Prospectiveness of Tidal Energy Development

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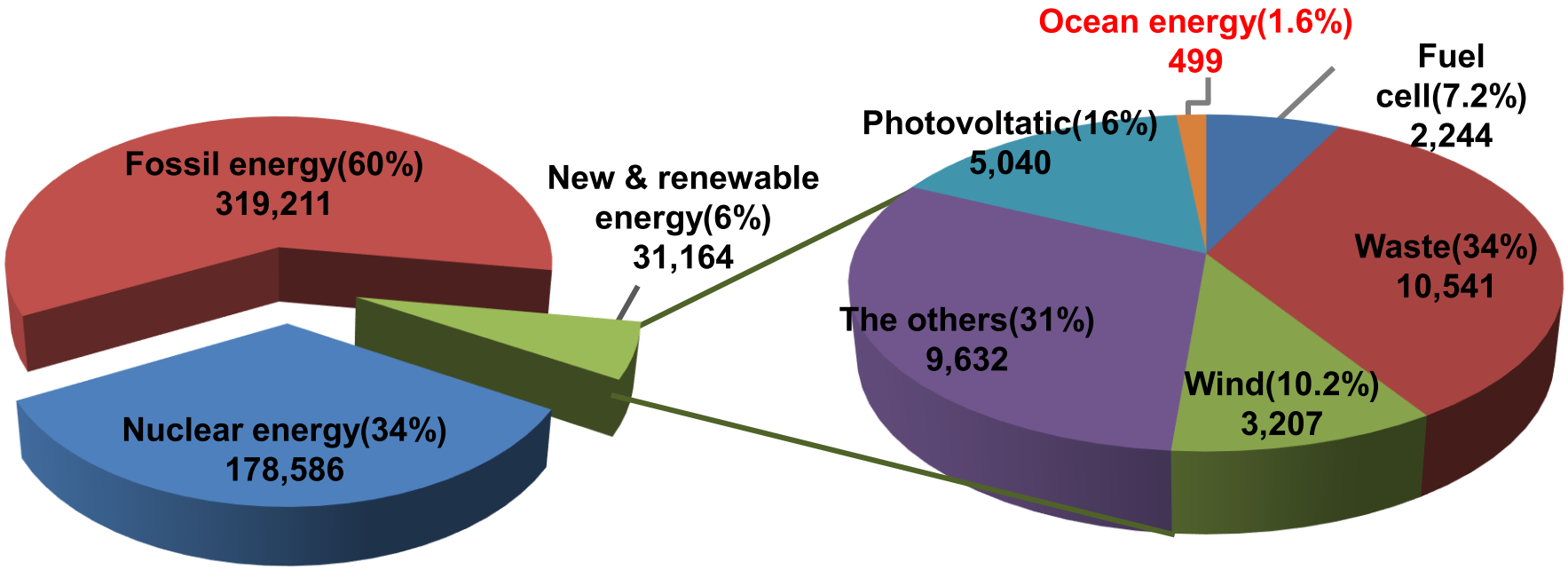
Sustainable Development Goals

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. The Goals interconnect and in order to leave no one behind, it is important that we achieve each Goal and target by 2030.

2017 Power supply in Korea

- ✓ Main energy source: Nuclear energy(34%), Fossil fuel(60%).
- ✓ Ocean energy accounts for 1.6% of new and renewable energy.



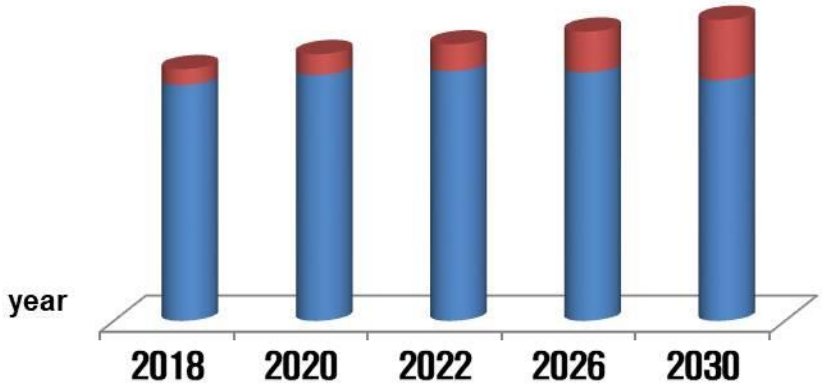
< 2017 Power Supply (GWh)>

3020 Plan for Development of New and Renewable Energy

◆ 3020 strategy of President Moon Government

✓ **Supply new and renewable energy to 20% of national electricity demand by 2030(MOTIE, 2017)**

ratio(%)	6.3%	7.8%	9.6%	14.1%	20.0%
New & renewable energy (GWh)	34,866	45,991	58,759	89,738	132,955
Total (GWh)	555,280	588,352	609,822	637,953	664,109



