Renewable Cooling under the Revised Renewable Energy Directive

Study commissioned under ENER/C1/2018-493 by the European Commission (December 2019 – June 2021)

Lukas Kranzl, TU Wien
Philippe Riviere, Armines

CA-RES – 10 October 2020

Content

- Context and overview of the study
  - Objectives of the study
  - Clarifying some system boundaries and relevant definitions of the study
  - Prospective cooling technologies
  - Content of the impact assessment

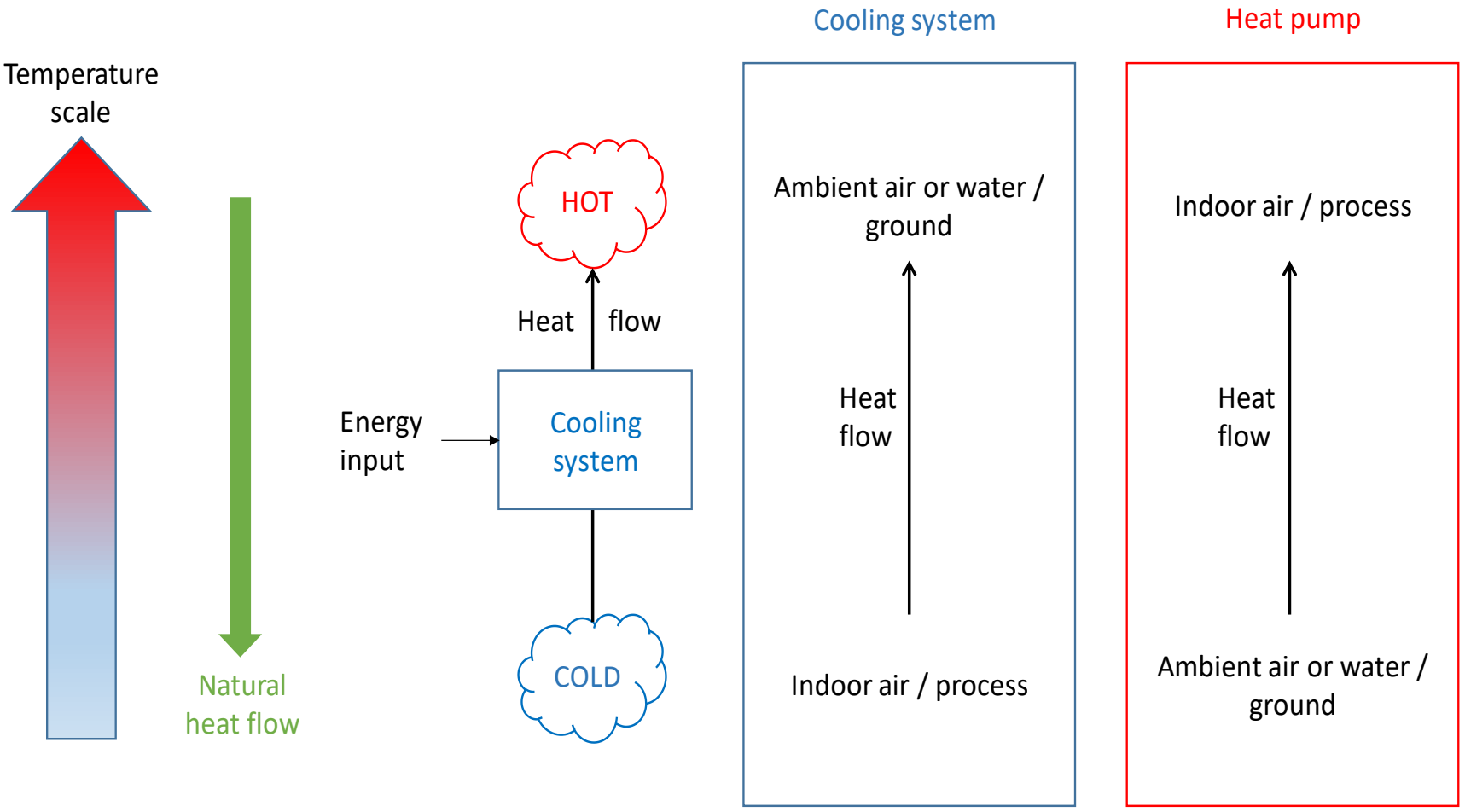
- Renewable cooling definition options

Overview – goals of the study in line with the ToR

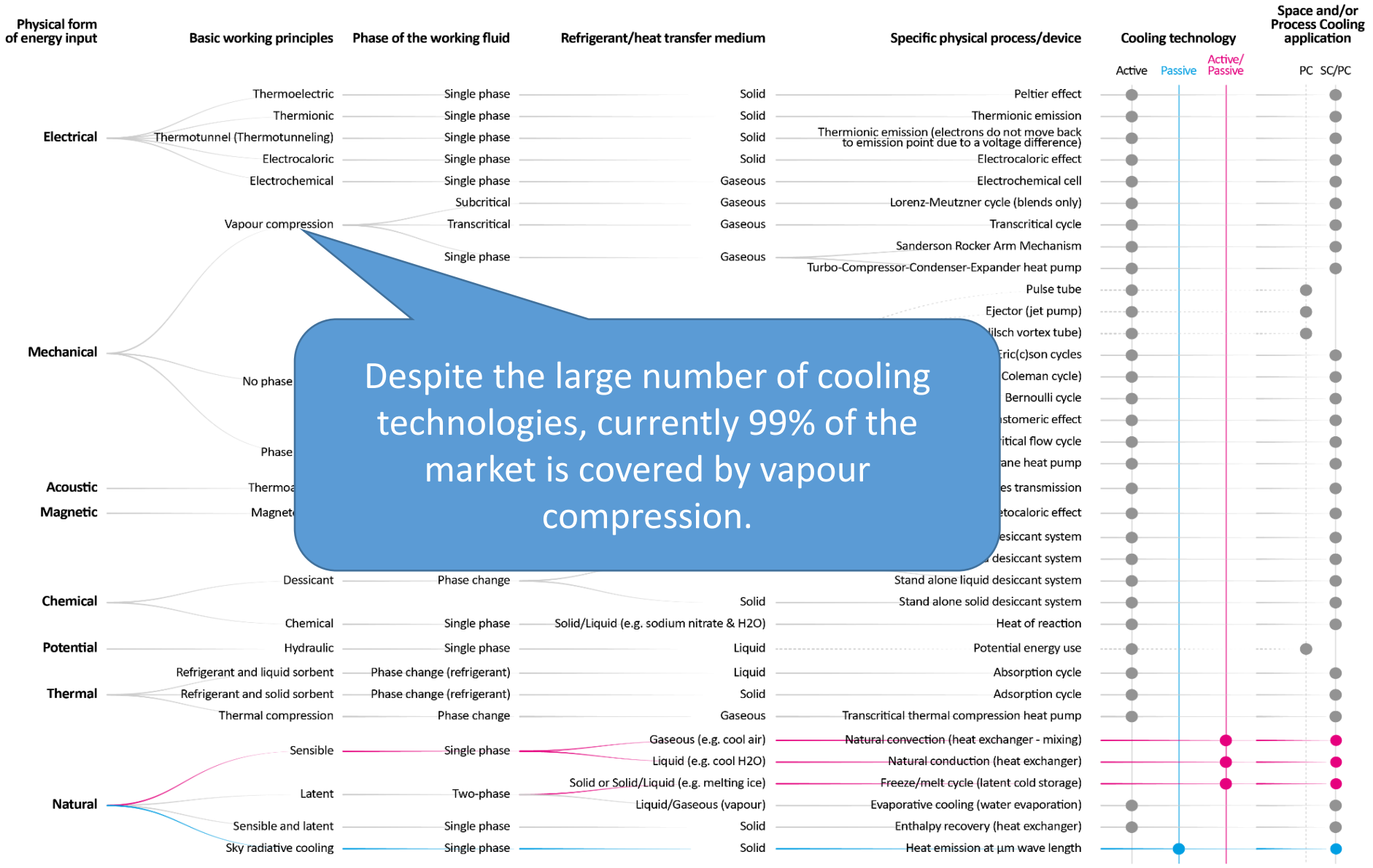
- ✓ Quantify current final energy consumption for cooling (as well as its development until 2030 and 2050);
- ✓ Overview of technologies for cooling and related technological trends;
- ✓ Investigate how much various cooling technologies are able to deliver renewable cooling;
- ✓ Renewable cooling definitions in line with RED II and related RES-shares;
- ✓ Deliver the equations with regard to the recommended methods;
- Impacts as well as benefits and costs of proposed definitions;
- Recommendations on how statistical reporting can be utilized for RES-C;

- Assure to be in line with the updated EPBD, implementing regulations of the Ecodesign and Energy Labelling Directives and the new F-gas Regulation
- Support implementing the RED II – accomplishment of the EU 2030 goal (Article 3), quantification of the renewable energy shares (Article 7), the provisions regarding H&C (Article 23) as well as DHC (Article 24).

Cooling process



Cooling technologies



Despite the large number of cooling technologies, currently 99% of the market is covered by vapour compression.

