UNIVERSITAT POLITÈCNICA DE VALÈNCIA

COOLING DOWN

# Renewable Cooling Integration based on SITE to integrate renewable cooling technologies into SECAPs

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LA PLAZETA
TEATRO
The impact of cooling


The challenge for cities

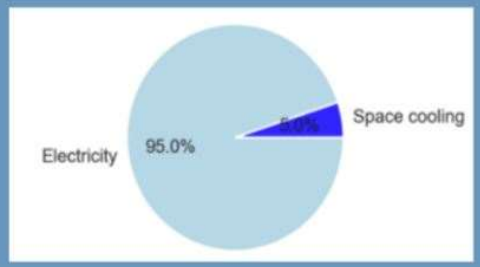

SITE tools to improve cooling governance

# The impact of Cooling

## $\%CO_2$ of the total electricity emissions

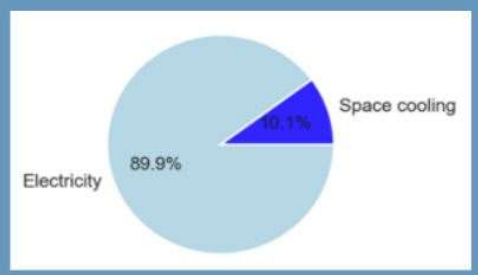
**Belgium**

**5%**



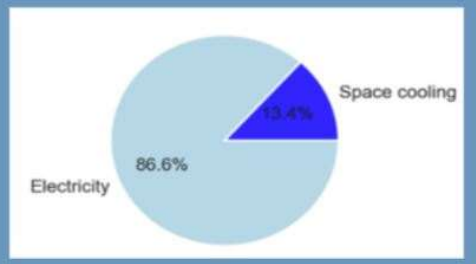

**Italy**

**10.1%**




**Romania**

**13.5%**




Cooling demand represents a growing share of electricity consumption, especially in Southern countries (e.g., Spain, Italy, Romania).

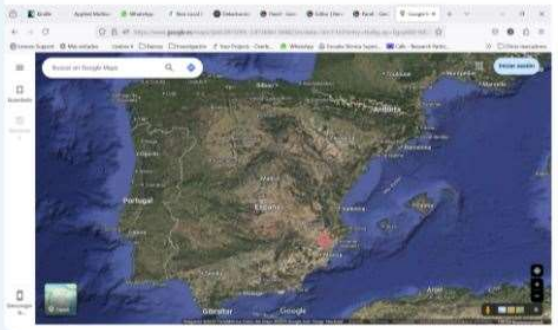
The trend is towards a much higher share.

# Impact on the electricity network

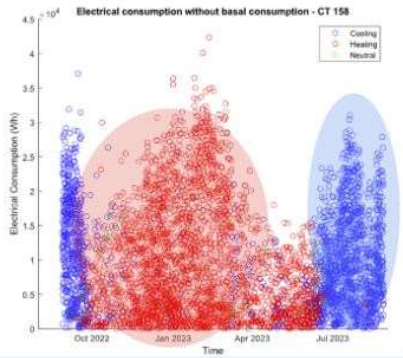
With the Crevillente Case Study

**Data year 2023**

## Crevillente - around 28000 hab

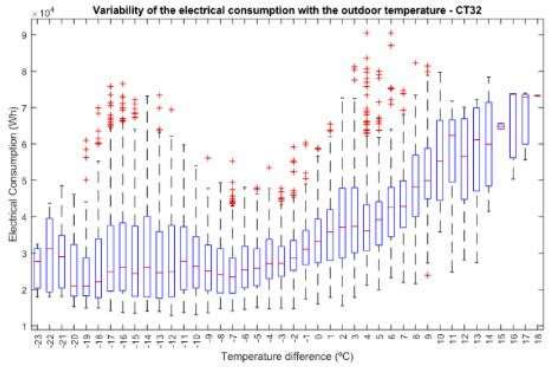



## Example of electric consumption ST 158




## Quantitative impacts

**8.65%** Cooling Consumption




**The trend with temperature is a basic finding in this case study**

**Electricity consumption typically doubles during cooling intensive hours**

# Findings

- Cooling is **relevant** and **stresses the electric grid**
- Costly investments for grid stabilization will be needed **if storage and efficient cooling technologies are not implemented**

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Introduction to SECAPs and SITE
Key findings in regard to Cooling and C...
DOTONBORI
Methodology
Implementation Example

# What are SECAPs ?

The **Strategy Energy and Climate Action Plans** in European cities were launched by the Covenant of Majors Agreement in 2008 under the umbrella of the COVENANT INNITIATIVE FOR CLIMATE AND ENERGY

Up to date, **more than 11.000 EU cities** have signed and the population covered is of about 341 Mio inh

It is one of the largest decarbonization framework in the world


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# We have (signed) a SECAP!... why bother !?