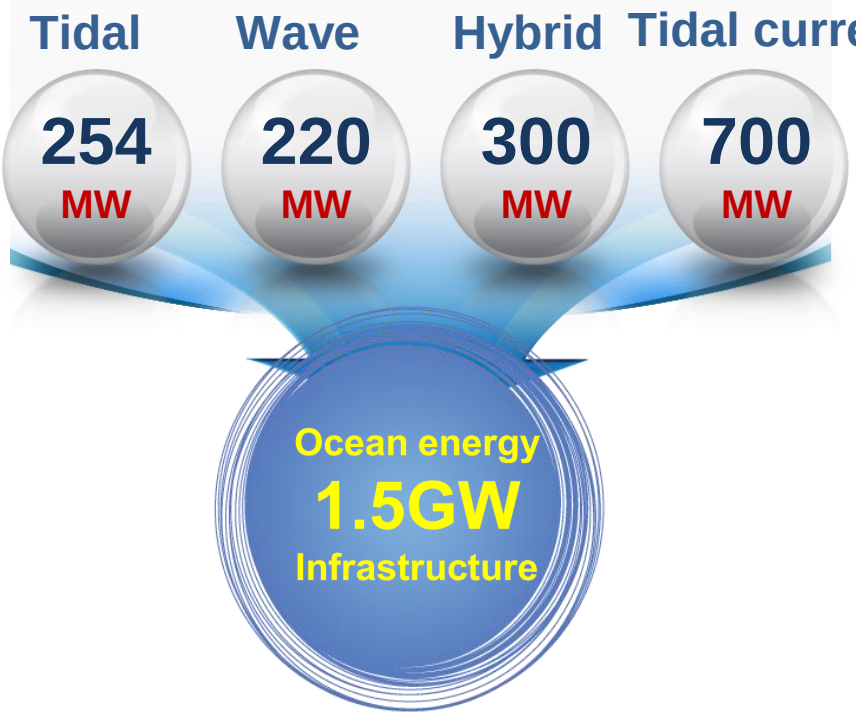
< New and renewable energy supply plan>

- **Expanding the 20GW infrastructure in 2017 to 76GW by 2030**
  - ✓ **Additional 50GW infrastructure is needed**
- **Expanding the new and renewable energy infrastructures consisting of wind power (including offshore wind, 13GW) and solar power (37GW)**

2030 Plan for Development of Ocean Energy

◆ 2030 Plan of Ministry of Oceans and Fisheries(MOF, 2017)

- ✓ **Development of 1.5GW ocean energy infrastructure by 2030**
- ✓ **Supply clean energy and build ORE industry (supply chain)**



- ***Strategy 1:*** *Expansion of R&D in ocean energy and establishment of test bed*
- ***Strategy 2:*** *Construction of large scale ocean energy farm*
- ***Strategy 3:*** *Entering the global market and expanding domestic supply*
- ***Strategy 4:*** *Establishment of ocean energy certification system and strength of policy support*

Ocean Energy Development in Korea

Sihwa Lake Tidal Power Plant

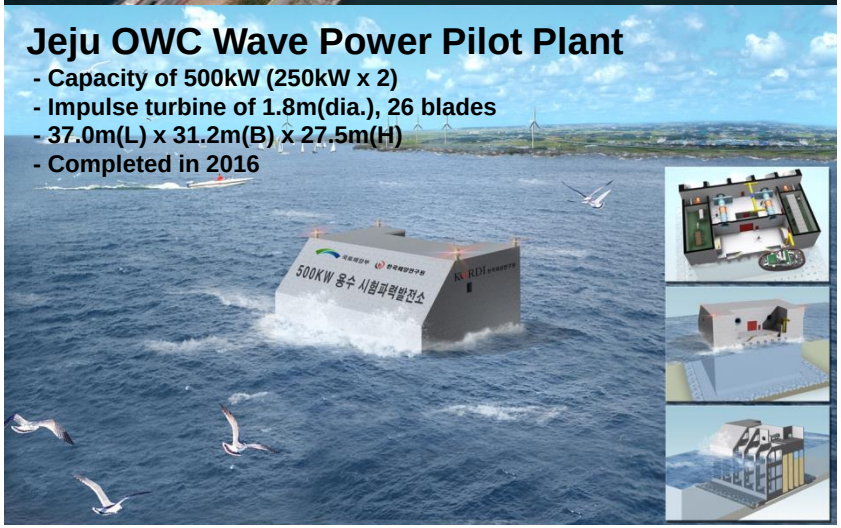
- Capacity of 254MW (25.4MW x 10)
- 8 Sluices
- Completed in 2011

Uldolmok Tidal Current Power Pilot Plant

- Capacity of 1,000kW (500kW x 2)
- Helical type Vertical Axis Turbine
- Completed in 2009

Jeju OWC Wave Power Pilot Plant

- Capacity of 500kW (250kW x 2)
- Impulse turbine of 1.8m(dia.), 26 blades
- 37.0m(L) x 31.2m(B) x 27.5m(H)
- Completed in 2016

