TECHNO-ECONOMIC ANALYSIS OF MICROALGAE-BASED WASTEWATER TREATMENT IN SMALL POPULATIONS

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ANÁLISIS TECNO-ECONÓMICO DEL TRATAMIENTO DE AGUAS RESIDUALES A BASE DE MICROALGAS EN PEQUEÑAS POBLACIONES

Introduction → Methods → Results & Discussion → Conclusion

UCA Universidad de Cádiz

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algades

Eutrophication is one of the major problems causing loss of water quality

Specific source

380 billion m³ each year and 80% untreated

Excess of nutrients
Nitrogen (N)
& Phosphorus (P)

Diffuse source

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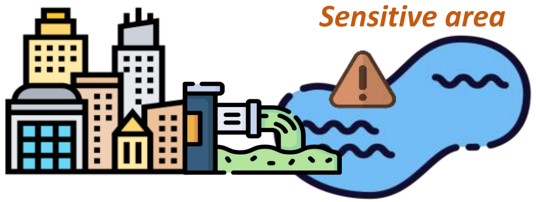
Ansari, A. A., Gill, S. S., Lanza, G. R., & Rast, W. (2011). Eutrophication: Causes, consequences and control. In Eutrophication: Causes, Consequences and Control. https://doi.org/10.1007/978-90-481-9625-8
WWAP. (2017). The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. Paris, UNESCO. In The United Nations World Water Development Report 2017. Wastewater: The Untapped Resource. Paris, UNESCO (Vol. 53, Issue 9).
Qadir, M., Drechsel, P., Jiménez Cisneros, B., Kim, Y., Pramanik, A., Mehta, P., & Olaniyan, O. (2020). Global and regional potential of wastewater as a water, nutrient and energy source. Natural Resources Forum, 44(1), 40–51. https://doi.org/10.1111/1477-8947.12187



>10,000 P.E.

Directive 91/271/EEC regulates the collection, treatment and discharge of urban wastewater and wastewater from the agro-food industry

>10,000 P.E.

Directive 2000/60/EC the Water Framework Directive

In addition to the removal of organic matter (COD and BOD_5)

N and P must also be removed

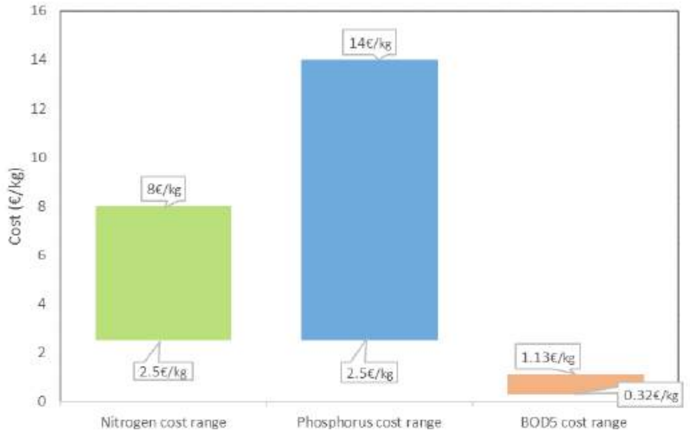
>10,000 p.e.

N and P must also be removed

There is not economically feasible and mature technology for the reduction of nutrients

80 %

Rarely have high nutrient removal efficiencies



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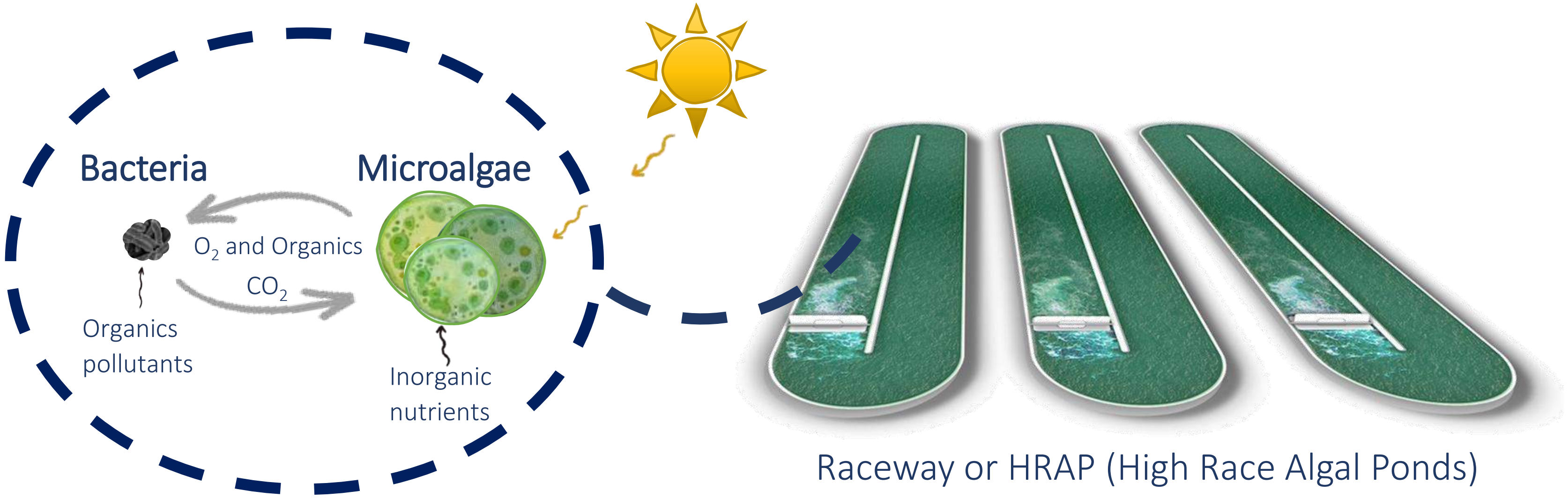
Fux, C., & Siegrist, H. (2018). Nitrogen removal from sludge digester liquids by nitrification / denitrification or partial nitritation / anammox : environmental and economical considerations. August, 19–26.
Kroiss, H., Rechberger, H., & Egle, L. (2008). Phosphorus in Water Quality and Waste Management.
Pérez Sánchez, P., & Egea Ruiz, C. (2014). Renewat project: Optimisation for energy saving in water treatment.

Phycoremediation using microalgae/bacterial consortia



Raceway or HRAP (High Race Algal Ponds)

- Easy to operate
- N and P removal occurs in a single tank
- Lower energy requirements compared to a conventional wastewater treatment plant (e.g., activated sludge system) 0.02 kWh/m^3 vs. 1 kWh/m^3
- Low capital costs compared to other photobioreactors (e.g., vertical tubular photobioreactors) 13-37 €/m^2 vs. 97 €/m^2

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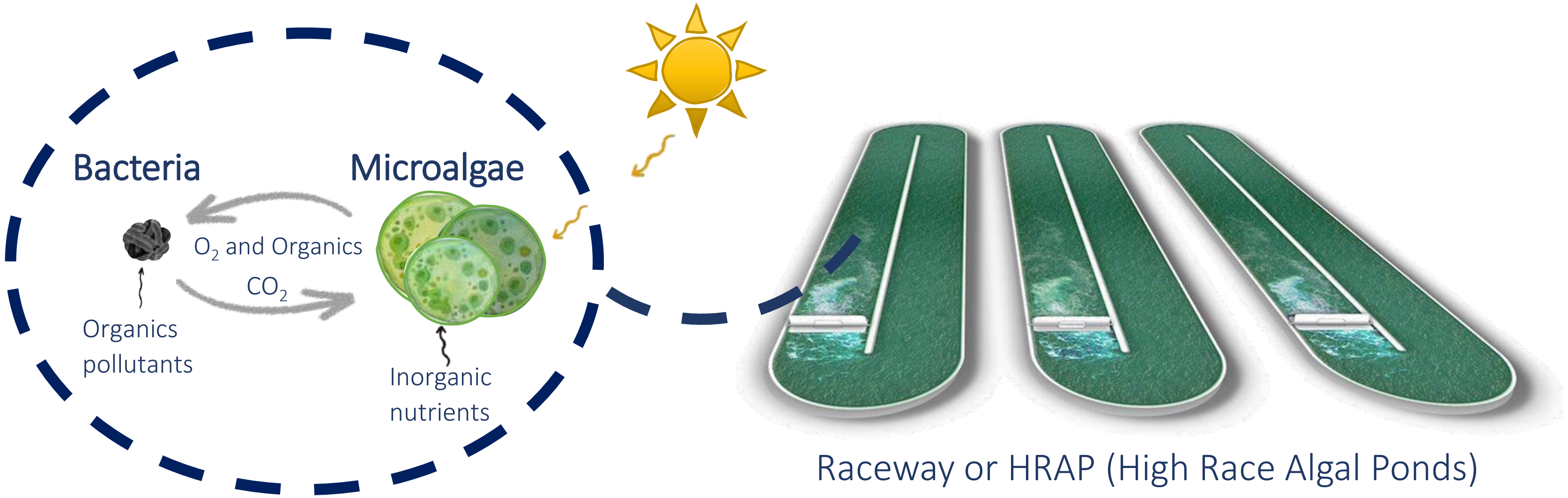
Phycoremediation using microalgae/bacterial consortia



Raceway or HRAP (High Race Algal Ponds)

- Large-scale research is still needed to optimise the process.
  → including cost analysis, as the cost of wastewater treatment with microalgae is poorly understood.