**55% GHG emissions abatement !**

**Real world example: from 256 municipalities which signed a SEAP within the Council of Valencia Area, only 12 sent a follow up report 5 years after signature**


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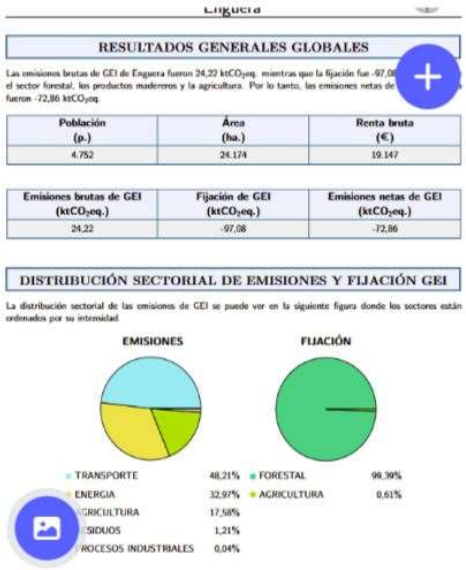
# Strategic Energy and Climate Action Plan


Knowledge + Big Data =

Strat

Know


Enguera

RESULTADOS GENERALES GLOBALES

Las emisiones brutas de GEI de Enguera fueron 24,22 ktCO2eq. mientras que la fijación fue -97,08 ktCO2eq. en el sector forestal, los productos madereros y la agricultura. Por lo tanto, las emisiones netas de GEI fueron -72,86 ktCO2eq.

| Población (p.) | Área (ha.) | Renta bruta (€) |
|---|---|---|
| 4.752 | 24.174 | 19.147 |

| Emisiones brutas de GEI (ktCO2eq.) | Fijación de GEI (ktCO2eq.) | Emisiones netas de GEI (ktCO2eq.) |
|---|---|---|
| 24,22 | -97,08 | -72,86 |

DISTRIBUCIÓN SECTORIAL DE EMISIONES Y FIJACIÓN GEI

La distribución sectorial de las emisiones de GEI se puede ver en la siguiente figura donde los sectores están ordenados por su intensidad.

EMISIONES

FIJACIÓN

TRANSPORTE 48,21%
ENERGIA 32,97%
GRICULTURA 17,58%
SIDUOS 1,21%
ROCESOS INDUSTRIALES 0,04%
FORESTAL 99,39%
AGRICULTURA 0,61%

## GHG inventoire of ALL emissions

Allows to highlight the most important and sensitive measures to be undertaken in a given territory either

Based on a TOP DOWN methodology from IPCC data

- consistent with national statistics
- includes carbon sinks / capture otentials
- allows to identify most sensitive measures
- allow a consistent and LOW COST picture o GHG emissions

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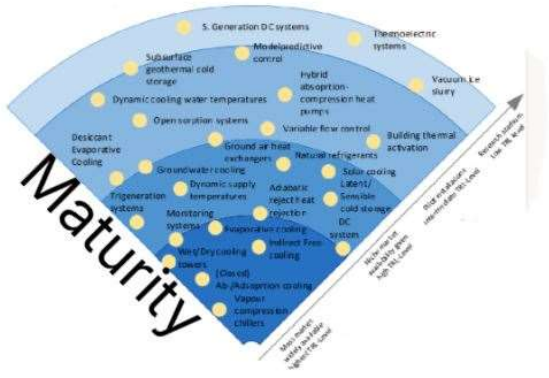
*Table 6: Summary of general findings*

| City | Has SEAP | Public Availability | Emissions Inventory | Monitoring Reports | Renewable Cooling Measures |
|---|---|---|---|---|---|
| Munich | Yes | Yes | Yes | Yes | Yes |
| Berlin | Yes | Yes | Yes | Yes | Yes |
| Brussels | Yes | No | Yes | No | No |
| Padova | Yes | Yes | Yes | No | No |
| Valencia | Yes | Yes | Yes | Yes | No |
| Bucharest | No | No | No | No | No |
| Orléans | Yes | Yes | Yes | No | No |
| Oradea | Yes | No | Yes | No | No |

