Energy efficiency of small waste water treatment plants in the Baltic Sea region – a comparative case study

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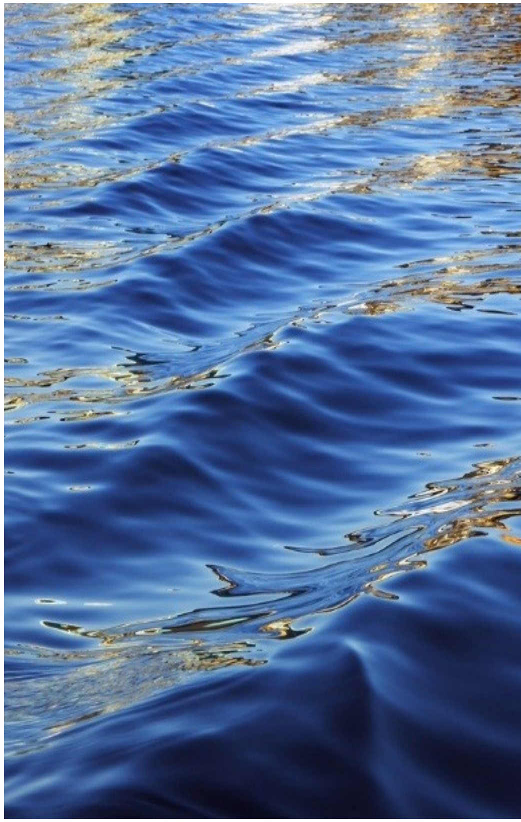

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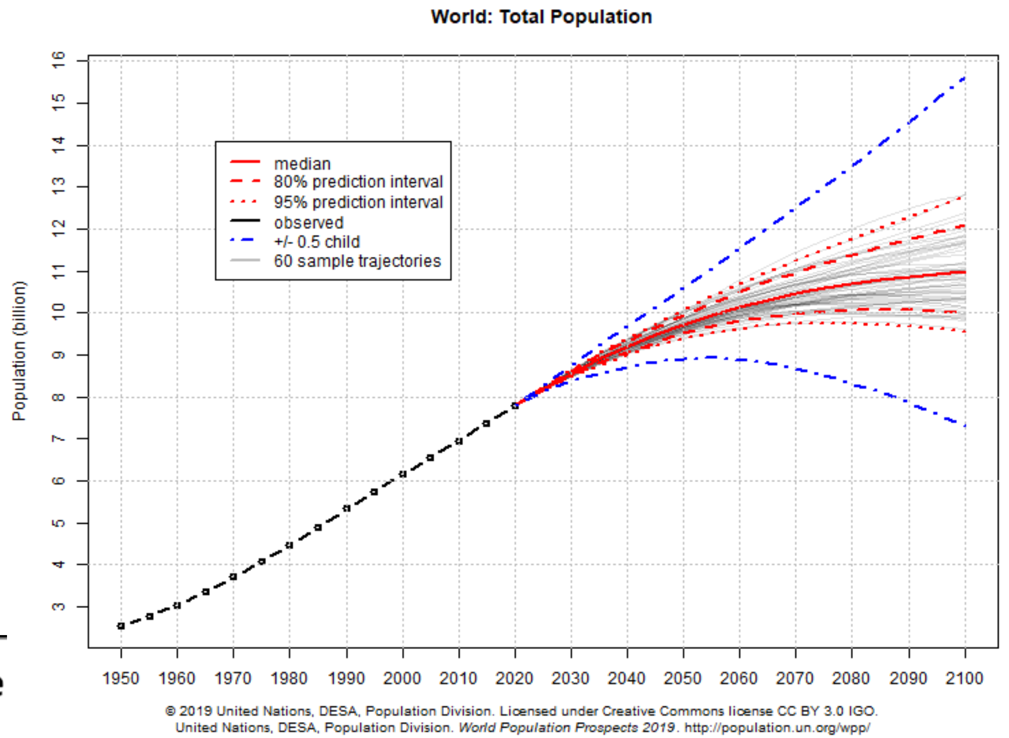
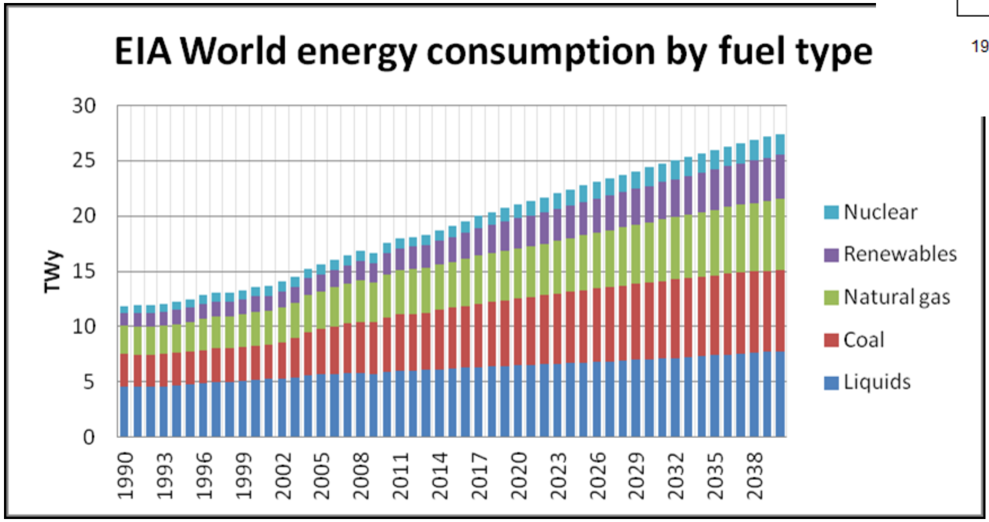
Energy efficiency – background of the research





