

OTEC ODA 4 RMI with CMI **for sustainable Food, Energy and Water resilience**



Hyeon-Ju Kim (hyeonju@kriso.re.kr)

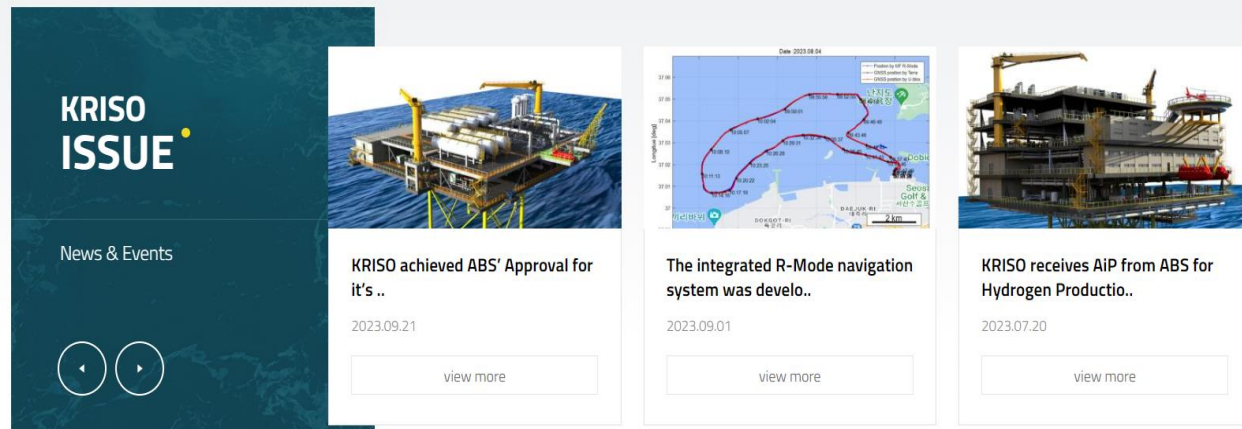
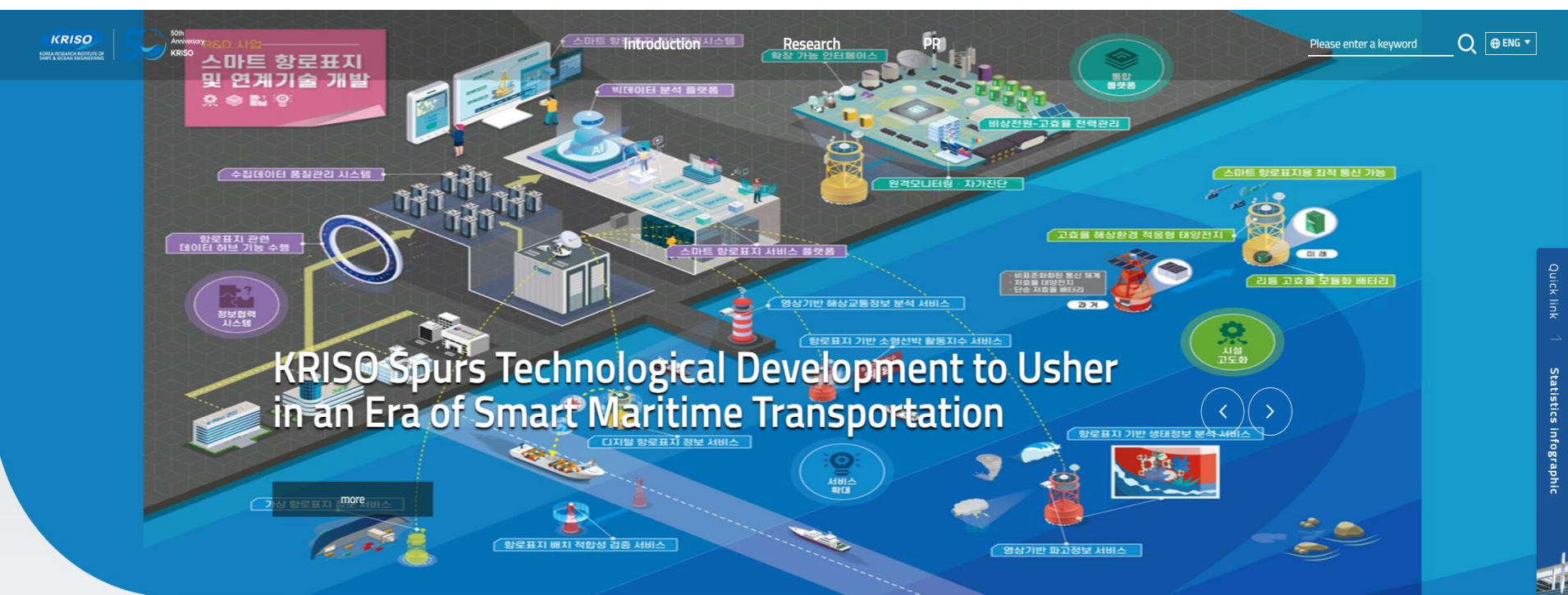
Director of Research Strategy

Seawater Energy Plant Research Center (SEPRC)

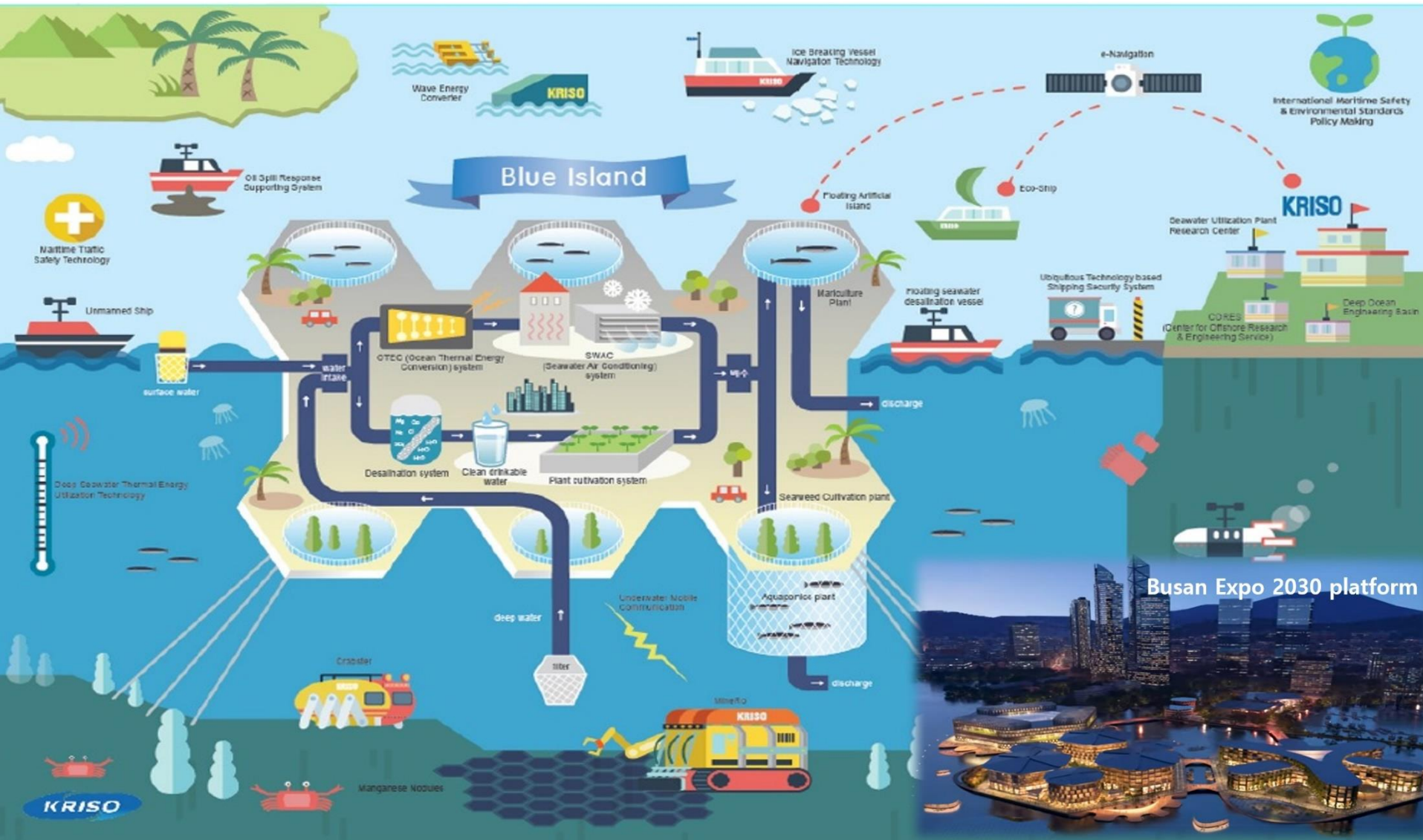
Korea Research Institute of Ships and Ocean Engineering (KRISO)

Ministry of Oceans and Fisheries(MOF) of Republic of Korea

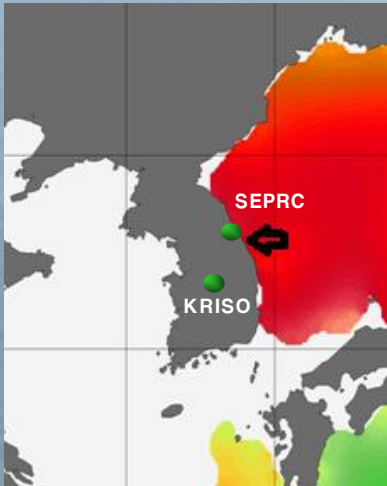
(Korea Research Institute of Ships & Ocean Engineering)







Location of SEPRC, KRISO (Seawater Energy Plant Research Center)





