



RE-WITCH

The coolest cold from
the cleanest heat



D14.1 Analysis of related EU, national and/or regional policies, and standards

Main author: Christina Kachacha, IEECP

Date: April 2025



This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement no. 101138697. The responsibility for the information and the views set out in this document lies entirely with the authors. The European Commission is not responsible for any use that may be made of the information it contains.

Project acronym	
Programme	Horizon Europe
Topic	HORIZON-CL5-2023-D4-01
Type of Action	Innovation action
Grant Agreement number	101138697
Start day	01/01/2024
Duration	48 Months
Contact	Project coordinator: Dr. Andrea Frazzica (andrea.frazzica@cnr.it)

Document information

Document fact sheet	
Full title	D14.1 – Analysis of related EU, national and/or regional policies, and standards
Work package	WP14
Task(s)	T14.2 – Standardization – analysis and identification
Author (organization)	Christina Kachacha (IEECP)
Reviewers	JER, SIGLA
Date	April 2025

Document Dissemination level

Dissemination level	
x	PU – Public
	PP – Restricted to other programme participants (including the EC)
	RE – Restricted to a group specified by the consortium (including the EC)
	CO – Confidential, only for members of the consortium (including the EC)

Document history

Version	Date	Main modification	Institution
V0.1	28.02.2025	Table of content	IEECP
V0.2	08.04.2025	First completed draft	IEECP
V0.3	18.04.2025	Revisions	JER,SIGLA
V0.4	22.04.2025	Editorial Revisions	IVL
V0.5	29.04.2025	Final Version	IEECP, CNR

Legal Notice

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the European Commission nor any person acting on behalf of the Commission is responsible for any use that may be made of the information contained therein.

© RE-WITCH Consortium, 2024 - All rights reserved; no part of this publication may be translated, reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the written permission of the publisher or provided the source is acknowledged.

Find the Project

Web: www.re-witch.eu

LinkedIn: <https://linkedin.com/company/re-witch>

About

The overarching aim of RE-WITCH, a project funded by the European Horizon programme, is to deliver cost-competitive, game-changing solutions in the field of sustainable industrial cooling and heating. To do so, RE-WITCH will demonstrate advanced thermally driven industrial cooling technologies based on Adsorption and Absorption processes driven by an optimized mix of low-grade waste and renewable sources (innovative high vacuum flat plate solar collectors).

Such solutions will be demonstrated in 4 demo sites (3 confirmed as of January 2024, in Greece, Spain and Poland) encompassing food and beverage sectors as well as industrial sectors where heat-to-cold solutions are not yet widely explored (bio-refinery). The activity will be completed by studying the replicability of proposed technologies in replication sites even integrated with District Heating Networks (DHN).

The project will be delivered by an industrial-driven consortium of 26 partners from 10 countries and it is composed by some of the most innovative SMEs, LEs and R&D centres in the field of industrial renewable H&C leveraging experience from industrial and EU-funded projects (HYCOOL, SO-WHAT, Indus3Es).

The multi-disciplinary composition of the consortium ensures that all the challenges (technical and non-) will be addressed to ultimately bring RE-WITCH solutions to the market by 2029. Innovative open access modelling platforms and engineering solutions will also be developed to facilitate the design, upscale, replication and integration in industrial processes of the proposed technologies. Thanks to a stakeholders' driven dissemination and communication campaign, RE-WITCH will ultimately demonstrate transformative technological solutions that unlock the combined potential of low-grade waste and renewable heat use in industries, hence also targeting integration of heat-to-cold technologies into relevant EU policies.

Project partners



Contents

1. Executive Summary.....	10
2. Introduction.....	11
3. Standardization and Relevant standards to RE-WITCH.....	12
3.1. Introduction.....	12
3.2. Relevant standards.....	14
3.3. List of relevant Workshop Agreements (CWAs) to the project.....	22
4. Products - labelling rules and requirements.....	22
4.1. Products policies and general description of regulations related to chillers.....	22
4.2. Ecodesign for Sustainable Products Regulation.....	27
4.3. F-gas regulation.....	27
5. Best available techniques to Industrial cooling systems BREF.....	28
5.1. Introduction.....	28
5.2. Industrial cooling systems BREF.....	28
6. Policy Framework.....	34
6.1. Introduction.....	34
6.2. Waste Heat in EU legislation.....	36
1. Waste heat in the renewable energy directive.....	36
2. Waste heat in the Energy Efficiency Directive.....	39
3. EU Taxonomy Regulation.....	39
4. National Policies.....	39
7. Conclusion.....	40
8. Bibliography.....	40

List of figures

Figure 1: Schematic approach detailed in ICS BREF (European Commission , 2001).....	30
Figure 2: Schematics of the most frequently used systems according to the BAT definition source: (Hlaváček & Vagenknechtová).....	31
Figure 3: Final energy demand for process and space cooling in the EU27 + UK((Reitze, Toro, Fleiter, Rehfeldt, & Schön, 2017)	34
Figure 4: Waste heat potential per industrial sector and temperature level for EU in 2014 (Michael Papapetrou, 2018)	35
Figure 5: Waste heat recovery technologies' classification (Sarah Brückner, 2015)	35

List of tables

Table 1: List of relevant technical committees	14
Table 2: Standards' codes and titles related to electric components.....	14
Table 3: Code and title of standards relevant for piping , mounting system and mechanical tools	15
Table 4: Code and title of standards related to fire prevention, electrical protection and safety .	15
Table 5: Standard related to the absorption material	16
Table 6: Standard rating conditions extracted from the standard AHRI/ANSI 560	19
Table 7: Application rating conditions as presented in standard AHRI/ANSI 560.....	20
Table 8: Solar Standards relevant for the RE-WITCH project.....	21
Table 9: List of CWA relevant for RE-WITCH project	22
Table 10: Minimum energy efficiency requirements for process chillers set by regulation ((EU) 2016/2281).....	24
Table 11: Minimum energy efficiency requirements for process chillers set by regulation ((EU) 2015/1095).....	25
Table 12: Information requirements for high temperature process chillers ((EU) 2016/2281)	26
Table 13: Examples of process requirements and BAT as presented in the ICS BREF (European Commission , 2001)	32
Table 14: Examples of sites's characteristics and BAT as presented in the ICS BREF (European Commission , 2001)	32
Table 15: BAT for increasing overall energy efficiency as presented in the ICS BREF (European Commission , 2001)	33
Table 16: BAT for reduction of water requirements as presented in the ICS BREF (European Commission , 2001)	33
Table 17: RED sectoral targets and waste heat eligibility (Marie-Theres Holzleitner-Senck, 2025)	38
Table 18: National policies extracted from MURE project database related to industrial waste heat (Manz & Eichhammer, 2024)	40

Abbreviations

Abbreviation	Definition
AFNOR	Association Française de Normalisation
AHRI	American Air conditioning, Heating and Refrigeration Institute
AIDMO	Arabic industrial development and mining organization
ANSI	American National Standards Institute
ARSO	African Organisation for Standardization
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BAT	Best Available Techniques
BREF	Best Available Techniques Reference Documents
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CHP	Combined Heat and Power
CIE	International Commission on Illumination
COP	Coefficient of Performance
COPANT	Pan American Standards Commission
CWA	Workshop Agreement
DIN	Deutsches Institut für Normung
EED	Energy Efficiency Directive
EN	European Standard
ESPR	Ecodesign for Sustainable Products Regulation
ESTIF	European Solar Thermal Industry Federation
ETSI	European Telecommunications Standards Institute
EU	European Union
HFC	Hydrofluorocarbons
ICS	Industrial Cooling Systems
IEC	International Electrotechnical Commission
IED	Industrial Emission Directive
IEEE	Institute of Electrical and Electronics Engineers
IRMM	Institute for Reference Materials and Measurements
ISO	International Organization for Standardization
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LLCC	Least life cycle costs
MEErP	Methodology for Ecodesign of Energy-related Products
MOT	Method of Test
PASC	Pacific Area Standards Congress
RED	Renewable Energy Directive
RES	Renewable Energy Source
SCOP	Seasonal coefficient of performance

SEER	Seasonal energy efficiency
SEPR	Seasonal energy performance ratio
TC	Technical Committee
TR	Technical report
TS	Technical specifications
TWG	Technical working group
UNI	Nazionale Italiano di Unificazione
VDMA	Verband Deutscher Maschinen- und Anlagenbau
WHR	Waste Heat Recovery
WHTC	Waste heat to cold
WHTH	Waste heat to heat
WHTP	Waste heat to electric power
$\eta_{s,c}$	Seasonal space cooling energy efficiency

1. EXECUTIVE SUMMARY

Waste heat driven industrial cooling provides an alternative to reduce reliance on conventional cooling systems with higher energy consumption and increases the overall energy efficiency. RE-WITCH project aims to demonstrate the feasibility of integrating solar thermal and harnessing waste heat for thermally driven sorption cooling across four energy-intensive industries: pulp and paper, brewing, food & drink, and biofuel production. In parallel, the project aims to promote these solutions by addressing the different challenges (technical and non-technical) facing the market uptake. Regulations and standards are the rules and boundaries of applications and set requirements that shape the markets.

D14.1 “Analysis of related EU, national and/or regional policies, and standards” collects and presents the information on the current status and latest advancements in standardization and EU policies relevant for RE-WITCH technologies. The standardization landscape includes the information on the relevant standards, the relevant standardization technical committees and the relevant workshop agreements. It is based on standardization key topics and interests identified through interviews with consortium partners. The analysis of the regulatory framework and review of current regulations affecting the deployment of RE-WITCH technologies, such as industrial cooling systems best available techniques, relevant products’ policies and policies related to waste heat recovery.

D14.1 is the first deliverable of Standardization task; it constitutes the foundation for further activities in the context of standardization, to ensure the alignment of the solutions with standards and to provide policy recommendation for efficient market deployment of RE-WITCH technologies.

2. INTRODUCTION

The project aims to develop innovative, cost competitive and efficient thermally driven cooling and heating technologies for industrial processes while optimising the use of low-grade waste and renewable heat in the industry sector. To achieve this, new generation adsorption and absorption cooling technologies will be developed and demonstrated across four demo sites in the food, beverage and biofuel sectors. In parallel, the project aims to bring these solutions to the market by addressing the different challenges (technical and non-technical) facing the market uptake of the sorption cooling technologies. Regulations and standards are the rules and requirements that shape markets. To facilitate future commercialization detailed business modelling and standardization analyses will be performed within WP 14-16.

Standardization plays an important role in boosting innovation in the market. It is considered an innovation-support measure; it allows bridging the gap between research and the market by bringing the research results to the market and helping in faster dissemination of technologies and acceptance of innovations.

