The water-energy nexus at city level: the case study of Skiathos

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Water

• mankind’s most precious resource
• domestic, agricultural and industrial uses
  ✓ direct consumption
  ✓ production of food
  ✓ washing, sanitation etc.
• essential element for
  ✓ extraction, refining, processing and conveying energy
  ✓ operation of hydroelectric and thermal power plants
Energy

• provision of water for any kind of human activities requires huge quantities of energy

• people use it to run their homes/industries

• pumping water, pressurizing water distribution systems and wastewater treatment
Water-Energy Nexus

• water and energy should be affordable for all people

• clean water needs energy to be produced and power plants need cooling water to operate

• using water wisely includes producing potable water and treating wastewater with less energy
Water-Energy Nexus

• nearly 4% of Greece’s electricity goes to moving and treating water and wastewater by public and private entities (EPRI)

• in a water-constrained world, it is critical to deeply understand the use of water throughout the entire life cycle of electricity production

• need for resource efficiency
Case Study

• small picturesque Greek island of 50 km² located in the northwest Aegean Sea

• Skiathos is the westernmost island in the Northern Sporades group

• Mercury is observed in water system of Skiathos

• Skiathos water is not potable
Case Study

• water and electricity monthly consumption of the island of Skiathos from 2010 to 2015

• daily time-series for water withdrawals and monthly for electricity

• Skiathos urban water includes some small agricultural, commercial and industrial uses

• electricity consumption is divided in:
  ✓ domestic
  ✓ commercial
  ✓ industrial
  ✓ public
  ✓ agricultural
Aim and Methodology

- investigate the correlation of urban water and total electricity

- two groups of consumptions:
  - water / agricultural, commercial, industrial and public electricity
  - water / domestic electricity

- normalization of data

- distance metrics were used:
  - Minkowski distance and
  - Pearson’s Correlation Coefficient
Distance Metrics

Minkowski Distance

\[ D_{MINK} = \left( \sum_{i=1}^{n} |x_i - y_i|^r \right)^{1/r} \quad (1) \]
- for \( r=1 \), (1) yields to Manhattan Distance
- for \( r=2 \), (1) yields to Euclidean Distance

Pearson’s Correlation Coefficient (PCC)

\[ R = \frac{E[XY] - E[X]E[Y]}{\sqrt{E[X^2] - E[X]^2} \sqrt{E[Y^2] - E[Y]^2}} \quad (2) \]
- for linear data
- measures the strength and direction of linear relationship between two variables
The consumption behavior of total consumption of water in relation to 4 uses of energy consumption
The consumption behavior of total consumption of water in relation to domestic energy consumption.
# PCC values and explanations

<table>
<thead>
<tr>
<th>Value of R</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R = \pm 1$</td>
<td>perfect linear correlation</td>
</tr>
<tr>
<td>$-0.3 \leq R &lt; 0.3$</td>
<td>no linear correlation</td>
</tr>
<tr>
<td>$-0.5 &lt; R \leq -0.3$ or $0.3 \leq R &lt; 0.5$</td>
<td>weak linear correlation</td>
</tr>
<tr>
<td>$-0.7 &lt; R \leq -0.5$ or $0.5 \leq R &lt; 0.7$</td>
<td>average linear correlation</td>
</tr>
<tr>
<td>$-0.8 &lt; R \leq -0.7$ or $0.7 \leq R &lt; 0.8$</td>
<td>strong linear correlation</td>
</tr>
<tr>
<td>$-1 &lt; R \leq -0.8$ or $0.8 \leq R &lt; 1$</td>
<td>very strong linear correlation</td>
</tr>
</tbody>
</table>
Minkowski values and explanations

• \( D_{MINK} \) varies from value 0 to 2
  ✓ the closer to 0 the \( D_{MINK} \) is, the more related the two time series are
  ✓ the closer to 2 the \( D_{MINK} \) is, the more unrelated the two time series are

• The variable \( a \), indicates if a test is significant or not
  ✓ \( a \geq 0.5 \) ▶ not significant
  ✓ \( a < 0.5 \) ▶ significant
### Values of PCC, Euclidean and Manhattan distance

<table>
<thead>
<tr>
<th>Consumption Water/Energy</th>
<th>PCC</th>
<th>Variable a</th>
<th>Euclidean Distance</th>
<th>Manhattan Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Water/Commercial-Agricultural-Public-Industrial (Energy)</td>
<td>0.829</td>
<td>0</td>
<td>0.069</td>
<td>0.375</td>
</tr>
<tr>
<td>Total Water/Domestic (Energy)</td>
<td>-0.053</td>
<td>0.703</td>
<td>0.095</td>
<td>0.560</td>
</tr>
</tbody>
</table>
Results

• The first PCC value (0,829) confirms a very strong linear correlation among the two consumptions, and the variable a, indicates that the specific test is significant

• The second PCC value (-0,053), reveals that there is no linear correlation between total water consumption and the domestic energy use and the test is not significant
PCC graph for total water and for 4 uses of energy consumption (agricultural, commercial, industrial and public)

\[ y = 1.0501x - 0.0016 \]

\[ R^2 = 0.6867 \]
PCC graph for total water and domestic use of energy consumption

\[ y = -0.0987x + 0.0197 \]

\[ R^2 = 0.0028 \]
Results

• both groups of consumptions, for Euclidean and Manhattan distance, are closer to 0 rather than to 2 – correlated

• total consumption of water and the 4 uses of electricity proved to be very correlated

• total consumption of water and domestic use of electricity don’t seem to correlate
Conclusions

• a water-energy nexus analysis for the Greek island of Skiathos was conducted

• after having all our data normalized we used PCC and Minkowski Distance

• different uses of energy were analyzed and we concluded that there is a very strong linear correlation with total water consumption

• domestic use of energy with total water consumption also was examined and the results showed no linear correlation between them
Thanks for your attention!

For further information please consult http://water4cities.eu/

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