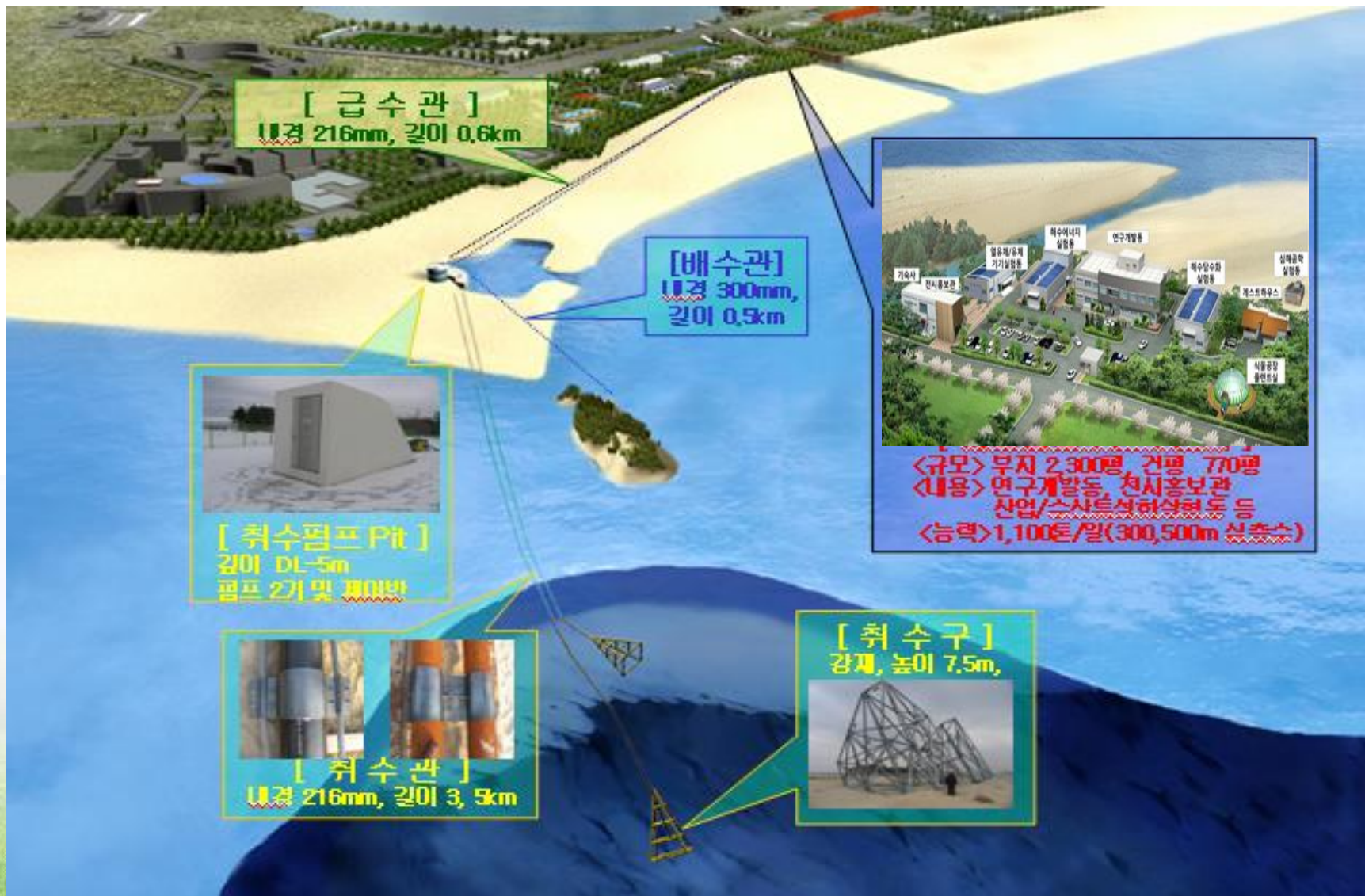
[Establishment of SUPRC (2001~2005)]

- Purpose: R&D of multi-purpose use of DOW
- Capability: 2,000ton/day of 300m/500m DOW
- Construction Period: '04.8 ~ '05.12
- Location: 245-7 Oho-ri, Jukwang-myeon, GW
- Facility : SWAC, OTEC & NF-RO test etc.



[SUPRC Building & Facility]

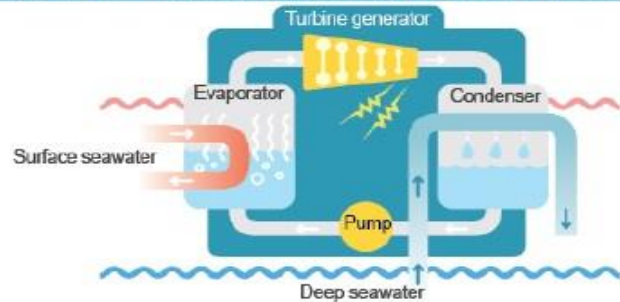
- Area 7,500m², Building 2,310m²
- HQ Bd, SWE Bd, DESAL Bd, Aqua/Agri-CULT Bd, Exhibit. Hall



SUPRC main research areas

SUPRC

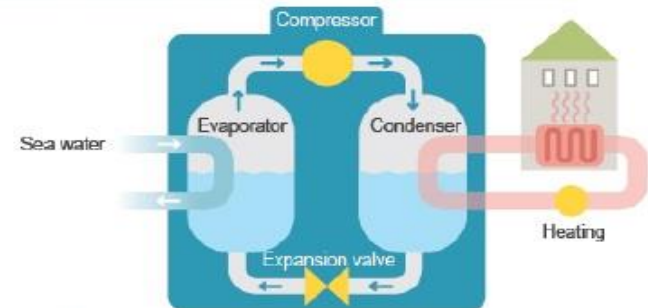
OTEC (Ocean Thermal Energy Conversion) system



- In OTEC, working fluid (R32, etc.) evaporates as it gains heat energy from warm surface seawater, and condenses as it loses heat to cold deep seawater.
- Resulting flow of the working fluid rotates the turbine and generates electricity.

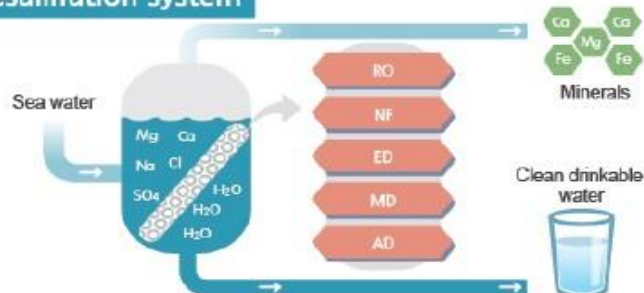
*Closed-cycle, Open-cycle, Hybrid-cycle can be applied for electricity and water

SWAC (Seawater Air Conditioning) system



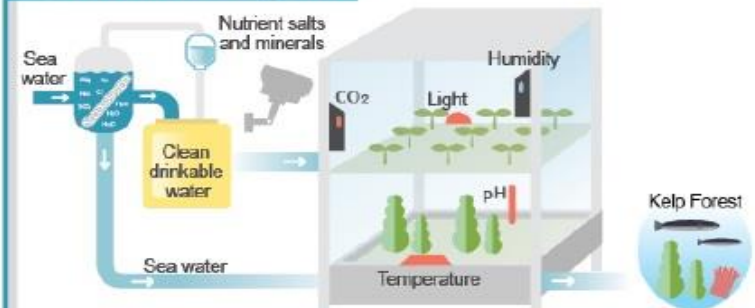
- SWAC utilizes coldness and heat of seawater as heat sources for heat pump for cooling, heating, freezing, and hot water supply.
- Heat pump can switch to cooling if three way valve is used from heating.

Desalination system



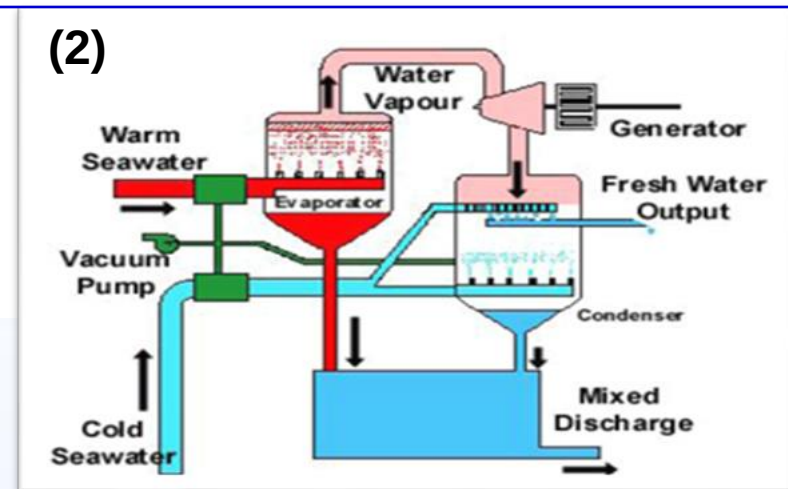
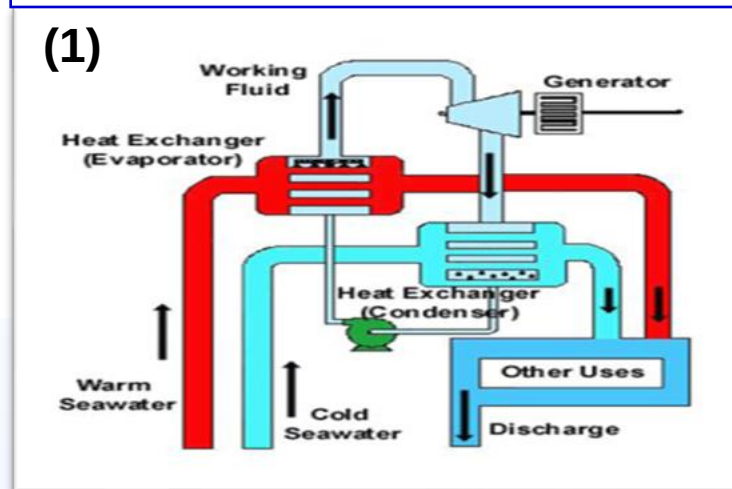
- Membrane desalination technologies turn deep seawater into clean drinkable water.
- Evaporative concentration and electrodialysis technologies extract minerals and produce concentrated deep seawater.
- Membrane technologies: RO(Reverse Osmosis), NF(Nanofiltration), ED(Electrodialysis)
- Extraction technologies: MVR(Mechanical Vapor Recompression), VMD(Vacuum Membrane Distillation), AD(Adsorption Desalination)

Plant cultivation system



- Nutrient salts and minerals from deep seawater are utilized as main components of nutrient solution and seawater-based heat pump controls temperature for optimal growth of marine plants such as seaweeds, microalgae, and land plants such as fruits and vegetables.
- Floating or movable seawater utilization plant cultivation plant (Seawater Farming Plant)

- Electric power can be generated by rotating a turbine using gaseous flow of evaporated working fluid. Warm surface and cold deep sea water are used for heat source and sink, respectively. OTEC can be applied in the (1) closed cycle and (2) open cycle modes.