Standardization is the process of creating protocols or setting guidelines or requirements for the creation of a good, service, or materials based on the consensus of all the relevant parties in the industry. The objective is to ensure that the practices within the industry are uniform, to enable the comparison with goods or services produced in the same industry and to certify that goods or services produced in a specific industry come with consistent quality. This can facilitate the international trade of the equipment; particularly the qualifications standards, the test methods or performance requirements standards could help in increasing the market adoption and in reducing the compliance cost for industries.

Regulation offers clarifications and certainty on the roadmap, the targets to achieve, the direction and innovation needed for the decarbonization. It sets clear performance expectations for all stakeholders.

The total energy demand accounted for about 4 000 TWh in 2019 including final energy and feedstock in the industrial sector of the European Union EU-27. Process heating used almost half of this total (about 1 860 TWh (Fleiter, Al-Dabbas, Clement, & Rehfeldt, 2023a). Consequently, process heating is the most important energy use in industry. The cooling demand in industrial applications, accounted for approximately 78% of Europe's total cold production as mentioned in deliverable D4.1 "First release of industrial cooling needs and RE-WITCH technology specifications". RE-WITCH project aims to demonstrate the feasibility and effectiveness of implementing sorption cooling technologies to optimize the waste heat recovery leading to improve the overall energy efficiency and contribute to the industrial decarbonization. Even though industrial decarbonization and an emission free environment are quoted explicitly as two of the key points of the EU Green Deal and ambitious targets have been foreseen for industrial sector in recent "Fit for 55 package", there is still a lack of technological acceptability and widespread despite the technological maturity of heat-to-cold technologies, and WHR/Thermal RES integration in industries. Many decarbonization solutions are not mature from a regulatory point of view and will require major efforts at policy level. The absence of specific policy support creates the competition for such technology against the other energetic solutions for industrial decarbonization. At this purpose RE-WITCH project, proving reliability of heat-to-cold systems, will open their market attractiveness, thus encouraging national government/energy regulators to

develop specific incentives/ supporting schemes for heat-to-cold and WHR/thermal RES integration in industries.

Business, exploitation and standardization activities are performed in parallel to technical development and the work spans during the project years to ensure efficient implementation and replication of the project. The first stage of work is dedicated to the identification of relevant information, structure it and make a first analysis. The second stage is to create a minimum viable product ready for market uptake and suggest exploitation activities to progress the results. The third and final stage focus on the exploitation of results beyond the project lifetime.

D14.1 is the first deliverable of standardization and policy recommendations tasks. It addresses the state of the art of the relevant standards as well as the relevant policies. The standardization landscape is detailed in Paragraph 3, product policies are analysed and presented in Paragraph 4. This document includes a description of Best Available Techniques Reference Documents BREF document on industrial cooling systems (Paragraph 5) and relevant policies to waste heat recovery are presented in Paragraph 6. It constitutes the reference for further development and activities within the Business Modelling, Exploitation and standardization work of WP14 to WP16 to facilitate the efficient market deployment answering the barriers for RE-WITCH solutions implementation.

3. STANDARDIZATION AND RELEVANT STANDARDS TO RE-WITCH

3.1. INTRODUCTION

Standardization is the process of creating protocols and standards to guide the creation of a good, service, or material based on the consensus of all the relevant parties in the industry.

Multiple organizations work on technical standards and contribute to the development, coordination, promulgation, revision, amendment, reissue or the deployment of technical standards. The standardization bodies operate at different levels (national, regional or international level).

At the international level, the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU) are the three largest standards organizations. Multiple independent international standards organizations also work on the development of standards for different uses such as The American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM) International, the International Commission on Illumination (CIE), the Institute of Electrical and Electronics Engineers (IEEE).

At the regional level, multiple standardization bodies exist such as the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), the European Telecommunications Standards Institute (ETSI), the Institute for Reference Materials and Measurements (IRMM), the Pacific Area Standards Congress (PASC), the Pan American Standards Commission (COPANT), the African Organisation for Standardization (ARSO), or the Arabic industrial development and mining organization (AIDMO). The standards created by CEN, CENELEC, and ETSI are recognized as European standards.

At the national level, multiple countries have national standards bodies: Deutsches Institut für Normung (DIN), Ente Nazionale Italiano di Unificazione (UNI), or Association Française de Normalisation (AFNOR).

The ISO defines standard as a document, established by a consensus of subject matter experts and approved by a recognized body that provides guidance on the design, use or performance of materials, products, processes, services, systems or persons. The technical document can include for example agreed definitions, description of methods, tests products, definition of terms and/or specification of dimensions, materials, performance, designs, or operations etc. Standards ensure consistency of essential features of goods, services, or materials such as quality, safety, efficiency and enable companies to comply with relevant laws and regulations. This facilitates the transfer of the latest technologies.

Standard documents come in different types. The most known document is the standard having a code depending on the organization under which it was developed, e.g. EN for European Standards, ISO or IEC for International standards. The 34 European national standardization organizations as members of CEN and CENELEC shall adopt EN standards, when it is developed and approved, as national standards and have to withdraw any existing national standard which could conflict with them.

Other types of standard deliverables can be developed:

- Technical Specifications (TS): developed when there is a possibility of agreement on an International Standard or when there is not enough consensus for an EN.
- Technical Reports (TR): provides information on the technical content of standardization work.
- Workshop Agreements (CWA): is an agreement developed and approved in a CEN or CENELEC Workshop; it results no obligation at national level. The agreement is developed by all interested stakeholders. Experimental innovation results are more suited for Workshop Agreements.

The interested parties and stakeholders such as consumers, manufacturers, academic experts or researchers .can initiate and participate in the development of new standards at all levels. This process includes knowledge and consensus building among experts that are organized in technical committees (TCs) based on the topic.

RE-WITCH project aims to demonstrate innovative and efficient thermally driven cooling and heating technologies for industrial processes, optimising the use of low-grade waste and renewable heat through new generation of adsorption and absorption chillers.

- The RE-WITCH project focuses on advancing adsorption cooling technology by building upon an innovative prototype design currently validated at Technology Readiness Level 5. The adsorption chiller leverages the capacity of solid sorbent materials to adsorb and desorb water vapour, utilising low-grade waste or renewable heat to drive the cooling process.
- The RE-WITCH project includes on the development of a novel hybrid absorption chiller technology and the adaptation of an absorption chiller to provide chilled water at two temperature levels. The first integrates a mechanical vapour compressor in the absorption cycle, between the evaporator and the absorber. The second integrates a pair of evaporators to cover the cooling demand at different temperatures.

For the standardization analysis, the relevant topics covers a wide scope not only focusing on the sorption chillers but also on other topics that can have an impact in the overall project.

As mentioned above, at the European level, the Technical Committees (TC) work on standards development. There is a TC for each distinct area of activity with a specific scope and field of operation. The following Table 1 includes a list of technical committees relevant to the project.

Table 1: List of relevant technical committees

Technical committee	Scope of activity
CEN/TC 312	Thermal solar systems and components
CEN/TC 182	Refrigeration systems, safety and environmental requirements
CEN/TC 227	Heating systems and water-based cooling systems in Buildings
CEN/TC 110	Heat exchangers
CEN/TC 113	Heat pumps and air conditioning units
CEN/TC 299	Gas-fired sorption appliances, indirect fired sorption appliances, gas-fired endothermic engine heat pumps and domestic gas-fired washing and drying appliances
CEN/TC 107	District heating and cooling systems

3.2. RELEVANT STANDARDS

This chapter introduces the standards that are related to RE-WITCH project. They are classified by topic:

- Design, construction, and testing of chillers
- Test system design and measurement
- Thermally driven chillers standards
- Solar thermal standards

➤ Design, construction, and testing of chillers

A wide range of standards including electrical systems, piping, pressurized systems etc. can be relevant for the design, construction, and operation of sorption chillers. It should be noted that the standards are not specific to chillers, but the fields are governed by standards.

General Electric components

Table 2: Standards' codes and titles related to electric components

Code	Title
------	-------

CE marking	It refers to compliance with the Low Voltage Directive
EMC Directive	
EN 50160	Voltage characteristics of electricity supplied by public electricity networks
EN 60038	CENELEC standard voltages
EN 60076	Power transformers
EN 60364	Electrical Installations for Buildings
EN 60364-5-52	Low voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – wiring systems
EN 60529	Degrees of protection provided by enclosures
EN 60664-1	Insulation coordination for equipment
EN 61000	Electromagnetic compatibility (EMC)
EN 61439	Low-voltage switchgear and control gear assemblies
EN 62271-200	High-voltage switchgear and control gear
EN/TR 61850-90-7	Object Models for power converters in distributed energy resources (DER) systems

Piping, mounting system, and mechanical loads

Table 3: Code and title of standards relevant for piping , mounting system and mechanical tools

Code	Title
ASCE 7-05	Minimum Design Loads for Buildings
DIN 1055	Actions on structures
EN 1090	Execution of steel structures and aluminium structures
EN 1993	Design of steel structures
2006/42/EU	Machinery directive
2014/68/EU	PED (Pressure Equipment Directive)
EN 13136: 2013 + A1:2018	Refrigerating systems and heat pumps - Pressure relief devices and their associated piping - Methods for calculation
EN ISO 10113:2020	Metallic materials. Sheet and strip. Determination of plastic strain ratio
EN 13480	Metallic Industrial Piping
EN ISO 5817:2014	Welding — Fusion-welded joints in steel, nickel, titanium, and their alloys (beam welding excluded) — Quality levels for imperfections
EN/ISO 12241	Thermal insulation for building equipment and industrial installations. Calculation rules

Fire prevention, electrical protection, and safety

Table 4: Code and title of standards related to fire prevention, electrical protection and safety

EN 13501-1	Fire classification of construction products and building elements
------------	--

2014/34/EU	ATEX directive
EN 60754	Test on gases evolved during combustion of materials from cables
EN 61034	Measurement of smoke density of cables burning under defined conditions
EN 61557	Electrical safety in low voltage distribution systems up to 1000 VAC. and 1 500 VDC. - Equipment for testing, measuring, or monitoring of protective measures
EN 62305-1 to 3	EN 62305-1 Protection against lightning
EN 378-3	Refrigeration systems and heat pumps - Safety and environmental requirements - Part 3: Installation site and personal safety

Material: absorbent/adsorbent

Table 5: Standard related to the absorption material

Code	Title
ISO 62:2008	Plastics -- Determination of water absorption

➤ **Test system design and measurement**

The following paragraph gives an overview of the relevant standards for test procedures, and performance evaluation. The latter may be specifically applied to electric driven chillers or compressors; however, the principle and methodologies can be used as reference for other similar cooling systems.