KEY FINDINGS (BRIEFLY)

1. Weaknesses in terms of follow up of measures
2. Cooling often not taken into consideration in City energy policies




# Technology related indicators

*Table 99: Calculation of indicators for each Renewable Cooling Solution*

| Renewable Cooling Solution | Renewable Cooling Energy ($E_{RES-C}$) [kWh$_{th}$] | Non-renewable Primary Energy Consumption (NRPEC) [kWh$_e$] | Seasonal Energy Efficiency Ratio (SEER) | Urban Heat Island Mitigation Index (UHMI) | $CO_2$ Emissions Reduction ($\Delta CO_2$) [kg $CO_{2e}$] | $CO_2$ Emissions Reduction per Euro Invested [kg $CO_{2e}$/€] | Relative $CO_2$ Emision Reduction [%] | Investment [€] | Energy and Economic Operating Savings | Limitations |
|---|---|---|---|---|---|---|---|---|---|---|
| Closed Loop Heat Pump | $E_{RES-C} = Q_{Cooling} * \varepsilon_{RES}$<br>$Q_{Cooling}$ is the annual cooling energy supplied by the cooling system in kWh$_{th}$<br>$\varepsilon_{RES}$ is the share of the cooling energy supply considered renewable, defined according to the Seasonal Energy Efficiency Factor (SEER) requirements. | $NRPEC = W_e \times PEF_{elect}$<br>$W_e$ is the electricity consumption of the entire system (heat pump and auxiliary components) in kWh during the cooling season<br>$PEF_{elect}$ is the non-renewable primary energy factor (PEF) for electricity | $SEER = \frac{Q_{Cooling}}{W_e}$<br>$Q_{Cooling}$ is the annual cooling energy supplied by the cooling system in kWh$_{th}$<br>$W_e$ is the electricity consumption in kWh of the entire system, including the ground loop pump and indoor unit, over the cooling season | Renewable cooling systems in a thermally saturated zone: UHMI = 10<br>Renewable cooling systems in a non-saturated zone: UHMI = 5 | $\Delta CO_2 = W_e \times EF_e - W_e \times EF_e$<br>$W_e$ is the energy consumption of the replaced conventional system in kWh during the cooling season<br>$W_e$ is the electricity consumption in kWh of the entire system, including the ground loop pump and indoor unit, over the cooling season<br>$EF_e$ : Emission factor of the baseline energy source (kg $CO_2$/kWh).<br>$EF_e$ : Emission factor of the electricity grid (kg $CO_2$/kWh). | $\frac{\Delta CO_2}{€} = \frac{\Delta CO_2}{Investment}$<br>$\Delta CO_2$ is $CO_2$ Emissions Reduction in kg $CO_2$<br>Investment: Total capital expenditure for implementing the closed-loop heat pump in euros. | Relative $CO_2$ Emission Reduction $= \left(\frac{\Delta CO_2}{CO_{2b}}\right) \times 100$<br>$\Delta CO_2$ is $CO_2$ Emission Reduction in kg $CO_2$ achieved by the renewable cooling solution<br>$CO_{2b}$ is $CO_2$ Emissions in kg $CO_2$ the baseline scenario. | Investment: Total capital expenditure for implementing the closed-loop heat pump in euros. | Energy Savings $= \left(\frac{E_{baseline} - E_{new}}{E_{baseline}}\right) \times 100$<br>Economic Savings $= (C_{baseline} - C_{new}) \times T$<br>$E_{baseline}$ is the annual energy consumption of the baseline system (kWh/year).<br>$E_{new}$ is the annual energy consumption after implementing the new technology (kWh/year).<br>$C_{baseline}$ is the annual operating cost of the baseline system (€).<br>$C_{new}$ is the annual operating cost after implementing the new technology (€).<br>T: Operational period (years). | **Spatial Requirements:** Installation necessitates substantial land area for drilling and subterranean piping infrastructure.<br>**Retrofitting:** Implementing in existing structures can be complex<br>**Geothermal Assessment:** A comprehensive evaluation of the site's geothermal potential is imperative to ensure system viability. |
| Open Loop Heat Pump | $E_{RES-C} = Q_{Cooling} * \varepsilon_{RES}$<br>$Q_{Cooling}$ is the annual cooling energy supplied by the cooling system in kWh$_{th}$<br>$\varepsilon_{RES}$ is the share of the cooling energy supply considered renewable, defined according to the Seasonal Energy Efficiency Factor (SEER) requirements. | $NRPEC = W_e \times PEF_{elect}$<br>$W_e$ is the electricity consumption of the entire system (heat pump and auxiliary components) in kWh during the cooling season<br>$PEF_{elect}$ is the non-renewable primary energy factor (PEF) for electricity | $SEER = \frac{Q_{Cooling}}{W_e}$<br>$Q_{Cooling}$ is the annual cooling energy supplied by the cooling system in kWh$_{th}$<br>$W_e$ is the electricity consumption in kWh of the entire system, including the water pump and indoor unit, over the cooling season | Renewable cooling system in a thermally saturated zone: UHMI = 10<br>Renewable cooling system in a non-saturated zone: UHMI = 5 | $\Delta CO_2 = W_e \times EF_e - W_e \times EF_e$<br>$W_e$ is the energy consumption of the replaced conventional system in kWh during the cooling season<br>$W_e$ is the electricity consumption in kWh of the entire system, including the ground loop pump and indoor unit, over the cooling season.<br>$EF_e$ : Emission factor of the baseline energy source (kg $CO_2$/kWh).<br>$EF_e$ : Emission factor of the electricity grid (kg $CO_2$/kWh). | $\frac{\Delta CO_2}{€} = \frac{\Delta CO_2}{Investment}$<br>$\Delta CO_2$ is $CO_2$ Emissions Reduction in kg $CO_2$<br>Investment: Total capital expenditure for implementing the open-loop heat pump in euros. | Relative $CO_2$ Emission Reduction $= \left(\frac{\Delta CO_2}{CO_{2b}}\right) \times 100$<br>$\Delta CO_2$ is $CO_2$ Emission Reduction in kg $CO_2$ achieved by the renewable cooling solution.<br>$CO_{2b}$ is $CO_2$ Emissions in kg $CO_2$ the baseline scenario. | Investment: Total capital expenditure for implementing the open-loop heat pump in euros. | Energy Savings $= \left(\frac{E_{baseline} - E_{new}}{E_{baseline}}\right) \times 100$<br>Economic Savings $= (C_{baseline} - C_{new}) \times T$<br>$E_{baseline}$ is the annual energy consumption of the baseline system (kWh/year).<br>$E_{new}$ is the annual energy consumption after implementing the new technology (kWh/year).<br>$C_{baseline}$ is the annual operating cost of the baseline system (€).<br>$C_{new}$ is the annual operating cost after implementing the new technology (€).<br>T: Operational period (years). | **Dependence on Aquifers:** Requires access to adequate groundwater resources, limiting applicability in regions lacking sufficient subterranean water.<br>**Environmental Impact Evaluation:** The extraction and reinjection thermal impact must be assessed. |