Techno-economic analysis (TEA)

Procedure which:

1) Determines process costs
2) Determines how the different variables influence the cost
3) Identifies critical points in the process

TEA tool

Microsoft® Office Excel spreadsheet software

Ruiz et al., 2016.

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Ruiz, J., Olivieri, G., De Vree, J., Bosma, R., Willems, P., Reith, J. H., Eppink, M. H. M., Kleinegris, D. M. M., Wijffels, R. H., & Barbosa, M. J. (2016). Towards industrial products from microalgae. Energy and Environmental Science, 9(10), 3036–3043. https://doi.org/10.1039/c6ee01493c

INPUTS

- Population
- Wastewater characteristics
- Equipment performances
- Specific parameters of microalgae and bacteria

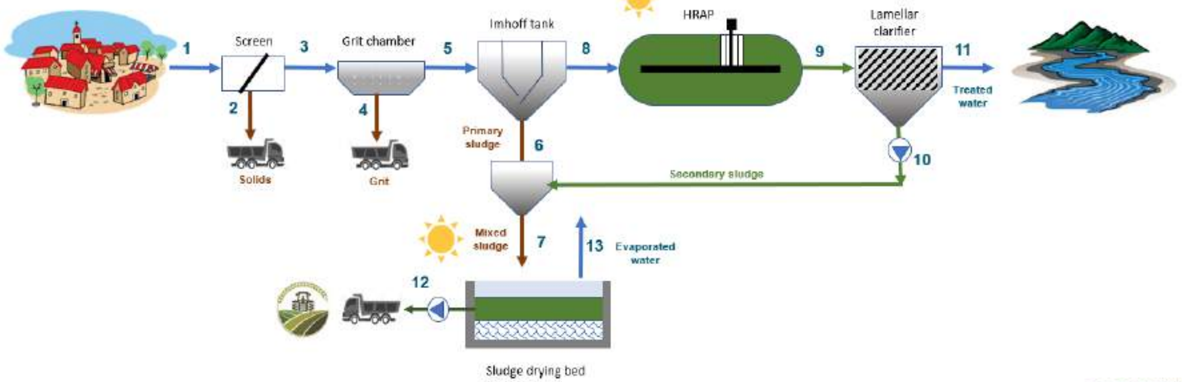
Calculations
Mass balance
Energy balance
Equipment design
Cost calculation (Lang Factor Method)

XLS

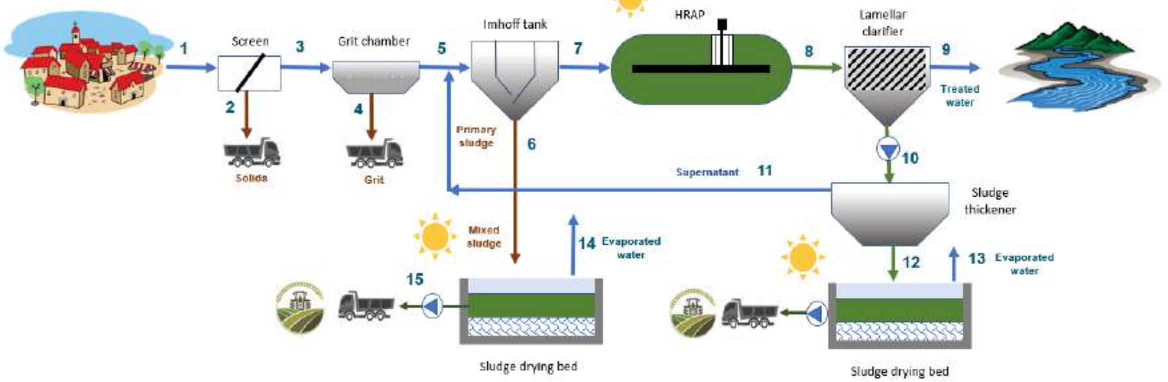
OUTPUTS

- Treated wastewater cost
- Energy consumption
- CAPEX & OPEX
- Surface per P.E.