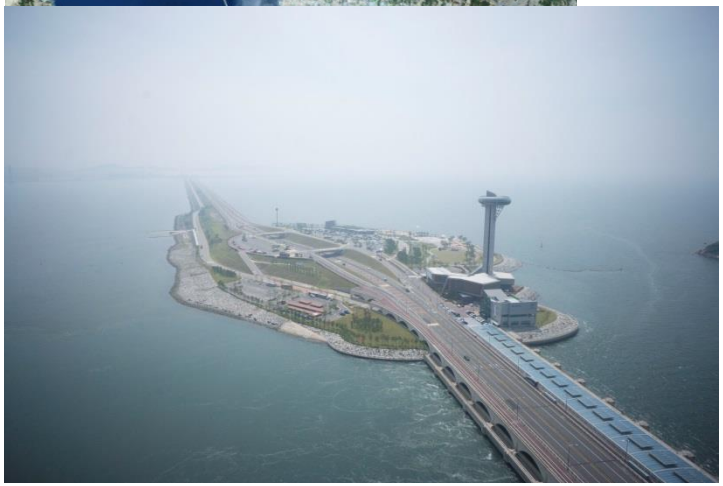


Goseong OTEC/SWAC Pilot Plant

60RT SWAC

20kW OTEC

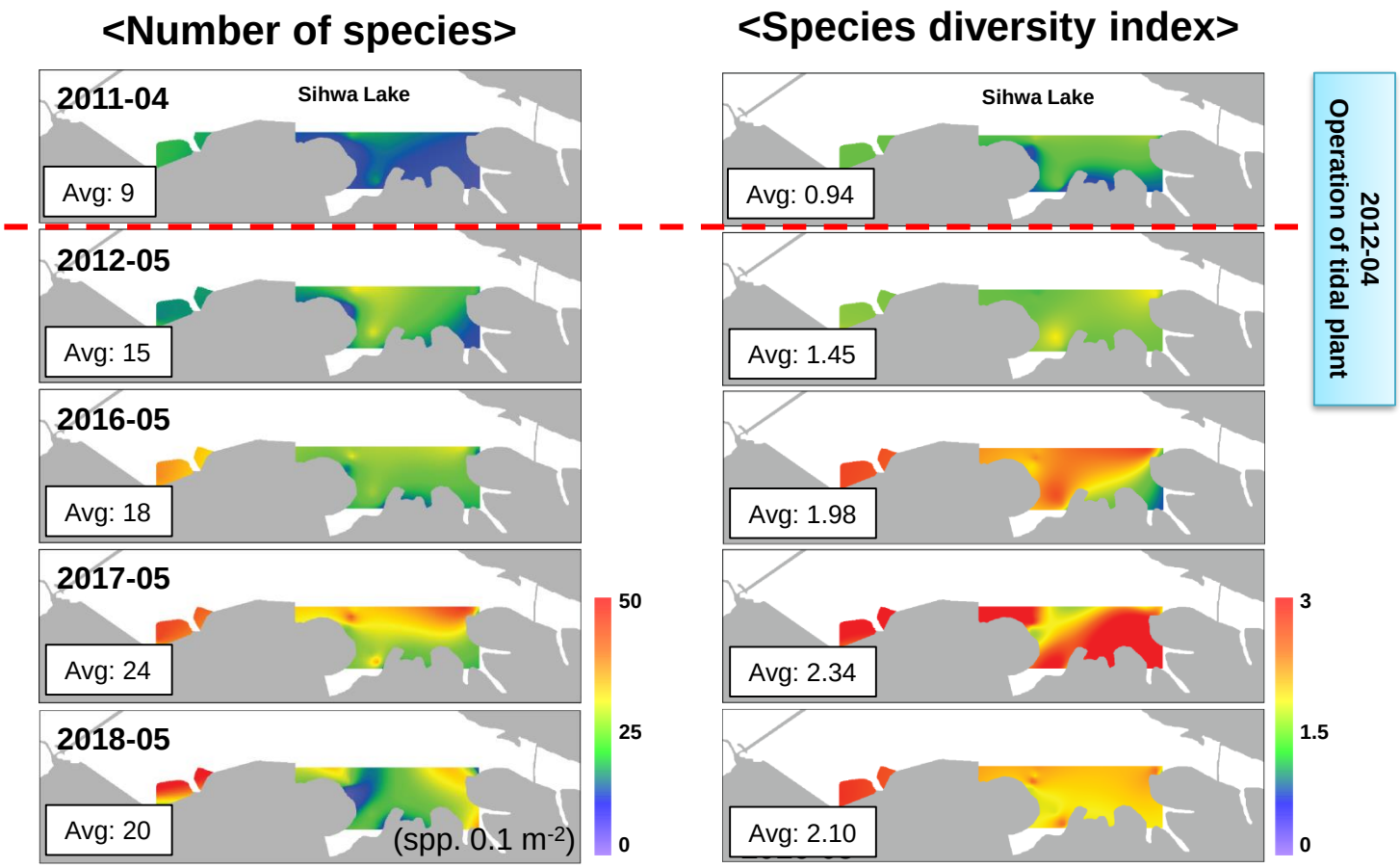
Sihwa Lake Tidal Power Plant



- **History**
  - ✓ Completion of Sea Dyke of 12.7km in 1994
  - ✓ Severe Lake water pollution
  - ✓ Tidal Power Plant was proposed as a counter measure, based on the findings from national R&D
  - ✓ Construction : 2004 ~ 2011
  - ✓ Total Project Cost : USD 355 million
- **Effects of Sihwa Tidal Power Plant**
  - ✓ Improve water quality in Sihwa Lake and environmental recovery
  - ✓ Generate renewable clean energy
  - ✓ Enhancement of regional economy by forming waterfront and tourist attraction
- **Power Output in 2011.8~2018.7 (3,258 GWh)**

2011 (8 ~)	52.3 GWh	2015	496.4 GWh
2012	465.9 GWh	2016	495.6 GWh
2013	483.8 GWh	2017	489.5 GWh
2014	492,2 GWh	2018(~7)	282.5 GWh