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I. Introduction

EU aims 2020 vs 2030

Aims for 2020

GHG emmission reduction: 20%

RES on the enrgy market: mix of 20%

Energy efficiency improvement of 20%

Aims for 2030

GHG emmission reduction: 40%

RES on the energy market:mix of 27%

Energy efficiency improvement of 25%

Energy use in the water sector in Poland (statistical review GUS 2018)

2013: 2631 GWh
2014: 2671 GWh (2,2 % y/y)
...
2016: 2903 GWh
2017: 2969 GWh (2,2 % y/y)

Primary Energy use of the water sector: (statistical review GUS 2018)

2013: 24 419 TJ
2014: 24 502 TJ (0,3 % y/y)
...
2017: 27955 TJ
2018: 28812 TJ (3 % y/y)

STEP project partership

Hoor municipality, partner

Bornholm, partner

Kłaipeda, partner

Goleniów, partner

Szczecin, LP

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Project budget

Partner	Budget [Eur]	%
ZUT Szczecin	251 580	22
Bornholm	207 700	18
Hoor municipality	199 125	17
Goleniów	309 850	27
Kłaipeda	191 400	17
	1 159 655	100

II. WWTP location and size comparison

Case study of selected small and medium WWTPs

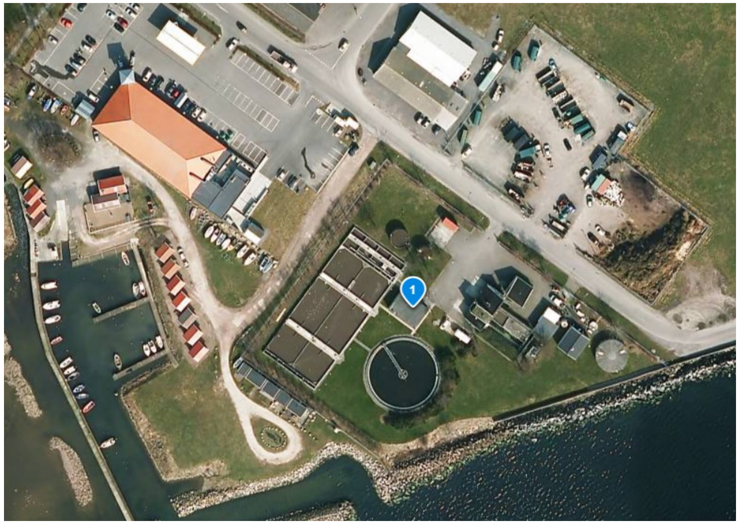
Locations


Location 2 - Sweden
Location 3 - Denmark
Location 1 - Poland
SWEDEN
Malmö
Ystad
DENMARK
Baltic Sea
BORNHOLM
Rønne
LITHUANIA
KLAIPĖDA REGION
Klaipėda
Kaliningrad
KALININGRAD REGION
RUSSIA
Gdynia
Gdańsk
Koszalin
POMORSKIE
ZACHODNIO-POMORSKIE
POLAND
Stralsund
Greifswald
VORPOMMERN
Szczecin

