# Energetic assessment of 1 ha microalgae production plant

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# Energetic assessment of 1 ha microalgae production plant


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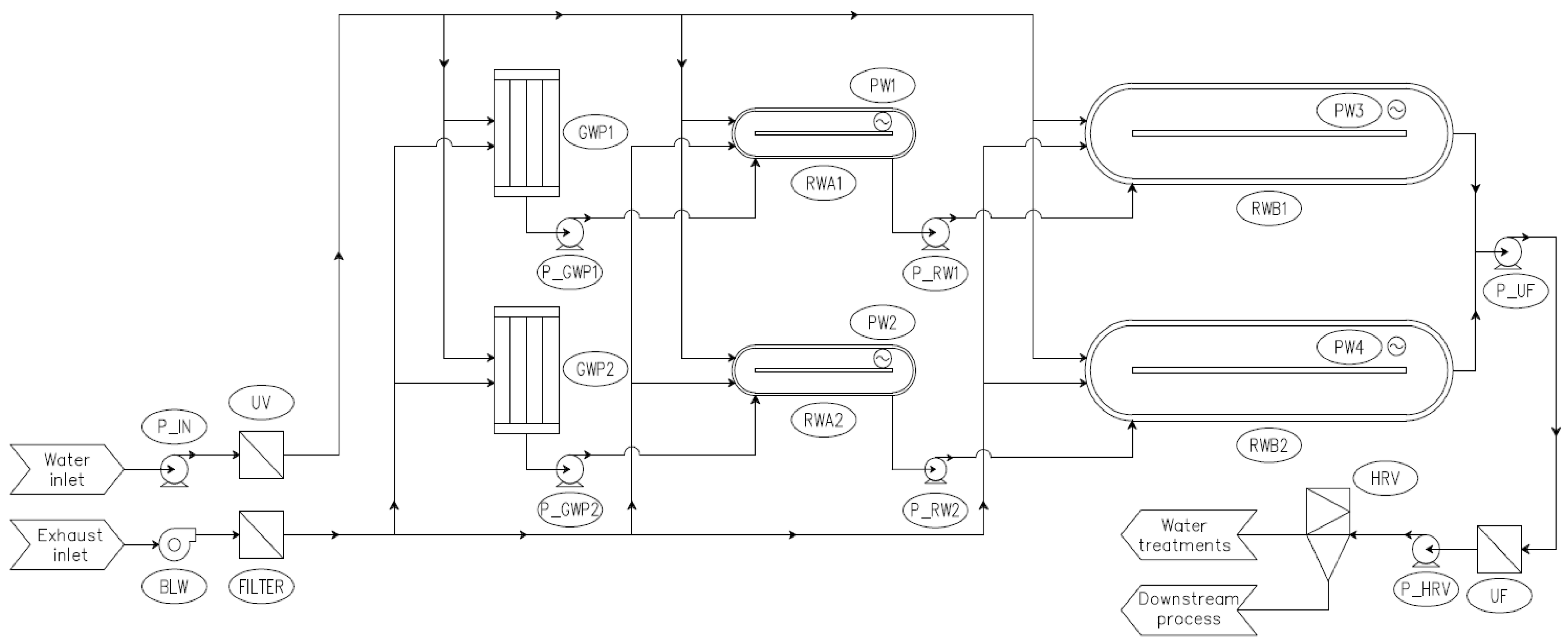
## Abstract

The size of the algae production plants today located in Europe is well represented by the dimension of 1 ha. This plant size can be considered as a functional unit, usefully scalable to other plant sizes.

The 1 ha plant, here analyzed, is constituted by five main areas: inoculation area, first and second growth stages, area for harvesting and post-processing and a fifth area for the ancillaries (water treatment, medium preparation, etc). The plant is located close to the seacoast and close to $CO_2$ source.