- **EN 378: Refrigeration systems and heat pumps – Safety and environmental requirements**

EN 378 is a key standard for refrigeration systems and heat pumps. It establishes requirements for safety, operation, and environmental considerations in different stages: in the design, manufacturing (tightness testing, material requirements and pressure, fatigue testing etc), installation, operation, maintenance, and disposal of refrigerating systems and appliances. It focuses on safety requirements, component requirements, safety testing and personal protection.

It consists of four parts:

- Basic Requirements, Definitions, Classification, and Selection Criteria: details the classification and selection criteria applicable to refrigerating systems.
- Design, Construction, Testing, Marking, and Documentation: used for the design, construction and installation of refrigerating systems.
- Location and Protection of Persons: lists the requirements on the site for safety.
- Operation, Maintenance, Repair, and Recovery: specifies requirements for safety and environmental aspects in relation to operation, maintenance, and repair of refrigerating

systems and the recovery, reuse and disposal of refrigerant, refrigerant oil, heat-transfer fluid, refrigerating system and part thereof.

- **EN 14511: Air conditioners, liquid chilling packages and heat pumps for space heating and cooling and process chillers, with electrically driven compressors**

This standard specifies the terms and definitions for the rating and performance of air conditioners, liquid chilling packages and heat pumps using either air, water or brine as heat transfer media, with electrically driven compressors when used for space heating and/or cooling. It also specifies the terms and definitions for the rating and performance of process chillers. Consequently, it is relevant to RE-WITCH technologies. The first part provides terminology and covers a wide range of terms and definitions related to the aforementioned systems such as definitions of various types of air conditioning systems, comprehensive definitions for heat pumps and terms related to compressors. The second part of the standard ensures that the systems are tested under the rigorous conditions by specifying the environmental and operational conditions under which tests should be conducted (ambient temperatures, source temperature, humidity ranges, sink temperature etc.). The third part presents test methods, the procedures and methodologies for performance evaluation. In particular, corrections related to lab conditions for thermal power and electric power or effects influencing the performance measurements are specified. It also includes a list of Key Performance Indicators (KPIs), such as electrical power, thermal power and COP, in heating mode, and cooling mode, and for the electricity also in standby mode and off-mode. The fourth part sets the requirements to be provided by the manufacturer such as the range of operation, type of oil, filling of refrigerant etc. The start-up performance should be tested. It also includes instructions for the installer.

- **EN 14825: Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling, commercial and process cooling. Testing and rating at part load conditions and calculation of seasonal performance**

The air conditioners, heat pumps and liquid chilling packages, including comfort and process chillers are covered in this standard including air-to-air, water (brine)-to-air, air-to-water and water (brine)-to-water units. Particularly, it provides the performance testing procedure under part load and the calculation methods for the determination of seasonal energy efficiency SEER and SEER_{on}, seasonal space cooling energy efficiency $\eta_{s,c}$, seasonal coefficient of performance SCOP, SCOP_{on} and SCOP_{net}, seasonal space heating energy efficiency $\eta_{s,h}$ and seasonal energy performance ratio SEPR. In addition, it specifies the test methods test methods for power input during thermostat-off mode, standby mode, off mode and crankcase heater mode. Specifically, the conditions and the temperatures are specified for the calculation of the seasonal energy ratio SEPR for process chillers.

- **EN 13771: Compressors and condensing units for refrigeration – Performance testing and test methods**

This focuses on testing of compressors and condenser units. It consists of two parts:

- Part 1 specifies testing of compressors units,
- Part 2 specifies testing of condenser units.

This standard is relevant for hybrid systems that integrate thermally driven chillers with mechanical compressors. In addition, it contains the maximum allowable deviation of test conditions during the testing, and the maximum allowable measurement uncertainty.

- **EN 12900: Refrigerant compressors – Rating conditions, tolerances and presentation of manufacturer’s performance data**

The testing conditions and tolerances for refrigerant compressors are detailed in this standard. These include single stage compressors and single and two stage compressors using a means of fluid subcooling.

➤ **Thermally driven chillers standards**

The standards or guidelines in this paragraph are complementary to the ones mentioned above and specifically focusing on sorption systems for heating or cooling.

- **EN 12309: Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW**

The standard was prepared by the Technical Committee CEN/TC 299 “Gas-fired sorption appliances and domestic gas fired washing and drying appliances”. The standard covers: gas-fired sorption chiller, gas-fired sorption chiller/heater, gas-fired sorption heat pump and hybrids based on gas sorption appliances.

It consists of following seven parts:

- EN 12309-1:2023 - Part 1: Terms and definitions
- EN 12309-2:2015 - Part 2: Safety
- EN 12309-2:2015/AC:2015 - Part 2: Safety
- EN 12309-3:2024 - Part 3: Requirements, test conditions and test methods
- EN 12309-6:2014 - Part 6: Calculation of seasonal performances
- EN 12309-7:2014 - Part 7: Specific provisions for hybrid appliances

This standard specifies the test methods for the calculation of the Gas Utilization Efficiency (GUE) of gas driven adsorption or absorption heat pumps in heating and cooling mode.

- **DIN 33830-4: Heat pumps; absorption heat pump units; performance and operational tests [Withdrawn]**

This German standard was published in June 1988 and withdrawn in 2013. Test conditions, operational tests and scope of testing of performance of absorption heat pump are described. The standard is applicable for water, ground or air source units; on the heat sink side, both water and air can be the heat transfer medium. DIN recommends the application of DIN EN 12309-1:1999-10, DIN EN 12309-2:2000-06.

- **ANSI/AHRI 560: 2023 Standard for Performance Rating of Water-cooled Lithium Bromide Absorption Water-chilling and Water-heating Packages**

The American Air conditioning, Heating and Refrigeration Institute (AHRI) is the trade association representing manufacturers of heating, ventilation, air conditioning, commercial refrigeration and water heating equipment. The AHRI standards process is accredited by the American National Standards Institute (ANSI). This standard establishes definitions, test requirements,

rating requirements, minimum data requirements for published ratings, marking and nameplate data, and conformance conditions for water-cooled lithium bromide absorption water-chilling and water-heating packages. This standard applies to lithium bromide water-cooled single-effect steam and hot water operated water-chilling units, water-cooled double-effect steam and hot water operated water-chilling units, and double-effect direct-fired (natural gas, oil, LP gas) water chilling/heating units. Water is the refrigerant and LiBr (lithium bromide) the liquid absorbent.

There are three sets of conditions for which data is to be taken:

- full load “standard rating conditions”
- full load “application rating conditions”
- part load conditions.

The standard conditions are precisely defined, while the application conditions allow the manufacturer to choose from within a range of values for temperatures and flow rates. The latter are presented in the following tables (Table 6 and Table 7) extracted from the standard. The published ratings shall include either standard ratings or application ratings.

Table 6: Standard rating conditions extracted from the standard AHRI/ANSI 560

	<i>Single-effect Indirect-fired</i>	<i>Double-effect Indirect-fired</i>	<i>Double-effect Direct-fired</i>
<i>Absorber / condenser water</i>			
Entering water temperature	85.00°F	85.00°F	85.00°F
Water flow rate	3.6 gpm/ton _R	4.0 gpm/ton _R	4.0 gpm/ton _R
Rating fouling allowance (water-side)	0.000250 h·ft ² ·°F/Btu	0.000250 h·ft ² ·°F/Btu	0.000250 h·ft ² ·°F/Btu
<i>Evaporator</i>			
Leaving water temperature	44.00°F	44.00°F	44.00°F
Water flow rate	2.4 gpm/ton _R	2.4 gpm/ton _R	2.4 gpm/ton _R
Rating fouling factor allowance	0.000100 h·ft ² ·°F/Btu	0.000100 h·ft ² ·°F/Btu	0.000100 h·ft ² ·°F/Btu
<i>Energy input</i>			
Fuel heat content	—	—	<i>HHV</i>
Steam pressure ¹	Note 2	Note 2	—
Rating fouling factor allowance (steam)	Note 2	Note 2	—
Hot water entering temperature	Note 2	Note 2	—
Hot water leaving temperature	Note 2	Note 2	—
Rating fouling factor allowance (water-side)	0.000100 h·ft ² ·°F/Btu	0.000100 h·ft ² ·°F/Btu	—
Notes:			
1. After energy control valve at inlet flange of chiller.			
2. Manufacturer specified conditions.			

Table 7: Application rating conditions as presented in standard AHRI/ANSI 560

Rating Value	Rating Conditions
<i>Evaporator</i>	
Leaving <i>evaporator</i> water temperature	40.00°F to 70.00°F in increments of 2.00°F
Water temperature difference	8.00°F to 15.00°F
<i>Fouling factor allowance</i>	0.000 to 0.00100 h·ft ² ·°F/Btu
<i>Water cooled absorber / condenser</i>	
Entering <i>absorber</i> water temperature	70.00°F to 95.00°F in increments of 5.00°F
Water flow rate limit	2.8 to 6.0 gpm/ton _R
<i>Fouling factor allowance</i>	0.000 to 0.00100 h·ft ² ·°F/Btu
<i>Input steam pressure at steam valve or inlet header</i>	
Single stage unit	0 psig to 15.0 psig in increments of 2.0 psi
Two stage unit	0 psig to 125 psig in increments of 15.0 psi
<i>Heating mode (double-effect)</i>	
Hot water (to <i>generator</i>) temperature	180.00°F to 400.00°F
Heating water flow rate	Manufacturer's standard gpm/ton _R

Note: Applies to *full load* only and not part load ratings

- **ANSI/ASHRAE 182-2020: Method of Testing Absorption Water-Chilling and Water-Heating Packages**

ANSI/ASHRAE Standard 182 provides a method of test (MOT) for factory performance testing of absorption chillers/heaters. The standard is to be used in conjunction with a rating procedure as included in the presented standard ARI 560. Standard 182-2020 constitutes the revised version of the 2008 edition. The standard covers products employing single- and double-effect absorption cycles. It covers the products that are directly fired by natural gas, LP gas, oil, or other fuel; or that are indirectly fired by steam, hot water, a hot gas stream, or other hot heat -transfer fluids. The standard is applied to absorption chillers using lithium-bromide/water or can be applied to absorption chillers using ammonia/water. The method of test can be applied to different modes of operation, cooling mode, heating mode or simultaneous heating and cooling mode. Cooling only mode is the most prescribed test.

- **VDI 4650-2: Simplified method for the calculation of the annual heating energy ratio and the annual gas utilisation efficiency of sorption heat pumps - Gas heat pumps for space heating and domestic hot water**

The Association of German Engineers publishes up to 250 VDI Standards per year; the standards are practice oriented. VDI 4650-2 provides a guideline and a procedure to estimate the annual heating energy ratio and the annual gas utilisation efficiency of sorption heat pumps for space heating and hot water preparation for the purposes of subsidy assessment. The current version of the standard was published in 2013.

