Renewable Cooling under the Revised Renewable Energy Directive

Executive summary of the study
"Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493"

Lukas Kranzl, Philipp Mascherbauer, Mostafa Fallahnejad, TU WIEN
Simon Pezzutto, Antonio Novelli, Andrea Zambito, Pietro Miraglio, Annamaria Belleri, Luigi Bottecchia, Sonia Gantioler, EURAC
Philippe Riviere, Alexandre Etienne, Pascal Stabat, Thomas Berthou, ARMINES
Jan Viegand, Christian Jensen, VIEGAND MAAGOE
Marcus Hummel, Andreas Müller, E-THINK
November – 2021

EUROPEAN COMMISSION

Directorate-General for Energy
Directorate C — Green Transition and Energy System Integration
Unit C.1 — Renewables and Energy System Integration

Contact: Eva Hoos

E-mail: Eva.Hoos@ec.europa.eu

European Commission
B-1049 Brussels

Renewable Cooling under the Revised Renewable Energy Directive

Executive summary of the study
“Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493”

Directorate-General for Energy
ENER/C1/2018-493

2022

EN

Manuscript completed in November 2021

First edition

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the European Commission is not liable for any consequence stemming from the reuse of this publication. More information on the European Union is available on the Internet (http://www.europa.eu).

PDF	ISBN 978-92-76-52340-6	doi:10.2833/59596	MJ-07-22-260-EN-N

Luxembourg: Publications Office of the European Union, 2022

List of contents

Abstract

The study is a background analysis supporting the preparation of a delegated act on a methodology to calculate renewable cooling under the Renewable Energy Directive. It provides an overview of cooling markets, consumption and technologies; analyses possible calculation methodology options and assesses their impacts, including via modelling, on the national and EU renewable shares and the renewable heating and cooling targets. The study recommends using seasonal performance factors defined in primary energy terms as the main criterion to qualify renewable cooling and provides implementation guidance for the suggested preferred option.

1. Introduction

As part of the “Clean Energy for all Europeans” package, the EC proposed an update of the Renewable Energy Directive (RED - 2009/28/EC). The revised RED was adopted in December 2018). The RED II includes a specific chapter on mainstreaming renewable energy into heating and cooling (H&C), Article 23 and district heating and cooling (DHC), Article 24.

While the RED II outlines the methodology to calculate RES shares for electricity, transport and heating, it does not provide methods on how to take into account renewable cooling. The RED II specifies that the EC shall adopt delegated acts to supplement the directive at the latest by the 31st of December 2021, including a methodology for calculating the amount of renewable energy utilized for cooling and district cooling (DC), and amend the directive accordingly.

In this context, the European Commission launched this study to develop a methodology for defining renewable cooling and for calculating corresponding RES-HC and RES shares. This also required a rigorous analysis of the status quo of cooling technologies and the cooling related energy demand. The specific goals of the study are:

- Providing an overview of technologies for cooling, related technologies and their technological development trends;
- Quantifying actual cooling demand as well as its development until 2030 and 2050;
- Providing options of renewable cooling definitions, which are in line with the RED II as well as elaborating options of possible methods for calculating renewable energy shares;
- Investigating impacts of proposed definitions on renewable cooling;
- Delivering well-grounded recommendations for choosing a fitting definition of renewable cooling, calculation methods as well as on how statistical reporting can be improved and utilized for renewable cooling together with a guidance document for renewable cooling share calculation;

During the project duration (from end of 2019 until August 2021) a series of stakeholder consultation events took place, including a survey of EU Member States energy statistics representatives and Eurostat, presentation and consultation at the CA-RES and CA-EED, two dedicated stakeholder workshops as well as bilateral meetings and consultations.

This executive summary provides an overview of the study. For each of the following parts, separate documents are available: The first part of the study provides an overview of technologies for cooling and their related technological development trends, as well as the quantification of the EU final energy consumption for cooling (country-by-country) [1]. The second part of the study discusses different concepts how to define the renewable energy quantity for cooling [2]. The third part of the study analyses the impact of different definition concepts and design options on RES-H&C shares as well as overall RES shares on Member State and EU-27 level [3]. The fourth document provides a guidance document to assist Member State representatives and statistical staff in calculating the quantity of renewable energy used for cooling [4].

