EURAC research

# Techno-economic analysis of air-to-water heat rejection systems

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# Outline

- Aim of the work
- Market analysis - methodology
- Climatic suitability
- Heat Rejection Operation
- Results

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# Aim of the work

- The work has been conducted within the framework of **IEA SHC Task 48 Subtask A**
- **Air-based heat rejection components** are the most widespread technology used in cooling processes
- **Fan electrical consumption** and **water usage** are limiting factors for achieving an efficient heat rejection in electrically-driven (EDC) or thermally-driven (TDC) cooling systems
- A better insight of **market-available variants** is therefore desiderable

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# Methodology (1/2)

- 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]

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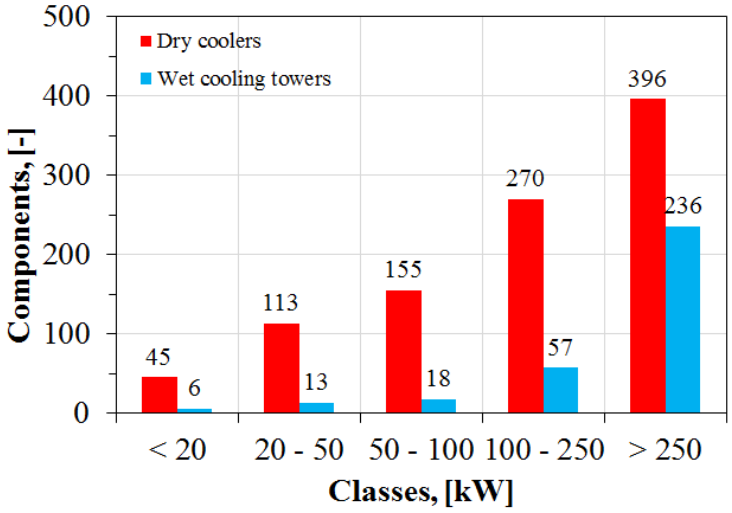
# Methodology (2/2)

- The database comprises heat rejection components from **small to large capacities** adopted in residential, industrial or tertiary applications
- **Correction factors** provided by the manufacturers have been used for calculating the off-design thermal performance
- The off-design electric performance has been evaluated by using a **validated Trnsys design model**



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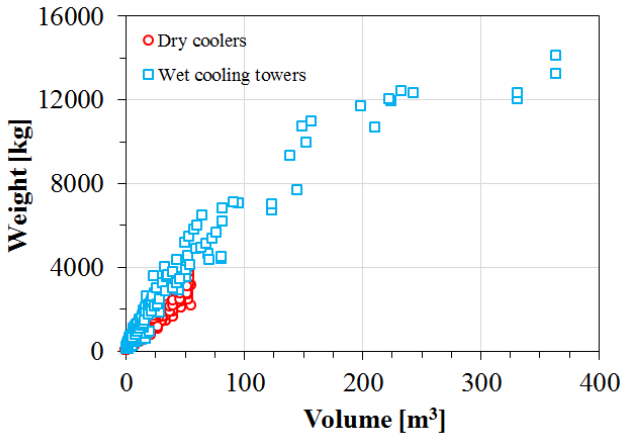
# Technical features: sizes (1/2)

