PICES-2024
Oct 26 - Nov 1, 2024 Honolulu, USA
The FUTURE of PICES: Science for Sustainability in 2030

CIGS キヤノングローバル戦略研究所
The Canon Institute for Global Studies

A Negative Emission Application Based on Floating Integrated System

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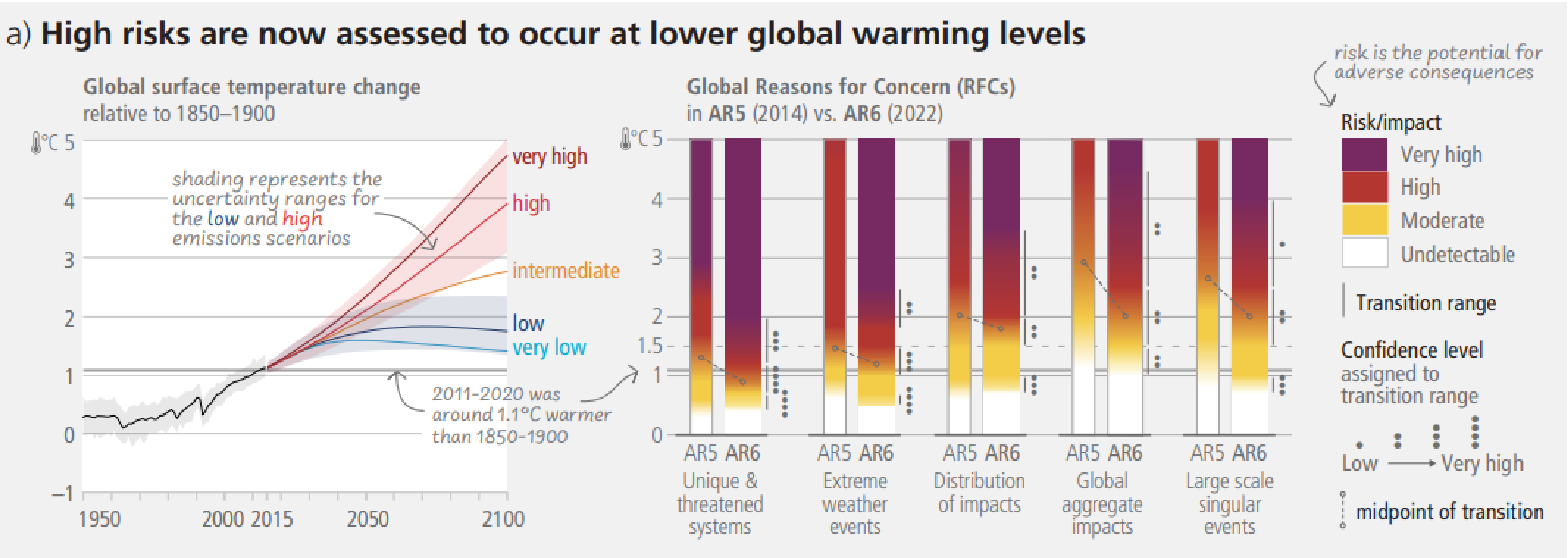
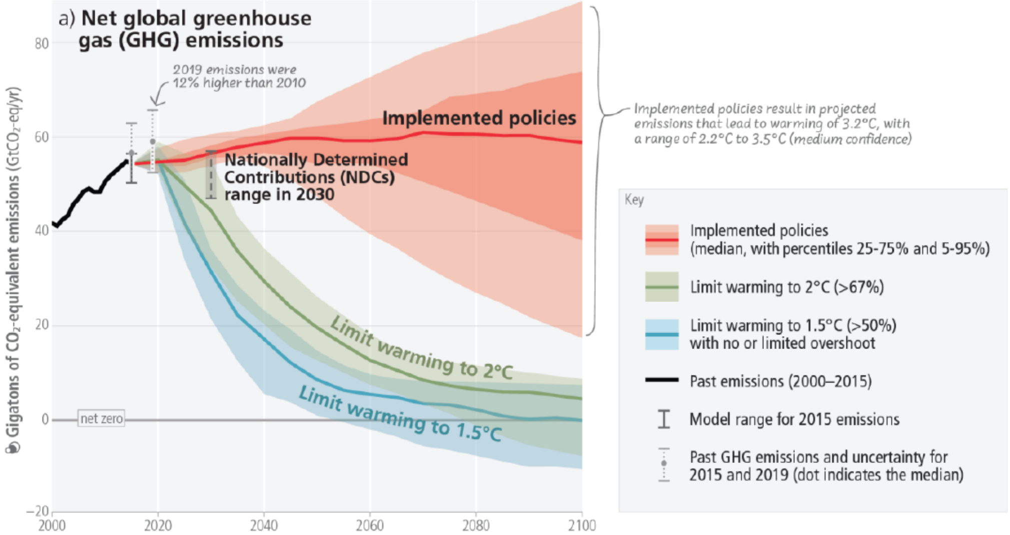
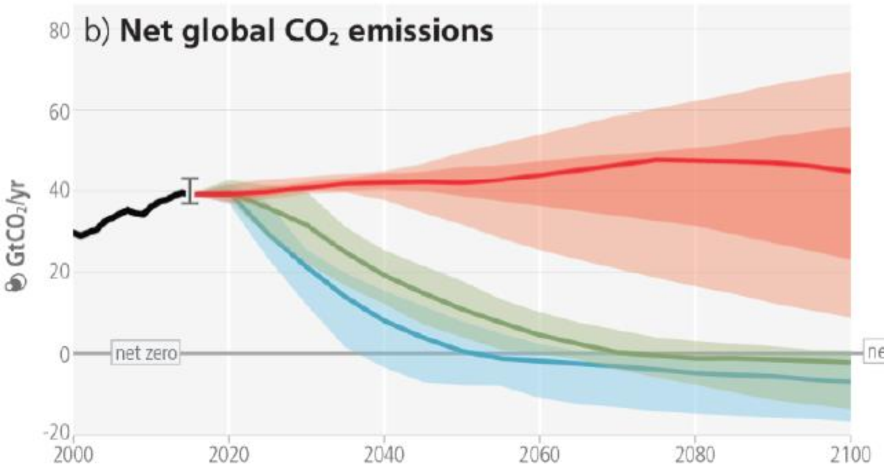
The Canon Institute for Global Studies

Background: Climate Change and Mitigation







Sources: IPCC AR6

Background: Contributions from the Ocean

To increase the carbon absorption:

- Ecosystem conservation and restoration
- Artificial ocean fertilization
- Sea water engineering

