hotter regions.
- **Selection for CoolLIFE Project**: Four technologies were selected for further consideration: split systems, VRF systems, district cooling networks, and portable air conditioners. Their high TRL and market readiness make them viable solutions for different building types and climates.

5.2.3. Overview of cooling measures

A comprehensive review of existing measures to reduce space cooling (SC) demand was conducted, with detailed results available in the deliverable D2.1 “Taxonomy of space cooling technologies and measures” (Duplessis et al, 2023). Identified measures were classified into three main categories:

- **Passive measures**: do not require energy input (e.g., shading devices, ventilative cooling, and nature-based solutions).
- **Active measures**: use energy to control indoor environments (e.g., smart glazing systems, adaptive facades, and ceiling fans).
- **Comfort lifestyle and user behaviour measures**: include occupant actions and adaptive behaviours to maintain thermal comfort.

Active and passive measures were further categorized based on their effects, such as reducing heat gains, enhancing personal comfort, removing sensible heat, and controlling indoor humidity. In total, 56 measures were classified: 28 passive, 13 active, and 15 lifestyle and behavioural measures.

Key Findings:

- **Passive measures**, such as shading devices, ventilative cooling, and thermal energy storage systems, are energy-efficient and applicable at both building and neighbourhood scales. Their effectiveness depends on building design, orientation, and climate conditions.
- **Active measures**, including ceiling fans, smart glazing systems, and adaptive facades, effectively reduce cooling demand but require energy input, with efficiency varying based on technology type and application scale.
- Behavioural **adaptations** involve personal and environmental adjustments, while physiological and psychological adaptations enable individuals to maintain comfort without mechanical cooling, often reducing energy demand without direct costs.
- The **effectiveness of behavioural measures** is influenced by building design, occupant habits, and contextual factors, with interventions like information provision, feedback, and monetary incentives encouraging energy-saving actions.
- The **classification** of measures into passive, active, and behavioural categories provides a foundation for selecting cost-effective and sustainable solutions tailored to different building types, climates, and user needs, supporting both short- and long-term cooling demand reduction.

5.2.4. Summary of current and projected cooling demand

A comprehensive assessment of space cooling (SC) demand in the European Union (EU27) was conducted using 2021 as a baseline, covering both the residential and service sectors. The complete dataset, including country-level breakdowns and technology-specific consumption figures, is available in Deliverable D2.2 “Energy Demand Assessment” (Duplessis et al, 2024).

The study quantified energy demand by technology type, sector, and country, revealing that **total space cooling demand** across both sectors amounted to approximately **545.51 TWh/year**. This demand is evenly split between *room air conditioners (RACs)* and *centralized air conditioners (CACs)*, each accounting for roughly 50% of the total.

In the **residential sector**, RACs dominate, representing over 90% of energy consumption. The most energy-demanding technologies are small split systems (<5 kW), with an annual demand of 59 TWh/year, followed by big split systems (>5 kW, including ducted systems) at 49 TWh/year and movables at 6 TWh/year. Chillers and VRF systems contribute marginally to residential demand. Five countries—Italy, Spain, Greece, Germany, and France—account for more than 90% of total residential SC demand.

In the **service sector**, CACs account for 60% of demand, with big split systems (>5 kW) consuming the most energy at 140 TWh/year. Rooftop and packaged units follow at 96 TWh/year, while variable refrigerant flow (VRF) systems consume over 52 TWh/year. Air-to-water and water-to-water chillers also contribute significantly. Again, Spain, France, Italy, Greece, and Germany collectively account for over 80% of service sector demand.

Overall, big split systems (>5 kW) are the most energy-intensive, consuming 188.75 TWh/year across both sectors.

The study found that space cooling demand is concentrated in Southern and Western Europe due to warmer climates and higher population densities.

Projections indicate that rising temperatures, changing building designs, and increased demand for thermal comfort will drive future growth in cooling demand, with climate change expected to further intensify demand in southern regions.

5.2.5. Overview of potential impact of different measures

A comprehensive impact assessment was conducted to evaluate the environmental, economic, and social effects of space cooling (SC) measures in the EU-27. The study explored the potential benefits of combining passive measures and improvements in active cooling technologies, using different scenarios to estimate energy savings, greenhouse gas (GHG) emissions reduction, and socio-economic benefits up to 2050. Detailed results and scenario analyses are available in Deliverable D2.3 “Impact Assessment” (Malla et al, 2024).

