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# Life cycle analysis of water resource recovery facilities based on algae-bacteria processes

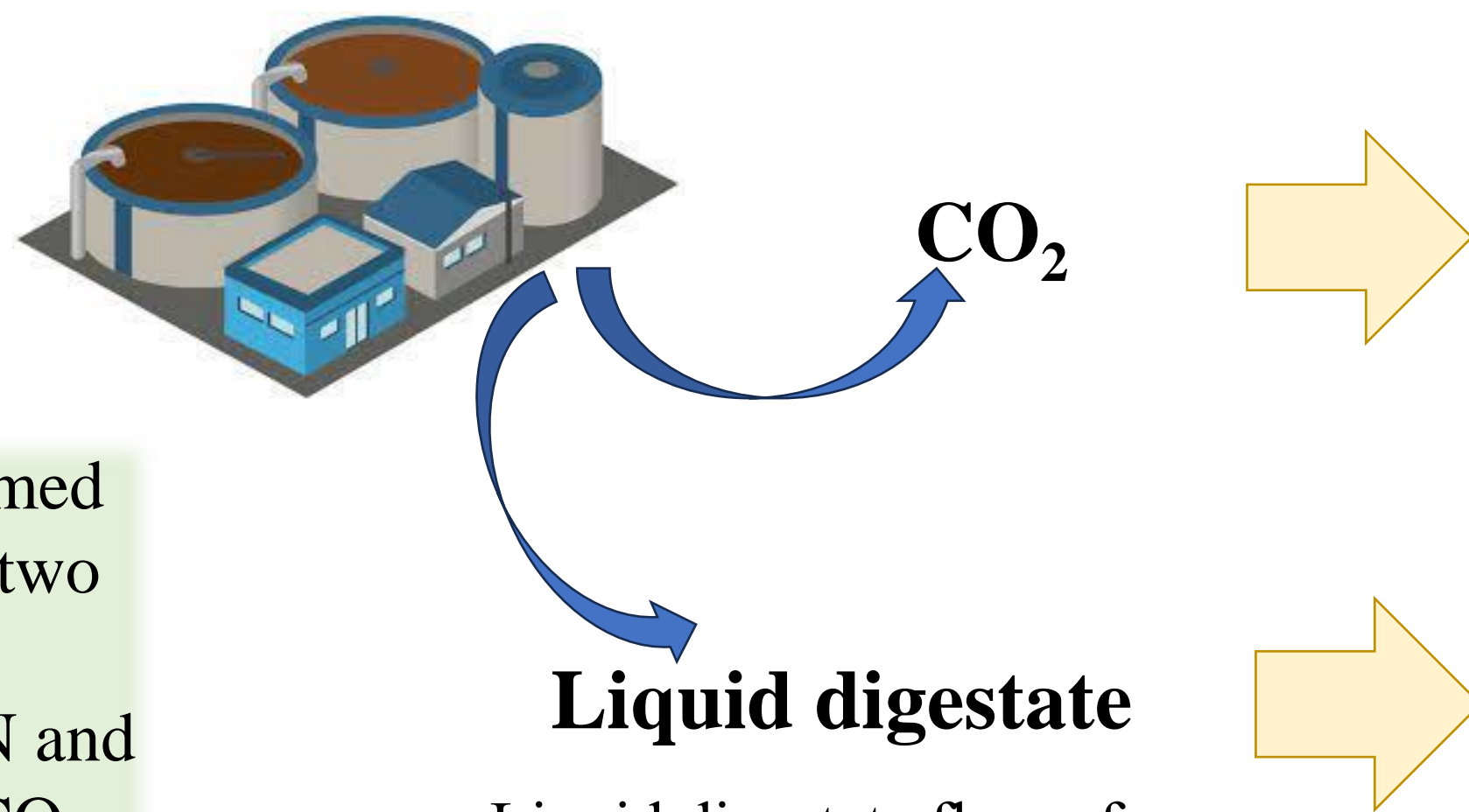
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A waste-to-energy LCA was performed for an open raceway system fed by two effluents from the environmental biorefinery process: digestate (for N and P source) from methanization and CO<sub>2</sub> from biogas upgrade process.

**Liquid digestate**  
Liquid digestate flow of 60.67 tones/d  
(3.33 kg total N/m<sup>3</sup> and 0.26 kg total P/m<sup>3</sup>).