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

  **DCs**: 45-126 kg/m$^3$

  **WCTs**: 41-101 kg/m$^3$

Sample: 82.7%

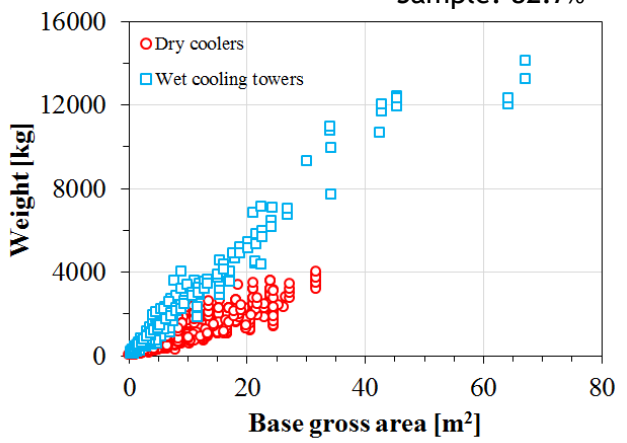



- **Weight-to-base gross area ratio:**

  **DCs**: 97-185 kg/m$^2$

  **WCTs**: 208-376 kg/m$^2$

Sample: 82.7%



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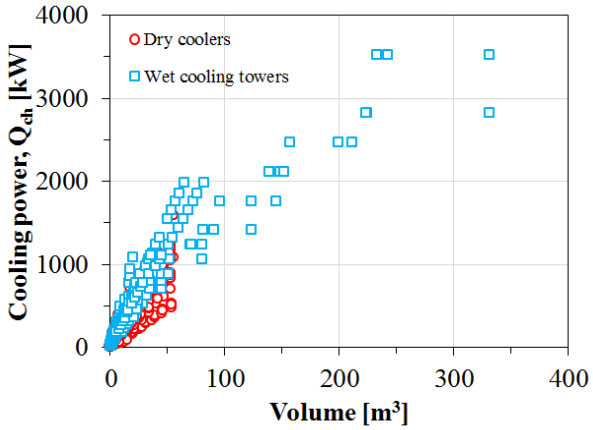
# Technical features: sizes (2/2)

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

  **DCs**: 10-40 kW/m$^3$

  **WCTs**: 8-47 kW/m$^3$

Sample: 82.7%

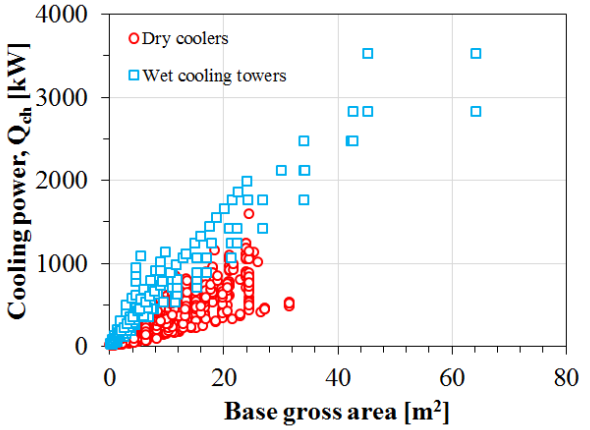



- **Chilling power-to-base gross area ratio:**

  **DCs**: 13-80 kW/m$^2$

  **WCTs**: 60-163 kW/m$^2$

Sample: 82.7%



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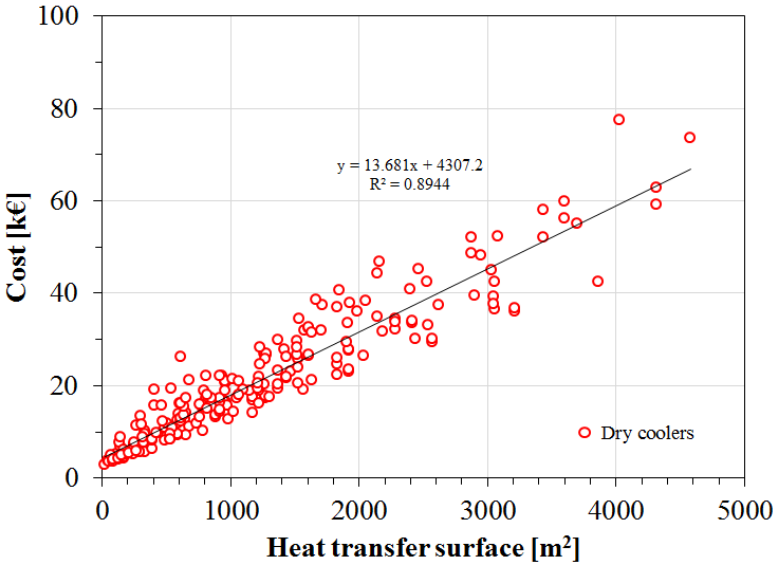
# Economic features