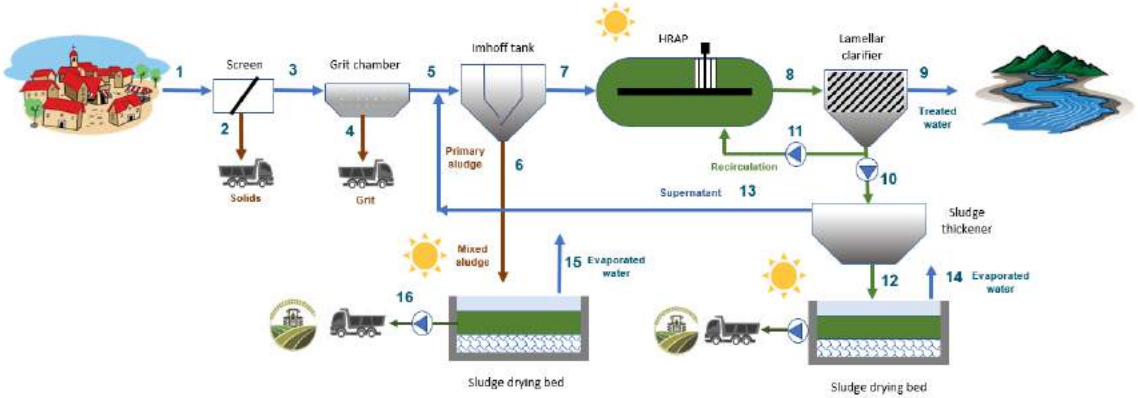
PROJECTION A
HRT= 5 days & SRT= 5 days



PROJECTION B
HRT= 20 days & SRT= 20 days



PROJECTION C
HRT= 5 days & SRT= 20 days



2000 P.E.

1

Flow rate= 300 m^3/d

40 mg N/L
8 mg P/L
COD= 500 mg O_2/L
BOD_5= 220 mg O_2/L
220 mg SS/L

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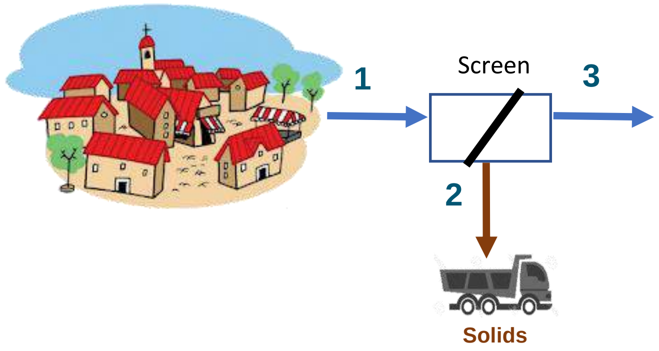
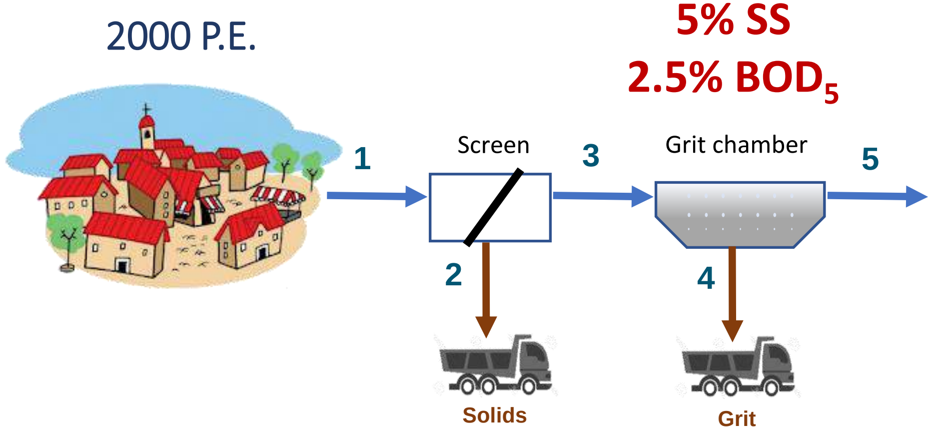
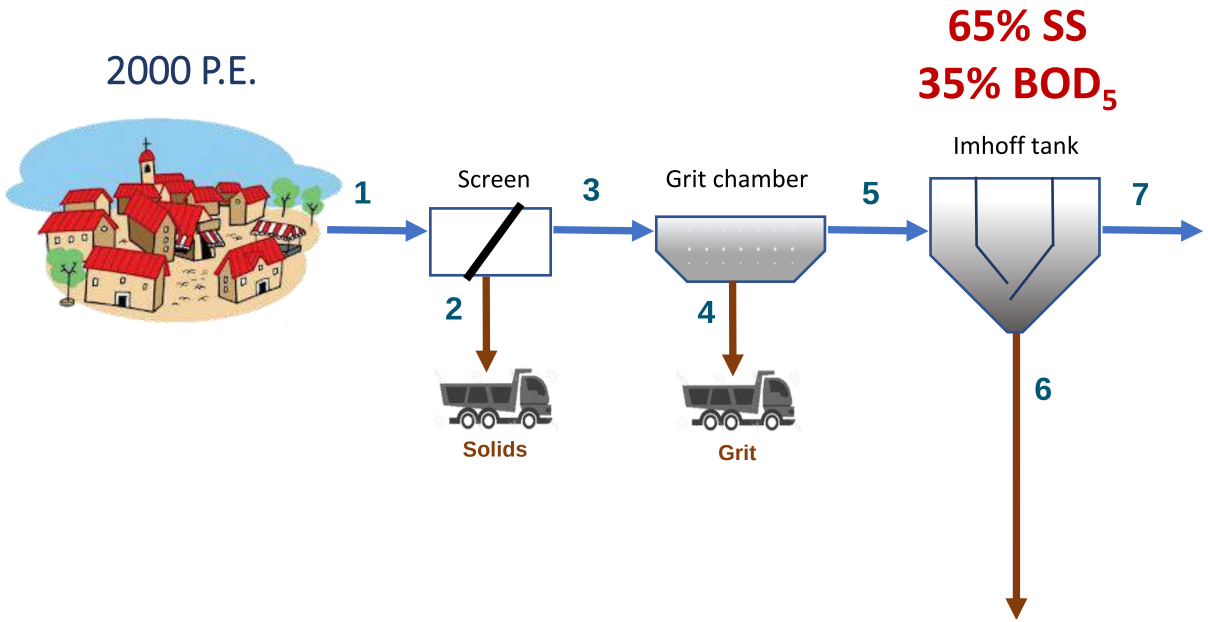
W. Metcalf and C. Eddy, "Metcalf and Eddy Wastewater Engineering: Treatment and Reuse," Wastewater Eng. Treat. Reuse McGraw Hill. New York, NY., 2003.

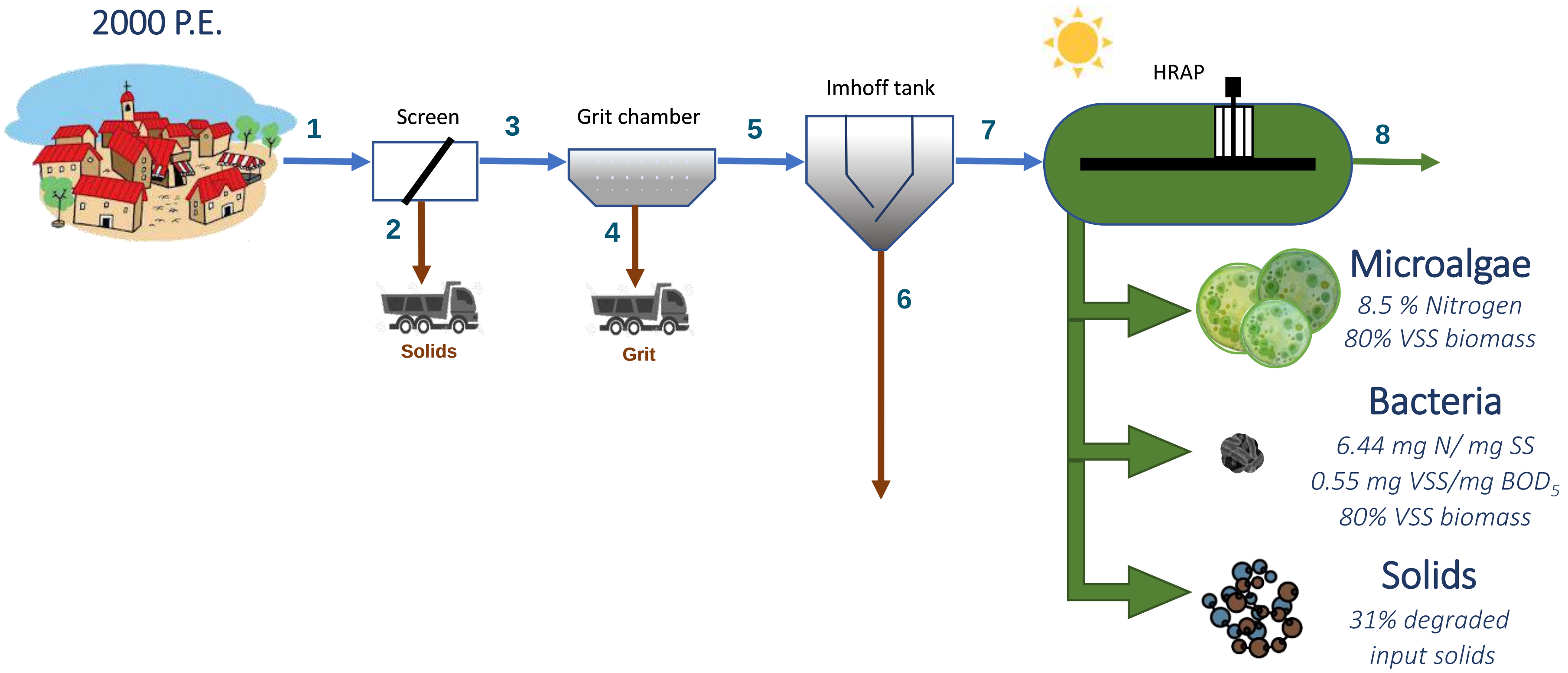
2000 P.E.

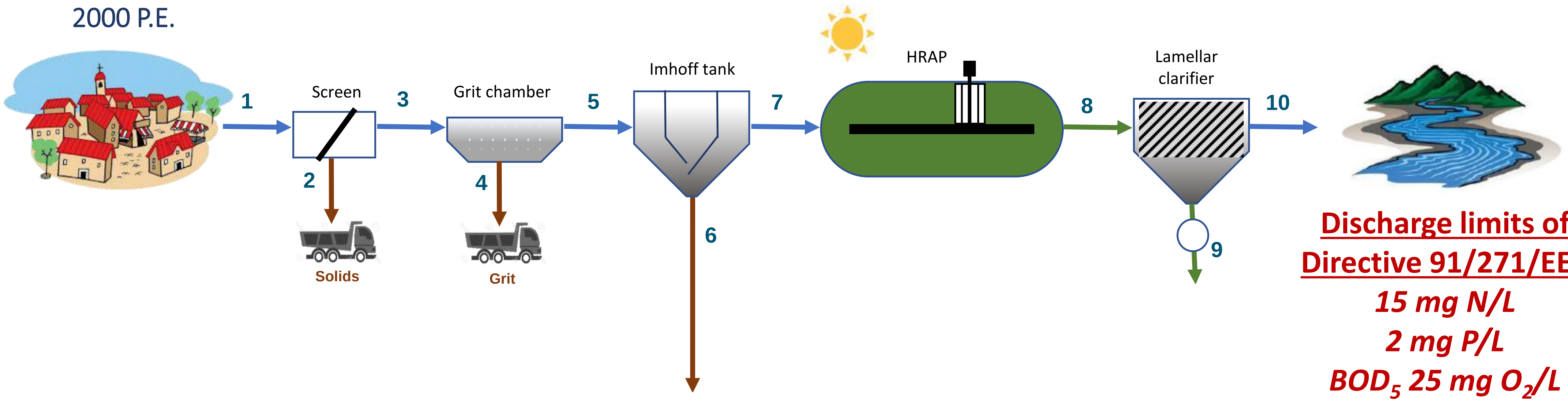



2000 P.E.
5% SS
2.5% BOD5
1
Screen
3
Grit chamber
5
2
4
Solids
Grit



65% SS
35% BOD_5
2000 P.E.
Screen
Grit chamber
Imhoff tank
1
2
3
4
5
6
7
Solids
Grit


