SIDISA 2024
XII International Symposium on Environmental Engineering
Palermo, Italy, October 1 – 4, 2024

Energy efficiency in wastewater treatment plant: benchmark analysis on more than 50 plants in Sicily

Daniele Di Trapani[1], Marco Carciola[1], Santo Fabio Corsino[1], Alida Cosenza[1], Gaetano Di Bella[2], Gianfranco Gravina[3], Luigi Gurreri[4], Giuseppe Mancini[4], Antonella Luciano[5], Michela Langone[6], Davide Mattioli[6], Luigi Petta[6], Gianpaolo Sabia[6], Giovani Sciortino[7], Michele Torregrossa[1], Gaspare Viviani[1]

[1] Department of Engineering, University of Palermo, Palermo, Italy,
[2] Faculty of Engineering and Architecture, University of Enna "Kore", Enna, Italy
[3] ACQUAENNA S.C.p.A., Enna, Italy.
[4] Department of Electrical, Electronic and informatic Engineering, University of Catania, Catania, Italy
[5] Laboratory Instruments for the Sustainability and Circularity of Productive and Territorial Systems, ENEA, CR Casaccia, Roma, Italy.
[6] Laboratory Technologies for the Efficient Use and Management of Water and Wastewater, ENEA, CR Bologna, Bologna, Italy.
[7] AMAP S.p.A., Palermo, Italy.

Speaker:

Dr. Gianpaolo Sabia

Palermo - October 2, 2024

UNIVERSITÀ DEGLI STUDI DI PALERMO

GITISA Gruppo Italiano di Ingegneria Sanitaria Ambientale

ANDIS ASSOCIAZIONE NAZIONALE DI INGEGNERIA SANITARIA AMBIENTALE

Scientific Background: Project and ENEA's role

Project: Smart Energy-Efficiency wastewater treatment Plants (SMARTEE PLANT)

Duration: *Jan. 2023 - Jun. 2025*
Total budget: *3.425.390,79 €*
Programme: *POC 2014-2020-Axis1-Action 1.1.1. (POR FESR 2014/2020-Action 1.1.5)*

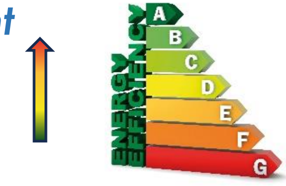
SMART - EE- PLANTS

Scientific Objectives:

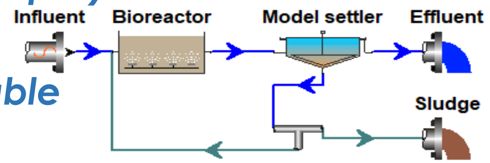
The project aims to promote energy efficiency in Sicilian WWTPs within the specific metropolitan areas of Catania, Palermo, and Enna municipal consortium.
Activities include the use of low-cost sensors to monitor the course of energy-intensive treatment processes (aeration, recirculation, etc.) and the development of control systems based on adaptive logics to reduce consumptions.

ENEA's main actions supporting UNIPA and UNICT:

Support to the analysis of WWTP energy balance to determine optimal management strategies for energy savings through the:



1. *definition of a WWTP benchmarking procedure;*
2. *analysis of WWTP energy balances and the estimation of GHG emissions;*
3. *modeling of three main WWTPs (AMAP S.p.A, Acquaenna S.c.p.A., SIDRA S.p.A) to simulate the energy consumption and the GHG emissions;*
   Evaluate the potential savings achievable by the implementation of suitable management strategies.