(Source: www.atlanticgreenfuels.com)

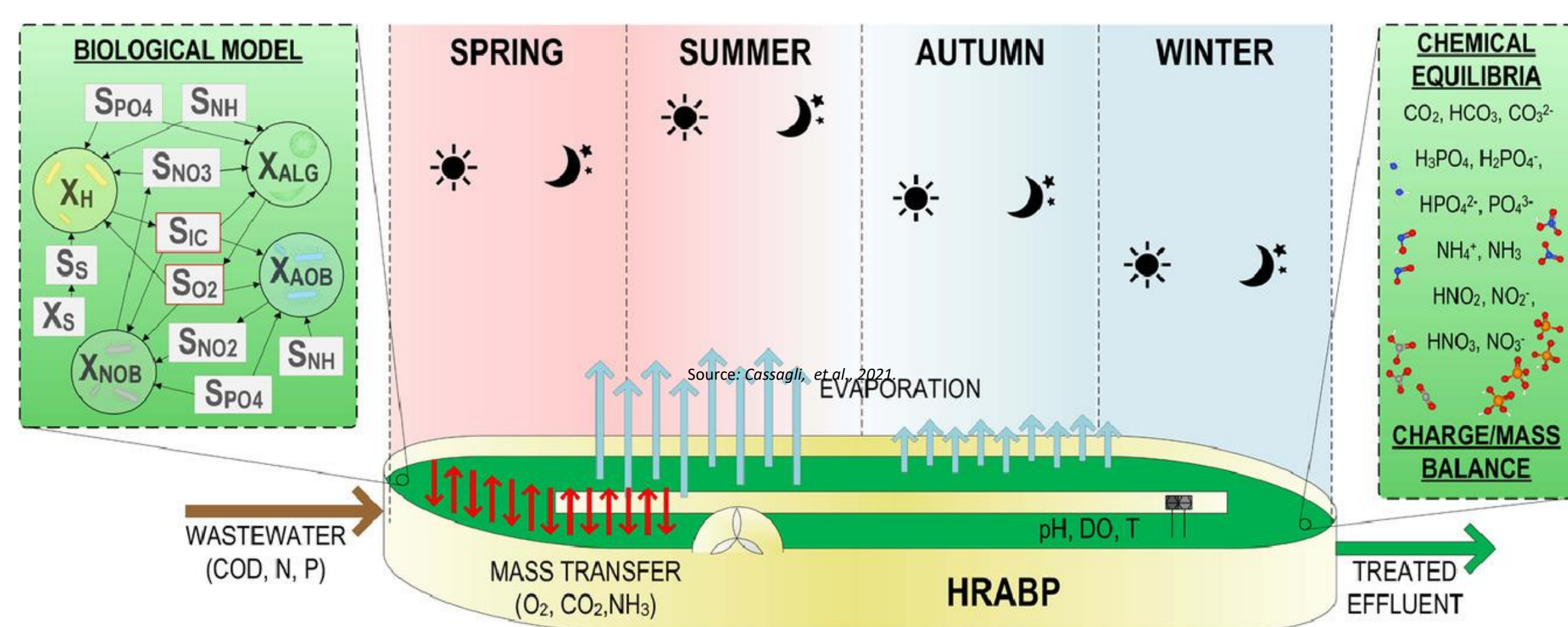
**Nutrients recovery in microalgae open raceways cultivation**