Changes of macrozoobenthos community



➢ ***Cumulative power generated from 2011 : 3,258 GWh (≈1.47 mil. Ton CO_2)***

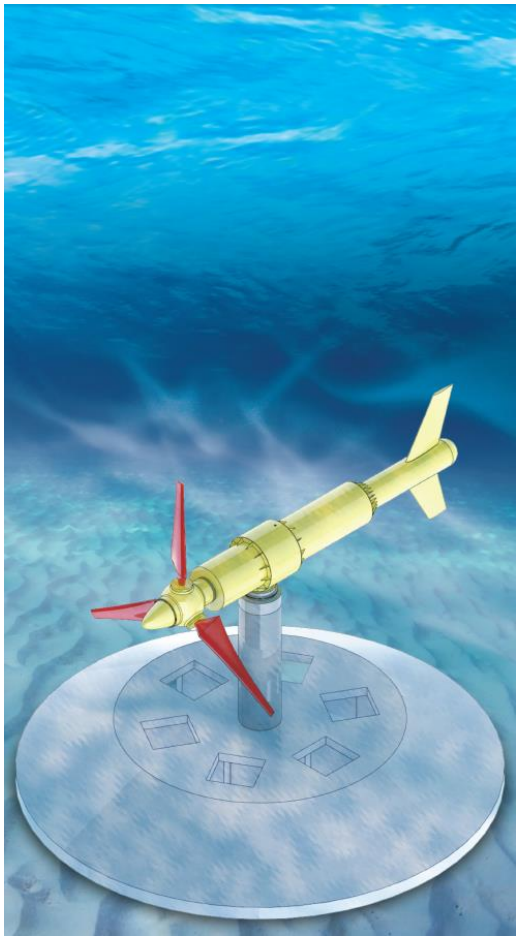
TEC with Active Controlled HAT

- **Medium Scale Model(1:10) Outdoor Experiment**
  - ✓ 2013~2014 / Uldolmok Test Site
  - ✓ Rotor Dia. : 2.4m
  - ✓ Blade Active Pitch Control
  - ✓ Passive/Active Yawing by Rudder
- **Design of KS200(1:2)**
  - ✓ 2014~2015
  - ✓ Based on Experimental Results
- **Fabrication of KS200**
  - ✓ 2016~2018
- **Installation**
  - ✓ 2018. 11 ~ 12
  - ✓ Near Uldolmok Test Site
- **Verification Test**
  - ✓ 1st : 2019
  - ✓ 2nd : 2019 ~ 2020
  - ✓ Performance Assessment
  - ✓ Environmental Impact Monitoring

- **KS200 (Korean Shark 200)**

Specification

Rotor		
Diameter	12m	
Swept Area	113m²	
Rotor speed	16 rpm	
Power regulation	Active blade pitch regulation	
Yawing system		
Type	Rudder pitch control	
Control type	Passive/Active	
Transmission system		
Type	Direct drive	
Mechanical brake		
Type	Hydraulically released	
Generator		
Type	Permanent Magnet Synchronous Generator (PMSG)	
Rated power	225kW	
Voltage	3Φ 575 V_{LL}	
Cooling system	Direct to passing sea water	
Monitoring system		
SCADA system	Server-client	
Remote control	Full turbine control	
Tower & Substructure		
Type of tower	Cylindrical tubular steel	
Type of substructure	Gravity type circular caisson	
Hub height	11m from seabed	
Operational data		
Cut-in current speed	1m/s	
Rated current speed	2.3m/s	
Weight		
Nacelle & Drive train	Less than 60 tons	
Tower & Substructure	Less than 700 tons	