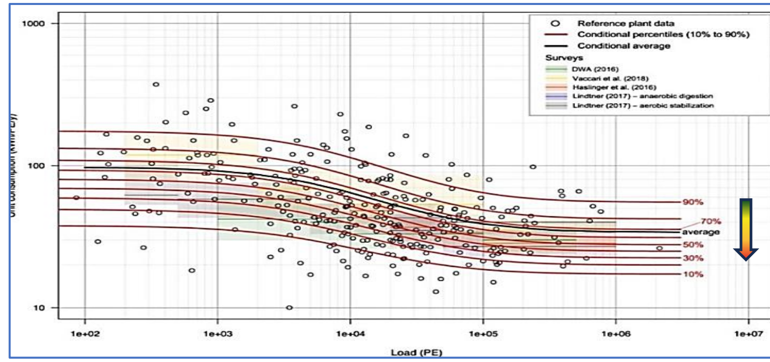


European Water Service system: energy use and GHG emissions

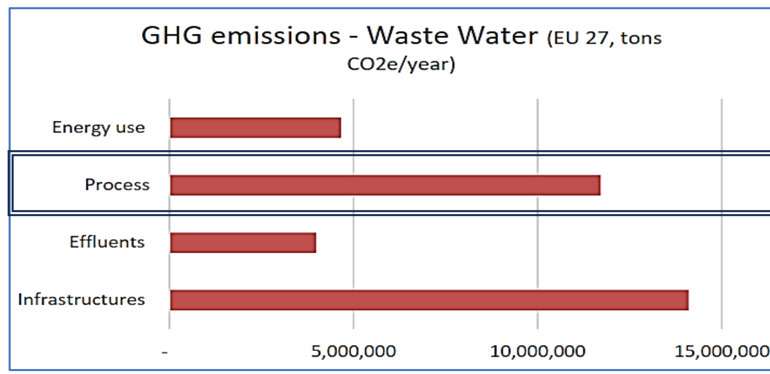
Table 1. Breakdown of volume treated and energy requirements for each stage of the water sector in 2017. (Source: water volumes: [Eurostat 2018], [GWI 2018], analysis: JRC)

Domain	Volume (billion m³)	Energy (GWh)	Energy (share)	Share of EU electricity
Drinking water supply	49.5	35 000	43.5 %	1.13 %
Desalination for municipal use	2.1	20 695	25.7 %	0.67 %
Wastewater treatment	47.9	24 747	30.8 %	0.80 %
Total	99.5	80 442	100 %	2.60 %

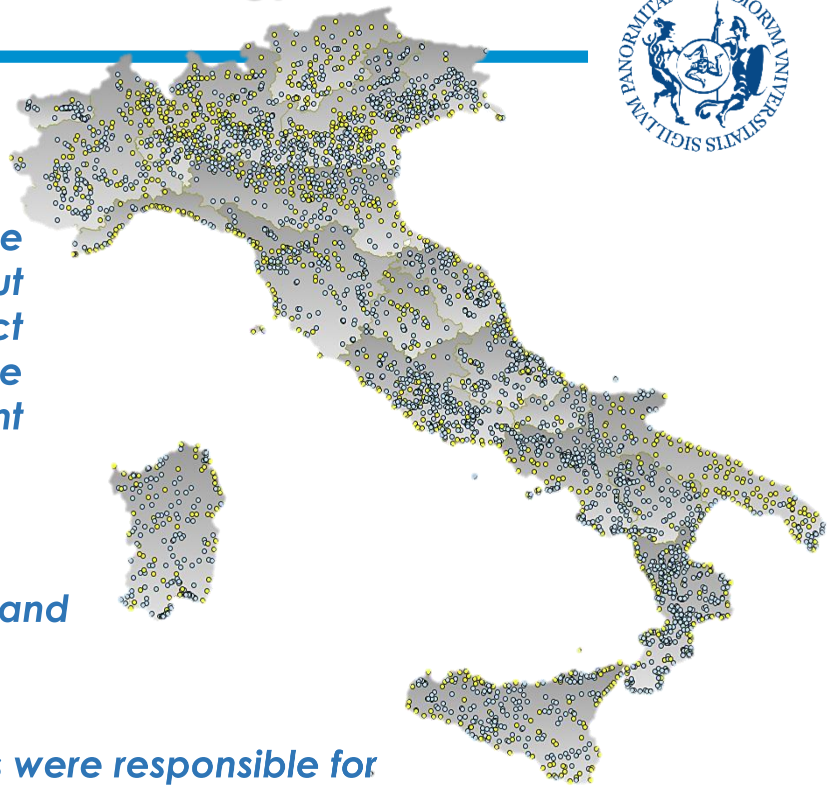
Energy use in EU Water Service and Potential savings: *In EU, in 2018 the WWTPs consumption totaled 24,747 GWh/y.*
Achievable savings amount to approximately 13,500 GWh/y by implementing stringent efficiency improvement targets. With less stringent measures, savings can be quantified at 5,500 GWh/y) (JRC, Ganora et al. 2019).



