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A methodology for tertiary buildings cooling energy need estimation: a case study of District Cooling in Marrakech

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4th International Conference on Smart Energy Systems and 4th Generation District Heating 2018
#SES4DH2018

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Outline

- **Why DC**
- **Context**
- **Methodology**
- **Results**
- **Conclusion**

Courtesy of District Energy in Cities Initiative, United Nations Environment Program

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Why DC

- Cooling demand grows as **spending on energy services increases** and more of the **population moves to cities** (UNEP, 2014)
- On current trends, energy needs for space cooling – almost entirely in the form of **electricity** – will **more than triple between 2016 and 2050**, driven mainly by the residential sector (IEA, 2018)
- Higher rate is expected in **developing countries and Middle East**: comfort cooling is no longer considered a luxury but rather a fundamental component of a building and necessary for **attracting business** (IEA, 2017).
- **KIGALI AGREEMENT**: Phasing down HFCs by replacing conventional cooling systems with district cooling

Context

Implementation in Marrakesh of the **District Energy in Cities Initiative** by UN Environment

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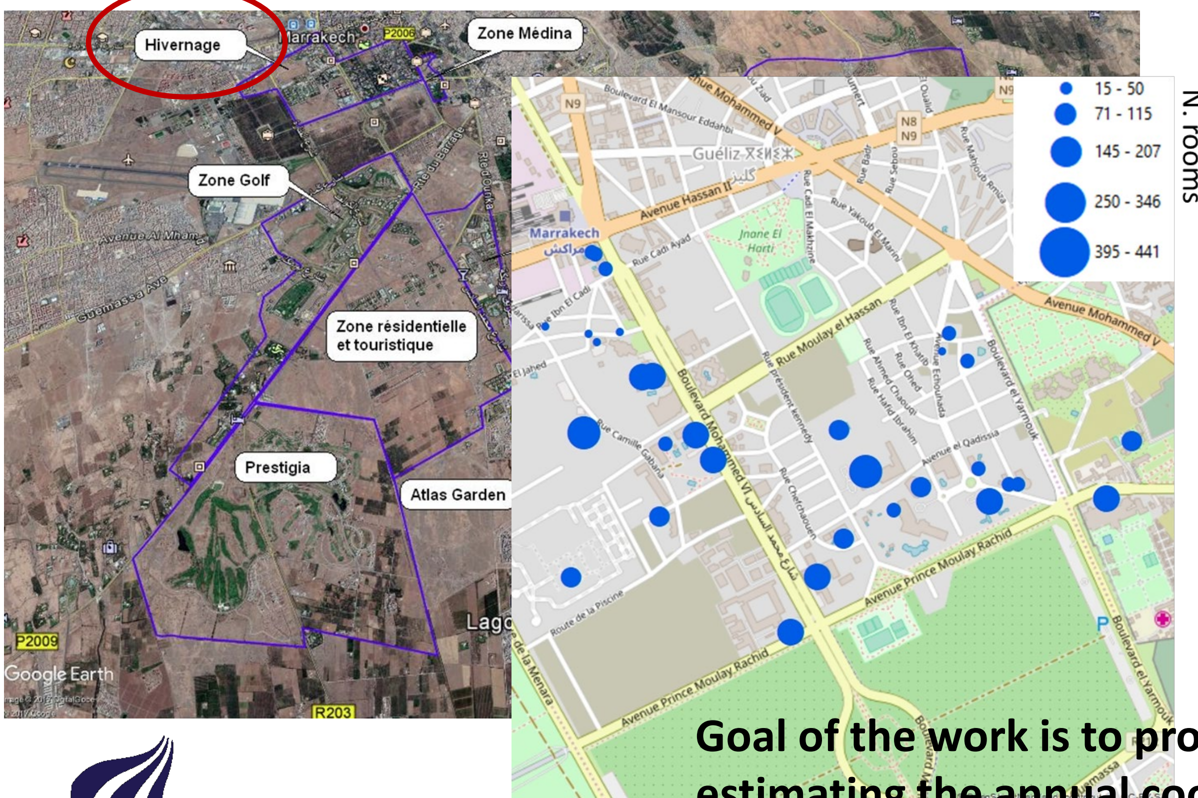

Supporting Marrakech (and Morocco national government) to speed up adoption of **best-practice policies** towards a **low-carbon** society through **district energy systems**, paving the way towards external investments.

Goal of the work is to propose a methodology for estimating the annual cooling demand of existing tertiary buildings at district level

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Methodology

Energy performance analysis of buildings requires gathering data such as:

- weather conditions (especially dry-bulb temperature and solar radiation),
- building envelope thermo-physical properties,
- occupancy and occupants behaviour,
- efficiency of cooling systems,
- etc.