Key Findings:

- **Energy Savings**: Combining high-efficiency passive measures with advanced cooling technologies can reduce energy consumption by up to 55% by 2030 and nearly 80% by 2050 compared to the baseline scenario. The non-residential sector benefits more from these measures due to its higher baseline energy demand.
- **Environmental Impact**: CO_2 emissions could be reduced by up to 45.5% by 2030 and 80% by 2050 compared to the baseline, supporting the EU’s net-zero emission target. NOx emissions also decline due to lower electricity consumption, improving air quality.
- **Economic Impact**: Implementing passive and active measures could increase the EU-27 GDP by approximately €6 billion annually until 2050. Investments in energy efficiency improvements are projected to generate between 124,000 and 300,000 full-time jobs annually.
- **Social Impact**: Improved air quality due to reduced electricity consumption could prevent around 145 premature deaths annually and avoid 36,600 lost working days by 2050. Enhanced thermal comfort, particularly during heatwaves, contributes to better health, productivity, and overall well-being.

Policy Recommendations:

- Financial incentives should be provided to encourage the adoption of passive measures.
- Regulations should promote the diffusion of advanced cooling technologies and set stricter energy efficiency standards.
- Public awareness campaigns can foster energy-saving behaviours, while flexible regulatory frameworks can accommodate future advancements.

5.2.6. Analysis of space cooling-related comfort requirements

This analysis examined the concept of thermal comfort and the preferred indoor temperatures of residential building occupants, considering both standardised criteria and sociocultural influences. Using a literature review and a survey conducted in Hungary, the study explored preferences, behavioural patterns, and factors affecting thermal comfort. For detailed data, refer to Deliverable D3.1 “Knowledgebase for Occupant-Centric Space Cooling” (Hurtado-Verazaín et al, 2023).

Key Findings:

- **Thermal Comfort Standards**: Recommended indoor summer temperatures range from 23°C to 26°C, with adaptive models allowing warmer limits in naturally ventilated buildings.
- **Sociocultural Influences**: Growing AC use has shifted preferences toward cooler environments, reducing tolerance for higher temperatures.
- **Survey Insights (Hungary)**: Most respondents set AC systems between 22°C and 25°C, with an average of 23°C. Around 20% were comfortable at 28°C during the day. Common cooling behaviours included using lighter clothing (97%), opening windows (86%), and shading devices (83%).
- **Adaptive Behaviours**: Personal control over indoor environments, such as window operation and fan use, significantly enhances thermal comfort.

The findings highlight that comfort preferences are individual and context-dependent, requiring flexible cooling solutions that balance energy efficiency and occupant satisfaction.

5.2.7. Overview of user behaviour interventions

A compilation of behavioural and lifestyle interventions adopted by building occupants to reduce SC needs and adapt to thermal discomfort was created within this project. The analysis distinguishes between **bottom-up behaviours**, driven by occupants’ actions, and **top-down interventions**, initiated through policies, financial incentives, and social influences. The study covers residential, office, and educational buildings, where behavioural changes have the highest potential to reduce SC demand. For detailed examples and case studies, refer to Deliverable D3.2 “Analysis of Behavioural Interventions Across Europe” (Gelesz et al, 2024)

Key Findings:

- Bottom-Up Behaviours:
    - Occupants influence SC demand through equipment use, cooling set-point preferences, window opening, and shading control.
    - Behavioural patterns vary by building type: residential users have the most control, while office and educational building occupants have limited autonomy, often relying on collective decisions.
    - Adaptation strategies, such as using fans, wearing lighter clothing, and natural ventilation, can reduce SC needs, particularly in naturally ventilated buildings.

- Top-Down Interventions:
    - *Monetary Incentives*: Dynamic pricing (e.g., time-of-use tariffs and real-time pricing) encourages shifting energy use away from peak periods, reducing grid demand and SC costs.
    - *Information Provision*: Providing feedback on energy consumption, efficiency tips, and health impacts during heatwaves helps occupants adopt energy-saving behaviours. Personalised feedback (e.g., on energy bills or through smart home systems) is particularly effective.
    - *Nudges*: Social comparisons (e.g., comparing household energy use with neighbours), default thermostat settings, and gamification techniques promote energy-efficient behaviours. For example, setting higher default cooling set-points can reduce energy use without compromising comfort.
- Building-Specific Interventions:
    - **Residential**: Interventions like promoting night-time ventilation, outdoor cooking, and limiting heat-generating equipment can reduce internal heat loads.
    - **Offices**: Relaxing dress codes during summer (e.g., "CoolBiz" initiatives), allowing flexible work hours to avoid peak heat periods, and providing real-time feedback on energy use can reduce SC demand.
    - **Educational**: Scheduling changes, such as shifting school start dates to cooler periods and using outdoor spaces, help reduce cooling needs during peak summer months.

Policy Recommendations:

- Develop region-specific occupancy profiles to improve energy demand modelling.
- Promote behavioural interventions alongside energy-efficient technologies for maximum impact.
- Provide clear, actionable information on energy-saving behaviours, emphasising both cost savings and health benefits.