**Electricity**

## Main objective

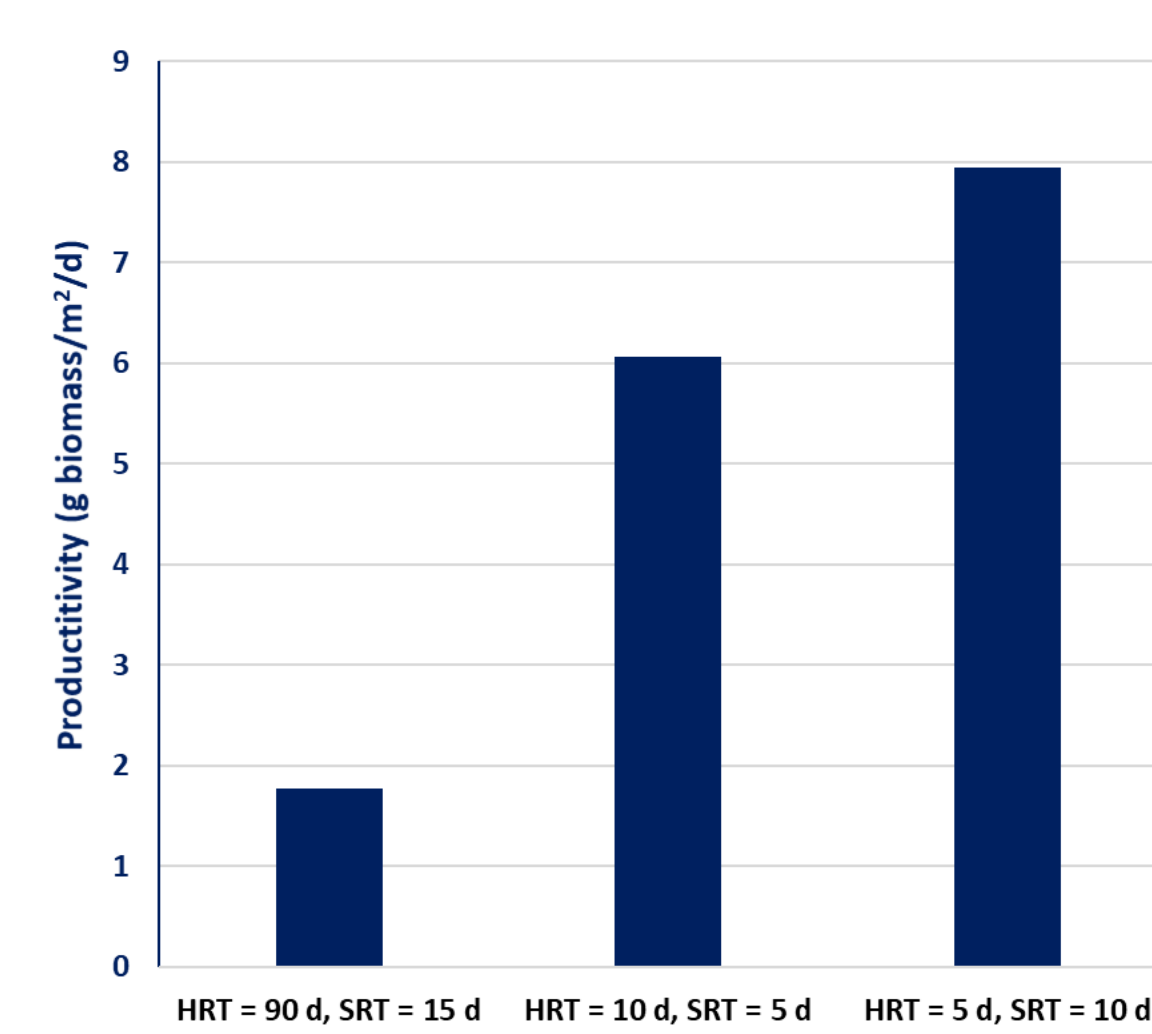
This study determines the effects of operational parameters, SRT and HRT, on microalgae biomass pond area, seasonal removal efficiency of nutrients (nitrogen and phosphorous) and environmental impacts. In addition, this case study provides a circular economy perspective on microalgae cultivation for liquid digestate by recycling of nutrients (nitrogen, phosphorous and CO<sub>2</sub>) and water, reducing the discharge to the natural environment, while producing compounds from microalgae to source green chemistry.

## MATERIALS AND METHODS



**Fig.1.** Microalgae growth model ALBA was used for determining productivities and mass balances of COD, C, O, H, N and P. This model describes algae-bacteria ecosystem evolution in an outdoor raceway for wastewater treatment, while local climate drives light and temperature (Casagli et al., 2021).

## RESULTS



**Fig.3.** Comparison of average annual biomass productivity for the three scenarios.

	1st Scenario	2nd Scenario	3rd Scenario
HRT/SRT	(90 / 15) d	(10 / 5) d	(5 / 10) d
Liquid depth	0.2 m	0.2 m	0.2 m
Area production	140000 m <sup>2</sup>	15000 m <sup>2</sup>	7500 m <sup>2</sup>
N° ORP units	15	2	1