…burdensome, costly and time-consuming

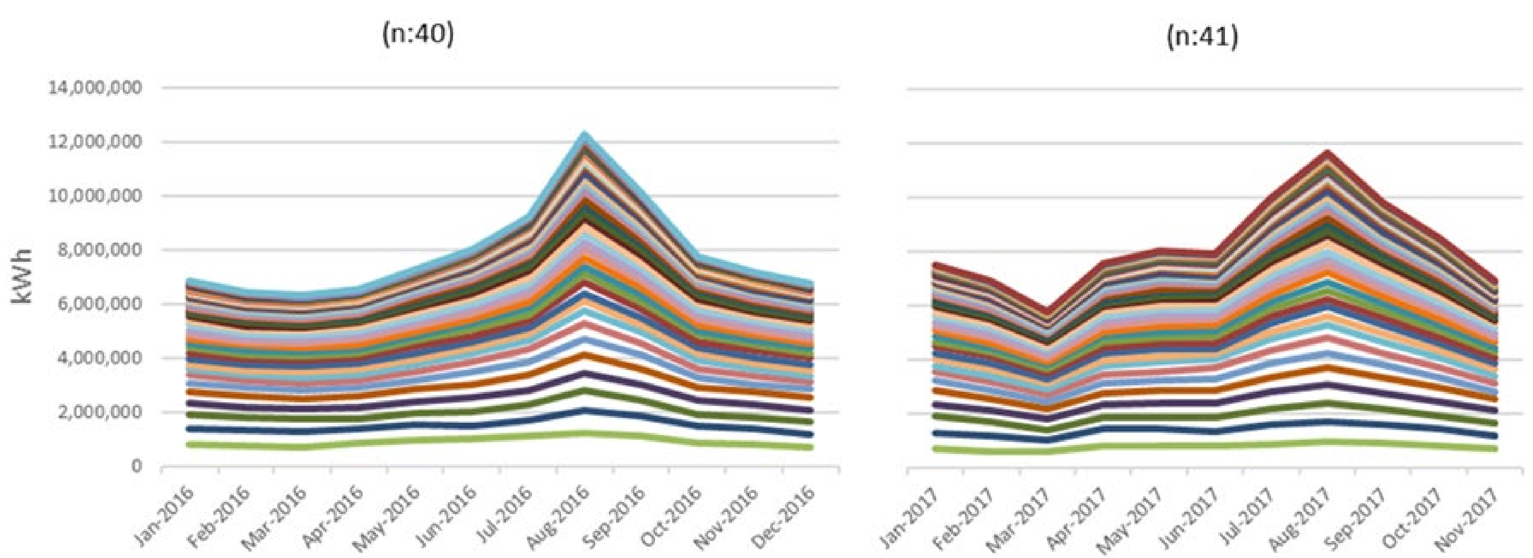
Even **more burdensome** when the analysis requires energy demand of building communities at **city scale**.

↓

Simplified approaches have been more employed as far as precise consumption prediction is quite difficult.

Methodology

1. **Cooling demand estimation**: Electricity bills method (from >40 hotels)



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Methodology

2. Identification of non-weather dependant uses -> **neutral month**
3. Cooling energy use and energy need estimation

$Q_{cooling,n} + Q_{heating,n} \approx 0$

n: neutral month

$Q_{tot,elec,n} = Q_{lighting,n} + Q_{services,n} + Q_{other,n} = A$

$A \approx const.$

Energy use for cooling $Q_{cooling} = \sum_{m=1}^{L} Q_{c,m} = \sum^{L} Q_{tot,elec,m} - \mathrm{L} \cdot Q_{tot,elec,n} = \sum^{L} Q_{tot,elec,m} - \mathrm{L} \cdot A$ [kWh]

Energy need for cooling $Q_{C,nd} = Q_{cooling} \cdot \eta_{C,sys}$ [kWh]

L: cooling season length

$\eta_{C,sys}$: *cooling system efficiency*

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Methodology

4. Hourly cooling load profile
   - External conditions: heat gain through building envelope, gains due to infiltration and ventilation of external air
   - Internal conditions: heat gains due to internal sources such as lighting, equipment and occupants.

$$\frac{dQ_{C,nd}}{dt} = \frac{dQ_{int}}{dt} + \frac{dQ_{ext}}{dt} \qquad \frac{dQ_{int}}{dt} = B = const. \qquad \frac{dQ_{ext}}{dt} = d(T, Rad)$$

- T: sol-air temperature (ASHRAE, 2009) is used. Meteonorm database for hourly distribution of temperatures and humidity.
- **Load profile** is obtained by distributing the total yearly cooling energy need proportional to the hourly **difference of sol-air temperature and cooling set point temperature**.
- Similar to the other methods such as degree-day methods and bin methods (ASHRAE, 2009).

