Task 48 - Overview on heat rejection systems

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Aim of the work

Looking to the solar cooling system as a whole, the heat rejection system is responsible for:

- a relevant part of the investment costs
- is the major responsible for electricity consumptions (around 50%)
- in some cases they are responsible also for a relevant water consumption

As such, the heat rejection system is a limiting factors to the diffusion of solar cooling systems on the market.

A better insight of **market-available variants** is therefore desiderable

http://task48.iea-shc.org/publications

Aim of the work

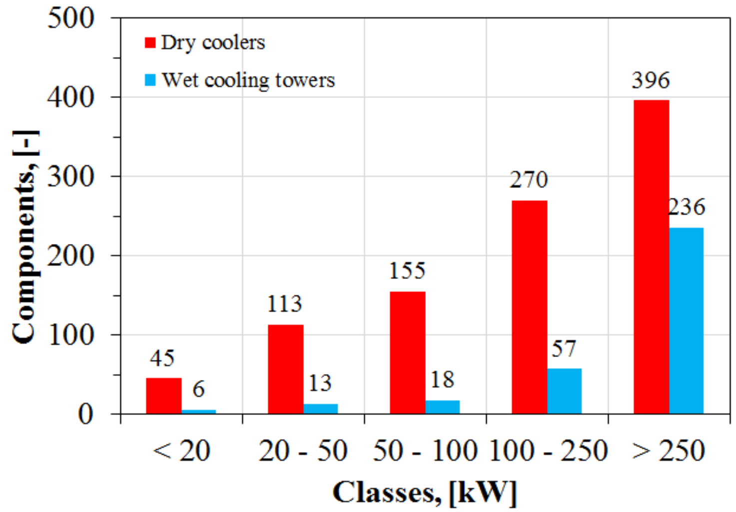
- A market survey has been conducted on **more than 1300 products** by using free-available technical documentation of 23 manufacturers
- A database of dry coolers (DCs) and wet cooling towers (WCTs) has been created according the following criteria:
  - general characteristics
  - rated performance (1)
  - fan parameters
  - coil parameters
  - catalog cost

DCs: $T_{w,in}$=40°C, $T_{w,out}$=35°C, T_{db}=25°C [ENV1048:1995]

WCTs: $T_{w,in}$=95°F (35°C), $T_{w,out}$=85°F (29.4°C), T_{wb}=78°F (25.5°C) [CTI STD-203:2005]

Aim of the work

The database comprises heat rejection components from **small to large capacities** adopted in residential, industrial or tertiary applications:



- **Rated performance are available in the database**
- **Off-design performance is calculation based on correction factors** provided by the manufacturers (thermal performance) and on simulation models (electric performance)