2000 P.E.
1
Screen
3
Grit chamber
5
Imhoff tank
7
HRAP
8
2
4
Solids
Grit
6
Microalgae
8.5 % Nitrogen
80% VSS biomass
Bacteria
6.44 mg N/ mg SS
0.55 mg VSS/mg BOD5
80% VSS biomass
Solids
31% degraded
input solids



Discharge limits of Directive 91/271/EEC

15 mg N/L

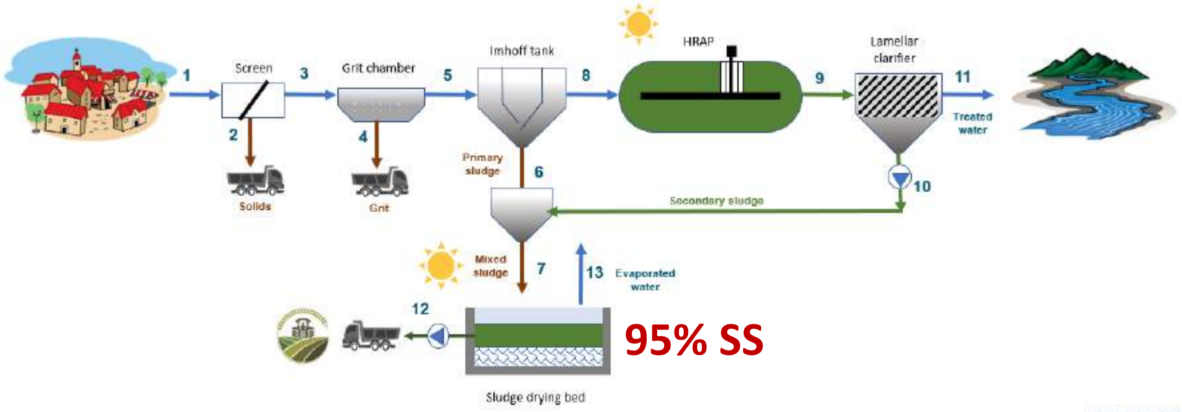
2 mg P/L

BOD_5 25 mg O_2/L

35 mg SS/L

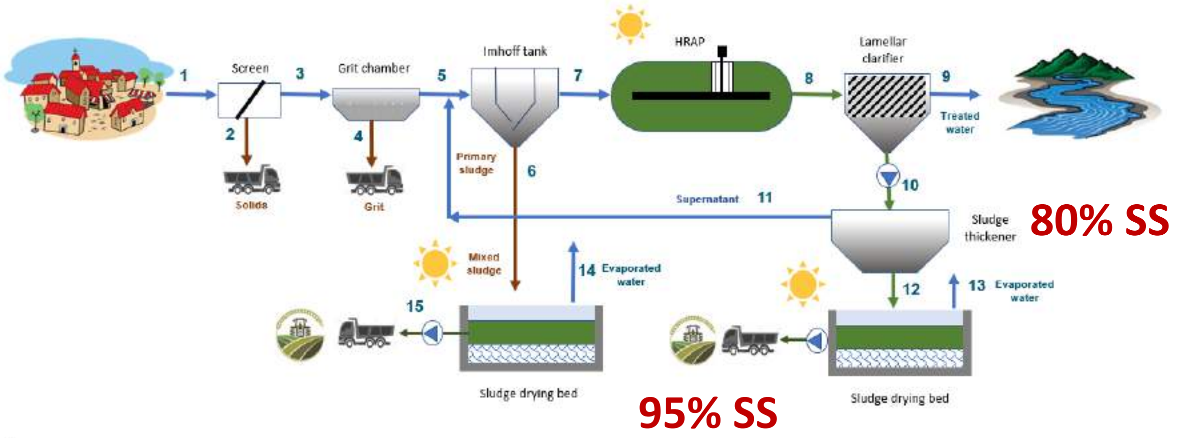
PROJECTION A

HRT= 5 days & SRT= 5 days



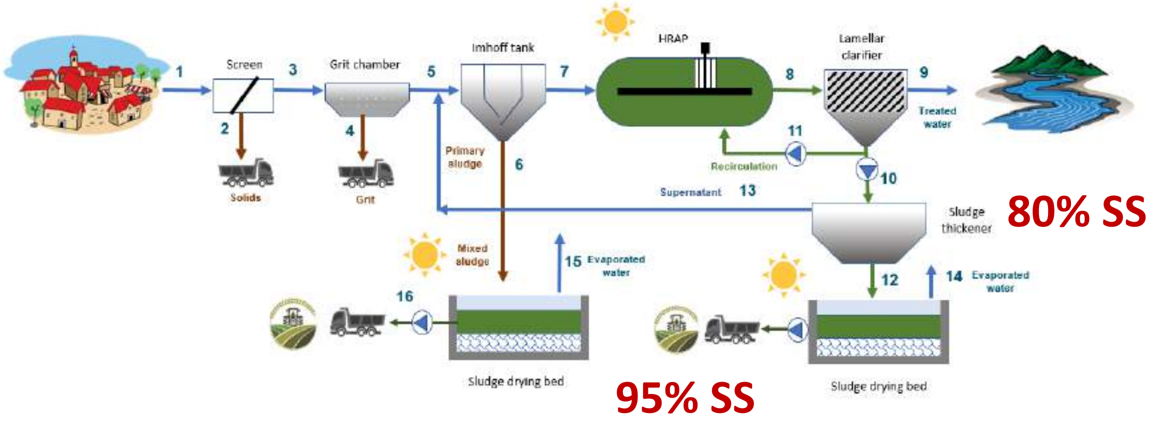
PROJECTION B

HRT= 20 days & SRT= 20 days



PROJECTION C

HRT= 5 days & SRT= 20 days

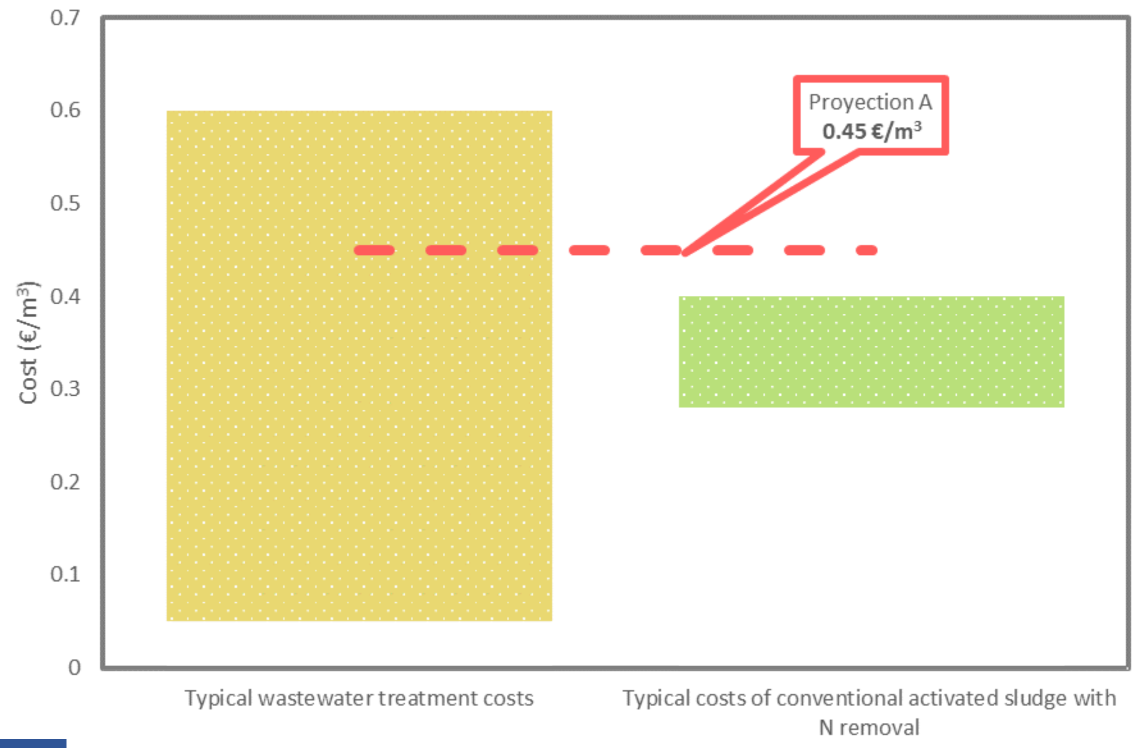


RESULTS

PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20
Population (P.E.)		2000	