2. Cooling Technologies Overview

The starting point of the study was a rigorous screening and description of types of cooling systems and cooling technologies. A comprehensive taxonomy of cooling technologies was developed and the different items described in terms of TRL(Technology Readiness Level), market share, applicability in space cooling vs process cooling, efficiency, type of fuel or energy input, their option to use renewable energy and costs.

Since the EU cooling market is dominated by electric VC (vapour compression), cooling technologies entering the cooling market have to compete with its technical and economical characteristics. Currently, the data/information availability does not allow to indicate reliable future developments, nevertheless, scientific literature on cooling technologies provides pieces of information on present and expected efficiency levels, costs, and technical barriers that still need to be overcome for a technology to be able to reach the EU cooling market. For the specific period of 2020-2030 potentially emerging cooling technologies were identified. For this purpose, we assumed theat such cooling technologies need to be ready to reach the EU cooling market, which corresponds to TRL levels of 5 to 9. This results in the shortlist of cooling technologies for the 2020-2030 period.

Overall, the shortlist of cooling technologies for the 2020-2030 period, based on the TRL threshold of 5 or above entails the following selection: vapour compression, vapour compression transcritical, vapour compression + photovoltaics, solar thermal absorption cooling, waste thermal absorption cooling, membrane heat pump, cold recovery in air handling units/rooftop, cold recovery in building panels, direct ambient air free cooling, indirect ambient air free cooling, use of liquid natural/waste cold source, evaporative cooling, which could be direct, indirect, or indirect + direct, and cold storage (centralized).

3. Market Shares and Consumption Data

As a second step, the share of different cooling systems and technologies on the market has been analysed for the residential and service sector (space cooling) as well as for industrial process cooling. Furthermore, an investigation of the district cooling (DC) sector in Europe (country-by-country) has been carried out.

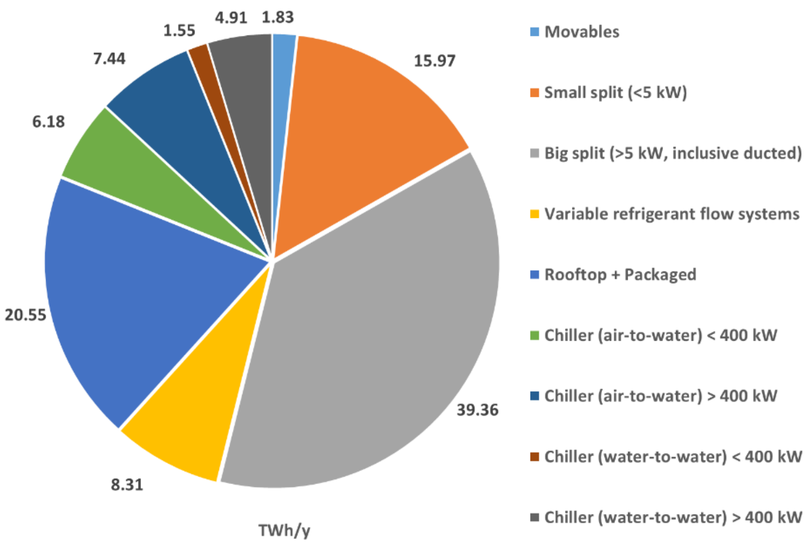

Figure 1 Final energy consumption for space cooling per type in the residential and service sectors, EU27+UK, reference year 2016 [1]

As shown in Figure 1, the most energy-consuming space cooling type are Big split (>5 kW, inclusive ducted) systems with almost 40 TWh/y. Rooftop plus packaged units follow with more than 20 TWh/y. Small split systems come next with almost 16 TWh/y. VRF systems and Chiller (air-to-water) > 400 kW and follow with more than 8 TWh/y and 7 respectively. Chiller (air-to-water) < 400 kW come next with more than 6 TWh/y. Chiller (water-to-water) > 400 kW follow with almost 5 TWh/y. Movables follow with almost 2 TWh/y. Chiller (water-to-water) < 400 kW are last positioned with more than 1 TWh/y. The total amount of final SC consumption in Europe's residential and service sector comes out to be 106 TWh/y. Concerning the entire final SC consumption (residential and service sectors) the RACs and CACs account for about the same percentage with approximately 50% of the final energy consumption each.