- **VDMA 24247-9, Energy efficiency of refrigerating plants — Part 9 Sorption refrigerating plants**

The VDMA is a German association of German and European mechanical and plant engineering companies; it publishes industry standards. This part of the VDMA standard series 24247 "Energy efficiency of refrigeration systems" is used as guideline to provide information on how sorption refrigeration systems can be integrated and operated in systems as energy-efficiently as possible by using various heat sources. As mentioned above, the sorption refrigeration system constitutes

energy-efficient supply of a refrigeration system in comparison to conventional chillers with higher electricity demand. It includes key figures for energy efficiency for different sorption refrigeration systems.

- **Japanese Standards Association JIS B 8622:2016: Absorption refrigerating machines**

This Japanese Industrial Standard specifies the absorption refrigerating machines, absorption water chilling and water heating packages and absorption heat pumps having the refrigerating capacity of 25 kW or over.

➤ **Review of available standards in Solar**

RE-WITCH aims to demonstrate two industrial cooling technologies driven by industrial waste heat (WH) and/or solar heat. The following paragraph presents the relevant standards in relation to thermal solar.

Table 8: Solar Standards relevant for the RE-WITCH project

Code	Title
EN 12975:2022	Solar collectors - General requirements
EN 12976	Thermal solar systems and components - Factory made systems Part 1: General requirements Part 2: Test methods
EN 12977	Thermal solar systems and components - Custom built systems Part 1: General requirements for solar water heaters and combisystems Part 2: Test methods for solar water heaters and combisystems Part 3: Performance test methods for solar water heater stores Part 4: Performance test methods for solar combistores Part 5: Performance test methods for control equipment
EN ISO 22975	Solar energy - Collector components and materials Part 1: Evacuated tubes - Durability and performance Part 2: Heat-pipes for solar thermal application Part 3: Absorber surface durability
EN ISO 24194	Solar energy - Collector fields - Check of performance
EN ISO 9488	Solar energy - Vocabulary
EN ISO 9806:2017	Solar energy - Solar thermal collectors - Test methods

Certification Keymark

Solar Keymark is an EU voluntary third-party certification for solar thermal products, demonstrating to end-users that a product conforms to the relevant European standards and fulfils additional requirements. The certification is identified by governments as a tool to ensure the quality of the products for end-consumers as it is required. It helps facilitating the trade and the use of good quality production within the market.

The Solar Keymark has been established by the European Solar Thermal Industry Federation (ESTIF) and CEN (European Committee for Standardization) in cooperation with leading European

test labs and with the support of the European Commission. It is dedicated to solar thermal collectors (based on European standard series EN 12975), factory made solar thermal systems (based on European standard series EN12976), and custom build solar thermal systems, storages and controllers (based on European standard series EN12977).

3.3. LIST OF RELEVANT WORKSHOP AGREEMENTS (CWAS) TO THE PROJECT

As mentioned in the previous paragraph, there are different type of standard documents such as CEN Workshop Agreements (CWA). These are suited for experimental topics, are valid for 3 years and can have a maximum lifetime of 6 years. At any point in its lifecycle, a CWA can be converted into another standardization deliverable (e.g. a TS or an EN), at the initiative of CEN Members or of a CEN and/or CENELEC Technical Body. The following Table 9 presents multiple CWA that has been proposed in recent years and are relevant to RE-WITCH project.

Table 9: List of CWA relevant for RE-WITCH project

Code	Title
CWA 17954:2022	Characterization of a hybrid heat pump module
CWA 17492:2022	Predictive control and maintenance of data intensive industrial processes (MONSOON)
CWA 18038:2023	Methodology for managing maintenance strategy and remanufacturing projects of large industrial equipment
CWA 18106:2024	Circularity Protocols for extending the useful Life of Large Industrial Equipment
CWA 17185:2017	Methodology for Improving the Resource Efficiency of Energy Intensive Industrial Processes (TOP-REF)

4. PRODUCTS - LABELLING RULES AND REQUIREMENTS

Regulations play a key role in a market transformation and set pathways for the direction of innovation. A key pillar of climate and energy strategy in the European Union (EU) is the improvement of energy efficiency of products. Products policies that are relevant to the RE-WITCH project are presented in this part.

4.1. PRODUCTS POLICIES AND GENERAL DESCRIPTION OF REGULATIONS RELATED TO CHILLERS

The EU introduced product policies that focused on energy efficiency to improve the environmental performance of appliances. In the late 1970s, the first EU products policies were adopted. Currently, they are organized under a clear framework directive that refine the regulatory process; the scale and ambitions has progressed. The products mandatory measures led to 46 Mtoe energy savings in 2020 (European Commission Directorate General for Energy, 2021).

Ecodesign Directive and Energy Labelling Regulation are the two cornerstones of the European Union’s product policies in the energy efficiency domain. The Ecodesign Directive establishes a framework for setting requirements for the environmental performance of energy-related products. The products must comply with these requirements in order to be used on the EU market. Energy Labelling Regulation is complementary to the Ecodesign directive with mandatory

labelling requirements; it sets the rules for product-related information; the latter will allow the customers to choose based on the efficiency of the products. The two policies contribute to the European Green Deal and supports circular economy approach.

In 1996, the first directive on energy efficiency requirements for appliances was implemented; it targeted household refrigerating and later in 2000 targeting ballasts for fluorescent lighting. In 2005, the EU commission implemented the Ecodesign Directive (2005/32/EC) shifting from independent product legislation based on Minimum Energy Performance Standard MEPS. The scope was expanded to Energy-related Products (ErP) by the new edition of the Ecodesign Directive 2009/125/EC (2009/125/EC) (Barkhausen, Durand, & Fick, 2022).

The Ecodesign requirements are elaborated using a well-defined methodology following the Methodology for Ecodesign of Energy-related Products (MEErP). It also takes into account, the best available technology and the legislation already set in countries. The MEErP include a techno-economic-environmental assessment at product level. MEErP identifies options based on the least life cycle costs (LLCC) and is supported by a ErP 'EcoReport Tool' that translates product characteristics into environmental impact indicators according to the life cycle analysis approach.

To drive the market towards sustainable products, the Ecodesign directive was complemented with Directive 2010/30 (2010/30/EU) (repealed by Regulation 2017/1369 (Regulation (EU) 2017/1369) that establishes a framework for energy labelling energy-related products

At present, 32 product groups are regulated by such implementing measures, covering a wide range of product groups. In particular, it includes heating, cooling and ventilation and refrigeration as product categories. These product groups are relevant to RE-WITCH and specifically the requirements of chillers will be presented in the following paragraphs.

Chillers in comfort and industrial process cooling applications shall comply with the following European regulations:

- Regulation 2016/2281 ((EU) 2016/2281): it sets energy efficiency requirements for chillers of up to 2000 kW that are used in air conditioning applications for comfort cooling and for industrial process cooling chillers of up to 2000 kW with a positive leaving water temperature. This regulation entered to force in 2018.
- Regulation 2015/1095 ((EU) 2015/1095): it sets energy efficiency requirements for industrial process cooling chillers with negative leaving water temperatures and is applicable from July 2018.

It should be noted that more meaningful key indicators as seasonal efficiency metrics were included in the new Ecodesign regulation for all product ranges, in all applications. It takes into consideration the seasonal variations and enable a precise evaluation of the energy consumption of the chillers. Particularly, Seasonal Energy Performance Ratio (SEPR) is used for process chillers; it measures the seasonal energy efficiency of process chillers by calculating the ratio between the annual refrigeration demand and the annual electricity consumption.

Namely, the minimum efficiency requirements for high temperature process chillers set by Regulation 2016/2281 (high temperature chillers) rated up to 2000 kW used in industrial process cooling applications are presented in Table 10. High temperature chillers are capable of delivering leaving water temperatures of between 2 °C and 12 °C.

Table 10: Minimum energy efficiency requirements for process chillers set by regulation ((EU) 2016/2281)

First tier seasonal energy performance ratio of high temperature process chillers

Heat transfer medium at the condensing side	Rated refrigeration capacity	Minimum SEPR ^(*) value
Air	$P_A < 400 \text{ kW}$	4,5
	$P_A \geq 400 \text{ kW}$	5,0
Water	$P_A < 400 \text{ kW}$	6,5
	$400 \text{ kW} \leq P_A < 1\,500 \text{ kW}$	7,5
	$P_A \geq 1\,500 \text{ kW}$	8,0

(b) From 1 January 2021, the seasonal energy performance ratio of high temperature process chillers shall not fall below the values in Table 6:

Second tier seasonal energy performance ratio of high temperature process chillers

Heat transfer medium at the condensing side	Rated refrigeration capacity	Minimum SEPR ^(*) value
Air	$P_A < 400 \text{ kW}$	5,0
	$P_A \geq 400 \text{ kW}$	5,5
Water	$P_A < 400 \text{ kW}$	7,0
	$400 \text{ kW} \leq P_A < 1\,500 \text{ kW}$	8,0
	$P_A \geq 1\,500 \text{ kW}$	8,5

By way of illustration the minimum efficiency levels/ requirements for low and medium temperature process chillers used in industrial process cooling applications that are set by Regulation 2015/1095, are presented in Table 11. Medium temperature process chillers are defined as units capable of operating at $-8 \text{ }^\circ\text{C}$ supply temperature. Low temperature means that the condensing unit is capable of delivering its rated cooling capacity at a saturated evaporating temperature of $-35 \text{ }^\circ\text{C}$.

Table 11: Minimum energy efficiency requirements for process chillers set by regulation ((EU) 2015/1095)

From 1 July 2016, the seasonal energy performance ratio (SEPR) of process chillers shall not fall below the following values:

Heat transfer medium at the condensing side	Operating temperature	Rated cooling capacity P_A	Minimum SEPR value
Air	Medium	$P_A \leq 300$ kW	2,24
		$P_A > 300$ kW	2,80
	Low	$P_A \leq 200$ kW	1,48
		$P_A > 200$ kW	1,60
Water	Medium	$P_A \leq 300$ kW	2,86
		$P_A > 300$ kW	3,80
	Low	$P_A \leq 200$ kW	1,82
		$P_A > 200$ kW	2,10

From 1 July 2018, the seasonal energy performance ratio (SEPR) of process chillers shall not fall below the following values:

Heat transfer medium at the condensing side	Operating temperature	Rated cooling capacity P_A	Minimum SEPR value
Air	Medium	$P_A \leq 300$ kW	2,58
		$P_A > 300$ kW	3,22
	Low	$P_A \leq 200$ kW	1,70
		$P_A > 200$ kW	1,84
Water	Medium	$P_A \leq 300$ kW	3,29
		$P_A > 300$ kW	4,37
	Low	$P_A \leq 200$ kW	2,09
		$P_A > 200$ kW	2,42

The regulation includes information requirements from manufactures as shown in Table 12 below.

