International Collaboration on Seaweed Biomass Supply & Industrialization

Oct. 24, 2023

Kyung Suk SEO(kseo@kimst.re.kr)

World Ocean Forum
2023.10.24~26

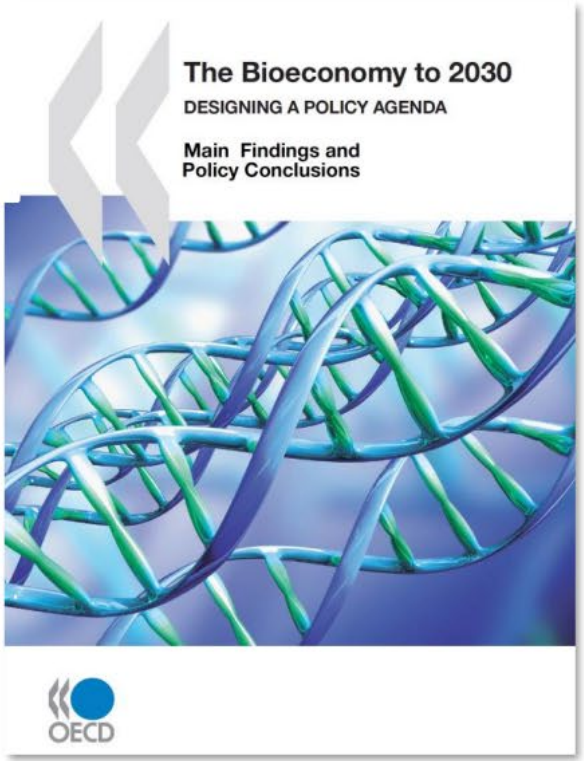
KIMST
해양수산과학기술진흥원

CONTENTS

WOF
World Ocean Forum
2023.10.24~26


KIMST
해양수산과학기술진흥원
I. Bio-Economy
WOF
World Ocean Forum
2023.10.24~26

Prospective OECD Reports for Bio-Economy(2009) & Marine Biotech.



1st OECD MBT Report (2013)

2nd OECD MBT Report (2017)

For Official Use DSTI/STP/BNCT(2016)10

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development

18-Jul-2016

English - Or. English

DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INNOVATION
COMMITTEE FOR SCIENTIFIC AND TECHNOLOGICAL POLICY

DSTI/STP/BNCT(2016)10
For Official Use

Working Party on Biotechnology, Nanotechnology and Converging Technologies

MARINE BIOTECHNOLOGY: DEFINITIONS, INFRASTRUCTURES AND DIRECTIONS FOR INNOVATION

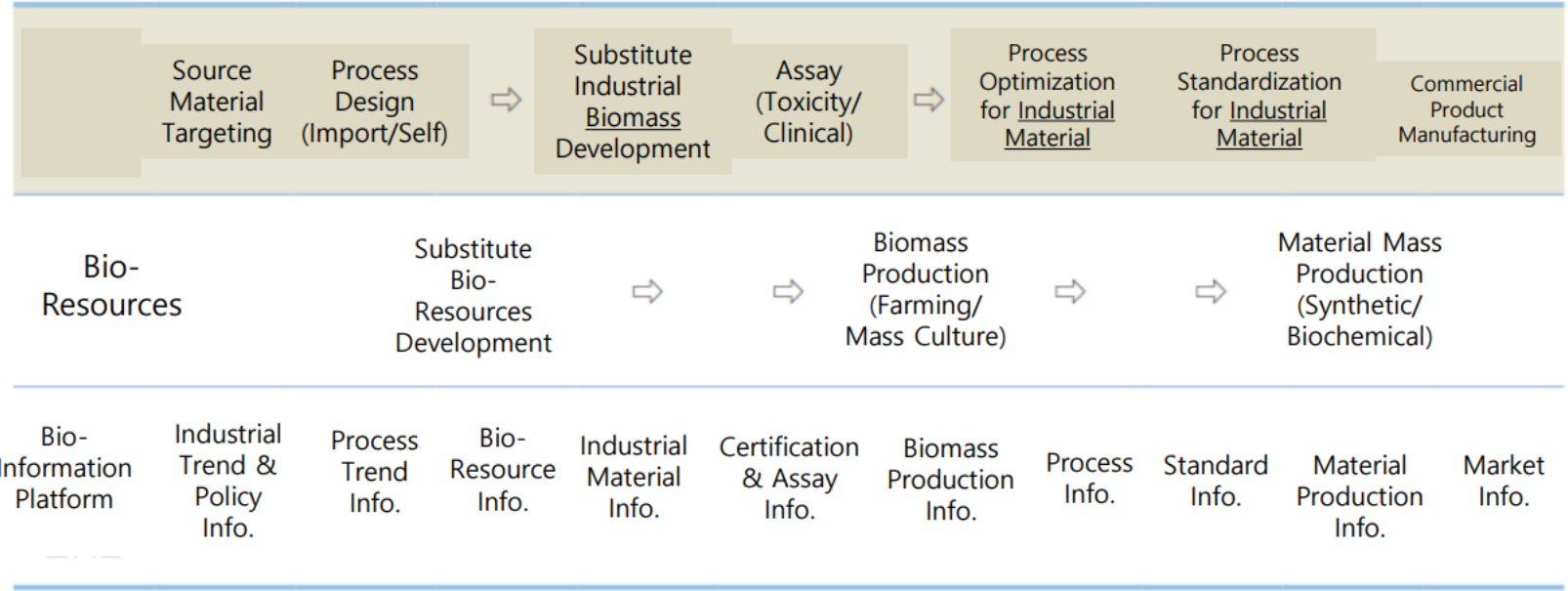
This document summarises the work on marine biotechnology that has been done under Programme of Work and Budget (PWB) 2013-2014 and falls under output area 3 on "Fostering STI to address global and social challenges". It was formerly listed as DSTI/STP/BIO(2014)17 but the document reference has been updated to reflect its release in 2016 under a different working party, the Working Party on Biotechnology, Nanotechnology, and Converging Technologies. This report is the final output result 3.1: an analytical report on science, technology and innovation (STI) and green growth: supporting the sustainable development of green growth. The report has been presented to the Delegates to the Working Party on Biotechnology, Nanotechnology and Converging technologies in the meeting of the Working Party in May 2015. Comments on this report were collected and processed after this meeting.

Action Required: Members of the Committee for Scientific and Technological Policy are invited to declassify this report by written procedure. Nil returns by 12 August 2016 will imply consent to proceed.