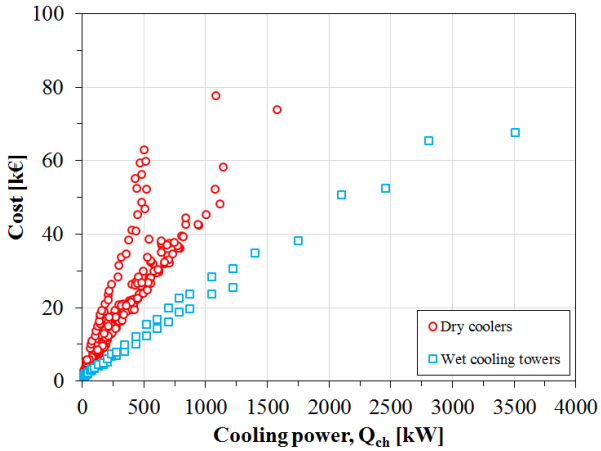
- **Investment costs-to-cooling power ratio:**

  **DCs**: 49-107 €/$kW_{ch}$

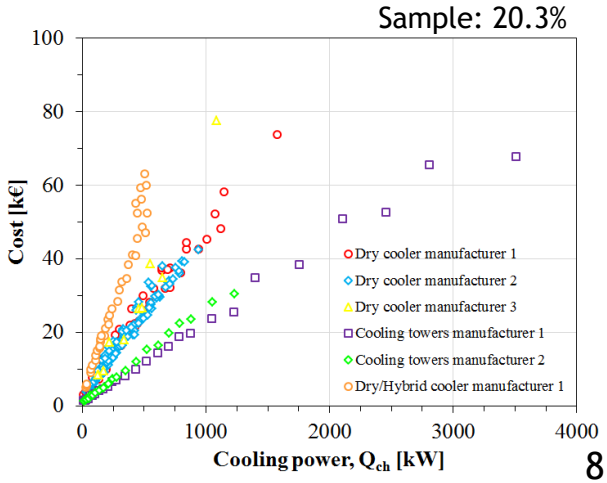
  **WCTs**: 22-27 €/$kW_{ch}$




Sample: 20.3%




Sample: 20.3%



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# 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:

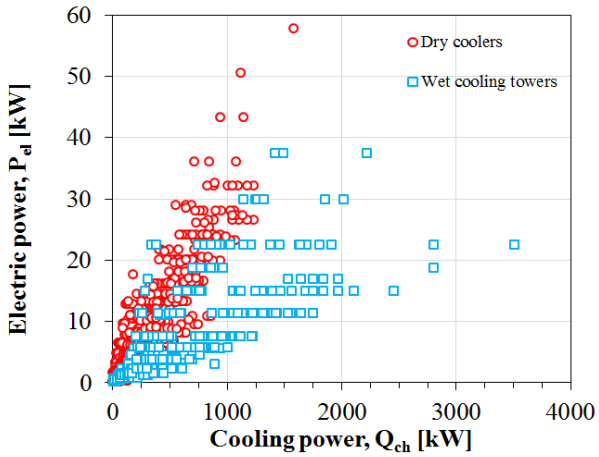
  0.010-0.060 $kW_{el}/kW_{ch}$

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

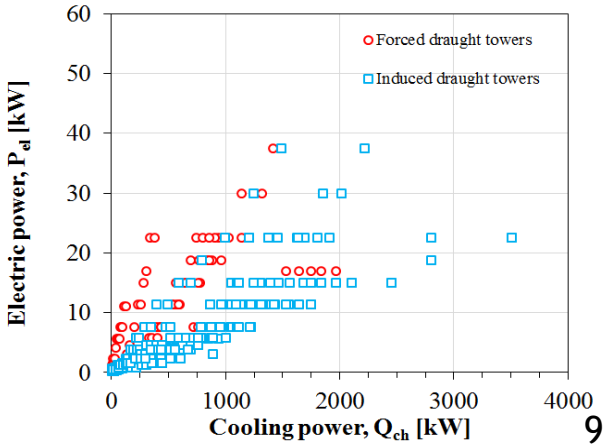
  **DCs**: 0.045, **WTCs**: 0.018,

  induced: 0.007, forced: 0.02

Sample: 90.1%




Sample: 98.8%



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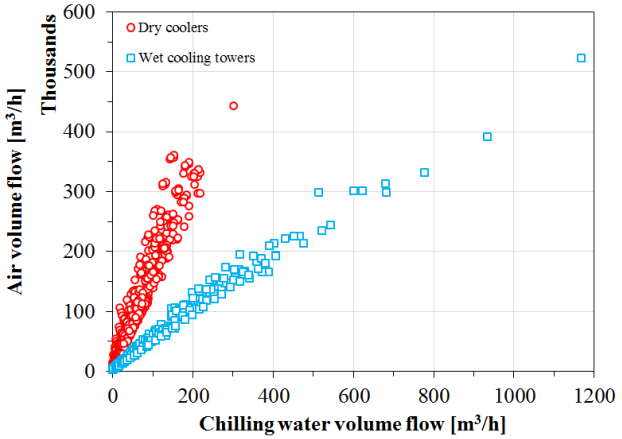
# Technical features: mass flow rate & noise level

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

  **DCs**: $1.7 \times 10^3$

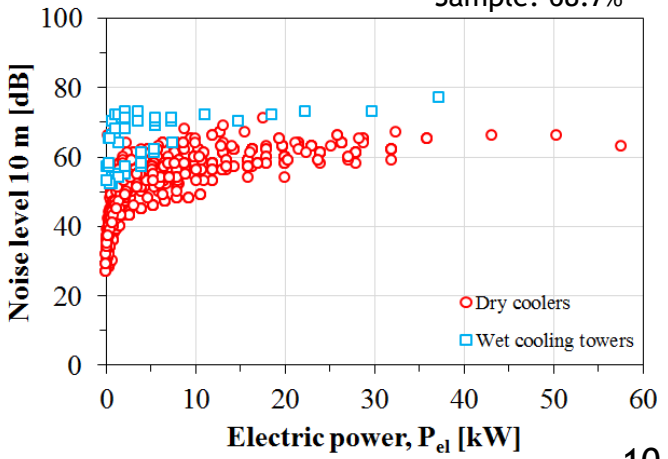
  **WCTs**: $0.49 \times 10^3$

Sample: 95.3%




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

Sample: 68.7%



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# Market analysis - Conclusions (1/2)

- Even though air-based heat rejection systems are a mature technology, a **better knowledge of market available products** is desiderable in order to support the design phase

- In some cases collected data are fragmented or even missing because of the **heterogeneity of the technical documentation.** Therefore in some cases a clear statement was not possible

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# Market analysis - Conclusions (2/2)

- 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 are characterized by higher costs during operation** due to fresh water consumption and legionella prevention: their adoption is **in some cases prohibited or discouraged** (i.e. Middle East, Hong Kong)

- Economic attractiveness of DCs or WCTs should always be discussed at the **system level**

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# Climatic suitability (1/3)

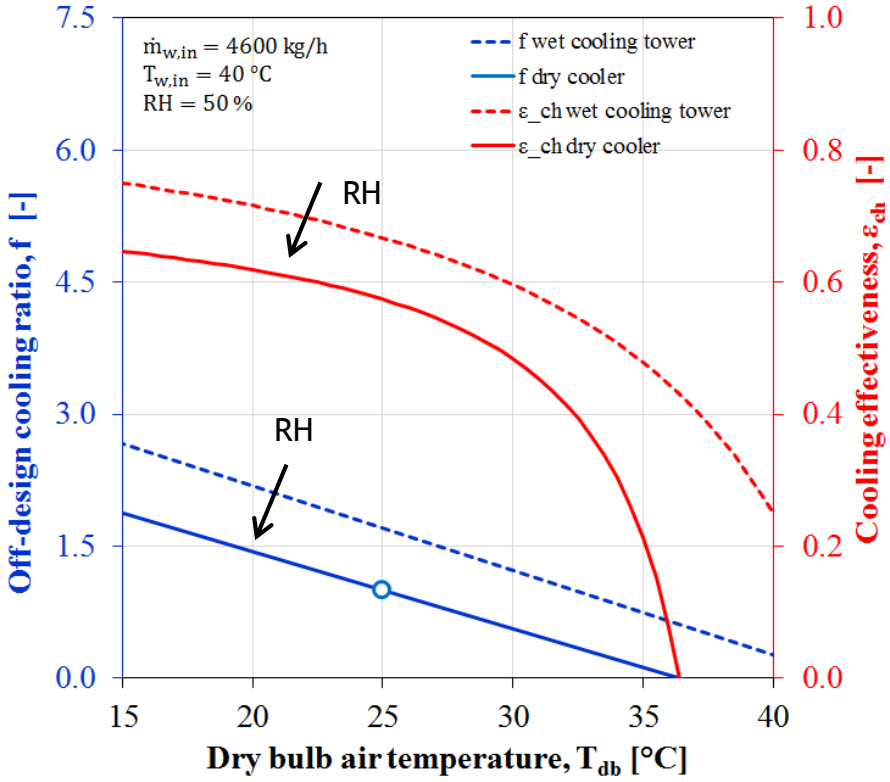
- In order to compare between DCs and WCTs, two figures of merit have been defined:

- Cooling performance factor

$$f = \frac{Q_{ch,act}}{Q_{ch,nom}}$$

- Cooling efficiency

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



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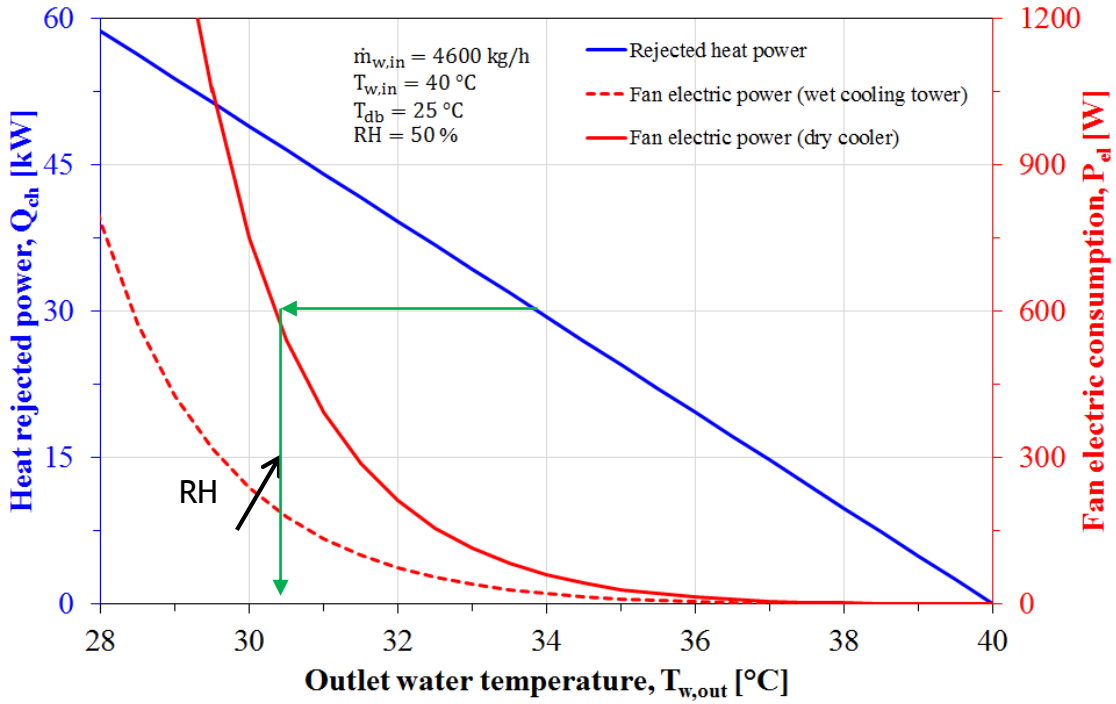
# Climatic suitability (2/3)

