International Conference EWaS 4th

June 25th, 2020

Valuing the "Water, Carbon, Ecological" footprints of human activities

Session 7 - WATER AND WASTEWATER TREATMENT INNOVATIVE OPTIONS

Energy benchmarking and optimization of wastewater treatment plants in Greece

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Introduction

- Water and energy are inextricably connected especially in urban environments, where most of the **population** and **economic activities** are constantly concentrating at global scale.
- Wastewater treatment consists of energy consumptive stages (*collection of effluent, conveyance, treatment processes, treated effluent disposal etc*.)
- Efficiency and energy savings measures are essential to maintain WWTPs **environmentally sustainable and economically viable**.

Energy consumption in WWTPs – 1/2

- Total energy consumption for the water treatment industry is **expected to increase by 130% until 2040** (IEA, 2016)
- Globally, energy consumption for wastewater treatment is estimated at 14% of the water treatment industry (IEA, 2018)
- In the European Union, **29,000 WWTPs** (> 800 million P.E.) are operating sewage treatment plants (EEA,2018)
- Worldwide, **WWTPs consumes about 200 TWh or 1% of world energy consumption** while at local administration WWTPs consume 30-50% of their total energy expenditure (IEA, 2016).

Energy consumption in WWTPs – 2/2

Is mainly affected by:

- The percentage of treated wastewater in relation to the total collection volume
- underground and rainwater penetration levels in the sewage systems, treatment level
- contamination levels
- the overall energy efficiency of all processes

energy consumption is becoming increasingly important with key objectives being to **reduce economic costs** and **greenhouse gas emissions** mitigating the global warming effects