Small and medium WWTP

Location 1

Location 2



Location 3

WWTP size comparison

WWTP	Incoming flow [m³]	Incoming flow exclusive excess water (estimated) [m³]	PE based on COD	PE based on BOD
Location 1 – Poland	2 200 616	1 301 975	35 828	13 666
Location 2 - Sweden	2 693 939	1 346 509	17 263	16 236
Location 3 - Denmark	3 190 701	1 800 000	65 964	46 360
Location 4 – Italy, Folgaria, data from [4]	n.a.	n.a.	24 000	n.a.
Location 5 – Portugal, Alveiro, data from [4]	n.a.	n.a.	78 000	n.a.

[4] Deborah Panepinto, Silvia Fiore, Mariantonia Zappone, Giuseppe Genon, Lorenza Meucci: "Evaluation of the energy efficiency of a large wastewater treatment plant in Italy", Applied Energy, Volume 161, 2016, Pages 404-411, ISSN 0306-2619

III. Energy efficiency indexes

Including the energy consumption and production

Index definitions

$$I_{p.e.} = \frac{P_{el,tot}\,[kWh]}{p.e.[\frac{1}{y}]}$$

$$I_{m3} = \frac{P_{el,tot}[kWh]}{Q_{waste}\,[m^3]}$$

$$I_{COD} = \frac{P_{el,tot}\,[kWh]}{COD_{removed}\,[kg]}$$

$$I_{Ntot} = \frac{P_{el,tot}\,[kWh]}{N_{tot,removed}\,[kg]}$$

where:

$I_{p.e.}$ – person equivalent (based on COD) energy efficiency index in kWh/person equivalent/year;

I_{m3} – cubic meter of wastewater treated energy efficiency equivalent in kWh/m^3;

I_{COD} – chemical oxygen demand energy efficiency index in kWh/chemical oxygen demand removal in kg of COD;

I_{Ntot} – total nitrogen energy efficiency index in kWh/total removed nitrogen in kg;

$P_{el,tot}$ – annual, total energy consumption in kWh.

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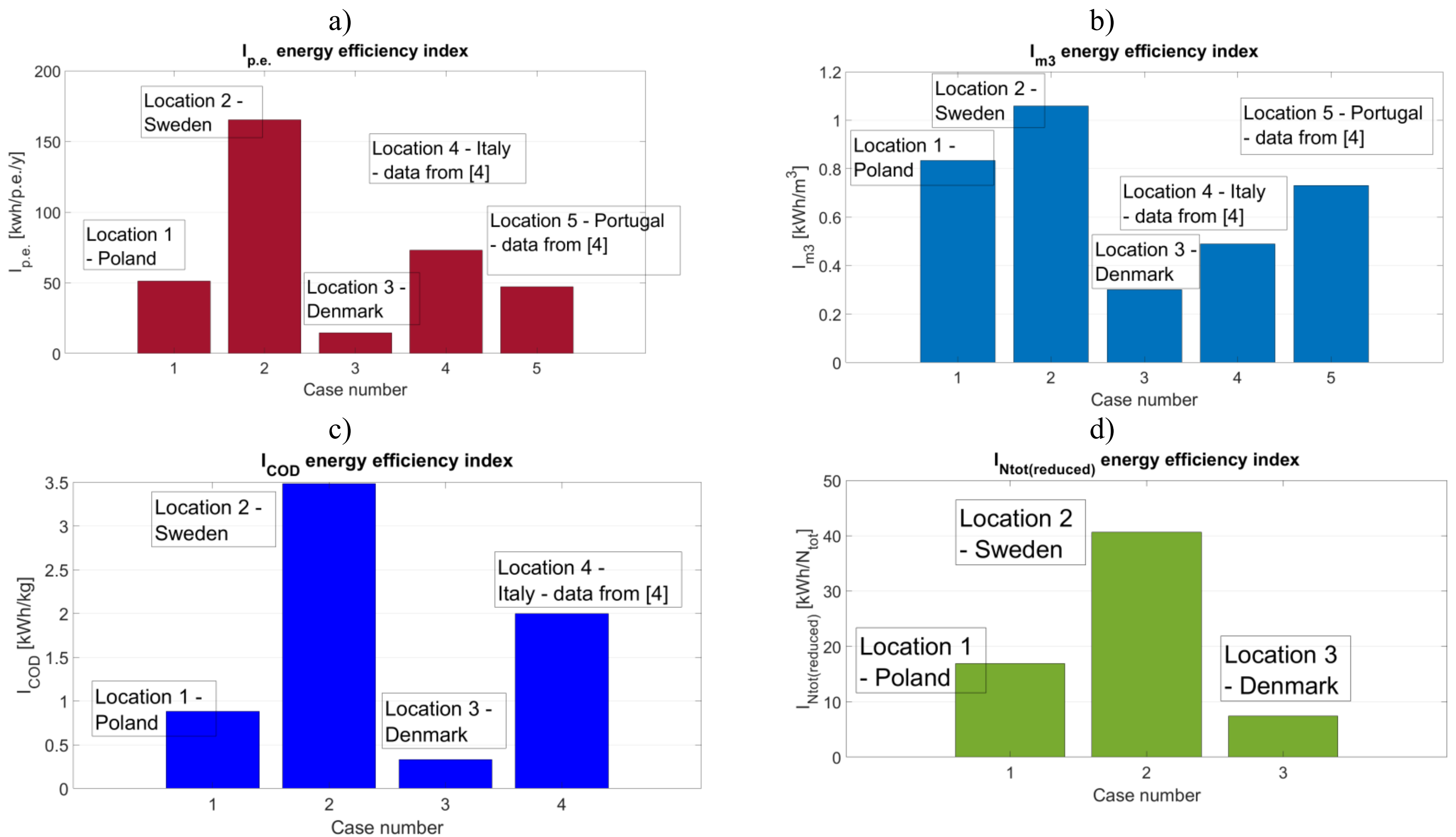
Calculated index values