As shown in [1] the most energy-consuming process cooling type are chiller (air-to-water) < 400 kW with more than 41 TWh/y. Chiller (air-to-water) > 400 kW follow with more than 40 TWh/y. Chiller (water-to-water) > 400 kW come next with about 20 TWh/y and chiller (water-to-water) < 400 kW are last positioned, with more than 8 TWh/y. The total amount of final PC consumption in Europe's industrial sector comes out to be 110 TWh/y.

According to the data derived in this study, a few countries by far dominate the cooling consumption in the EU: Spain and Italy (each about 50TWh), France (about 30 TWh), Germany, UK and Greece (each about 10 TWh).

It needs to be emphasized that compared to other energy end-use sectors, there is a lack of data and information concerning cooling. In particular, concerning process cooling and district cooling, the study team experienced notable difficulties in finding data/information – even more than for space cooling. A comparison of data from different sources also showed significant deviations. Not all collected information appears to be trustworthy. Notably, the latter concerns market size and efficiency values for cooling equipment. Such data have been excluded from carried-out calculations. Moreover, it has to be underlined that the final energy consumption values indicated above do not entail the refrigeration sector, due to the potential of RES for freezing is very limited and thus not being in the scope of the present study.

4. Renewable Cooling Definition and Methodology

In this part of the work, the study team compared different possible approaches for defining the renewable energy quantity for cooling. For this purpose, a general introduction to cooling and cooling systems was made, in order to discuss what could potentially be considered as renewable cooling according to the RED II and to propose a possible scope for renewable cooling definitions. Subsequently, definition options to quantify the renewable cooling energy were elaborated; the potential implications of implementing these definition options were also discussed qualitatively. After consultation with Member States and other stakeholders, some choices regarding definition options have been made, which allow to build the calculation methodology to evaluate the renewable cooling energy quantity.

Two main energy flows can be considered when analysing the possible approach to calculate renewable cooling quantities: The cold source and the energy input (see also Figure 2):

(1) **Cold source**: Cooling systems extract heat from the space or process to be cooled. The heat extracted is transferred or rejected outside the cooling system, ultimately in the environment in ambient air, ambient water or to the ground. Where the heat is transferred is called the cold source. Cold source can also be called heat sink. The cold source can be genuinely cold, i.e. have a lower temperature than the temperature of the space / process to be cooled, as would be the case for free cooling. The cold source can have a higher temperature than the temperature of the space or process to be cooled. In that situation, a cooling generator is needed.

(2) **Energy input**: When it follows the natural flow of energy (**Error! Reference source not found.**), the heat extraction and rejection only require energy for heat transportation (energy required to put heat carriers in motion). This transfer of heat requires additional energy when it goes against the natural flow of energy from hot to cold. This heat transfer must be used when there is a need for cooling and when the natural flow of energy is not available, not sufficient or not used. This transfer of heat is operated by a cooling generator.

The sum of the energy consumption for heat transportation and to operate the cooling generator is named **energy input**, and is noted E_{INPUT}.

The energy balance of cooling systems can simply be written as in Equation 1; it is also shown in Figure 2.

$$Q_{C\_Source} - E_{INPUT} = Q_{C\_Supply} \quad \textit{Equation 1}$$

Where:

- Q_{C_Source} is the heat rejected to the cold source.
- E_{INPUT} is the energy input to the cooling system.
- Q_{C_Supply} is the cold supplied to the room or process to be cooled.

The energy balance of cooling systems is illustrated in Figure 2.

