International Conference On Smart Energy Systems

4th Generation District Heating, Electrification, Electrofuels and Energy Efficiency

The 6th International Conference on Smart Energy Systems took place on 6-7 October 2020 as an online event.

Thank you to everyone who participated in making this a successful event.

The website is currently undergoing updates.
The correlation between variable renewable energy sources and energy demand for heating&cooling

Jasmine Ramsebner
ramsebner@eeg.tuwien.ac.at

Reinhard Haas
haas@eeg.tuwien.ac.at

Pedro Linares
pedro.linares@iit.comillas.edu
IIT, Universidad Pontificia Comillas, Calle de Santa Cruz de Marcenado 26 28015 Madrid
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Climate goals promote the integration of VRE, adding new challenges to the energy system

The intermittency of sun and wind - variable renewable energy (VRE) - causes substantial daily and seasonal variability.

How can this be used as an advantage?

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entsoe (2020)
How can this be used as an advantage?

Heating & cooling demand largely depend on outdoor temperature

We assume that the temperature is substantially influenced by wind speed and solar radiation

**Research Questions:**

- Is there a significant correlation between wind speed or solar radiation and heating or cooling demand that enables direct use of VRE?
- Is short term storage still required? (thermal, pumped hydro…)
- Would the conversion of power into hydrogen be convenient for heating&cooling?
  - To decouple demand and supply
  - Considering the applicability of the technology in the specific country
1. We use the following climate data to analyze the correlation between VRE and heating/cooling demand:
   - Solar Radiation \([\text{W/m}^2]\)
   - Wind speed \([\text{m/s}]\)
   - Temperature \([T]\) \([\text{°C}]\)
   - Temporal resolution: Hourly and daily average

2. The temperature data defines heating/cooling demand via HDD and CDD*

   If \(T_{h/d} \leq T_H\) then \([\text{HDD} = \sum_i (T_{\text{Room}H} - T_{h/d}^i)]\) else \([\text{HDD} = 0]\)

   If \(T_{h/d} \geq 24\text{°C}\) then \([\text{CDD} = \sum_i T_{h/d}^i - T_{\text{RoomC}}]\) else \([\text{CDD} = 0]\)

   \(T_{h/d}^i\) … air temperature of hour/day

<table>
<thead>
<tr>
<th>Heating demand: (T_H = 15\text{°C})</th>
<th>Desired Room T: (T_{\text{Room}H} = 18\text{°C})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling demand: (T_C = 24\text{°C})</td>
<td>Desired Room T: (T_{\text{RoomC}} = 21\text{°C})</td>
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</table>

*HDD… Heating degree days, CDD… Cooling degree days

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3. We analyze the **correlation coefficient $r$ after Pearson** for the following scenarios:

- $R_H$ between HDD & wind speed **winter time** = 1.October – 30.April

$$ R = \frac{\text{Cov}_x,y}{\sigma_x \sigma_y} \quad -1 < r < +1 $$

- As correlation with hourly resolution of climate data ($h - R_{Hh} / R_{Ch}$)
- As correlation with average daily resolution of climate data ($d - R_{Hd} / R_{Cd}$)

4. $R$ is interpreted as the following:

<table>
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<th>$R$</th>
<th>Interpretation</th>
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<tr>
<td>&lt; 0.19</td>
<td>Very weak</td>
</tr>
<tr>
<td>0.20-0.39</td>
<td>Weak</td>
</tr>
<tr>
<td>0.40-0.59</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.60-0.79</td>
<td>Strong</td>
</tr>
<tr>
<td>0.80-1.00</td>
<td>Very strong</td>
</tr>
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Evans (1996)
Exemplary case study for Austria/Vienna

- This study uses climate data for Vienna from 2018
Heat demand (HDD) increases with decreasing temperatures

Example: If $T = 12°C$ then $\text{HDD} = \sum_i(18°C - 12°C) \quad \text{HDD} = 6°C$

Once the Temperature falls below $T_H$, heating is required

Exemplary day of hourly wind speed & HDD
Cooling demand (CDD) increase with increasing temperatures

Example: If \( T = 28^\circ C \) then \( \text{CDD} = \sum_i(28^\circ C - 21^\circ C) \) \( \text{CDD} = 7^\circ C \)

Once the Temperature exceeds \( T_C \), cooling is required

Exemplary day of hourly Solar Radiation & CDD

Graphs showing temperature and CDD over time and solar radiation and CDD over a day.
Results

Hourly and daily correlation between…
1. … HDD & Wind Speed for the winter months
2. … CDD & Solar Radiation for the summer months
The correlation between wind and HDD is higher with daily average climate data

The hourly correlation ($R_{Hh}$) is 'Very weak'.

The daily correlation ($R_{Hd}$) is 'Weak'.

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Characteristics of heating degree days & wind speed applying hourly and daily resolution

$R_H$ is much higher with average daily climate data, which implies the need for hourly to daily storage for a most direct, local use of wind power for heating.

Monthly average of hourly and daily correlation

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The correlation between solar radiation and CDD is quite significant throughout the day.

The hourly correlation ($R_{Ch}$) is 'Moderate' with a value of 0.52.

The daily correlation ($R_{Cd}$) is 'Weak' with a value of 0.32.

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Characteristics of cooling degree days & solar radiation applying hourly and daily resolution

$R_C$ is more substantial with hourly climate data, which implies a very direct, short-term correlation and potential of PV power use for cooling.
Vienna – as a central European city - has neither extreme availability of wind nor solar radiation
The correlation is not very strong in either scenario (Wind/HDD or Solar Radiation/CDD)

Wind speed and heating demand require a wider time frame to improve correlation.
This implies the need for hourly to daily storage.

Solar radiation and cooling demand correlate more obviously on hourly basis.
This implies potential for very direct, short-term use of PV power for cooling.
Conclusions & outlook

Conclusions

Importance of temporal resolution for correlation results

A lack of correlation and the seasonal variability may suggest the conversion of VRE into hydrogen

We expect stronger results for countries with higher dominance of wind or sun availability

Future Research

Analysis of different climate zones (AT, DK, ES)

Considering spatial variation within countries

The impact of climate change on the development of HDD and CDD.

Derive policy implications
Jasmine Ramsebner
ramsebner@eeg.tuwien.ac.at

Reinhard Haas
haas@eeg.tuwien.ac.at

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