Greenhouse gas emissions: *In 2018 (Parravicini, 2022), wastewater treatments were responsible for 34.45 Mt $CO_{2eq.}$/year - about 0.86% of total EU greenhouse gas emissions (4% CH_4, 3% N_2O).*
GHG emissions related to operational activities stood at 13,03 Mt $CO_{2eq.}$/year : energy use (electricity) for the collection and the treatment of WW contributed for 4,6 Mt, while the treatment process for 8,4 Mt $CO_{2eq.}$/year .



Italian Water Service background: use of energy and GHG emission



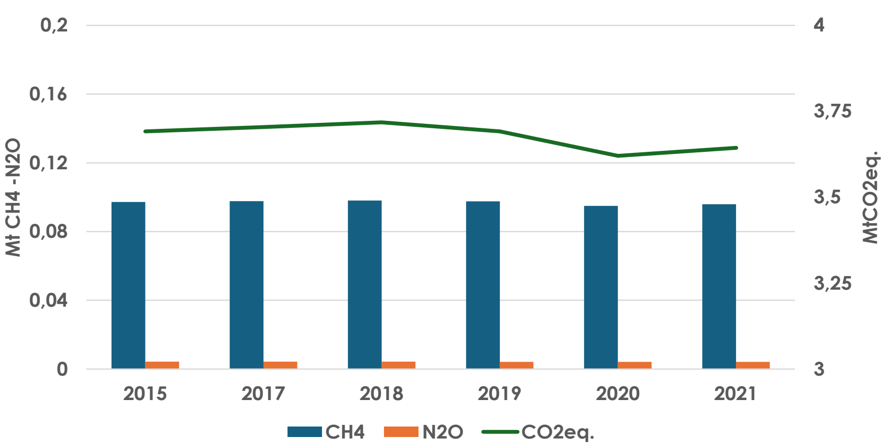
Energy use in EU Water Service and potential savings: *the national Water Service System requires 7,264 GWh, about 2% of energy consumption nationwide. The aqueduct service accounts for 4,350 GWh (59,9%), the sewerage network for 577 GWh (7,9%) while wastewater treatment 2,337 GWh (32,2%) (RSE, 2018).*

The study reports possibilities to improve energy efficiency of the WSS with energy-saving scenarios of 11%, 13%, and 6.5% for the three services, respectively.

Greenhouse gas emissions: *In 2018, wastewater treatments were responsible for 3,718 Mt $CO_{2eq.}$/year (5% CH_4 and 7% N_2O of national emissions).*

Trend in GHG emissions from the waste sector (ISPRA, 2023)

WWTPs	2015	2017	**2018**	2019	2020	2021
CH_4 (Mt)	0,097	0,098	**0,098**	0,098	0,095	0,096
N_2O (Mt)	0,004	0,004	**0,004**	0,004	0,004	0,004
$CO_{2eq.}$ (Mt)	**3,692**	**3,704**	**3,718**	**3,692**	**3,620**	**3,643**

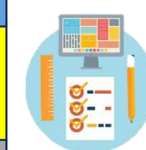


Analysis of Sicilian WWTPs: Survey and data elaborations

- *A technical survey was conducted by providing project partner Water Utilities with a structured template to collect data monthly for 4 years (2020-2023).*
- *The acquired data were related to: plant configuration, operating parameters, pollutant removal rates, energy consumption.*
- *The acquired data were checked and validated.*

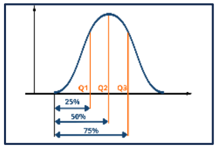
- *WWTP energy consumptions were related to operative parameters calculating (**ECI**, Energy Consumption Indicators) values for each class:*

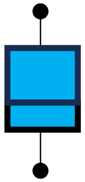
$ECI_{\mathrm{m3}} = \dfrac{\text{Energy consumption } [\frac{KWh}{y}]}{\text{Treated wastewater flowrate } [\frac{m^3}{y}]}$	$\left[\dfrac{KWh}{m^3}\right]$
$ECI_{COD} = \dfrac{\text{Energy consumption } [\frac{KWh}{y}]}{\text{COD load removed } [\frac{kgCOD_{rem}}{y}]}$	$\left[\dfrac{KWh}{kgCOD_{rem}}\right]$
$ECI_{PE} = \dfrac{\text{Energy consumption } [\frac{KWh}{y}]}{\text{Population equivalent } [\mathrm{P.E.s}]}$	$\left[\dfrac{KWh}{\mathrm{P.E.s}\ year}\right]$



