5th Low Energy Wastewater Treatment Systems Conference. Cranfield, UK

H2020 Project ENERWATER – Quantification and reduction of energy expenditure in WWTP

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Introduction. ENERWATER objectives

This project develops, validates and disseminates a standard methodology for the evaluation and increase of energy efficiency in WWTPs

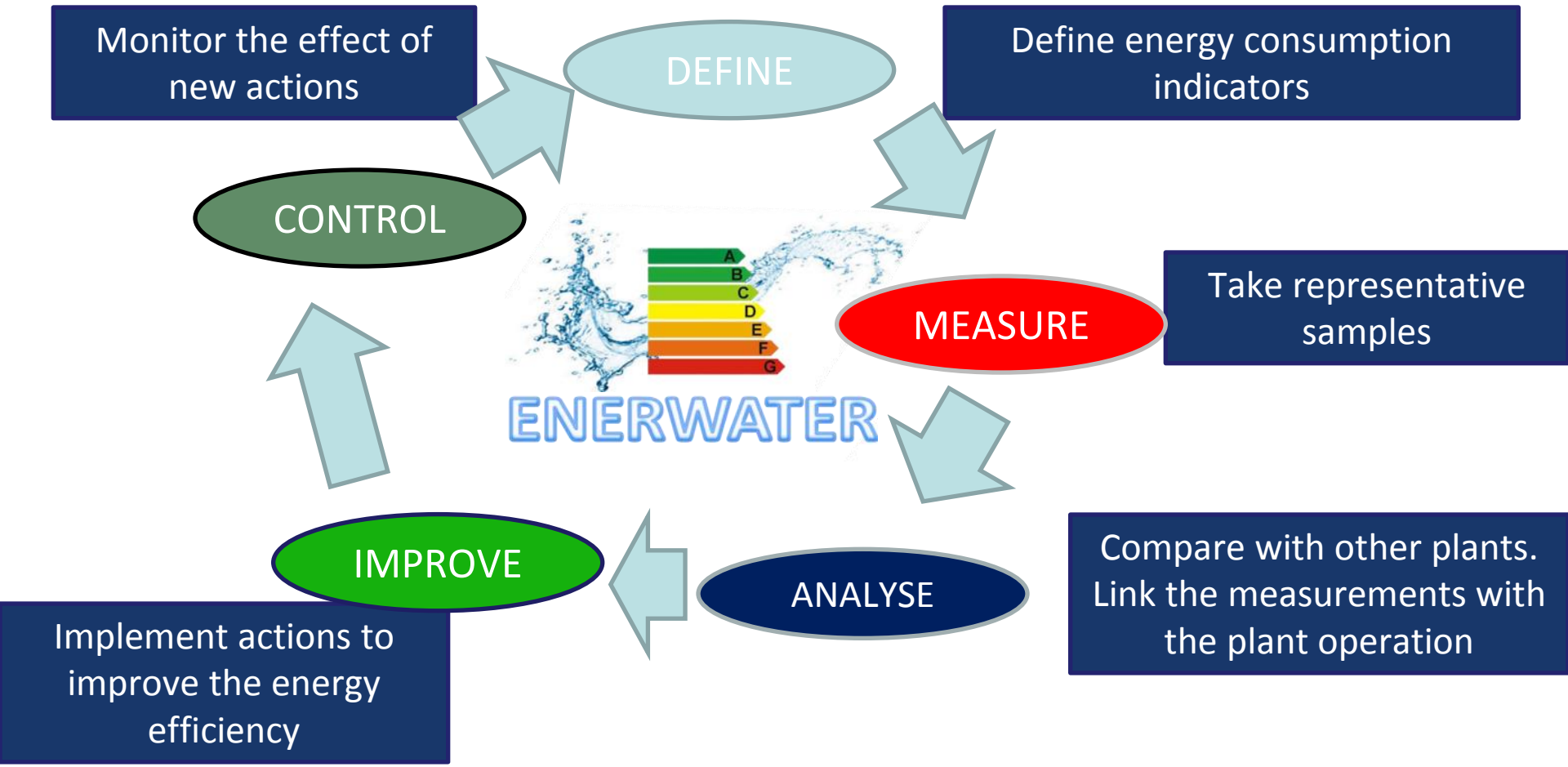
The methodology must be:

- **Standardized**: to allow sound comparisons between different plants and operators

- **Generic**: Adapted to different typologies of WWTPs

- **Open**: Anyone must be capable of using it and understand how the results are obtained.