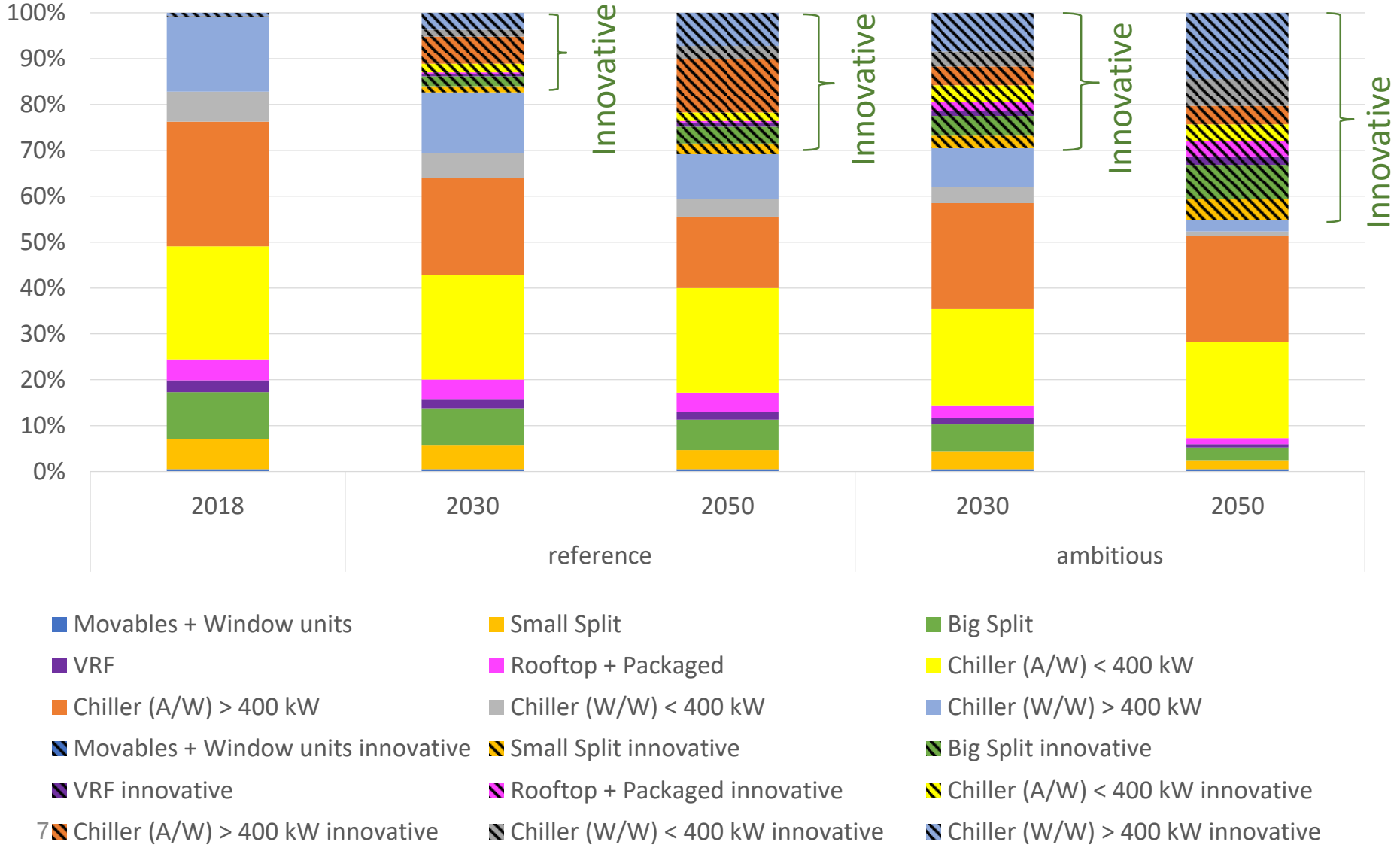
Classification dimensions of main cooling technology clusters

Dimension 1: Cooling type	Dimension 2: Energy Input	Dimension 3: Cold source (Heat sink)
Moveables	Electricity (grid)	Air
Small Split (<5kW)	Fuel (fossil)	Ambient water
Big Split (>5kW)	Electricity (local renewable)	Ground
Variable refrigerant flow systems	Fuel (renewable)	Aquifer
Rooftop + Packaged	Renewable Heat	Waste cold
Chiller <400 kW	Waste Heat	
Chiller >400 kW		

Favourable, innovative cooling systems

- Identification of 77 cooling technology clusters resulting from reasonable combinations of these dimensions

Market penetration of cooling technology clusters and possible evolution scenarios (preliminary data)



Cooling systems – Principles 1

- **Passive cooling** ⇛ Not in the scope of calculations (fourth sub-para Art.7(3))
  - Cooling can occur naturally without the intervention of a cooling device, using natural flow of energy from hot to cold
  - Includes actions aiming at reducing the cooling load not requiring an external energy input: such as stores, blinds, building insulation, green roofs, natural ventilation
- **Active cooling: free cooling** ⇛ In the scope of calculations
  - Cooling systems using and/or facilitating the natural energy flow
  - There is a cold source which has lower temperature than the space/process to be cooled.
  - Only requiring (fans and) pumps to assist heat transportation.
- **Active cooling: cooling generator** ⇛ In the scope of calculations
  - When natural heat flow not available, not used or not sufficient
  - Energy input, additional to heat transportation means, is required.

Cooling systems: Principles 2

- Cooling systems' components:
  - A **heat extraction system**
  - One or several **cooling devices**
  - A **heat rejection system**

+ cooling medium through wich the heat transfer (extraction and rejection) operates ⇛ only needed in active cooling

+ **heat sinks or cold sources**: where the heat is rejected

Heat sinks which have lower temperature than the space or process to be cooled can be used in free or partial free cooling ⇛ they are genuine cold sources.

+ **cooling generator**: part of the cooling device in active cooling, which generates the cold

Remarks on the boundaries with waste heat

- Most cooling generators work as heat pump (HP). Heat pumps are heat transfer devices. They extract heat from a space or process (cooling) and transfer it to another space or process (heating).
- Cold is provided by the cold side of the heat pump → (can be) used for cooling
- Heat is provided by the hot side of the heat pump → (can be) used for heating

→When **HP is used for heating** it **extracts heat from** the ambient air, surface and sewage water, i.e. **ambient energy** and ground, i.e. **geothermal energy** – these are **renewable energy sources** – see Art 2(1), (2), (3) of REDII