**Fig.4.** Comparison of productivity area, number of units and size of raceway ponds for the three scenarios.

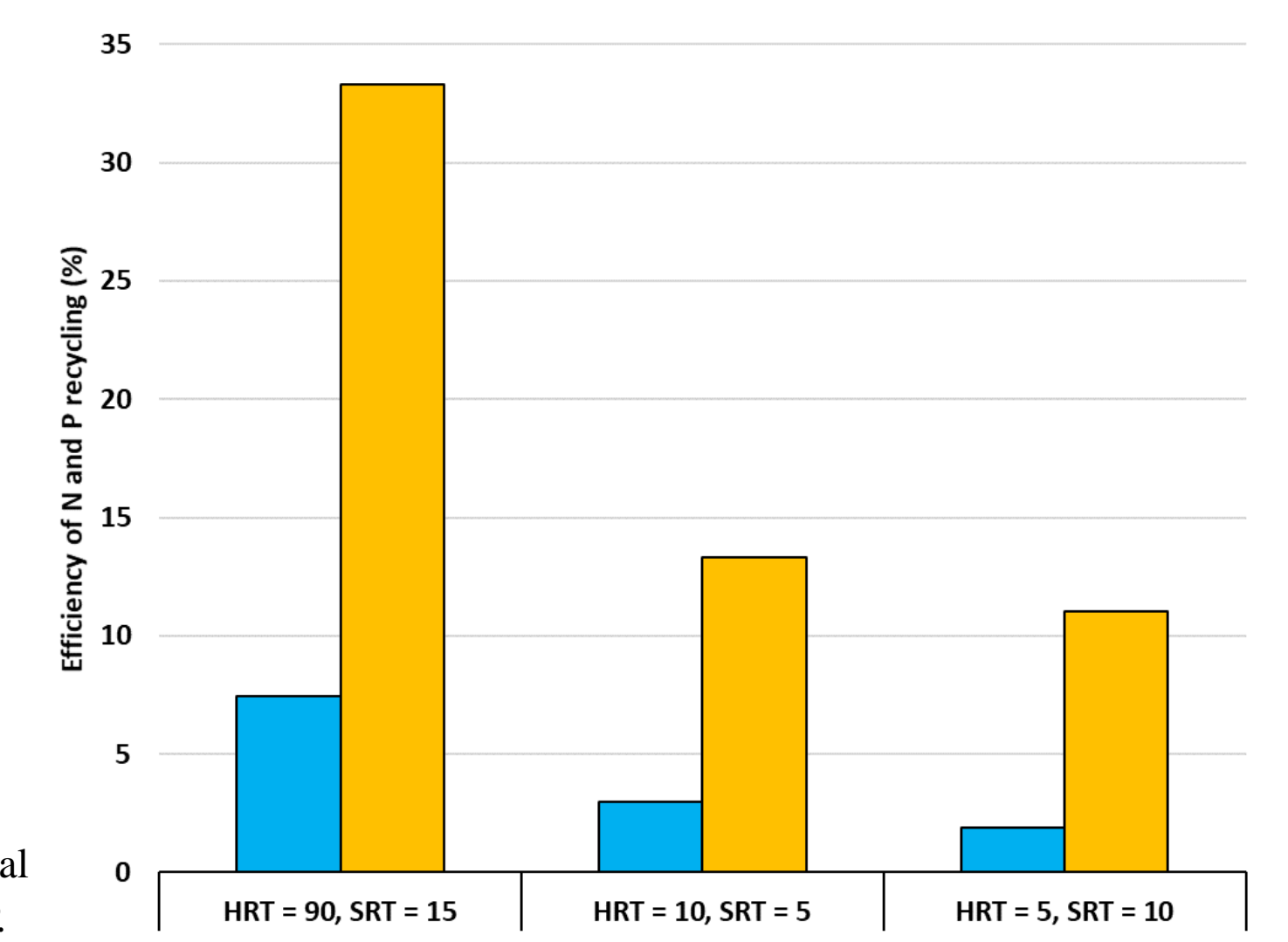
$$Eff_{N,RECYC} = (Flux_{Nout,ALG} / Flux_{Nin}) * 100$$

where: Flux<sub>Nout,ALG</sub> is the mass flow of Nitrogen [gN d<sup>-1</sup>] in the harvested algal biomass and Flux<sub>Nin</sub> is the mass flow of Nitrogen [gN d<sup>-1</sup>] fed to the HRABP.