210kW-OTEC(USA'93)



50kW-OTEC(Japan'13)



15kW-OTEC(French'11)



20kW-OTEC(Korea'13)

History of OTEC R&D and Projects



1881 :
d'Arsonval



1930 :Georges
Claude

22kW
In 1930



1974: Hawaii
established
Natural Energy
Laboratory
(NELHA)



1975: NSF OTEC
Studies
(Lockheed, TRW)



1979: 50 kW
Mini-OTEC
(Lockheed & Makai)



1981: OTEC-1
Test
(DOE)



1981: 100kW
OTEC Nauru
Plant
(Toshiba)



1983: CWP At
Sea Test
(TRW for DOE)



1993: 250kW
Open Cycle
(PICTHR)

210kW
In 1993



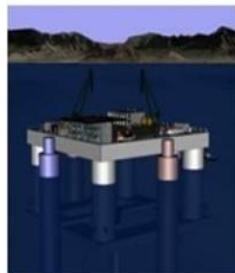
1996-2000:
50kW Hx
testing
(NELHA)



2000: India
1MW OTEC
Plant
(NIOT)



2005: Diego
Garcia
Feasibility
(OCEES SBIR)



2007-present: Pilot
Plant Design
(Lockheed Martin Team)



2011 : 15kW OTEC
(DCNS)



2013 : 50kW OTEC Test
(Saga Univ')

100kW
In 2016



2013 : 20kW OTEC Pilot Plant
(KRISO-OTEC, Korea)

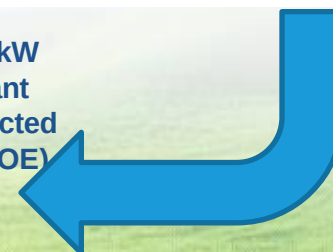


338kW
In 1993

2019 : 338kW
Floating OTEC plant
(K-OTEC 1000, KRISO, Korea)



2015 : 100kW
OTEC plant
Grid-connected
(NELHA/MOE)



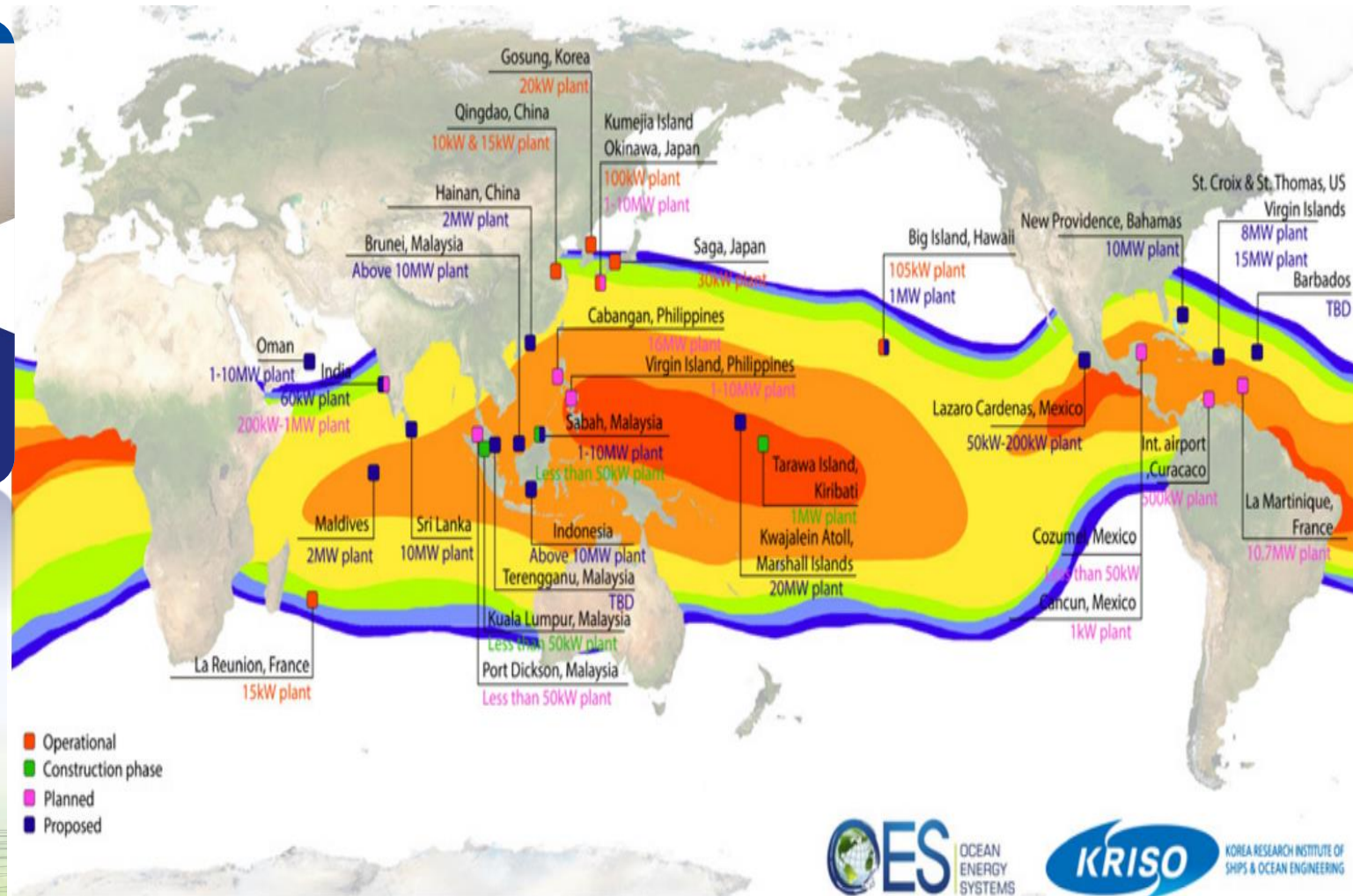
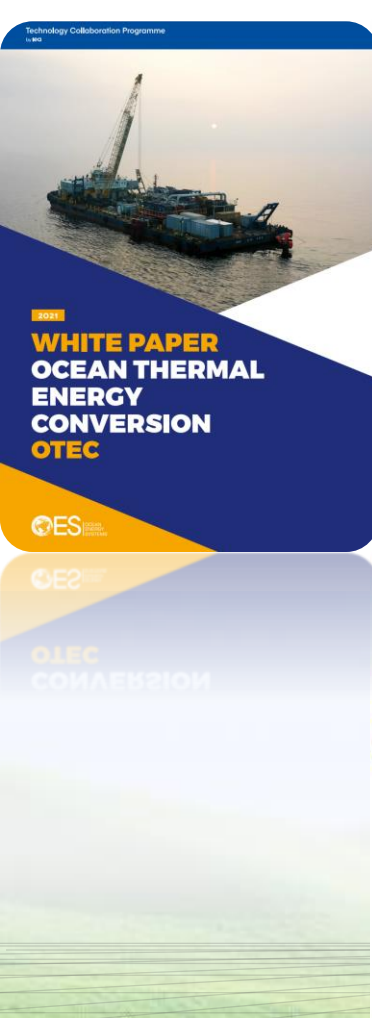


Figure 4.6 Present and future planned OTEC/SWAC projects around the world

Summary data averaged for each stage of deployment, and each technology type

Deployment Stage	Variable	Wave		Tidal		OTEC	
		Min	Max ¹	Min	Max	Min	Max
First array / First Project ²	Project Capacity (MW)	1	3 ³	0.3	10	0.1	5
	CAPEX (\$/kW)	4000	18100	5100	14600	25000	45000
	OPEX (\$/kW per year)	140	1500	160	1160	800	1440
Second array/ Second Project	Project Capacity (MW)	1	10	0.5	28	10	20
	CAPEX (\$/kW)	3600	15300	4300	8700	15000	30000
	OPEX (\$/kW per year)	100	500	150	530	480	950
	Availability (%)	85%	98%	85%	98%	95%	95%
	Capacity Factor (%)	30%	35%	35%	42%	97%	97%
	LCOE (\$/MWh)	210	670	210	470	350	650
First Commercial-scale Project	Project Capacity (MW)	2	75	3	90	100	100
	CAPEX (\$/kW)	2700	9100	3300	5600	7000	13000
	OPEX (\$/kW per year)	70	380	90	400	340	620
	Availability (%)	95%	98%	92%	98%	95%	95%
	Capacity Factor (%)	35%	40%	35%	40%	97%	97%
	LCOE (\$/MWh)	120	470	130	280	150	280

LCOE of K-OTEC (KRISO)

Conditions	Even price
Basis	\$0.39/kWh
CDM 20\$/t	\$0.38/kWh
Reduce initial cost : 15%	\$0.34/kWh
Reduce initial cost : 30%	\$0.30/kWh

KRISO's Goal

\$380~390/MWh

< 1MW OTEC >

2025

\$190~200/MWh

< 10MW OTEC >

2030

\$90~100/MWh

< 100MW OTEC >

2035

Rank	Country	Price (¢/kWh)	Electricity supply(%)	Renewable Energy Production (MWh)	Renewable Energy Percentage(%)	Population (thousand)
1	Vanuatu	18~159	27	1328	2	246
2	Solomon Islands	80~85	15	2365.3	3.1	552
3	Cook Islands	44~65	99	592.8	2	24
4	Kiribati	33~58	90	19.4	0.1	100
5	Tuvalu	31~58	92	200	2	10
6	Niue	41~57	97	90	3	1.6
7	Micronesia	37~56	65	3000	4.3	106
8	Tonga	47	95	15.192	0.03	105
9	Samoa	35~42	95	28.108	0.04	184
10	Nauru	8~41	100	2.057	0.01	10
11	Palau	28.2~40.5	99	67.44	0.1	21
12	Marshall Islands	33~40	90	16.71	0.03	55

IEA-OES (2015.5)

< 2010 >

Basic cycle

Basic cycle

Heat added

Heat added

Generator

Basic cycle

Reheater

Reheater

Turbine 2EA

Basic cycle

Heat added

Generator

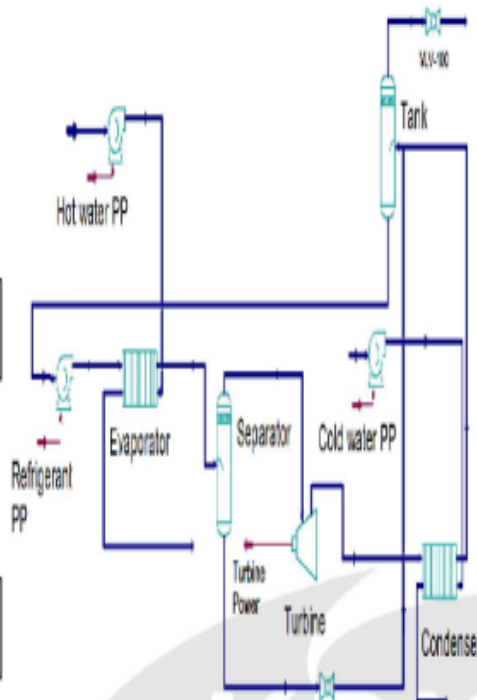
Reheater

Heat added

Generator

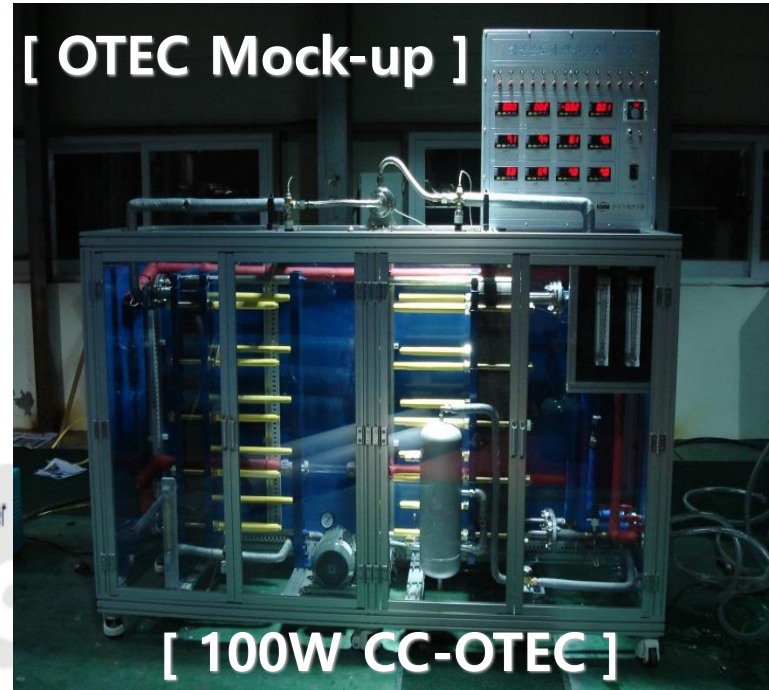
Reheater

Turbine 2EA



[OTEC Mock-up]