- 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%

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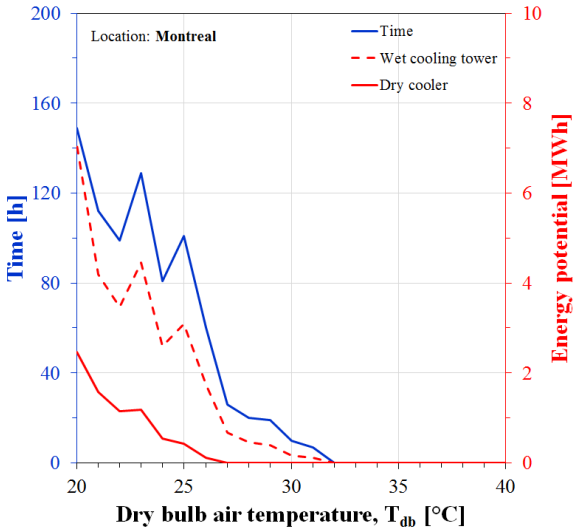
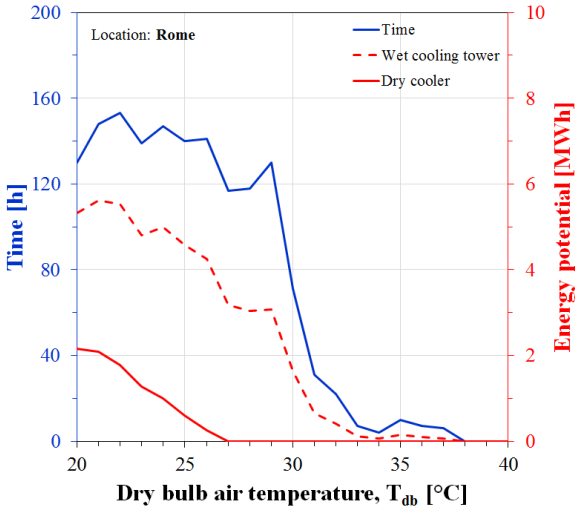
# Climatic suitability (3/3)

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



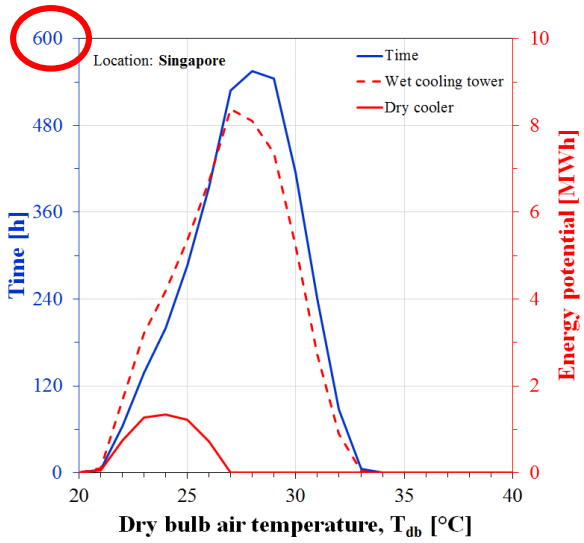

Location: **Montreal**
DC: 7.48 MWh
WCT: 28.43 MWh

**≈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

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# 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:

SolaRück

- Practical hints
- Systems comparison

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# HR systems operation

SolaRück

Practical hints:

- Ideally the HRD is positioned in a shady place, e.g. on the northern side of a building (in the northern hemisphere).
- Installation on or near black and metal surfaces which are exposed to the sun are to be avoided.
- To make sure that the HRD is protected from pollutants as this may deposit on the heat transfer area of the HRD and decrease performance.
- For HRD with spraying devices (nozzles) it must be assured that the blow off water is drained.
- Wet cooling towers must be installed considering the resulting plume.
- Piping of the HRD and its insulation must be protected from weather and damage by animals.

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# HR systems operation

SolaRück

## Maintenance:

| Description of Service | Start–Up (see Note 1) | Monthly | Every six months | Shut- Down | Annually |
|---|---|---|---|---|---|
| Inspect general condition of the system | X | | | X | X |
| Inspect heat transfer section(s) for fouling | X | | X | | |
| Inspect water distribution | X | | X | | |
| Inspect drift eliminators for cleanliness and proper installation | X | | X | | |
| Inspect sump | X | | X | | |
| Check and adjust sump water level and make-up | X | | X | | |
| Check chemical feed equipment | X | X | | | |
| Check proper functioning of blow-down | X | X | | | |
| Check operation of sump heaters (if applicable) | X | | X | | |
| Clean sump strainer | X | | X | | |
| Drain sump & piping | | | | X | |