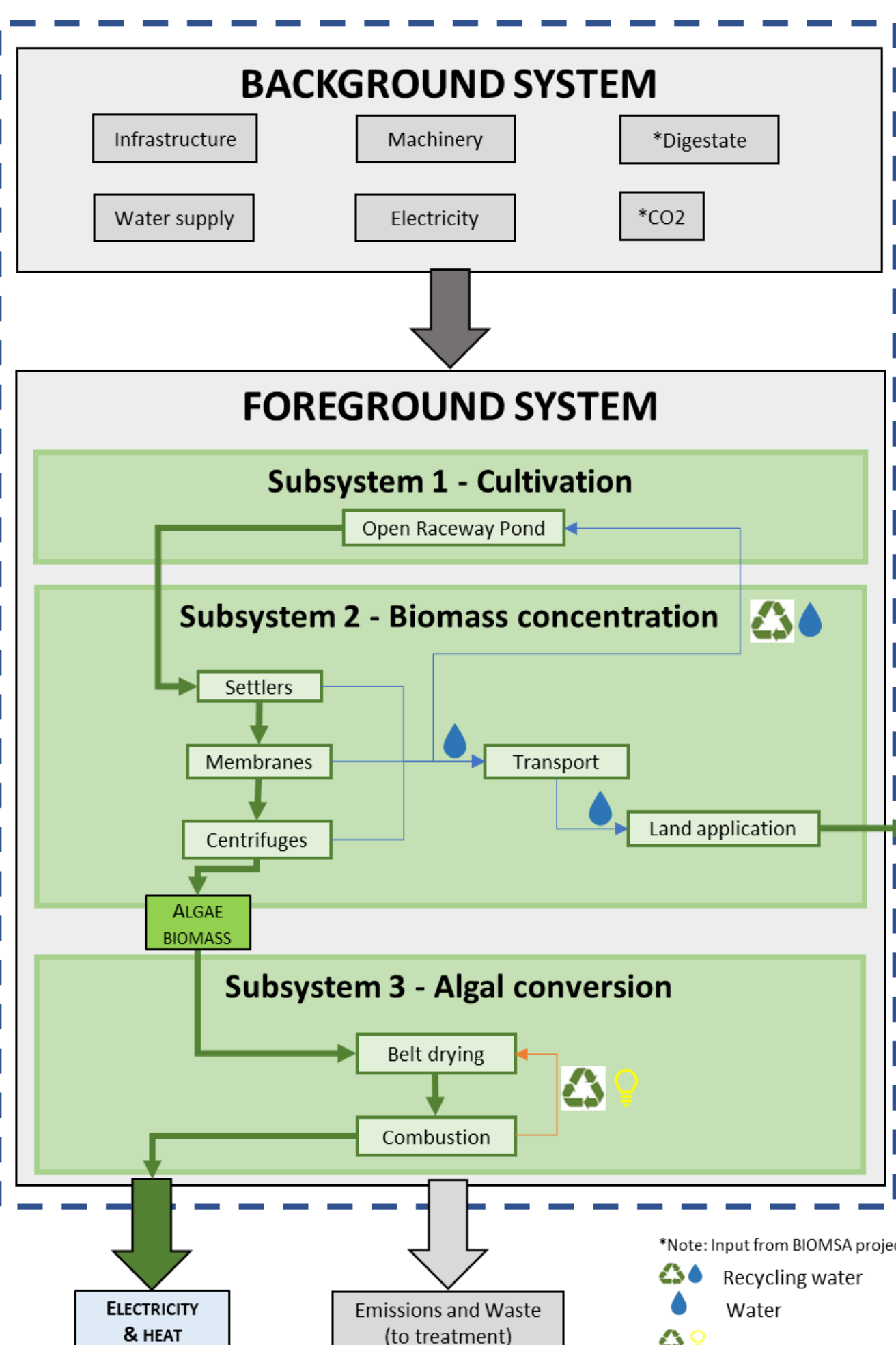
$$Eff_{P,RECYC} = (Flux_{Pout,ALG} / Flux_{Pin}) * 100$$

where: Flux<sub>Pout,ALG</sub> is the mass flow of Nitrogen [gP d<sup>-1</sup>] in the harvested algal biomass and Flux<sub>Pin</sub> is the mass flow of Nitrogen [gP d<sup>-1</sup>] fed to the HRABP.