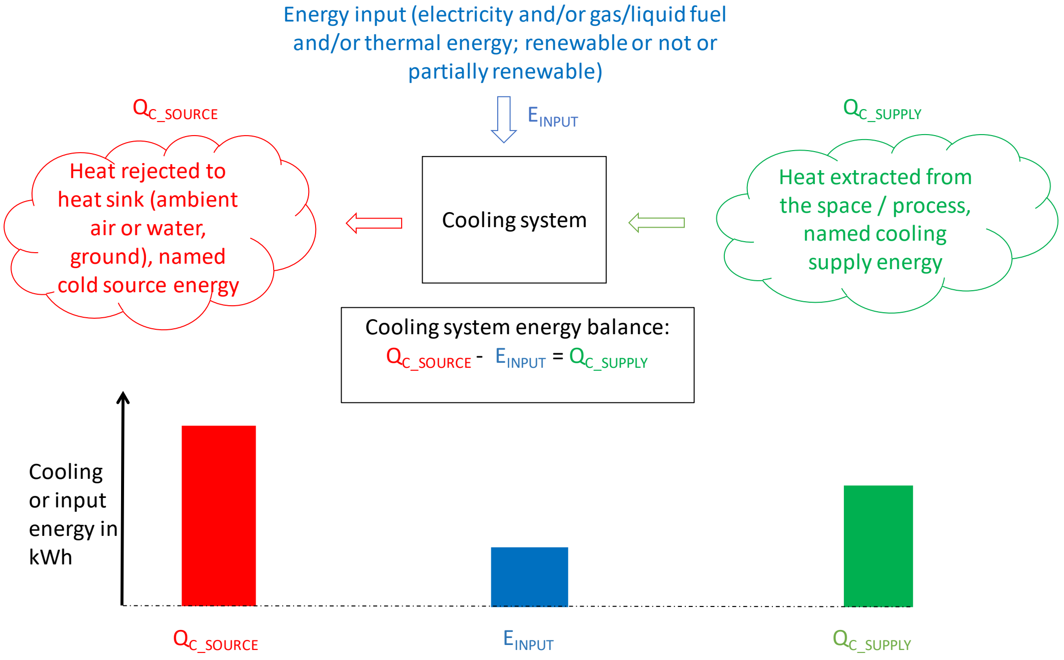

Figure 2 Energy balance of cooling systems

The SPF is the Seasonal Performance Factor[1], which is a ratio used to measure the efficiency of cooling systems during the cooling season.

Based on this understanding of the cooling energy flow, the question is what may qualify a cooling system to be renewable along the two above mentioned energy flows? (1) A strict definition of renewable cooling could be to only accept free cooling as renewable cooling. Free cooling systems are cooling systems with the highest possible SPF values. In the context of

[1] As described in [2], the SPF can be defined in final and primary energy terms, in the latter case denoted as SPF_p, which is identical to $\square_{s,c}$ defined in Regulation (EU) 2281/2016.

the RED II, we propose to use the SPF[2] of cooling systems as the main criterion to qualify the presence of cold source energy to potentially count as renewable cooling. (2) In terms of considering the renewable energy input in the renewable cooling definition, there are constraints due to the fact that double counting in the renewable energy statistics needs to be avoided. After detailed discussions and analyses of possible RES-C definition options in [2], the study team proposed following main approach:

The **renewable energy quantity for cooling $E_{RES\text{-}C}$** is defined as the part of the cooling supply that is generated with a certain energy efficiency expressed as Seasonal Performance Factor, which quantitatively corresponds to a portion of the heat released by the cooling system to ambient air, ambient water or to the ground.

It is calculated as follows (Equation 2):

$$E_{RES-C} = (Q_{C_{Source}} - E_{INPUT}) \times s_{SPF\_p} = Q_{C_{Supply}} \times s_{SPF\_p}$$ *Equation 2*

$Q_{C_{Source}}$ is the amount of heat released to ambient air, ambient water or to the ground.

E_{INPUT} is the energy consumption of the cooling system, which can be electricity and/or gas and/or fuel and/or heat depending on the specific cooling system.

$Q_{C_{Supply}}$ is the cooling energy supply of the cooling system.

s_{SPF_p}: is defined at cooling system level as the share of the cooling supply, which can be considered as renewable according to the SPF_P requirements, expressed as a percentage.

The calculation of $s_{SPF,P}$ includes a low SPF_P threshold denoted SPF_{plow} and a high threshold denoted SPF_{phigh} . Above the low threshold s_{SPF_P} increases linearly with increasing SPF_P values:

If $SPF_P < SPF_{pLOW}$, $s_{SPF_P} = 0$ % and if $SPF_P > SPF_{pHIGH}$, $s_{SPF_P} = 100$ %. *Equation 3*

If $SPF_{pLOW} \leq SPF_P \leq SPF_{pHIGH}$, $s_{SPF_P} = \frac{SPF_p - SPF_{p\_LOW}}{SPF_{p\_HIGH} - SPF_{p\_LOW}}$ %. *Equation 4*

The SPF_{pLOW} and SPF_{pHIGH} thresholds are proposed to be 2.8 and 9.5, respectively.