5.2.8. Quantification of occupant behaviour effect on space cooling demand

Quantification of how occupant behaviour influences space cooling (SC) energy consumption in both residential and non-residential buildings was delivered by the project. Detailed data and simulation methodologies are available in Deliverable D3.3 "Multiple Socioeconomic Impacts of Sustainable Space Cooling" (Caballero et al, 2024). Using building energy simulations, the study assessed the impact of occupant presence, window use, shading, cooling setpoints, and internal heat loads on SC demand. Three behavioural profiles were analysed:

- Unconscious (relying on mechanical cooling)
- Mitigative (using passive and adaptive measures in response to discomfort)
- Adaptive (preventing discomfort through proactive measures).

Key Findings:

- Residential Buildings:
    - Behavioural measures can reduce SC demand by up to 97-100% in the Adaptive scenario and by 69-84% in the Mitigative scenario compared to the Unconscious profile.
    - Reducing internal heat loads from 10 W/m² to 4 W/m² and limiting appliance usage achieved the largest energy savings, reducing SC demand by nearly 20 kWh/m²/year.
    - Conscious shading behaviour decreased SC demand by 10 kWh/m²/year (Italian multifamily house case study). Night ventilation further reduced demand by 5 kWh/m²/year.
- Non-Residential Buildings:
    - Behavioural measures reduced SC demand by 40-76% across hospitals, hotels, educational buildings, and offices, with the highest savings in offices.

    - Increasing cooling setpoints by 1°C lowered annual SC demand by 0.5-12 kWh/m²/year, reducing demand by 5-68% depending on the building type and scenario.
    - Shading reduced SC demand by 39% on average in offices, with potential savings ranging from 6-65% depending on orientation and location.
    - Night ventilation significantly reduced demand, particularly in educational and office buildings.
- Climate and Building Envelope Effects:
    - Climate change will increase SC demand, but the rise is largest in the Unconscious scenario (4.10 kWh/m²/year on average). Adaptive behaviour significantly mitigates this increase.
    - Improved building envelopes do not always reduce SC demand, especially if not paired with adaptive occupant behaviour.
- Social and Environmental Benefits:
    - Reducing SC demand through behavioural measures can lower electricity consumption by 12% in the residential sector and 6-15% in non-residential subsectors.
    - This reduction could prevent 15 premature deaths annually due to air pollution and save 4,284 lost working days in the EU-27.
    - Increasing setpoints and reducing electricity use also contribute to lower emissions and improved air quality.

5.2.9. Summary of current EU-level legislation and Member States' policies relevant to sustainable space cooling

A summary of key European Union (EU) regulations and national policies related to sustainable space cooling (SC) was done within the project. The review covers EU directives, adaptation strategies, and national building regulations, highlighting both advancements and gaps in promoting energy-efficient cooling solutions. Detailed information and country-specific regulations are available in Deliverable D4.1 "Review and Mapping of Legislations and Regulations on Sustainable Space Cooling at EU and National Levels" (Broc et al, 2024).

Key Findings:

- EU Legislation:
    - The Energy Efficiency Directive (EED) and Energy Performance of Buildings Directive (EPBD) mandate improving building energy performance, including cooling, with specific provisions for reducing overheating and promoting passive measures.
    - The Renewable Energy Directive (RED) aims to increase the share of renewable energy in cooling systems, while the Ecodesign for Sustainable Products Regulation (ESPR) sets energy efficiency standards for cooling products.
    - The Fluorinated Greenhouse Gases (F-gas) Regulation phases down high-GWP refrigerants, encouraging the use of climate-friendly alternatives.
    - The EU's Climate Adaptation Strategy promotes measures like green roofs and urban shading to mitigate heatwaves, while the Fit for 55 Package reinforces these initiatives with more ambitious energy efficiency targets.
- National Regulations:
    - All Member States integrate space cooling into energy performance calculations, but only some set explicit limits for cooling demand or address summer comfort.
    - Countries like Austria, Croatia, and France have specific provisions to limit overheating and promote passive cooling. For example, Austria sets a maximum cooling energy limit of 1 kWh/m²/year for new buildings, while France's RE 2020 regulation has adaptive comfort models.
    - Indoor temperature limits typically range from 26°C to 28°C for residential buildings, with slightly lower thresholds for non-residential spaces.
    - Cooling system efficiency requirements are often included in building codes, especially for new constructions and major renovations.

  - National Adaptation Strategies (NAS) and National Adaptation Plans (NAP) increasingly address the impact of heatwaves, with measures like urban green spaces, reflective materials, and improved ventilation. However, integration with energy policies remains limited in most countries.

Policy Gaps and Recommendations: - Space cooling is still primarily addressed as a technological issue, with insufficient emphasis on reducing cooling demand through building design and occupant behaviour. - Greater coordination between EU, national, and local policies is needed to promote climate-resilient building design and urban planning. - Financial incentives and regulatory measures should prioritise passive cooling and energy-efficient technologies to reduce reliance on mechanical cooling systems.