Table 12: Information requirements for high temperature process chillers ((EU) 2016/2281)

Information requirements for high temperature process chillers			
Information to identify the model(s) to which the information relates:			
Type of condensing: [air-cooled/water-cooled]			
Refrigerant fluid(s): [information identifying the refrigerant fluid(s) intended to be used with the process chiller]			
Item	Symbol	Value	Unit
Operating temperature	t	t	°C
Seasonal energy performance ratio	$SEPR$	x,xx	[-]
Annual electricity consumption	Q	x	kWh/a
Parameters at full load and reference ambient temperature at rating point A ⁽¹⁴⁾			
Rated refrigeration capacity	P_A	x,xx	kW
Rated power input	D_A	x,xx	kW
Rated energy efficiency ratio	$EER_{DC,A}$	x,xx	[-]
Parameters at rating point B			
Declared refrigeration capacity	P_B	x,xx	kW
Declared power input	D_B	x,xx	kW
Declared energy efficiency ratio	$EER_{DC,B}$	x,xx	[-]
Parameters at rating point C			
Declared refrigeration capacity	P_C	x,xx	kW
Declared power input	D_C	x,xx	kW
Declared energy efficiency ratio	$EER_{DC,C}$	x,xx	[-]
Parameters at rating point D			
Declared refrigeration capacity	P_D	x,xx	kW
Declared power input	D_D	x,xx	kW
Declared energy efficiency ratio	$EER_{DC,D}$	x,xx	[-]
Other items			
Capacity control	fixed/staged ⁽¹⁵⁾ /variable		
Degradation co-efficient chillers ⁽¹³⁾	C_{de}	x,xx	[-]
GWP of the refrigerant			kg CO ₂ eq (100 years)
Contact details	Name and address of the manufacturer or of its authorised representative.		

It should be noted that Regulation 2016/2281 does not apply to high temperature process chillers in which refrigeration is affected by an absorption process that uses heat as the energy source (see Reg. 2016/2281 Article 1, sentence 2. (l)) and Regulation 2015/1095 does not apply to absorption chillers.

The European Commission is now operating under the Ecodesign Working Plan for the 2022-2024 period, adopted in March 2022 to ensure that this successful policy will continue to contribute to the EU’s energy efficiency targets. The working plan includes the review of the Ecodesign and energy labelling measures for air heating products, cooling products, high temperature process chillers, and fan coil units. Some products currently outside the scope of the Ecodesign Regulation such as high temperature process chillers using evaporative condensing and absorption technology may help in achieving energy and emissions savings. In parallel, a review study is currently being carried out to review Commission Regulation (EU) 2015/1095 (Ecodesign of professional refrigeration products). This follows the requirement within the regulations to

review them in the light of technological progress no later than five years after they enter into force. Phase 1.1 includes assessments of the appropriateness of setting Ecodesign requirements for process chillers using evaporative condensing and process chillers using absorption technology.

4.2. ECODESIGN FOR SUSTAINABLE PRODUCTS REGULATION

The EU products related policies were focused on energy efficiency more than resource efficiency aspects. Regulations can play a crucial role in pulling industry actors towards the circular economy. The Ecodesign for Sustainable Products Regulation (ESPR) is part of a package of measures enabling EU to achieve the target of the 2020 Circular Economy Action Plan and fostering the transition to a circular, sustainable, and competitive economy. The ESPR helps in achieving energy efficiency targets by 2030, reach climate goals and increase the circularity rate of material use by improving energy performance, recyclability and durability of products placed on the EU market. Consequently, sustainable business models will be fostered and the resilience of the EU economy will be strengthened. The ESPR replaces the Ecodesign Directive 2009/125/EC and extends it in two ways:

- The extension of the scope of application. In fact, the Ecodesign directive is applied only to energy-related products while the ESPR covers virtually all physical products. Only a few exceptions apply, for example, for food and feed, and medicinal products.
- The requirements set for products are expanded to include requirements relating to durability, circularity and the overall reduction of the environmental and climate footprint of products, amongst many others.

Currently, the ESPR lays the foundation for the subsequent adoption of concrete rules on product by product or on the basis of groups of products with similar characteristics. The process will begin with a prioritisation exercise. In the first half of 2025, the Commission will adopt the first ESPR working plan, setting out which products will be prioritised over the coming years. Development of product rules will then start, based on inclusive planning, detailed impact assessments and regular stakeholder consultation within a dedicated Ecodesign Forum.

4.3. F-GAS REGULATION

F-gas is another key regulation affecting chillers and refrigeration systems. The revised F-gas Regulation 2024/573 ((EU) 2024/573), entered into force in March 2024, represents a significant challenge for the industrial air conditioning and refrigeration world. Fluorinated gases (F-gases) are a group of synthetic gases commonly used in equipment and processes such as heat pumps, refrigeration, air conditioning and used in industrial processes. F-gases highly contribute to global warming. The European Commission established a quota system in 2015 to limit the amount of the hydrofluorocarbons HFCs placed on the EU market. In 2050, HFCs will be phased out in the EU. Chillers use (HFCs) as refrigerants. Compliance with the new regulations requires to develop and to propose products with low-GWP and natural refrigerants. In the long-term, this regulation will promote the application of natural refrigerants.

Sorption chillers are a viable solution and offer an alternative cooling technology to vapour compression chillers that uses F-gas as refrigerant. The new regulation can contribute to the development and attractiveness of the sorption cooling technologies.

5. BEST AVAILABLE TECHNIQUES TO INDUSTRIAL COOLING SYSTEMS BREF

5.1. INTRODUCTION

Industrial production processes account for a considerable share of the overall pollution in Europe. To address this issue and to prevent and control industrial emissions, different policies and practices are being implemented for the environmental and human health protection. A framework based on integrated permitting was developed at the EU level. In environmental protection law, the integrated permit is used as a tool to regulate environmental conditions and principles of operation of specific installations. The total environmental performance of the plant should be taken into account within the permit; the objective is to refrain from shifting the pollution from one environmental medium to another. The Industrial Emissions Directive (IED) is the main EU instrument regulating pollutant emissions from industrial installations. The IED was adopted on 24th November 2010 and entered into force on 6th January 2011. It is the revision of seven previous legislation regarding industrial emissions. It lays down rules to prevent and control pollution into the air, water and land (soil) and to avoid generating waste from large industrial installations and to use resources efficiently. More than 50,000 EU installations are covered by the IED. Only the installations possessing an integrated permit are allowed to operate. To prevent and control industrial emissions, the installation must apply the best available techniques (BATs) adopted by the Commission. The pollutant emissions thresholds level associated with the BATs shall not be exceeded. The policy applies for pollutants emissions to air and to water.

BAT play a key role in the IED. Article 3 defines BAT as *the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole.*

At EU level, the process of defining BAT and the BAT-associated environmental performance consists of an exchange of information between experts from member states, industry and environmental organisations arranged in Technical Working Group (TWG). The process is coordinated by the Commission Joint Research Centre's (JRC) European IPPC Bureau located in Seville (Spain). It results in BAT reference documents (BREFs). The EU Commission adopts the BAT conclusions included in BREFs as Implementing Decisions and have a value of EU law. There are two types of BREFS:

- Vertical BREFs are sector-specific covering industrial activities. It focuses on minimizing the environmental impacts and provide guideline on BATs for specific industrial sectors.
- Horizontal BREFs covers address cross-sectoral issues such as industrial cooling systems, energy efficiency, and emissions from storage. The guidelines on BATs are suitable to various industrial sectors.

5.2. INDUSTRIAL COOLING SYSTEMS BREF

The Industrial Cooling Systems (ICS) BREF (European Commission , 2001) was published in 2001 and is one of the horizontal BREFs. The term “industrial cooling systems” refers to systems that

remove excess heat from any medium, using heat exchange with water and/or air to bring down the temperature of that medium towards ambient levels.

An integrated approach to have a BAT for ICS is presented in this BREF; it acknowledges that the BAT solution is primarily dependant on the site. This approach takes into consideration the environmental performance of the cooling system operating within an industrial process. The following steps are included in the BAT approach can lead to what may be called “Best available cooling technique” to reduce emissions and environmental impacts:

- reduce the final level of waste heat produced, considering options for reuse
- define process requirements
- consider general site conditions
- assess environmental requirements:
 - options for minimisation of resource consumption
 - options for reduction of emissions
- develop system operation (maintenance, monitoring and risk prevention)
- apply economic requirements

The following scheme, Figure 1, presents the most important factors involved leading to determine a BAT for industrial cooling systems.