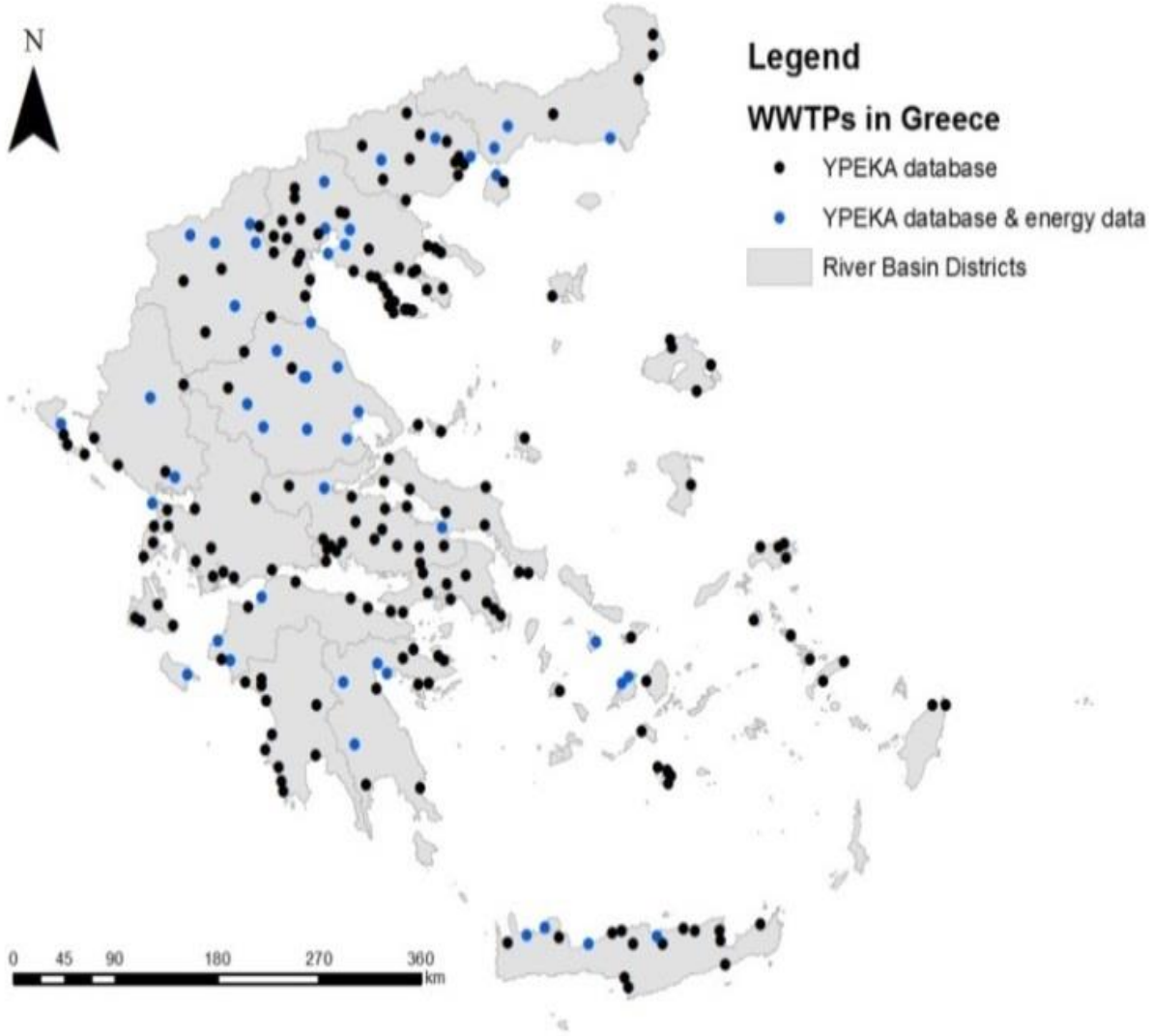
Operational and energy consumption DB

Data input from

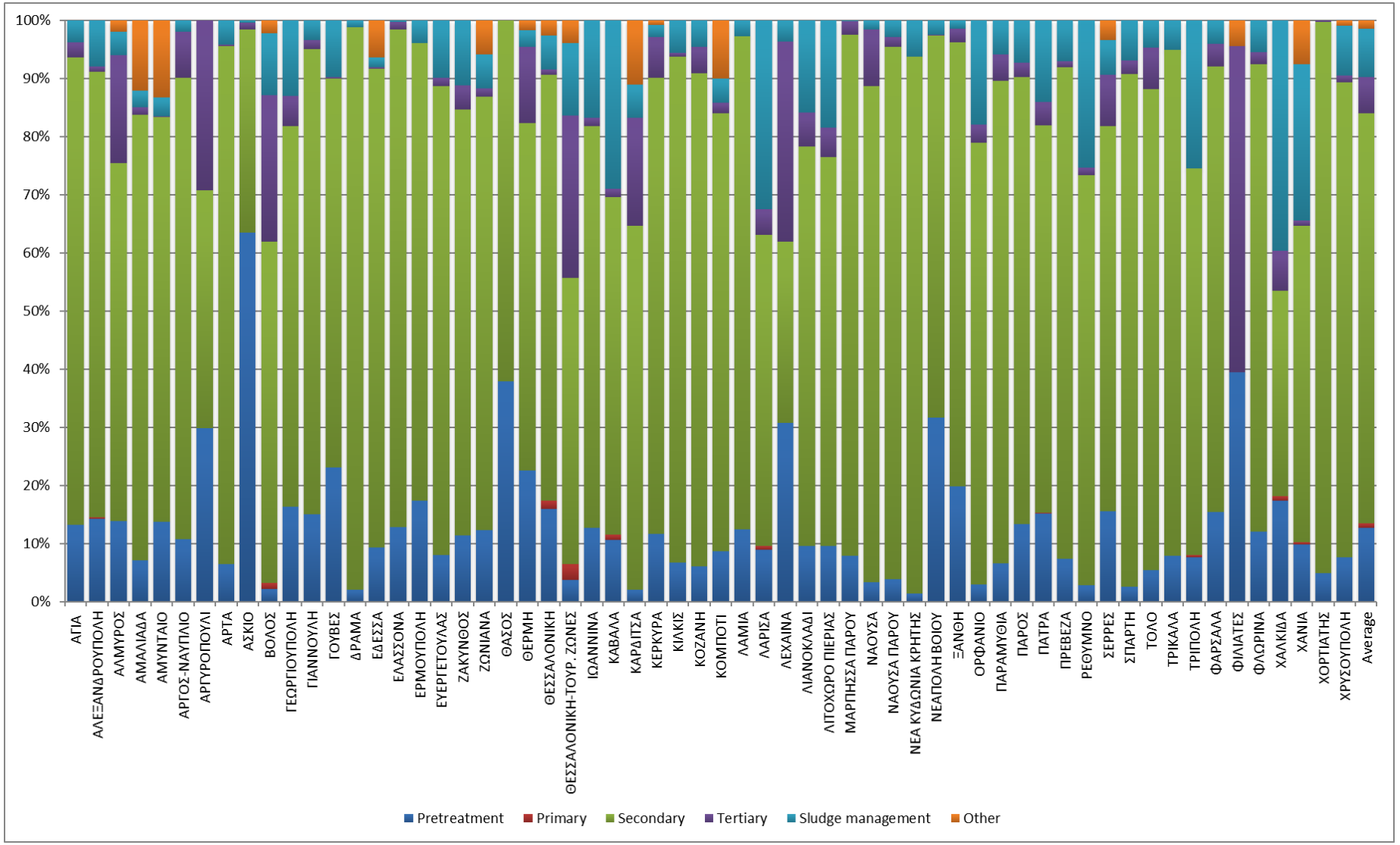
- Greek Wastewater Treatment Plants Database (ΥΠΕΚΑ, 2019)
  243 facilities
- European Database of WWTPs – Waterbase (EEA, 2019) for gap filling purposes
- Data reporting to our questionnaire on energy consumption
  61 facilities (25% in number of facilities, 50% in P.E.)