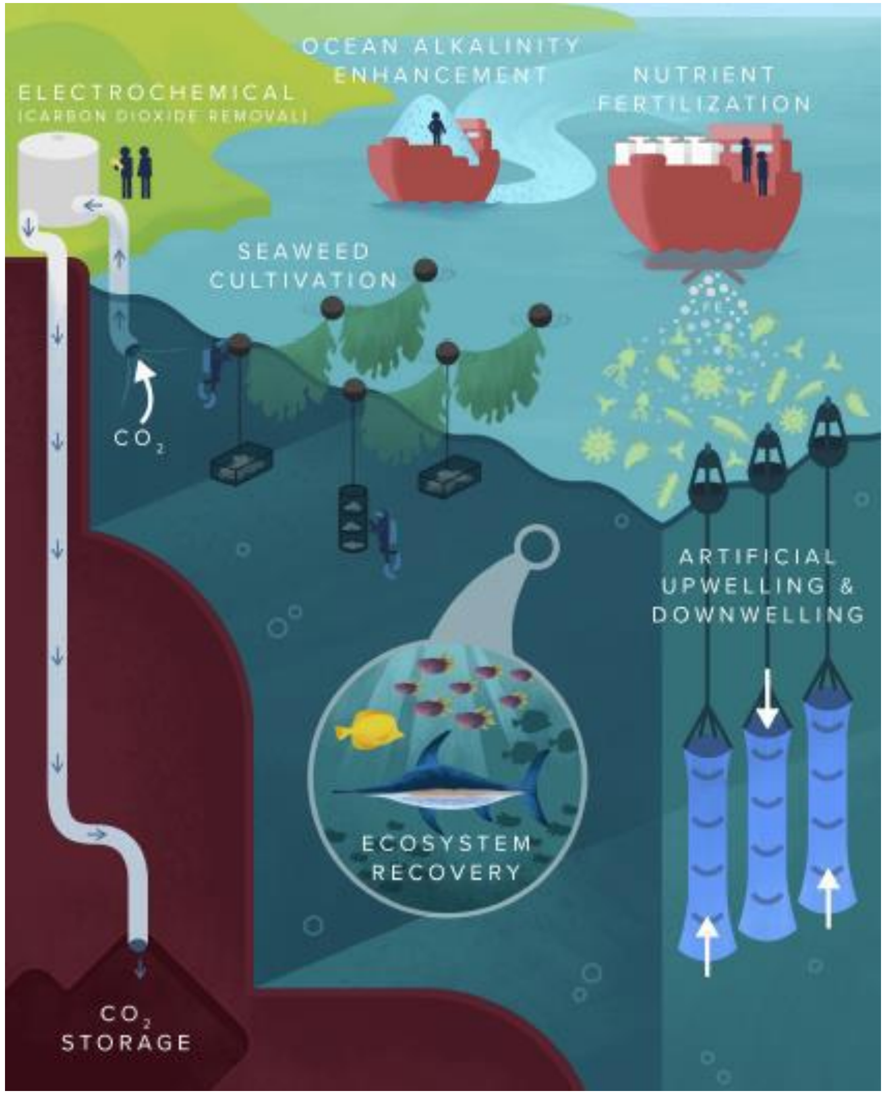
To provide the space for carbon storage:

- CCS beneath sea bed

To reduce the anthropogenic carbon emission:

- Providing carbon free energy
  - Offshore wind
  - Ocean energy

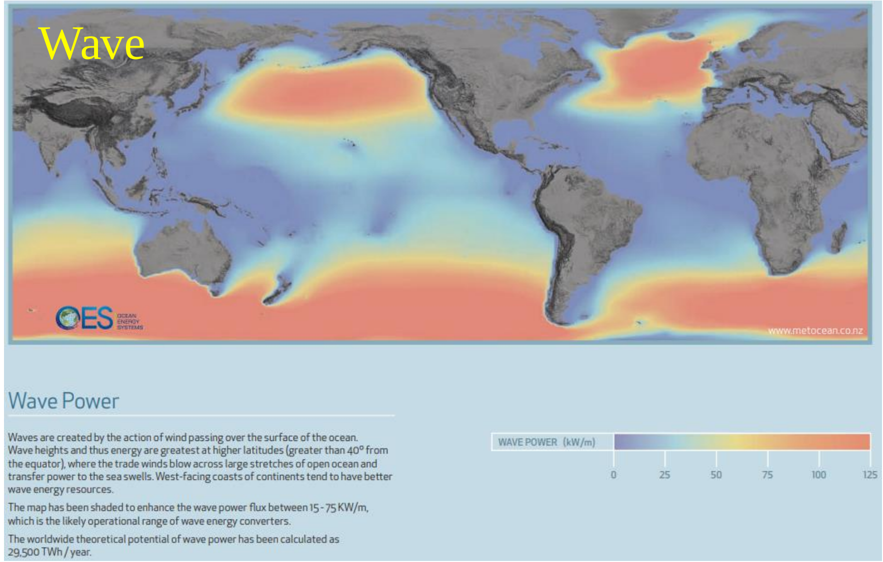
Background: Ocean Based CDR

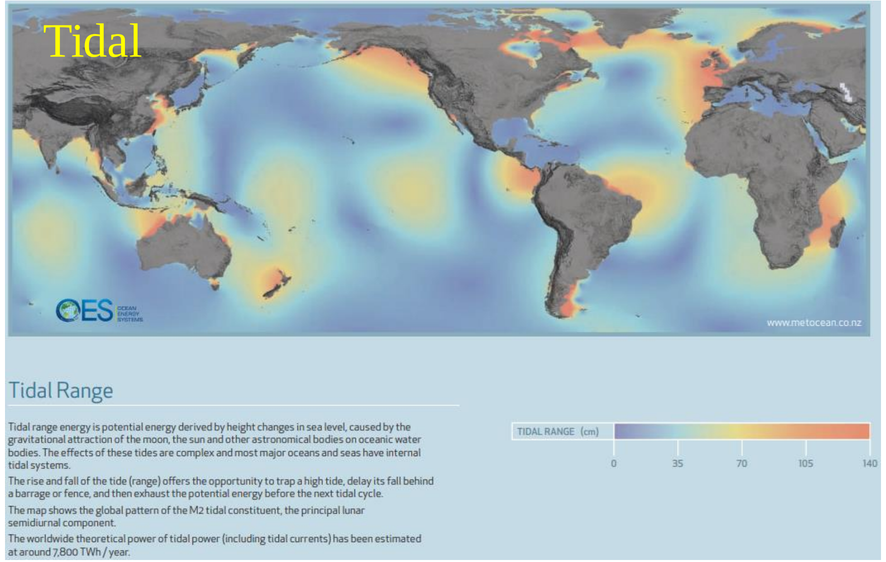


	Ocean Nutrient Fertilization	Artificial Upwelling/ Downwelling	Seaweed Cultivation	Ecosystem Recovery	Ocean Alkalinity Enhancement	Electrochemical processes
Knowledge Base	Medium-High	Low-Medium	Medium-High	Low-Medium	Low-Medium	Low-Medium
Efficacy	Medium-High	Low	Medium	Low	High	High
Durability	Medium	Low-Medium	Medium-High	Medium	Medium-High	Medium-High
Scalability	Medium-High	Medium	Medium	Low-Medium	Medium-High	Medium-High
Environmental Risk	Medium	Medium-High	Medium-High	Low	Medium	Medium-High
Social Considerations	Challenging	Challenging	Challenging + Positive Impacts	Less Challenging + Positive Impacts	Challenging	Challenging
Co-benefits	Medium	Medium-High	Medium-High	High	Medium	Medium-High
Cost of scale-up	Low	Medium-High	Medium	Low	Medium-High	High
Costs and challenges of C accounting	Medium	High	Low-Medium	High	Low-Medium	Low-Medium
Cost of environmental monitoring	Medium					
Additional resources needed	Low-Medium	Medium-High	Medium	Low	Medium-High	Medium-High

Sources: National Academies of Sciences, Engineering, and Medicine. 2021. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration.