Results

Marrakech climate

- Low need of dehumidification (hot semi-arid Steppe climate)
- Cooling Degree Days (CDD): 650 (base temperature 22 ^{o}C)
- Heating Degree Days (HDD): 606 (base temperature 18 ^{o}C)
- Average soil temperature during summer: about 26 °C

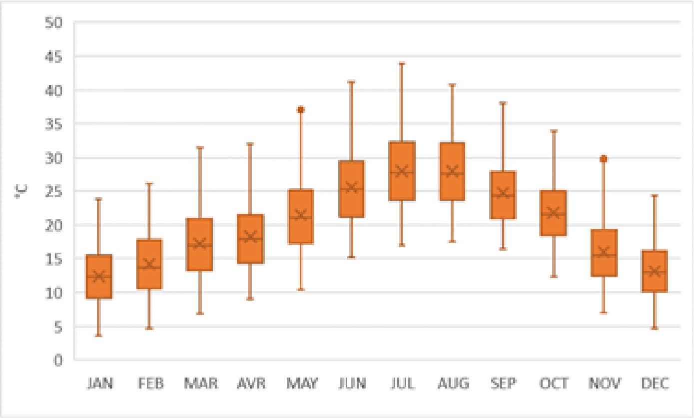

Figure 1 Hourly temperature distribution during each month

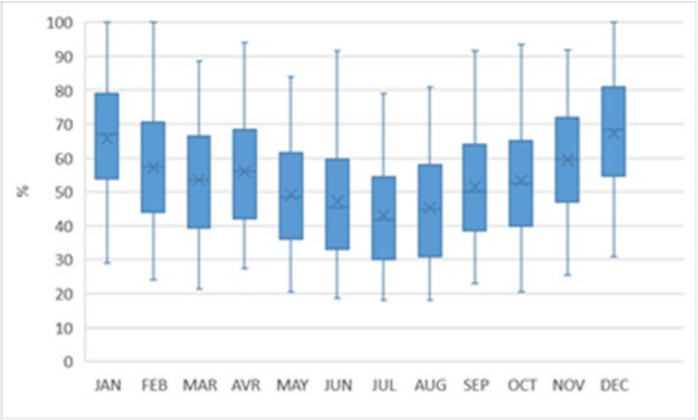

Figure 2 Hourly humidity distribution during each month

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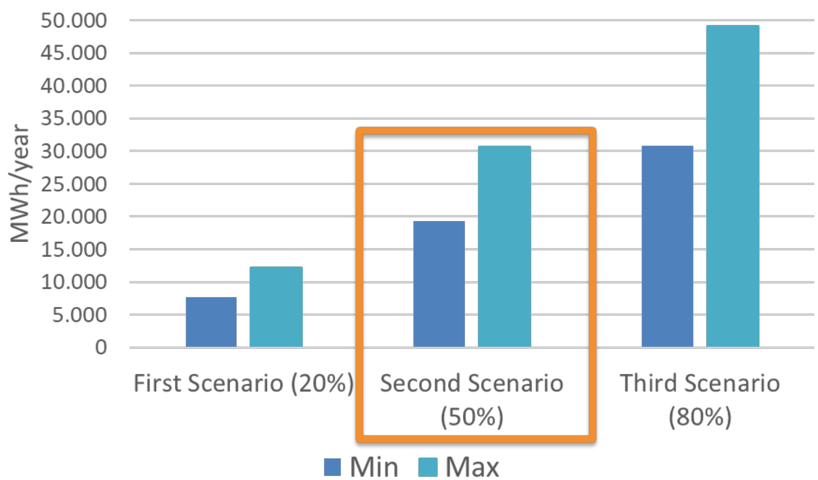
Results

Cooling energy need of Hivernage hotels

3 scenarios of building connection: 20%, 50%, 80%.



- **Neutral month**: March, minimum electricity consumption (6000 MWh)
- Total Hivernage hotels cooling demand varies between **8 to 49 GWh**
- Peak consumption approximately 12 000 MWh
- Average yearly share of cooling 20% of electricity consumption