Wastewater treated (m^3/year)		102,094.63	
Wastewater treated cost (€/m^3)	0.45	0.73	0.47
Investment (€)	248,756.09	544,030.26	274,032.06
Total cost (€/year)	45,660.72	74,804.93	48,245.26
Land requirement (m^2/P.E.)	2.47	9.87	2.47
Energy consumption (kWh/m^3)	0.15	0.52	0.19
CAPEX (€/P.E. year)	6.25	13.67	6.88
OPEX (€/P.E. year)	16.58	23.74	17.24

RESULTS

WASTEWATER TREATED COST



PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20

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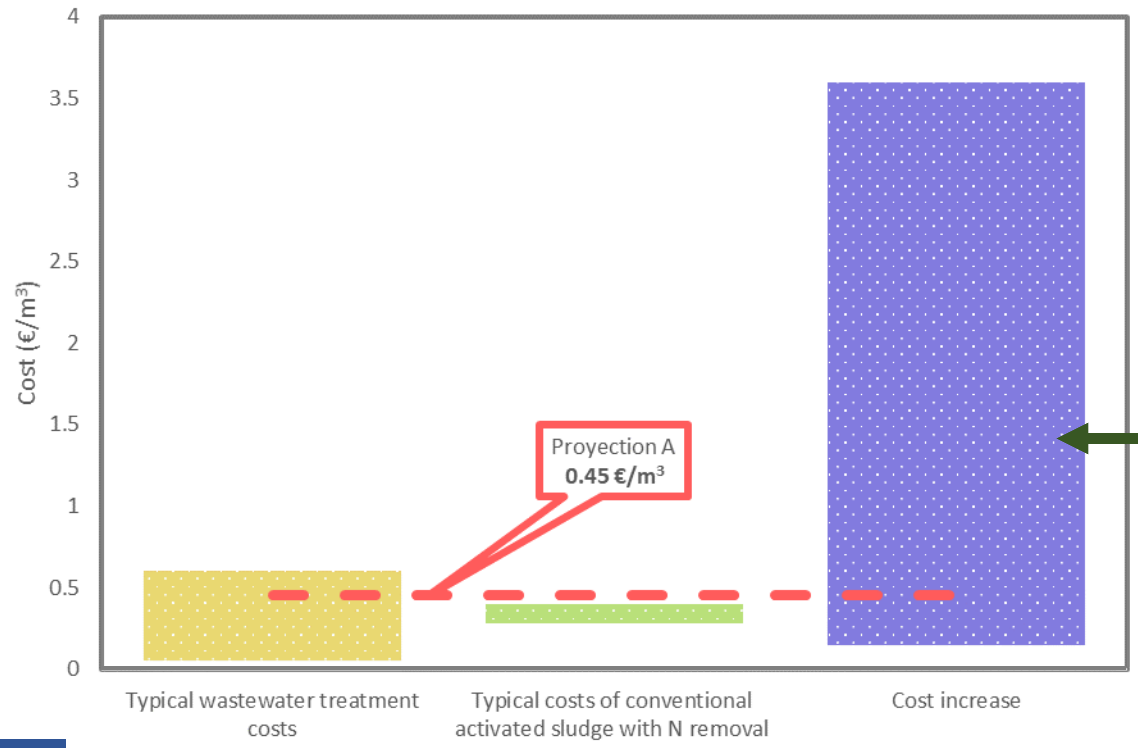
RESULTS

WASTEWATER TREATED COST

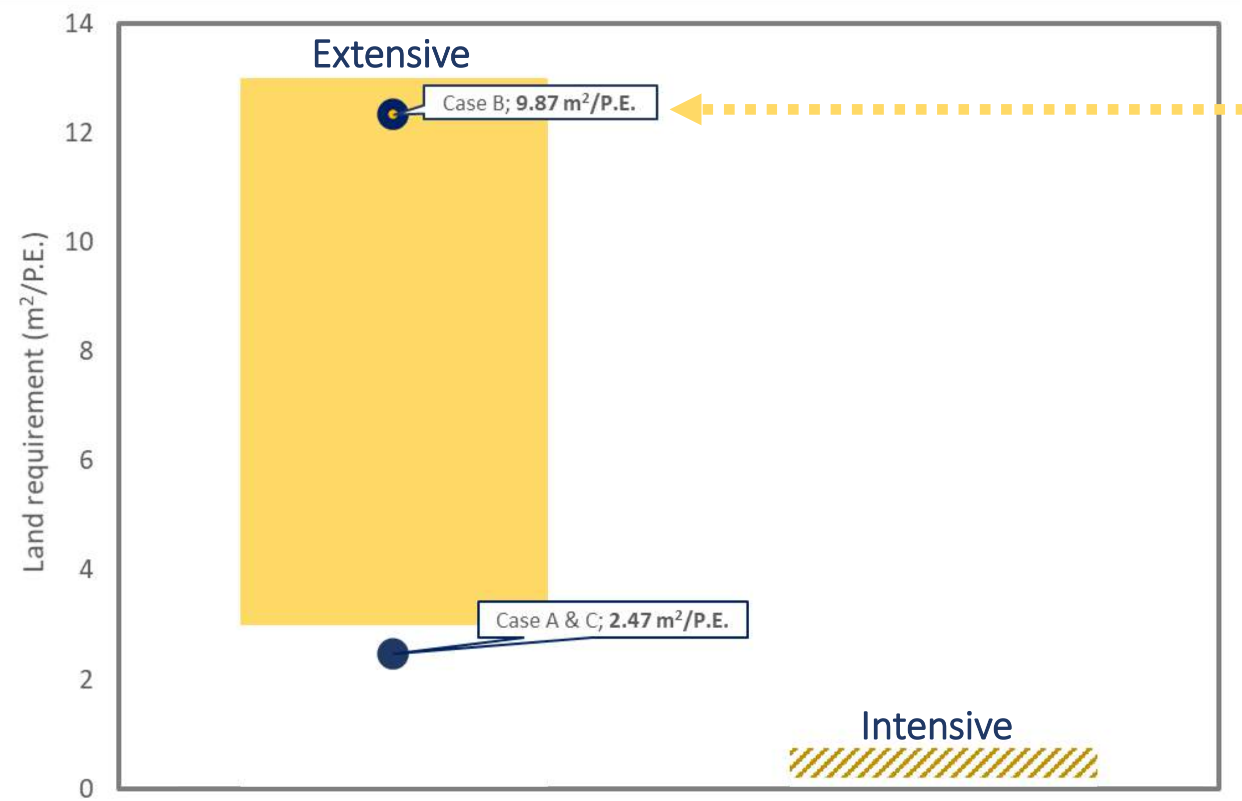


Wastewater treatment costs are higher by **200 to 500% for small-scale plants (<2000 p.e.)**

PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20

RESULTS

LAND REQUIREMENT



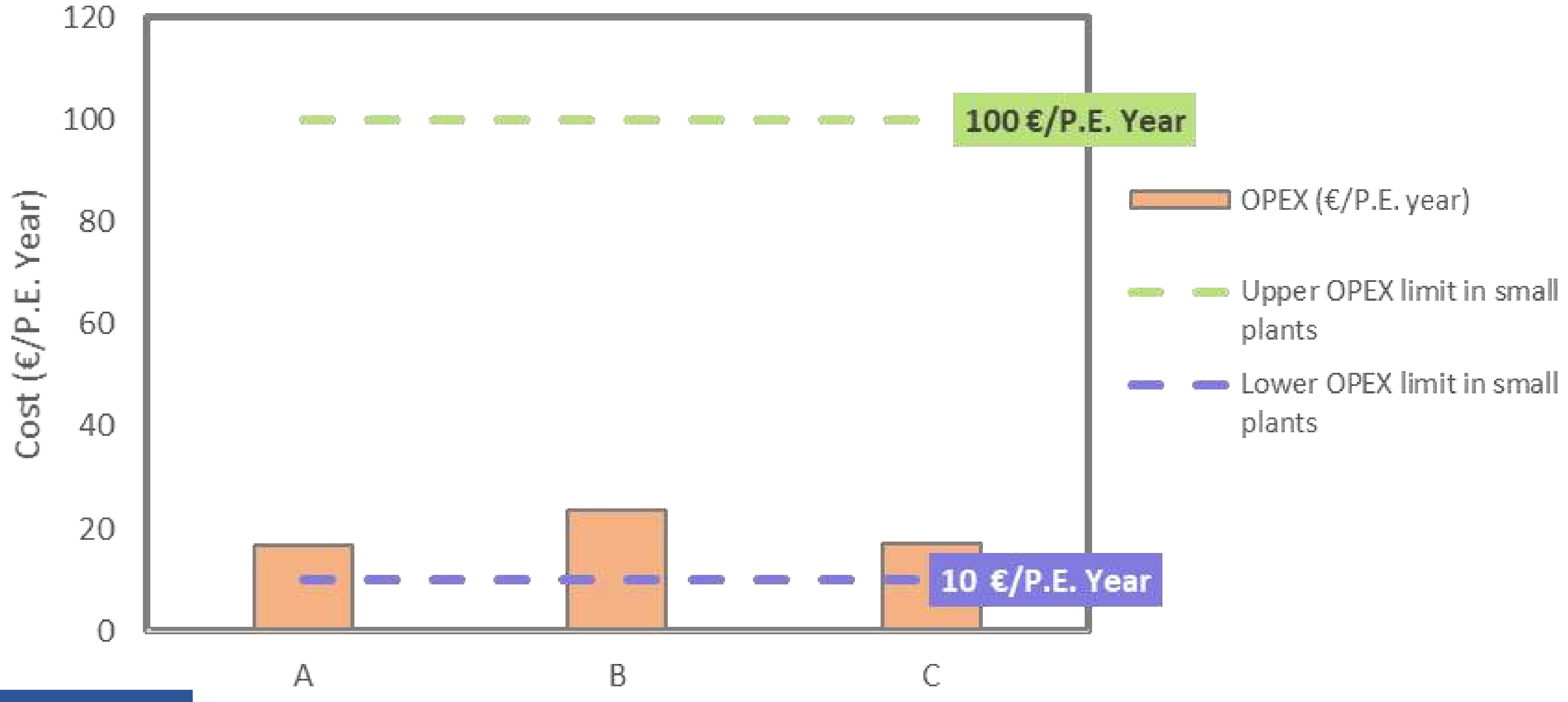
CASE B

x 4

PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20

RESULTS

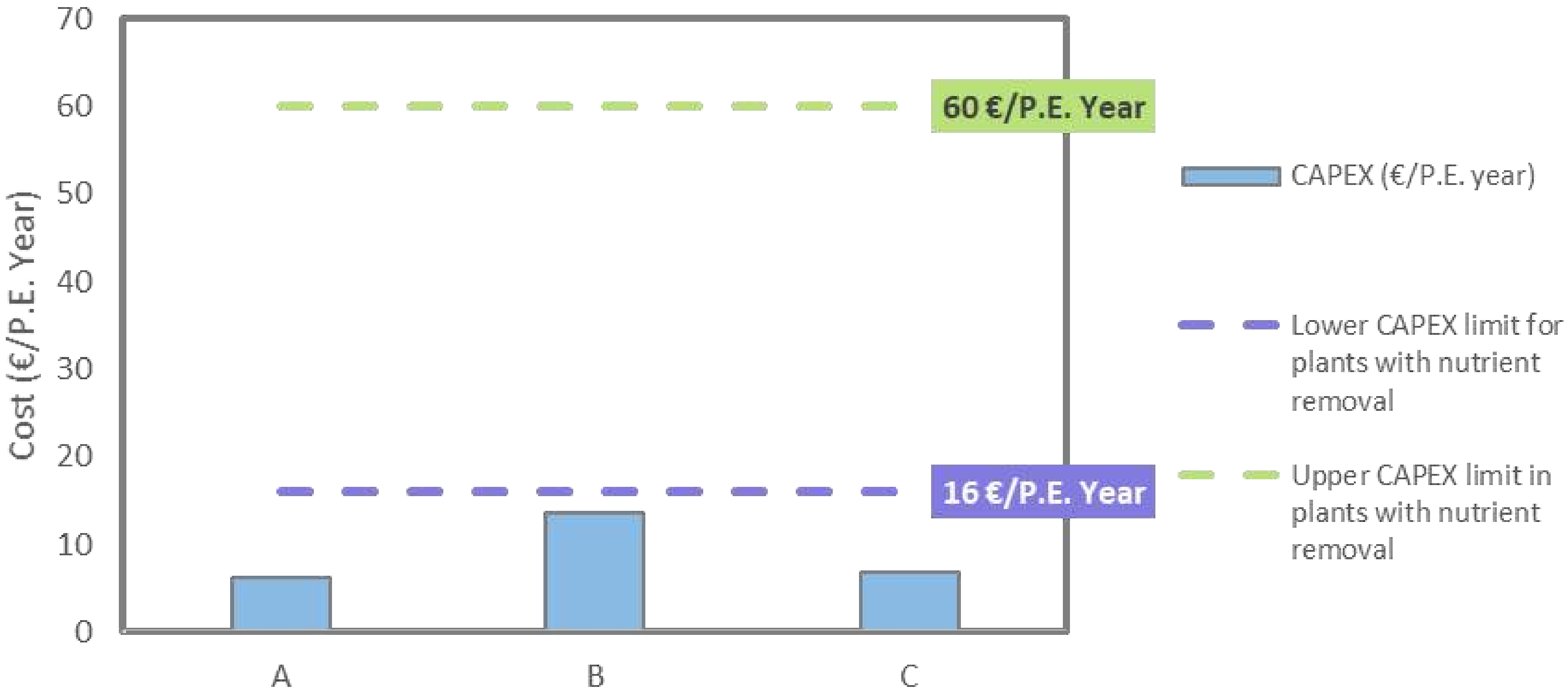
OPEX



PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20

RESULTS

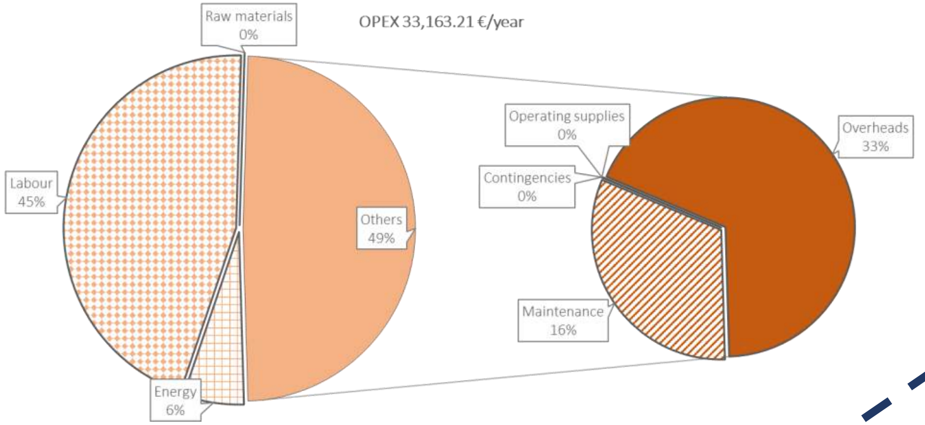
CAPEX