- The whole database represents all reported facilities in the Greek national registry with a total capacity of almost 14 million P.E
- while 25% of the facilities have tertiary treatment available. This represents more the 50% of the nation’s P.E. capacity.
- Influent volumes rise to 836,000 m^3 while the total dry sludge (DS) production is about 92,000 tons/year.
- Based on present 302 million m^3 of treated effluent only 8% of it is currently reused;

Spatial coverage of the database



Energy consumption (%) per treatment stage

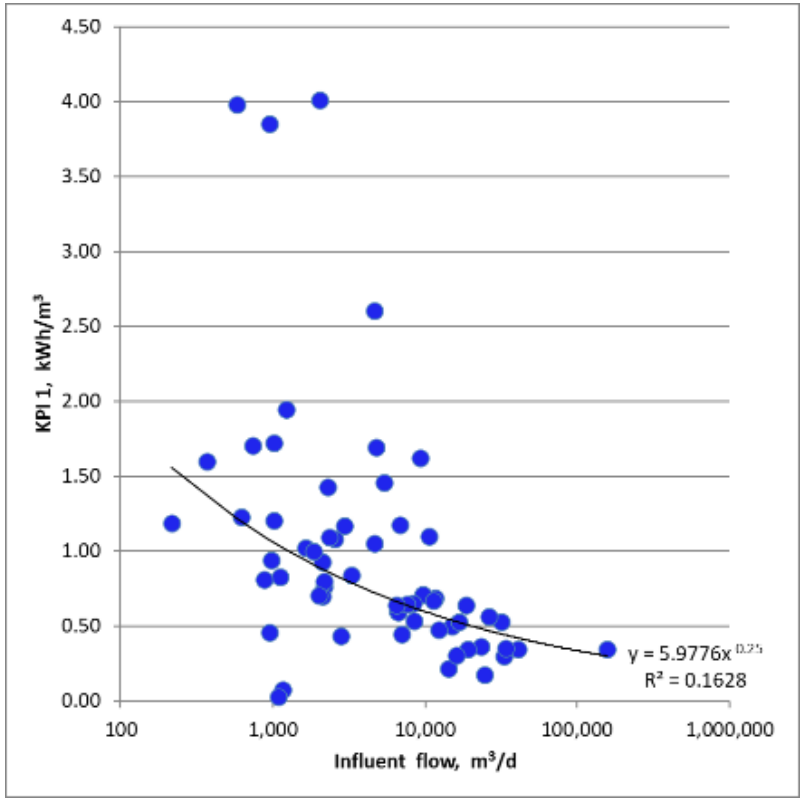


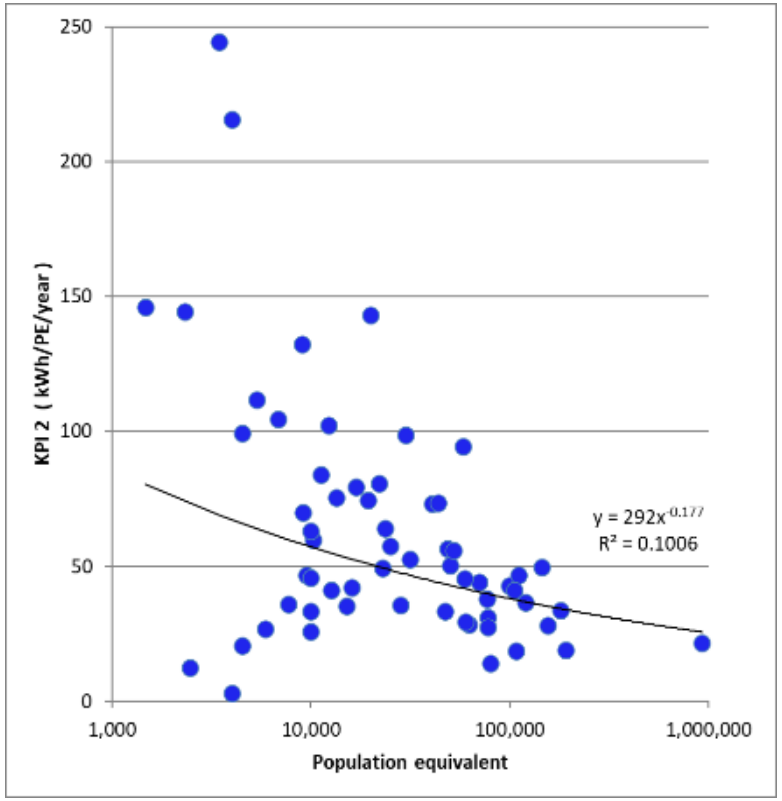
Energy efficiency indicators

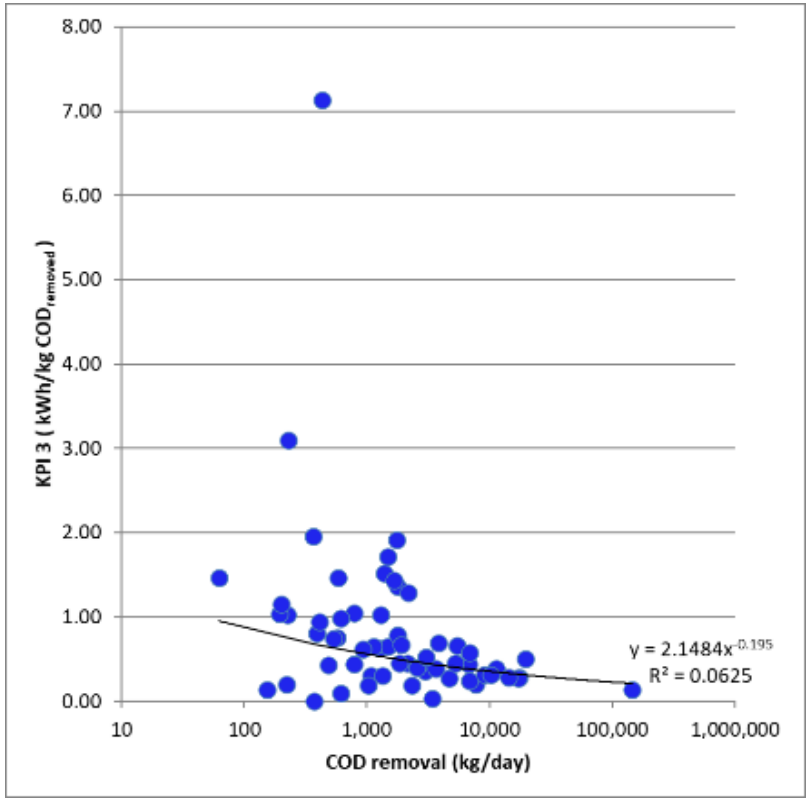
The energy efficiency is assessed by Key Performance Indicators (KPIs) considering different dimensions of the WWTP

- **KPI-1 = kWh/m^3 of treated effluent**
  not fully representative of the energy consumption of a WWTP, as in the case of combined or mixed systems is affected by dilution due to inflow of rainwater
- **KPI-2 = kWh/P.E. on annual basis**
  WWTPs served by combined sewerage system present higher specific energy values in terms of kWh/P.E.
- **KPI-3 = kWh/kg COD$_{removed}$**