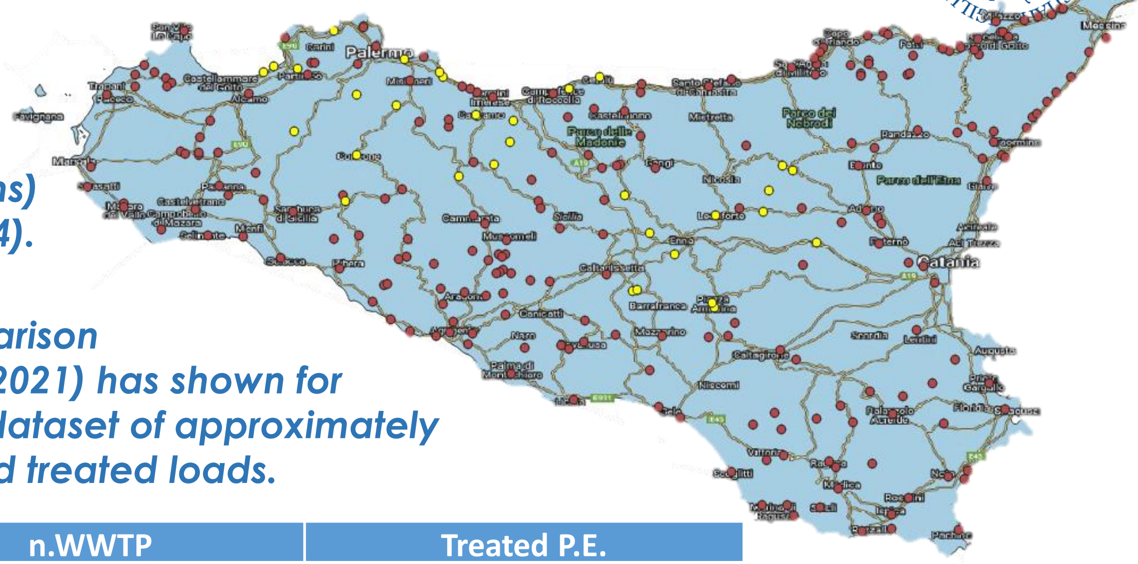
- *Four design-based plant size classes were defined :*
  - *(1) P.E.<2.000*
  - *(2) 2.000≤P.E.<10.000*
  - *(3) 10.000≤P.E.<50.000*
  - *(4) P.E.>50.000*

- *ECIs value analysis and calculation of statistics for benchmarking analysis*





Results: Survey



The data validation process (completeness of data for ECI calculations) led to the selection of the 42 WWTPs (of 54).

In terms of representativeness, the comparison with the EEA survey on WWTPs (data call 2021) has shown for Sicily a coverage of the SMARTEE PLANT dataset of approximately 15% both in terms of number of plants and treated loads.

	n.WWTP			Treated P.E.		
Class size	**SmP**	**EEA**	**%**	**SmP**	**EEA**	**%**
P.E.<2k	7	25	28,0%	3.910	36.341	10,8%
2k ≤ P.E.<10k	22	128	17,2%	47.492	669.267	7,1%
10k ≤P.E.<50k	10	86	11,6%	109.400	1.895.701	5,8%
P.E.≥50k	3	25	12,0%	472.764	1.831.850	25,8%
Tot.	42	264	15,9%	633.566	4.433.159	14,3%