[100W CC-OTEC]



Demonstration of 20kW OTEC pilot plant based on R-32 Rankine cycle
developed by Korea Research Institute of Ships and Ocean Engineering

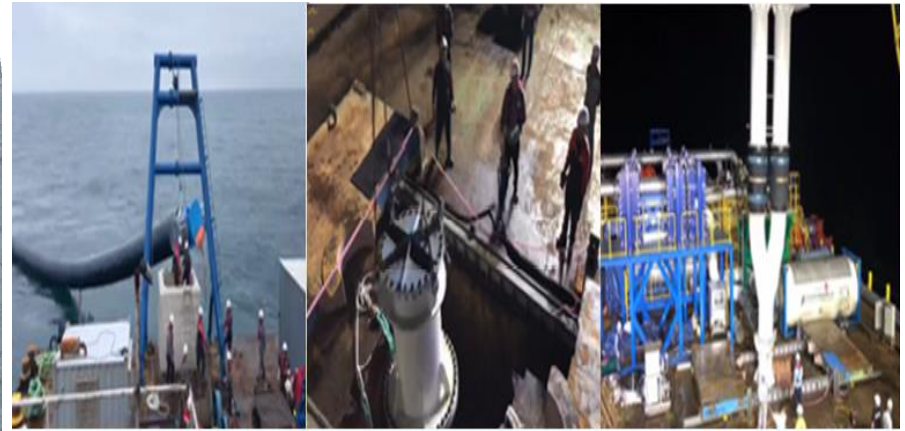
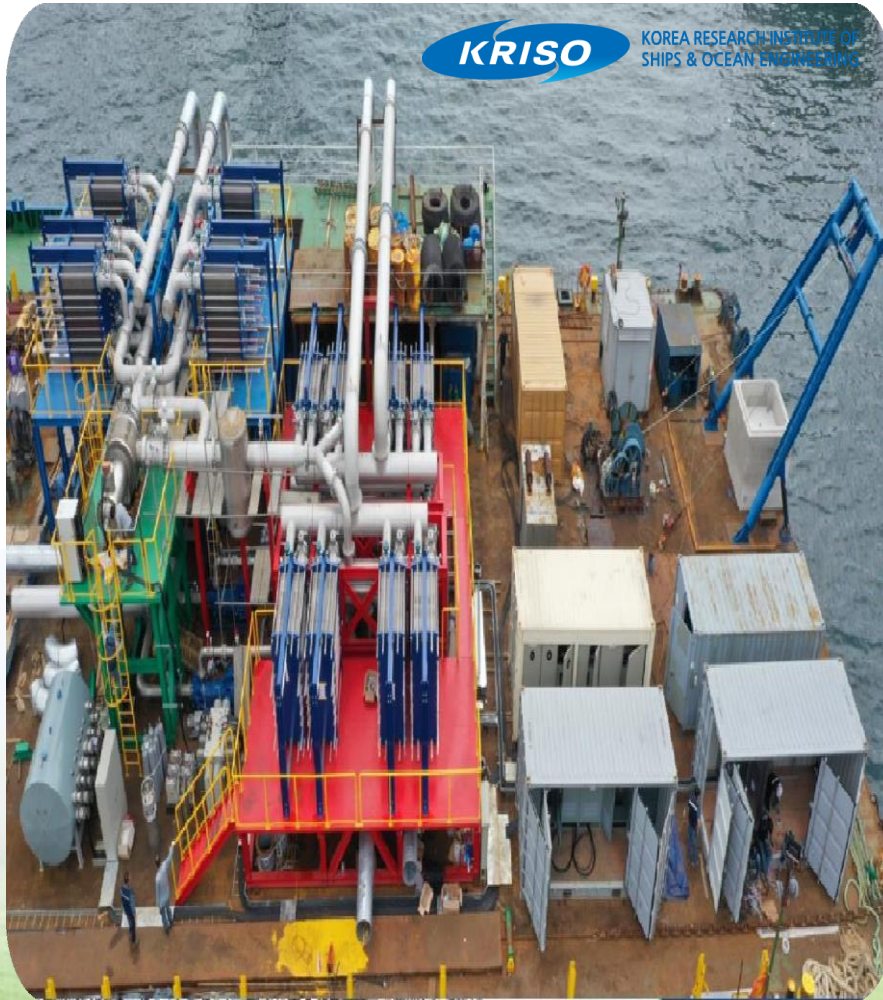
2013. 12. 24



3. OTEC

Assembly and Operation of 1MW OTEC barge

< 2019 >



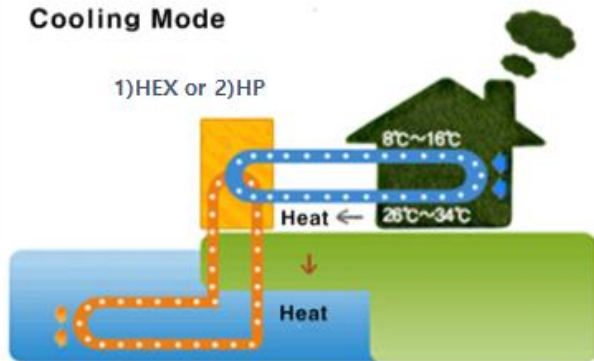
Sea Water Air Conditioning by HP or HEX

- **Air-conditioning source can be acquired from**
 - 1) direct heat exchanger by cold deep ocean water
 - 2) cold heat of evaporator of heat pump by use of seawater as a condensing heat source

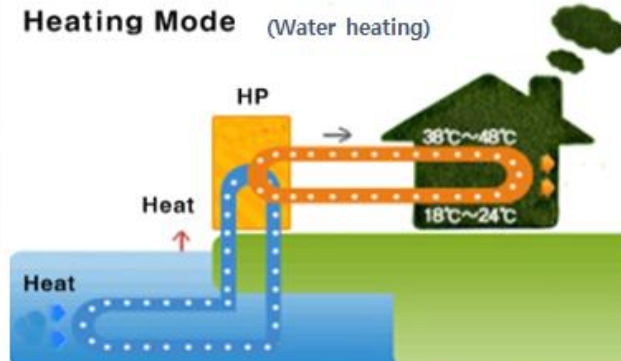


Cooling Mode

1)HEX or 2)HP



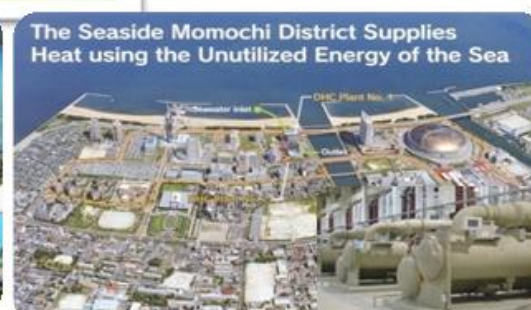
Heating Mode (Water heating)



HEX & HP (SUPRC, KRISO)

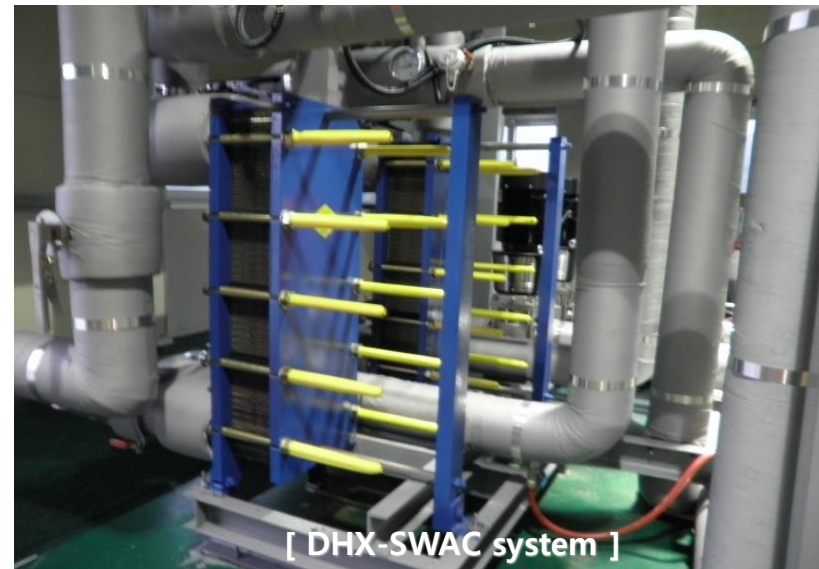


HEX (Resort, Bora Bora)



HP (Momochi district, Japan)

By applying SWAC to SPERC building in 2010, we cut down 80% of energy cost.

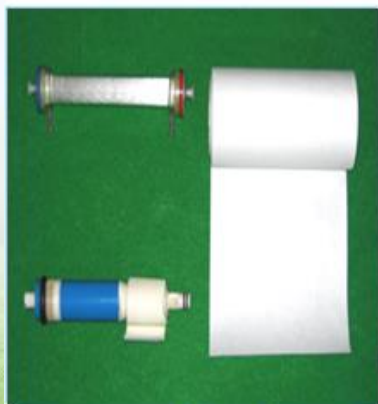
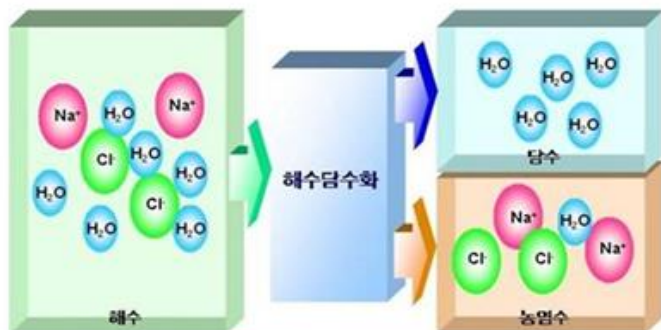


[60RT SWAC systems (DHX & Tandem HP) for SUPRC building]

Seawater Desalination and Extraction

Desalination is the method of desalting salt from seawater to produce drinkable fresh water

- Desalination method : RO, NF, MSF, MED...
- Salt making method : DE, SD, VRSD...