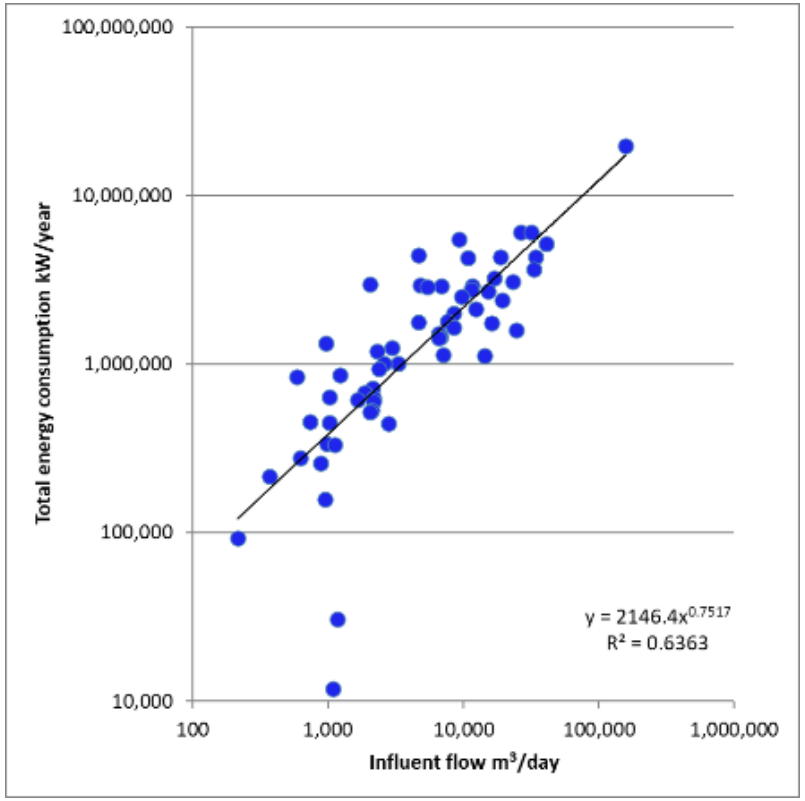
Results

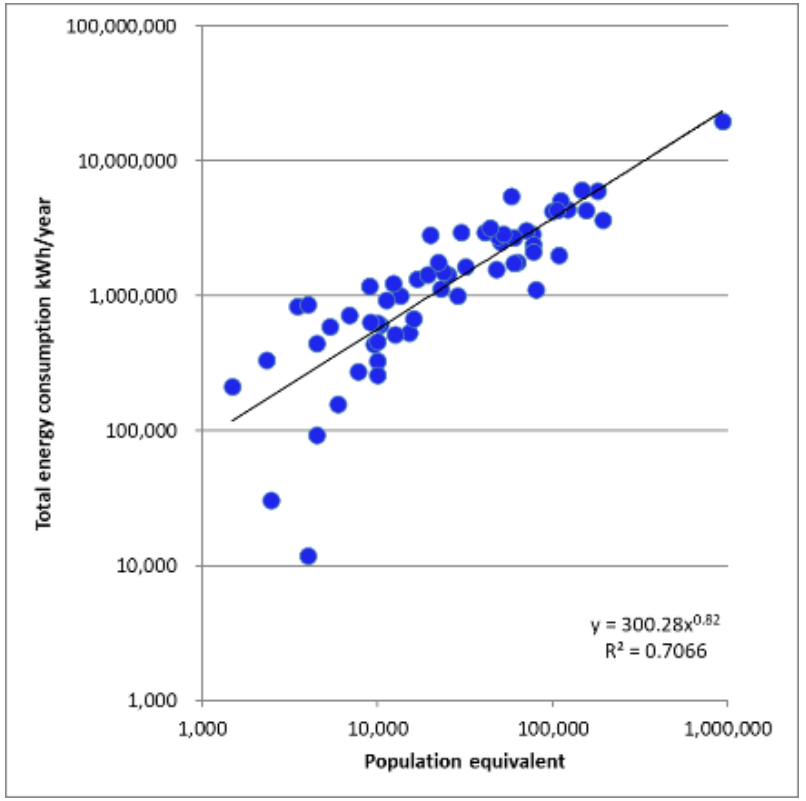

KPI 1, kWh/m³
Influent flow, m³/d
y = 5.9776x^-0.25
R² = 0.1628

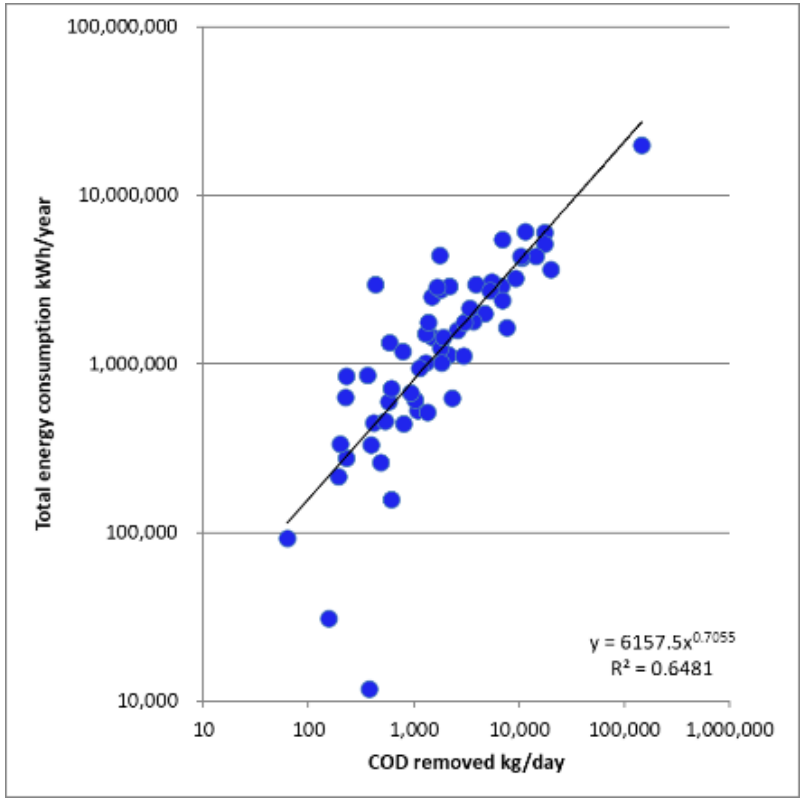

KPI 2 (kWh/PE/year)
Population equivalent
y = 292x^-0.177
R² = 0.1006


KPI 3 (kWh/kg COD removed)
COD removal (kg/day)
y = 2.1484x^-0.195