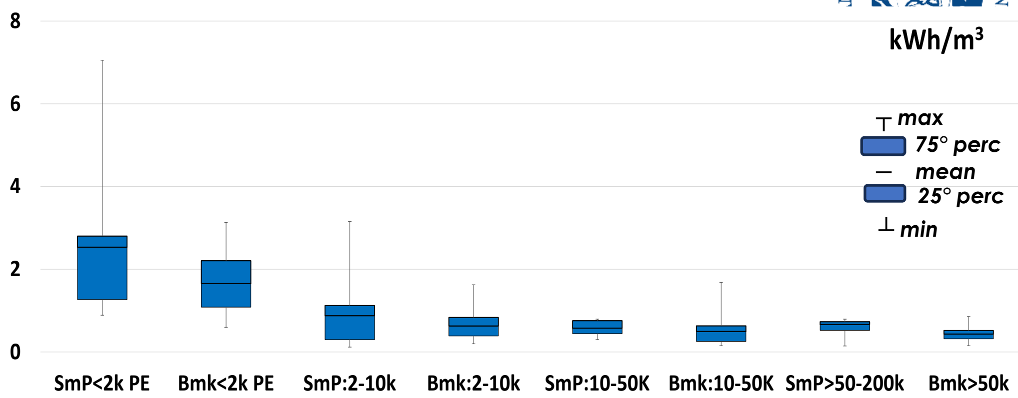
WWTP characteristics:

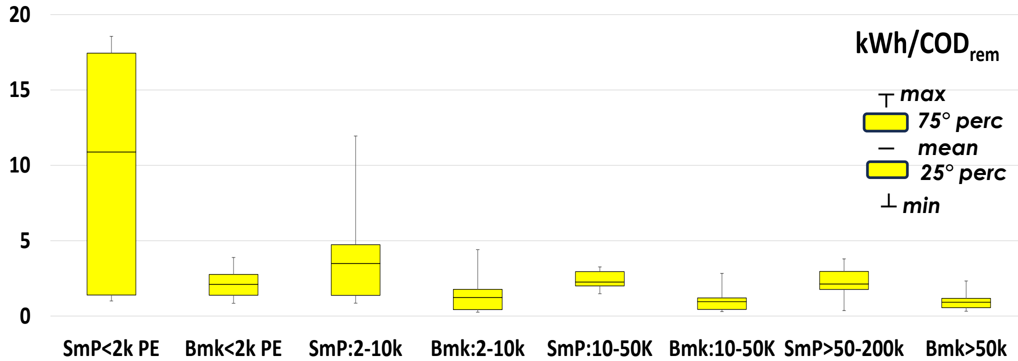
- *The analysed WWTPs mostly present process configurations of the water line structured on conventional activated sludge treatments (reduced cases designed to accomplish nitrification and denitrification);*
- *The sludge line most frequently involves mixed sludge stabilization processes based on prolonged aerobic digestion;*
- *Sludge dewatering is often carried out naturally on drying beds.*

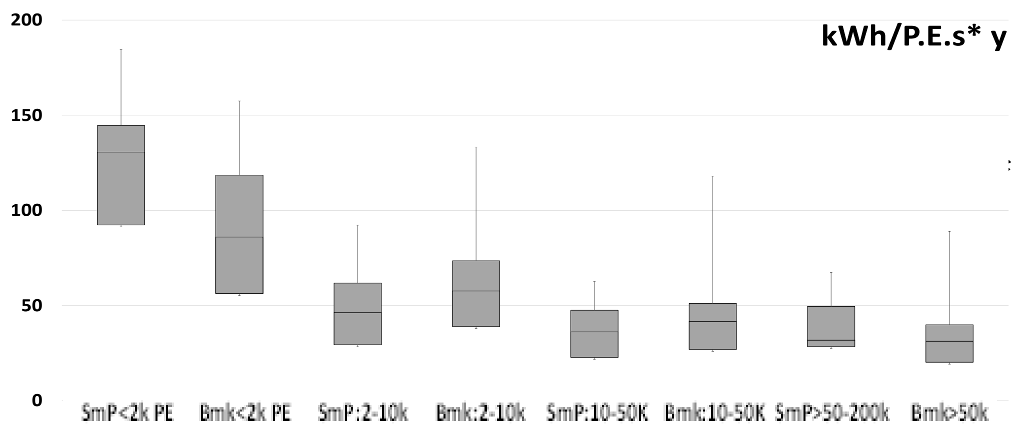
ECIs and benchmarking: Results and preliminary conclusions

- *The SmP WWTP group is on average less energy efficient than the respective benchmark (Bmk).*
- *Plus-sized plants result in being more closely aligned regarding energy performance with benchmarks.*
- *ECIm^3 has shown the closest values to the relevant benchmark references, for all WWTP's size classes.*
- *ECI$_{COD}$ values are generally higher than the benchmark, showing higher energy consumption. The reasons are to be associated with elements such as low values of organic loads, and sludge stabilization by prolonged aeration.*

Higher differences in smaller WWTPs are also to be related with lower data accuracy (less frequent monitoring) and the lack of process control/regulation systems.