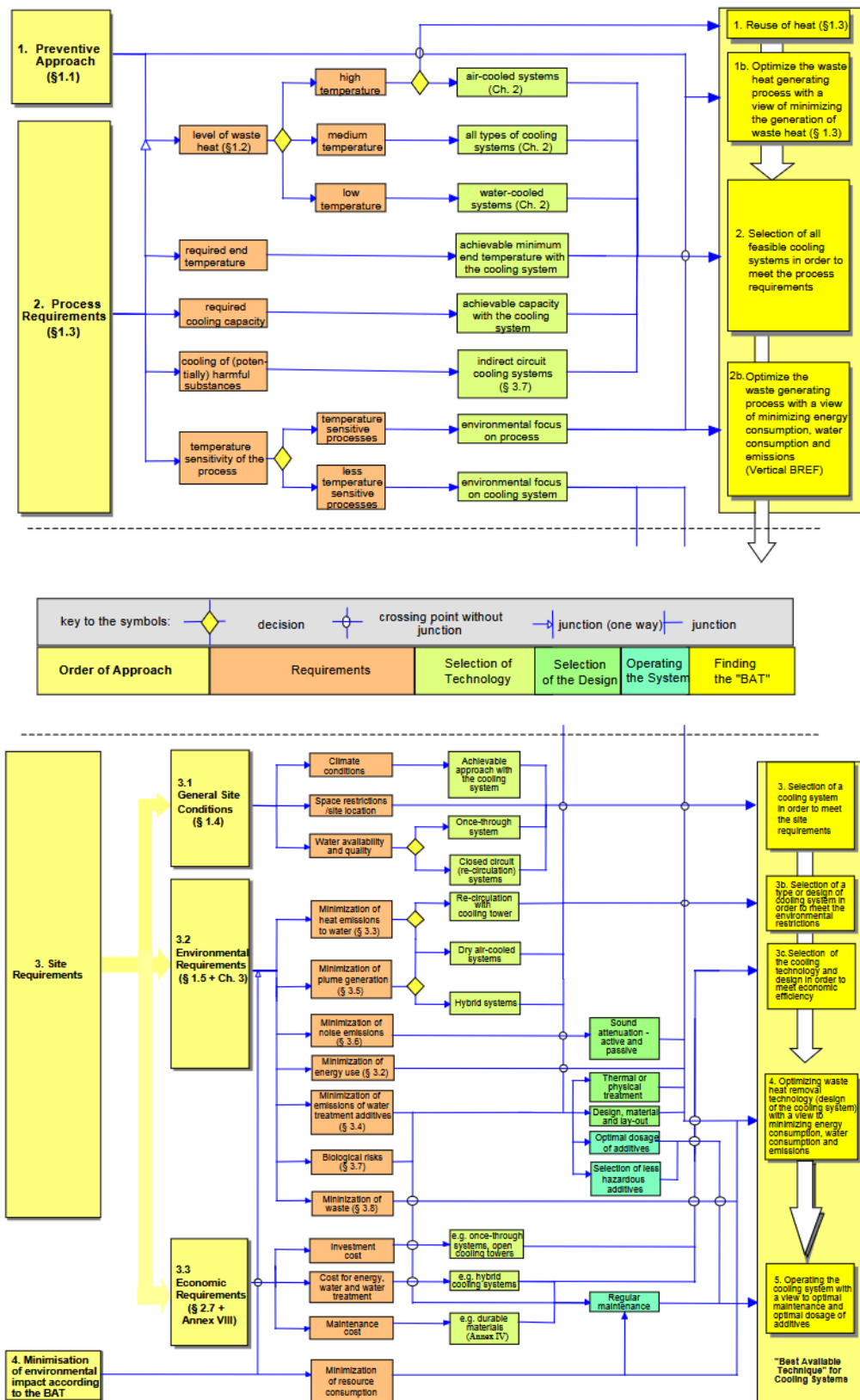


Figure 1: Schematic approach detailed in ICS BREF (European Commission, 2001)

In particular, the following industrial cooling systems or configurations are covered in this BREF document (Figure 2):

- Once-through cooling systems (with or without cooling tower)
- Open recirculating cooling systems (wet cooling towers)
- Closed circuit cooling systems
 - air-cooled cooling systems
 - Closed circuit wet cooling systems
- Combined wet/dry (hybrid) cooling systems
 - open hybrid cooling towers:
 - closed circuit hybrid tower

An attempt has been made to identify a general approach and to reach at BAT was made for each of these cooling configurations as well as for each environmental issue.

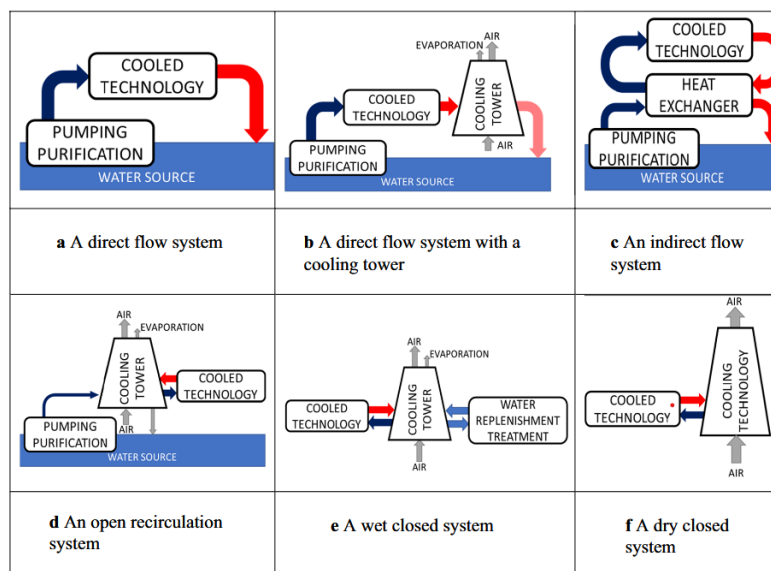


Figure 2: Schematics of the most frequently used systems according to the BAT definition source: (Hlaváček & Vagenknechtová)

There are multiple possibilities of application and techniques or operational practices of ICS within an industrial process. Consequently, it is difficult to compare the techniques that leads to general considerations on BAT. However, it is possible to identify general preventive approach.

Within the preventive approach or, primary BAT-approach, it is acknowledged that the final BAT solution will be a site-specific solution. The pragmatic options to reuse of heat should be assessed and used in prior to the dissipation of the heat into the environment. For some specific issues, techniques could be identified as general BAT. Table 13 and Table 14 present respectively examples of process characteristics and of site's constraints applicable particularly to new installations and the corresponding primary BAT approach.

Table 13: Examples of process requirements and BAT as presented in the ICS BREF (European Commission , 2001)

Process characteristics	Criteria	Primary BAT approach	Remark	Reference in ICS BREF
Level of dissipated heat high (>60 °C)	Reduce use of water and chemicals and improve overall energy efficiency	(Pre) cooling with dry air	Energy efficiency and size of cooling system are limiting factors	Section 1.1/1.3
Level of dissipated heat medium (25 – 60°C)	Improve overall energy efficiency	Not evident	Site-specific	Section 1.1/1.3
Level of dissipated heat low (<25 °C)	Improve overall energy efficiency	Water cooling	Site selection	Section 1.1/1.3
Low and medium heat level and capacity	Optimum overall energy efficiency with water savings and visible plume reduction	Wet and hybrid cooling system	Dry cooling less suitable due to required space and loss of overall energy efficiency	Section 1.4
Hazardous substances to be cooled involving high environmental risk	Reduction of risk of leakage	Indirect cooling system	Accept an increase in approach	Section 1.4 and Annex VI

Table 14: Examples of sites' characteristics and BAT as presented in the ICS BREF (European Commission , 2001)

Characteristics of site	Criteria	Primary BAT approach	Remarks	Reference in ICS BREF
Climate	Required design temperature	Assess variation in wet and dry bulb temperature	With high dry bulb temperature, dry air cooling generally has lower energy efficiency	Section 1.4.3
Space	Restricted surface on-site	(Pre-assembled) roof type constructions	Limits to size and weight of the cooling system	Section 1.4.2
Surface water availability	Restricted availability	Recirculating systems	Wet, dry or hybrid feasible	Section 2.3 and 3.3
Sensitivity of receiving water body for thermal loads	Meet capacity to accommodate thermal load	<ul style="list-style-type: none"> optimise level of heat re-use use recirculating systems site selection (new cooling system) 		Section 1.1
Restricted availability of groundwater	Minimisation of groundwater use	Air cooling if no adequate alternative water source is available	Accept energy penalty	Section 3.3
Coastal area	Large capacity >10 MW _{th}	Once-through systems	Avoid mixing of local thermal plume near intake point, e.g. by deep water extraction below mixing zone using temperature stratification	Sections 1.2.1 and 3.2, Annex XI.3
Specific site requirements	In cases of obligation for plume reduction and reduced tower height	Apply hybrid ²⁵ cooling system	Accept energy penalty	Chapter 2

ICS BREF concluded that BAT is a technology, method or procedure. It is the result of an integrated approach to reduce the environmental impact of industrial cooling systems. In addition, techniques have been identified for a number of environmental aspects. The techniques are presented, considered BAT, following on from the primary BAT-approach for:

- increasing the overall energy efficiency,
- reduction of use of water and of cooling water additives,
- reduction of emissions to air and water,
- reduction of noise,
- reduction of entrainment of aquatic organisms and
- reduction of biological risks

Table 15: BAT for increasing overall energy efficiency as presented in the ICS BREF (European Commission , 2001)

Relevance	Criterion	Primary BAT approach	Remarks	Reference
Large cooling capacity	Overall energy efficiency	Select site for once-through option	See text above table	Section 3.2
All systems	Overall energy efficiency	Apply option for variable operation	Identify required cooling range	Section 1.4
All systems	Variable operation	Modulation of air/ water flow	Avoid instability cavitation in system (corrosion and erosion)	
All wet systems	Clean circuit/ exchanger surfaces	Optimised water treatment and pipe surface treatment	Requires adequate monitoring	Section 3.4
Once-through systems	Maintain cooling efficiency	Avoid recirculation of warm water plume in rivers and minimise it in estuaries and on marine sites		Annex XII
All cooling towers	Reduce specific energy consumption	Apply pumping heads and fans with reduced energy consumption		

Table 16: BAT for reduction of water requirements as presented in the ICS BREF (European Commission , 2001)

Relevance	Criterion	Primary BAT approach	Remarks	Ref.
All wet cooling systems	Reduction of need for cooling	Optimisation of heat reuse		Ch.1
	Reduction of use of limited sources	Use of groundwater is not BAT	Site-specific in particular for existing systems	Ch.2
	Reduction of water use	Apply recirculating systems	Different demand on water conditioning	Ch.2/3.3
	Reduction of water use, where obligation for plume reduction and reduced tower height	Apply hybrid cooling system	Accept energy penalty	Ch.2.6/ 3.3.1.2
	Where water (make-up water) is not available during (part of) process period or very limited (drought-stricken areas)	Apply dry cooling	Accept energy penalty	Section 3.2 and 3.3 Annex XII.6
All recirculating wet and wet/dry cooling systems	Reduction of water use	Optimization of cycles of concentration	Increased demand on conditioning of water, such as use of softened make-up water	Section 3.2 and section XI

It is complex to optimize a cooling system to reduce the environmental impact and cannot be precise as a mathematical comparison. As mentioned in the ICS BREF, “combining techniques selected from the BAT-tables does not lead to a BAT cooling system. **The final BAT solution will be a site-specific solution.**”

6. POLICY FRAMEWORK

The RE-WITCH project demonstrates innovative and efficient thermally driven cooling and heating technologies for industrial processes contributing in industrial decarbonization. Novel designs and systems of absorption and adsorption chillers will be developed. The technologies that will be demonstrated in four sites constitute an alternative solution for waste heat valorisation. In fact, waste heat recovery represents an energy efficient resource to be exploited across many sectors and applications. Consequently, waste heat recovery plays a crucial role in the decarbonization path. Regulation and policy set pathways for the direction of innovation. The potential and promotion of waste heat recovery should be recognized in different sectors. In the part, an overview of the current policy framework regarding waste heat recovery is presented.

6.1. INTRODUCTION

Process heating is the most important energy use in industry. In 2019, it used almost half of energy demand accounted for the industrial sector in EU-27 (about 1,860 TWh) (Fleiter, Al-Dabbas, Clement, & Rehfeldt, 2023a). In EU, the cooling demand for industrial cooling or process cooling is affected by the national industrial needs. Figure 3 (Reitze, Toro, Fleiter, Rehfeldt, & Schön, 2017) highlights the final energy demand for process cooling and space cooling in the EU27+UK according to the required supply temperature levels.