Electricity used for cooling **not** strongly affected by occupancy rate

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Results

Cooling energy need of Hivernage hotels

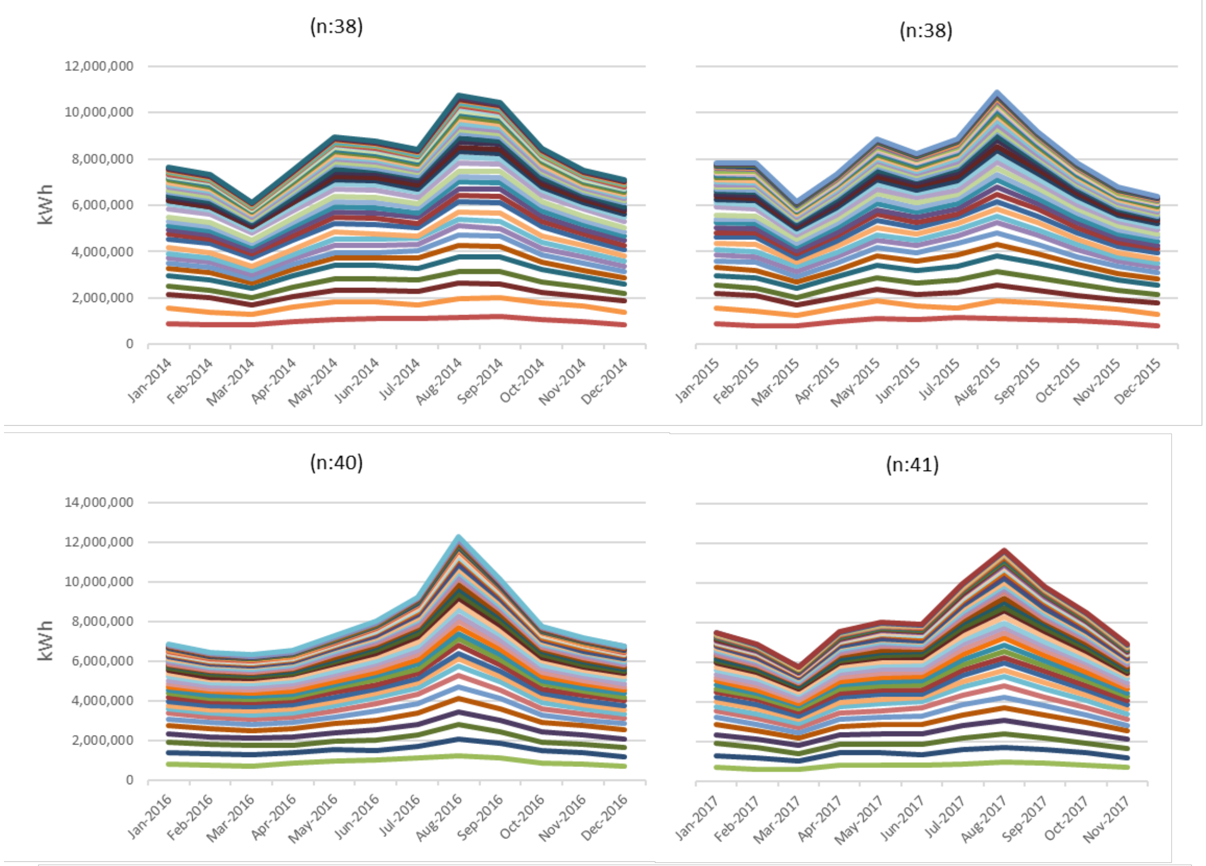
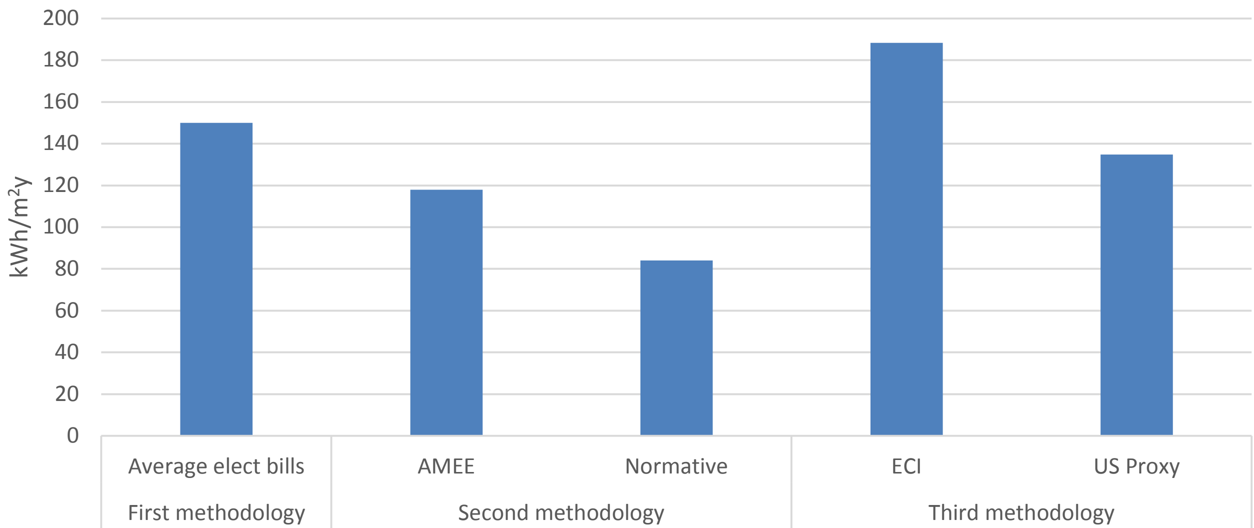


Figure 3 Sum of monthly electricity consumption of Marrakech hotels from 2014 to 2017. "n" shows number of considered hotels in each year.