Technology transfer to produce high-priced bottled water from deep sea water

Hydroponics & Aquaponics

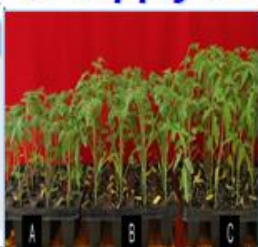
Hydroponics and aquaponics

Seaweed culture in open sea or tank on land

Deep seawater, rich with its nutrient salts, provides most ideal condition for seaweeds. Seaweeds are used as food, cosmetic products, and bioenergy. Also, they absorb carbon dioxide through photosynthesis, which helps reducing global warming.



[Seawater and heat supply for agriculture] [Seawater and heat supply for aquaculture]



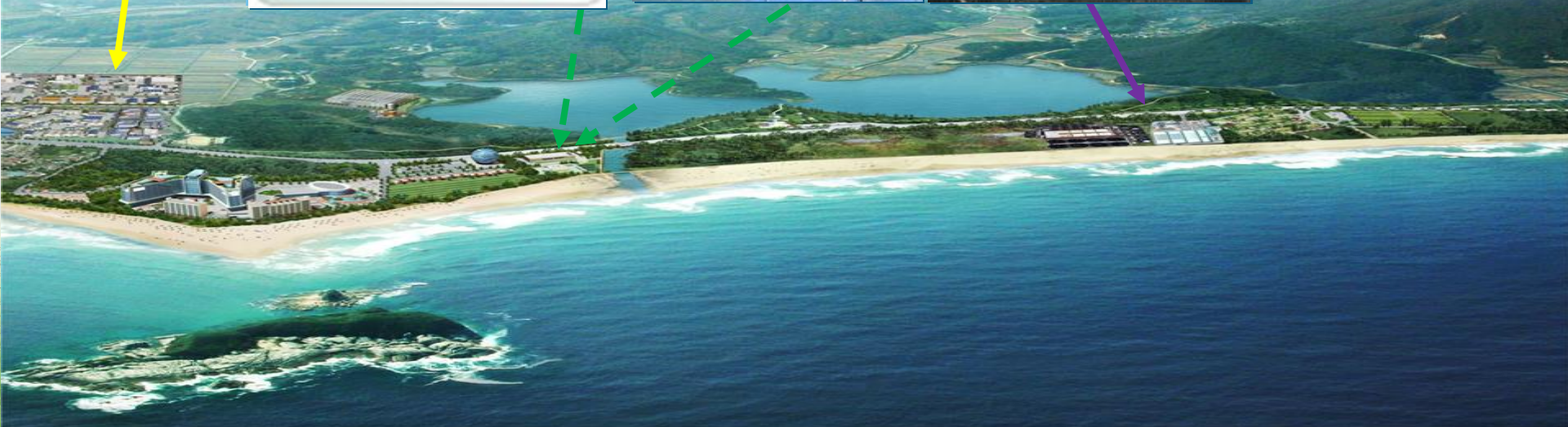
7. Industrialization

Establishment of DOWA Industrial Park

[Bottled water, salt and heat supply for food making]

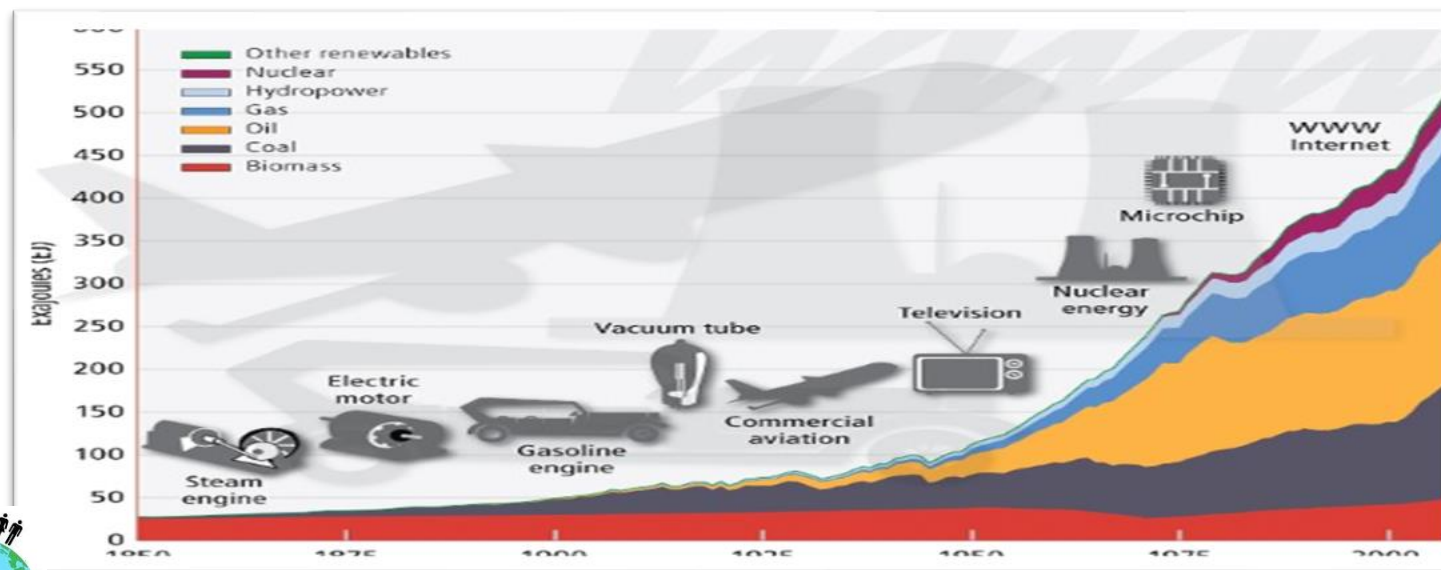


[Seawater and heat supply for aquaculture]

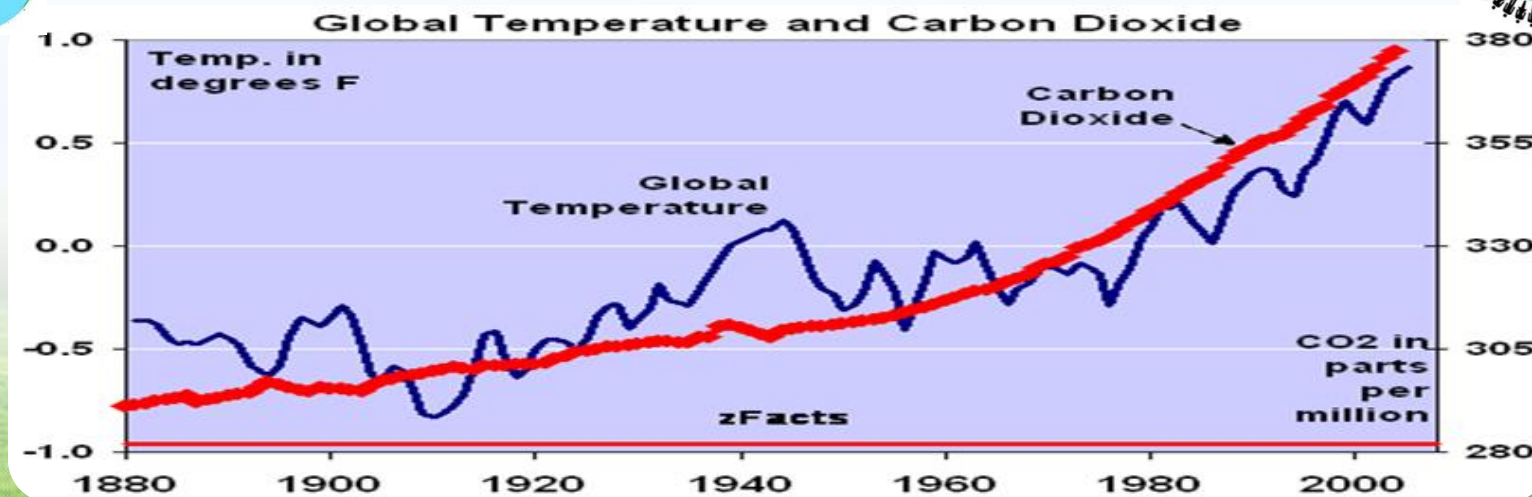


8. Climate Crisis

Energy consumption and CO₂ emission



<http://www.iiasa.ac.at/>



Food Supply affected by climate change

1

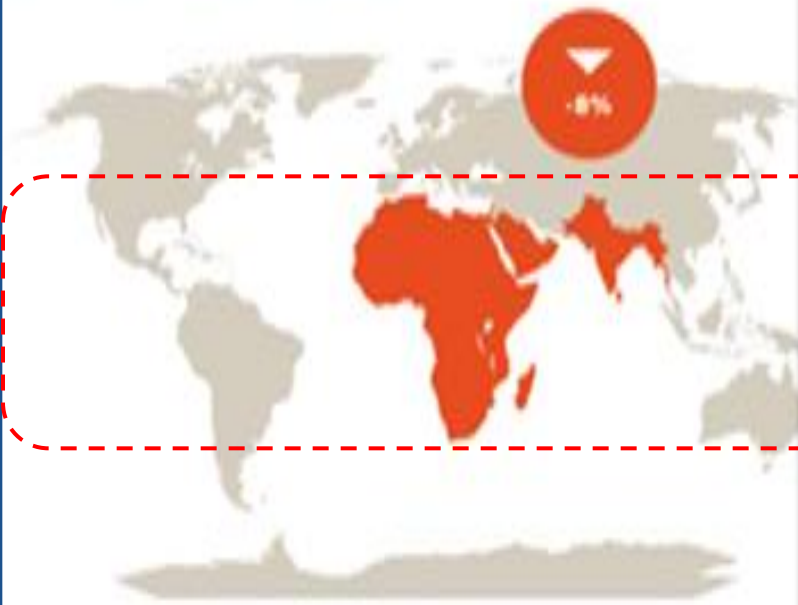
The future of food and farming: 2050s

By 2050, climatic impacts on food security will be unmistakable. There are likely to be 9 billion people on the planet, most people will live in cities and demand for food will increase significantly.