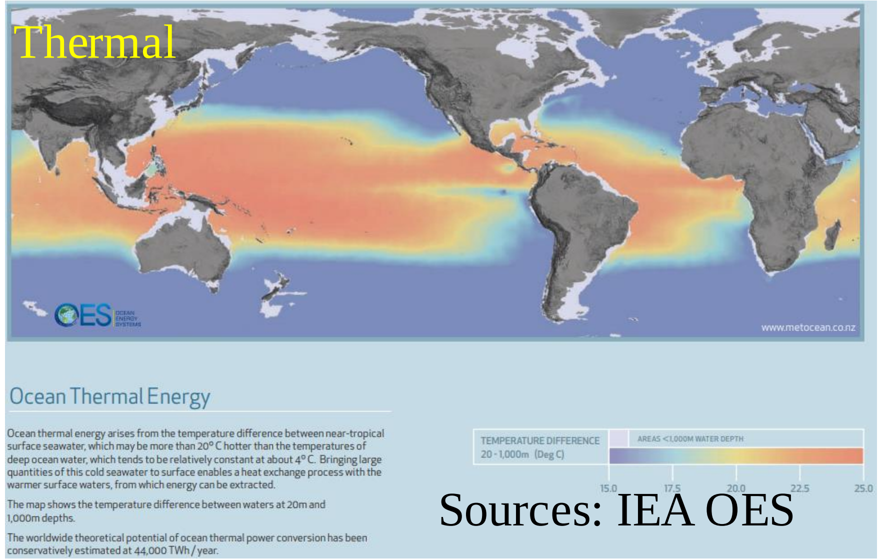
Background: Ocean Energy





Theoretical Potential (TWh/yr)	
Wave	29,500
Tidal	7,800
Thermal	44,000

Global electricity consumption (2022): 26,933 TWh



Sources: IEA OES

Research Purpose

To design a conceptual system combining ocean energy utilization with a negative carbon dioxide emission technology based on an offshore floating structure.

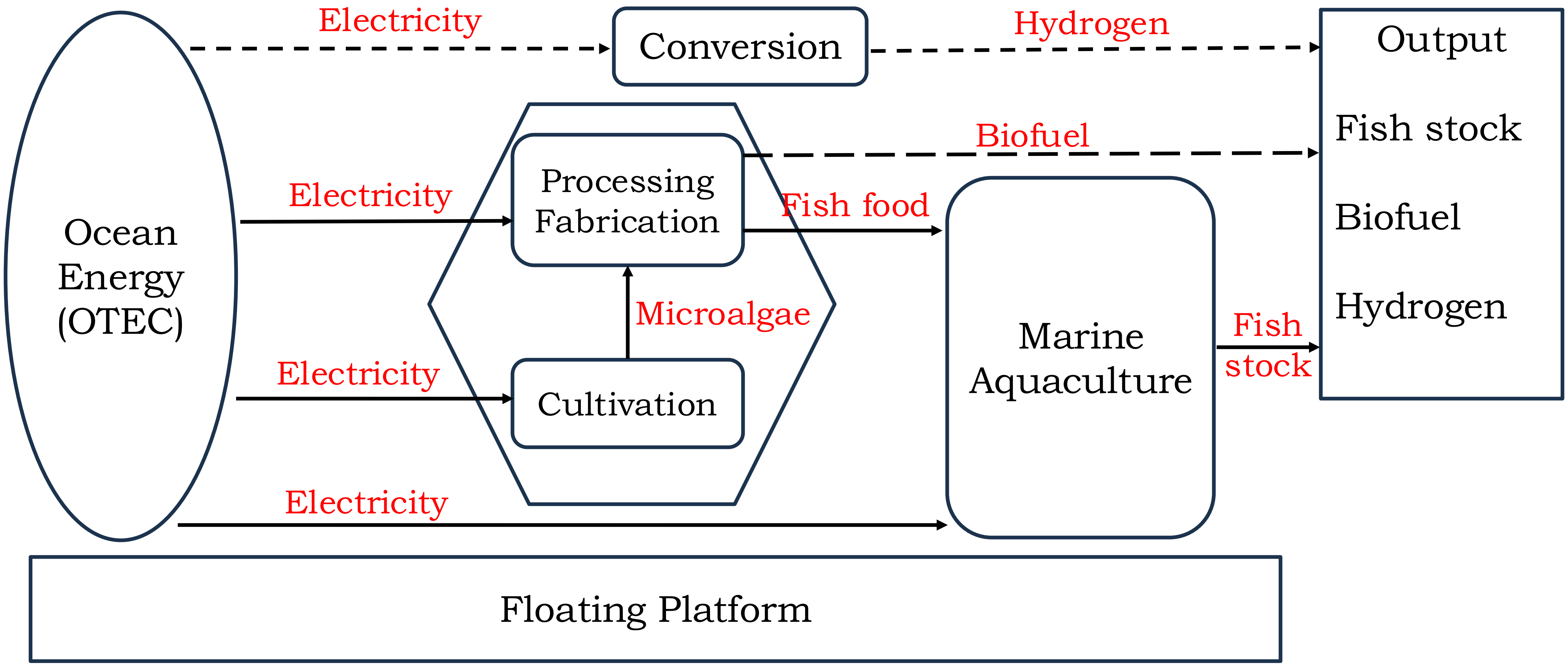
Main concepts

Energy resource: ocean thermal energy (OTEC)
Negative emission technology: microalgae cultivation and artificial upwelling
Economic activity: offshore aquaculture

Assessment

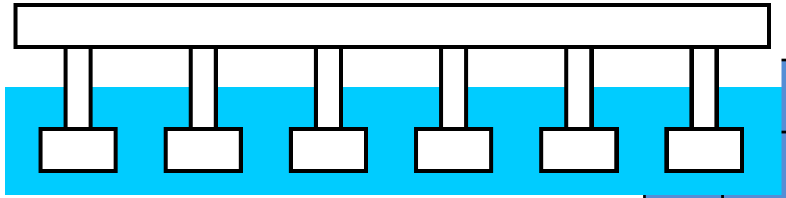
Carbon footprint calculation to examine the system capacity
An integrated index estimation to evaluate the sustainability performance