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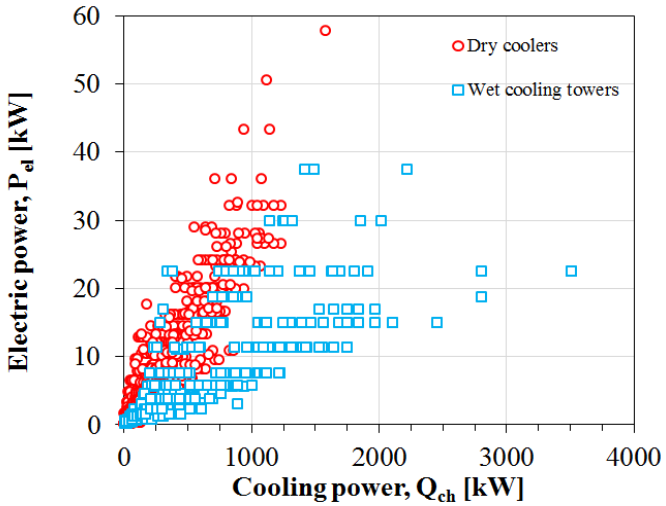
# HR systems operation

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

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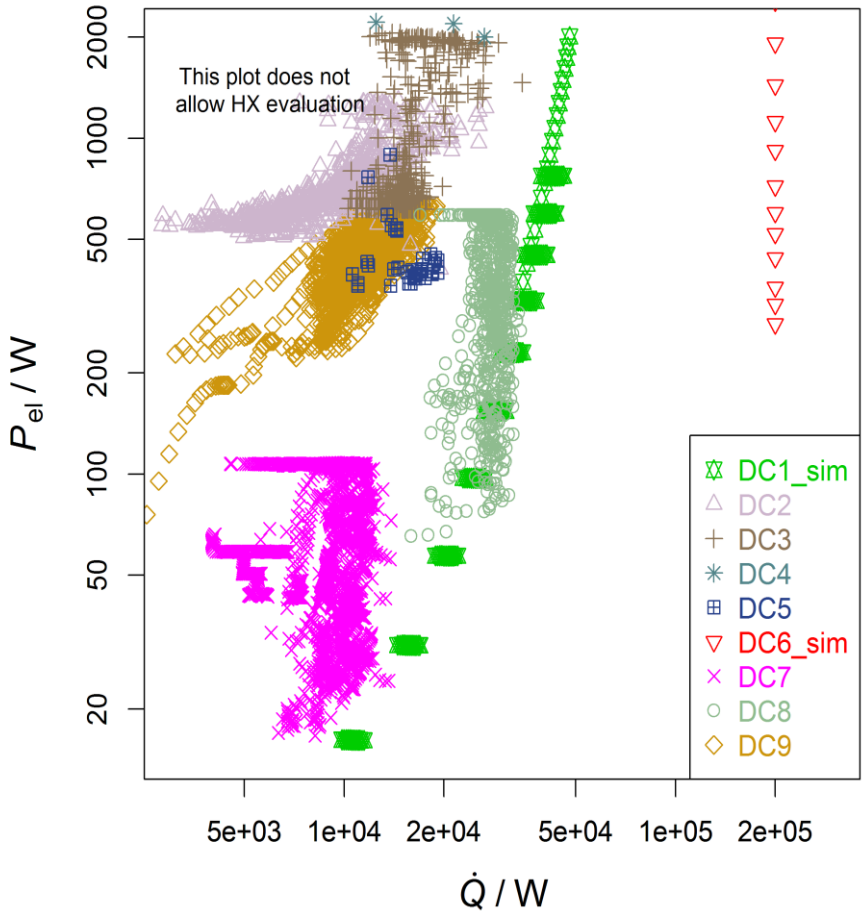
# HR systems operation

Comparison:



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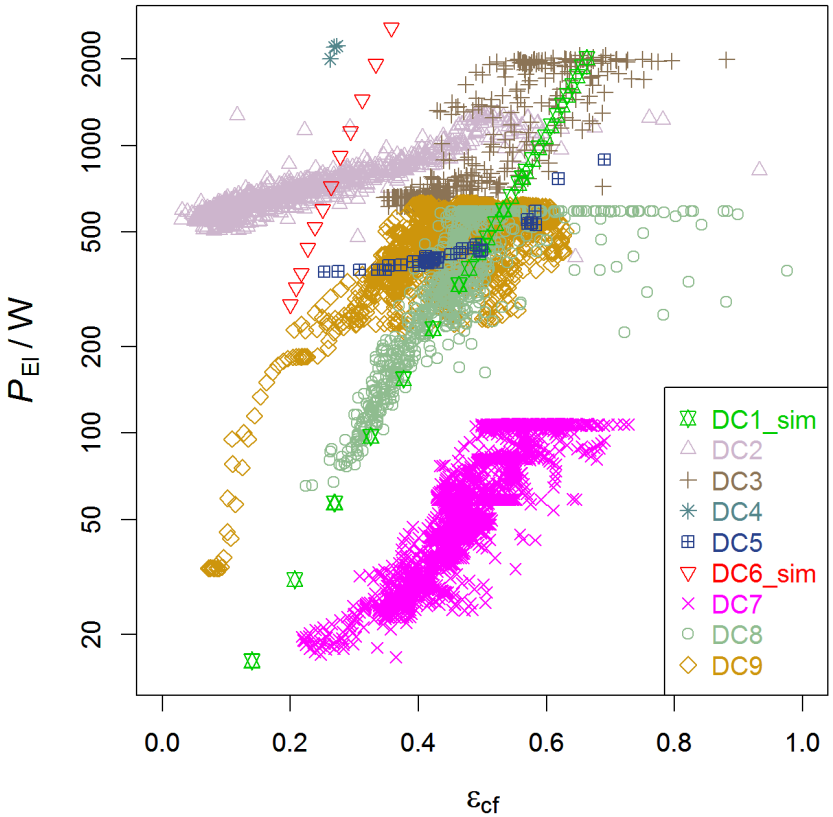
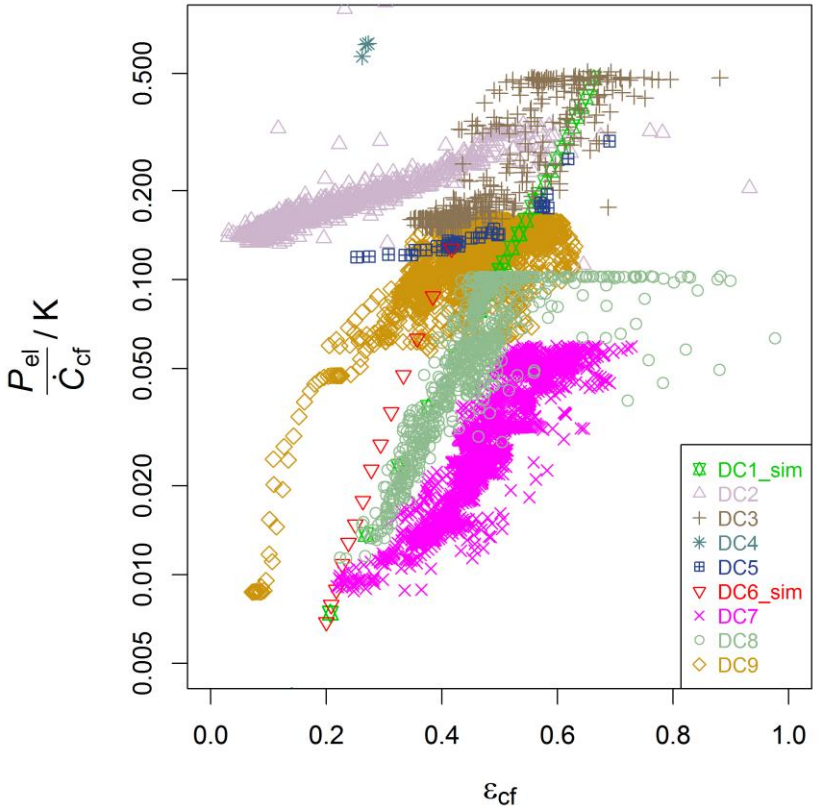
# HR systems operation

SolaRück

Comparison:



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# Thank you for your attention

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