Introduction. ENERWATER objectives



Introduction. ENERWATER consortium

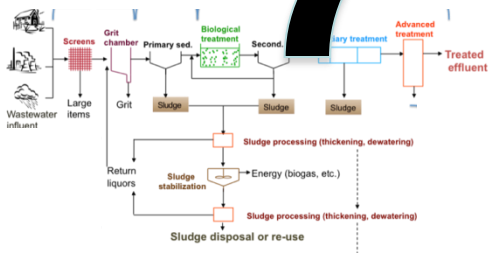
Budget 1 731 087 €

March 2015 – February 2018

University of Santiago de Compostela (ES)
University of Verona (IT)
University of Cranfield (UK)
Technical University of Cologne (DE)
Espina y Delfín (ES)
ETRA (IT)
Aggerverband (DE)
AENOR (ES)
Wellness Smart Cities (ES)

ENERWATER methodology. Overview

Online energy monitoring



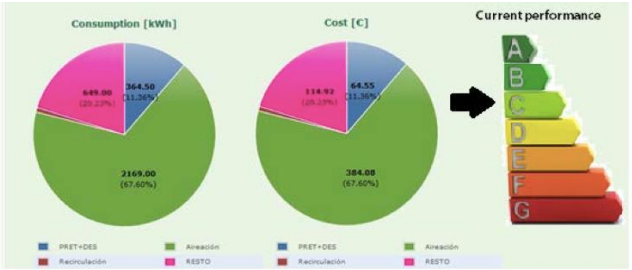
WWTP

DATA TREATMENT

Influent and effluent analysis

Communication

Water Treatment Energy Index - WTEI



Diagnosis

Which stages are less efficient?

DEFINE

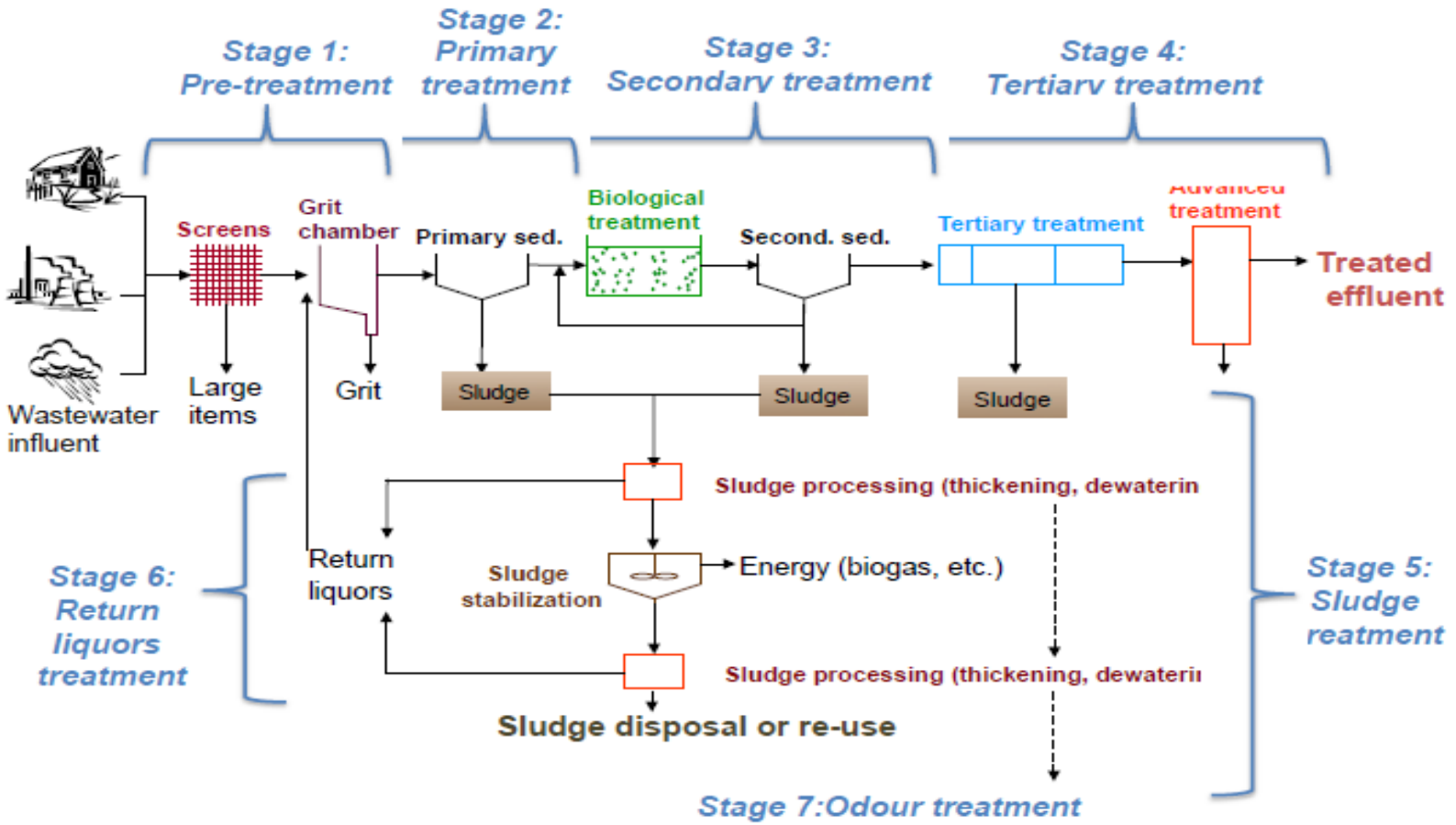
MEASURE

ANALYSE

ENERWATER methodology: Define

STAGE CLASSIFICATION

In order to disaggregate the energy consumption data, taking into account the different processes and treatment schemes applied in municipal WWTPs, 7 stage



