# Making EU policies fit for sustainable space cooling: first reducing the needs by adopting a systemic view

Simon Pezzutto, Flavia Trovalusci (EURAC)
Jean-Sébastien Broc, Indriany Lionggo, Dimitris Athanasiou, Jérémy Clero (IEECP)
Giulia Conforto (E-THINK)
Bruno Duplessis (ARMINES / Mines Paristech)

## Abstract

Final energy consumption for space cooling in residential buildings tripled between 2010 and 2019 in the 19 euro-area countries, while households' equipment rate in air conditioning in Europe rose from 14% in 2010 to about 20% in 2019. Cooling alone accounts for around 4% of final energy demand in the EU, with 106 TWh for space cooling and about 110 TWh for process cooling complemented by 0,6 TWh for district cooling. More frequent and intense heat waves accelerate this trend, and contribute to peak loads, and even power cuts. Above all, this represents a major risk for health, with over 70,000 excess deaths in Europe in 2003, and more than 60,000 in 2022. Heatwaves cause about 90% of fatalities related to climate-related extreme events.

Summer comfort is thus a major challenge for both, mitigation and adaptation policies. Policies for space cooling may be too much focused on cooling technologies, overlooking solutions to avoid, or at least minimise, cooling needs while ensuring summer comfort. Cooling demand is indeed influenced by various factors beyond cooling devices' efficiency, including passive architecture building design based on bioclimatic principles, urban environment (e.g. urban heat island) and behaviours.

This paper reviews how space cooling is addressed in the EU policy framework, including changes brought by the fit-for-55 package. The paper then analyses policies and strategies of the five countries with the largest cooling demand (Spain, France, Italy, Germany, Greece), focusing on national building regulations, comprehensive assessments on heating and cooling, draft updates of National Energy and Climate Plans, and National Adaptation Strategies and Plans. These analyses are crossed with a scouting of solutions for sustainable space cooling, to discuss their coverage in the current EU policy framework. We conclude that a shift may be needed in the policy framework to prioritise first measures that can minimise cooling needs, acknowledging that their implementation implies a coordination between EU, national and local policies, as the local level can best take into account local climate conditions and adapt urban planning.

## Introduction

Final energy consumption for space cooling in residential buildings tripled between 2010 and 2019 in the 19 euro-area countries (Eurostat)[1], while households' equipment rate in air conditioning in Europe rose from 14% in 2010 to about 20% in 2019 (ODYSSEE). Cooling alone accounts for around 4% of EU final energy in 2016, with 106 TWh for space cooling and about 110 TWh for process cooling complemented by 0.6 TWh for district cooling (Gerard et al. 2022). More frequent and intense heat waves accelerate this trend, and contribute to peak loads, and even power cuts such as in Italy in summer 2023[2]. Above all, this represents a major risk for health, with over 70,000 excess deaths in Europe in 2003, and more than 60,000 in 2022 (Ballester et al. 2023). Heatwaves would cause about 90% of fatalities related to climate-related extreme events (Quefelec 2023).

Summer comfort is thus a major challenge for both, mitigation and adaptation policies. Lizana et al. (2022) highlighted that policies for space cooling tend to be too much focused on cooling technologies, overlooking solutions to avoid, or at least minimise, cooling needs while ensuring summer comfort. Cooling demand is indeed influenced by various factors beyond cooling devices' efficiency, including bioclimatic architecture principles in buildings' design, urban environment (e.g. urban heat island) and behaviours.

[1] https://www.eea.europa.eu/publications/cooling-buildings-sustainably-in-europe/cooling-buildings-sustainably-in-europe
[2] https://www.theguardian.com/world/2003/jun/27/italy

This paper summarises preliminary findings of the CoolLIFE project[3] (November 2022 – October 2025) about policies for sustainable space cooling, with the aim to provide the ground for experience sharing and identify how policies could be improved to ensure summer comfort in a sustainable way. The paper starts with reviewing how space cooling is addressed in the EU policy framework, including changes brought by the fit-for-55 package. It then looks more specifically at the five countries with the largest energy consumption for space cooling (Spain, Italy, France, Greece, Germany), analysing key national planning documents relevant to space cooling and available for all Member States, and whether links are made between mitigation and adaptation plans. This is then crossed with a scouting of solutions for sustainable space cooling, to discuss how a systemic approach could be promoted, prioritising solutions to minimise cooling needs.

## Space cooling in the EU policy framework

In this paper, we focus the analysis of the EU policy framework on its parts that include provisions specific to space cooling. For example, we do not discuss policies for building renovation in general. More information and analysis about financing schemes for building renovation can be found in (Conforto and Hummel 2024).

### *The 2016 heating and cooling strategy*

The European Commission published in February 2016 an EU strategy on heating and cooling[4], with the aim to better integrate efficient heating and cooling into EU energy policies, especially in the Clean Energy for all Europeans' package. The strategy is not limited to space heating and cooling. It also covers industrial use of heating and cooling, and refrigeration systems in services. Still, buildings represent a major sector of its scope. The main axes highlighted about space heating and cooling include the renovation of buildings (especially improving the building envelope), increasing and decarbonising heating and cooling systems, and increasing the share of RES (Renewable Energy Sources) in the heating and cooling supply.

The analyses and recommendations are mostly focused on space heating, as it is the largest energy use in buildings. The strategy mentions a few solutions for space cooling (well-designed street vegetation, green roofs and walls, shading, innovative low energy cooling technologies). In terms of EU policies in place at that time, the only ones that were specific (or strongly related) to space cooling were about cooling systems: the Regulation (EU) 517/2014 on fluorinated greenhouse gases, and the ecodesign regulations for air conditioners and comfort fans (Regulation (EU) 206/2012) and for cooling products (Regulation (EU) 2016/2281).

The strategy included a few recommendations to Member States (e.g. about addressing split incentives or energy poverty). Most of the actions suggested at EU level were related to the legislative proposals made in the Clean Energy for all Europeans' package. Some could contribute to reduce energy consumption for space cooling, mostly through boosting building renovations. Only few provisions were specific to space cooling.