Conceptual System Design

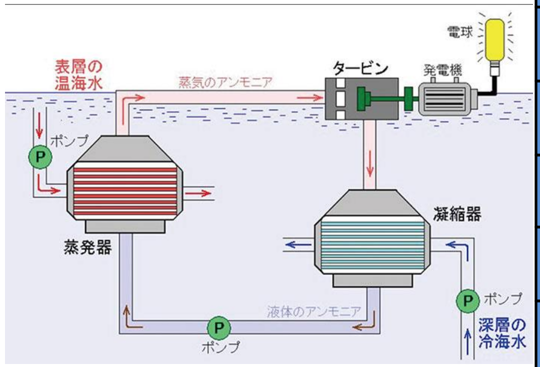


System Components

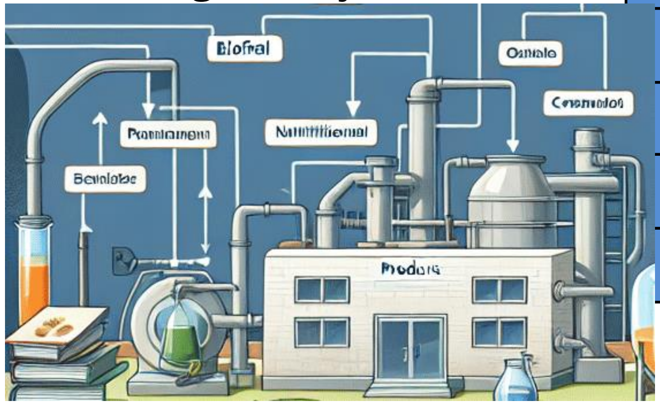
Central Structure

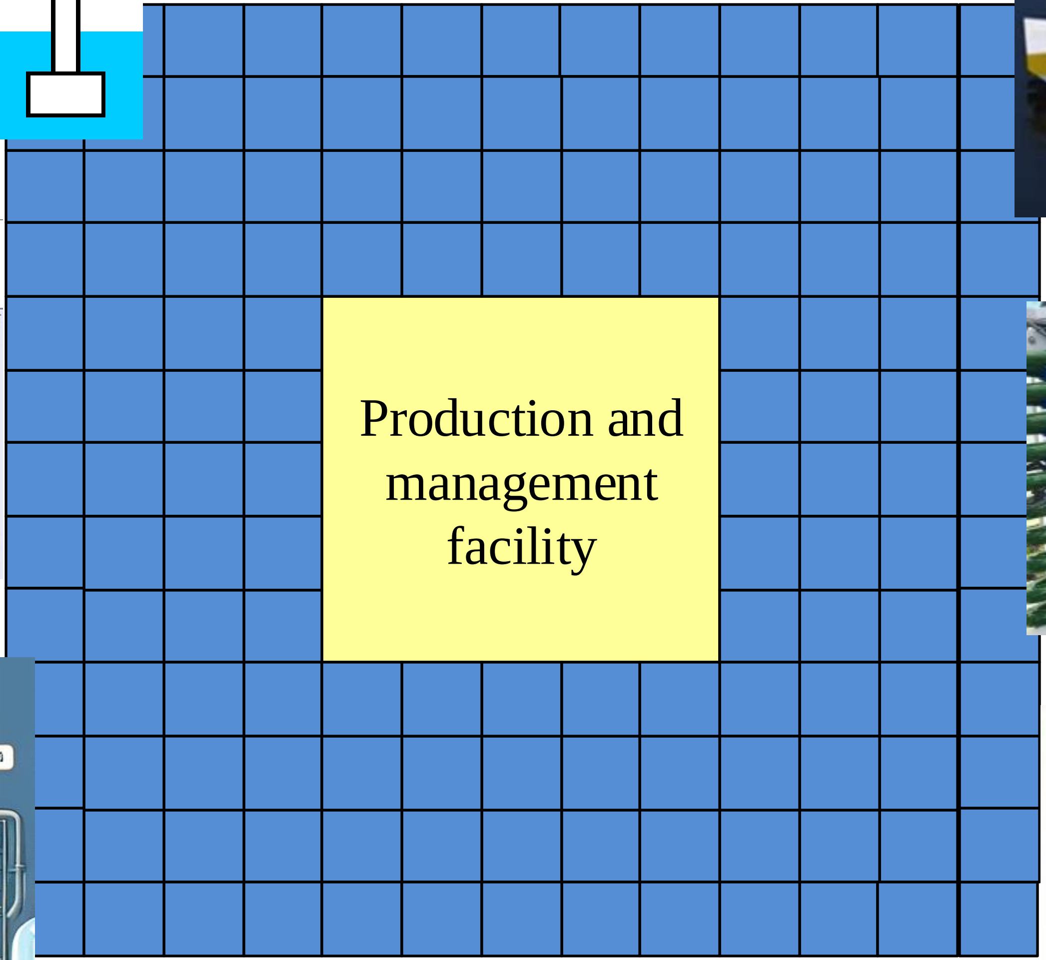


OTEC

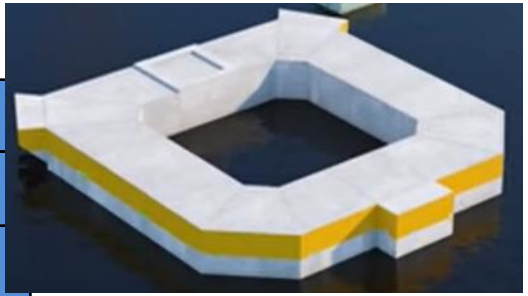


Processing facility

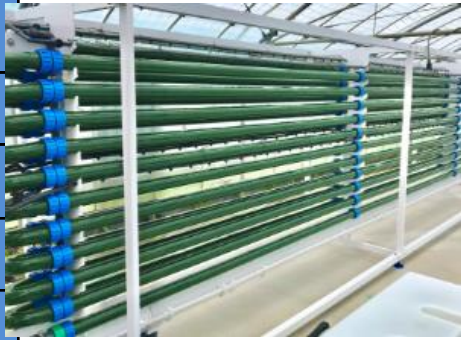




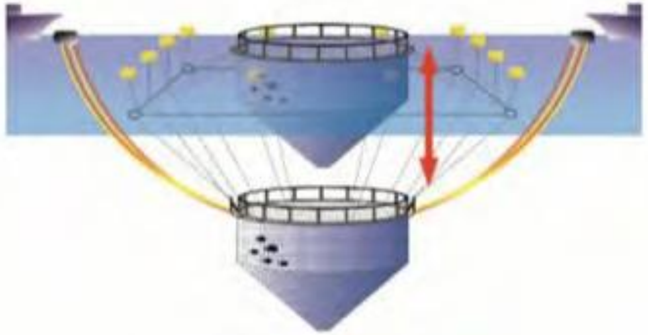
Surrounding Structure



Photoreactor



Cage



OTEC

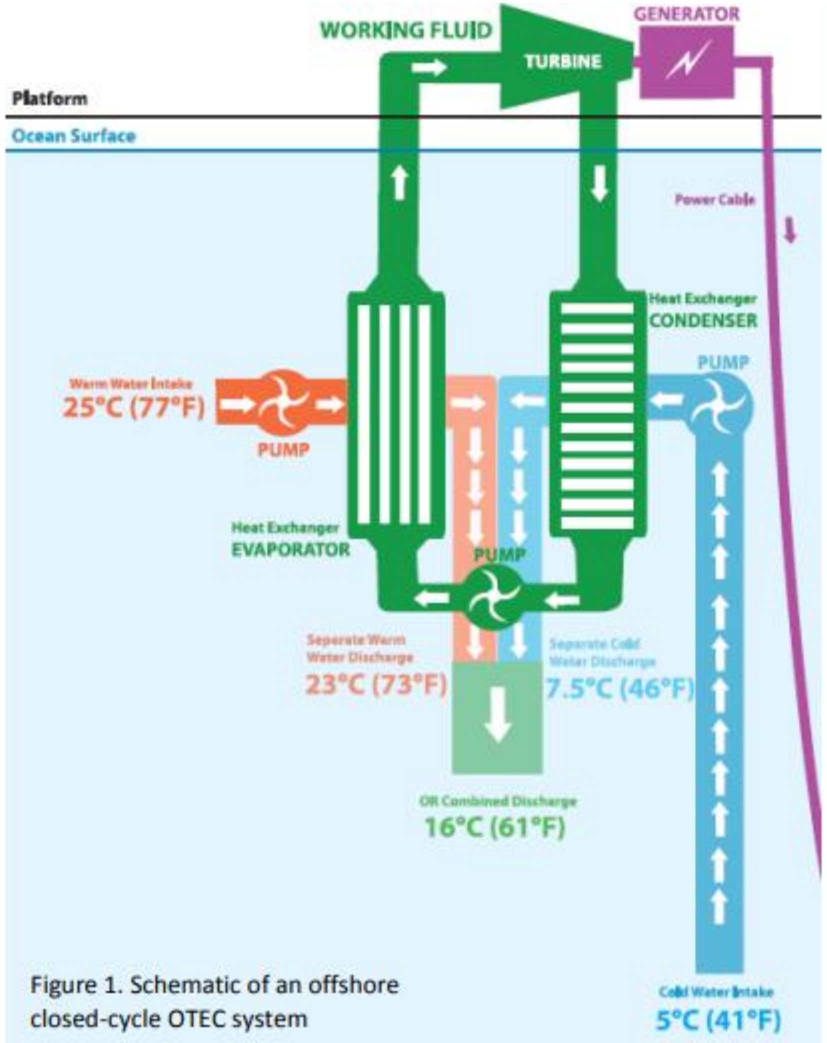


Figure 1. Schematic of an offshore closed-cycle OTEC system

Sources: NOAA

SST °C	Generation kW	Consumption kW	Output kW
19-20	9250	5200	4050
20-21	10650	5200	5450
21-22	12000	5200	6800
22-23	13350	5200	8150
23-24	14600	5200	9400
24-25	15800	5200	10600
25-26	16950	5200	11750
26-27	18000	5200	12800
27-28	19000	5200	13800
28-29	20000	5200	14800