ENERWATER methodology: Define

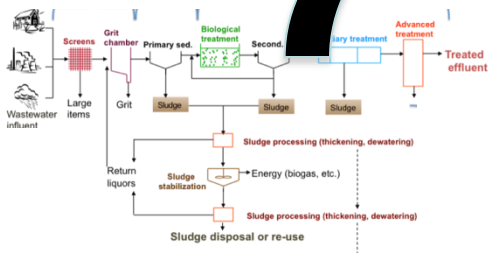
KEY PERFORMANCE INDICATORS (KPIs)

There is a clear need to establish suitable KPIs within the WWTP that allow a comparable, realistic and universal form of reporting the energy data.

STAGE CLASSIFICATION	KPIs
STAGE 1	kWh/m^3
STAGE 2	$kWh/kg\ TSS_{removed}$
STAGE 3	$kWh/kg\ COD_{removed}$, $kWh/kgTP_{removed}$
	$kWh/kg\ TN_{removed}$, $kWh/kgNH4_{removed}$
STAGE 4	$kWh/kg\ TSS_{removed,}$ $kWh/kgNH4_{removed}$
	$kWh/kg\ TN_{removed}$, $kWh/kgTP_{removed}$
	$kWh/Log_{\ reduction}$
STAGE 5	$kWh/kg\ TS_{processed,}$ $kWh_{produced}/kgVS_{removed}$
STAGE 6	$kWh/kgTP_{removed}$, $kWh/kg\ TN_{removed}$
STAGE 7	$kWh/kg\ VOCs_{\ removed}$, $kWh/kg\ VICs_{\ removed}$

ENERWATER methodology. Overview

Online energy monitoring



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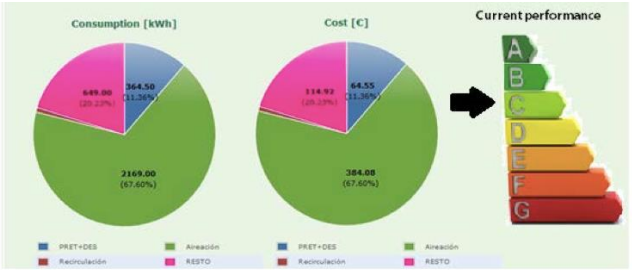

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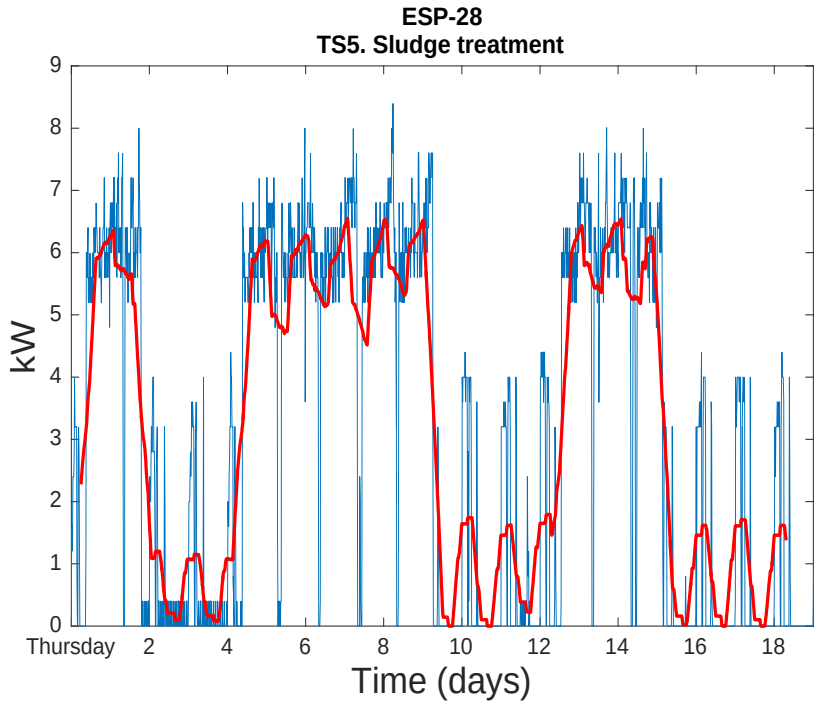
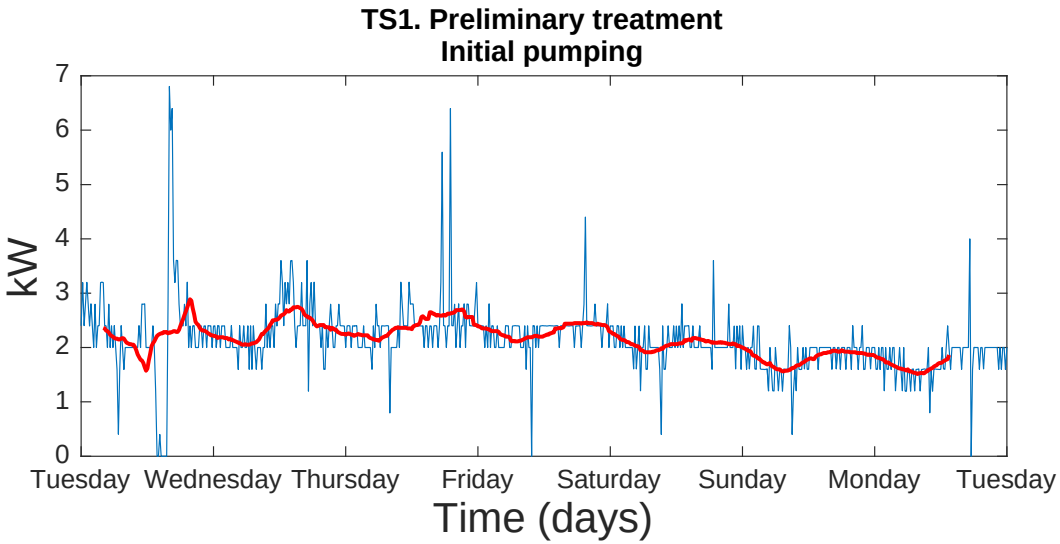
ENERWATER methodology: Measure