Results

Cooling energy need of Hivernage hotels



Results

Cooling load profile

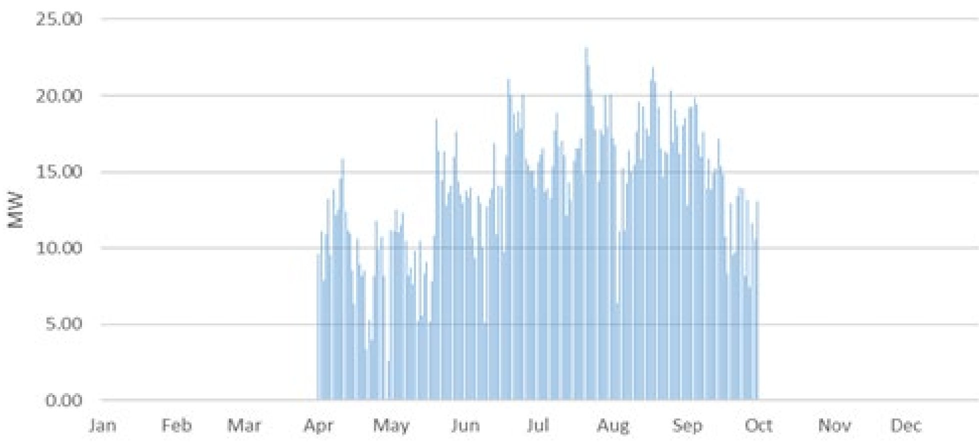
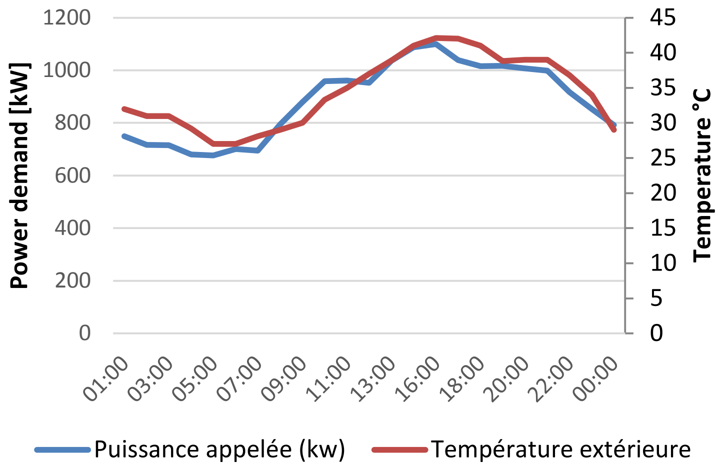


Figure 1 Hourly cooling load profile



Outdoor temperature and electric power variations of a hotel building in Marrakech during a typical summer day

Maximum cooling power required: 23 MW
Average cooling power: 6 MW

Conclusion

- The input parameters in this method can be summarized as:
  - electricity bills
  - cooling season length
  - conditioned area (to calculate **cooling intensity** [kWh/m^{2}y])
  - cooling system efficiency

- The input parameters of this method can be collected **relatively easy** and also quick and therefore low cost
- This methodology can be employed during the **feasibility and planning phases** of district cooling system design
- Suitable for tertiary buildings in particular

Conclusion

Technical solutions

Alternative	Heat rejection component	Scenario	Average seasonal COP	Water Consumption [m³/year]
1	Dry cooler	Air cooled	3.4	-
2	Treated grey water	Water cooled	3.8	-
3	Evaporative cooler	Cooling tower	5.1	87 810 (*)