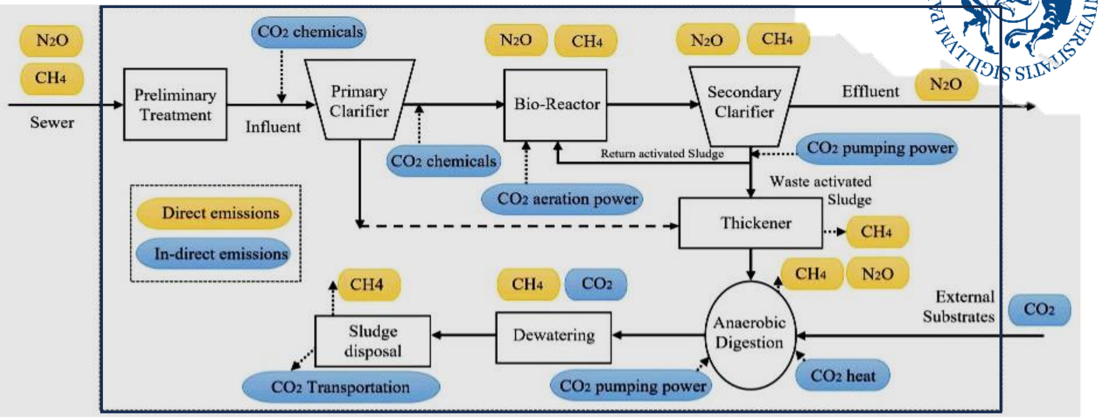






Analysis of Sicilian WWTPs: GHG estimation methodology

The WWTP carbon footprint was estimated by quantifying the Direct (DE) (biogenic and fossil) and Indirect (IE) (fossil) emissions.



$CH_{4\_sew\_sett.basin}$ = *(IPPC, 2019)*	**[(TOW-S)x EF]**
	TOW = organics in wastewater, kg BOD/yr
	S = organic component removed from WW in sludge, kg BOD/yr
	EF= 0,018 emission factor for settling basins/anaerobic pockets, kg CH_4/kg BOD

$N_20_{den\text{—}nitri\_N}$= *(IPPC, 2019)*	**TN_{DOM}x EFxCF**
	TN_{DOM} =tot. nitrogen in domestic WW, kg N/yr
	EF= 0,016 kg N_2O-N/kg N
	CF=1,57 kg N_2O/kg N_2O-N

$CO_{2\text{'}b\_decay}$= *(IWA, 2024)*	**[(CF×HRT× MLVSS× Kd)]**
	CF=1.947 kg CO_2/kg MLVSS

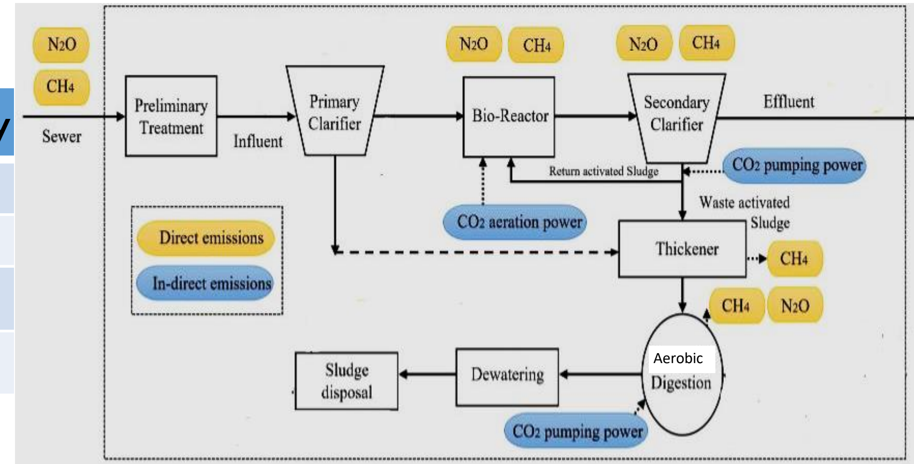
$CO_{\text{'}b\_growth}$= *(IWA, 2024)*	**(CF_m × BOD_{rem}× ($CF_{BOD5\text{-}BOD}$-1,42×Y))**
	CF_m=1.1 kg CO2/COD (mineralization)
	$CF_{BOD5\text{-}BOD}$= 1.47
	$CF_{MLVSS\text{-}BOD}$=1.42 kg BOD/kg MLVSS