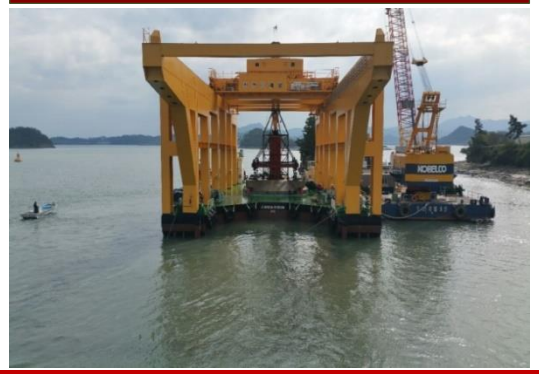


TEC with Active Controlled HAT

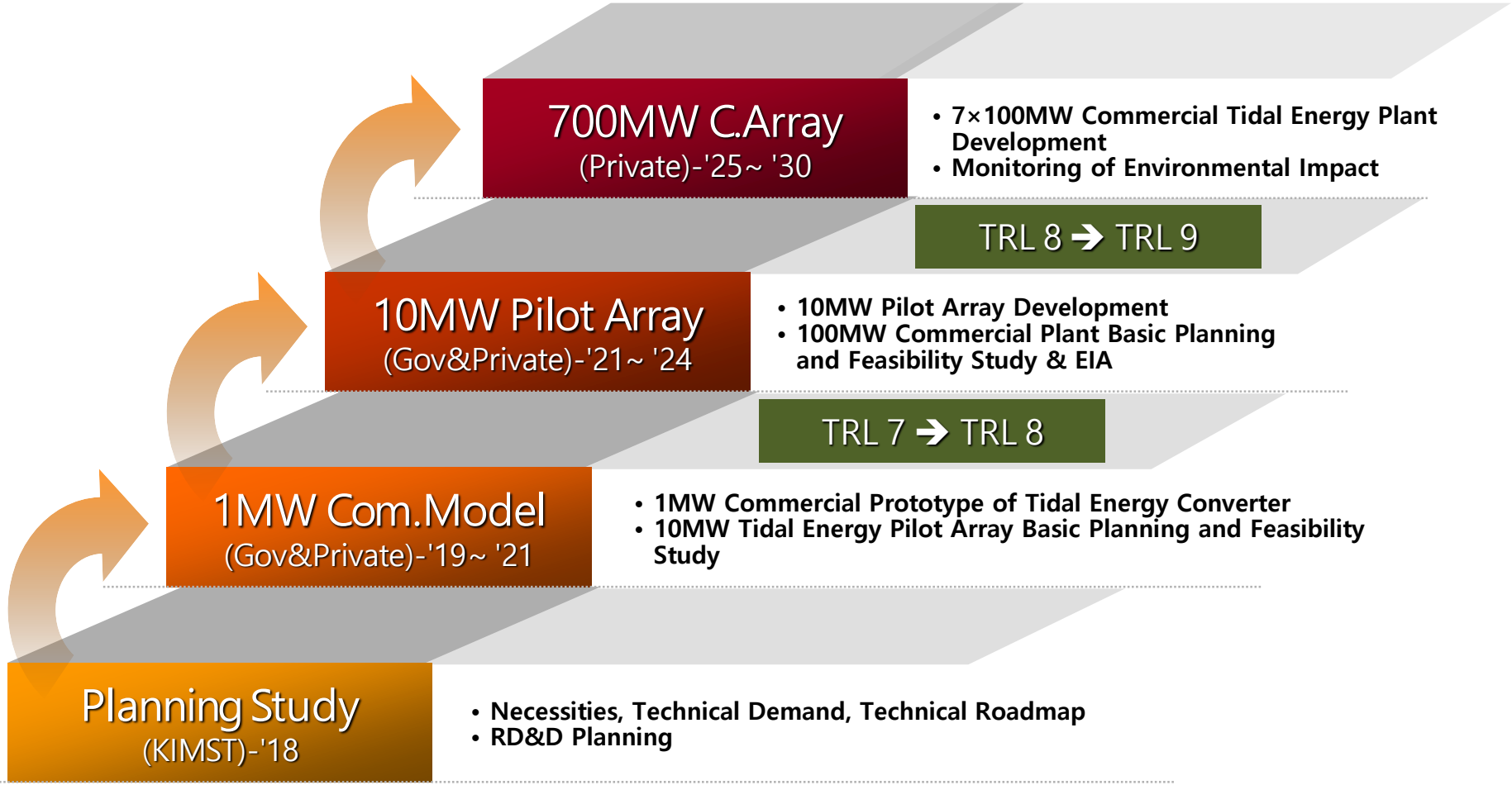
- **KS200 Fabrication and Test**

- **Supporting Structure**

24 Oct. 2016



Commercialization Plan of Tidal Current Energy



R&D Projects for Tidal Power Development

'01	~	'10	'11	~	'17	'18	'19	'20	'21	'22	'23	'24	'25	'26-'30

Vertical axis turbine at Uldolmok tidal current power plant

Establishment of foundation for performance of TEC

Development of 200kW active-controlled TECs

KS200

Application

Establishment of 4.5MW sea test bed for TEC

Establishment of assessment techniques for TEC performance

Sea test

Plan

1MW active-controlled TECs

Performance assessment

Expansion

Application

Private industry-leading

Plan

Feasibility assessment

10MW Tidal current energy pilot array

700MW TEC farm

Application

Application

Plan

7MW wind-tidal current hybrid power system

5MW Wind + 1MW double TEC

10MW Tidal Energy Pilot Array

❖ Feasibility Study & Environmental Assessment

- Outlines
  - ✓ Period: 2019 ~ 2021
  - ✓ Funded by MOF & Power Companies
- Scope
  - ✓ Comprehensive Survey
  - ✓ Basic Design
  - ✓ Technical, Economical and Environmental(SEA & EIA) Feasibility

❖ Development of 10MW Tidal Energy Pilot Array

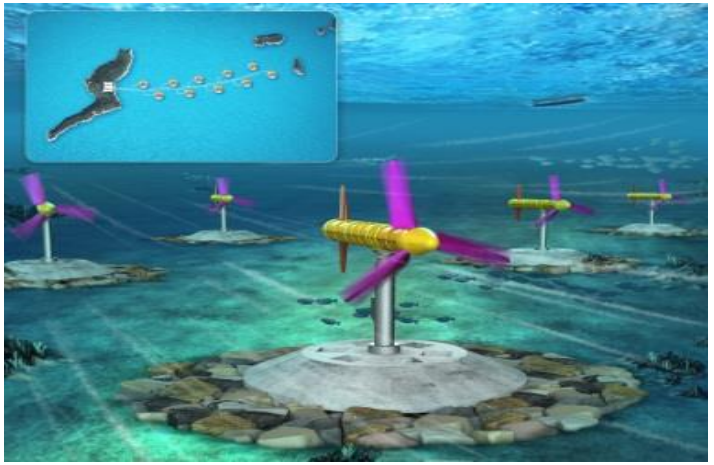
- Outlines
  - ✓ Period: 2022 ~ 2025
  - ✓ Funded by MOF & Power Companies
- Scope
  - ✓ Comprehensive Survey
  - ✓ Basic & Detailed Design
  - ✓ Construction and Operation including submarine cable and offshore substation
  - ✓ Performance Evaluation
  - ✓ Monitoring of Environmental Effects

Tidal Energy Economy

● LCOE for 10MW Tidal Power Pilot Array

Operation Period	○ 20 Years - OES-IEA International LCOE for ocean energy technologies (2015) - JRC Ocean Energy Status Report (2016)
Power Output	○ Installed Capacity : 10MW ○ Annual Output : - Case 1 : (Capacity Factor 30%) 26,280 MWh - Case 2 : (Capacity Factor 33%) 28,908 MWh - Case 3 : (Capacity Factor 40%) 35,040 MWh
Cost	○ CAPEX : 92.8 B.Won (= 84.4 M.US$ = 9.28 B.Yen) ○ OPEX : 3.1 B.Won/Year (= 3.4% of CAPEX) - ETRI (2014), European Commission, pp34 ~ 36
Discount Rate	○ Case 1 : 4.5% (Korean Government Guideline) ○ Case 2 : 10.0% (Guideline of OES-IEA(2015) & JRC(2016))