29-30	20850	5200	15650
30-31	21200	5200	16000

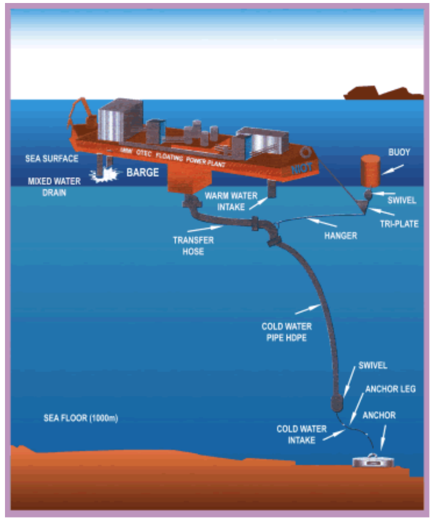
Outputs of a 10MW OTEC（Deep sea water temperature 5.5℃）

Sources: Report on power generation demonstration toward advanced utilization of deep sea water (2015)

OTEC

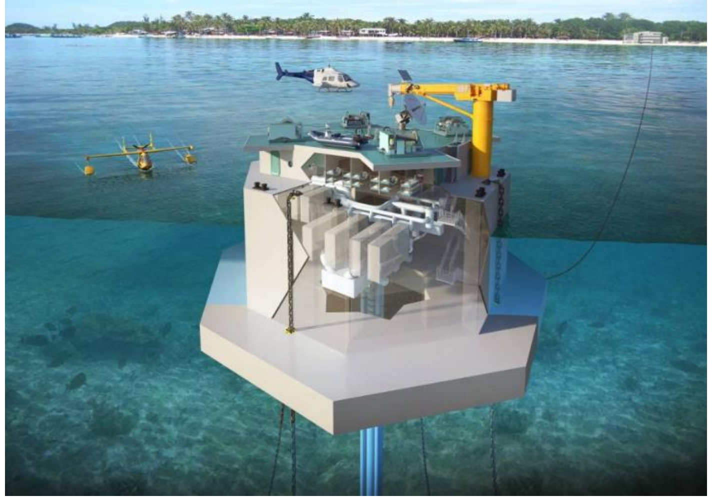
Experimental plant in Hawaii, USA

Demonstration plant in Kumejima, Japan



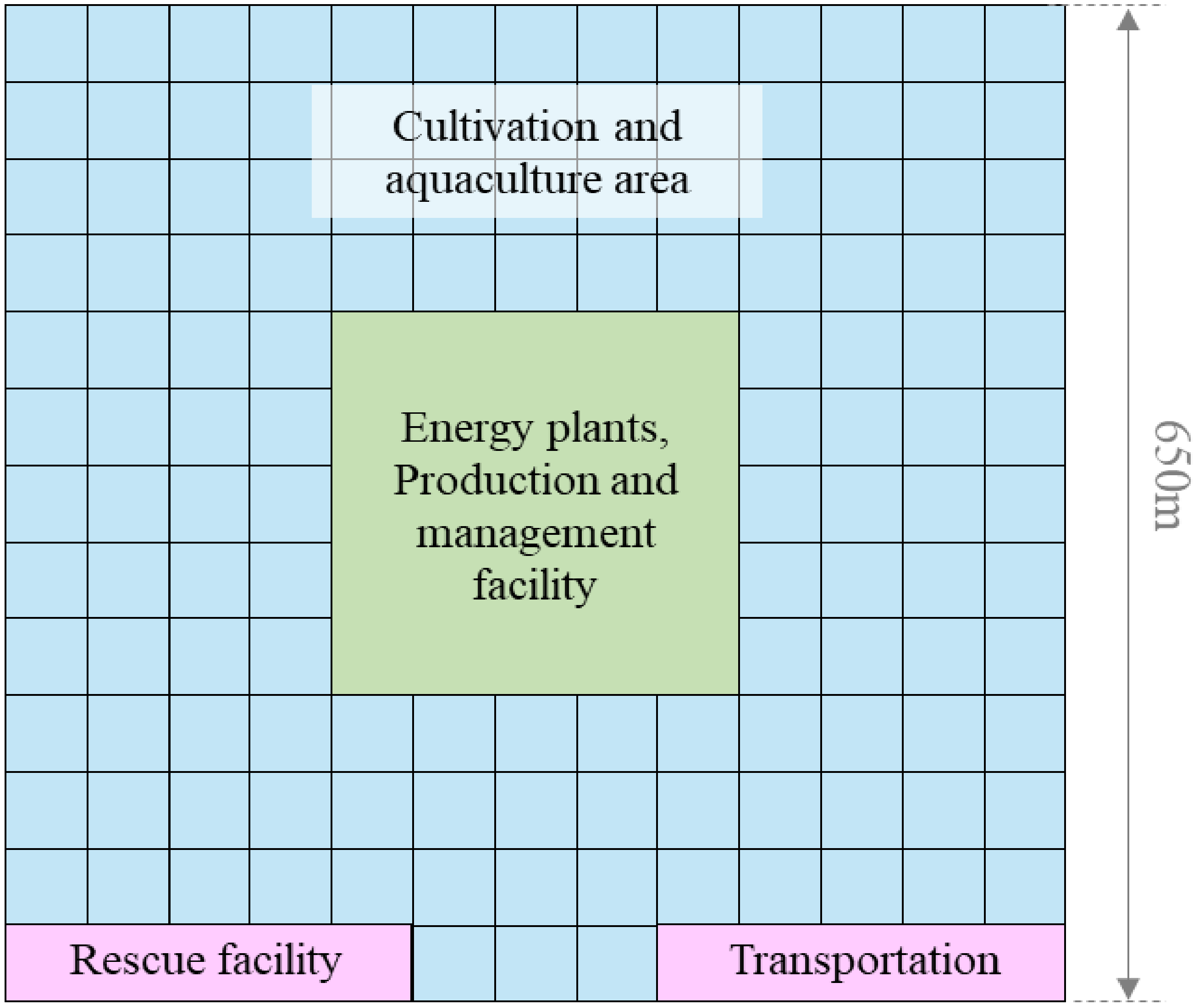
Demonstration plant in Tamil Nadu, India

Preliminary design by Lockheed Martin



Preliminary design by KRISO

Standardized Specific



Specific

Central float size
250*250m
Barge float size
50*50m
Barge float number
134
OTEC capacity
12.5MW
Design life time
50 years
Microalgae
Euglena
Fish
Tuna

Assessment Methods

To evaluate the mitigation capability.