5.2.10. Overview of current financing schemes for cooling

This section summarises available financing schemes supporting sustainable space cooling (SC) at both EU and national levels. The analysis covers public and private funding options aimed at improving building energy efficiency, promoting renewable energy for heating and cooling (H&C), and supporting district heating and cooling (DHC) networks. For further details, refer to Deliverable D4.2 “Review of Financing Schemes Relevant for Sustainable Space Cooling at EU and National Levels” (Conforto et al, 2024).

Key Findings:

- Funding Availability:
  - A total of 556 financing schemes were identified across EU-27, with 350 public and 206 private schemes. Public funding is more prevalent, reflecting government efforts to address high initial costs and long payback periods.
  - Public schemes mainly offer grants (51%), loans (14%), and tax incentives (8%), while private schemes focus on green loans (57%), green mortgages (22%), and green bonds (7%).
- Target Sectors and Scope:
  - 71% of schemes target residential buildings, while 49% focus on non-residential premises.
  - 53% of schemes specifically address space cooling, but often jointly with heating.
  - Funding is more accessible for building envelope efficiency (82%), H&C efficiency (84%), and renewable energy systems (77%), with fewer schemes for district cooling (33%).
- Geographical Disparities:
  - Countries with the highest number of schemes include Germany (48), France (46), Poland (36), Austria (33), and Belgium (32).
  - Cooling-specific schemes are inconsistently available in countries with high Cooling Degree Days (CDD), such as Spain (5) and Malta (5), while Portugal (16) and Cyprus (12) offer more comprehensive support.
- Barriers and Challenges:
  - Cooling is still often perceived as a luxury rather than a necessity, limiting the availability of dedicated funding schemes.
  - Fragmented information and rapid changes in funding programs create obstacles to accessing financing, particularly for smaller projects.
  - The financial sector favours traditional instruments, raising questions about the scalability of innovative financing approaches.
- Expert Insights:
  - Interviews with H&C experts highlight the need to address cooling as an essential component of building energy performance, especially for vulnerable populations and productivity in commercial spaces.
  - Simplified access to financing, better awareness of available schemes, and improved coordination between EU, national, and local policies are key to closing the investment gap.

5.2.11. Geoscientific datasets for investment decision support and strategic planning of 5GDHC

This section provides an overview of geoscientific datasets and mapping tools that support investment decisions and strategic planning for 5th Generation District Heating and Cooling (5GDHC) networks. The focus is on tools that visualise energy consumption, renewable energy availability, and potential thermal energy reuse, helping urban planners, policymakers, and investors design cost-effective and sustainable heating and cooling networks.

Types of Tools:

- A total of 16 tools were analysed, including 11 open-source and 5 commercial tools, covering energy consumption, emissions, costs, and district network simulations.
- Open-source tools such as HotMaps Toolbox, Planheat, Thermos, and Heat Roadmap Europe 4 (HRE4) provide accessible platforms for energy demand assessment and future scenario simulations.
- Commercial tools like Invert/EE-Lab and SimStadt offer advanced modelling capabilities, integrating real-world urban data for detailed energy scenarios.

Geoscientific Datasets:

- Tools use datasets that include building geometry, energy consumption patterns, climate data, and renewable energy availability (solar, geothermal, and industrial waste heat).
- For district cooling planning, datasets highlight potential sources of excess heat and cooling, such as lakes, rivers, and industrial processes.
- Geographic Information Systems (GIS) are integrated into platforms like EMB3Rs and CitySim Pro to visualise spatial energy flows, supporting the optimal placement of 5GDHC networks.

Energy Demand Modelling:

- Tools use both top-down (macro-level trends) and bottom-up (building-level data) approaches to estimate space heating and cooling demand, accounting for building characteristics, occupancy, and climate impacts.
- City Energy Analyst (CEA) and EnergyPlus simulate energy consumption and CO_2 emissions at the neighbourhood and city scales, while IDA ICE evaluates building performance with dynamic simulations.

Decision Support for 5GDHC:

- Tools like Thermos and Heat Roadmap Europe 4 help identify optimal locations for district cooling networks, considering population density, infrastructure costs, and environmental impact.
- EMB3Rs assesses the techno-economic feasibility of reusing industrial excess heat and cooling for 5GDHC, improving energy efficiency and reducing CO_2 emissions.

User Feedback and Challenges:

- User feedback highlights the need for improved data accuracy, easier integration of local datasets, and better visualisation of energy scenarios.
- Limited availability of high-resolution cooling demand data remains a challenge, especially in regions with emerging cooling needs.

These tools and datasets provide essential support for planning 5GDHC networks, helping cities transition to low-carbon heating and cooling systems.