Cases	LCOE (Won/kWh)	
	DC(4.5%)	DC(10.0%)
Case 1 (CF 30%)	384	522
Case 2 (CF 33%)	349	475
Case 3 (CF 40%)	288	392



➢ ***LCOE of Sihwa TPP : about 80 Won/kWh (Excluding Existing Barrage Cost)***

Reference for LCOE of Tidal Energy

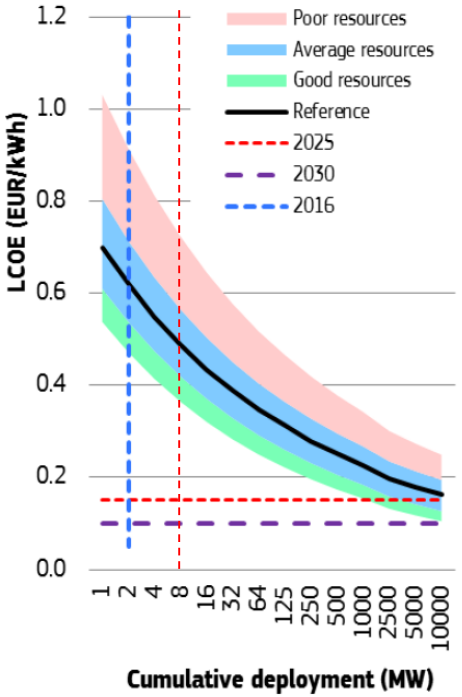
- IEA-OES 2016 Annual Report

UK Contract for Difference(CfD) for less established technologies : Draft Strike Prices (£/MWh)

TECHNOLOGY	2021/22	2022/23
Offshore wind	105	100
Advanced conversion technologies (with or without CHP)	125	115
Advanced conversion technologies (with or without CHP)	140	135
Dedicated biomass with CHP	115	115
Wave	310	300
Tidal stream	300	295

** £ 300 = 435,000 Won*

** £ 295 = 427,750 Won (£ 1 = 1,450 Won)*



LCOE predictions for tidal arrays (ETRI 2014), JRC 2016

✱ Goal : 300,000 Won/MWh in 2030 (= £200)

Concluding Remarks

- ✓ Technology for the tidal current energy development could be considered to reach at the beginning of commercial stage (TRL 9).
- ✓ Economical feasibility could be ensured in 2025, by significant reduction of the Levelised Cost of Energy (LCOE)
- ✓ However, enhancing promotion policies on ocean energy will be necessary to a certain period
- ✓ For the sustainable development of ocean energy, the followings should be studied,
  - Guideline of SEA & EIA
  - Guideline of environmental monitoring
  - Interaction between the tidal turbines and the marine environment
  - Cumulative effects for the energy farm

Thanks

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy

Facts :

- Energy is central to nearly every major challenge and opportunity.
- Working towards this goal is especially important as it interlinks with other Sustainable Development Goals.
- Energy is the dominant contributor to climate change, accounting for around 60 per cent of total global greenhouse gas emissions.
- The share of renewable energy in final energy consumption has reached 17.5% in 2015

Targets :

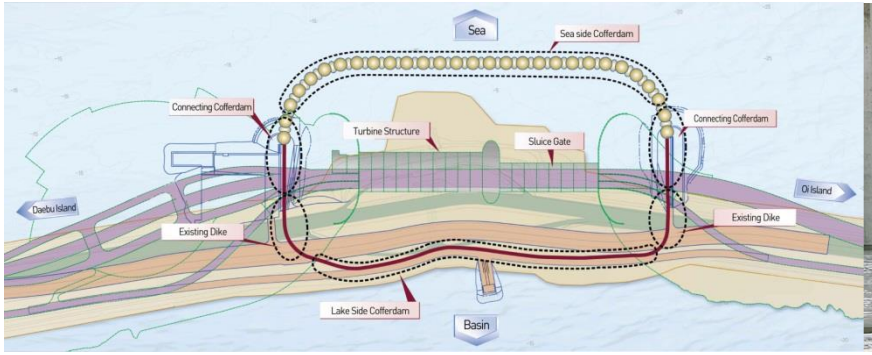
- By 2030, ensure universal access to affordable, reliable and modern energy services
- By 2030, increase substantially the share of renewable energy in the global energy mix
- By 2030, double the global rate of improvement in energy efficiency
- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

Goal 14: Conserve and Sustainably Use the Oceans, Seas and Marine Resources

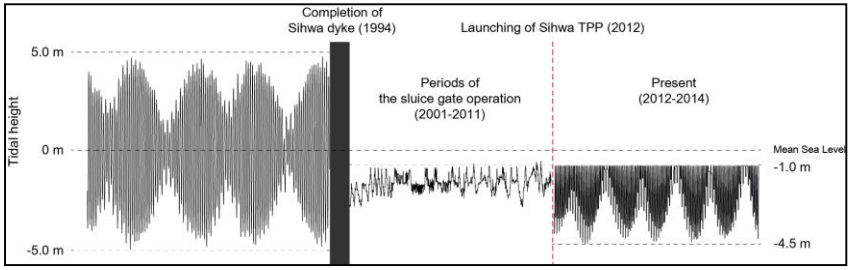
Targets :

