Feasibility study on a sailing solar cell raft system in low-latitude Pacific Ocean

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Sailing solar cell raft in the Pacific Ocean, 5km by 5km in its ultimate dimension.
(Illustration by Civil & Envir. Eng. Dept, Chuo Univ.)
BACKGROUND & OBJECTIVES

In order to reduce CO$_2$ emission, it is urged to shift from fossil fuels to reusable energies.

Solar cell system is rapidly put into use worldwide in parallel with its innovations in the efficiency and the production technology.

In Japan, unlike desert countries, it is considered that the domestic capacity of the solar power generation cannot be large enough to serve as a major energy source due to the cloudy and rainy climate and the small land area.

Proposal:
Huge Solar Cell Raft in Low-Latitude Pacific Ocean

Always wind-sailing & generating electricity in international seas. No territory conflicts & little environmental problems to sea-lives.
Computation on Generated Electricity

Basic Conditions for Computation
Solar cell raft size: 5 km x 5 km
Daily sunshine energy: 8 kWh/m²/day
Solar cell efficiency: 12% (a quite practical value at this moment)

Energy Generated Daily
8 (kWh/m²) × 0.12 × 25,000,000 (m²) = 24,000,000 kWh

Average Generation Capacity
8 (kWh/m²) × 0.12 × 25,000,000 (m²) / 24(h) = 1,000,000 kW
(Equivalent to a Nuclear Power Station of 1000 MW capacity)

Electric energy is transported by battery tankers to Japan.
Previous similar ideas

• A similar idea on a marine solar power station was proposed (Escher et al. 1977, Ohta 1978).
• Hydrogen is produced by solar heat energy collected by mirrors on floating rafts.
• Rafts stay at a fixed location in tropical seas and transported by hydrogen tankers.

Proposed energy system

• The energy system is characterized by power generation using solar cells on a gigantic raft, sailing by wind and sea-currents.
• The solar cell seems to have a great advantage over the solar mirror in the ocean, because the raft can have a larger allowance of rolling and pitching by ocean waves, making it easier to enlarge the rafts.
• Always sailing in open seas to pursue clear weather and favorable oceanic conditions and impacts on marine lives can be minimized.
• The navigation route is computerized in advance by using weather satellites and other information.
Major Technical Breakthrough Needed.

Essential to make 3 major technical breakthroughs.

1. Solar cell
   - Thin flexible solar cell with high conversion efficiency.
     - 12% → 20% or more
   - Flexible solar cell substrate serving as sail-clothes

2. High energy-density battery
   - Next generation battery with high energy density (e.g., Zinc-Air battery)
   - Energy density:
     - 0.1 (now)
     - 0.7 kWh/kg (in 30 yrs.)

3. Raft
   - New design
   - New material
   - Easily foldable
   - In-operation maintenance
1. Thin Flexible Solar Cell

Widespread sailcloth covered with thin flexible solar cells.

A thin chemical film (CIGS) is promising; low material consumption and high conversion efficiency.

The efficiency; 10-12% for 1 m² module, 20% for 1 cm² cell at this moment, and large potential promising.

Flexible substrate of textiles is yet to be developed.

In 20 to 30 years, seamless solar cell sailcloth as large as 100 x 100 m² with efficiency much higher than 12 % may be realized.
2. High Energy-Density Battery

The current energy density is 0.1 kWh/kg (lithium-ion).

According to NEDO Japan, a next generation battery with 0.7 kWh/kg can be targeted in 20 years (Zinc-Air battery, as one of the candidates).

When this becomes available, the battery weight necessary to transport the electricity generated by the 5 x 5 km$^2$ raft is 3.4 x10$^5$ kN daily.

If a battery tanker as large as the largest oil tanker (3-5 x10$^6$ kN) is constructed, then electricity generated for 10 days to 2 weeks (3-5 x10$^6$ kN / 3.4 x10$^5$ kN/day) can be transported by one tanker shuttle.

The energy for transportation is less than 7% of the pay load.
3. Innovative Raft Units

A great number of raft units needed to realize 5 x 5 km$^2$ raft.

Essential to create an innovative raft units, made of high-strength/lightweight materials, floats, masts and sailcloth covered with thin flexible solar cells, readily foldable.

Floats of a semi-submerged type to minimize wave effects.

Raft units inter-connected by wires, pressure tubes, and electrical cables.

Masts and sail-cloths controlled to a certain degree for low-speed, energy-saving wind sail and also for tracking the sun.

A number of raft units folded compactly and towed by mother-ships starting from a home port and spread out swiftly in operation.

Appropriate materials and innovative designs to make them lightweight, flexible and highly durable, and to minimize the construction costs.
Sunshine Intensity in Low-Latitude Pacific Ocean

Sun-shine of 5～7.0 kWh/m²/day on annual average in wide area. The energy more than 8.0 kWh/m²/day can be attained by sailing to seek for the optimum sunshine throughout a year.

*1) Surface meteorology and Solar Energy: Release 6.0 Data Set, NASA, Jan 2008
**Annual Averaged Wind Speed**

![Graph showing annual averaged wind speed with color-coded regions indicating wind speeds from 1.0 to 9.0 m/s.]

*1) Surface meteorology and Solar Energy: Release 6.0 Data Set, NASA, Jan 2008

**Seasonal Wind Speed & Directions**

*January*

![Map showing wind direction and speed for January.]

*July*

![Map showing wind direction and speed for July.]

JMA (2003): Marine climate in North Hemisphere Pacific Ocean, Japan Meteorological Agency
In low-latitude Pacific, wave height is lower than 1 m throughout a year !!!

JMA (2003): Marine climate in North Hemisphere Pacific Ocean, Japan Meteorological Agency
Sea-Currents in Central Pacific Ocean

It may be possible to use North/South Equatorial Current and Equatorial Counter Current for energy-saving navigation of the Solar Cell Raft Fleet!!!

SUMMARY

• Huge Solar Cell Raft 5 km x 5 km in Low-Latitude Pacific Ocean with generation capacity as large as a 1000 MW nuclear power station is proposed.

• In Low-latitude Pacific Ocean, vast open seas exist with solar energy much higher than Australian deserts. By sailing around throughout a year, daily solar energy larger than 8 kwh/m²/day will be easily attained by the proposed solar-cell raft.

• Winds and waves are favorable for the energy-system to operate in Low-Latitude Pacific. Energy-saving sailing seems possible by using winds and sea-currents.

• 20-30 years are targeted to realize this energy system by making 3 major technical breakthroughs.