# Implementation protocol

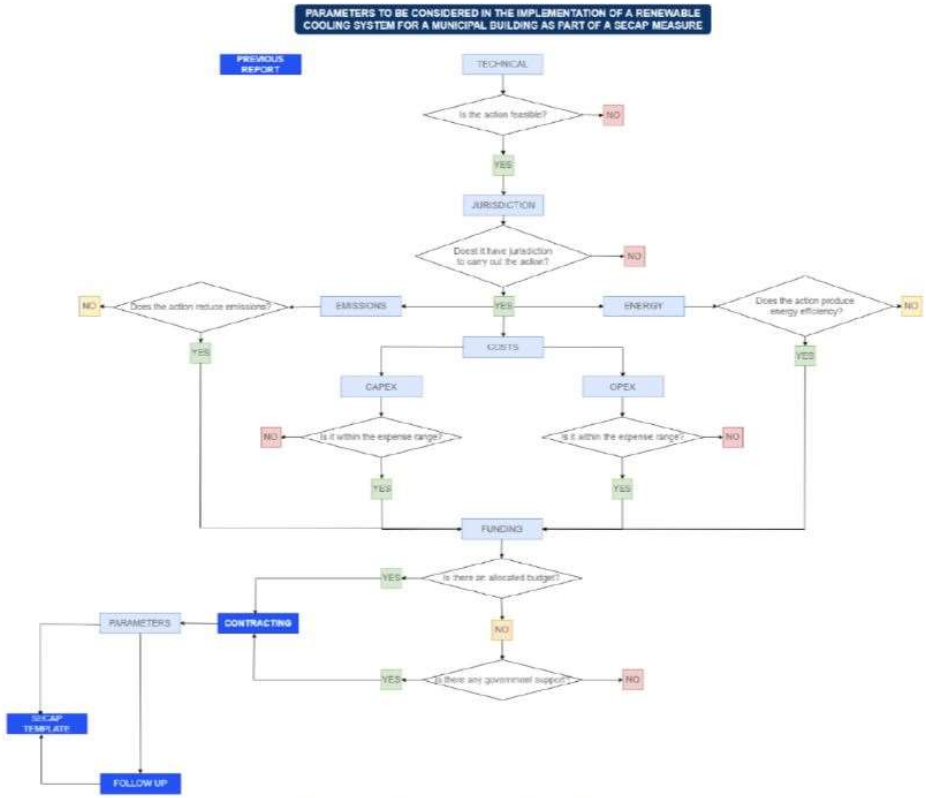
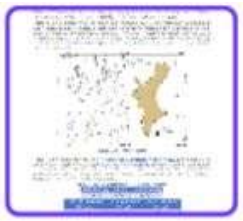



*Figure 27: SITE implementation protocol*



Valencia. This substitution maintains the integrity and applicability of the project's findings, demonstrating the flexibility and scalability of the developed methodologies.

Paterna is a municipality in the province of Valencia, part of the Valencian Community in Spain. Located approximately 5 kilometers northwest of Valencia city, it covers an area of about 36.8 square kilometers (see Figure 29). As of 2023, Paterna has a population of 73,389 inhabitants. The town is known for its historical heritage, including the Torre de Paterna and the Cuevas de la Torre. Paterna experiences a Mediterranean climate, with hot, dry summers and mild, wet winters.

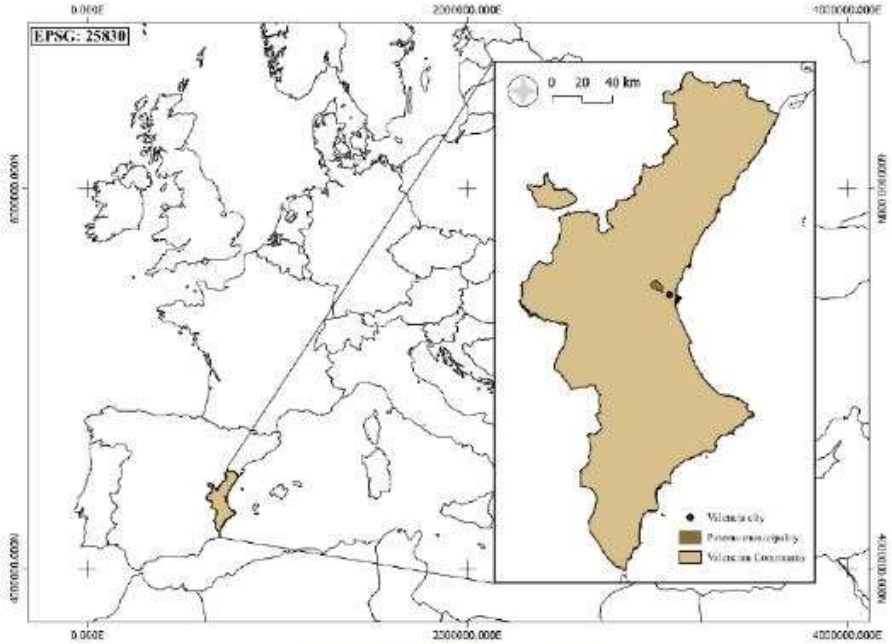



*Figure 29: Location of Paterna*

Table 10 shows the main results of its latest GHG emission inventory (2022), the gross GHG emissions of Paterna were 341.20 $ktCO_2eq$, while sequestration was -4.06 $ktCO_2eq$ through the forest sector, wood products, and agriculture. Therefore, the net GHG emissions for Paterna were 337.14 $ktCO_2eq$ (see Annex 3: Inventory of emissions from the municipality of Paterna (in Spanish) for further information).