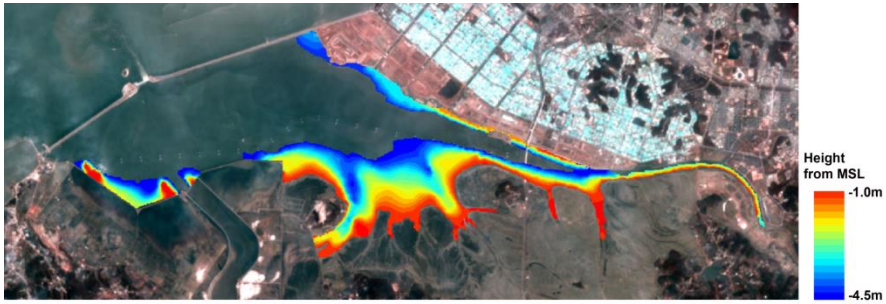
- By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
- By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
- Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
- By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
- By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information
- By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation
- By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism
- Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries
- Provide access for small-scale artisanal fishers to marine resources and markets
- Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want

Sihwa Lake Tidal Power Plant

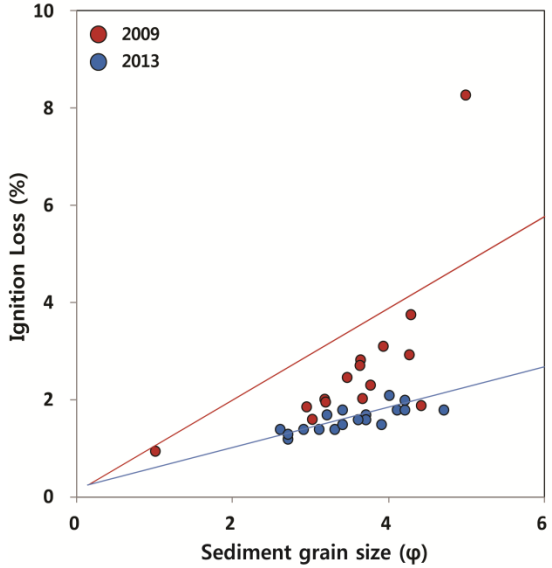


- **Water Level Variations & Restored Tidal Flat**

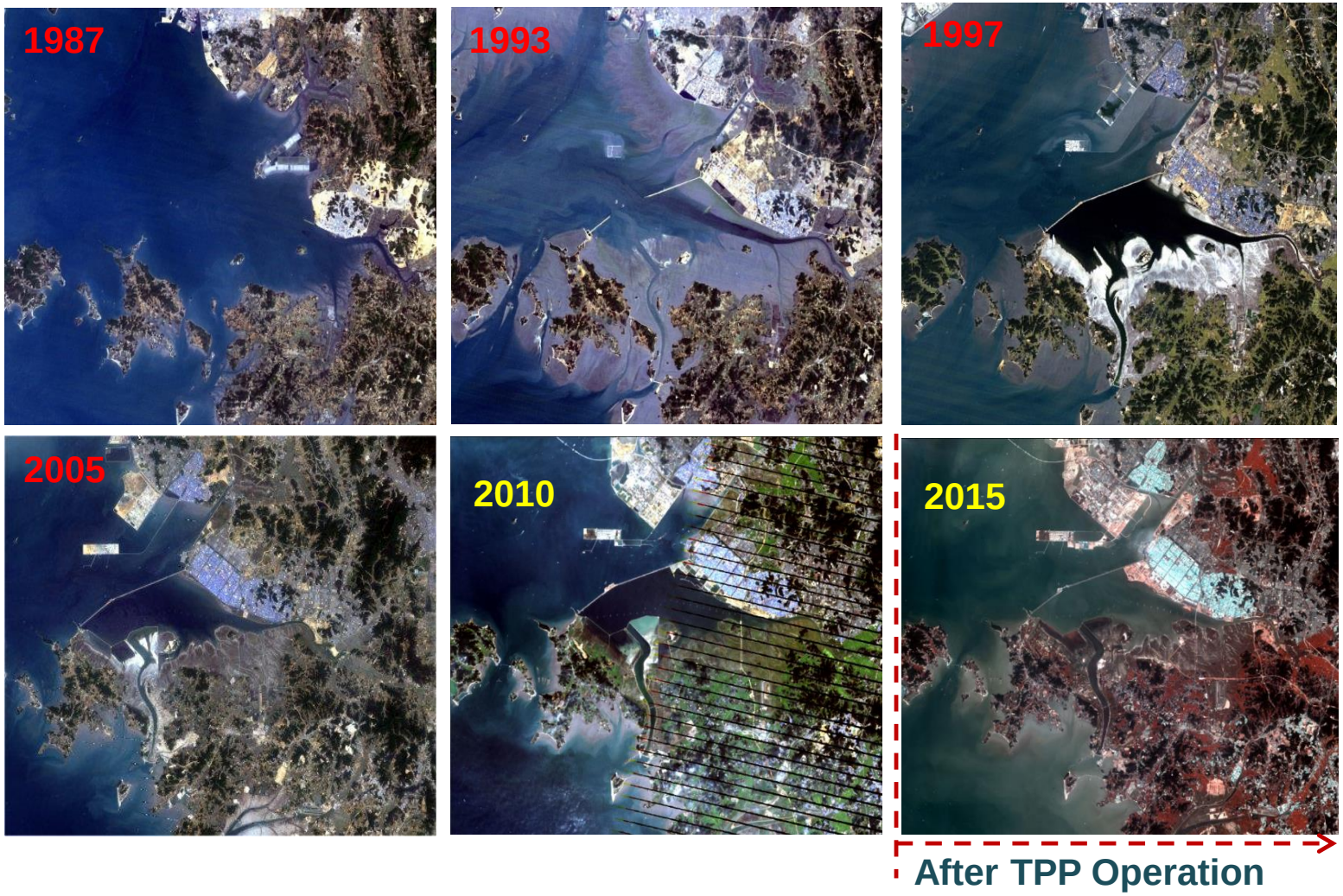




- **Variation of ignition Loss in tidal flat**