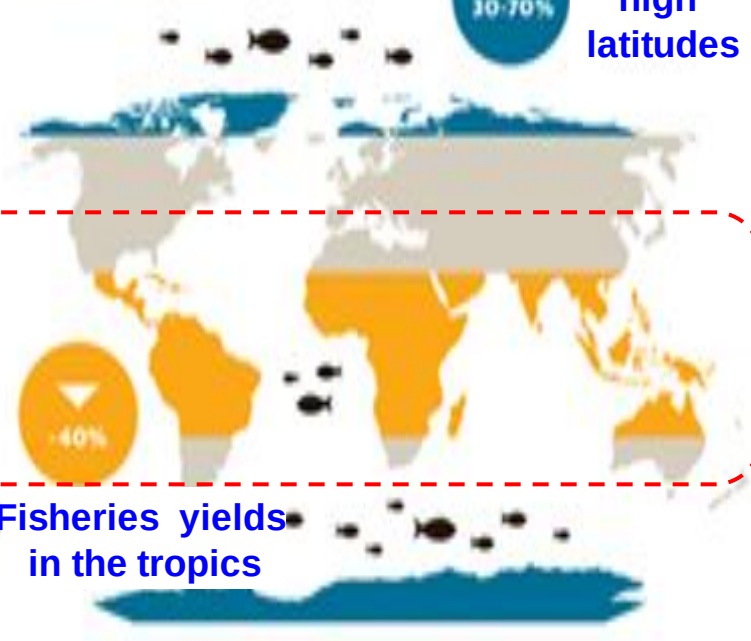


Widespread impacts on food and farming are highly likely

Average decline in yields for eight major crops across Africa and South Asia



Marine fisheries will also be affected



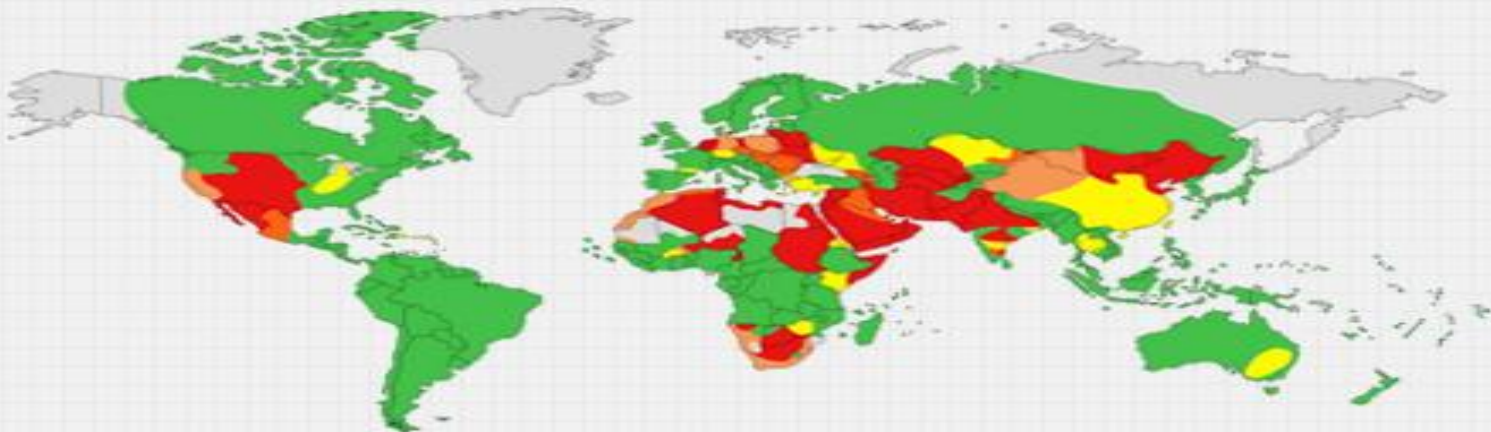
SOURCES: Porter, J. R., Xie, L., Challinor, A., Cochrane, K., Howden, M., Iqbal, M. M., Lobell, D., Travasso, M. I. 2014. Food Security and Food Production Systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. <http://www.ipcc-wg2.gov/> With data from Cheung et al 2010, Cochrane et al 2009, Knox et al 2012



Future of water and water shortage

2

Today: A Look at the World's Water Stressed Areas



% of Population By Water Stress Level



Water Stress Level



% of GDP By Water Stress Level

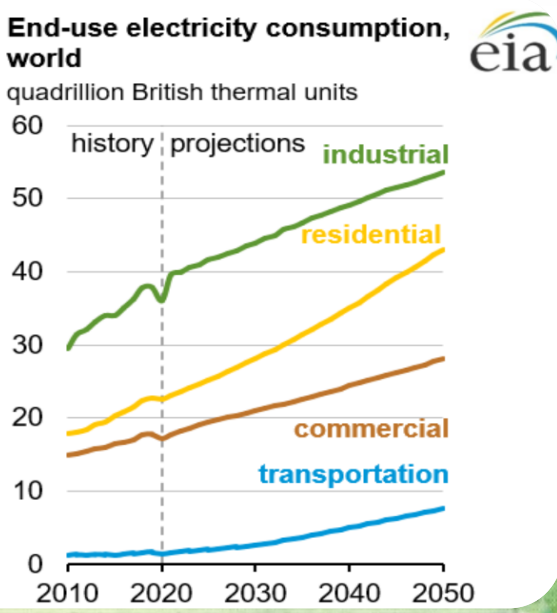
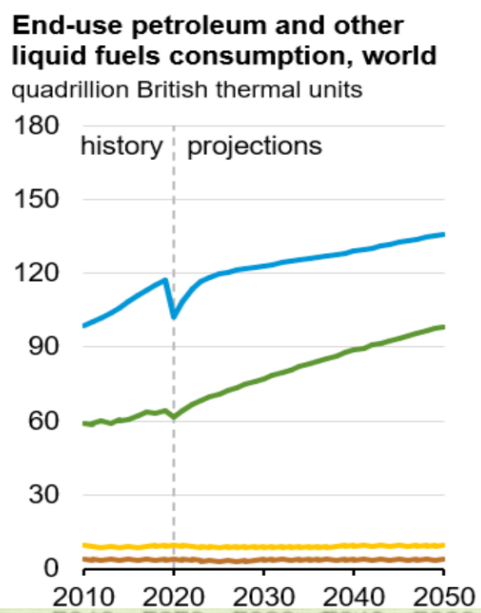
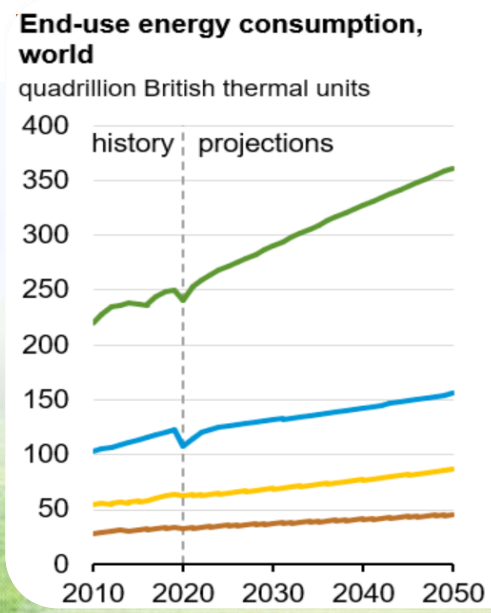
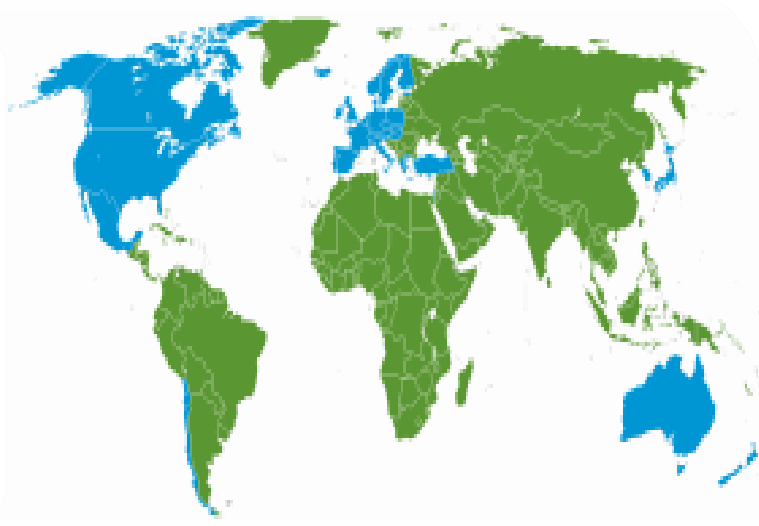
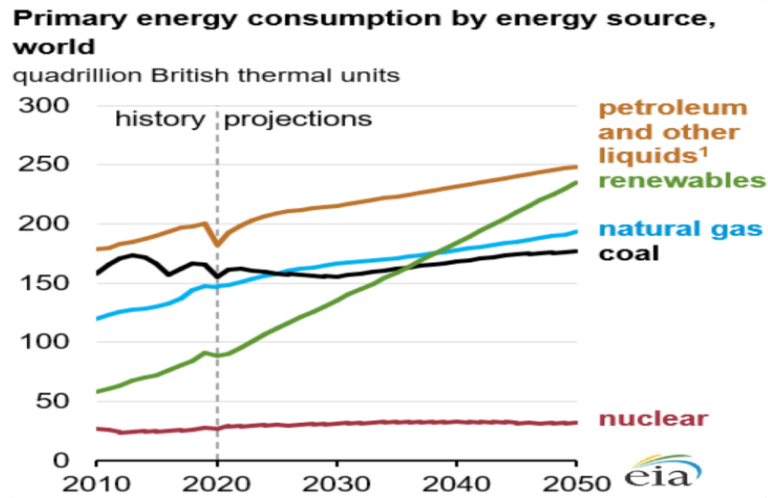


Today, 2.5 billion people, almost 40% of the world's grain production and almost one quarter of the global economy are presently at risk because of non-sustainable water use.