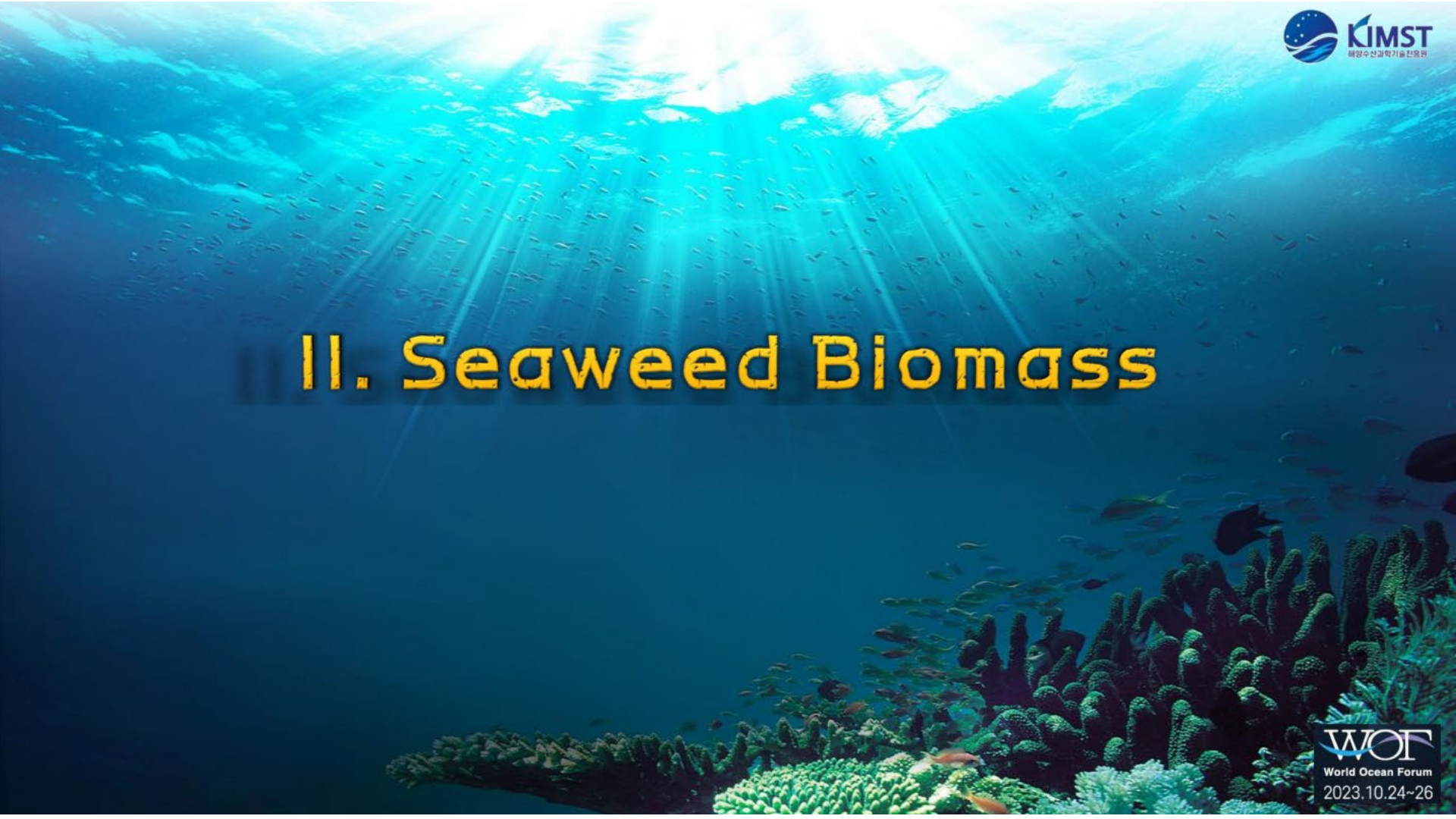
For further information, please contact:
David Winickoff. Tel: (33 1) 45 24 92 32; E-mail: david.winickoff@oecd.org