In terms of planning and implementation at national level, the strategy made the link with the upcoming National Energy and Climate Plans (NECPs) that were part of the proposal for the Governance Regulation of the Energy Union. The strategy mentioned that the NECPs should integrate the heating and cooling sector.

The strategy was complemented with an accompanying document in two parts. The first part provided a detailed analysis of energy consumption for heating and cooling, and an overview of heating and cooling technologies. It estimated the energy consumption for space cooling in EU buildings at that time: 18.6 TWh for the residential sector and 100.6 TWh for the services sector. It discussed a possible exponential growth based on recent trends, also pointing to the large uncertainty about future cooling demand. The second part included a focus on cooling technologies, pointing out the expected increase in the sales of residential air conditioning units from about 3 million units per year in 2010, to 4.5 million by 2030. Italy, Spain, Greece and France together accounted for the majority of sales in the EU. However, this growth in the equipment rate was expected to be compensated by energy efficiency improvements from the ecodesign requirements and energy labels.

The accompanying document raised the issue that improved building insulation may lead to higher indoor temperatures in summer, generating higher cooling demands. Which can be mitigated by a building design or renovation taking into account local climate conditions (e.g. with a better integration of natural ventilation).

The document also pointed out the development of summer peak load, with the examples of Spain in July 2015 where very high temperatures created a surge of 8% in electrical demand due to air conditioning, and Italy where since 2006 the summer daily peaks in electricity demand were higher than winter peaks. Examples of measures

[3] https://coollife.revolve.media/

[4] COM(2016) 51 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1575551754568&uri=CELEX:52016DC0051

to address these summer peaks were mentioned from Australia that required the inclusion of a demand-response enabling device in all household air-conditioners sold since 2011, and the development of a standard for demand-response interface for air-conditioners, facilitating the reception and response to energy utilities' signals that provide an incentive to consumers who accept the remote control of their air conditioner in case of peaks.

The document mentioned a few examples of national plans or strategies for heating and cooling. It is noticeable that all were heat plans or strategies, with only minor aspects related to space cooling (if any). When data or provisions about space cooling were included, this was often due to the comprehensive assessment required by the Energy Efficiency Directive (EED).

The EU strategy on heating and cooling has not been revised. But the Commission has published several studies providing updates about developments and possible future pathways (see for example Braungardt et al. 2023).

## *From the equipment to the building level and supply efficiency*

**Two key issues at the equipment level: their energy efficiency and the refrigerants they use**

About energy efficiency, the EU legislation ensures the information of consumers through the Energy Labelling Directive, that established the first energy labels for room air conditioners in 2003, with minimum requirements on energy labelling of air conditioners coming into force in 2011 (cf. Regulation (EU) No 626/2011). Minimum energy performance requirements for small air conditioners and comfort fans were first introduced in 2012 by the ecodesign regulation (EU) No 206/2012, further updated in 2014 and 2018. This regulation was expected to save 11 TWh/year by 2020. Larger air conditioners (capacity larger than 12 kW) are covered by the ecodesign regulation on air-heating and cooling products ((EU) 2016/2281). A joint revision of the energy labelling and ecodesign regulations for air conditioners and comfort fans was on-going in 2023, with an adoption of the new regulations planned for 2024[5]. This revision aims, among other objectives, at increasing consistency between both regulations and making it easier for consumers to compare products, improving the method to calculate products' energy efficiency and remove the least efficient products from the market (Huang et al. 2018).

The Energy Performance of Buildings Directive (EPBD) also includes requirements for cooling systems, once in use, with mandatory regular inspections for large air-conditioning systems, and provisions for the installation of building automation and control systems and devices that regulate temperature at room level.

About refrigerants, the major concern is due to their very high Global Warming Potential (GWP), that can be from 1000 to 10000 times the one of $CO_2$. The EU Regulation 842/2006 thus introduced requirements to reduce leakages of HFCs from refrigeration and air-conditioning systems, for example with mandatory training of technicians and mandatory leak testing of large systems. This regulation was repealed by the EU Regulation 517/2014 (F-gas regulation) setting the ground for an overall phase-down of the quantity of HFC refrigerant that can be sold in the EU (79% decrease by 2030) and bans on certain refrigerants in specific applications. The new regulation was meant to stimulate a progressive shift to low GWP alternatives.

The energy labelling, ecodesign and F-gas regulations are directly imposed in the Member States. According to the review of the energy labelling and ecodesign regulations for air conditioners and comfort fans done in 2018 (Huang et al. 2018), there is therefore no other major legislation at national level about energy requirements for air conditioners. This review mentions that some countries have previously implemented alternative ecolabels and different taxes to limit the use of fluorinated greenhouse gases.

**Space cooling not very visible in the energy performance requirements and renovation of buildings**

The EPBD is the key European legislative framework for boosting the energy performance of buildings, considering five main end-uses that include space cooling and ventilation, through a broad range of policies and support measures aiming to the decarbonisation of the EU building stock by 2050. The EPBD requires that Member States set cost-optimal minimum energy performance requirements for new buildings (that must be nearly zero-energy buildings), for existing buildings undergoing major renovation and for the replacement or retrofit of building elements, including for heating and cooling systems, roofs and walls. The EPBD does not set requirements specific to space cooling. Each Member State is free to set such requirements in its building regulations. The new recast of the EPBD keeps this flexibility but highlights more explicitly the need to consider summer comfort (see more details below about space cooling in national regulations).

Low thermal performance and poor building quality can contribute to overheating risks and uncontrolled increasing energy consumption for cooling. Most of the EU's building stock was constructed before thermal standards were introduced, and nearly 75% of the stock is energy inefficient. In 2020, between 5% and 39% of

[5] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13358-Energy-efficiency-ecodesign-rules-for-air-to-air-conditioners-air-to-air-heat-pumps-and-comfort-fans-review-_en

the population, depending on the Member State, lived in dwellings with leaking roofs, damp walls, floors or foundations, or rot in window frames or floors, according to Eurostat. Newly constructed or renovated buildings can also overheat, even if they are well insulated.

