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

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Alexandra Ioannou and Chrysi Laspidou*

University of Thessaly

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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

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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

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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

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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

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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

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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

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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

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Distance Metrics

Minkowski Distance

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

Pearson's Correlation Coefficient (PCC)

- $R = \frac{E[XY] - E[X]E[Y]}{\sqrt{E[X^2] - E[X]^2}\sqrt{E[Y^2] - E[Y]^2}}$ (2)
- for linear data
- measures the strength and direction of linear relationship between two variables

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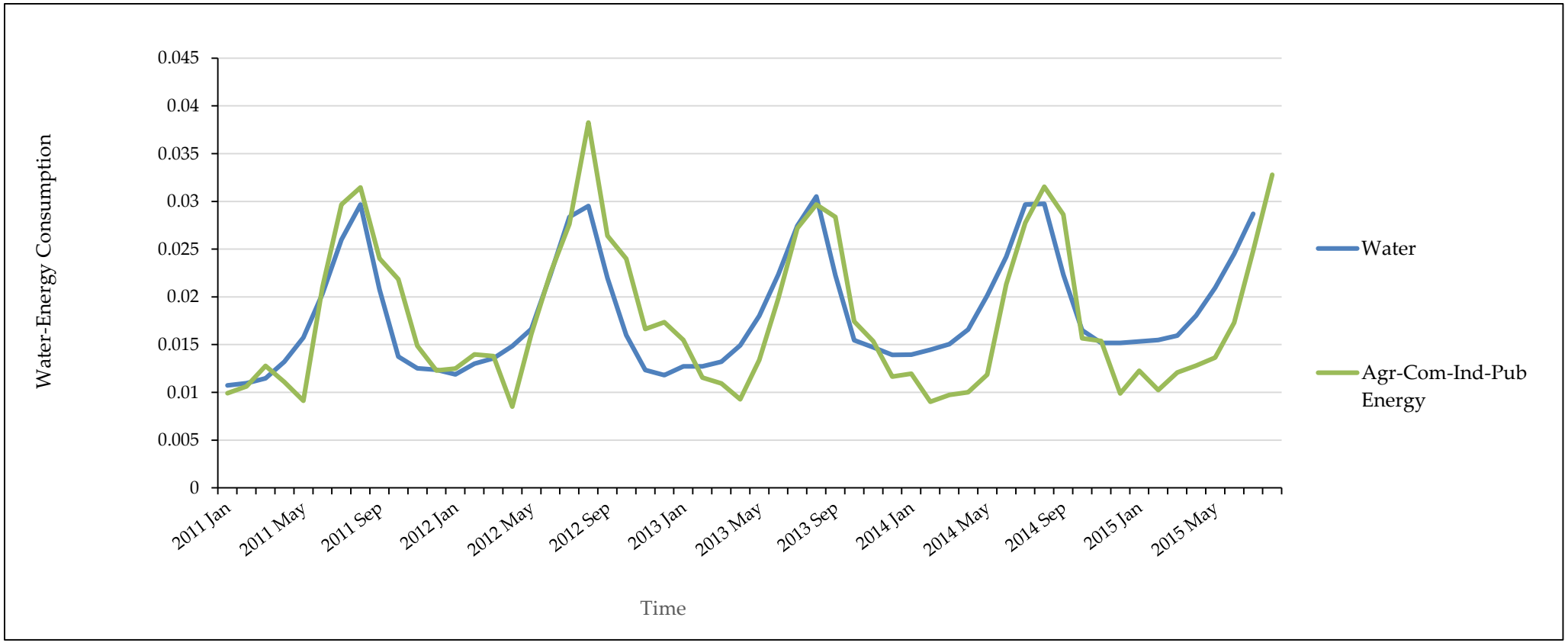
The consumption behavior of total consumption of water in relation to 4 uses of energy consumption