JT03399320

Bio-Industry needs Stable Supply of Biomass & Basic Materials

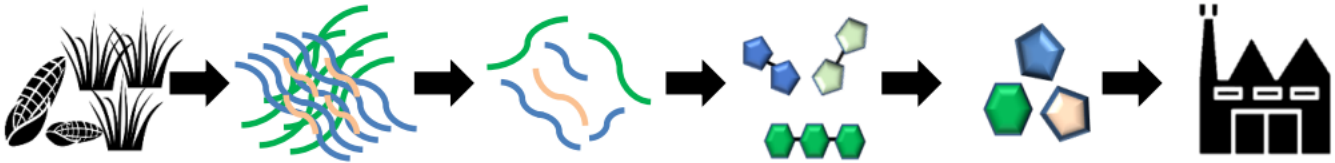


Schematic Diagram for Bio Technology Industrialization System


KIMST
해양수산과학기술진흥원
II. Seaweed Biomass
WOF
World Ocean Forum
2023.10.24~26

Difficulties of Land-based Biomass

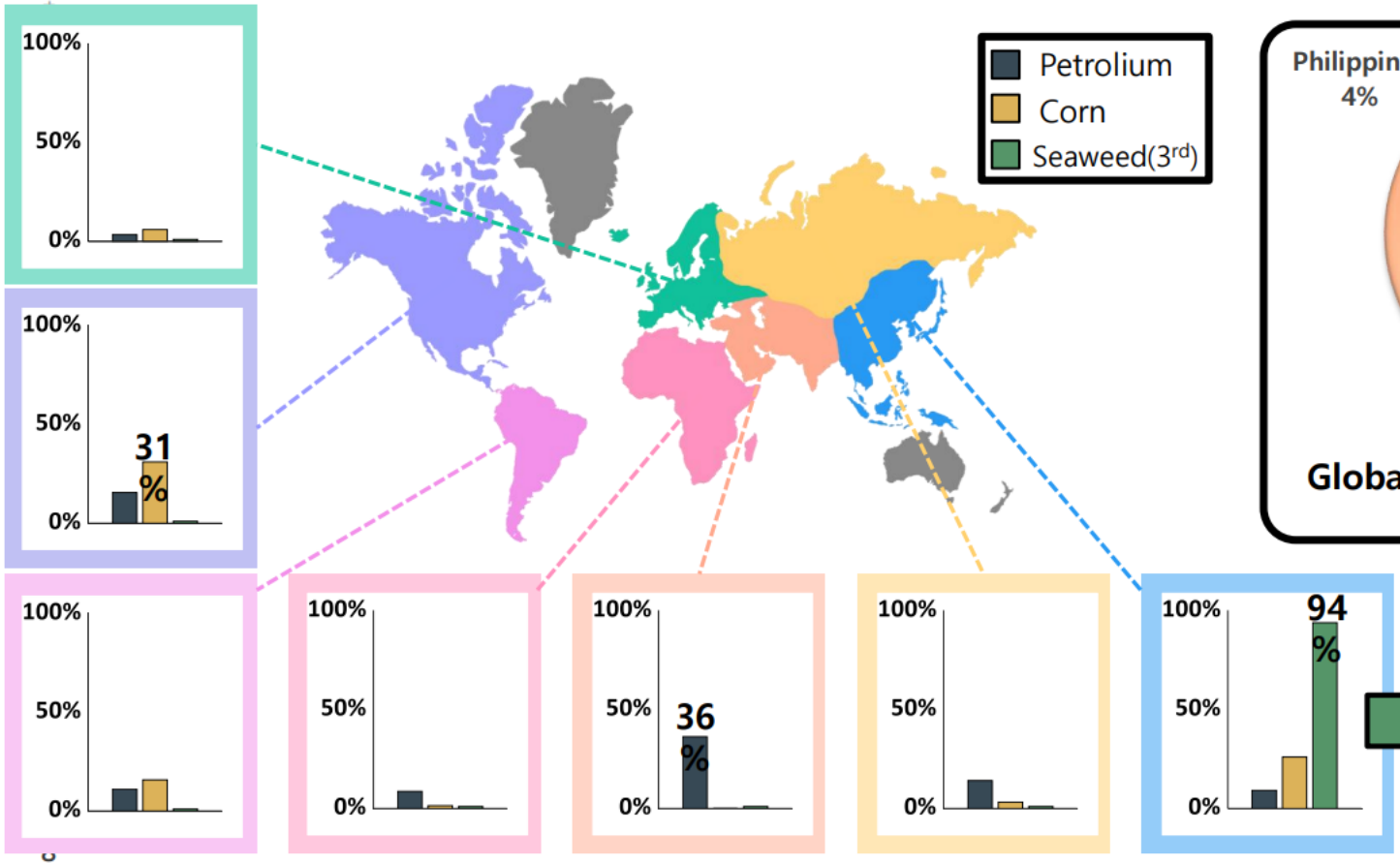
Bio-Process for Land-Based Biomass



Biomass	Characters	Prime Cost	Bio-Refinary Process			
Starch(1st)	• Corn etc. • Expensive Price • Threat Food Supply	$600/ton	Gelatinization	Enzyme based Liquid Glycosylation	Fermentation & Post-Treatment	
	Cost Ratio		58%	8%	32%	
Xylem(2nd)	• Lumber, Rice Straw, Paper • Expensive Lignin Removal Process	$41/ton	Lignin Removing Process	Pretreatment with Acidification	Enzyme based Liquid Glycosylation	Fermentation & Post-Treatment
	Cost Ratio		33%	23%	18%	26%

Expensive prime cost, ethic problems, strain-growth inhibition materials(Lignin)

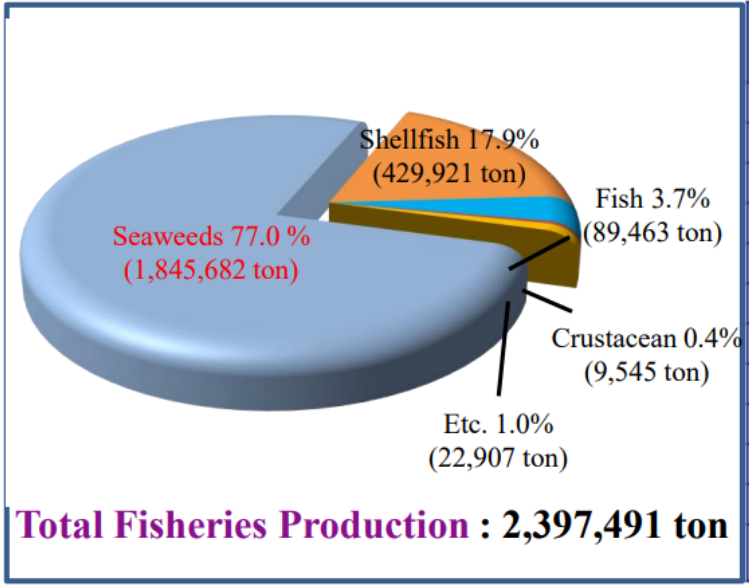
Global Biomass Production Map



World Ocean Forum
2023.10.24~26

✓ **Korea is the 3rd seaweed producing country in the world.**

✓ Farming seaweeds are 10 species (3 green, 5 brown, 2 red) in 908 recorded (123 green, 193 brown, 592 brown)..



species	2021			
	production(ton)	Ratio(%)	Price (1,000 $)	Ratio(%)
Kelp	677,537	36.7	118,778	15.6
Sea Mustard	574,585	31.1	136,799	18.0
Laver	547,587	29.7	474,955	62.5
Hizikia	20,180	1.1	9,554	1.3
Codium	11,317	0.6	3,830	0.5
Green Laver	7,958	0.4	6,033	0.8
Capsosiphon	2,981	0.2	8,810	1.2
Ecklonia	2,262	0.1	716	0.1
Gracilaria	932	0.1	281	0.0
Sargassum	342	0.0	664	0.1
Etc.	1	0.0	-	0.0
Total	1,845,682	100	760,426	100

Commercial value of seaweed is occupying 23.1% (7.5 trillion dollars), out of total value of fisheries in Korea (33 trillion dollars)

Alternative in the Era of Bio-economy : Seaweed Biomass

Category	Advantages
Abundance	- Well-studied on biomass - Perennial plant - Grow making forest - World-wide distribution
Environment-friendly	- No competition to land food sources - No need for purified water(no harm for drinking water supply) - Eliminate carbon
Scalable	- Possible mass production in most ocean area - Commercial aquaculture production in Asia for long - Existence of approved supply chain
Price Competitiveness	- High sugar contents - No lignin for complicated extra-process - Lower cost than Brazilian sugarcane - Possible to gain other various industrial resource materials


KIMST
해양수산과학기술진흥원
III. Application of Seaweed
WOF
World Ocean Forum
2023.10.24~26

Seaweed Merchandises

- ✓ With an attention for sustainable, healthy, and begun food, seaweed based food was developed recently.
- ✓ Mara Seaweed (UK) : Seaweed seasonings in Tesco, Amazon, etc.
- ✓ The Savourists (UK) : Healthy snack bar with salty taste
- ✓ Seagreen Nordic (Sweden) : Snack bar with Spirulina, Chlorella
- ✓ The Golden Duck (Singapore) : World famous chili crap flavored seaweed snack

Healty Functional Food

Cosmatic

Fertilizer

Feed

Market Value for Seaweed based Bio-Industry

- ✓ Seaweed is useful for various bio-material for industries of food, medicine, fertilizer etc.
- ✓ Market size of phyco-colloids with carrageenan and agar from red algae is growing 4.4% annually and will be expected to be reached a 10 billion dollar value by 2027.
- ✓ Market for carrageenan solely is growing 5.6% annually and will take 1.2 billion dollar scale by 2025.
- ✓ Market size of Agar was 2.8 billion dollar on 2022.