ENERWATER methodology: Measure

Diurnal and weekly trends

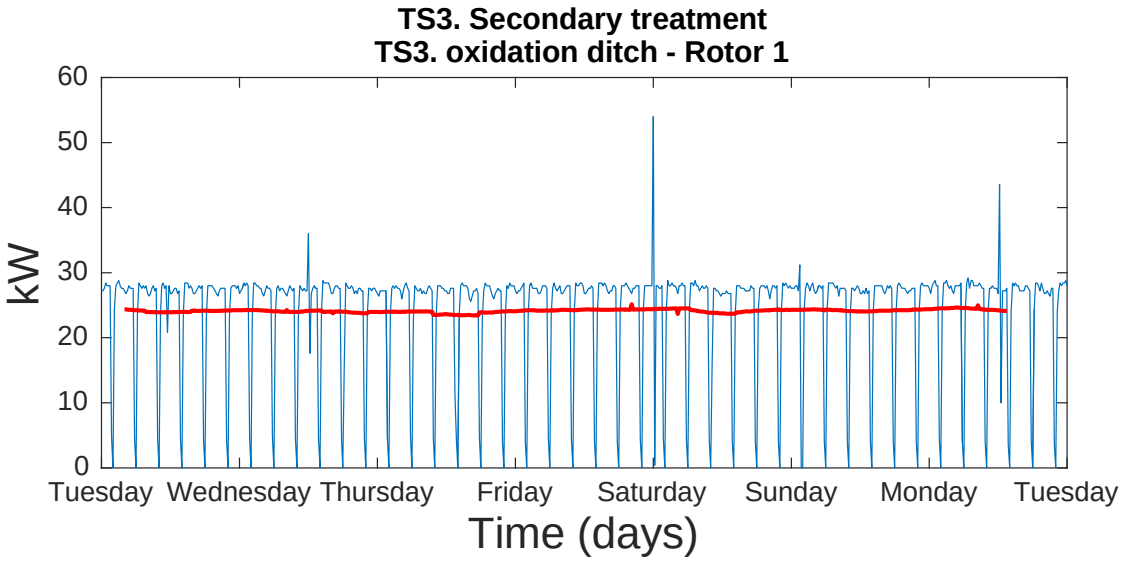




Weekly and diurnal trends can be detected -> utilize capacity for better electricity tariffs

ENERWATER methodology: Measure

Detailed trends provide information about dynamic and control



Pumping shows that the influent flow rate changes along the week. However, the energy consumed for aeration does not change

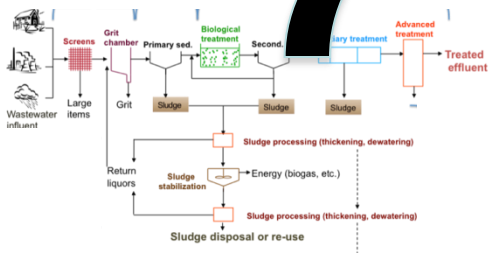
i) Automatic control not working

ii) Too high oxygen set point

It is likely that the system is over aerated. It is possible to save energy by adjusting the aeration flow rate