(*) = equivalent to water consumption of 1330 inhabitants

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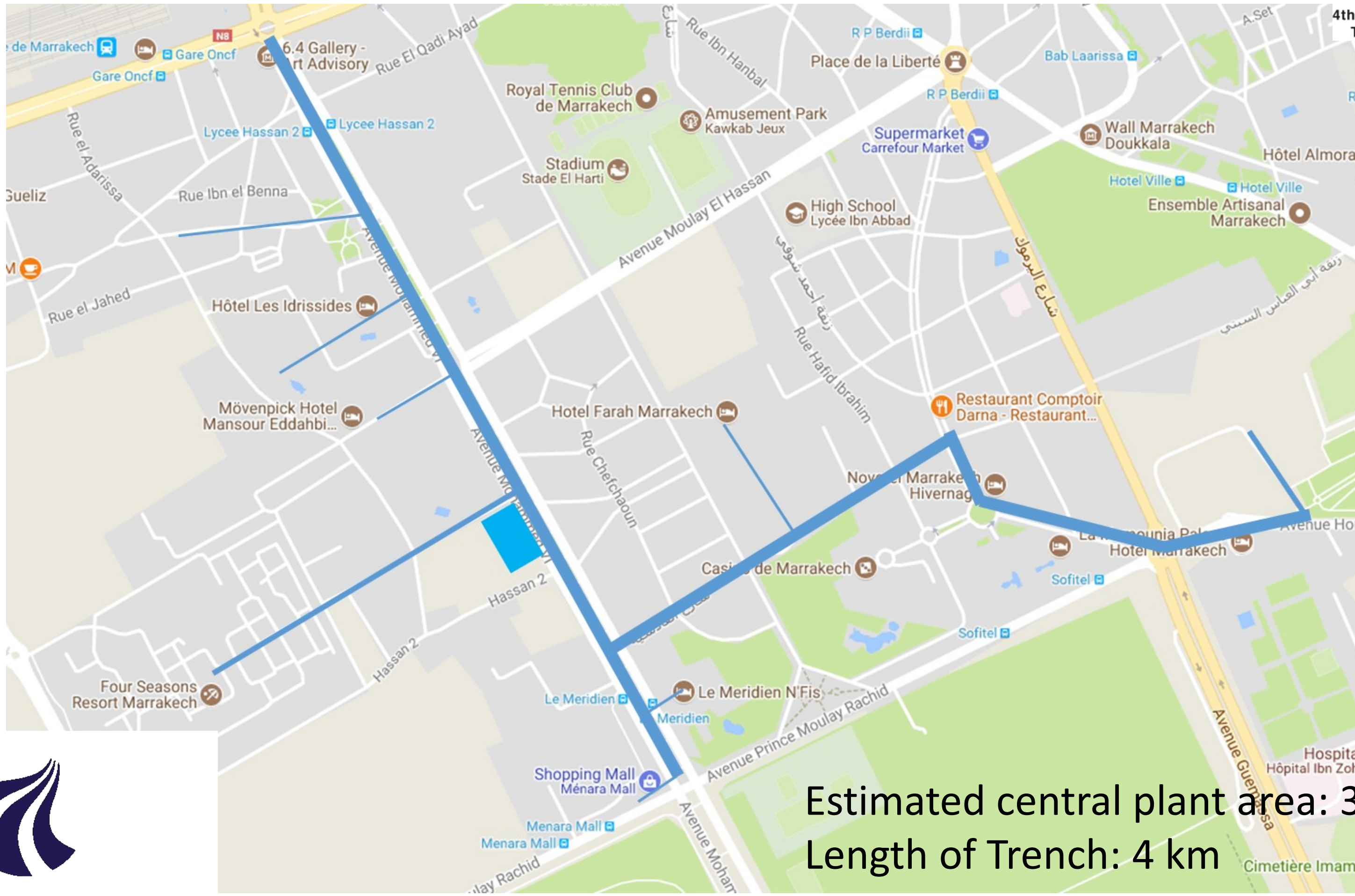
Conclusion

Preliminary network



Estimated central plant area: 3000 m2
Length of Trench: 4 km

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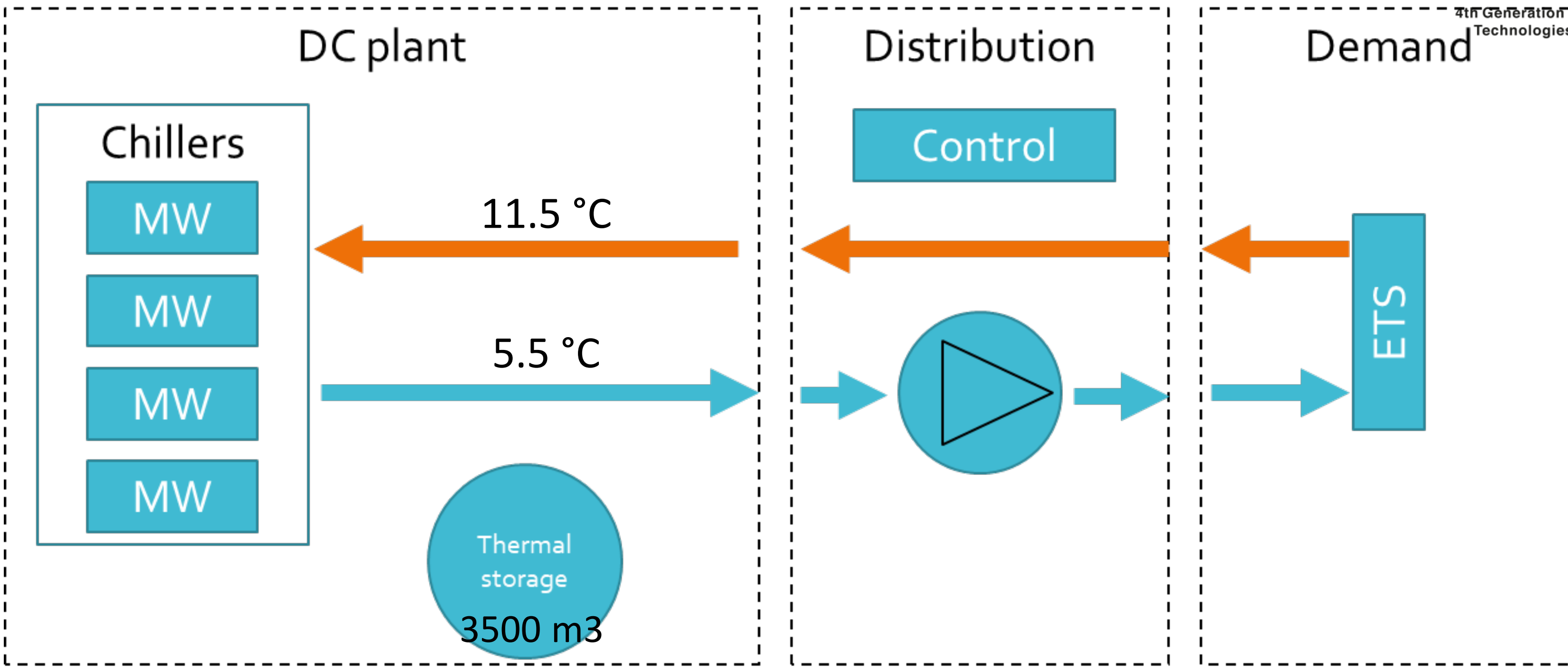
Conclusion