<http://growingblue.com/water-in-2050/>

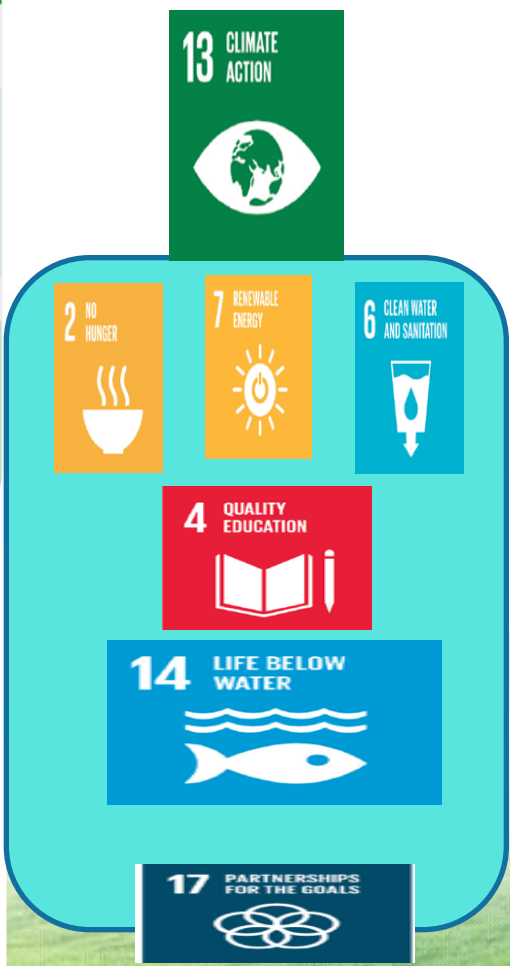
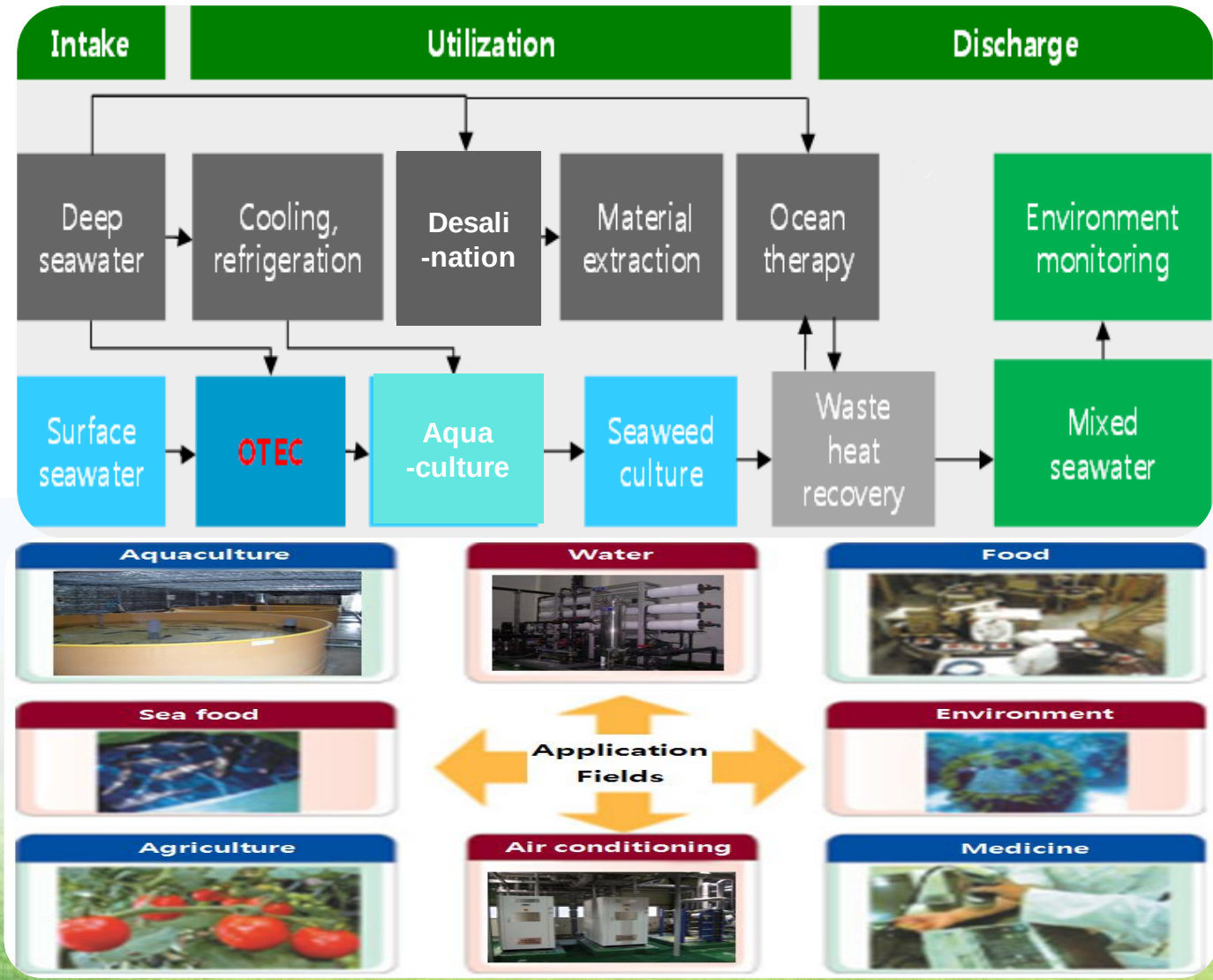
3

World Energy Consumption



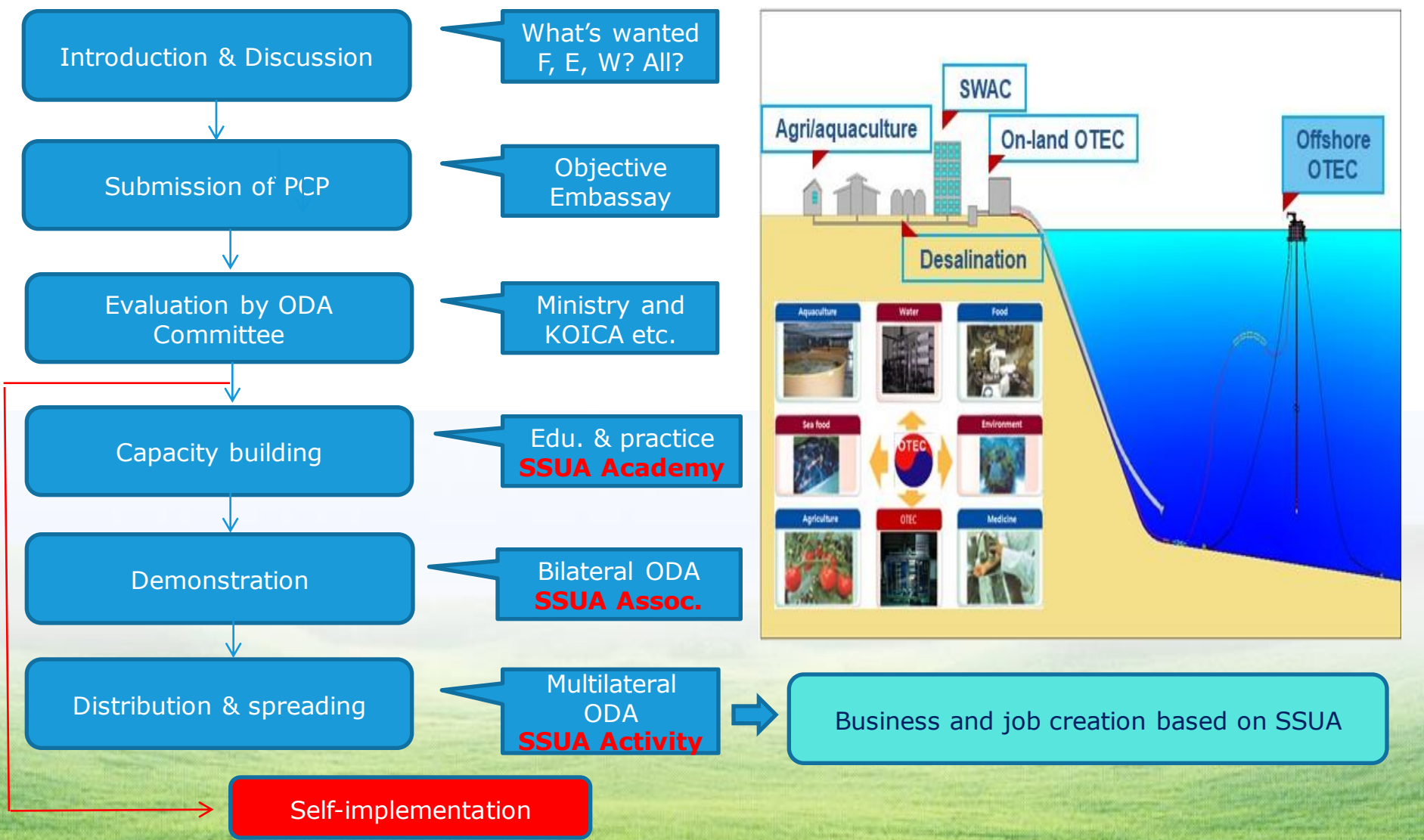
Food, Energy and Water from the Ocean

for UN's Sustainable Development Goals(SDGs) action



Meaningful Capacity Building

Framework of SSUA program for SDGs achievement in PICs



Capacity building program in Tarawa, Kiribati(2016)



Sustainable
Seawater
Utilization
Academy



Prof. K. H. Kim
Chungnam Uni.
Water Quality



Prof. N'Yeurt
USP
Bioenergy



Prof. Michaela
USC
Renewable
Energy and
Entrepreneurship



Prof. Choi
Korea Uni.
Eco-Toilet



Dr. H. J. Kim
KRISO
Program
Manager
OTEC/DOWA



Prof. Nuttall
USP
Logistics/Finance



Prof. H. G. Kim
Gangneung-
Wonju Uni.
Seaweed



Dr. D. S.
Moon
KRISO
Desalination



Prof. J. K. Kim
Cheonnam
Uni.
Marine survey



Dr. H. S. Lee
KRISO
OTEC



Prof. Ahmed
USP
OTEC



Prof. S. G.
Jeon
Hangyang Uni.
Finance



Mark Day
SPC
Coastal
construction



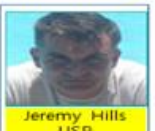
Prof. Albert Kim
UHM
Desalination



Director
Yoon
Seabase
Diving



Prof. W. H.
Kang
Kangwon Uni.
Agriculture



Jeremy Hills
USP
ODA
program



Honorary Advisor
(FP, Kiribati) A. Tong



KRISO Coordinator
S. W. Kim



USP Coordinator
M. Toingaa



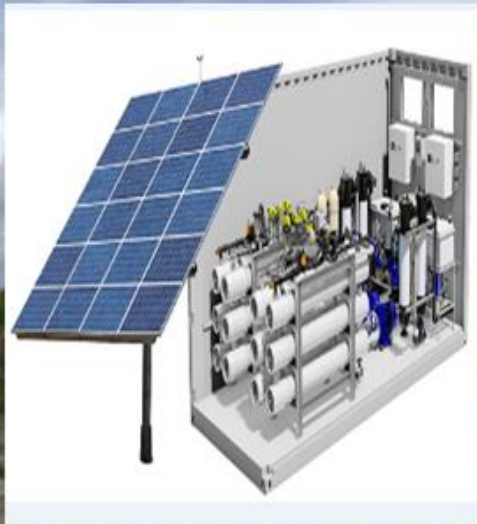
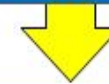
SSUA
Sustainable Seawater Utilization Academy