ENERWATER methodology. Overview

Online energy monitoring



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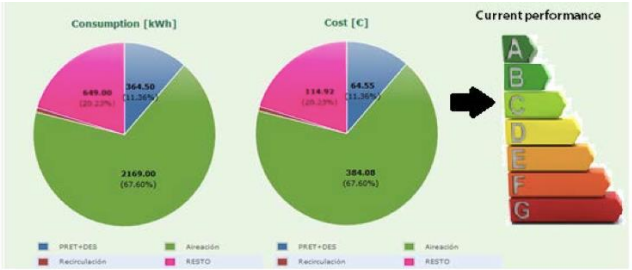

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ENERWATER methodology: Analyse

Calculation of Energy Performance Index from KPIs

PROS of composite indexes

- Can summarise complex, multi-dimensional realities with a view to supporting decision makers.
- Are easier to interpret than a battery of many separate indicators.
- Can assess progress of plants/processes over time.
- Reduce the visible size of a set of indicators

CONS of composite indexes

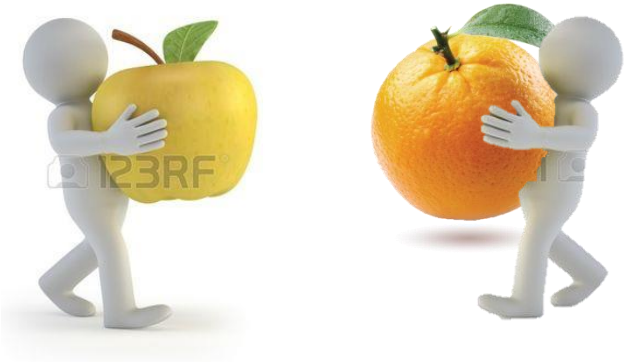
- May send misleading messages if poorly constructed or misinterpreted.
- May invite simplistic conclusions.
- The selection of indicators and weights has a large impact on the index

ENERWATER methodology: Analyse

Calculation of Energy Performance Index from KPIs

How to combine KPIs?
How to add apples and oranges?

$$KPI_{norm} = \frac{KPI - min(KPI)}{max(KPI) - min(KPI)}$$



How to weight each KPI for the composite index?

$$\text{EPI (per Stage)} = \sum_i w_i KPI_i = w_1 KPI_1 + w_2 KPI_2 + w_3 KPI_3 + \cdots + w_i KPI_i$$

$$\text{EPI (whole Plant)} = 0.14\, KPI_1 + 0.003 KPI_2 + 0.70 KPI_3 + 0.04 KPI_4 + 0.11 KPI_5$$

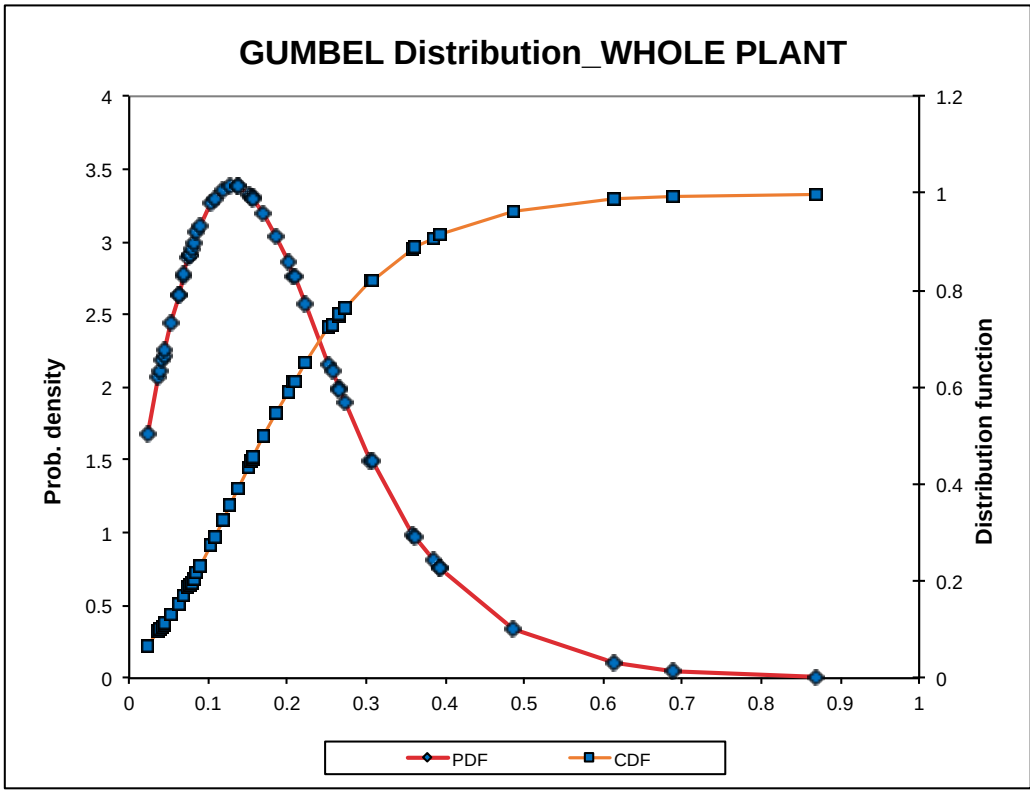
weights obtained from our database
>60 WWTPs