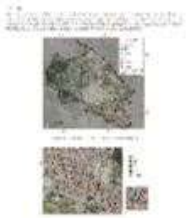
*Table 10: Main parameters from GHG emission inventory*

| Population (p.) | Area (ha) | Gross Income (€) |
|---|---|---|
| 70,195 | 3,585 | 26,956 |

| Gross GHG Emissions ($ktCO_2eq$) | GHG Sequestration | Net GHG Emissions ($ktCO_2eq$) |
|---|---|---|
| 341.20 | -4.06 | 337.14 |

GHG Inventoire






- **Agriculture**: 3.26%

The sectoral distribution of quantified GHG emissions is shown in Table 11, prioritizing the most relevant indicators. In Paterna, the top 10 indicators account for 69.13% of total GHG emissions.

*Table 11: Top 10 GHG emissions indicators of Paterna*

| Indicator | Emissions ($ktCO_2eq$) | Percentage |
|---|---|---|
| 2.2.1 - Automobiles (Private) | 75.76 | 22.20% |
| 2.6.2 - Industrial Tractors (Non-public) | 25.72 | 7.54% |
| 1.3.2 - Residential (Fuel Burning) | 23.96 | 7.02% |
| 2.2.3 - Heavy-duty Service Trucks | 20.73 | 6.07% |
| 1.7.2 - Industrial (Electricity Use) | 18.88 | 5.53% |
| 1.7.2 - Industrial (Electricity Use) | 18.88 | 5.53% |
| 3.6.1 - Global Refrigeration & A/C | 14.88 | 4.36% |
| 1.7.3 - Commercial/Institutional (Electricity) | 14.76 | 4.33% |
| 1.2.3 - Chemicals (Fuel Burning) | 14.62 | 4.28% |
| 1.7.1 - Residential (Electricity Use) | 13.93 | 4.08% |
| 1.3.1 - Commercial/Institutional (Fuel Burning) | 12.65 | 3.71% |

Table 12 reflects energy consumption and $CO_2$ emissions across various consumer groups as part of the refrigeration-focused action plan specifically for municipal buildings. Only relevant entries are included to support targeted measures within municipal facilities.

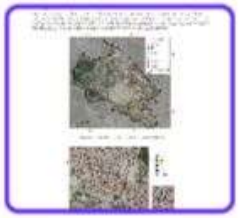
*Table 12: Energy consumption and $CO_2$ emissions of different consumer groups*

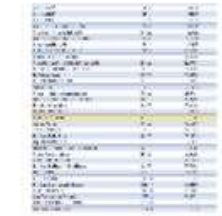
| Consumer Group | Consumption Type | MWh | % of Total Energy Consumed | $tCO_2$ |
|---|---|---|---|---|
| Mobility | Thermal | 488,826.8 | 43.07% | 130,516.8 |
| Industrial Sector | Electric & Thermal | 225,681.8 | 19.88% | 74,653.7 |
| Residential Sector | Electric & Thermal | 166,904.6 | 14.71% | 57,890.8 |
| Tertiary Sector | Electric | 121,628.7 | 10.72% | 53,881.5 |
| Agricultural Sector | Thermal | 58,619.4 | 5.16% | 15,651.4 |
| Public Installations (Lighting & Public Buildings) | Electric & Thermal | 45,704.5 | 4.03% | 15,540.3 |
| Other Consumer Groups | Electric | 24,457.8 | 2.15% | 10,834.8 |
| Water Treatment Plant | Electric | 3,137.6 | 0.28% | 1,390.0 |

Building upon the data presented in the previous table, a detailed analysis of the 'Public Installations' consumer group, specifically municipal buildings, is conducted to assess energy

## Impact on Mitigation








buildings.

By concentrating on these municipal structures, opportunities for enhancing energy efficiency and implementing sustainable cooling solutions can be identified. This targeted approach not only contributes to the municipality's overall energy reduction goals but also serves as a model for other public installations aiming to optimize their energy consumption.