R² = 0.0625

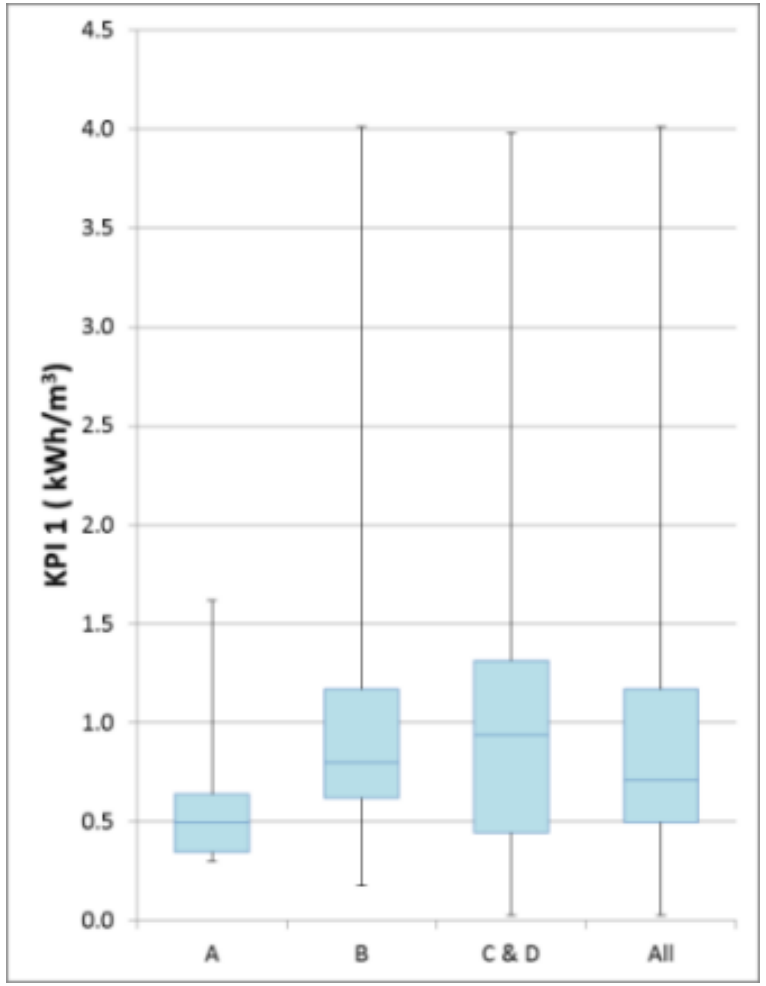
Results

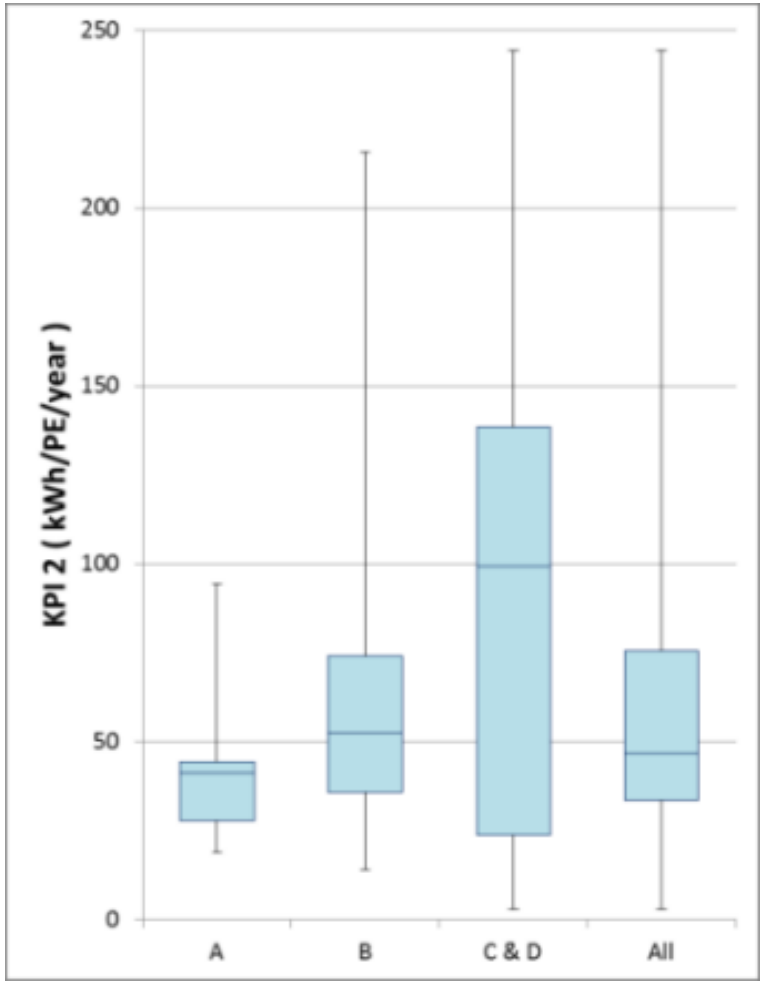

100,000,000
10,000,000
1,000,000
100,000
10,000
Total energy consumption kW/year
y = 2146.4x^0.7517
R² = 0.6363
100
1,000
10,000
100,000
1,000,000
Influent flow m³/day

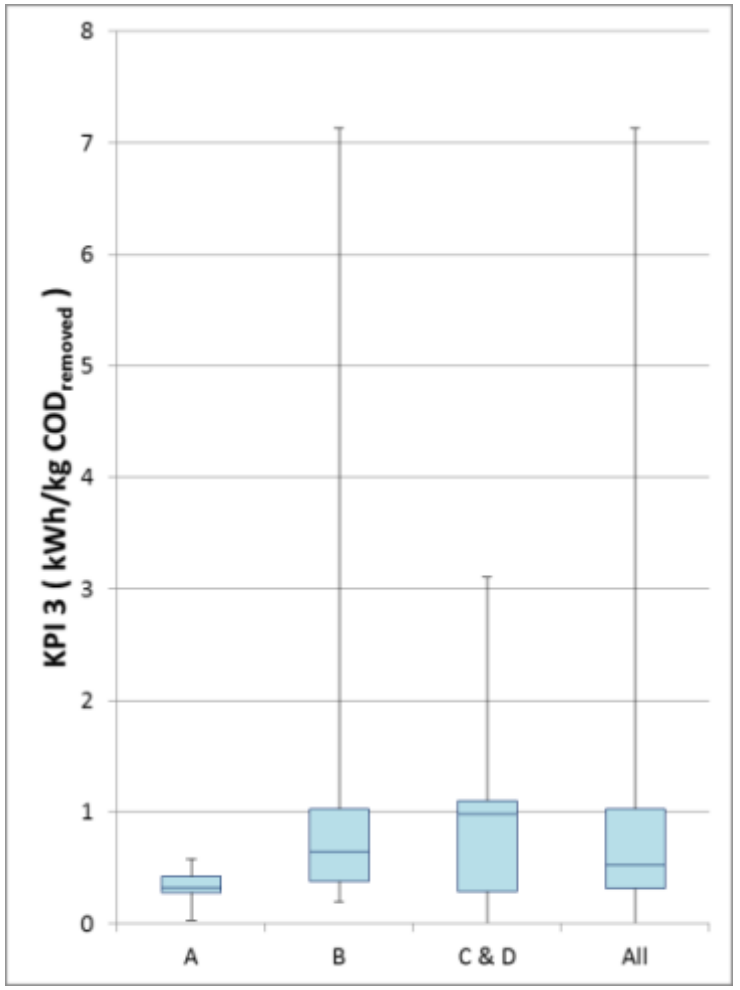

100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
Total energy consumption kWh/year
y = 300.28x^0.82
R² = 0.7066
1,000
10,000
100,000
1,000,000
Population equivalent


100,000,000
10,000,000
1,000,000
100,000
10,000
Total energy consumption kWh/year
y = 6157.5x^0.7055
R² = 0.6481
10
100
1,000
10,000
100,000
1,000,000
COD removed kg/day