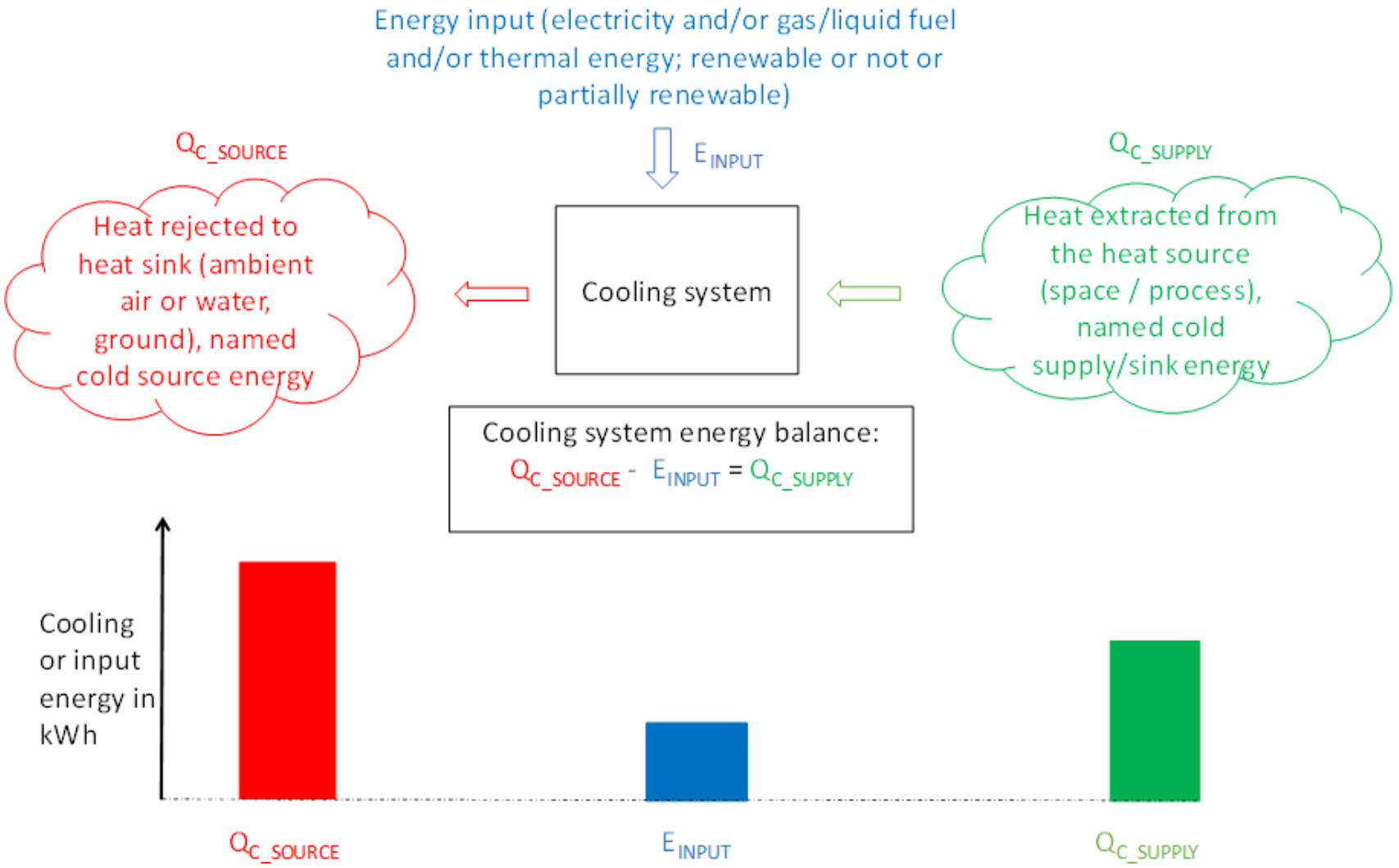
→When **HP is used for space cooling**, it **extracts heat from indoor air**, which **is not renewable**, or a process and rejects it to outdoor/ambient air, water or ground, which are renewable and in this instance operates as heat sinks, which are cold sources. **The rejected heat is waste heat**. This waste heat could be further used as an energy input for a cooling or heat generator. This waste heat recovery is desirable because it reduces heat pollution and energy waste (increase energy efficiency).

→While this **recovery of waste heat from cooling** is desirable, it does not transform the waste heat into renewable even if it is done by HP. However, such recovered heat, if mediated by district heating and cooling can count towards the Article 23, 24 targets – see Art 2(9) of REDII.

Remarks on the boundaries with waste cold

- Waste cold is produced from industrial and service sector processes. A typical example is LNG terminals, where the liquid gas is evaporated and the evaporation extracts heat out from the environment.
- Such industrially generated cold can be used as a heat sink, similarly to natural heat sinks that are colder than the space/process to be cooled, such as surface water or ground, and are natural cold sources.
- **Natural cold sources are renewable** and covered by the definitions of ambient energy and geothermal energy under points 1, 2 and 3 of Article 2 of REDII.
- **Waste cold does not qualifies as renewable energy** and is covered under point 9 of Article 2 of REDII.
- However, **waste cold as a cold source/heat sink can be counted** towards the **Article 23 and 24 targets**, if a calculation method would be available/ agreed. Such calculation method is currently not a legal requirement but will be elaborated under the study.

Cooling systems: energy streams and balance



Cooling: Possible renewable elements

Cooling elements that could be considered renewable:

- The presence of constantly **low temperature cold source** as heat sink
  - →eliminating or reducing the need for a cooling device/generator and enhancing the efficiency of the cooling process
- **High Seasonal Performance Factors**
  - →often signalling the presence of a cold source
- **Renewable energy input (local)** to the cooling generators
  - → currently not included in the calculation of renewable heating from heat pumps ⇢ Shall we consider including it in renewable cooling?
  - ⇢ only ambient heat (**ambient heat energy** and **geothermal heat energy** since REDII), i.e. the heat source from which heat is extracted is counted in renewable heating;
  - ⇢ energy input, even if renewable, is not counted in renewable heating's shares;
  - ⇢ such energy input for heating is counted in renewable electricity shares if this is the energy input;
  - ⇢ if the energy input is renewable gas or heat for heat pumps used for heating, it is not counted in renewable shares either of electricity or heat ⇢ minor fraction of heat pumps currently on the market and gas driven heat pumps are no longer produced for the residential sector.