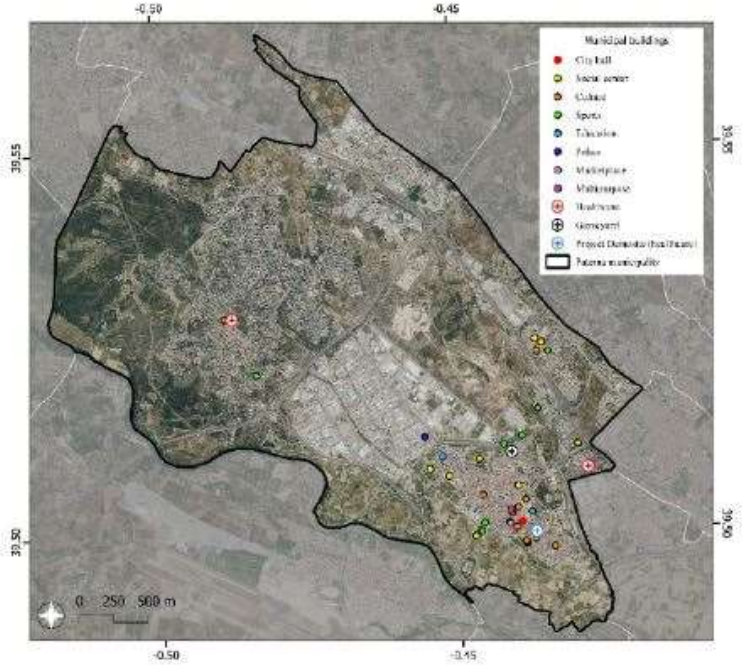



*Figure 30: Distribution of Municipal Buildings of Paterna*

This visual representation facilitates the identification of buildings with significant cooling needs, allowing targeted interventions to improve energy efficiency and reduce overall consumption (see a summary in Table 13). The information obtained from this simulation is fundamental for the strategic planning of sustainable cooling solutions in the municipality.