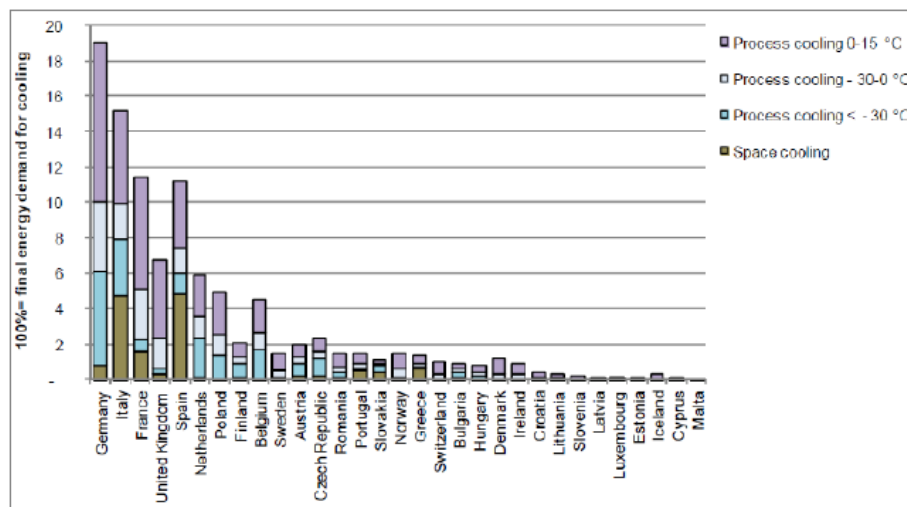


Figure 3: Final energy demand for process and space cooling in the EU27 + UK (Reitze, Toro, Fleiter, Rehfeldt, & Schön, 2017)

In parallel, Europe has considerable opportunities for waste heat recovery from power production, industry and other sectors that are not totally exploited. The excess heat in the EU was estimated in “Heat Roadmap Europe” Project and accounts to 245 Mtoe/year (David Connolly, 2013). It is equivalent to the EU’s total energy demand for heat and hot water in residential and service sector buildings. The technical potential for waste heat recovery from industries in Europe was assessed in other studies (Michael Papapetrou, 2018) at around 300 TWh/year and classified by temperature level, Figure 4.

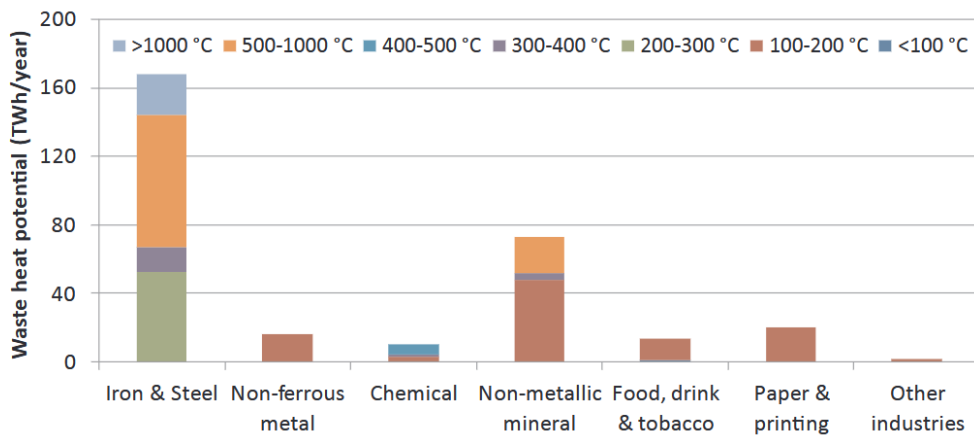


Figure 4: Waste heat potential per industrial sector and temperature level for EU in 2014 (Michael Papapetrou, 2018)

Consequently, with the significant heat waste occurring in Europe it is essential to prioritize waste heat recovery in regional and national policies. In this study (Sarah Brückner, 2015), the authors classified waste heat recovery technologies on the use of the heat basis; waste heat can be directly used at the same or lower temperature, or it can be transformed to electricity or upgraded to higher level of temperature. Accordingly, the technologies are divided into passive or active technologies. As shown in Figure 5 below, active technologies include sorption systems. It should be noted that an additional classification of active technologies is presented; it is based on the type of energy and the level of temperature upgrading or downgrading the temperature: waste heat-to-heat (WHTH), waste heat-to-cold (WHTC) or waste heat-to-electric power (WHTP).

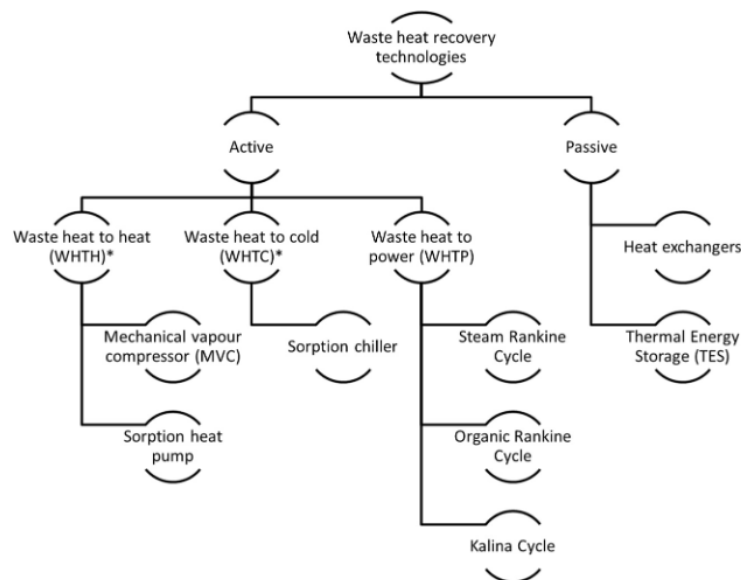


Figure 5: Waste heat recovery technologies' classification (Sarah Brückner, 2015)

These waste heat technologies can be used on site for the energy need of the process itself, or it can be supplied to an industrial process or a district heating and cooling nearby. This improves industrial symbiosis and further reduce the overall energy demand.

In the RE-WITCH project, innovative and efficient thermally driven cooling and heating technologies for industrial processes will be demonstrated. The technologies optimise the use of low-grade waste and renewable heat through new generation of adsorption and absorption chillers, contributing to industrial decarbonization. The solutions will be demonstrated across four demo sites in the food, beverage and biofuel sectors.

Even though industrial decarbonization and an emission free environment are quoted explicitly as two of the key points of the EU Green Deal and ambitious targets have been foreseen for industrial sector in recent “Fit for 55 package”, there is still a lack of technological acceptability and widespread despite the technological maturity of heat-to-cold technologies, and WHR/Thermal RES integration in industries. (Christodoulides, Gregoris, & Panayiotou, 2022) have identified several constraints establishing barriers for the implementation of waste heat recovery technologies:

- lack of information and technical expertise
- the technological risks
- the high initial, operational, and maintenance costs associated with such systems
- inadequate financial support and government incentives
- spatial and size limitations
- insufficient infrastructure
- production constraints and the potential for disruption
- adverse effects on business operations
- restrictive policies and regulations

The RE-WITCH project helps in addressing the barriers. The technological progress and the benefits of the use of these technologies will be demonstrated. In parallel, regulatory reforms and/or financial incentives are needed to address the barriers. Waste heat in EU legislation will be presented.

6.2. WASTE HEAT IN EU LEGISLATION

The European Green Deal was presented in December 2019 by the European Commission. It is a set of policy initiatives constituting a roadmap for Europe becoming a climate-neutral by 2050. To implement the Green Deal’s objectives, the EU has enacted several important directives such as the Renewable Energy Directive (RED). Waste heat in RED III ((EU) 2023/2413) gained a considerable attention in comparison to RED II which represents a notable progress. In addition, regulation on the use and evaluation of waste heat is included in the revised version of the Energy Efficiency Directive (EED III) ((EU) 2023/1791). Nevertheless, in recital 105 of EED, it is specified that the legal definition of RED III is the key element in the implementation of its provisions. These EU directives are translated to the national policies. The RED III and EED III require the integration of waste heat into the national decarbonization strategies of the Member States within certain context and the assessment of potential applications of waste heat.

1. WASTE HEAT IN THE RENEWABLE ENERGY DIRECTIVE

Red III legally defines waste heat as "*Unavoidable heat or cold generated as a by-product in industrial or power generation installations, or in the tertiary sector, which would otherwise be dissipated unused into the air or water without access to a district heating or cooling system,*

where a cogeneration process has been used or will be used or where cogeneration is not feasible." (Article 2(9)). The main elements constituting the definition of waste heat are:

- The unavoidability which comprises the impossibility to reduce that heat.
- The by-product attribute: Waste heat is defined as heat resulting from an unintended consequence of a main process operation and it is not the main goal of the producer.
- Sectoral differences: Waste heat is defined as heat originating only from industrial process (manufacturing plants and process factories) or electricity generation, or in the tertiary sector (services such as hospitals, data center etc.) are considered relevant. No other sources are considered.
- Unused: Waste heat is defined as heat that was not exploited for energy use and without any initiative it will be released into the surrounding environment, such as the air or water.

The main objective of RED III is to increase the share of renewable energy in the energy mix. The share of renewable targets is specified for each sector in the directive. Waste heat gained significant focus in the latest version; waste heat and cold is counted partially towards renewable energy targets in buildings, industry, heating and cooling sectors. However, waste heat and cold is counted towards full fulfilment of the renewable energy targets in district heating and cooling. RED III allows member states to include waste heat to a specified percentage into their national energy and climate plans. The following Table 17 presents the sectoral targets and waste heat eligibility as presented in (Marie-Theres Holzleitner-Senck, 2025):

Table 17: RED sectoral targets and waste heat eligibility (Marie-Theres Holzleitner-Senck, 2025)

Sector	Article	RES Target	Waste Heat Eligibility	Target increment due to consideration of waste heat
Building sector	15a	49% of final energy consumption by 2030. Member States define individual targets	Up to a limit of 20%	The reference value for the national share is increased by half of the percentage of waste heat used that is counted towards this share
Industrial sector	22a	The indicative target is to take the form of an annual indicative value of 1,6 percentage points per annum for the periods 2021–2025 and 2026–2030 as a calculated average	Up to a limit of 0,4 percentage points	The average annual increase will be increased by half the percentage points of the waste heat taken into account
The heating and cooling sector	23	At least 0,8 percentage points/a (2021–2025) and 1,1 percentage points/a (2026–2030)	Up to a limit of 0,4 percentage points	The average annual increase is increased by half of the percentage points of waste heat and cooling consumed
District heating sector	24	2,2 percentage points/an increase in the share of renewable energies compared to 2020 is standardized	Waste heat is regarded as an equivalent of renewable energy	

In the industry sector, Member States shall increase the share of renewable sources in the amount of energy sources used for final energy and non-energy purposes. Particularly, in the industrial sector, the accounting of waste heat is subject to restrictions; the RED restricts the inclusion of waste heat in renewable energy benchmark: the waste heat or cold should be transferred through a district heating and cooling operator from other industrial site or building in order to be counted. The waste heat used on site without being sold or distributed can not be counted. Waste heat and cold can be counted for the annual increase up to a limit of 0.4 percentage points. This methodology ensures that the counted waste heat is external and not from an internal reuse. Members states are required to include the policies and measures planned and taken to achieve the renewable energy targets in their integrated national energy and climate plans according to article 22a.