The study team suggested to distinguish the assessment of small scale cooling systems in the form of standardized approach, using default values and the assessment of large scale cooling systems where measured SPF values can be used. For more detailed and concrete guidance on the calculation methodology see [4].

For more detailed and essential definitions and the exact scope of the proposed renewable cooling definition see [2] and [4].

5. Impact assessment

In order to better understand and quantify the possible impact of different RES-C options, a broad set of RES-C definition variants has been modelled and assessed regarding their impact, mainly on RES-HC and overall RES shares in the different Member States and for EU-27 as a

[2] in primary energy terms

whole. For this purpose, the study defined two scenarios ("ambitious" and "baseline") with different penetration of innovative cooling technologies. This led to following insights:

- The lower the SPF_P threshold, the lower is the incentive to use innovative cooling technologies.
- Member States with relatively high cooling consumptions are especially affected by the different renewable cooling definition options.

The following factors have the most relevant impact on the results:

- The share of cooling energy consumption on total energy consumption and heating energy consumption, respectively.
- The "renewable" cooling definition itself. Depending on the calculation method, the results vary strongly.
- The share of technologies, which exceed the SPF_P threshold and are therefore counted as "renewable" influence the impact of the different definition options.
- To some extent, the starting level of the renewable and renewable heating share has also an impact; this however is observed only under some specific settings of the RES-C definition methodology.
- The amount of local, concomitant renewable energy input and the extent to which it will be measured and thus applied also has a significant impact on the results.
- The evolution of primary energy conversion factor of electricity generation $1/\eta$ and how it is considered in the calculation. In addition, the question whether national values of $1/\eta$ may be applied or not will have an impact.
- If national values of $1/\eta$ are applied, it is in favor of countries with a high η-value whereas countries with a current low η-value will have increased RES and RES HC shares when using EU-wide η-values. These countries have typically a very high cooling consumption.

All these influencing variables are subject to uncertainty, not only with respect to the future development but also for the base year. In particular, there are significant uncertainties regarding cooling energy demand and the stock of cooling systems with their specific use of different cold sources and resulting SPF_P values. Thus, the parameter variations carried out provide additional insights into possible ranges of expected impacts.

6. References

[1] Pezutto S., Kranzl L., Mascherbauer P., Fallahnejad M., Novelli A., Zambito A., Miraglio P., Belleri A., Bottecchia L., Gantioler S., Riviere P., Etienne A., Stabat P., Berthou T., Viegand J., Jensen C., Hummel M., Müller A., Cooling Technologies Overview and Market Shares, Part 1 of the study Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493, 2021

[2] Kranzl L., Mascherbauer P., Fallahnejad M., Pezutto S., Novelli A., Zambito A., Miraglio P., Belleri A., Bottecchia L., Gantioler S., Riviere P., Etienne A., Stabat P., Berthou T., Viegand J., Jensen C., Hummel M., Müller A. Renewable cooling definition options and calculation methodology, Part 2 of the study Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493, 2021

[3] Kranzl L., Mascherbauer P., Fallahnejad M., Pezutto S., Novelli A., Zambito A., Miraglio P., Belleri A., Bottecchia L., Gantioler S., Riviere P., Etienne A., Stabat P., Berthou T., Viegand J.,

Jensen C., Hummel M., Müller A. Analysis of the impacts of the renewable cooling energy definition, Part 3 of the study Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493, 2021

[4] Kranzl L., Mascherbauer P., Fallahnejad M., Pezutto S., Novelli A., Zambito A., Miraglio P., Belleri A., Bottecchia L., Gantioler S., Riviere P., Etienne A., Stabat P., Berthou T., Viegand J., Jensen C., Hummel M., Müller A. Proposed Renewable Cooling Calculation Methodology, Guidance Document for Renewable Cooling share calculation. Part 4 of the study Renewable Cooling under the Revised Renewable Energy Directive ENER/C1/2018-493, 2021

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

– by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

– at the following standard number: +32 22999696, or

– by email via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from: https://op.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

Open data from the EU

The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, for both commercial and non-commercial purposes.

ENER/C1/2018-493

MJ-07-22-260-EN-N

ISBN 978-92-76-52340-6

Publications Office
of the European Union