The EPBD includes provisions for long-term renovation strategies (LTRS), now Building Renovation Plans (BRP), for the transformation of existing buildings into nearly zero-energy buildings, which implicitly covers the same end-uses as for building regulations (i.e. including space cooling). The LTRS or BRP provisions do not include specific requirements for renovation schemes to address space cooling or summer comfort, nor to consider future climates (despite a short reference to health). Similarly, the Commission's communication on the Renovation Wave (COM(2020) 662 final) has one of its three focus areas about decarbonising heating and cooling. But it is in practice mostly about decarbonising heating, as cooling is mostly supplied from electricity. The impact thus mostly depends on how electricity is produced in each country. The communication includes "high health and environmental standards" among its key principles for building renovations, dealing among others with protection against climate-related hazards. The actions listed in the annex to the communication indeed include "supporting the development of climate-resilient building standards". The conclusion of the communication mentions that roofs and walls can contribute to improve the urban climate, for example by increasing their green surface. However, nor the EPBD as amended in 2018 nor the Renovation Wave's documents discuss the risk that renovation may worsen summer (dis)comfort, and thereby increase cooling needs, if it is not planned with both winter and summer comfort in mind.

**Energy efficiency in the cooling supply and decarbonisation of cooling**

The EED addresses efficiency in heating and cooling supply, especially by requiring Member States to prepare comprehensive assessments about heating and cooling. These assessments have been more detailed about heating than cooling. But it may contribute to identify the potential for district cooling. Member States are required to implement measures to support the development of district heating and cooling, where relevant.

The EED recast adopted in 2023 reinforced slightly only the link between the comprehensive assessments and the LTRS, by referring to the LTRS as inputs to be considered when assessing future energy demand. In parallel, the EED recast introduced new requirements for regional and local authorities to prepare local heating and cooling plans. This could be an opportunity for more integrated approach and a better consideration of local conditions, also thanks to a participatory process encouraged by the EED recast.

The EED recast strengthened the links between the EED comprehensive assessments and the assessments about potentials for renewable energy sources (required by the Renewable Energy Directive, RED), as both are now due as part of the NECP. In line with the Renovation Wave, there is also an obligation for Member States to design policies and measures for the decarbonisation of heating and cooling, including through district heating and cooling. But unlike heating, cooling typically does not involve the direct use of fossil fuels and currently 99% of cooling is electricity-driven. The key drivers for the decarbonisation of space cooling include first the reduction of space cooling demand, then the transformation of the electricity sector, increasing the share of cooling technologies using renewable heat or waste heat or cold, and thermal energy storage.

The definition and calculation methodology of renewable cooling has not yet been established due to so far relatively low statistical weight of cooling in overall EU energy consumption (even if in specific countries this share can be significant). The RED sets requirements and targets for increasing the share of renewable energy in cooling. This part of the policy framework goes beyond the scope of this paper.

## *The emerging link with adaptation*

**The EU framework on adaptation stressed the importance of considering climate resilience for buildings**

As part of a larger plan to lessen and prepare for climate change effects, the European Union has created a thorough policy framework that addresses climate adaptation. The relationship between cooling adaptation and the EU policy framework is varied, with a number of directives, initiatives, and papers, including the European Green Deal, 2030 Climate Target Plan, and EU Climate Law. Despite the efforts to mitigate climate change, the latest publications by the Intergovernmental Panel on Climate Change (see e.g., IPCC 2023) confirm that climate change effects are inescapable, including rising temperatures, increasing frequency and intensity of heat waves.

The European Commission adopted a new EU strategy on adaptation to climate change on 24 February 2021[6], reminding among other aspects that heatwaves are the "deadliest" of the climate disasters, and that creating more green spaces can reduce their impacts. But this type of solutions is "lagging behind". Therefore, one of the key objectives of the strategy is to accelerate the rollout of adaptation solutions and to reduce climate-related risks.

[6] COM/2021/82 final: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:82:FIN

More specifically about buildings, the Commission pointed out the need to "prepare Europe's building stock to withstand the impacts of climate change", making the link with the Renovation Wave. Examples include the use of green roofs and walls to reduce the effects of Urban Heat Islands (UHI), integrating climate resilience considerations in the revision of the EPBD and in procurement criteria for public buildings.

The European Climate Law (Regulation (EU) 2021/1119, Article 5(4)) requires Member States to adopt and implement National Adaptation Strategies and Plans (NAS/NAP), and to report about their implementation every two years. But there is no mandatory template for these NAS/NAP, and the list of information on adaptation actions set in Annex VIII of the Governance Regulation of the Energy Union remains very general.

Likewise, the mandatory template for the NECPs (see Annex I of the Governance Regulation) includes only a very short reference for Member States to include adaptation goals "if available". In practice, Member States' reporting on mitigation and adaptation is usually done separately: the NECPs are mostly focused on mitigation, while adaptation is addressed in the NAS/NAP. At the opposite, the Long-Term Strategies (LTS) about achieving carbon neutrality are supposed to include information on policies and measures for both mitigation and adaptation (see Annex IV of the Governance Regulation). But the template for the LTS is indicative, and the first LTS reported by Member States vary significantly in terms of levels of details and quality.

Overall, the importance to consider climate resilience and to develop actions to reduce the effects of heat waves is well acknowledged in the EU framework for adaptation. But in practice, the linkage between mitigation and adaptation policies and measures relevant to space cooling and summer comfort is still to be done.

**Points relevant to space cooling and summer comfort in the National Adaptation Strategies and Plans**

A review of Member States' NAS/NAP (Lionggo et al. 2023) showed that climate hazards and key topics of adaptation measures can be summarised in seven clusters, one being 'temperature variability' that includes heat waves. Each country has been analysed according to whether they include or exclude references to measures and actions for each cluster. All but one (Germany) of the countries analysed in this paper reported measures or actions to address heatwaves. Typical examples of linkage between adaptation measures and measures to reduce space cooling demand include adding provisions about green walls in building regulations, or introducing requirements that a minimum share of the building areas should be converted to green areas.

Another example from the review of national adaptation actions in 2023 is Austria's reporting that climate change and climate vulnerability, along with a decrease in heating energy consumption and an increase in cooling energy demand, are likely the causes of fluctuations in its energy demand. Austria also anticipated changes in the number of degree days for heating and cooling. France emphasised that uncontrolled air conditioning development may lead to new summer demand peaks. Portugal stated that in choosing mitigation strategies, the effects of climate change must be considered.