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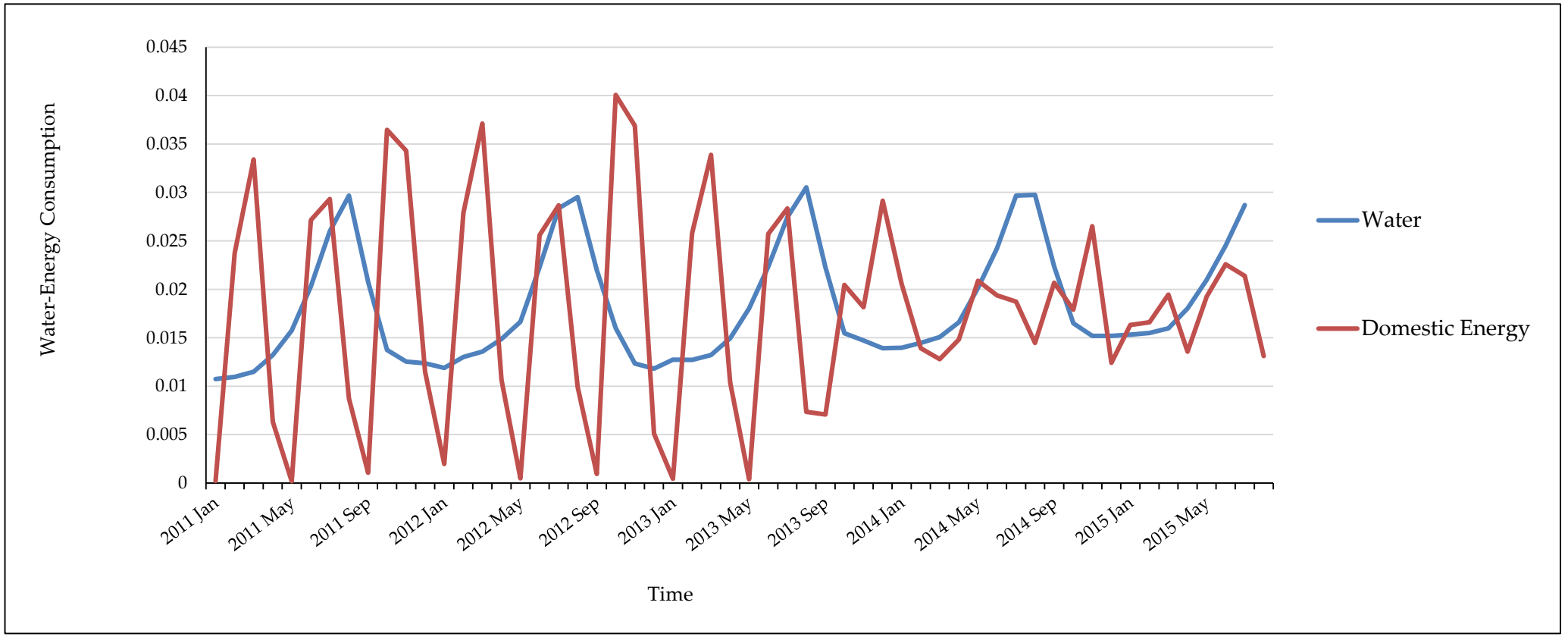
The consumption behavior of total consumption of water in relation to domestic energy consumption



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PCC values and explanations

Value of R	Correlation
R =±1	perfect linear correlation
-0,3 ≤ R < 0,3	no linear correlation
-0,5 < R ≤ -0,3 or 0,3 ≤ R < 0,5	weak linear correlation
-0,7 < R ≤ -0,5 or 0,5 ≤ R < 0,7	average linear correlation
-0,8 < R ≤ -0,7 or 0,7 ≤ R < 0,8	strong linear correlation
-1 < R ≤ -0,8 or 0,8 ≤ R < 1	very strong linear correlation

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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≥ 0,5 ► not significant
  - ✓ a< 0,5 ► significant

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Values of PCC, Euclidean and Manhattan distance

Consumption Water/Energy	PCC	Variable a	Euclidean Distance	Manhattan Distance
Total Water/Commercial-Agricultural-Public-Industrial (Energy)	0,829	0	0,069	0,375
Total Water/Domestic(Energy)	-0,053	0,703	0,095	0,560

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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

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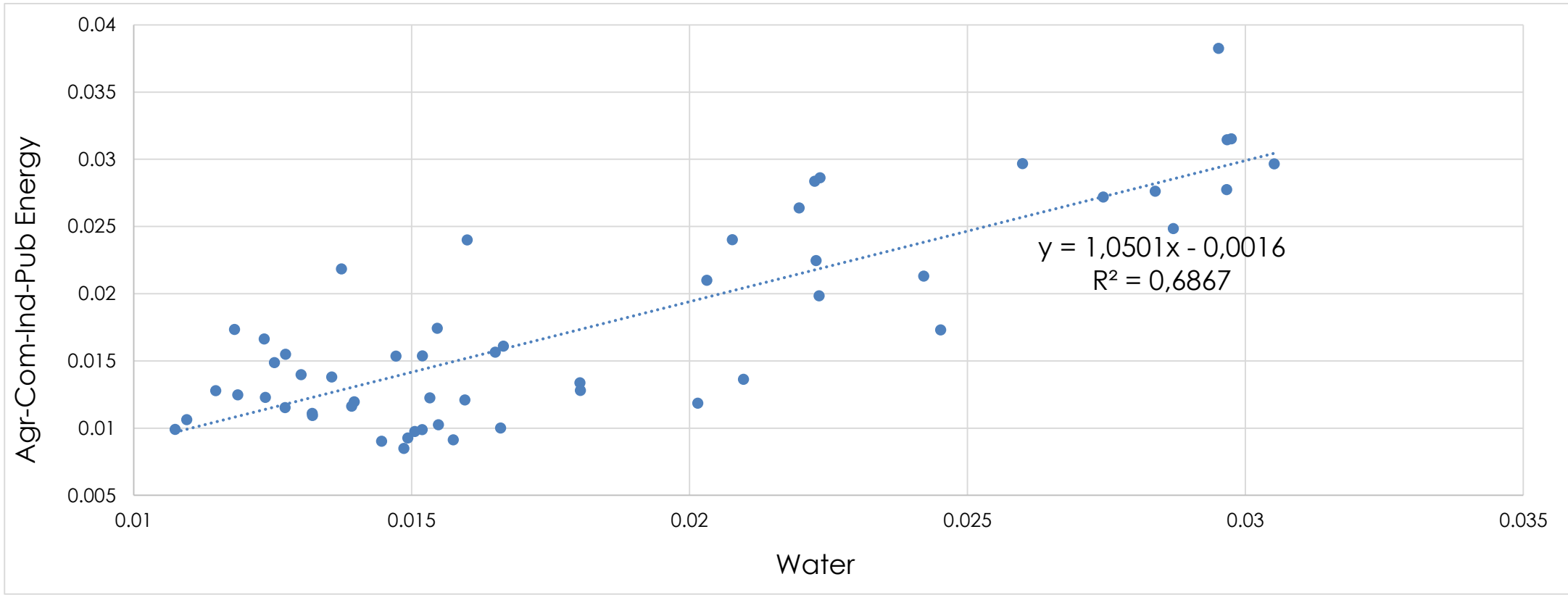
PCC graph for total water and for 4 uses of energy consumption (agricultural, commercial, industrial and public)