<Phycocolloids>

Ice-cream, Crab-meat (Red Algae)

Carrageenan

Juice, Jam, Mayonnaise, Lotion (Brown Algae)

Alginates

Eatable Dye for Pasta, Meat (Brown Algae)

Fucoxanthin

Milk Products (Brown Algae)

Phlorotannins

Bio-fuel

Fertilizer

Compounds

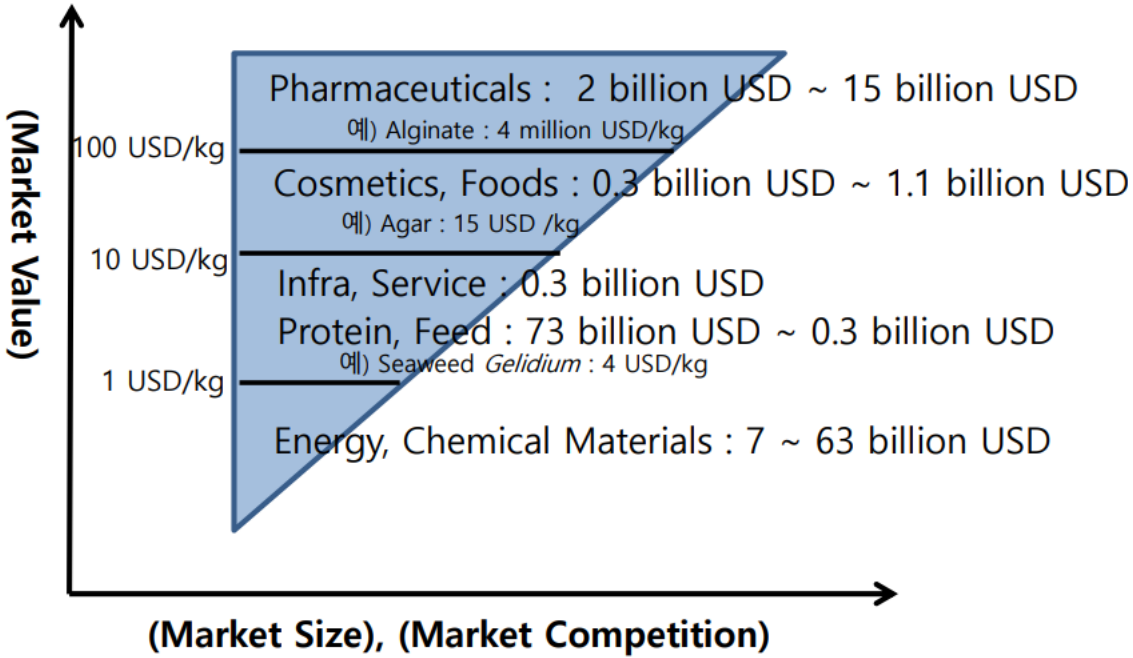
Phycocolloids

Food

Medicene/Cosmatic/ Nutrient supplement

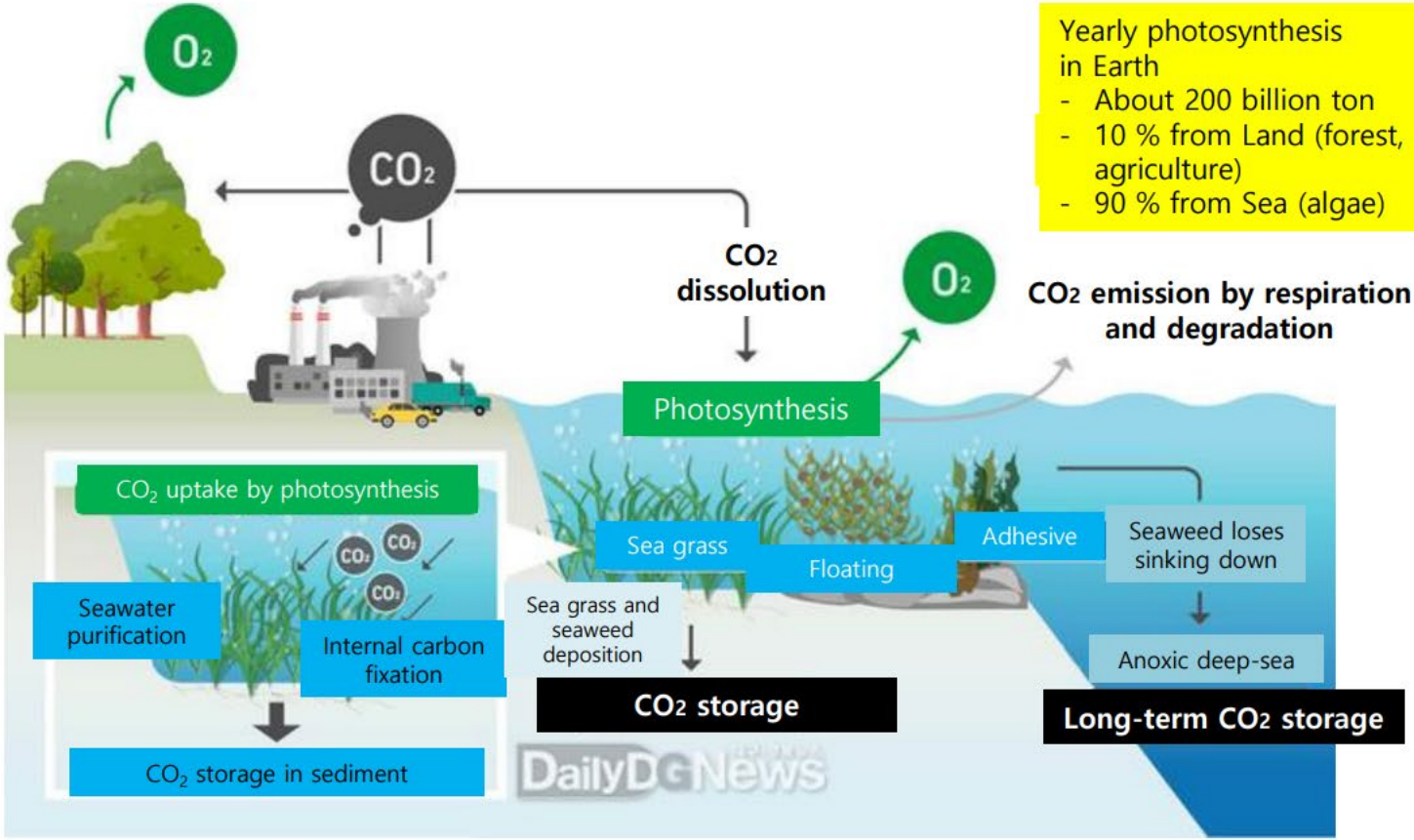
Raja et. 2022

Seaweed Industry Value Chain Diagram



References :
1. SEAI. 2009, A review of the potential of marine algae as a source of bio-fuel in Ireland.
2. OECD. 2013. Marine Biotechnology: enabling solutions for ocean productivity and sustainability.
3. ESF. 2010. Marine Biotechnology : a new vision and strategy for Europe.
4. KIMST. 2011. Industry trend report on marine biotechnology.