An indirect link with sustainable space cooling is that it is anticipated that there may be variations in the availability of RES (wind, solar, biomass, and hydropower) as a result of extreme weather events including floods, storms, and heavy precipitation, as well as decreased water availability, particularly during the summer (as stressed in the reporting of Austria, Greece, Spain and Sweden). As electricity is the main energy source for space cooling technologies, this may be an issue to ensure that space cooling consumption can be met with RES.

## *The EU framework mostly addresses space cooling as a technical or technological issue*

Lizana et al. (2022) pointed five main factors of the dominance of air-conditioners to meet cooling needs:

- building energy policies based only on energy efficiency
- air-conditioning considering only temperature rather than other thermal comfort parameters
- building-centric design instead of occupant-centric design
- businesses guided exclusively by product sales
- lack of innovation beyond the standard operational phase of incumbent technology

Some of the barriers and issues raised by Lizana et al. are addressed by the EU framework, such as the GWP of F-gases or removing the least efficient devices from the market. However, the EU framework does not really address other barriers or issues that are either not related to technology (e.g. user behaviour, other thermal comfort parameters than temperature), or about prioritising passive measures (usually related to adaptation) and complementing with actives measures (usually related to mitigation) when needed only. More generally, the EU framework is focused on regulating markets for products (e.g. air-conditioners) or buildings: it does not address conditions for the development of the market of cooling as a service (or thermal comfort as a service).

# Policies in the five Member States with the largest space cooling demand

## *Space cooling demand in the EU27*

The confluence of escalating temperatures, transformative shifts in building design, and an expanding inclination towards optimal thermal comfort has precipitated a surge in the demand for space cooling, reflecting the ever-increasing reliance on space cooling technologies for maintaining comfortable indoor environments. According to Pezzutto et al. (2022), the cumulative final energy consumption for space cooling, encapsulating both the residential and service sectors indicate for an aggregate annual consumption of 106 TWh in 2016. Cooling is currently 99% electricity-driven (vapor compression systems and heat pumps), such that unlike heating, cooling typically does not involve the direct use of fossil fuels. Only 1% is supplied by gas or heat driven cooling generators (absorption cooling) used mainly in industry and district cooling systems. The figure below shows final energy consumption for space cooling per country. It reveals a notable concentration within a small number of countries, meaning an uneven distribution of space cooling demand across the continent.

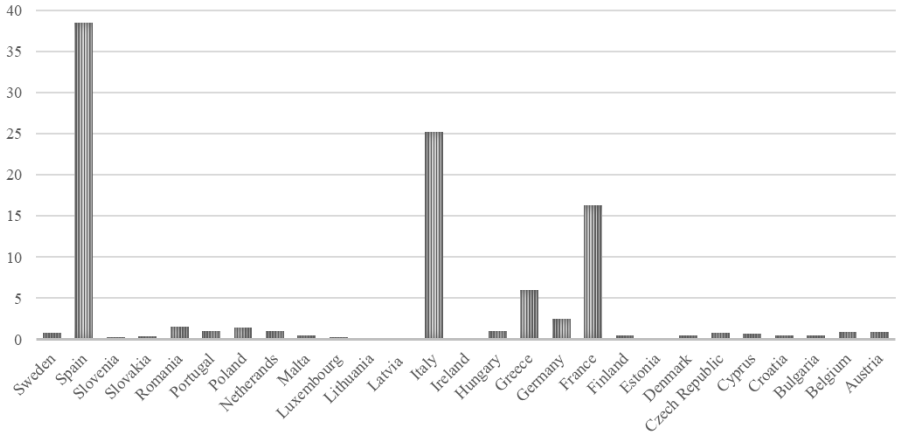


*Figure 1. Space cooling demand per country (in TWh/year) in the residential and service sectors in 2016 (EU27).*

More specifically, Spain, Italy, France, Greece, and Germany contribute altogether to over 86% of the total energy consumption for space cooling. This concentration underscores the influence of regional variations in climate, population density, and economic activities on the demand for space cooling solutions. In contrast, the remaining 22 Member States account for the remaining ca. 14%, reflecting a lower but still significant level of demand. This data underscores the imperative for policymakers and energy planners to consider these variations in formulating targeted strategies aimed at sustainable space cooling solutions in the diverse landscape of EU Member States.

The following sections focus on the five Member States with the most substantial cooling requirements: France, Germany, Greece, Italy and Spain. This review looked at contents about space cooling and summer comfort in the main strategic documents about energy planning and adaptation that are (1) relevant to space cooling and (2) systematically available for all Member States: national building regulations, comprehensive assessments on heating and cooling, draft NECP update, National Adaptation Strategies and Plans (NAS and NAP).

## *Space cooling in the national building regulations*

While the EPBD does not addresses space cooling separately, space cooling is included among the typical energy needs and the associated energy uses for the calculation of the energy performance of a building[7], a concept that applies both to heating and cooling. Thus, well-insulated buildings allow for more thermal comfort and lower energy consumption for both heating and cooling. More specifically about space cooling and summer comfort, national regulations may include:

- **Specific definitions about space cooling or summer comfort**: this is the case for France, Italy and Germany (no clear definition in Greece's and Spain's regulations that refer to thermal comfort in general).
- **Space cooling considerations in the calculation methodology, and minimum energy performance requirements in terms of maximum allowed cooling demand or related to space cooling or summer comfort, for new and existing buildings**: in line with the EPBD, space cooling is always included in the methodology for energy performance calculation for both residential and non-residential buildings, in terms

[7] space heating, space cooling, domestic hot water, ventilation, lighting and other technical building systems.

of global energy performance, without specific requirements on space cooling alone. Likewise, the minimum energy performance requirements are usually set in total energy demand, which includes cooling. Greece's regulation includes minimum efficiency requirements for cooling systems for new buildings and major renovations. France's regulation for new buildings set requirements to limit summer discomfort, defined by the number of degree-hours above a base temperature that should not be exceeded (per year). France's regulation for major renovations also includes cooling-related provisions (e.g. about sun shading).

- **Standard values about the use of space cooling** (e.g. indoor temperature setpoint): most countries set (mandatory or indicative) minimum temperature setpoints not to exceed (see table below).