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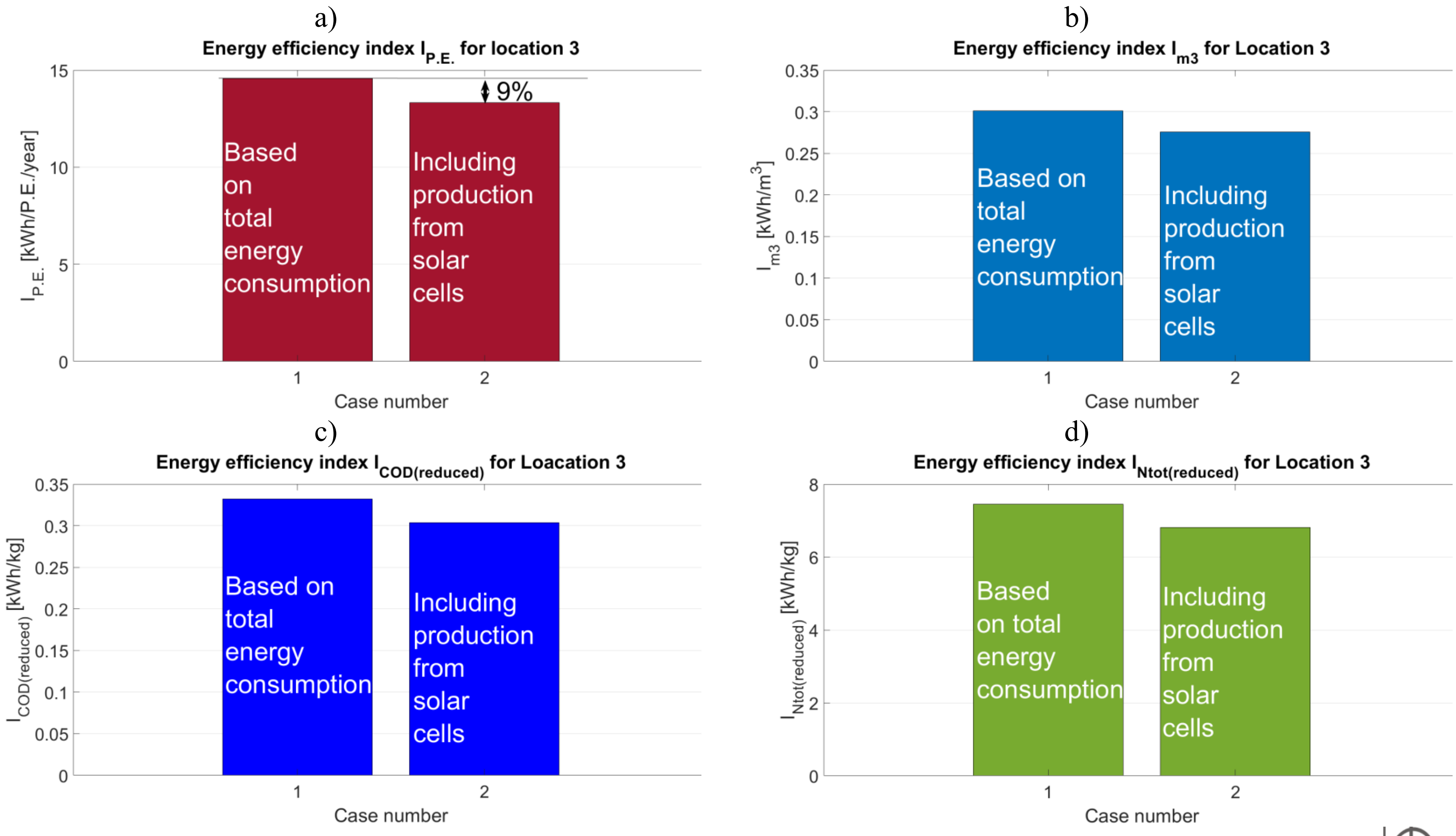
Calculated index values for case 3