Ecological Value of Seaweed in Ocean



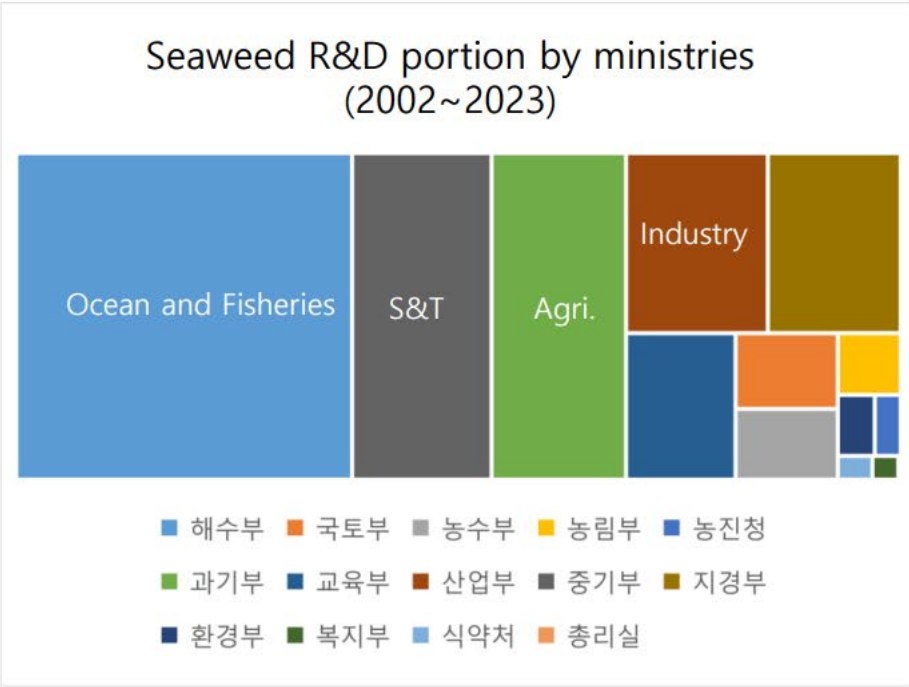
IV. KIMST & ARPA-E

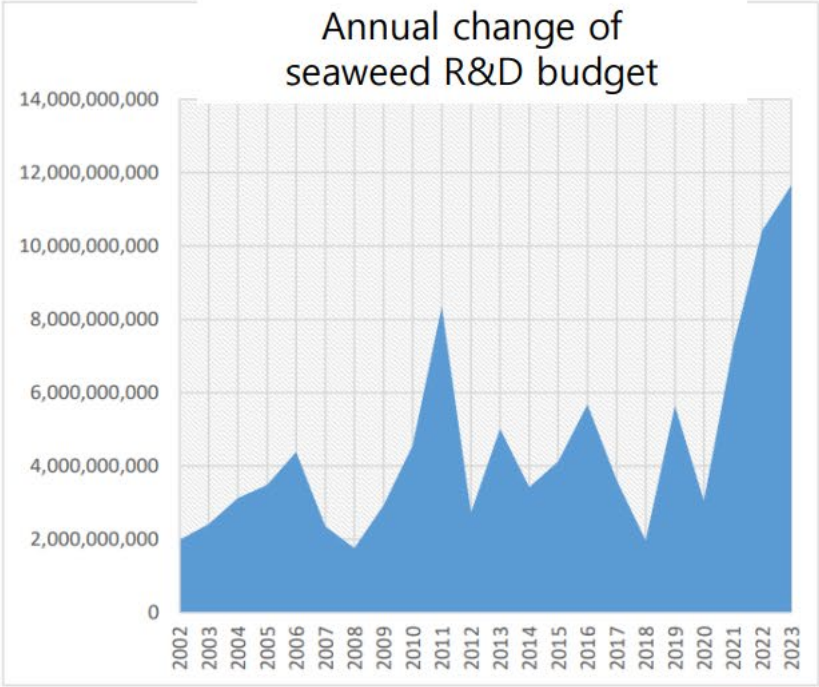
KIMST
해양수산과학기술진흥원

WOF
World Ocean Forum
2023.10.24~26

Seaweed R&D in Korea

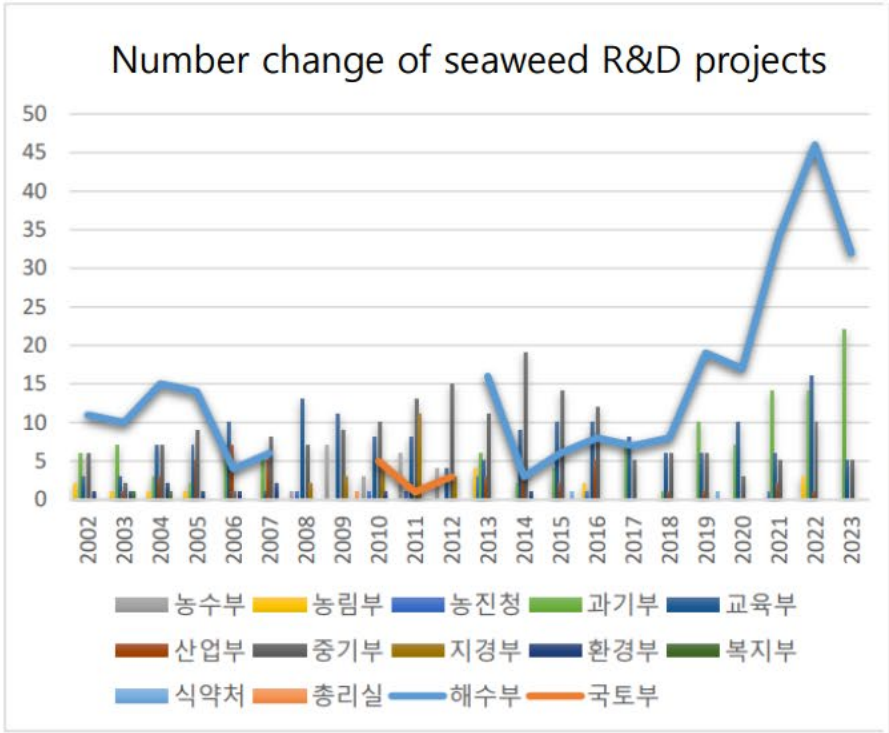
- ✓ 10 million USD was invested for Seaweed R&D for last 22 years(2002~2023).
- ✓ Ministry of Ocean and Fisheries, M. Agriculture, M. S&T are major investing Ministries.
- ✓ Government investment is on growing recently.