SSUA Association project (Kiribati; 2018~2020)

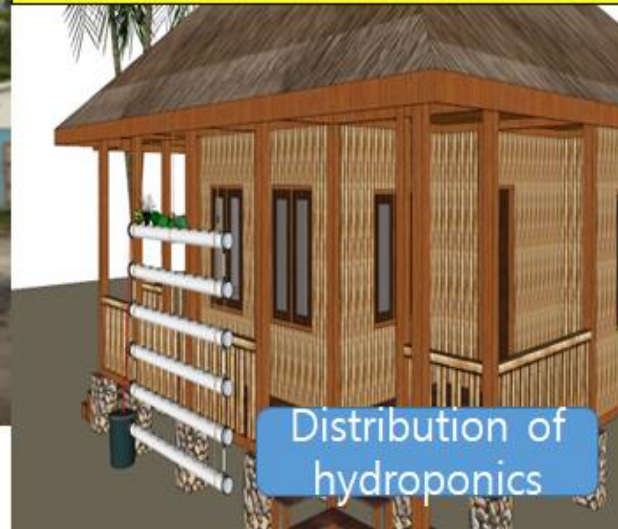


Vegetables and fruits are high in demand
but supply is limited
Price is very expensive
(a stick of carrot sold at 2~3 AUD)
Salinity intrusion and sea-level rise



Solar powered RO system

New model of cultivating food is necessary
-a model that **does not depend on land**
-a model that **maximizes surface area**

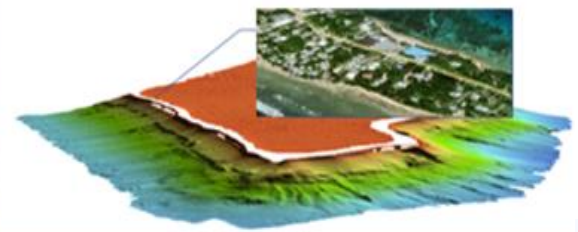
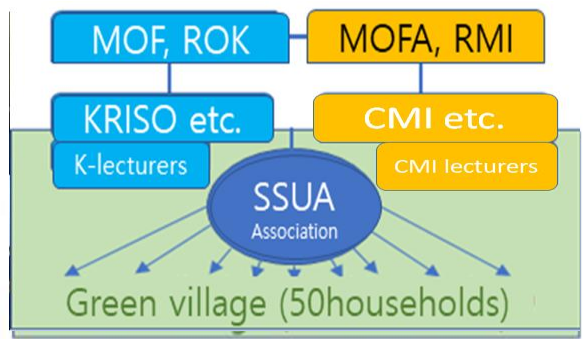
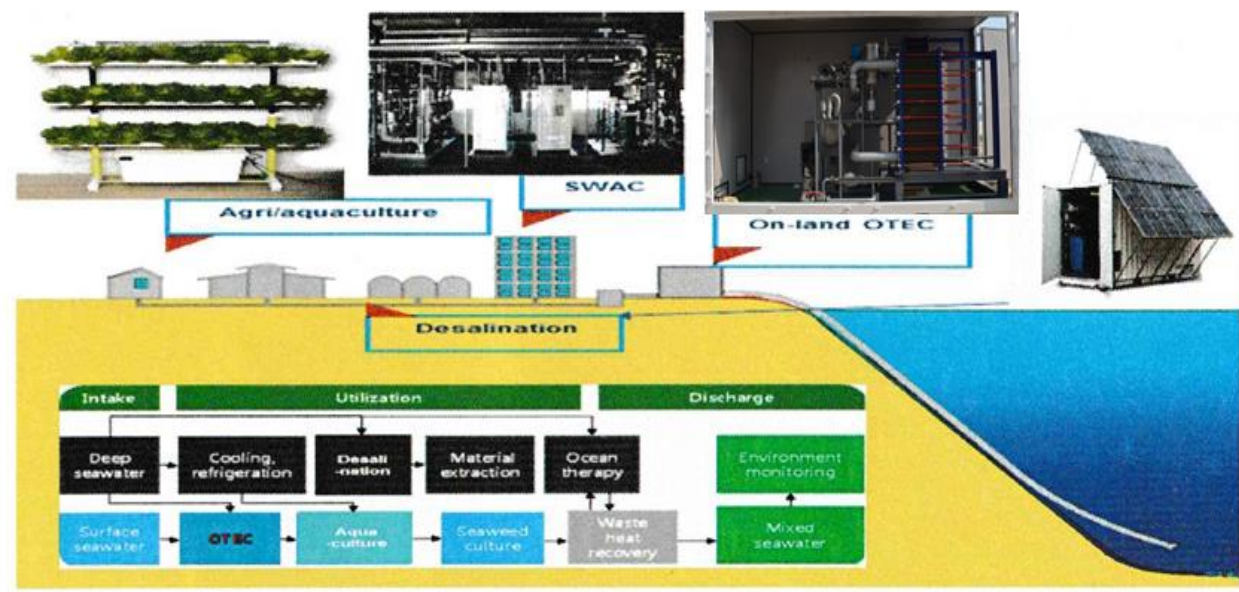


Distribution of hydroponics



OTEC ODA project based on SSUA

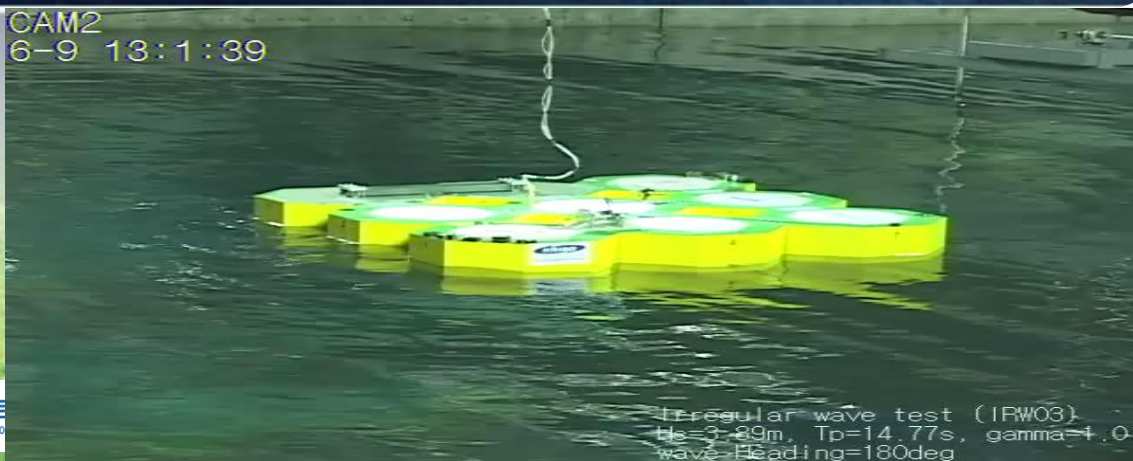
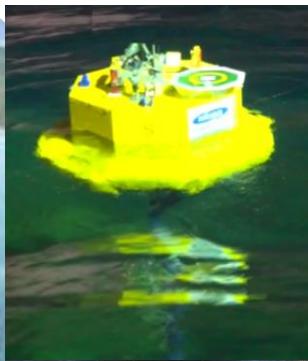
(Majuro, Marshall Islands; 2023~2026)



Component	Details	2023	2024	2025	2026
SSUA	Collaboration with the USP Marshall Islands Campus				
Power supply & cooling	50kW OTEC + 150RT SWAC				
Renewable desalination	PV power supply type 20m³/day				
Renewable hydroponics	100 sets of hydroponic cultivation equipment (3-stage type)				

=> To create an energy-independent green village for 50 homes

Blue Island proposal for tropical SIDS



12. Networking

Join to SNS of SSUA & OTEC



OTEC & SWAC님이 Hyeon Ju Kim님의 상태를 공유했습니다.
10월 25일 · 16

현재 기후변화의 고통을 받고 있는 태평양 도서국가, 키리바시의 Tong 대통령께서 2014.10.21에 강원도 고성의 KRISO 해수플랜트를 찾으셨습니다.
저희가 주장하고 있는 해수자원으로 부터 생존 필수자원인 식량(물(W)을 확보하는 해수플랜트기술의 실용화 가능성에 관심이 있습니다. 저희는 "연중 해수온도가 증분하고, 태풍의 영향도 없... 해안에서 ... 더 보기 (사진 6장)

Welcome to Seawater Utilization Plant Research Center
President Anote Tong
Oct 21, 2014 · KRISO · 100

SSUA
Sustainable Seawater Utilization Academy

게시물 · 정보 · 연금 · 알로워 · 사진 · 동영상 · 더 보기

대표 콘텐츠
SSUA 2016년 12월 23일 · 6
I am so happy to reveal our dream for SSUA in Kiribati to the world.
From now on, all we have to do is to...

태어자 - 커뮤니티
033-630-5010
swkim@kriso.re.kr
kadowa.com
웹사이트 홍보하기

SSUA 2016년 12월 11일 · 1
This video was produced by KRISO to introduce SSUA program that was delivered to Tarawa, Kiribati, in 2016 as ODA project supported by KOICA. Based on this, 100... 더 보기

SSUA님이 회원님의 게시물을 공유했습니다.
Ju Kim [?] · 5월 10일 · 6

SSUA Kiribati campus에서 개최되고 있습니다.

SSUA4GCF Workshop
2016.5.9-2016.12.30 / USP Kiribati campus

Facebook interface showing two pages: OTEC & SWAC and SSUA.

OTEC & SWAC
페이지 · 메시지 · 알림 · 인사이트 · 게시 도구

홍보하기 · 이번 주 · 9 게시물 도달 · 5 게시물 참여 · 0 웹사이트를 탐색

최근 · 2015년 · 2014년 · 2013년

SSUA
Kiribati by Upwelling Seawaters
홍보하기 · 이번 주 · 13 게시물 도달 · 3 게시물 참여 · 0 웹사이트를 탐색

최근 · 2015년 · 2014년 · 2013년

태어자 - 커뮤니티 · Jay Cho님 외 친구 76명 · 이번 주 게시물 도달 13명

KRISO 선박해양플랜트연구소
KOREA RESEARCH INSTITUTE OF SHIPS & OCEAN ENGINEERING

Join to SNS of RMI-SSUA





SSUA-RMI
@ssua.rmi

[+ 스토리에 추가](#) [프로필 편집](#)

[아바타로 만들기](#)
[커버 사진 수정](#)

[대표 사진 추가](#)

사진

사진 모두 보기



 **SSUA-RMI**
8시간 · 🌐

We, the Korean OTEC ODA team, landed at Majuro air port last night, and started to meet EPA, MOFA and MOE etc. to ask support for our activity. We are so delighted to meet RMI friends here.





32