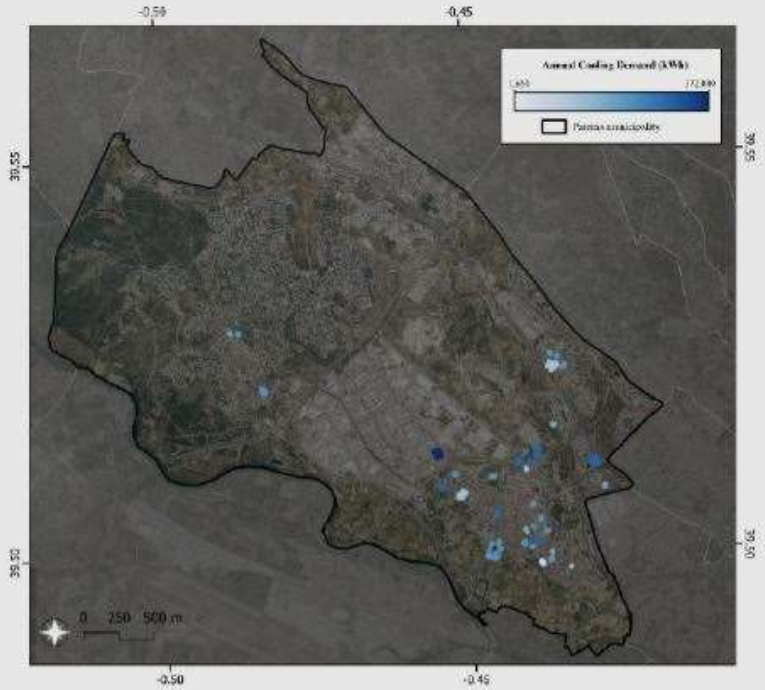


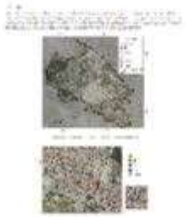

*Figure 32: Cooling demand intensity of municipal buildings*

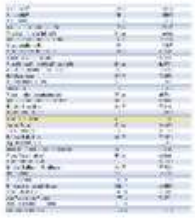
Target assesment

| | | |
|---|---|---|
| Coves del BatA | 91.00 | 1,899.39 |
| Coves del BatĀ | 91.00 | 1,908.79 |
| Coves del BatĀ | 99.00 | 2,109.08 |
| Agencia de lectura municipal La Coma | 77.33 | 5,828.19 |
| Cementerio Municipal de Paterna | 178.00 | 8,270.49 |
| Agencia de lectura municipal Campament | 92.00 | 9,034.29 |
| Centro Social Santa Rita | 99.22 | 9,940.72 |
| Centro de la Corda Pepin Damian | 85.00 | 11,466.07 |
| Consultorio medico Terramelar | 159.00 | 12,356.69 |
| Consultorio auxiliar de Paterna Campamento | 210.00 | 13,370.00 |
| Biblioteca Publica Municipal La Canyada | 203.00 | 23,074.90 |
| Edificio multiusos | 207.00 | 23,907.95 |
| Polideportivo Valterna Nord | 683.00 | 29,732.80 |
| Teatro Capri | 196.00 | 31,745.24 |
| Centro social de conductas adictivas | 581.00 | 31,875.73 |
| Agencia de lectura municipal Terramelar | 569.00 | 31,963.04 |
| Biblioteca la Cova Gran | 806.00 | 35,311.91 |
| Escola Personas Adultes | 440.00 | 38,472.19 |
| ***Centro social La Coma*** | ***425.00*** | ***45,772.41*** |
| Torre de Paterna | 101.00 | 49,510.69 |
| Sala estudio Arcoiris | 740.00 | 56,113.86 |
| Polideportivo La Coma | 891.00 | 56,207.19 |
| Esport Paterna C Cristo | 775.00 | 56,589.52 |
| Museo Municipal de la Ceramica de Paterna | 445.00 | 62,624.67 |
| Centre Polivalent Alborgi | 296.00 | 63,355.27 |
| Centro Salud La Canyada | 712.00 | 65,875.26 |
| Polideportivo Municipal Ctra Manises | 960.00 | 69,733.64 |
| Mercat Municipal | 636.00 | 74,717.80 |
| Casa de la Juventud | 1194.00 | 80,122.76 |