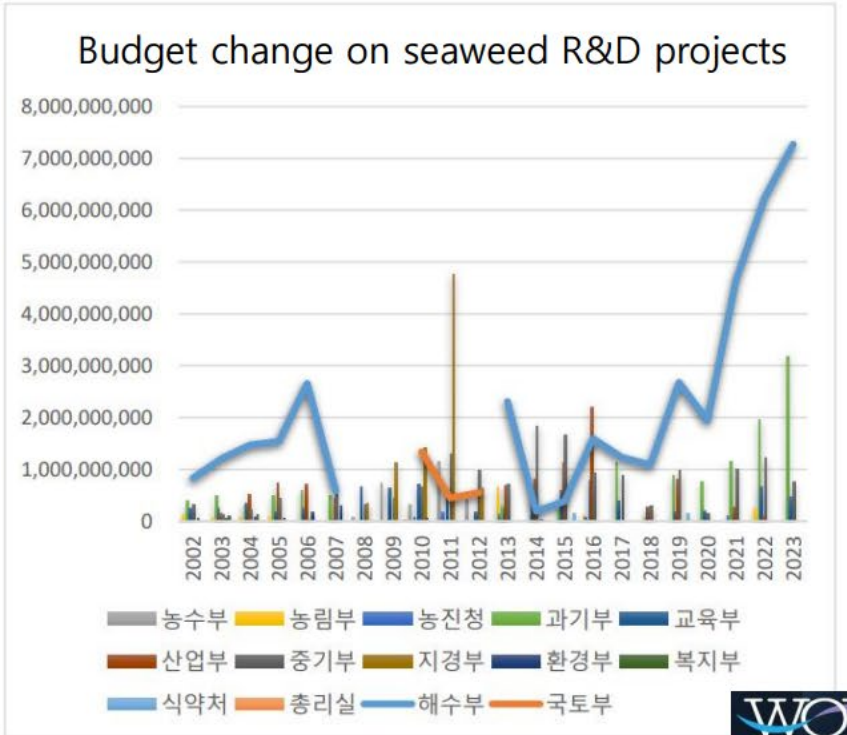




Seaweed R&D investment by ministries

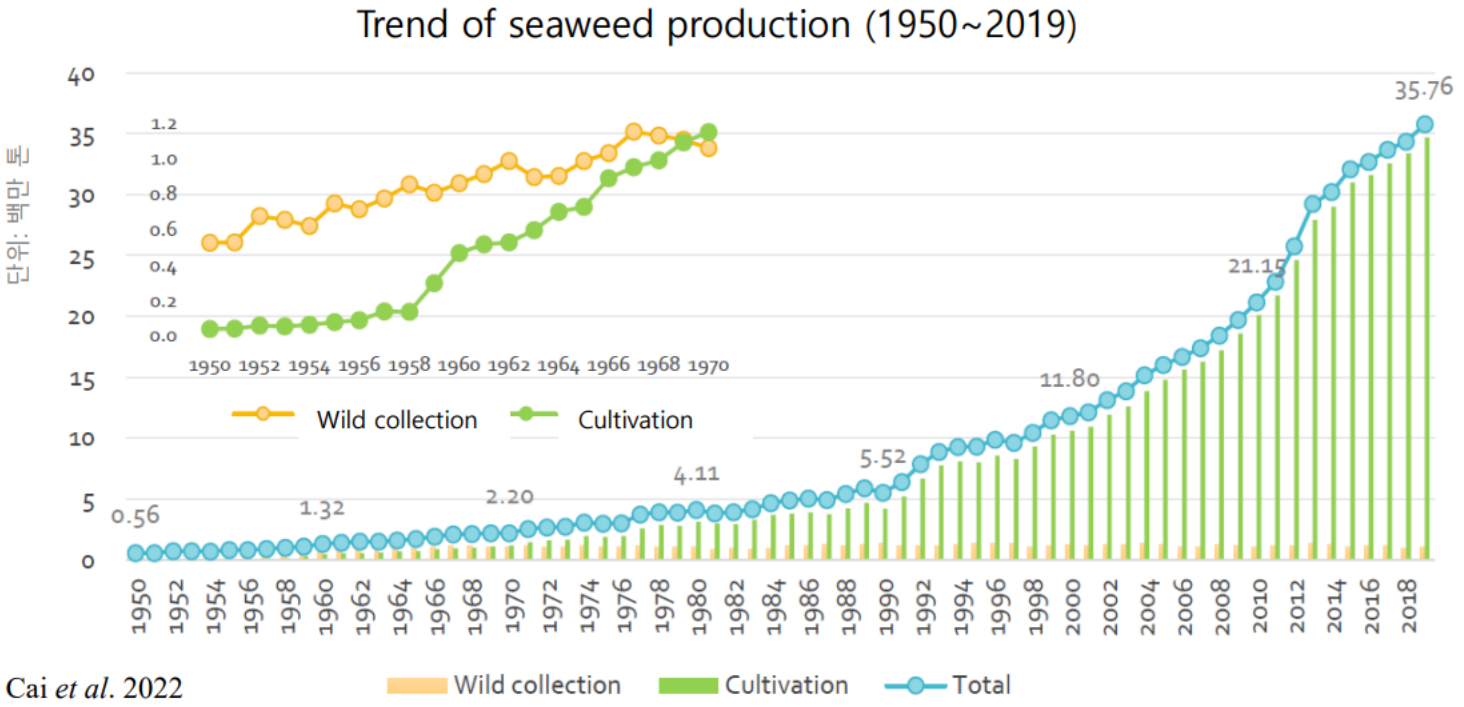
- ✓ Number and budget of seaweed R&D projects by Ministry of Ocean and Fisheries have increased in 2020s.
- ✓ On 2011, Ministry of Economy did a focused investment on the bio-energy with seaweed R&D with 4.8 M USD.