**Table 1. Standard values about the use of space cooling in the national building regulation for the five countries with the largest cooling demand (Spain, France, Italy, Germany, Greece).**

| Spain | France | Italy | Germany | Greece |
|---|---|---|---|---|
| High and low setpoint temperatures (°C) for different months | Mandatory minimum temperature not to exceed (26°C) | Mandatory minimum temperature not to exceed (27°C) with 2°C tolerance (so real limit is 25°C), for non-residential buildings | Unclear | Indicatively 26°C for residential and 20-26°C for non-residential (depending on building usage) |

The recast of the EPBD states in a new recital[8] that "*priority should be given to strategies which enhance the thermal performance of buildings during the summer period, through measures which avoid overheating, such as shading and sufficient thermal capacity in the building construction, and further development and application of passive cooling techniques, primarily those that improve indoor environmental quality, the micro-climate around buildings and the urban heat island effect*". The upcoming revision of the national building regulations to align with the EPBD recast will be an important opportunity to ensure that cooling needs are thoroughly addressed for both, new buildings and renovation of existing buildings.

## *Space cooling in the comprehensive assessments of national heating and cooling potentials*

The review of the first comprehensive assessments (CAs) due by Member States in 2015 highlighted that the level of detail in describing the cooling demand was much lower than for heating demand. Nine reports even contained no description of cooling demand and 3 contained partial descriptions only. Nine countries only included cooling demand into the Cost-Benefit Analysis (CBA) (Jakubcionis et al. 2018). The review also stressed that information provided about policies and measures was mostly related with CHP and district heating. The amending EED adopted in 2018 and the complementary Commission's Recommendation (EU) 2019/1659 provided a clearer basis for the CAs due by Member States in 2020. The contents partly overlap with the requirements for NECP, first due in 2019 (e.g. about targets and policies and measures). Hence some Member States referring to the NECP in their CA. From 2024, the CAs should be part of the NECP which may solve this.

Looking at France, Germany, Greece, Italy and Spain, targets mentioned in the CAs are most often the general ones from the NECP, sometimes with an assessment of what share of the targets is expected to come from improvements in heating and cooling, but never setting targets specific to space cooling (nor even cooling[9]). About overall strategies, none of the CAs analysed refers to a national heating and/or cooling strategy. Instead, they refer to the NECP (or other national overall planning or climate law), sometimes also making the link with the long-term renovation strategy, previous National Renewable Energy Action Plan and/or National Energy Efficiency Action Plan (or similar national plans for RES and energy efficiency). This shows that the measures relevant to heating and cooling are integrated in the overall energy and climate planning and strategy. This may also be due to the absence of formal targets specific to heating and cooling.

Cooling demand is more frequently assessed in the second CAs than in the first CAs. But the focus is still on heating, especially when describing policies and measures, and even for the five countries with the largest cooling demand. This may be explained by the prominent weight of space heating compared to space cooling in the final energy consumption. Another explanation may be that cooling is not a direct challenge for decarbonisation (as mostly supplied from electricity), whereas heating remains a major source of direct $CO_2$ emissions. Data scarcity about cooling can also be an issue for estimating the demand, but should not be an argument for neglecting cooling in the policies and measures.

[8] Recital 52 of the public version from the provisional agreement between the Council and Parliament: https://data.consilium.europa.eu/doc/document/ST-16655-2023-INIT/en/pdf

[9] In the scope of the CAs, cooling is broader than space cooling and includes cooling processes in industry, refrigeration for wholesale and retail, etc.

About policies and measures, most of the CAs analysed cover a broad scope, for example including measures for energy efficiency in buildings (building codes and schemes for building renovation), promotion of RES (mostly for heating) and development of district heating (sometimes also district cooling). The link with space cooling is rarely explicit, except for some references to energy labelling and regulations for air conditioners or cooling products, measures to promote district heating and cooling (when district cooling is clearly mentioned), and measures for RES for cooling (mostly about geothermal). When discussing measures for building renovation, the focus is usually on reducing the heating demand, the possible impact on the cooling demand being rarely mentioned (the same for shading for example). The description of the renovation schemes mentions that actions related to space cooling are eligible only for one Spanish programme (National Housing Plan 2018-2021), where efficient air conditioners and connection to district cooling can be eligible. Spain's CA also mention a specific tax on fluorinated gases. It should be reminded that the information reported in the CAs do not necessarily reflect the whole policies and measures in place nor their details. For example, France mentioned its white certificates scheme, but without pointing that the catalogue of standardised actions eligible to this scheme includes action types about space cooling. Similarly for Italy and its tax credit where sun shading is eligible.

None of the CAs analysed made an explicit reference or link to adaptation strategy, plan or measures. Likewise, issues related to heat waves or urban heat islands are not mentioned. These points were not included in the Commission's Recommendation (EU) 2019/1659.

Looking forward, only a few of the announced new or planned measures had an explicit link with space cooling: update of the national regulation for thermal energy systems for buildings (Spain), measures to develop district cooling (France, Greece and Italy), specific consideration about the possible introduction of new limits on the use of cooling systems to be evaluated by defining restrictions related to the climate zone of reference (Italy).

### *Space cooling in the National Energy and Climate Plans*

The mandatory NECP template includes few points about cooling, and always jointly dealing with heating, except for the data of number of Cooling Degree Days. The other points are: target, trajectory and measures for RES for heating and cooling, possible energy efficiency objectives for heating and cooling, assessment of the necessity to build new infrastructure for district heating and cooling produced from renewable sources, and current potential for the application of high-efficiency cogeneration and efficient district heating and cooling (both related to the comprehensive assessments). The Commission's guidance (2022/C 495/02) for the update of the NECP due in June 2023 (draft) and June 2024 (final) does not include further elements about space cooling, except clarifying that the final NECP update should include the updated comprehensive assessment.

Consequently, the draft NECP updates do not include specific sections on cooling, and overall little information about space cooling and related objectives and measures, apart from the RES target for heating and cooling and possible measures to develop district heating and cooling that are also the few points on cooling in the Commission's EU-wide assessment of the draft NECP updates (COM(2023) 796 final)[10].