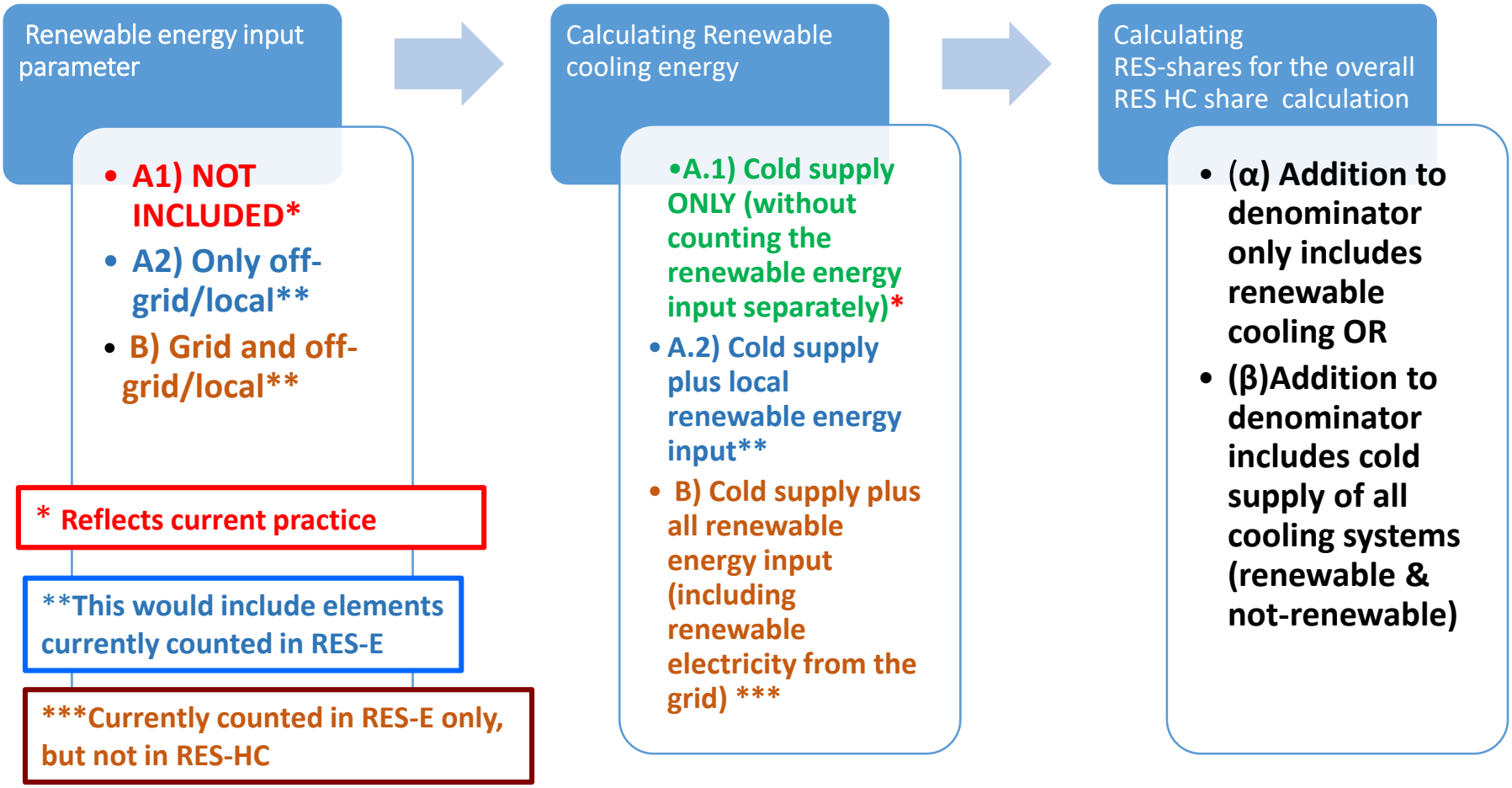
Note! SPF is a mandatory element for reversible heat pumps (Art. 7(3) sixth sub-paragraph)

RES-C definitions (1): possible cooling systems in scope

The table includes waste cold as cold source and waste heat as energy input to the cooling device/generator. These are **not in the scope of renewable cooling** investigations, but in the scope of the counting of waste cold and waste heat as eligible under the flexibility in Article 23(2)(a), which allows these to be counted towards the heating/cooling target and district heating/cooling targets, but not the overall RES target under Article 3 of REDII.

Cold source	Energy input					
	Electricity		Gas/liquid fuel		Heat	
	Grid	Off grid photovoltaics	Grid / fossil	Local renewable	Renewable	Waste heat
Ambient air	Vapour compression, membrane heat pump	Vapour compression, membrane heat pump	Vapour compression, ab(ad)sorption,	Vapour compression, ab(ad)sorption,	Ab(ad)sorption,	Ab(ad)sorption,
Ambient water	Vapour compression, Free-cooling	Vapour compression	Vapour compression, ab(ad)sorption	Vapour compression, ab(ad)sorption	Ab(ad)sorption	Ab(ad)sorption
Ground ***Vertical borehole and aquifers***	Vapour compression, Free-cooling	Vapour compression	Vapour compression, ab(ad)sorption	Vapour compression, ab(ad)sorption	Ab(ad)sorption	Ab(ad)sorption
Waste cold	Vapour compression, Free-cooling	Vapour compression	Vapour compression, ab(ad)sorption	Vapour compression, ab(ad)sorption	Ab(ad)sorption	Ab(ad)sorption