Technical solutions

Approximately 23 MWcold | 8 km piping (DN450) | 15-20 substations



Primary variable speed pumping

Secondary variable speed pumping

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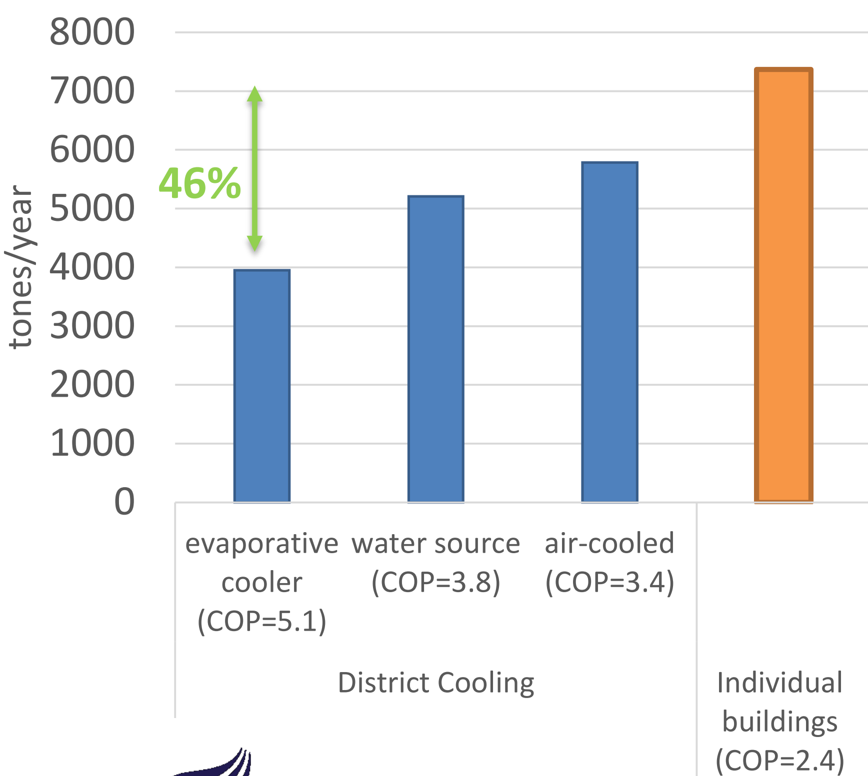
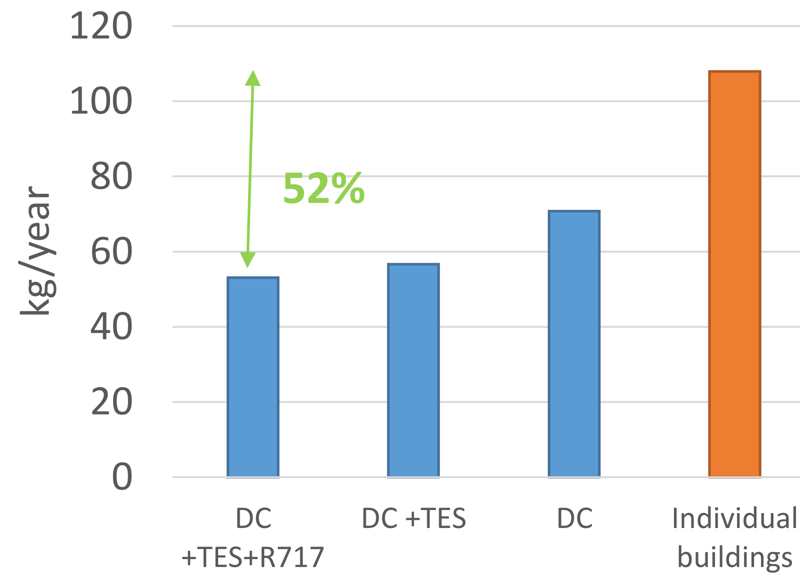
Conclusion

