2006-04-01

Solar Energy Conversion Through Seaweed Photosynthesis with Combustion in a Zero-Emission Power Plant

Evgeny Yantovski
Independent researcher

Jim McGovern
Technological University Dublin, jim.mcgovern@tudublin.ie

Recommended Citation

Yantovski, Evgeny I. and Jim McGovern, Poster. The 2nd International Conference of Renewable Energy in Maritime Island Climates, 26–28 April 2006, Dublin, Ireland.

Solar Energy Conversion through Seaweed Photosynthesis with Combustion in a Zero-Emission Power Plant

Evgeny I. Yantovski[†] and Jim McGovern[‡]
[†]Elsass str. 58, D-52068 Aachen, Germany
[‡]Dublin Institute of Technology, Bolton Street, Dublin 1, Ireland
[‡]Corresponding Author

Ulva rigida C. Agardh New Quay, Co. Clare, Ireland; extensive growths at MLWN 29 Mar 2002. Photographer: M.D. Guiry, © M.D. Guiry (used with permission).

Abstract

A proposed 'closed cycle' power plant scheme, referred to as SOFT (Solar Oxygen Fuel Turbine), is described. The scheme involves the cultivation of macroalgae in a pond, combustion of their organic matter in a fluidised bed boiler that generates steam for a Rankine cycle steam power plant and the return of the combustion products to the pond to feed the algae. Oxygen, equivalent to that used for combustion, is re-released to the atmosphere by photosynthesis, while the carbon dioxide that is produced by combustion is absorbed by photosynthesis and thereby recycled.

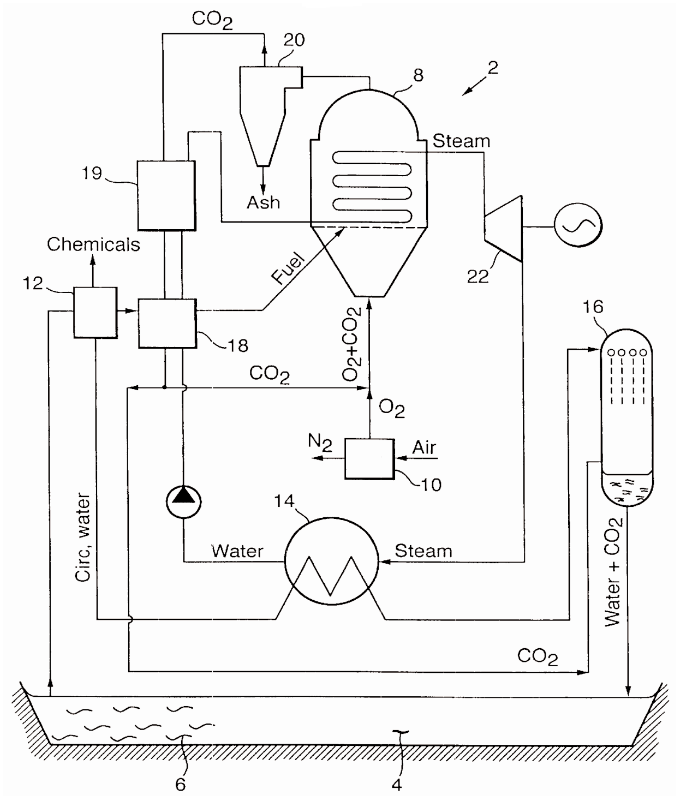


Figure 1. Schematic diagram with fluidised bed combustor (8) and steam turbine (22) (U.S. Patent 6,477,841 B1).

It is proposed that the seaweed Ulva, which is common in Irish coastal waters, can be used in the solar pond. The solar energy conversion efficiency is less than that which can be achieved by the use of photovoltaic panels, but the energy expenditure to construct algae ponds as solar energy receivers is much less. Therefore the proposed scheme can be economically, as well as environmentally, attractive. For a power unit of 100 kW the pond surface area in Ireland would be about 6 hectares.

Principles

The overall reaction for photosynthesis, by cianobacteria, for micro- and macroalgae is as follows:

$$CO_2 + H_2O + light \Rightarrow CH_2O + O_2$$

A major weakness of most existing or proposed schemes for the combustion of biomass is the rather small fraction of CO_2 in the flue gases, where the dominant gas is the inert nitrogen. Energy-efficient separation of CO_2 from nitrogen after combustion has turned out to be an insurmountable problem.

However, the combustion of biomass in 'artificial air', made up of either oxygen and steam or oxygen and carbon dioxide, produces flue gases without nitrogen and the CO_2 generated in combustion can be returned to a pond to feed algae.

Power Plant

A schematic diagram of the proposed plant is shown in Figure 1. This is a conventional Rankine steam cycle.