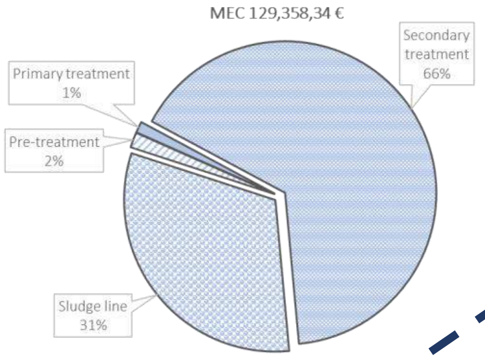


PROJECTION	A	B	C
HRT (days)	5	20	5
SRT (days)	5	20	20

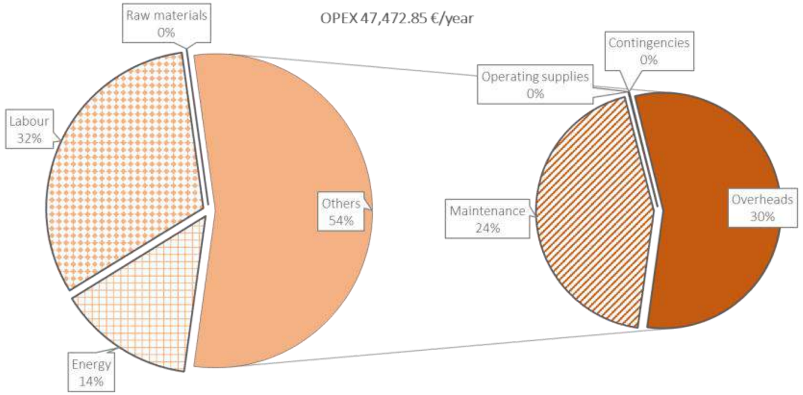
BREAKDOWN OF COST

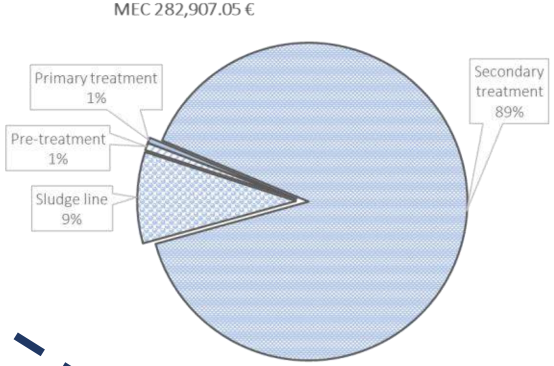
PROJECTION A
HRT= 5 days & SRT= 5 days



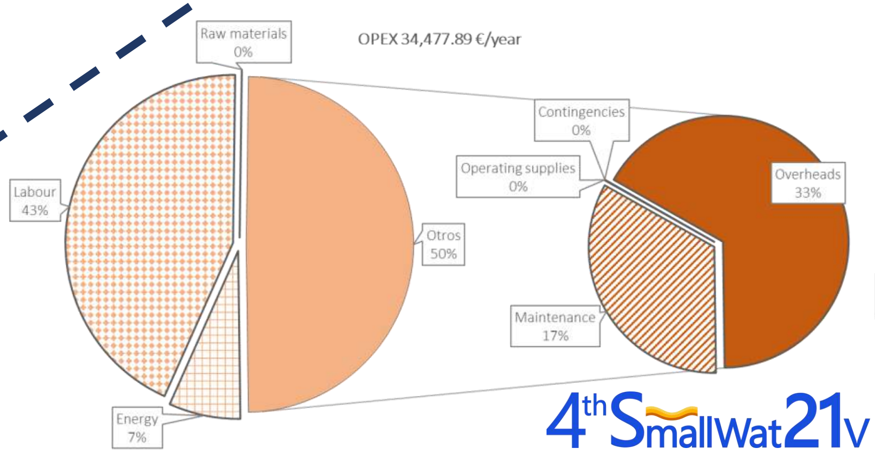


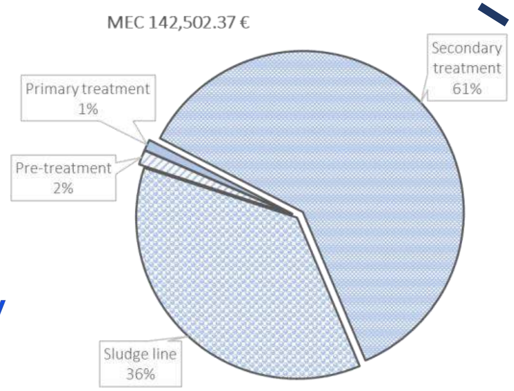
PROJECTION B
HRT= 20 days & SRT= 20 days