Life cycle carbon footprint

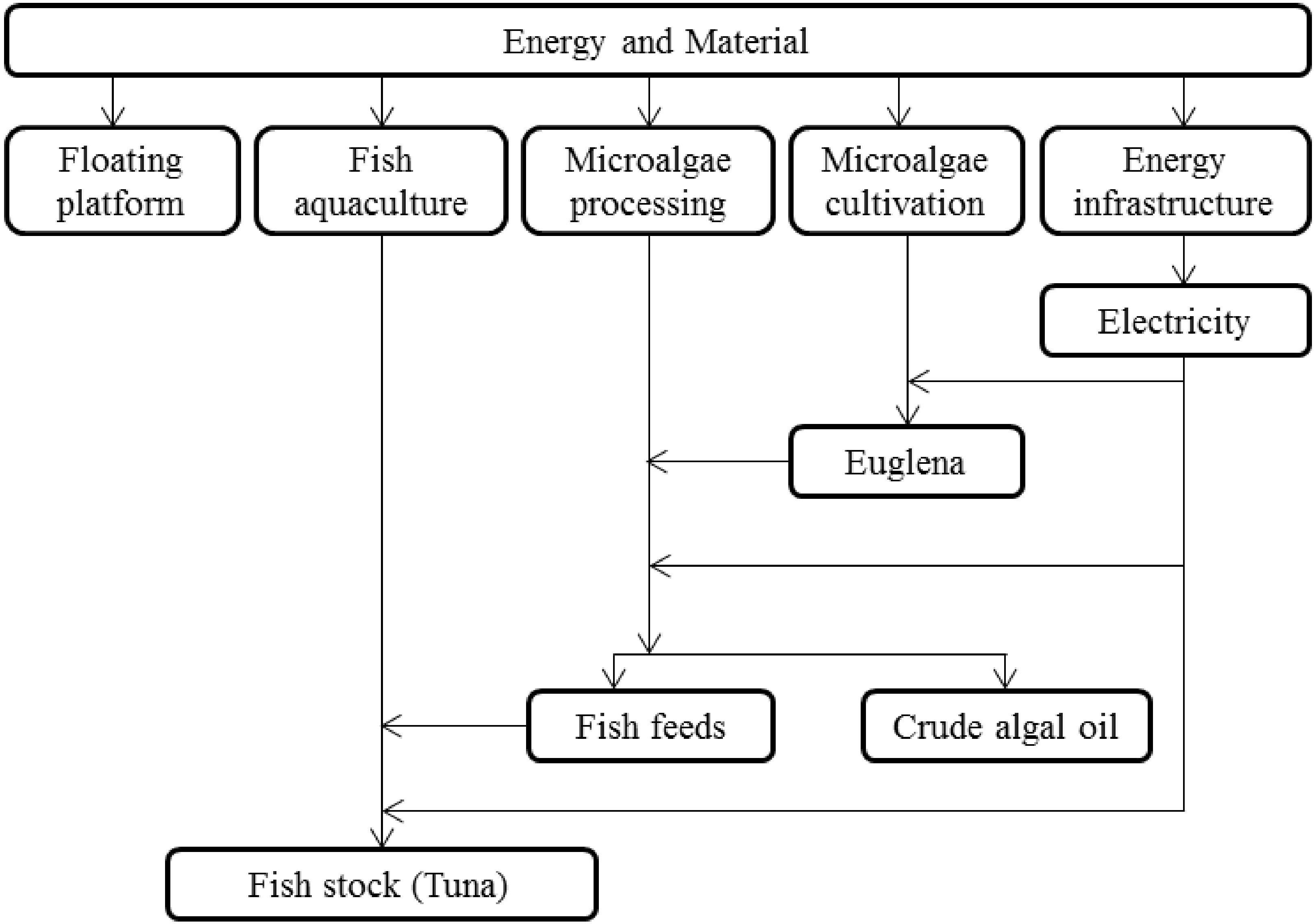
To evaluate the system sustainability

$$III_{light} = (EF - BC) + \gamma(C - B)$$

EF: *Ecological Footprint* BC: *Bio-capacity* C: *Cost* B: *Benefit* γ: ration of EF to GDP

	Cost	Benefit
Environment	Material production Operation	Replace the traditional production Replace the fossil fuel Ocean fertilization effect
Economy	Life time input	Revenue of fish stock and fuels