(Casagli et al., 2023)

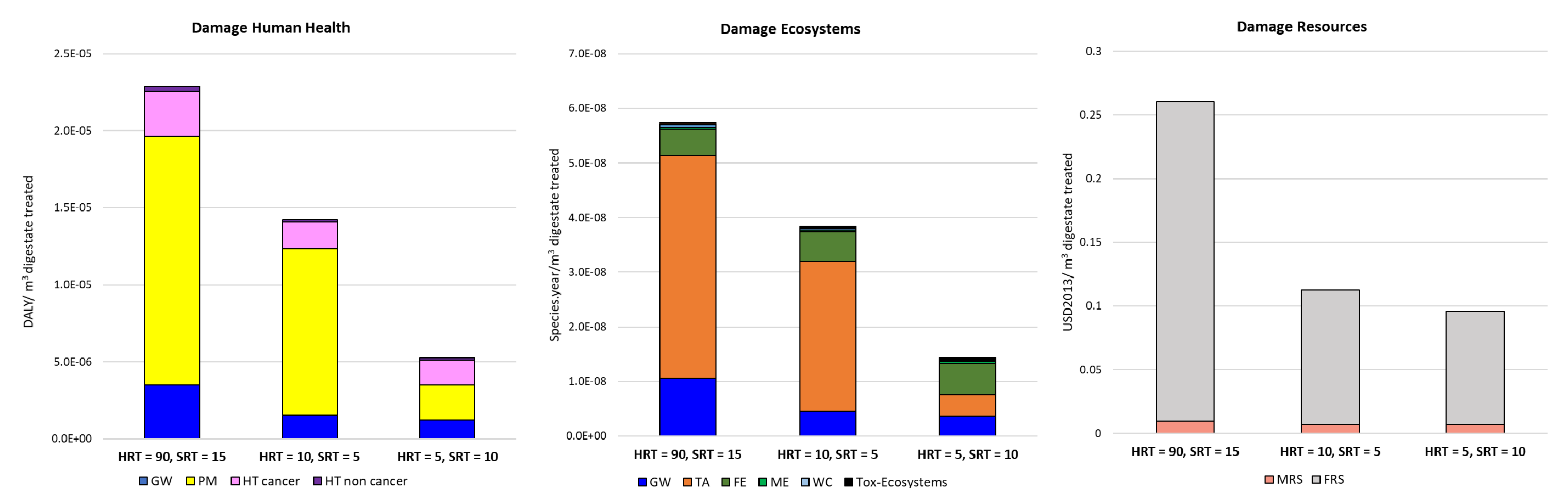


**Fig.5.** Efficiency of Nitrogen and Phosphorous recycling.



**Fig.2.** System boundaries.

- The boundaries include the biomass production, infrastructure, machinery production, emissions, and transport related to the chemical and materials used in the process units. The dismantling and final disposal of machinery and infrastructure material are also included.
- The functional unit (FU) is 1 m<sup>3</sup> of liquid digestate entering the microalgae cultivation system.
- ReCiPe (H) v1.005 was used as life cycle impact method using midpoint and endpoint approach.
- Three case studies at different HRT (Hydraulic Residence Time) and SRT (Solid Residence Time):
  - HRT: 90 d, SRT: 15 d
  - HRT: 10 d, SRT: 5 d
  - HRT: 5 d, SRT: 10 d



**Fig.6.** Endpoint environmental impact results. NOTE: GW: global warming; PM: particulate matter formation; HT cancer: Human toxicity, cancer effects; HT no cancer: Human toxicity, non-cancer effects; TA: terrestrial acidification; FE: freshwater eutrophication; ME: marine eutrophication; Tox-Ecosystems: terrestrial, freshwater and marine ecotoxicities; MRS: metal resource depletion; FRS: fossil resource depletion.

## ACKNOWLEDGEMENT

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## REFERENCES

- Casagli et al, 2021. ALBA: A comprehensive growth model to optimize algae-bacteria wastewater treatment in raceway ponds. *Water Research*, 190, 116734.
- Casagli et al, 2023. Optimizing resource recovery from wastewater with algae-bacteria membrane reactors. *Chemical Engineering Journal*, 451, 138488.

## CONCLUSIONS

The best scenario from a point of view of environmental impacts is scenario (HRT= 5 d, SRT= 10), with the lowest impacts in damage to human health, ecosystems and resources. In addition, this scenario leads to a high productivity with a reduced production area (lower than 10,000 m<sup>2</sup> ponds) for treating the digestate. More scenarios should be analyzed to find the best trade-off between productivity, N and P removals and reduced environmental impacts.