| Polideportivo y piscina La Canyada | 2615.00 | 80,633.92 |
| Centro Social Ctra Manises | 1862.00 | 91,842.94 |
| Gran Teatro Antonio Ferrandis | 1362.00 | 94,477.22 |
| Piscina climatizada casco urbano | [illegible] | 114,722.45 |
| Ayuntamiento de Paterna | 1301.00 | 127,641.24 |

Impact optimization








municipality's Sustainable Energy and Climate Action Plan (SECAP).

*Table 14: Input Data for SITE Analysis*

| Indicator | Data Source |
|---|---|
| **Renewable Cooling Energy** | Derived from EUReCA simulations using cadastral data of the building. Renewable Factor based on system SEER values (requires a technical report on the heat pump system SEER) |
| **$CO_2$ Emission Conversion Factors** | Ministry's emission factor document. Source |
| **Non-Renewable Primary Energy Conversion Factor** | Ministry's official document for primary energy conversion factors. Source |
| **Electricity Cost** | Current electricity tariffs. Source |
| **Urban Heat Island (UHI) Effect** | Heat map from the Institute for Energy Diversification and Saving (IDAE). See Figure 34. Source |
| **Seasonal Energy Efficiency Ratio (SEER)** | Efficiency obtained from the geothermal potential study of the installation. |
| **Investment (€)** | Project budgeting. Results from D4.2 "Report of novel business models for solar and geothermal cooling" of the project |
| **Baseline** | An air-source heat pump with a Seasonal Energy Efficiency Ratio (SEER) of approximately 2.2, which is typical for older systems operating in very hot climates with high summer temperatures |

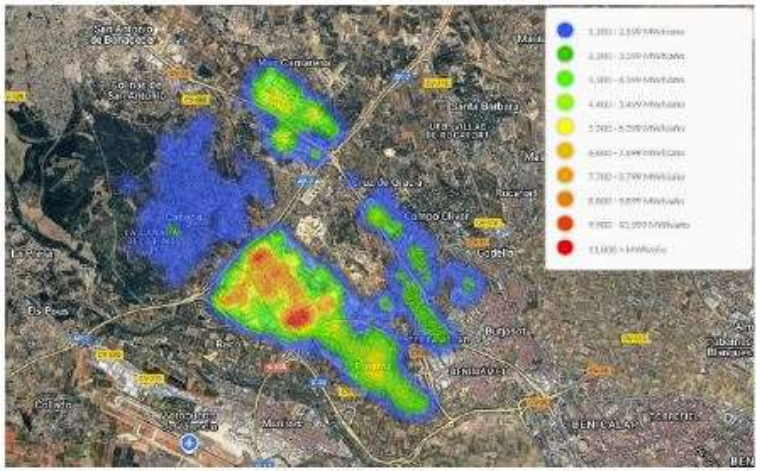


*Figure 34: Heat Map of Paterna*

## Monitoring

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# Thanks for watching!

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