Options for renewable cooling definition



Exploratory options for RES-C: Case A1 and A2

- Only low temperature cold supply is considered: A1
- Low temperature cold supply + <u>local</u> renewable energy input are considered: A2
- Criteria based on cold source type AND/OR minimum SPF
  - SPF replaced by $SPF_{RE(WH)}$ for local renewable energy input

Example for solar absorption

$$SPF_{RE} = \frac{Q_{C\_Supply}}{E_{INPUT\_RE(LOCAL)} + Egas_{grid} + \frac{Eelec_{grid}}{\eta}}$$

SPF THRESHOLDS						
	Energy input					
	Electricity		Gas/liquid fuel		Heat	
Cold source	**Grid**	**Off grid photovoltaics**	**Grid / fossil**	**Local renewable**	**Renewable**	**Waste heat**
Ambient air	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}
Ambient water	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}	SPF_{HIGH}
Ground	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}
Waste cold	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}	SPF_{LOW}

- SPF_{HIGH} above best available technologies; SPF_{LOW} at Ecodesign MEPS levels
- SPF low and high values may be adjusted depending on source / sink combinations, metrics available by source type and boundary conditions

Options A1 and A2: impact of SPF_{RE}

- Impact of discounting E_{INPUT_RE} on $SEER_{RE}$ illustrated for air conditioners
  - Complementary efforts in terms of energy efficiency and RES integration

Future MEPS level

Future label scale impact

SEER	E_{INPUT_RE} / E_{INPUT}										
	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
6	6.3	6.7	7.1	7.5	8.0	8.6	9.2	10.0	10.9	12.0	
6.5	6.8	7.2	7.6	8.1	8.7	9.3	10.0	10.8	11.8	13.0	
7	7.4	7.8	8.2	8.8	9.3	10.0	10.8	11.7	12.7	14.0	
7.5	7.9	8.3	8.8	9.4	10.0	10.7	11.5	12.5	13.6	15.0	
8	8.4	8.9	9.4	10.0	10.7	11.4	12.3	13.3	14.5	16.0	
8.5	8.9	9.4	10.0	10.6	11.3	12.1	13.1	14.2	15.5	17.0	
9	9.5	10.0	10.6	11.3	12.0	12.9	13.8	15.0	16.4	18.0	
9.5	10.0	10.6	11.2	25.0	12.7	13.6	14.6	15.8	17.3	19.0	
10	10.5	11.1	11.8	12.5	13.3	14.3	15.4	16.7	18.2	20.0	
10.5	11.1	11.7	12.4	13.1	14.0	15.0	16.2	17.5	19.1	21.0	
11	11.6	12.2	12.9	13.8	14.7	15.7	16.9	18.3	20.0	22.0	
11.5	12.1	12.8	13.5	14.4	15.3	16.4	17.7	19.2	20.9	23.0	
12	12.6	13.3	14.1	15.0	16.0	17.1	18.5	20.0	21.8	24.0	

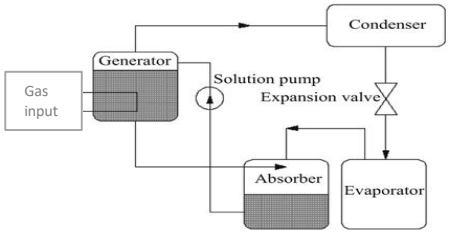
High SPF threshold Options A1 and A2

Integration of RES in cooling, growing $SEER_{RE}$

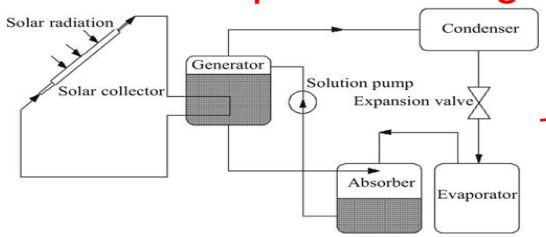
Note: absolute numbers are for illustration purpose only!