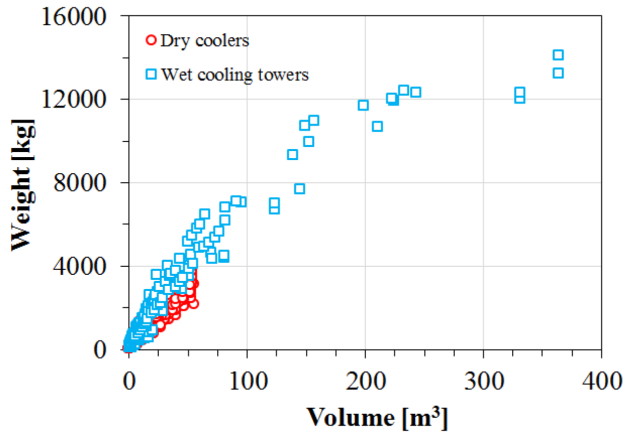
Technical features: sizes

- **Weight-to-volume ratio:**

  DCs: 45-126 kg/m³

  WCTs: 41-101 kg/m³

Sample: 82.7%

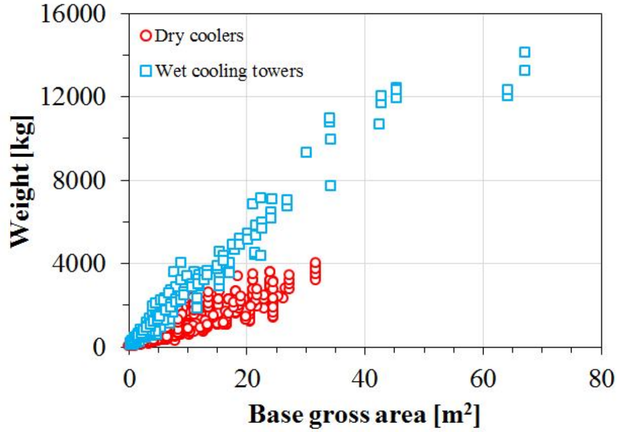


- **Weight-to-base gross area ratio:**

  DCs: 97-185 kg/m²

  WCTs: 208-376 kg/m²

Sample: 82.7%



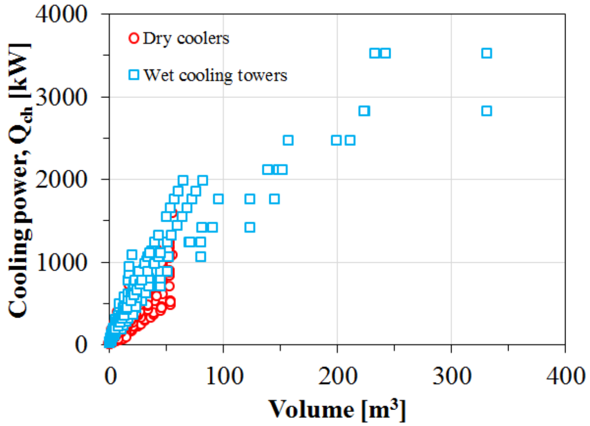
Technical features: sizes

- **Chilling power-to-volume ratio:**

  DCs: 10-40 kW/m^3

  WCTs: 8-47 kW/m^3

Sample: 82.7%

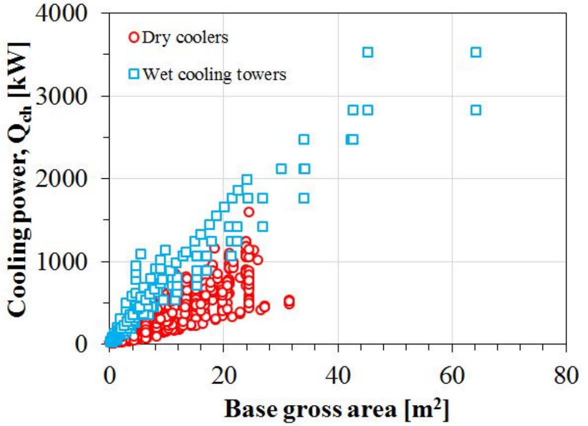


- **Chilling power-to-base gross area ratio:**

  DCs: 13-80 kW/m^2

  WCTs: 60-163 kW/m^2

Sample: 82.7%



Technical features: thermal & electrical power

- **Electrical-to-thermal power ratio:**

  DCs: 0.013-0.091 kW_{el}/kW_{ch}

  WCTs: 0.005-0.060 kW_{el}/kW_{ch}

  Induced draught:

  0.005-0.025 kW_{el}/kW_{ch}

  forced draught towers:

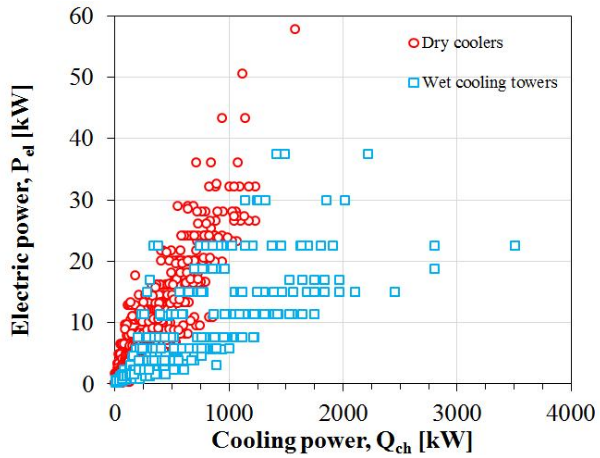
  0.010-0.060 kW_{el}/kW_{ch}

- **Literature:** Eicher et al., 2012; Saidi et al., 2011 (quantities in kW_{el}/kW_{ch}); Solarrück