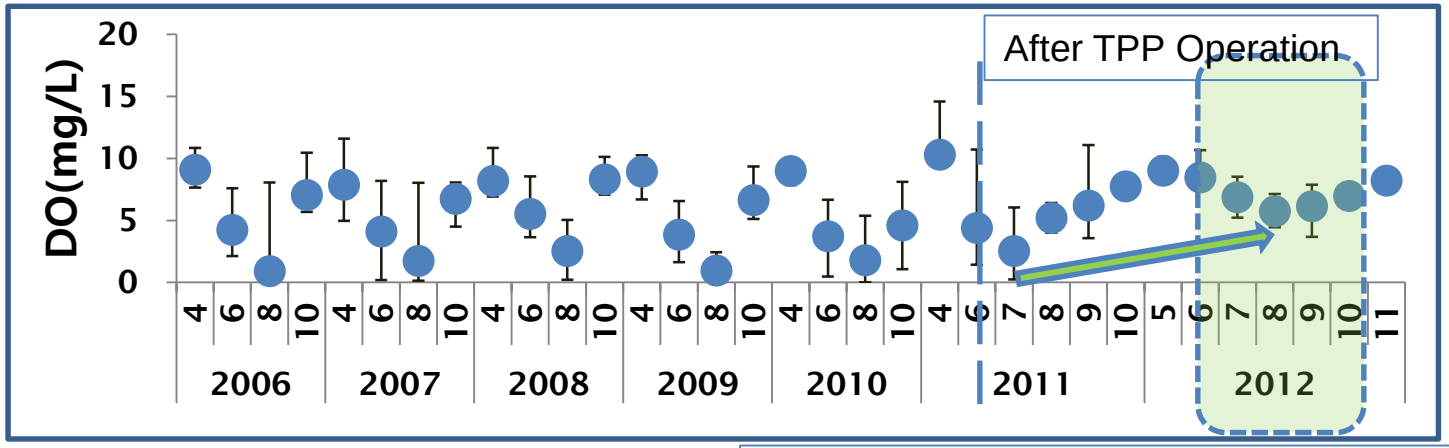


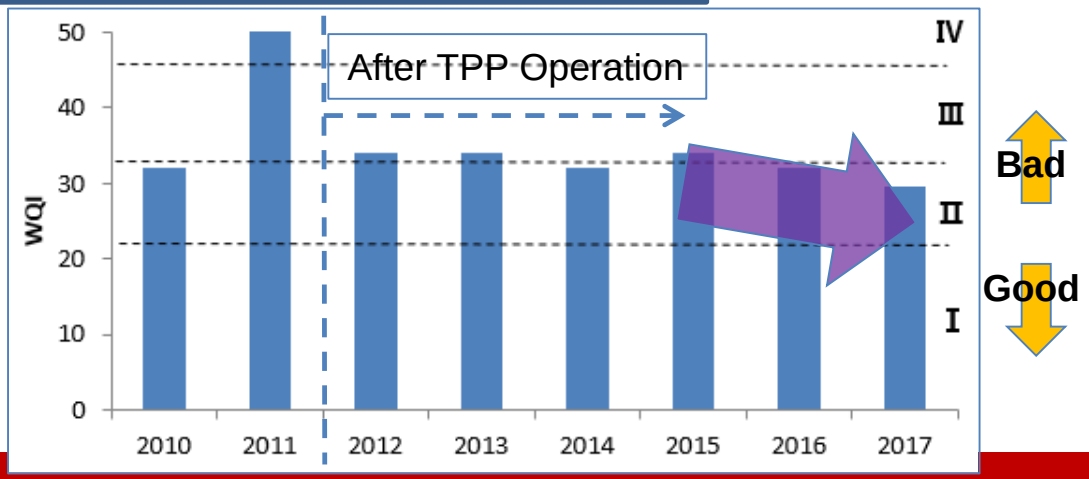
Change of Water Quality from Satellite Images



Water quality before & after TPP operation

- Improving water quality after TPP operation
- Empty oxygenated water (DO less than 3mg/l) disappears due to increase in seawater circulation





MeyGen Project (UK)

2010. 10	MeyGen Ltd. got the approval of 398 MW Tidal Energy Farm Project from UK Government
2014. 9	Financial Close (51.3 M. Pound for 6MW MeyGen Phase1A) (≈ 11.3 M. US$ /MW)
2015. 1	Construction commences at the Ness of Quoys site
2015. 10	Offshore subsea array cables installed in inner Sound (11.5km)
2016. 6	Onshore building works complete, and grid connection energised
2016. 10	Offshore installation of foundation and turbines commenced
2017. 8	Installation of 3 Andritz–HS1000 (1.5 MW) Atlantis Resources AR1500 (1.5 MW)