Options A1 and A2: SPF_{RE} of renewable cooling solutions

- Gas absorption



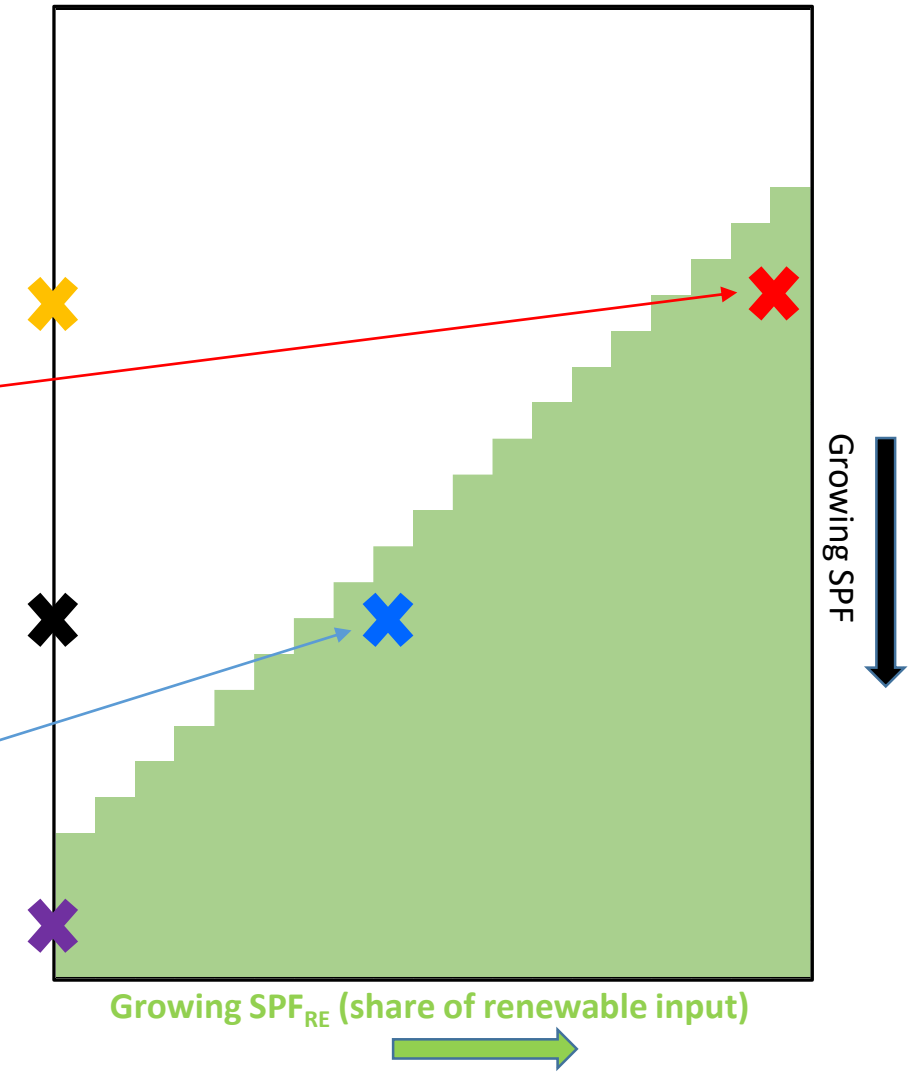
- Solar absorption cooling



- Split air conditioner

- Split air conditioner + PV

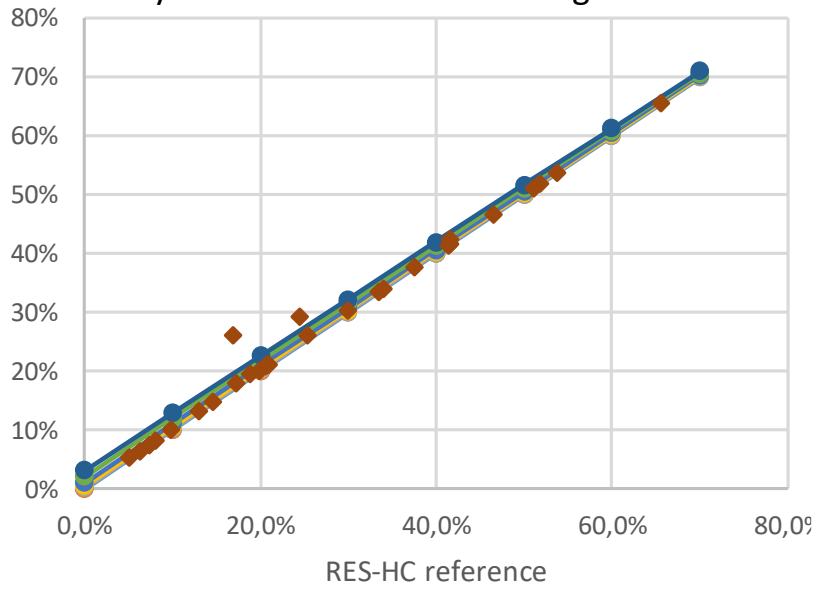
- Free cooling



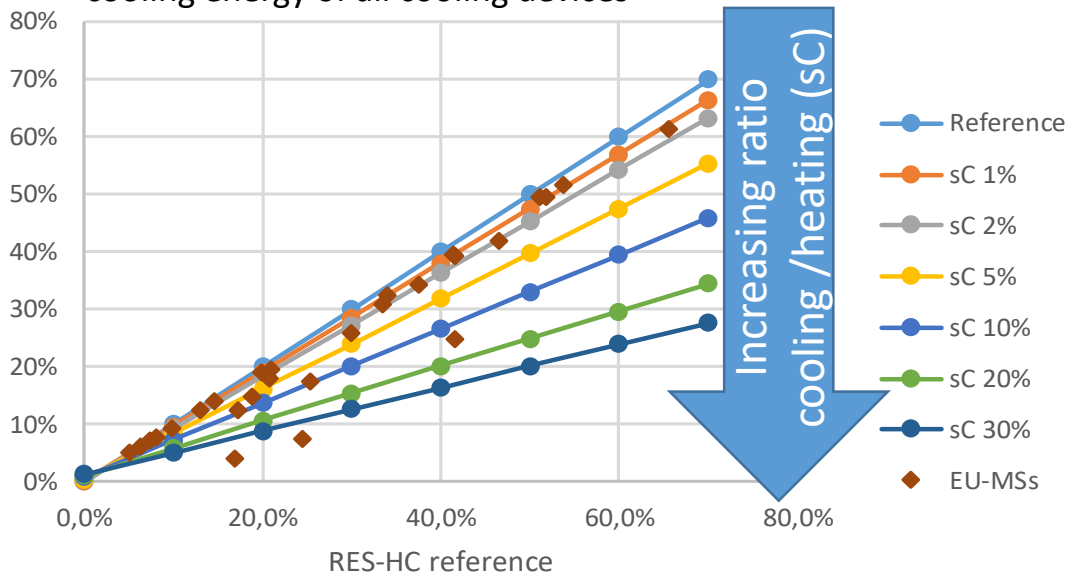
Preliminary, indicative results on impact assessment, 2016, **high** constraints on renewable cooling generators