The WWTP in Location 3 has also electricity generation possibilities using a photovoltaic power plant. The installed nominal power of this installation is 93 kWp at nominal array irradiation.



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Improvement possibilities

As suggested in [4] and resulting from this study energy efficiency can be increased by the means of:

- Own electrical energy or CHP generation (5 – 30%)
- Regular maintenance and exchange of aged equipment – 5%
- Building isolation improvement, Energy efficient lightning systems – 10%
- Pump optimization, inverter use – 5 – 30%
- Sedimentation improvement by coagulants – 25%
- Automated and optimized aeration – 20%
- Mixing optimization – up to 90%.

[4] Deborah Panepinto, Silvia Fiore, Mariantonia Zappone, Giuseppe Genon, Lorenza Meucci: "Evaluation of the energy efficiency of a large wastewater treatment plant in Italy", Applied Energy, Volume 161, 2016, Pages 404-411, ISSN 0306-2619

Table 3. Energy Efficiency Strategies for Municipal WWTPs

	Focus Efforts for Energy Savings	
✓	Process Energy	Focus on biggest energy consumers at WWTP
✓	Operational Controls	Tailor operations to meet seasonal and diurnal changes
✓	Quality vs. Energy	Balance water quality goals with energy needs
✓	Repair and Replacement	Consider equipment life and energy usage to guide repair and replacement
✓	Biosolids	Consider tradeoffs between treatment energy and improved biosolids quality
✓	Infiltration/Inflow	Address I&I to reduce treatment energy
✓	Leaks and Breaks	Address leaks and breaks to reduce pumping energy
✓	On-Site Renewable Energy	Consider opportunities for on-site generation to reduce energy purchases
✓	Conservation	Educate the community: Less water reduces WWTP loads and energy needs

Energy Efficiency Strategies for Municipal Wastewater Treatment Facilities

J. Daw and K. Hallett

National Renewable Energy Laboratory

J. DeWolfe and I. Venner

Malcolm Pirnie, the Water Division of ARCADIS

Prepared under Task No. IGST.1104

Calculated sludge related index values

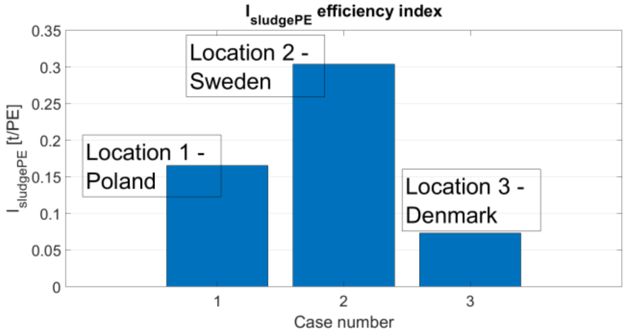
$$I_{sludgePE} = \frac{m_{sludge,dewatered}\,[t]}{P.E.}$$

$$I_{sludge,polymer} = \frac{m_{polymer}\,[kg]}{m_{sludge,dewatered}\,[t]}$$

$$I_{sludge,Pel} = \frac{P_{el,tot}\,[kWh]}{m_{sludge,dewatered}\,[t]}$$

where:
P.E. – person equivalent (based on COD);
$m_{sludge,dewatered}$ – mass of annual dewatered sludge production in tonnes;
$m_{polymer}$ – mass of polymers consumed for decanter tanks in kilograms;
$P_{el,tot}$ – annual, total energy consumption in kWh.