We focus here our findings from the targeted review of the draft NECP updates of France, Germany, Greece, Italy and Spain, on other examples of analysis or measures dealing with space cooling or summer comfort. The first one is common to the five countries, about the role that heat pumps could play to meet the cooling needs while contributing to the RES target. Most of the countries also refer to the F-gas regulation. France mentions a new tax to reduce the use of HFCs (but postponed to 2025). The analysis and details about the schemes for building renovation sometimes remind that they can contribute to reduce the space heating and cooling needs, and thereby the achievement of the RES target. But this analysis is likely more about space heating than space cooling (e.g. Italy's report). Then the draft NECP updates rarely include the actions related to space cooling and that could be eligible (case for the two main renovation schemes of Germany where ventilation systems and the replacement of windows and external doors to improve summer thermal insulation are eligible).

Another group of analysis or measures is about behaviours. France's energy sufficiency plan has been updated in June 2023 to take better account of summer comfort and promote 26°C as minimum temperature setpoint for air-conditioning. Interestingly, this is also the minimum setpoint mentioned in the building regulation. This communication thus implicitly acknowledges that usual behaviours are not in line with the assumptions of the building regulations. Italy's report briefly highlights the importance to raise consumer awareness and active role using, for example, home automation, network digitalisation and smart metering technologies.

Except Germany, the four other draft NECP updates include some discussions related to adaptation. France mentions that its new building regulation (RE2020) considers the need to adapt living and working space to future climatic conditions and especially for summer comfort. Italy's requirements for nearly zero energy

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:796:FIN

buildings include a criterion on "summer equivalent solar area per useful floor area", and the next revision of the building regulations may consider introducing new limits on the use of cooling systems according to the climate zones (e.g. about days of use, times, temperature setpoints). Similarly, Greece mentions the need to revise the building regulations and to adapt urban planning considering the already occurring impacts of climate change, speaking of the thermal environment in cities. Greece refers to sound urban and architectural bioclimate planning and the use of sustainable materials in bioclimate planning (cool materials, shading structures, vegetation), mentioning examples such as urban green areas (e.g. green routes and urban green canyons). The issue of higher summer energy needs is also raised due to the importance of the tourism sector in the Greek economy. More generally, the analysis of the risk to the electricity system due to increasing summer peak loads is highlighted in Italy's report, mentioning the risks of black-out. A link can then be found between the expected increase in summer peak load and the development of measures for demand-side management that covers space cooling (often among other end-uses). A measure under consideration in France is for example economic incentives or regulatory obligations for the piloting of new equipment (including air-conditioning systems).

The draft NECP updates are not comprehensive about all measures or initiatives relevant to space cooling. First because they cover all dimensions of the Energy Union and cannot therefore provide details about all issues: they focus on the main measures to meet the EU obligations and targets. Second because they tend to focus on government-led and national measures. They rarely inventory measures of local authorities, or accompanying measures developed by public agencies or other stakeholders. The European project CoolLIFE is therefore collecting good practices about measures for sustainable space cooling, to fill the gap about experience sharing in this field. One example of good practice not included in the draft NECP updates is the online platform 'Cooler my city' developed by ADEME in France[11].

### *Actions and measures relevant to summer comfort in the NAS/NAP*

Following the identification of priority areas, Member States incorporate their adaptation methods into more comprehensive national policies. NAS/NAP consists of specific actions and adaptation strategies, such as climate-resilient infrastructure in the building sector and sustainable land-use planning techniques.

In France, special attention is given to collective buildings to prevent the penetration of solar radiation, mostly from glass window facades. Potential tax incentives, such as tax credits, have been considered for contributing to enhancing summer thermal comfort in residential and commercial buildings through the use of energy-efficient devices such as blinds, green rooftops, and vertical gardens. France's heat wave action plan ("Plan Canicule"[12]) is a comprehensive approach designed to protect vulnerable populations during hot periods. It has a four-level colour-coded alarm system based on temperature thresholds. The measures include campaigns for public awareness, house calls, public cooling centres, healthcare readiness, and data tracking. Several cities in Italy, Germany and Portugal are following France's step to keep track of citizens vulnerable to heatwaves and promote solidarity networks to ensure no one is left behind. Greek cities are adapting urban planning to improve the thermal environment by updating the building regulations (K.Ev.A.K.[13]). The plan includes appropriate architectural redesign of spaces and the integration of greenery into existing structures (ceilings, vertical surfaces, etc.) as a priority.

Spatial cooling measures have also been implemented in Spain, where Northern Spain utilises the 'right to the sun' methodology, employing specific relationships with the sun to design buildings, streets, and vegetation. The transformation towards the integral improvement of buildings and the establishment and maintenance of adequate habitability conditions requires diverse resources and solutions to make buildings more climate-proof.

Beyond the five countries with the largest cooling needs, another interesting example is Austria, which aims to implement structural measures to ensure thermal comfort by utilising alternative cooling technologies to improve thermal efficiency. Anticipating a rise in demand for cooling, the Austrian government implemented the so-called passive cooling strategies as one of the construction measures, as well as optimising building orientation to enable natural ventilation. Austria put in place numerous support schemes to encourage the construction and restoration of environmentally efficient and climate-friendly buildings. Efficient energy use, building cooling, thermal rehabilitation (including shade systems), and information and awareness-raising campaigns, including health aspects and guidance for individuals at higher risk of heatstroke, are all important aspects of adaptation.

[11] Platform in French, meant to support local authorities: https://plusfraichemaville.fr/
[12] France's heatwave action plan: https://www.gouvernement.fr/risques/se-preparer-a-une-situation-durgence
[13] See: https://www.kenak.gr/

# Is the current policy framework suitable for promoting sustainable cooling solutions?

## *Overview of sustainable cooling solutions*

Air-conditioning systems relying on vapour compression technology represent almost the only cost-efficient systems on the current market. Only a very small part of the market (about 1%) is made of thermally-driven heat pumps (Elnagar et al. 2023). Elnagar et al. also provide a comprehensive understanding of the most promising solutions to supply space cooling. Although there are many alternative technologies with a large range of capacities and promising higher (even very higher) energy efficiency, their work show that these technologies still have either technological scalability or cost-efficiency barriers to unlock before challenging the current technologies. Nevertheless, over the next decade, vapour compression technologies could undergo profound changes as a result of developments in European regulations on fluorinated gases (European Parliament, 2024).