ENERWATER methodology: Analyse

		ES_33	50_WWTPs			
STAGE	KPI		Average	St.Dev	Min	Max
1	[kWh/m^3]	0.153	0.073	0.08	0.001	0.533
3	[kWh/KgCOD_rem]	0.31	0.49	0.41	0.08	2.02
	[kWh/KgTN_rem]	3.8	6.71	5.31	1.3	28.3
	[kWh/KgTP_rem]	7.01	8.27	6.97	1.62	35.46
	[kWh/KgPEQ_rem]	0.049	0.057	0.046	0.11	0.22
5	[kWh/KgTS_proc]	0.19	0.31	0.34	0.001	1.59

ENERWATER methodology: Analyse

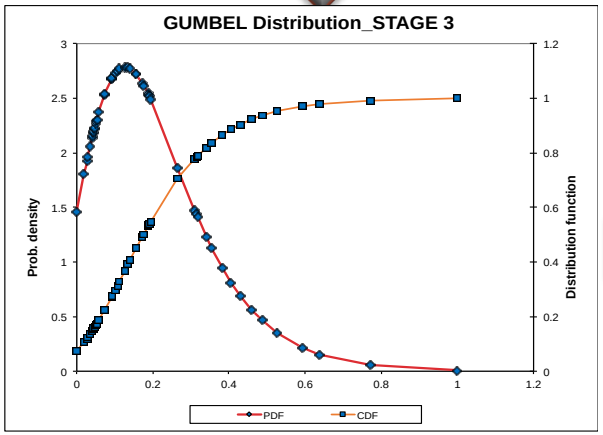
WHOLE PLANT	
ϒ=	0.5772
β=	0.108683938
μ=	0.130947349
E[X]=	0.193679718
Var(X)=	0.019410592
Std. Dev.=	0.139321901
Mode=	0.130947349
Med(X)=	0.091113281
Variance	0.019410592
Skewness	1.141227937
Ex.Kurtosis	2.4
Entropy	-0.6421112

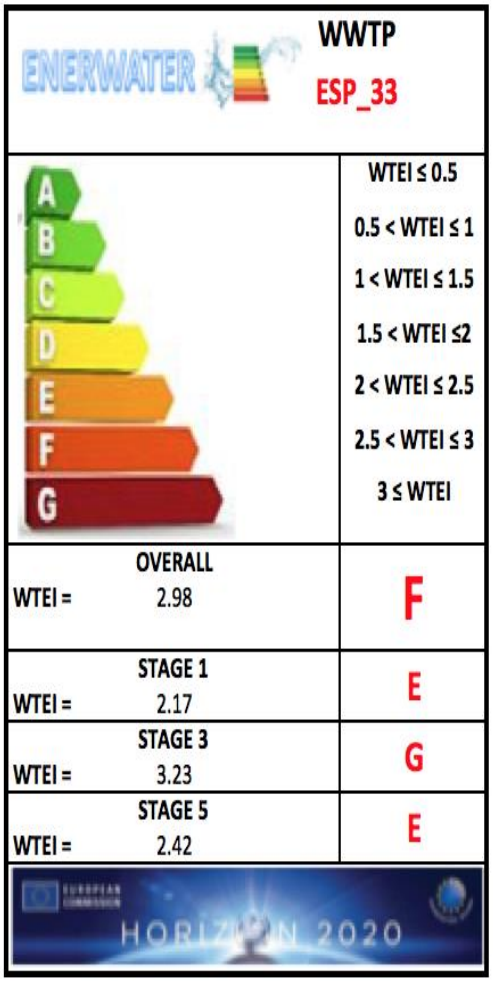


ENERWATER methodology: Analyse

Determination of WTEI and energy class

DATA TREATMENT (EPI)





Communication
Water Treatment Energy Index - WTEI

Diagnosis
Which stages are less efficient?

What can ENERWATER do for you?