Energy efficiency per WWTP category

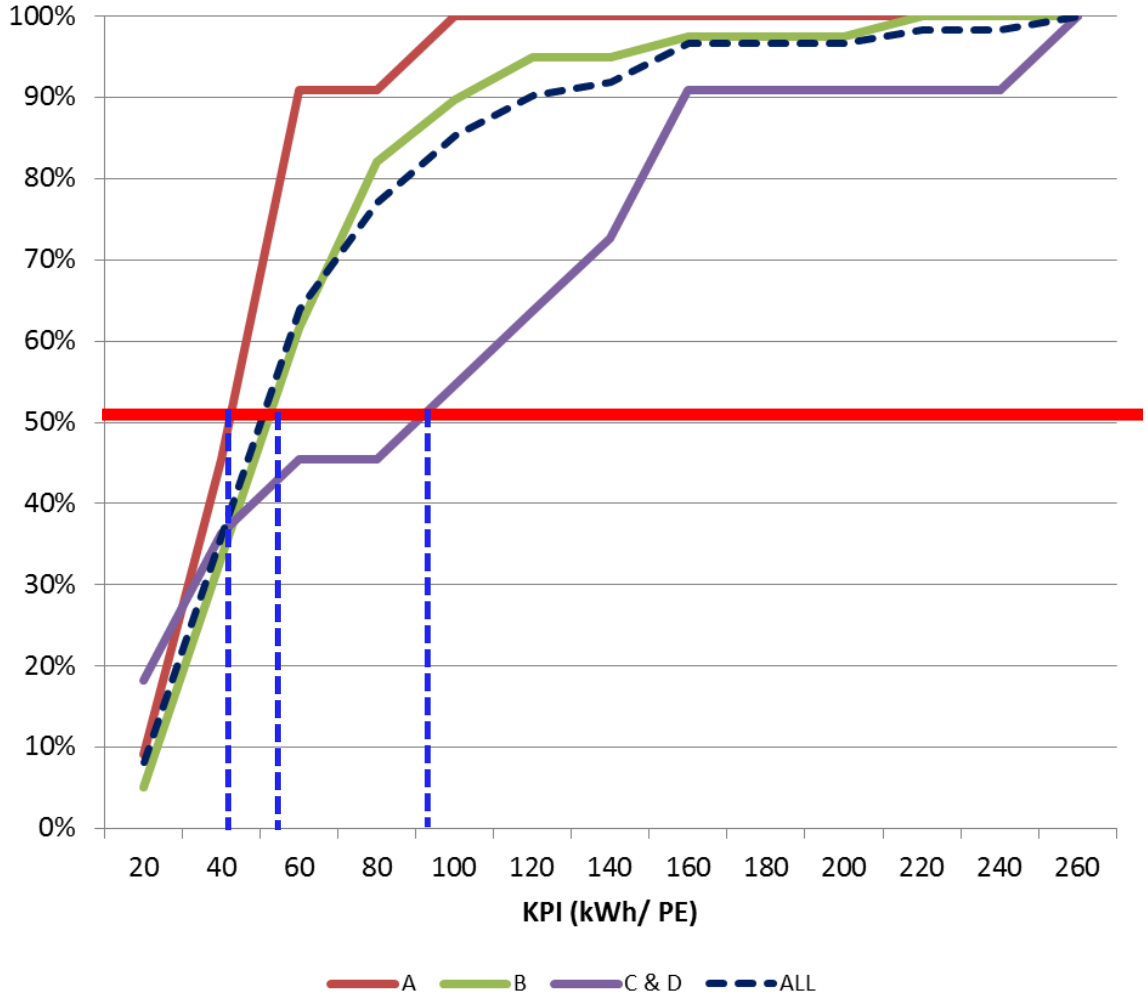






Energy benchmarking per WWTP category

- Cumulative distribution curves have been utilized to define the initial benchmark values at 50%
- KPI-2 (kWh/P.E.)
  - Category A = 35
  - Category B = 45
  - Categories C&D = 92
  - All WWTPs ≈ 50



Conclusions

- Energy consumption benchmarking is powerful management tool, using specific indicators to determine the optimal energy efficiency assessment of a WWTP.
- Benchmarking supports the identification of opportunities energy savings and can help prioritize optimization with targeting measures.
- the stage which contributes the most in energy consumption is the secondary processing, by means of 72%
- The largest plants with PE > 100,000 appear quite independent from COD concentration, while a decreasing trend was observed for plants up to 100,000 PE. Also, these plants exhibit the lowest values of organic load removal performance indicators such as kWh/kg COD, kWh/kg N, kWh/kg P και kWh/kg TPE.
  - advantage of sharing fixed quota of energy consumption on a greater organic load (in the denominator)
  - more stable operating conditions, while small plants undergo frequent transitional periods which are particularly energy intensive; automation and optimization tools such as variable-frequency drives in aeration or pumping, etc.
- Higher specific energy indicators for organic loads removal are observed in diffused air systems.

Thank you for your attention

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Funded by:

ΕΣΠΑ 2014-2020 ανάπτυξη - εργασία - αλληλεγγύη

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Ευρωπαϊκή Ένωση Ευρωπαϊκό Ταμείο Περιφερειακής Ανάπτυξης