Among active measures that aim at mitigating space cooling demand, advanced technological measures, such as smart-glazing, active shading devices and adaptive façades, have investment costs that prevent them from being widely used, particularly in existing buildings (Duplessis et al. 2024). In contrast, as long as cooling demand is not excessive, ceiling or room fans demonstrate superior adaptability and suitability for supplying cost-effective thermal comfort in summer, especially when passive measures like (manual) shading devices and/or natural ventilation strategies are implemented by the room occupants (Hurtado-Verazaín et al. 2023). Other passive measures are still under development or require a significative change in structure to be implemented in existing buildings.

Duplessis et al. (2024) have also assessed the costs and benefits of a set of measures and technologies supplying space cooling. Their work highlights that the relevant solution for space cooling supply strongly depends on the building environment and the urban context, as well as the occupants' sensitivity to discomfort. In this way, defining an optimal cooling strategy is definitively a challenge that requires further research, taking greater account of the diversity of occupants, building types and their environment.

## *Crossing the set of solutions and the set of policies*

The table below summarises the current coverage of the main solutions or issues relevant to space cooling, by the EU policy framework.

**Table 2. Current coverage of the space cooling solutions by the EU policy framework.**

| Solutions or issues | EU legislation and initiatives |
|---|---|
| Vapour compression systems and heat pumps | Energy labelling and ecodesign regulations aim at removing most inefficient systems from the market and promoting the most efficient ones. Updated regulations to be adopted in 2024.<br>EU Heat Pump Action Plan to be adopted in 2024 |
| Fluorinated gases | F-gas regulation (EU 517/2014) aims at overall phase-down of the quantity of HFC refrigerant.<br>Revision of the F-gas regulation now adopted and to be published soon. |
| Alternatives to F-gas systems | Alternatives to the use of fluorinated gases encouraged by the F-gas regulations. EU research and innovation programmes may be used to develop them. But no flagship initiative in this field. |
| Ceiling or room fans | Energy labelling and ecodesign regulations aim at removing most inefficient systems from the market and promoting the most efficient ones. Updated regulations to be adopted in 2024. |
| Active measures to mitigate cooling demand and other passive measures. | For new buildings, in theory encouraged by energy requirements, but in practice often no specific requirement on space cooling. Further support measures may be needed.<br>Rarely considered in renovation schemes. Further analyses could be helpful to identify when additional costs can be reduced, according to the type of renovation projects. |
| Risk of renovations worsening summer comfort | Issue raised in the 2016 EU strategy on heating and cooling. But it is not explicitly covered in the EPBD provisions nor in the Renovation Wave's communication. The former mentions the issues of 'inadequate ventilation' and 'healthy indoor climate conditions' (about energy performance requirements). The latter considered the development of climate-resilient building standards. |
| Behavioural measures | The EED and EPBD include general provisions on consumer information. Measures specific to space cooling and summer comfort may be implemented at national or local level. |
| Solutions to reduce urban heat islands | Briefly mentioned in the 2016 EU strategy on heating and cooling, in the Renovation Wave's communication and now in the EPBD recast, but no measure or provision at EU level to promote them. These solutions may however be part of national adaptation strategies and plans, required by the EU Climate Law. |
| District cooling | The provisions of the EED about efficiency in cooling supply specify a definition for efficient district heating and cooling, and require Member States to assess potential for district cooling and adopt supporting measures when relevant. |

| | |
|---|---|
| RES for cooling | The RED set a target and requirements to increase the share of RES in heating and cooling. In practice, this mostly applies to heating (due to space cooling being mostly electrified). |

## Conclusion and discussion

The shift to an integrated reporting of all the dimensions of the Energy Union means that the main national planning document reported in the EU context (NECP) does not enter into the details of each and every topic, and particularly of topics such as space cooling that, despite its growth, represents a small share of most Member States' final energy consumption, and is already almost fully electrified (so not a major direct challenge for decarbonisation, apart from that of electricity production itself). Still, space cooling is already an important issue for security of electricity supply in a few countries (e.g. Greece, Italy and Spain) already facing significant increases in summer peak loads. National adaptation strategies and plans also often raise increasing summer temperatures and heat waves as major changes to anticipate, emphasising the impacts on health as well as economic activity (e.g. tourism). More integrated approaches for summer comfort would be needed.

The EU framework covers the dominant space cooling technologies (vapour compression systems) with regulations to remove the least efficient devices from the market, inform consumers about the efficiency and consumption of the devices, and plan the phase out from fluorinated gases (due to their very high GWP). Updates of these regulations should soon be adopted to strengthen the requirements and stimulate the developments of more efficient and climate-friendly alternatives. A recent review of space cooling technologies however showed that these alternatives are rarely ready to be massively deployed. Policy measures to complement the regulations may therefore be needed.

At building level, while space cooling is assumed to be included in the energy performance calculations and requirements due to the EPBD, the way it is addressed in national building regulations may vary among countries. The EPBD recast emphasises the need to consider summer comfort. Its transposition could be an opportunity to enhance the requirements to minimise cooling needs in new buildings, and to ensure that major renovations do not worsen the conditions for summer comfort. The development of climate-resilient building regulations could help to address these issues.

At urban level, the EED promotes the development of district cooling which remains rare so far. But going beyond the building level is above all relevant to address urban heat islands, and more generally to adapt urban planning and make use of nature-based solutions. Ensuring summer comfort and other cooling needs in a sustainable way indeed implies the consideration of current and future changes in local climate conditions, and therefore an integrated approach from both the mitigation and adaptation sides. This should start with minimising cooling needs through urban planning and building design or renovation, and enabling occupants to meet their comfort expectations in simple and efficient ways.

In the EU framework, the main requirements applicable to space cooling have mostly been focused on cooling devices, district cooling and developing the share of RES in heating and cooling. This technical focus did not favour the development of integrated approaches. The changes from the fit-for-55 package may improve this, for example with the EPBD recast emphasising more the importance of summer comfort, and the EED recast introducing an official EU definition of energy poverty, clarifying that adequate cooling is part of the basic levels and decent standards of living and health.