- Receive information from our activities. Join the ENERWATER network at www.enerwater.eu

- Use our methodology to check the efficiency of your WWTP and hopefully, save some energy

- Send us your energy consumption data. We can treat them, benchmark them against our database and provide conclusions

To know more

Longo et al. 2016. Applied Energy, 179, 1251

Monitoring and diagnosis of energy consumption in wastewater treatment plants. A state of the art and proposals for improvement

Stefano Longo [a], Benedetto Mirko d'Antoni [b], Michael Bongards [c], Antonio Chaparro [d], Andreas Cronrath [c], Francesco Fatone [b], Juan M. Lema [a], Miguel Mauricio-Iglesias [a], Ana Soares [e], Almudena Hospido [a,*]

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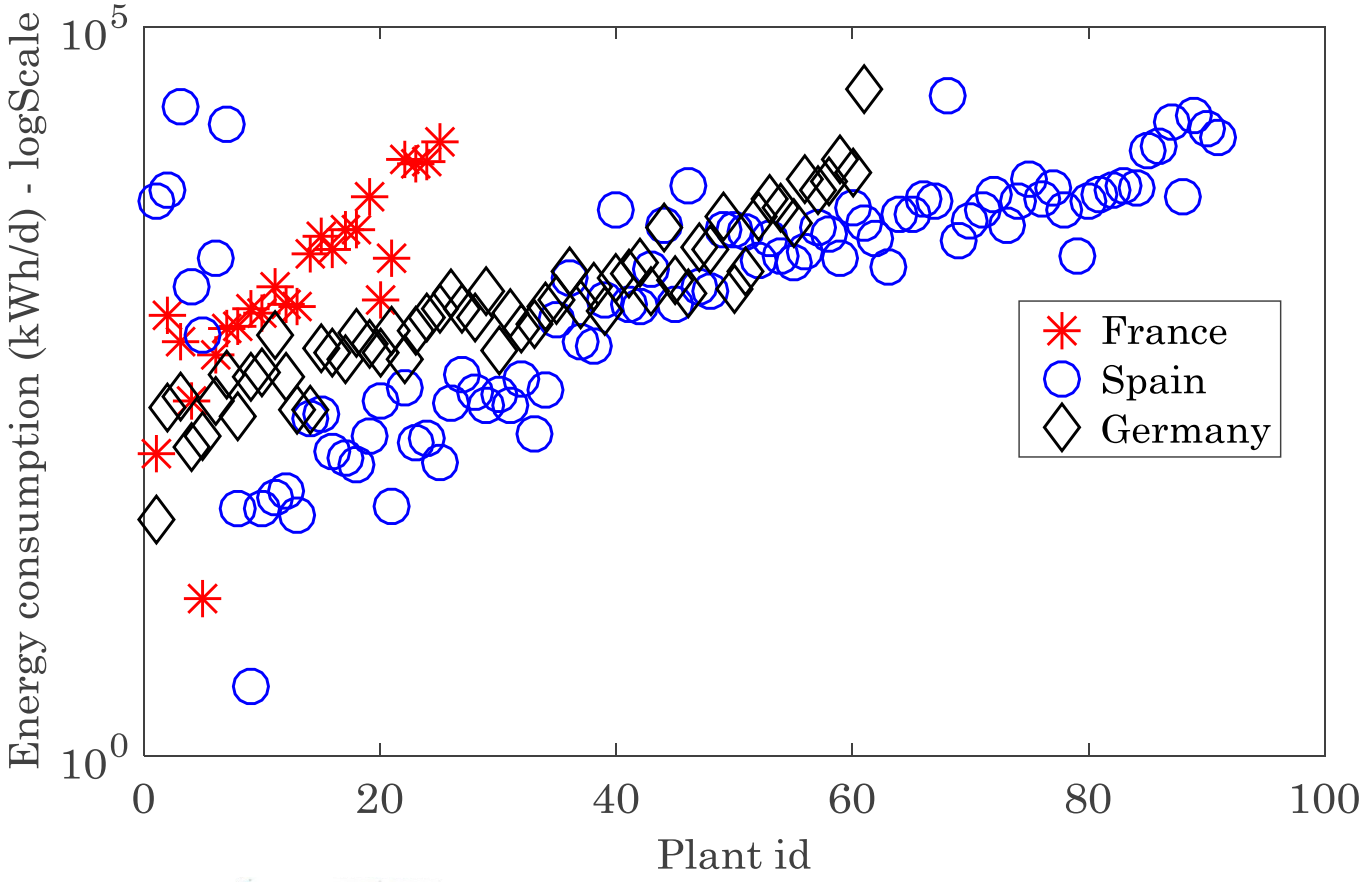
-CSA H2020 ENERWATER

A STANDARD METHOD AND ONLINE TOOL FOR ASSESSING AND IMPROVING THE ENERGY EFFICIENCY OF WASTEWATER TREATMENT PLANTS

Data treatment for diagnosis

Does the country location impact the WWTP energy consumption?

Set of 187 WWTPs with influent and effluent characteristics



Data treatment for diagnosis

Does the country location impact the WWTP energy consumption?