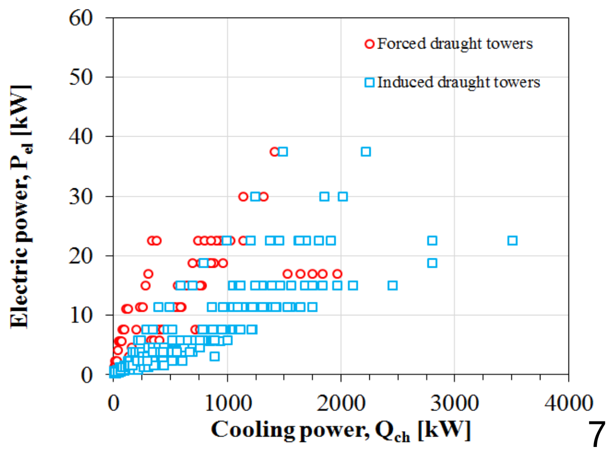
  DCs: 0.045, **WTCs**: 0.018,

  induced: 0.007, forced: 0.02

Sample: 90.1%



Sample: 98.8%



Technical features: mass flow rate & noise level

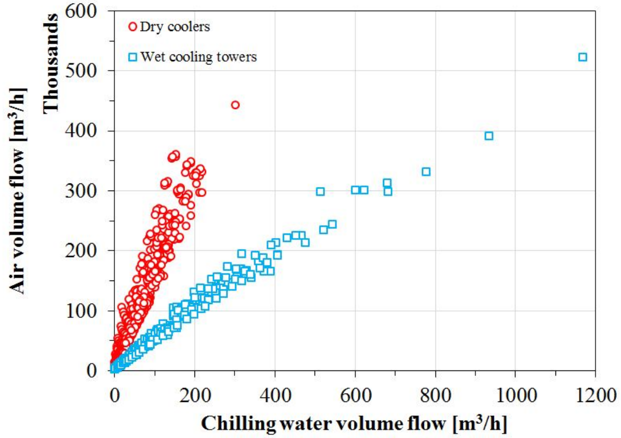
- **Air-to-chilling water mass flow rate ratio:**