Carbon Footprint Boundary



Case Studies

Case 1: feasibility study in the South China Sea

Case 2: application potential analysis in east and southeast Asia

Case 3: application possibility in sub-tropic offshore area

Case 1: production and carbon footprint

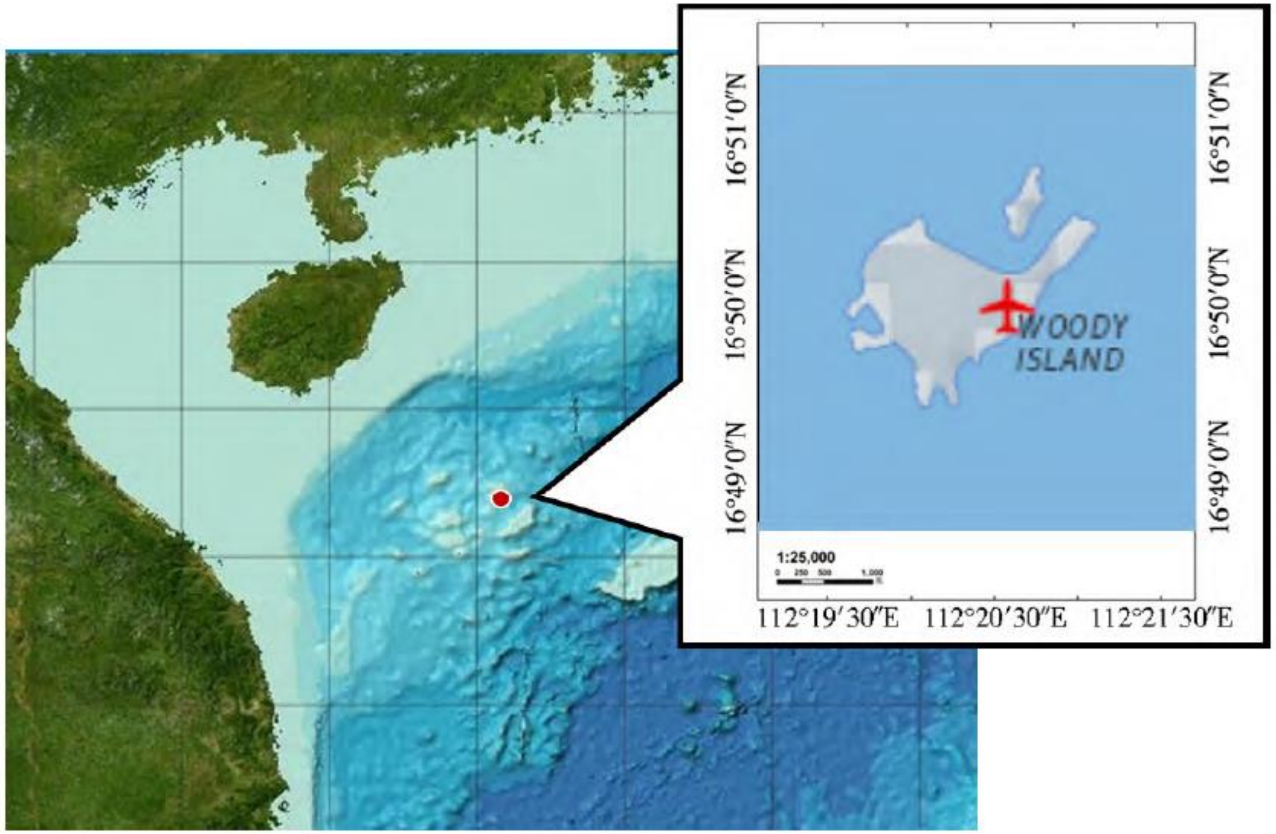
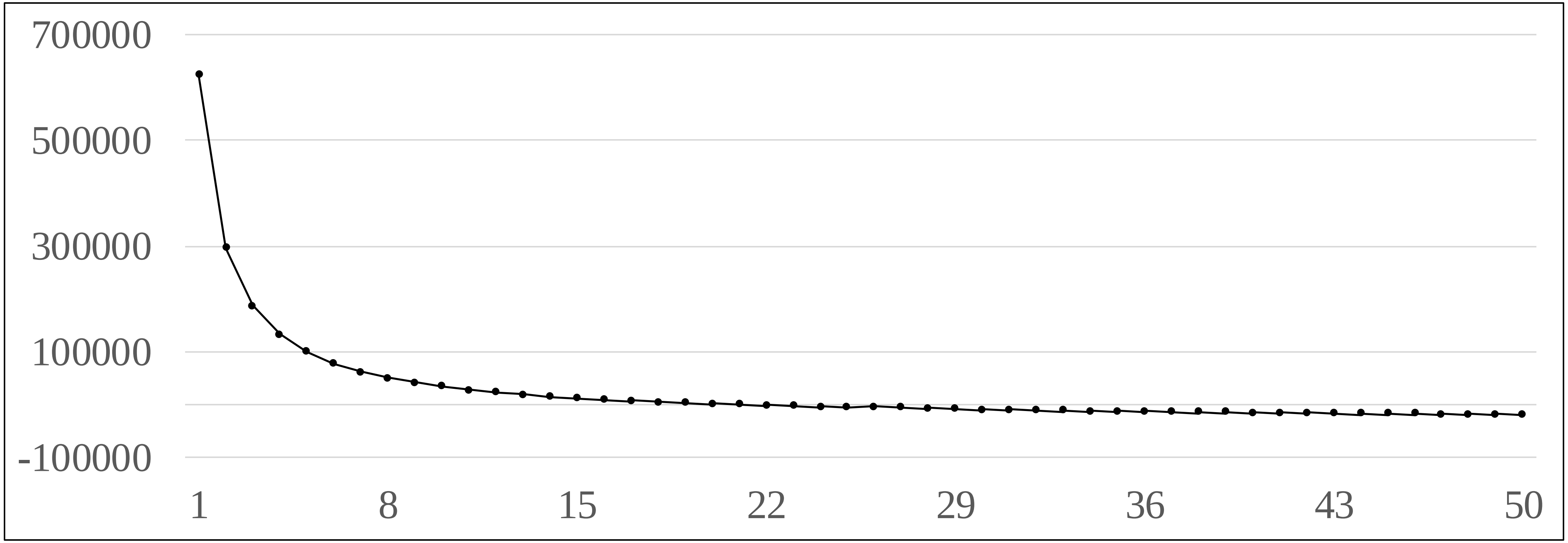


Fig.2.5 The geographical location of Woody Island

Operation period	265 days
Algal oil production	1,963t
Tuna production	2,400t

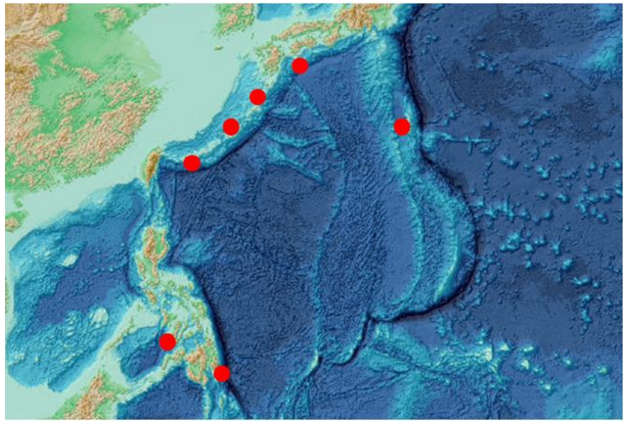
Total CO2 emissions	Total CO2 avoidance and removal	Annual CO2 reduction
1,801,256t	2,629,200t	16,500t

Case 1: system sustainability performance



EF (1,000gha)	BC (1,000gha)	Cost (Billion Yen)	Benefit (Billion Yen)	III_{light} (1,000gha)
9.42	29.32	7.81	6.63	-18.41