World-wide seaweed production

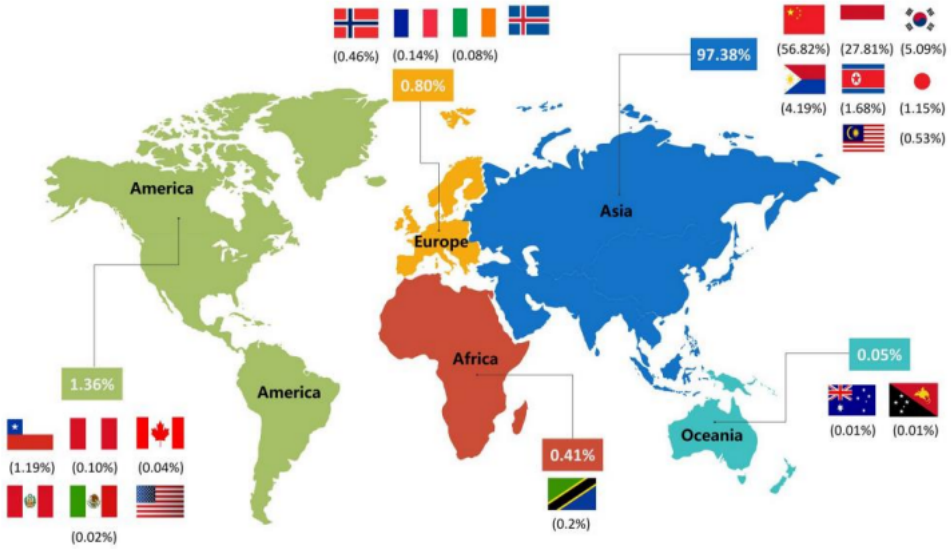
- ✓ Seaweed is about 20% of whole fisheries production, and 96.9% of seaweed production comes from cultivation.
- ✓ World wide seaweed production increases 6.5% annually for 10 years (9.4% for Korea).
- ✓ Seaweed is expected to be more attractive food source, accordingly to the population growth.



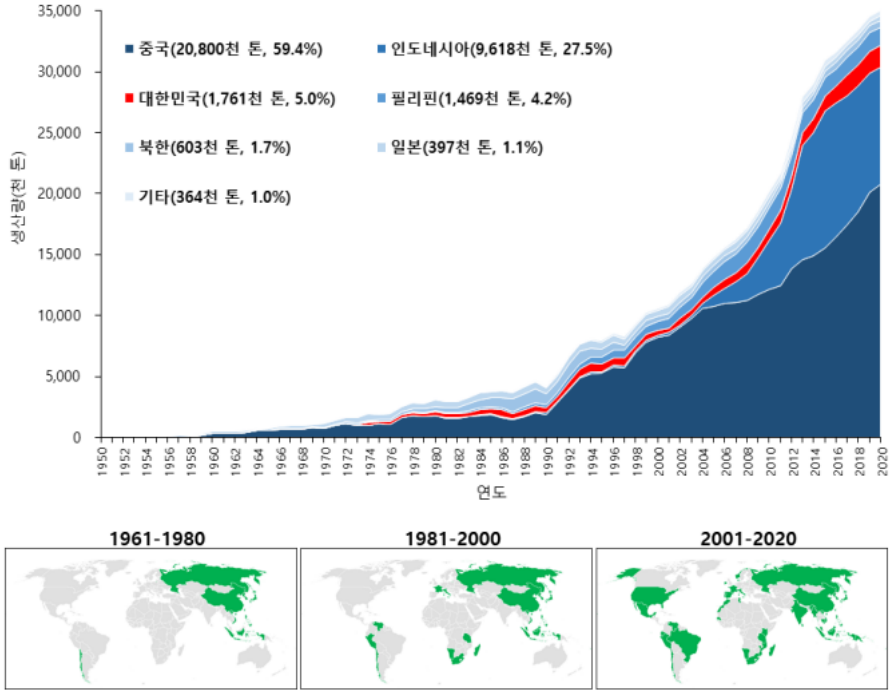
Cai *et al*. 2022

Comparison of cultivation scale by country

- ✓ Amount of seaweed production by cultivation is about 0.35 hundred million ton (164 hundred million USD), and 5% (1,700 thousand ton) of the total production comes from Korea.
- ✓ Asian counties such as China, Indonesia, Korea are leading the seaweed production and Europe is joining rapidly on seaweed cultivation recently.



FAO, 2022



Seaweed biomass production in Europe and U.S.

✓ **Europe-North Sea Farm Foundation**
- Eco-friendly non-profit unit with over 100 organizations
- Test aquafarming facility operates in North Sea of Netherland

✓ **Europe-Jurassic Sea Farm**
- Aqua-farming start-up company from U.K.
- Seaweed-shell IMTA using AI tech.

✓ **U.S.-Alaska Fisheries Development Foundation(AFDF)**
- Education program for local seaweed farming beginners Alaska
- Teach evaluation technique for aqua-farming site and operation farming facilities etc.

✓ **U.S.-DOE ARPHA-E**
- Purpose : Energy production and carbon sinking
- Cultivation scale : about 40.5 ha

The plans for giant seaweed farms in European waters

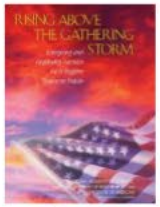
8 August 2022

The seaweed in the pilot test was harvested by a mechanical arm

- First case of seaweed cultivation of deep sea in 12 km away from North European Sea
- 2.7 hundred million Euro
- Target : 8 million ton of seaweed production in North Sea (400 km^2) by 2030

History of ARPA-E

In 2007, The National Academies recommended Congress establish an Advanced Research Projects Agency within the U.S. Department of Energy to fund advanced energy R&D.



2007

Rising Above the Gathering Storm **Published** - warning policymakers that U.S. advantages in science and technology had begun to erode

America COMPETES Act **Signed** – authorizing the creation of ARPA-E

American Recovery & Reinvestment Act **Signed** – Providing ARPA-E its first appropriations of $400 million, which funded ARPA-E's first projects

2009

2023

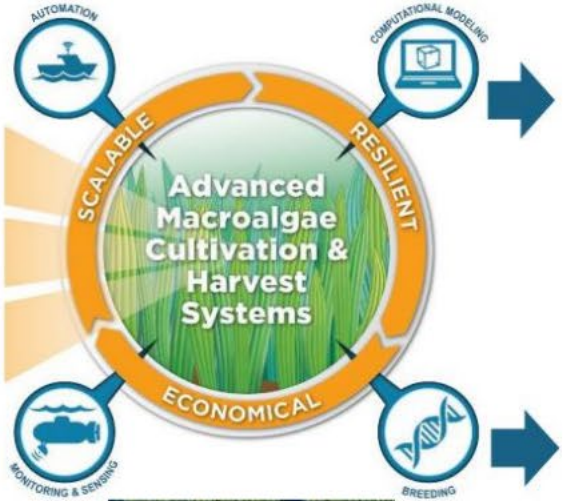
1,468+ Awards
69+ Programs

Current Funding:
$470M
(FY23)