Member States may implement measures to address urban heat islands, promote efficient behaviours in case of heat waves or include passive measures in construction or renovation schemes. But due to the focus of the EU requirements, these types of measures are rarely described in Member States' reporting to the EU obligations (e.g. comprehensive assessments, draft NECP updates). This makes experience sharing in this field more difficult. The soon available CoolLIFE tool will contribute to fill this gap by making data about cooling needs, sustainable space cooling solutions and related policies easily available. The analysis of the EU framework presented in this paper shows that space cooling is a topic that illustrates well the need to consider more integrated approaches, beyond siloed technical solutions, and addressing jointly mitigation and adaptation. This work is currently complemented with gathering good practices of national measures, to show how it can be done.

## Acknowledgements

This paper was prepared as part of the CoolLIFE project that has received funding from the European Union's LIFE programme under grant agreement No 101075405. The views expressed in this paper are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission. The authors thank the CoolLIFE partners who contributed to the data collection and analyses, and the reviewers for their constructive and useful comments.

## References


Ballester, J., Quijal-Zamorano, M., Méndez Turrubiates, R. F., Pegenaute, F., Herrmann, F. R., Robine, J. M., Basagaña, X., Tonne, C., Antó, J. M., & Achebak, H. (2023). Heat-related mortality in Europe during the summer of 2022. *Nature Medicine*, 29(7), 1857–1866. https://doi.org/10.1038/s41591-023-02419-z

Braungardt, S., Bürger, V., Fleiter, T., Bagheri, M., Manz, P., Billerbeck, A., Al-Dabbas, K., Breitschopf, B., Winkler, J., Fallahnejad, M., Harringer, D., Hasani, J., Kök, A., Kranzl, L., Mascherbauer, P., Hummel, M., Müller, A., Habiger, J., Persson, U., & Sánchez-García, L. (2023). Renewable heating and cooling pathways: Towards full decarbonisation by 2050. Final Report of Öko Institute, Fraunhofer ISI, TU Wien, E-THINK and Halmstad University to the European Commission. https://data.europa.eu/doi/10.2833/036342

Conforto, G., Hummel, M. (2024). EU-27 Country Mapping of Financing Schemes to decarbonize Buildings, Heating and Cooling. Proceedings of the ECEEE 2024 Summer Study, paper 3-197-24.

Duplessis B., Elnagar E., Fontenaille T. Fraboni R, Gelesz A., Radice Fossati, V. (2024). Taxonomy of space cooling technologies and measures. CoolLIFE project – WP2, Public report.

Elnagar, E., Pezzutto, S., Duplessis, B., Fontenaille, T., & Lemort, V. (2023). A comprehensive scouting of space cooling technologies in Europe: Key characteristics and development trends. *Renewable and Sustainable Energy Reviews*, 186, 113636. https://doi.org/10.1016/j.rser.2023.113636

European Commission (2016). An EU Strategy on Heating and Cooling. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2016) 51 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1575551754568&uri=CELEX:52016DC0051

European Parliament (2024). European Parliament legislative resolution of 16 January 2024 on the proposal for a regulation of the European Parliament and of the Council on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014, (COM(2022)0150 – C9-0142/2022 – 2022/0099(COD)). https://www.europarl.europa.eu/doceo/document/TA-9-2024-0002_EN.pdf

Gerard, F., Smit, T., Rademaekers, K., Braungardt, S., Monejar Montagud, M. E., & Guevara Opinska, L. (2022). Policy support for heating and cooling decarbonisation: Roadmap. Report of Trinomics, Öko Institute and DTU for the European Commission. https://data.europa.eu/doi/10.2833/977806

Huang, B., Riviere, P., Skov Hansen, P.M., Viegand, J., Asloune, H. Dittmann, f. (2018). Air conditioners and comfort fans, Review of Regulation 206/2012 and 626/2011. Final report of Viegand Maagøe and ARMINES to the European Commission. https://minesparis-psl.hal.science/hal-01796759/document

Hurtado-Verazaín, L., Gelesz, A., Csizmady, A., Szabó, H., Ferencz, Z, Vincze, A., Kőszeghy, L. Caballero, N., Reith, A. (2023). Knowledgebase for occupant-centric space cooling. Deliverable 3.1 of the CoolLIFE project. https://coollife.revolve.media/resources/

IPCC (2023). AR6 Synthesis Report Climate Change 2023. Intergovernmental Panel on Climate Change, March 2023. https://www.ipcc.ch/report/ar6/syr/

Jakubcionis, M., Moles, C., Kavvadias, K., Santamaria, M., Carlsson, J. (2018). Synthesis report on the evaluation of national notifications related to Article 14 of the Energy Efficiency Directive. Joint Research Centre report JRC112225.

Lizana, J., Miranda, N. D., Gross, L., Mazzone, A., Cohen, F., Palafox-Alcantar, G., Fahr, P., Jani, A., Renaldi, R., McCulloch, M., & Khosla, R. (2022). Overcoming the incumbency and barriers to sustainable cooling. *Buildings and Cities*, 3(1), 1075–1097. https://doi.org/10.5334/bc.255

Lionggo, I., Viero, G., Pizzini, G., Clero, J. (2023). Lessons learnt and insights for the funding of climate resilience in national and regional adaptation plans from the European Budget. Deliverable 2.4 of the Regilience project. https://regilience.eu/wp-content/uploads/2023/09/REGILIENCE_D2.4_v2.0_2023.pdf

Pezzutto, S., Quaglini, G., Riviere, P., Kranzl, L., Novelli, A., Zambito, A., Bottecchia, L., & Wilczynski, E. (2022). Space Cooling Market in Europe: Assessment of the Final Energy Consumption for the Year 2016. Sustainability, 14(5), 2667. https://doi.org/10.3390/su14052667

Quefelec, S. (2023). Cooling buildings sustainably in Europe: Exploring the links between climate change mitigation and adaptation, and their social impacts. Briefing no. 20/2022 of the European Environment

Agency. https://www.eea.europa.eu/publications/cooling-buildings-sustainably-in-europe/cooling-buildings-sustainably-in-europe