Case 2: production and carbon footprint



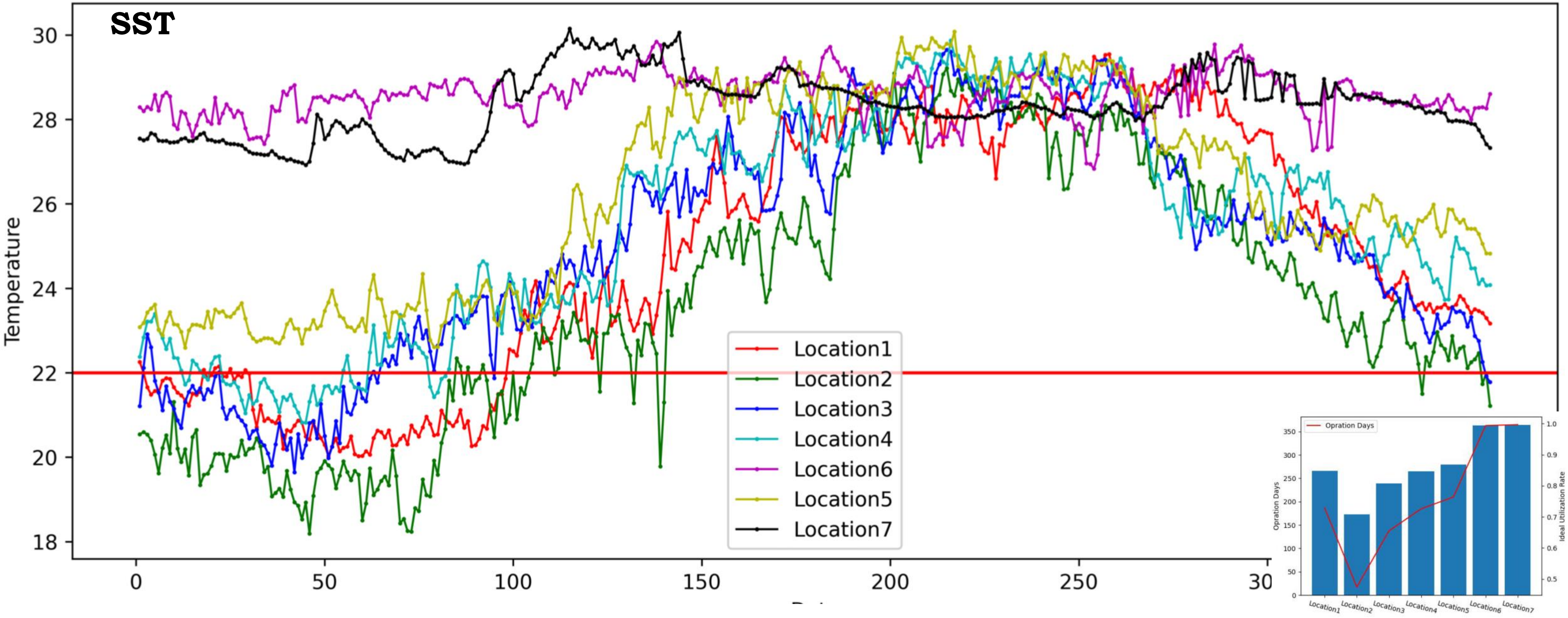
	1	2	3	4	5	6	7
Operation period (days)	226	173	239	265	279	363	364
Algal oil production (ton)	1870	1495	1886	1823	2070	3052	3061
Tuna production (ton)	2287	1828	2306	2229	2531	3732	3742

Application	1	2	3	4	5	6	7
CO2 emissions (tons)	1,772,249	1,655,765	1,777,255	1,758,059	1,834,443	2,138,394	2,140,999
CO2 avoidance and removal (tons)	2,421,843	1,911,537	2,477,136	2,501,110	2,771,166	3,933,817	3,944,654
Annual CO2 reduction (tons)	12,992	5,115	13,998	14,861	18,734	35,908	36,073

Case 2: system sustainability performance

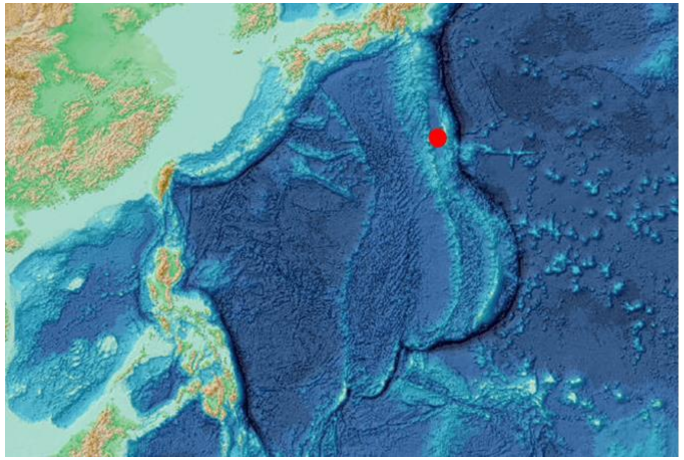
Application	1	2	3	4	5	6	7
EF (1,000gha)	9.27	8.66	9.29	9.19	9.59	11.18	11.20
BC (1,000gha)	25.87	20.08	26.95	28.70	30.88	41.77	41.88
Cost (Billion Yen)	7.76	7.54	7.77	7.73	7.88	8.45	8.46
Benefit (Billion Yen)	6.31	5.05	6.37	6.15	6.99	10.30	10.33
III_{light} (1,000gha)	-14.63	-7.52	-15.77	-17.29	-20.35	-34.71	-34.86
Sustainable year	24th	33rd	23rd	22nd	20th	14th	14th

Case 2: influence factor analysis



Operation rate in sub-topic areas is relative lower than tropic area, thereby the production decrease causes the poorer sustainability performance.

Case 3: carbon footprint



Option 1	To combine a wind power generation system with a capacity of 11.2MW
Option 2	To scale up the OTEC capacity to 23MW

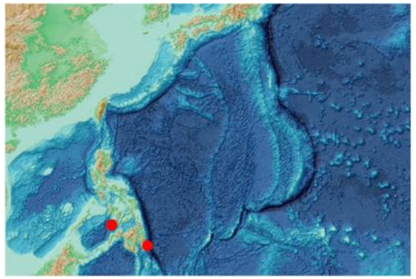
	CO_2 emissions (tons)	CO_2 avoidance and removal (tons)	Annual CO_2 reduction (tons)
Option 1	1,646,705	3,839,000	43,846
Option 2	1,631,532	4,883,800	97,676

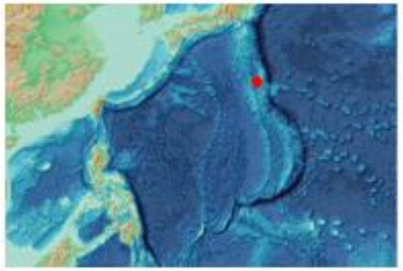
Case 3: system sustainability performance

Application	Option 1	Option 2
EF (1,000gha)	8.70	8.64
BC (1,000gha)	26.10	37.45
Cost (Billion Yen)	8.53	8.73
Benefit (Billion Yen)	10.46	11.19
III_{light} (1,000gha)	-19.84	-31.91
Sustainable year	19th	15th

Sensitivity Analysis

Effect of ocean fertilization
Modified estimations by reducing the effect for several cases





Option 1	To combine a wind power generation system with a capacity of 11.2MW
Option 2	To scale up the OTEC capacity to 23MW

	CO_2 emissions (tons)	CO_2 avoidance and removal (tons)	Annual CO_2 reduction (tons)	Annual economic benefit (Billion Yen)
No. 6 in Section 3.2	2,138,394	2,791,394	13,060	1.85
No. 7 in Section 3.2	2,140,999	2,799,084	13,162	1.87
Option 1 in Section 3.3	1,646,705	2,706,050	21,187	1.93
Option 2 in Section 3.3	1,631,532	2,799,200	23,353	2.46

Summary

- A conceptual system integrated ocean energy utilization, micro algae cultivation, marine aquaculture, and biological productivity enhancement based on an offshore floating platform was designed for the purpose of realizing negative CO2 emissions.
- The efficacy of removing CO2 was estimated by life time carbon footprint, and the sustainability of the system itself was evaluated by introducing the inclusive index III_{light}, which is calculated based on ecological footprint, bio-capacity, cost and benefit.
- The assessment results of case studies suggested the system could be self sustained and beneficial to climate change mitigation in large ocean area.
- Further examinations, especially from the viewpoints of the floating structure and marine aquaculture, are essential to realize the concept.

Thank You Very Much
For Your Attention!

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