a)



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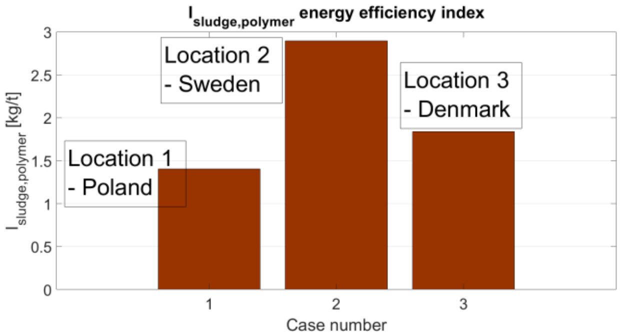

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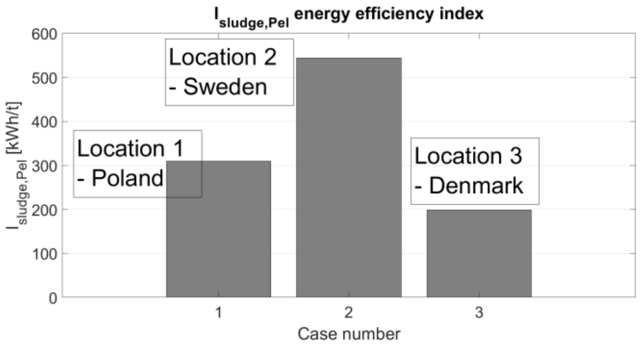

Discussion

- Average energy efficiency PE index for small WWTP analyzed is **77 kWh/PE/y**
- Average Energy efficiency per cubic meter of waste water is **0,73 kWh/m^3**
- Average sludge related index is **180 kg/PE/y**
- Sludge Energy intensity index has an average of **350 kWh/t**

IV. Summary and conclusions

Summary and conclusions:

- Best index values are obtained for the Location 3 – Denmark,
- worst values were obtained for the Swedish WWTP. The difference is very significant – average energy consumption per person equivalent in Sweden is 11,3 times higher than in Denmark.
- Probable reason is the non-optimal efficiency of blowers, which can contribute up to 50% of total electrical energy consumption [4]. Efficiency of blowers can vary between 55% and 77% (as an index of blower power to air volume per unit of time – kW/m3/h, [4]). Fine – pore (fine – bubble) aerators offer 3 times higher standard aeration efficiency compared to surface aerators or coarse – bubble systems [5]. This is one of the possible reasons of lower energy efficiency indexes in this location. Second possible explanation of this results is a large volume of excess waters in the sewage system resulting in increased energy consumption for all the stages of wastewater processing. As can be noticed from Table 1 while the PE index of this location is 2,07 times lower than for Location 1 (Poland) the total inflow is comparable and even slightly (122%) higher for Location 2 (Sweden) then in Location 1.

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Thank You

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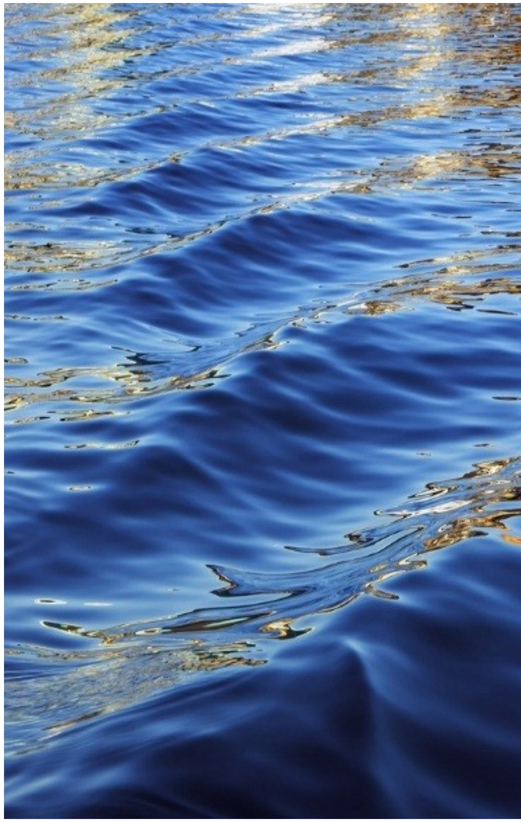

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