In addition, it is required that member states lay down the measures necessary for the increase of the share of energy from renewable sources and from waste heat and cold in district heating and cooling in their integrated national energy and climate plans submitted (Article 24).

In heating and cooling sector, Member States should conduct an assessment the potential renewable energy sources and of the use of waste heat and cold in accordance with the energy efficiency first principle and part of the integrated national energy and climate plans (Article 23).

2. WASTE HEAT IN THE ENERGY EFFICIENCY DIRECTIVE

The EED III contains also regulations and provisions related to waste heat. The definition of waste heat as defined in RED III is applicable in the EED III according to the Recital 105. The integration of waste heat into a district heating is required following the definition.

Particularly, Article 26 defines an "*efficient district heating system*". Compliance with this definition include the use of at least 50% renewable energy, 50% waste heat, 75% cogeneration CHP heat, or 50% of a combination of these forms of energy or heat until the end of 2027. The increase of the renewable share will occur gradually in 2028, 2035, 2040, and 2045.

In addition, according to Article 26, companies must study the feasibility of increasing energy efficiency of heating and cooling when planning or developing new installations or refurbishing existing ones. Notably, the assessment of waste heat uses on-site and off-site for industrial installation with a total average annual power greater than 8 MW must be established. Member States are required to assess the technical and economic feasibility and the impact on energy efficiency of the use of waste heat for data center with a total rated energy input exceeding 1 MW level. It should be noted that the assessment of waste heat should include the evaluation of current technologies; mainly the use of heat exchangers, heat pumps, and heat to power technologies are cited in the directive. In addition, the assessment includes the direct use of waste heat or its upgrading to higher temperature levels. It is also mentioned that the use of waste heat directly or the upgrading of the waste heat to higher level of temperature should be considered in the assessment. The downgrading of the level of the waste heat is not mentioned.

In addition, in line with the article 25, member states shall conduct a heating and cooling assessment and submit it to the Commission. The cost-benefit analysis will ease the identification of resource- and cost-efficient solutions considering the Energy Efficiency First Principle to reach heating and cooling needs. It should also be supported with measures to stimulate the use of waste heat in the development of installations including in the industrial sector and to develop of efficient district heating and cooling infrastructure. Industrial installations with a total thermal input exceeding 20 MW, generating waste heat or cold and their potential for heating or cooling supply should be identified. Moreover, member states should implement policies ensuring the use of waste heat and integrate these policies as part of the update of its national energy and climate plan.

3. EU TAXONOMY REGULATION

EU Taxonomy ((EU) 2020/852) recognised the use of waste heat used to produce heat and cool for district heating/ district cooling networks as a climate mitigation measure and green investment (EU Taxonomy Delegated Act, Annex I).

4. NATIONAL POLICIES

The member states transpose these EU directives into their national legal frameworks. The use of industrial waste heat is stimulated through multiple national policies.

The Odyssee-Mure project (odyssee-mure, n.d.), supported by LIFE-CET programme of the European Commission provides a detailed database containing a description and impact evaluation, whenever available, of all energy efficiency measures implemented at EU or national

level. The MURE database (www.odyssee-mure.eu) lists measures related to waste heat in industry (Manz & Eichhammer, 2024).

Table 18: National policies extracted from MURE project database related to industrial waste heat (Manz & Eichhammer, 2024)

Country	Sector	Title	EU	Type	Starting Year
Austria	Industry	Program klimaaktiv for Businesses	No	Information/training	2005
Croatia	Industry	Development and maintenance of the central heat energy production system (Razvoj i održavanje sustava centralne proizvodnje toplinske energije)	No	Mandatory information	2021
France	Industry	EU-related: EU Emission Trading Scheme (2003/87/EC) - National allocation plan for greenhouse gas emissions allowances (Quota Carbone)	Yes	Market-based Instruments	2005
France	Industry	EU-related: Promotion of the Use of Energy from Renewable Sources (Directive 2012/27/EC) - Heat Fund (Fonds chaleur) - Fatal heat component	No	Financial	2009
Germany	Industry	KfW Energy Efficiency/Environmental Program (KfW-Energieeffizienz/Umweltprogramm)	No	Financial	1984
Germany	Industry	Federal support for energy and resource efficiency in the economy (Bundesförderung für Energie- und Ressourceneffizienz in der Wirtschaft (EEW))	No	Financial, General programme	2019
Germany	Industry	Refrigeration-Climate Directive (Kälte-Klima-Richtlinie)	No	Financial, Mandatory information	2020
Latvia	Industry	Improving energy efficiency and promoting the use of RES technologies in industry: EU funding 2021-2027 planning period	No	Financial, Others	2022
North Macedonia	Industry	Introduction of efficient electric motors	No	Market-based Instruments	2020
Serbia	Industry	Improvement of energy efficiency in the industrial sector (Unapređenje energetske efikasnosti u sektoru industrije)	No	Financial, Information/training	2010
Serbia	Industry	Supplementary actions for the promotion of energy efficiency in the industrial sector	No	Information/training	2025
Slovenia	Industry	Financial incentive for increasing the energy efficiency and use of RES in industry	No	Financial	2017
Slovenia	Industry	Implementation of energy audits in large enterprises	No	Mandatory information	2016
Slovenia	Industry	Financial incentives for investment in energy efficiency and renewable energy sources in small and medium-sized enterprises	No	Financial	2015
United Kingdom	Industry	Industrial Heat Recovery Support programme (IHRS)	No	Financial	2020

7. CONCLUSION

This deliverable report highlights standards and guidelines relevant to RE-WITCH technologies, in particular thermally driven absorption and adsorption chillers, chillers, hybrid solutions and solar thermal. In addition, it presented EU product policies impacting refrigeration systems and ICS BREF. Also, it gives an overview of the current policy framework regarding waste heat recovery.

This first deliverable of standardization will serve as a foundation for upcoming activities in the RE-WITCH project as part of exploitation, business modelling and standardization development. It will be complemented with further activities to ensure the alignment of the solutions with standards and to provide policy recommendation for efficient market deployment of RE-WITCH technologies.

8. BIBLIOGRAPHY

- (EU) 2015/1095. (n.d.). *Commission Regulation (EU) 2015/1095 of 5 May 2015 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for professional refrigerated storage cabinets, blast cabinets, condensing units and .*
- (EU) 2016/2281. (n.d.). *Commission Regulation (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products, with regard to ecodes.*
- (EU) 2020/852. (n.d.). *Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088.*
- (EU) 2023/1791. (n.d.). *Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast).*

- (EU) 2023/2413. (n.d.). *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council* .
- (EU) 2024/573. (n.d.). *Regulation (EU) 2024/573 of the European Parliament and of the Council of 7 February 2024 on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014* .
- 2005/32/EC. (n.d.). *Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC*.
- 2009/125/EC. (n.d.). *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast)*.
- 2010/30/EU. (n.d.). *Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (recast)*.
- (2024). *Annex 58: High temperature heat pump, Task 4 Recommendations for defining and testing of specifications* .
- Barkhausen, R., Durand, A., & Fick, K. (2022). Review and Analysis of Ecodesign Directive Implementing Measures: Product Regulations, Shifting from Energy Efficiency towards a Circular Economy.
- Christodoulides, P., Gregoris, L. A., & Panayiotou, P. (2022). Adoption of waste heat recovery technologies: reviewing the relevant barriers and recommendations on how to overcome them.
- CWAs resulting from an EU-funded project (or more generally a Europe-wide project with public co-funding)*. (n.d.). Retrieved from <https://www.cencenelec.eu/get-involved/research-and-innovation/horizon-europe-projects/cwa-download-area/>
- David Connolly, B. V. (2013). *Heat Roadmap Europe 2: Second Pre-Study for the EU27*. Department of Development and Planning, Aalborg Universit.
- Diego Menegon, P. F. (n.d.). *Task 48 Deliverable B1: Report on system characterization in the laboratory* . Solar Heating and Cooling Programme IEA.
- European Commission . (2001). *Reference Document on the application of Best Available Techniques to Industrial Cooling Systems*.
- European Commission Directorate General for Energy. (2021). *Ecodesign impact accounting annual report 2020*.
- Fleiter, T., Al-Dabbas, K., Clement, A., & Rehfeldt, M. (2023a). *The impact of industry transition on a CO2 neutral European energy system*.

Gonzalez-Torres, M., Bertoldi, P., Castellazzi, L., & Perez-Lombard, L. (2023). Review of EU product energy efficiency policies: What have we achieved in 40 years.

Hlaváček, O., & Vagenknechtová, A. (n.d.). Reduction of water consumption for heating plant, cooling with an indirect cooling system.

Malenković, I. (2012). *Task Report 5.3.3: Review on Testing Procedures and Quality Standards for Thermally Driven Chillers*.

Manz, P., & Eichhammer, W. (2024). *Industrial excess heat and energy efficiency policies*.

Marie-Theres Holzleitner-Senck, S. M. (2025). Waste heat inconsistency in EU policies . *Utilities policy*.

Michael Papapetrou, G. K. (2018). Industrial waste heat: Estimation of the technically available resource in the EU per industrial sector, temperature level and country. *Applied Thermal Energy* .

odyssee-mure. (n.d.). Retrieved from <https://www.odyssee-mure.eu/>

Regulation (EU) 2016/2281. (n.d.). *Commission Regulation (EU) 2016/2281 of 30 November 2016 implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products, with regard to ecodes*.

Regulation (EU) 2017/1369 . (n.d.). *Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU*.

Reitze, F., Toro, F., Fleiter, T., Rehfeldt, M., & Schön, M. (2017). Prozesskältebedarf in Industrie und Gewerbe – wo liegen die Bedarfsschwerpunkte in Europa?

Sarah Brückner, S. L. (2015). Industrial waste heat recovery technologies: An economic analysis of heat transformation technologies. *Applied Energy* .