For the inoculation stage the GWP reactors has been chosen, because of their capacity to produce high quality inoculum. The main production stage growth is carried out in raceway ponds (RWPs) because today these systems still represent the technology with lower CAPEX and OPEX. Harvesting is made by two technologies: cross-flow ultra-filtration and centrifugation. The current analysis ends with the wet paste. Further down-stream processes are not here considered as the final market for algae plant productions is still object of strong discussions.

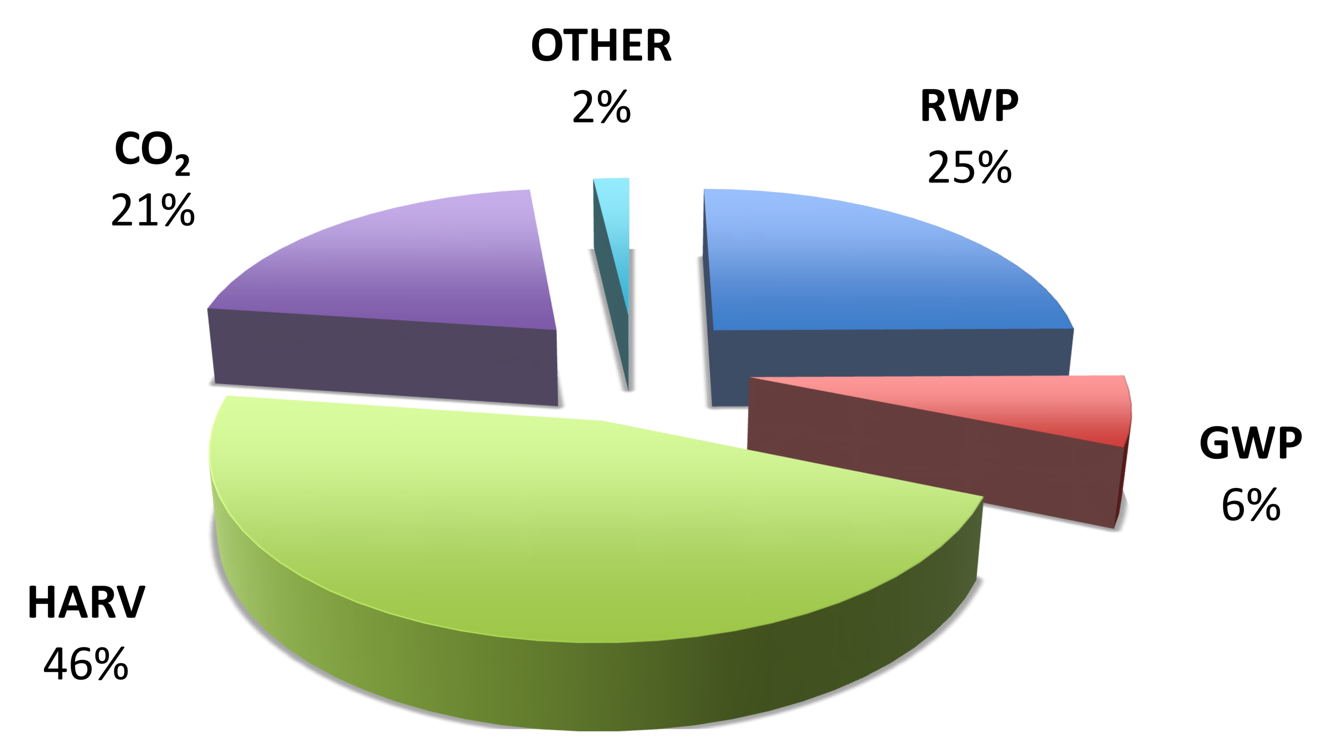



| CODES: DEVICE | CODES: AREA | NOTES | AVERAGE NOMINAL POWER (kW) | DAILY USE ($h\ day^{-1}$) | ENERGY CONSUMPTION ($kWh\ day^{-1}$) |
|---|---|---|---|---|---|
| BLW | $CO_2$ | Exhaust gas from power plant @13% $CO_2$ | 15.00 | 8.0 | 120.0 |
| UV | OTHER | Water sanitization | 0.84 | 12.5 | 10.5 |
| GWP-1 | GWP | GWP (no cooled) module 1 | - | - | 18.2 |
| GWP-2 | GWP | GWP (no cooled) module 2 | - | - | 18.2 |
| P_IN | RWP | Integration of daily evaporation (1.5 cm $day^{-1}$) | 1.20 | - | 9.6 |
| | | Filling up GWP pump | 0.75 | 0.5 | 0.4 |
| | | Filling up RWA pump | 3.00 | 2.0 | 6.0 |
| | | Filling up RWB pump | 3.00 | 2.0 | 6.0 |
| P_GWP | | GWP to RWA pump | 0.75 | 1.0 | 0.8 |
| PW1 | | Paddle wheel RWA1 @50% PN nightime | 1.05 | 24.0 | 18.9 |
| PW2 | | Paddle wheel RWA2 @50% PN nightime | 1.05 | 24.0 | 18.9 |
| P_RW | | RWA to RWB pump | 3.00 | 2.0 | 6.0 |
| PW3 | | Paddle wheel RWB1 @50% PN nightime | 2.10 | 24.0 | 37.8 |
| PW4 | | Paddle wheel RWB1 @50% PN nightime | 2.10 | 24.0 | 37.8 |
| P_UF / UF | HRV | Ultrafiltration | - | - | 209.3 |
| P_HRV / HRV | HRV | Centrifugation | - | - | 54.0 |
| | | | | TOTAL | 572.3 |

The design of the plant allows the dimensioning of the main and the auxiliary equipment. The knowledge of the operation conditions of each device allows also for a clear estimation of the energetic and operational costs. The energy consumption for each operational area is here reported.