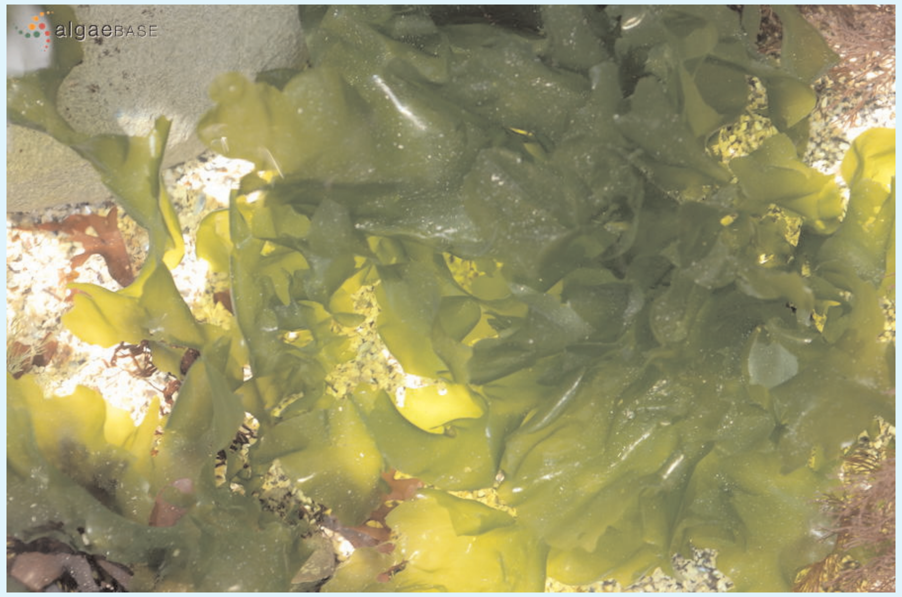
As a numerical example let us consider a small decentralized power plant of 100 kW output (without features to enhance cycle efficiency). We make the following assumptions:

- Fuel is wet (50% water content)
- Air-separation-unit power consumption for 98% oxygen purity 0.22 kWh/kg O_2
- Superheated steam before turbine 130 bar, 540°C
- Isentropic coefficients of turbine and feed pump 0.80 and 0.75 respectively
- Seaweed productivity 16 kg/(m² year) or 10 W(th)/m² (at Israeli insolation level)
- Photosynthesis efficiency 4.6%.

Calculated results:

- Heat input 425.5 kW (th)
- Net output 107.3 kW (el)
- Cycle efficiency 25.2%
- Pond surface 4 hectare

With an improved cycle efficiency of 35%, which is quite possible for a Rankine cycle with reheat, the required surface area of the pond is 3 ha. If the seaweed productivity in Ireland were only half the value assumed above (because of the lower intensity of solar radiation) the required pond area would be 6 ha.



Ulva rigida C. Agardh. Black Hd., Co. Clare, Ireland; lower-shore rock pools 16 Mar 2006. Photographer: M.D. Guiry, © M.D. Guiry (used with permission).

There would be no emission of flue gases and no net consumption of environmental oxygen, which is consumed in combustion but released in photosynthesis. The only requirement is solar energy and a pond of shallow seawater.

Gasification

In the proper energy mix not only electricity, but also gaseous or liquid fuel is needed. In the SOFT cycle this is attainable by a small modification (Figure 2). The difference is the incomplete combustion (gasification) in the fluidised bed reactor, which is now a gasifier.

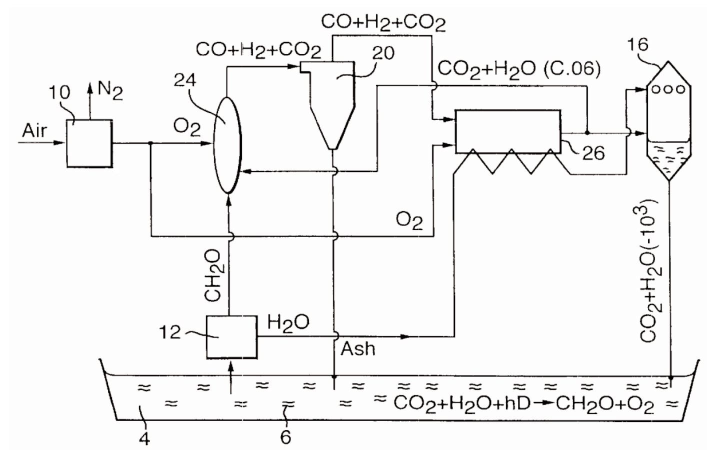


Figure 2. Schematic diagram with gasifier (24) and engine (26) (U.S. Patent 6,477,841 B1).

Conclusion

The SOFT power cycle is of practical interest to countries such as Ireland with sufficient solar radiation and the possibility of using or creating shallow ponds for the cultivation of algae. The concept is ready for engineering and economic evaluation. It would seem worthy of demonstration on a small scale.

The 2nd International Conference of Renewable Energy in Maritime Island Climates 26–28 April 2006, Dublin, Ireland