MARINER Program Structure

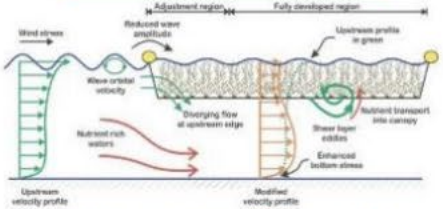
Category 2: Design & Experimental Deployment of Critical Component Technologies

Category 4: Design & Deployment of Aquatic Monitoring Technology and Tools



Category 1: Design & Experimental Deployment of Cultivation and Harvesting Systems

Category 3: Development & Validation of Computational Modeling Tools



Category 5: Research & Development of Breeding and Genetic Tools

Proposal of collaborative program, proposed by ARPA-E

Phase One: 1 year

Environmental survey and modeling

Cost: US$3M, 50% cost share

Phase Two: 3 years

Phase 2A:
Experimental farm design, deployment, and testing

Phase 2B:
Research on carbon capture and emissions mitigation using seaweed

Cost: US$27M, 50% cost share

Phase One Milestones:

1. Oceanographic survey of candidate regions completed
2. Two optimal farming locations identified based on nutrient availability, ocean conditions, location, and bathymetry

Factors to be concerned for Seaweed Mass Production and Utilization

MARINER 1. Cultivation & Harvesting System(양식 및 수확)
MARINER 2. Critical Component Technologies(양식 장비)
MARINER 3. Computational Modeling Tools(환경 모델링)
MARINER 4. Aquatic Monitoring Technology & Tools(모니터링)

MARINER 5. Breeding & Genetic Tools(품종개량)

Automation & Economical efficiency
(Nutrients supply, Temperature, Environment & Sustainability controlling mechanics)

Sterility, Temp. adaptability, Rapid growth & Purity
(Selective/Crossing/Mutation/Molecular Breeding)

Breed Improvement

Mass Production

Secure Freshness, Safety & Homogeneity
(Food/Fodder)

Primary Production

Eco-friendly & Market competibility
(Bio-fuel, Bio-plastic, Drug)

Bio-Product Selling

Spore Production

Secure Mature leaves & Effective culture facility
(Spore /Gamete production)

Harvest & Transfer

Rapid connection to facilities & Economical efficiency
(Pre-treatment mechanics for de-salinity & drying)

Bio-Refinary Plant

Efficiency, Safety & Monomer mass providing
(Chemical engineering for acidification, de-salinity & degradation)

Carbon Capture

International Recognition of Seaweed Value
(Securing and evaluation technology for environmental & ecological safety)

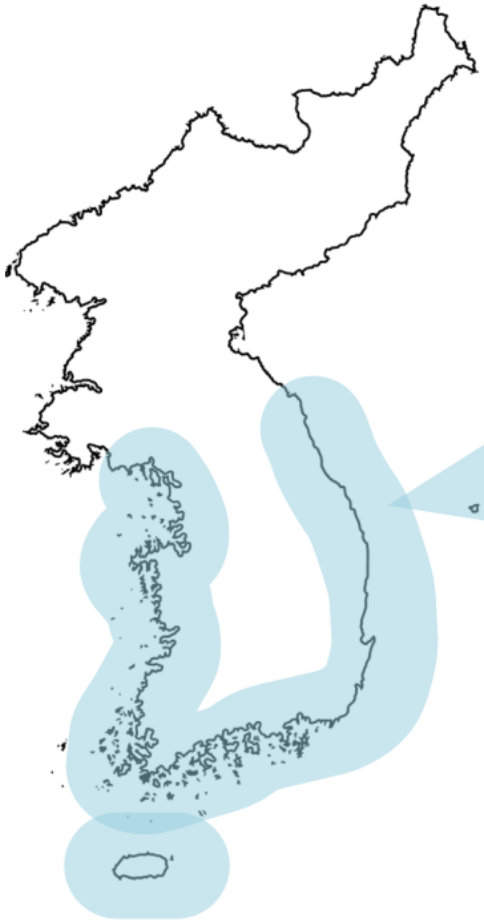
Common Issues : 1. Intellectual Property and Legal Issues / 2. Acceptance of Local and Public Sector / 3. Sharing Data and Information etc.

Mutual Areas of Interest

Area	ARPA-E	KIMST
International Relations Contact	Dr. Simon Freeman, MARINER Program, ARPA-E	Dr. Kyung Suk Seo, R&D Design Office, KIMST
Scientific Subjects*	1. Design & Experimental Deployment of Cultivation and Harvesting System	1. Construction of Automated Seaweed Aquaculture, Harvesting, and Storage System 1.1. Identification of Optimal Aquaculture Locations 1.2. Long-distance Sensing, Control and Communication 1.3. Automation of Aquaculture Structure and Facilities 1.4. Stabilization of Aquaculture System in Endangered Situation 1.5. Automated Aquatic Monitoring, Harvesting and Storage System
	2. Design & Experimental Deployment of Critical Component Technologies	
	3. Development & Validation of Computation Modelling Tools	
	4. Design & Deployment of Aquatic Monitoring Technology and Tools.	
	5. Research & Development of Breeding and Genetic Tools	2. Seaweed Aquaculture Technology Management Platform 2.1. Digitalization of Breeding and Seedling Technology 2.2. Seedless Strain Production 2.3. Field Test of Seaweed Strain
	6. Sensing Exports of Anthropogenic Carbon through Ocean Observation	3. Carbon Elimination with Seaweed Biomass 3.1. Sensing and Calculation of Uptake & Storage Coefficient 3.2. Environmental Risk Assessment and Management

*Scientific subjects proposed here are for the beginning of these bilateral research collaboration between ARPA-E and KIMST, and all inquiring technologies for seaweed farming facility engineering, automation in macroalgae mass production, processing, utilization including potential carbon capture, and commercialization of macroalgal biomass and its derivatives shall be collaborative research subjects by mutual agreement of the Parties.

Concept of a lifecycle management of seaweed bio-industry



Seaweed cultivation

- Seaweed biomass production for industrial resource supply

Biomass supply chain / hinterland infrastructure

- Harvesting/managing/transport/distribution industry for seaweed biomass

- Substitute petroleum-chemistry based economy to seaweed biomass based economy
- Support nation's carbon neutrality

High value bio-chemical products

- Direct use of seaweed biomass to high value bio-complex and products in bio-chemical factories

Seaweed based bio-refinery


KIMST
해양수산과학기술진흥원
Thank you
Dr. Freeman (ARPA-E)
Prof. SR Park (Jeju National University)
Prof. KY Chung (POSTECH)
Dr. EK Whang (National Institute of Fisheries Science)
Prof. HK Choi (Wonkwang University)
WOF
World Ocean Forum
2023.10.24~26