  DCs: 1.7x10^3

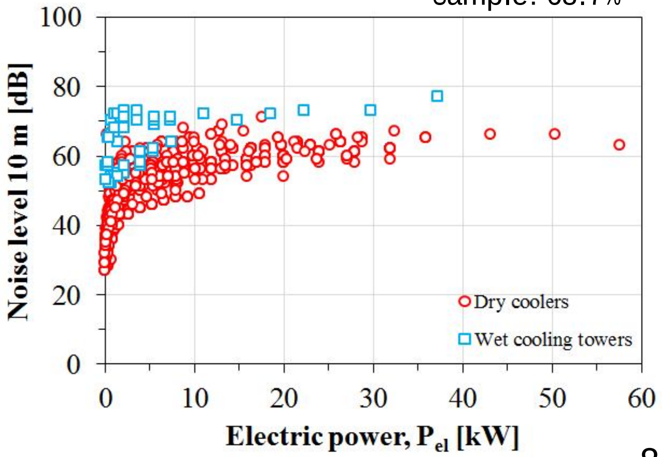
  WCTs: 0.49x10^3

- **Noise level:** values measured at a distance of 10 m

Sample: 95.3%



Sample: 68.7%



EURAC research

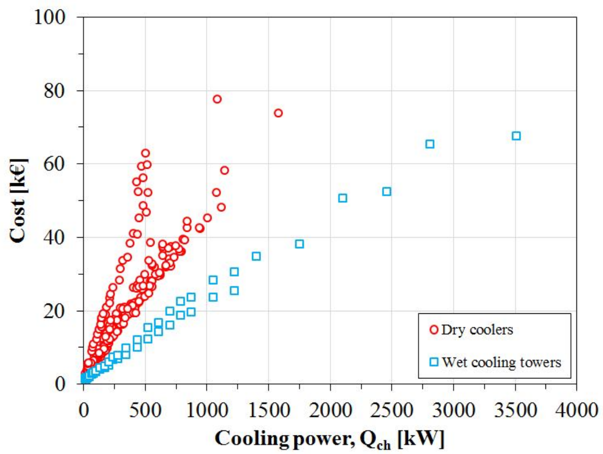
Economic features

- **Investment costs-to-cooling power ratio:**

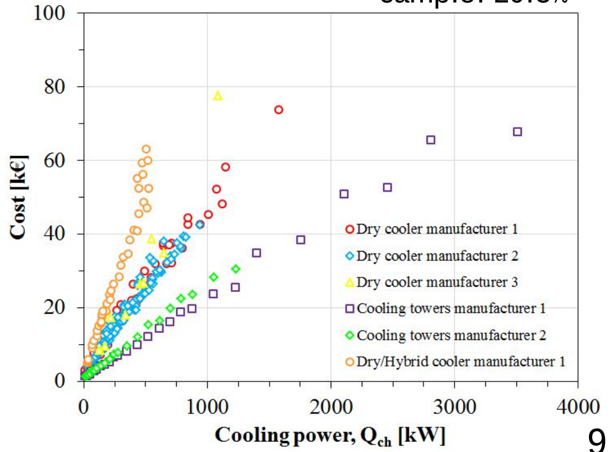
DCs: 49-107 €/kW_{ch}

WCTs: 22-27 €/kW_{ch}

Sample: 20.3%



Sample: 20.3%



Market analysis - Conclusions

- WTCs can reject more thermal power than DCs under the same climatic and operation conditions with **a lower average specific consumption** (0.033 kW_{el}/kW_{ch}) compared to DCs (0.017 kW_{el}/kW_{ch})

- **WTCs** have also a **lower investment cost even though are characterized by higher costs during operation in relation to fresh water consumption and legionella prevention measures**: their adoption is **in some cases can be discouraged** (i.e. Middle East)

Climatic suitability

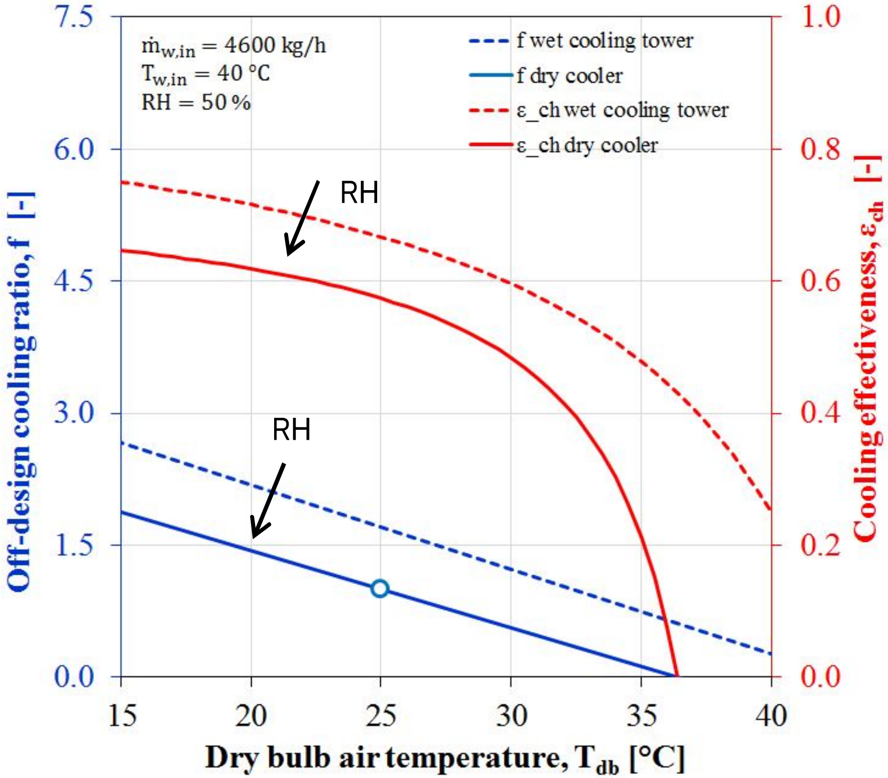
- In order to compare between DCs and WCTs, two figures of merit have been defined:

- Cooling performance factor

$$f = \frac{Q_{ch,actual}}{Q_{ch,rated}}$$

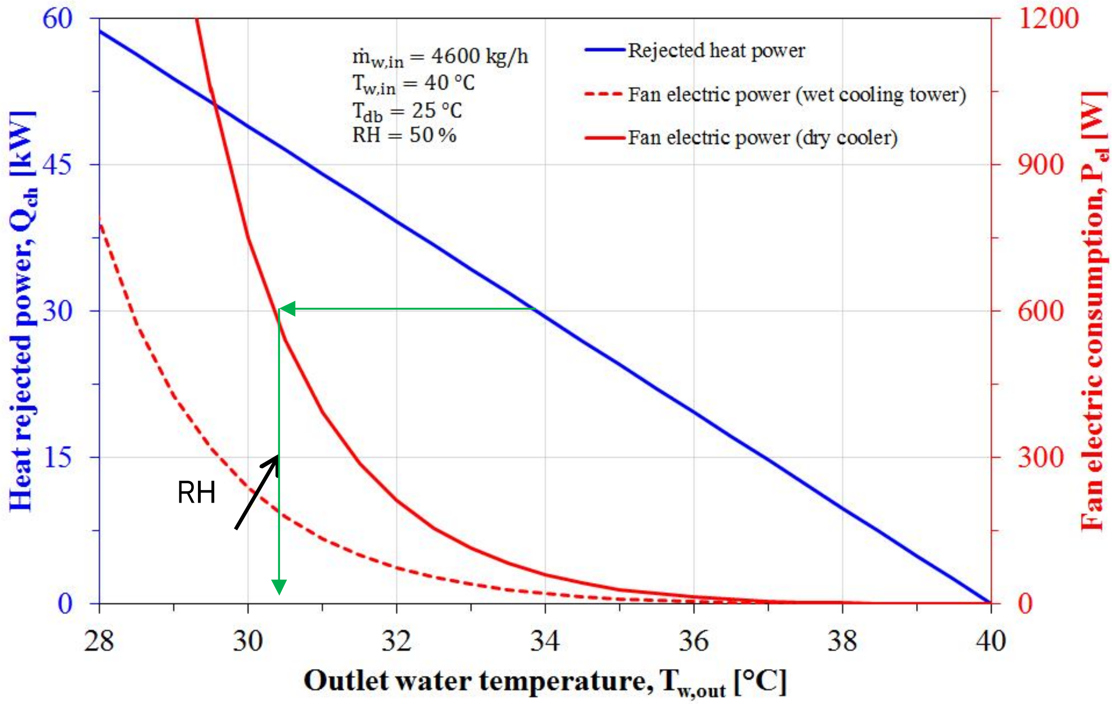
- Cooling efficiency

$$\varepsilon_{ch} = \frac{\Delta T_w}{T_{w,in} - T_{sink}}$$



Climatic suitability

- Fan electric consumption is key in any air-based heat rejection component:



$m_{w,in}$=4600 kg/h

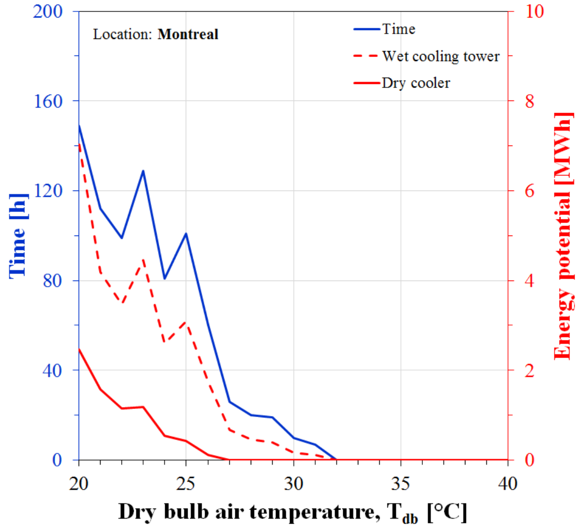
$T_{w,in}$=40°C

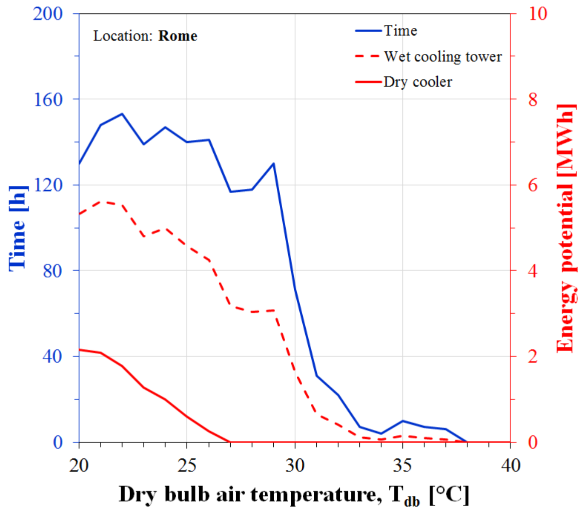
T_{db}=25°C

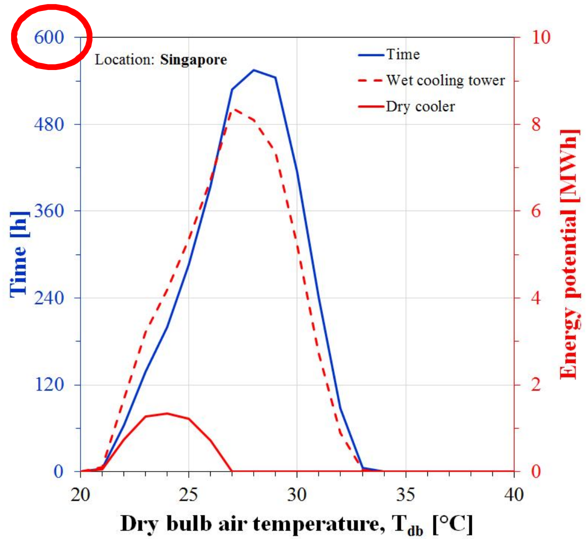
RH=50%

Climatic suitability

- **Heat rejection potential** quantifies the amount of heat that can be dissipated in a given location







Location: **Montreal**
DC: 7.48 MWh
WCT: 28.43 MWh

≈4

Location: **Rome**
DC: 9.16 MWh
WCT: 47.59 MWh

≈5

Location: **Singapore**
DC: 5.37 MWh
WCT: 53.98 MWh

≈10

$T_{w,in}$=32°C | $T_{w,out}$=27°C

HR systems operation

A number of standards have been classified for EU, USA and Australia

Practical experience has been collected for 9 DC heat rejection systems within the Solarück project:

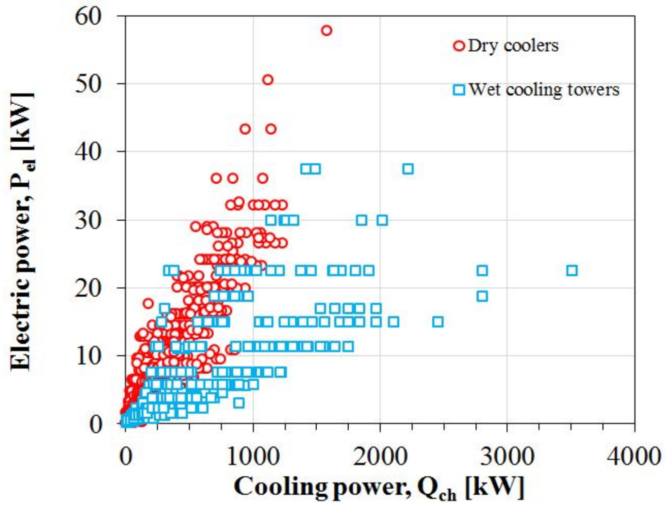
- Practical hints for installation and maintenance
- Practical hints for control

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

HR systems operation

Control:

- Attention to control of the fans
- Heat rejection control has to consider the pumps as part of the system itself
- Water spraying has to be treated carefully to avoid blockage and waste of water → alternate spraying only when it is needed
- Control has to consider the building energy use



Source: EURAC

Thank you for your attention

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