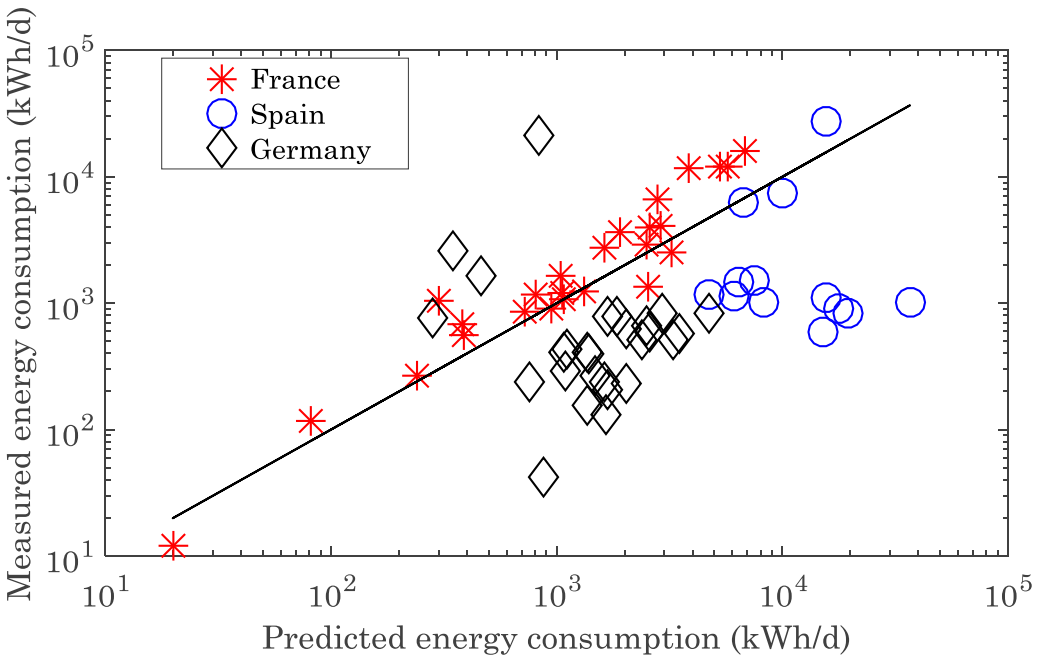
	Germany	France	Spain
No control	-0.497*** (0.084)	0.614*** (0.157)	0.797***(0.110)
Log(F)	-0.425*** (0.059)	0.541*** (0.110)	0.680*** (0.077)
Log(F), CODinf	-0.300*** (0.065)	0.609*** (0.107)	0.416*** (0.099)
Log(F), CODinf, PLF	-0.270*** (0.063)	0.528*** (0.104)	0.378*** (0.095)
Log(F), CODinf, PLF, 2treat	-0.133 (0.155)	0.840*** (0.114)	0.003 (0.235)

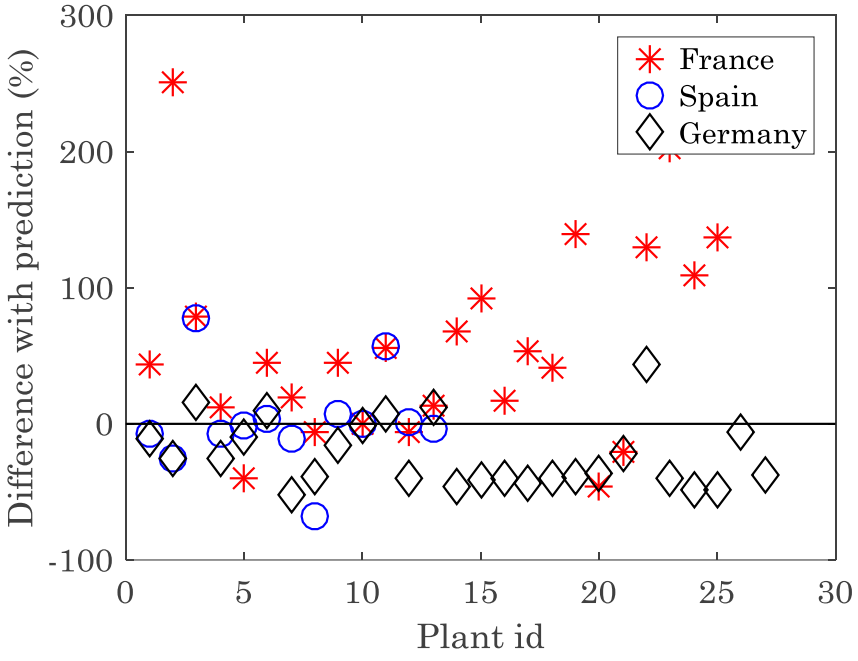
- Differences between France and the rest persist as we control for more covariates

- When controlling for the secondary treatment, the difference between Germany and Spain is no longer significant

Data treatment for diagnosis

Does the country location impact the WWTP energy consumption?





French WWTPs consume around 50% more energy than comparable German and Spanish WWTPs