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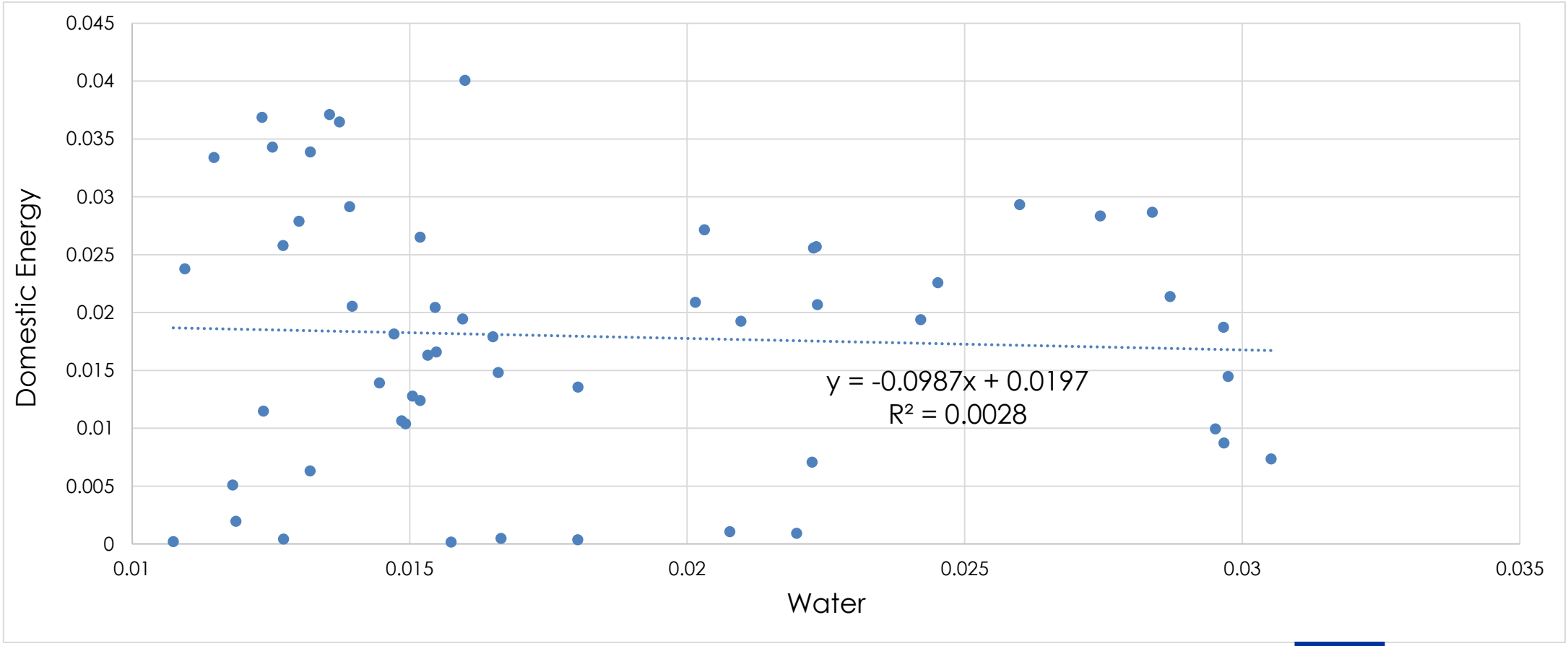
PCC graph for total water and domestic use of energy consumption



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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

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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

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alexandra.e.ioannou@gmail.com
laspidou@uth.gr

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