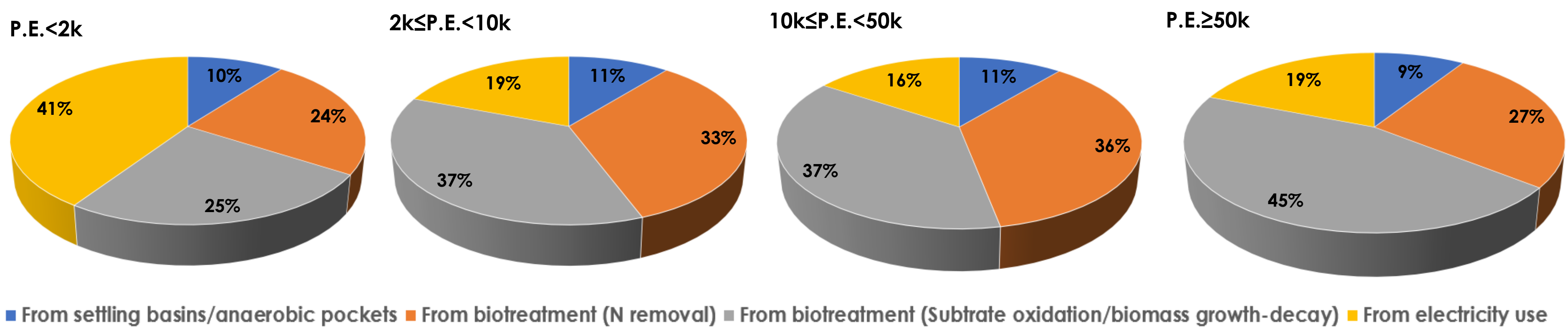
$CO_{2,Ee}$= *(ISPRA, 2023)*	**E_{Ee}*CF_{uE}**
	E_{Ee}= Use of Electric Energy , KWh/y
	CF_{uE}=0,245 Kg CO2/KWh

GWP values for 100-year time horizon		
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

GHG emissions: Results and preliminary conclusions

Class Size	n.WWTP	$kgCO_{2eq}/y$	P.E.s	$kgCO_{2eq}/P.E.s*y$
P.E.<2k	2	396.021	3.910	101,3
2k≤ P.E.<10k	14	2.572.035	47.492	54,2
10k≤ P.E.<50k	7	5.244.946	109.400	47,9
P.E.≥50k	3	28.760.276	472.764	60,8





- *In smaller WWTPs, the energy use (IE) implies a larger contribution to total emissions.*
- *In contrast, in greater WWTPs the bio-treatments account for the higher share emissions (DE).*

Thank you!!!!

Contacts:

gianpaolo.sabia@enea.it
luigi.petta@enea.it

Special thanks to the coauthors, the staff of UNIPA and UNICT, and all the SMARTEE PLANT team

Supported by

ARS

Regione Siciliana
PRESIDENZA

Città di Palermo

ORDINE DEGLI INGEGNERI DELLA PROVINCIA DI PALERMO

EWA EUROPEAN WATER ASSOCIATION

ARPA SICILIA Agenzia Regionale per la Protezione dell'Ambiente

IWA the international water association YOUNG WATER PROFESSIONALS ITALY

AIAT Associazione Ingegneria Ambiente e Territorio - APS

MINISTERO DELL'AMBIENTE E DELLA SICUREZZA ENERGETICA

COMMISSARIO STRAORDINARIO UNICO PER LA DEPURAZIONE

CONAI CONSORZIO NAZIONALE IMBALLAGGI