PROJECTION C
HRT= 5 days & SRT= 20 days

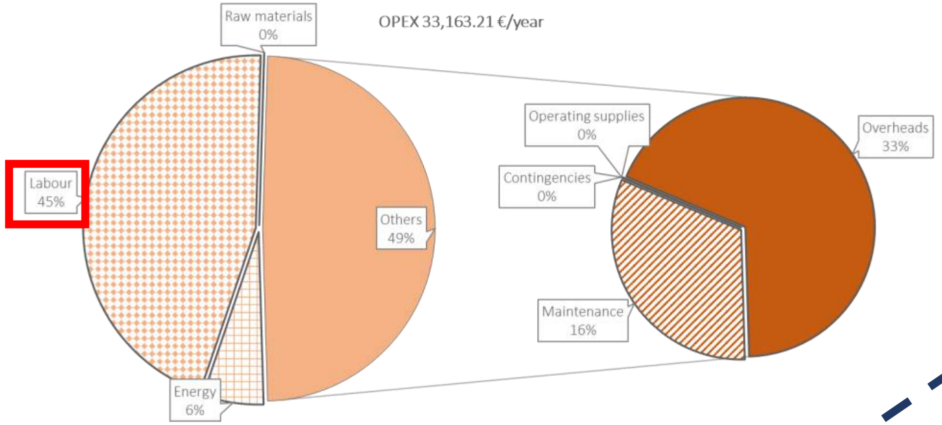


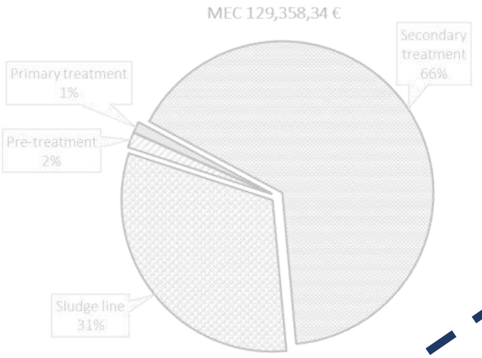


**MEC – Major Equipment Cost*

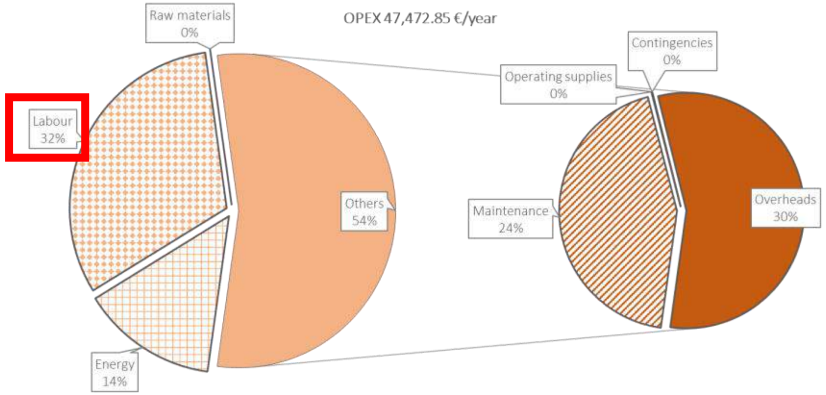
BREAKDOWN OF COST

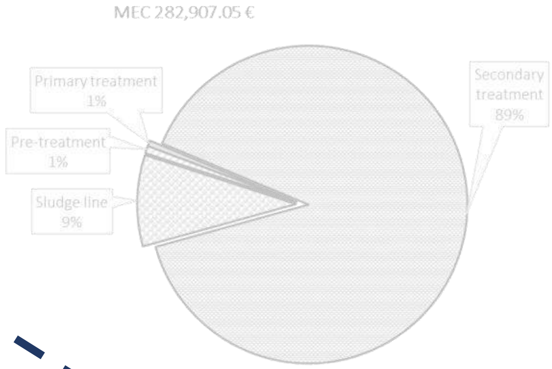
PROJECTION A
HRT= 5 days & SRT= 5 days



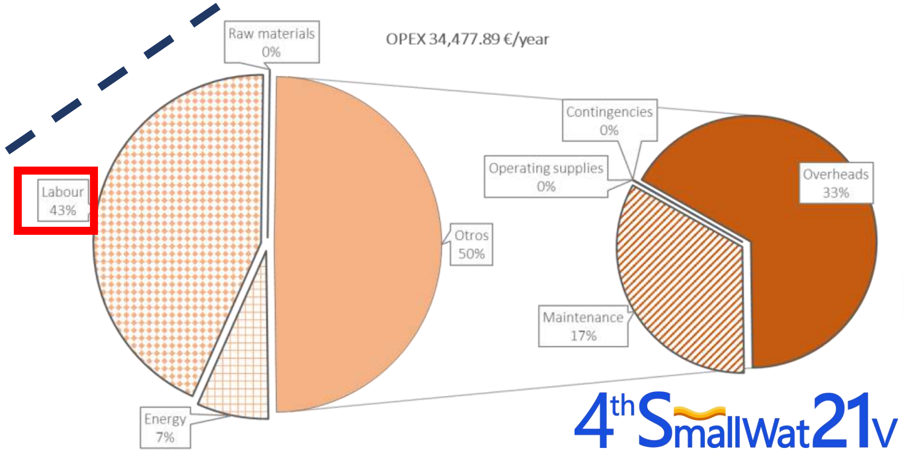


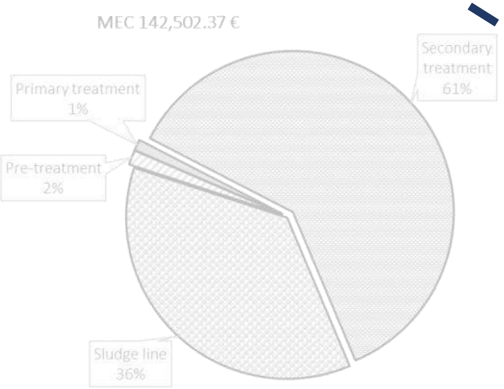
PROJECTION B
HRT= 20 days & SRT= 20 days





PROJECTION C
HRT= 5 days & SRT= 20 days





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BREAKDOWN OF COST

PROJECTION A
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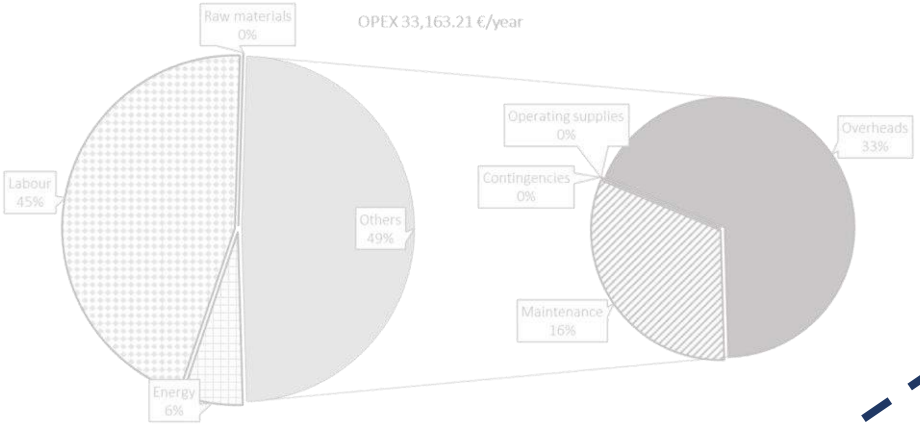
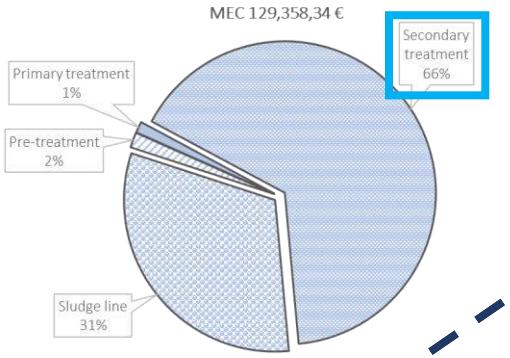
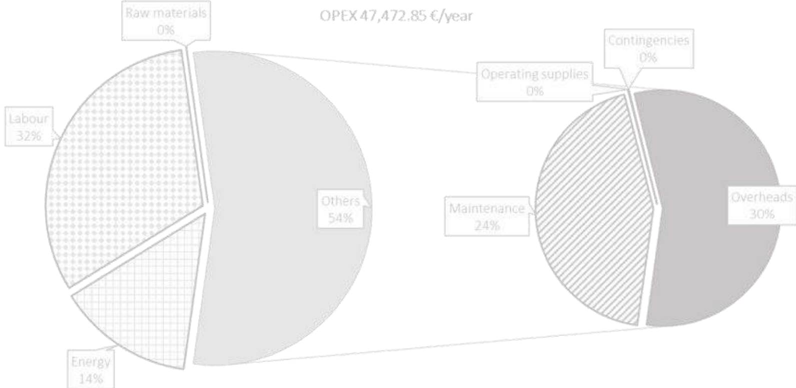
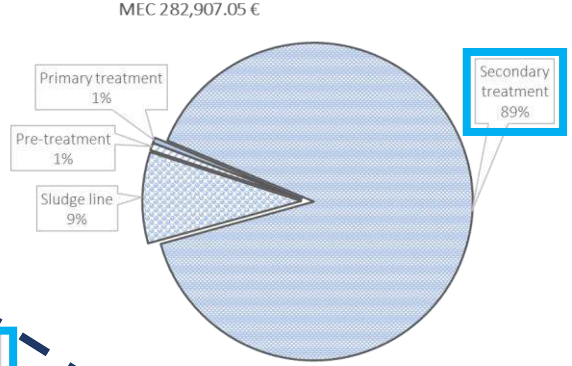


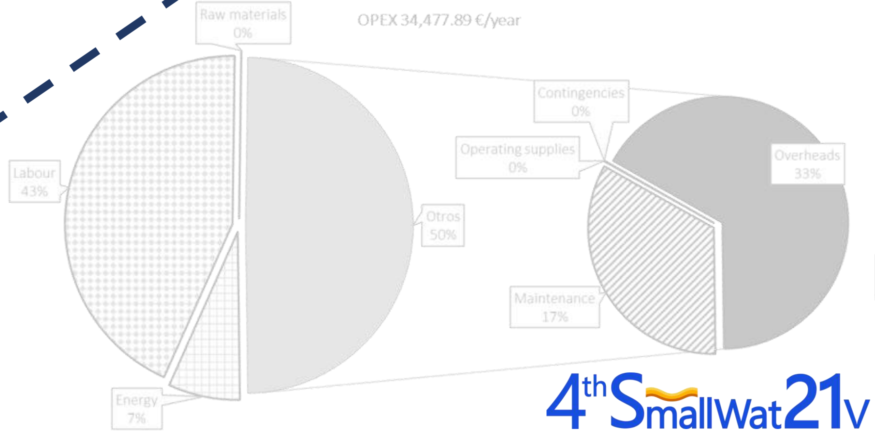


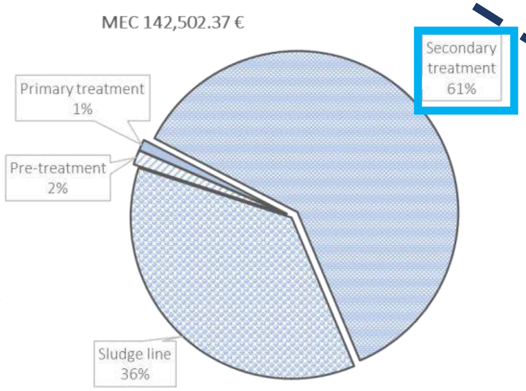
PROJECTION B
HRT= 20 days & SRT= 20 days





PROJECTION C
HRT= 5 days & SRT= 20 days





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*MEC – Major Equipment Cost

1. The results of the wastewater treatment costs for the three projections simulated in this techno-economic analysis could be competitive (0.45-0.73-0.47 €/m^3) when compared to the cost of conventional technologies in Europe (0.3-1€/m^3 (UNEP, 2005)).

2. Processes based on microalgae are much simpler and impose a low CAPEX. OPEX is also lower as maintenance is simple and does not require machinery and therefore lower energy consumption.

3. In addition, this process removes nitrogen and phosphorus without high costs. It is therefore a feasible solution for small populations, which have limited resources. However, the right compromise in operational conditions must be chosen. Since by working at different hydraulic and solids retention times, varying results can be obtained.

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