| ENERGY CONSUMPTION | | | NOTES |
|---|---|---|---|
| RWP | 142.1 | $kWh_{el}$ | 23.2 |
| GWP | 36.4 | $kWh_{el}$ | 5.9 |
| HARV | 263.3 | $kWh_{el}$ | 42.9 |
| $CO_2$ | 120.0 | $kWh_{el}$ | 19.5 |
| OTHER | 10.5 | $kWh_{el}$ | 1.7 |
| TOTAL | 572.3 | $kWh_{el}\ day^{-1}$ | |
| TOTAL | 2.8 | $kWh_{el}\ kg^{-1}$ | @20 gr $m^{-2}$ $day^{-1}$ |
| PRIMARY | 986.7 | $kWh_{primary}\ day^{-1}$ | @20 gr $m^{-2}$ $day^{-1}$ |

| | | |
|---|---|---|
| Biomass productivity | gr $m^{-2}$ | 20 |
| | kg $day^{-1}$ | 200 |
| Biomass LHV | kWh $kg^{-1}$ | 6.7 |
| | MJ $kg^{-1}$ | 24 |
| $E_{out}$ | kWh $day^{-1}$ | 1333 |
| $E_{primary}$ | kWh $day^{-1}$ | 987 |
| NER | - | 1.4 |




## Conclusions

$$NER = \frac{E_{out}}{E_{in}} = \frac{BM * LHV_{BM}}{E_{cons.} + E_{emb.en.} + E_{fertil.}}$$

*Not considered in this work*

The production of a wet algae paste, in the plant layout here considered, requires a total of 2.8 $kWh_{el}$ $kg_{algae}^{-1}$, (considering 20 gr $m^{-2}$ $day^{-1}$). This corresponds to a primary energy of 4.8 kWh $kg_{algae}^{-1}$. Considering a total Gross Heating Value of 6.7 kWh $kg_{algae}^{-1}$ for the dry algae, the NER of the plant is close to 1.4. This result is partial, because energy for nutrient and embodied energy of the materials of the plant are not considered. Nonetheless, the results allow to highlight the critical operative parts of the plant. In a real plant the most important energy consumption area is related to the harvesting, accounting for about 46%, followed by culture mixing (about 25%) and $CO_2$ supply (21%).

The results indicate that the major effort has to be focused in implementing new solutions and optimization for harvesting.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