Resulting RES-H&C share

Option α: addition to the denominator only includes renewable cooling



Option β: addition to the denominator includes cooling energy of all cooling devices



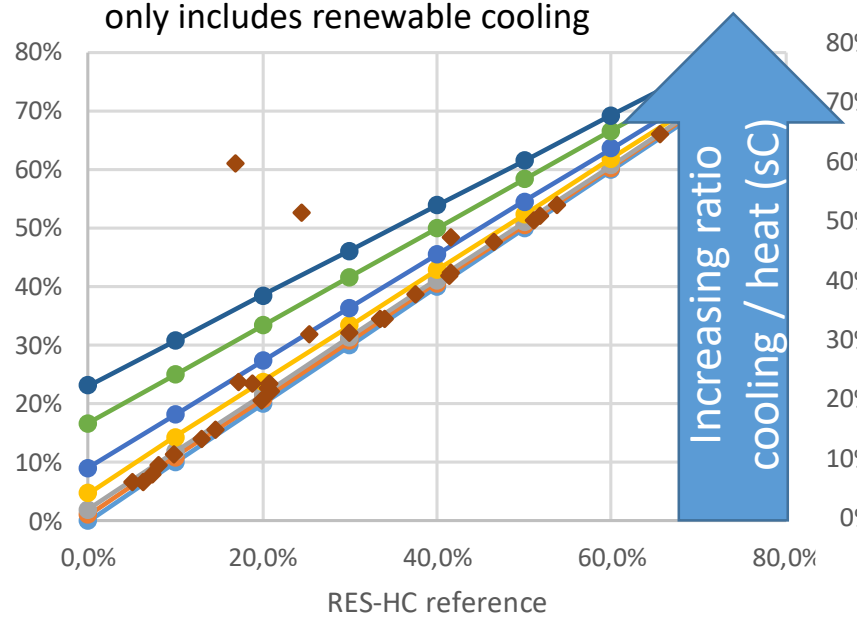
- sC: Ratio between final energy consumption for cooling and final energy consumption for heating
- „high constraints“: constraints are set in a way that 1% of current cooling generators are counted as renewable

Source: own calculations, based on SHARES-Tool

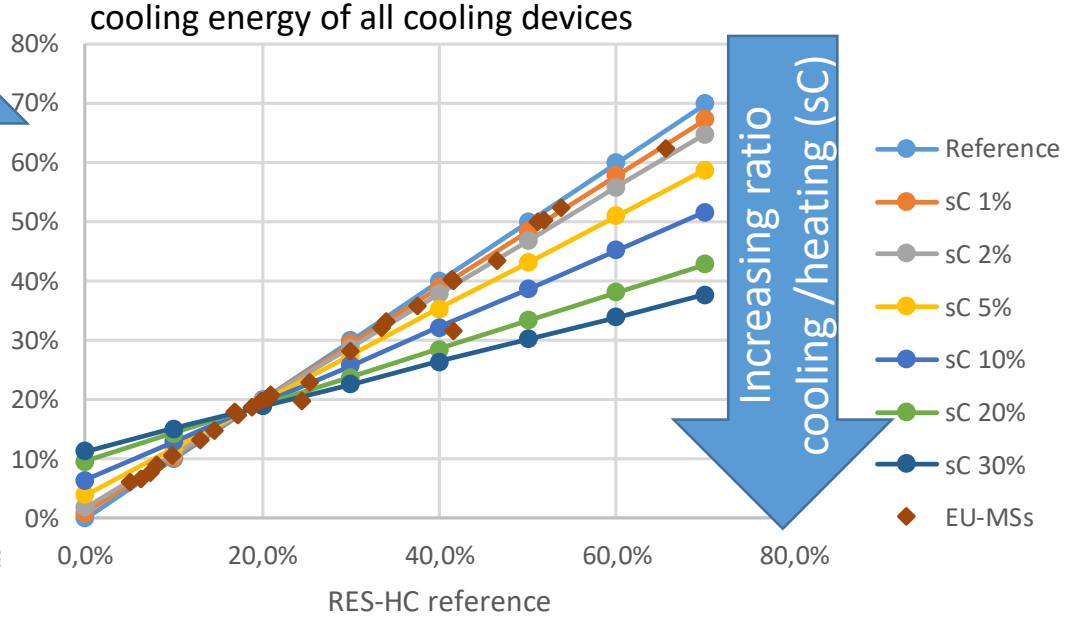
Preliminary, indicative results on impact assessment, 2016, **moderate** constraints on renewable cooling generators

Resulting RES-H&C share

Option α: addition to the denominator only includes renewable cooling



Option β: addition to the denominator includes cooling energy of all cooling devices



- sC: Ratio between final energy consumption for cooling and final energy consumption for heating
- „moderate constraints“: constraints are set in a way that 10% of current cooling generators are counted as renewable

Source: own calculations, based on SHARES-Tool

Outlook

- Assessing the impacts of various definition options
- Proposing final definition and calculation methodologies
- Guidance documents

Feedback is welcome!

Thanks!

Orig. Photo: Patrick Stargardt