Environmental benefits

Equivalent CO_2 emissions



Refrigerant emissions



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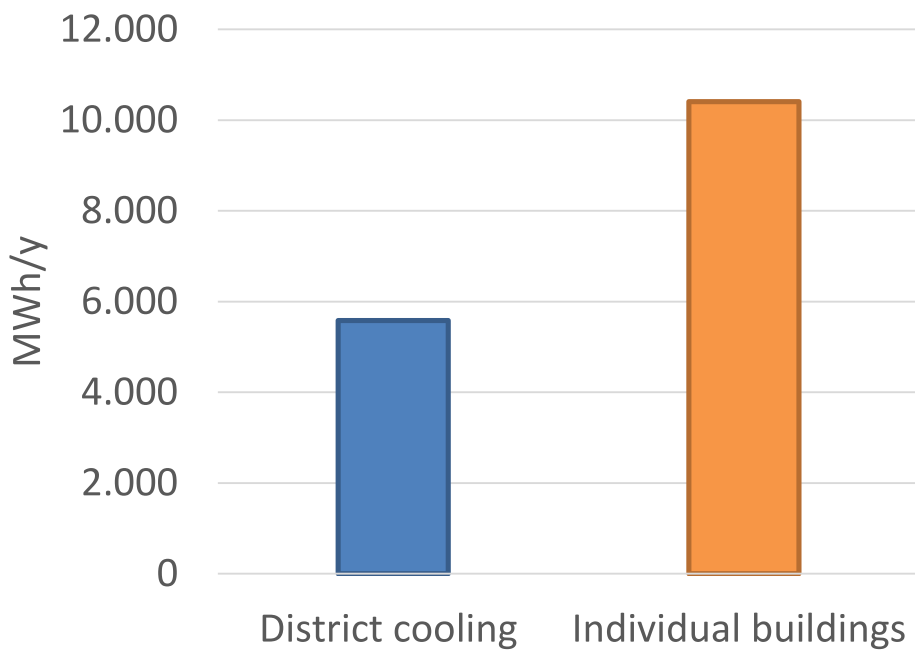
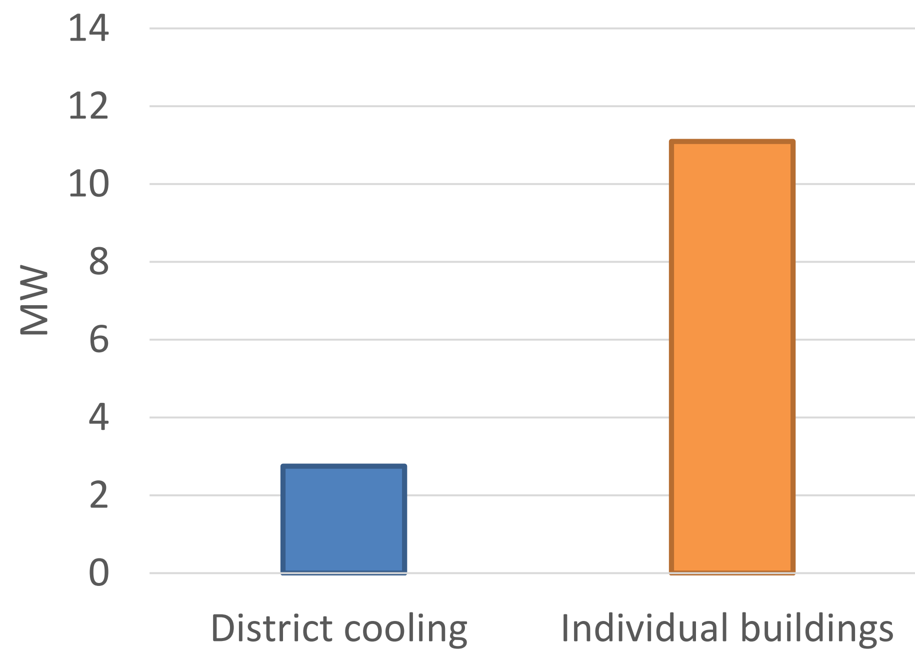
Conclusion

Electricity consumption and peak power





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Thank you