Current and Future of Floating Photovoltaic Technology

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2023.10.17

SCOTRA

Floating PV System

Solar

Energy

Environment

CONTENTS

1. About Chang-sub, Won

- Name Chang-sub, Won
- Nationality Republic of Korea
- Affiliation SCOTRA.CO. LTD., R&D Center
- Position Chief Technical Officer
- Research Area **FPV System**

- Chief Technical Officer, SCOTRA.CO. LTD., R&D Center, 2019.2.25 ~ present
  - Research on the improvement of stability, anti-corrosion, long-term reliability and power performance of raft-type floating photovoltaic systems.
  - Principal Researcher of the government grant project for offshore Floating PV systems
- Lecturer, Electrical Department graduate School, Konkuk university, 2023.3.1 ~ present
- Visiting Research Fellow, UNSW(University of New South Wales), 2022.9.3 ~ present
- Principal Researcher, LS Electric, R&D Division, Power conversion Team, 2010~2019
  - Research on photovoltaic modules with anti-moisture, waterproofing, lead-free, and anti-PID properties
- 10 patent Inventor related floating PV system

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1. About SCOTRA

"EVERYTHING ON THE WATER"

- Company : SCOTRA Co., Ltd.
- Foundation : **27. Mar. 2007**
- CEO : Jong Mok Lee
- Employees : 78 (as in Apr. 2022)
- Hq. office : Pyeongtaek City, South Korea
- Factory : Gunshan city
- Business Area: **FPV buoys / Structure, Leisure,**

SCOTRA
Floating PV System

- 5 Certification registrations, 4 Design registrations
- 22 Patent registrations / 5 Patents pending
- **14 patent registrations related floating PV system**

- 2004 developed 1st float product
- 2007 established SCOTRA Co., Ltd.
- 2009 obtained Venture Business Certification
- 2010 established R&D Center
- 2011 obtained INNO-BIZ certification
- **2012 constructed world 1st commercial floating PV system on hydroelectric power plant dam**
- 2018 Complete 18.7MW Gunsan FPV project
- **2019 Complete 25MW Namjeong reservoir**
- **2020 Construct Gunshan Factory**
- **2021 Complete 41MW Hapcheon Dam**
- **2022 Complete 13.7MW Taiwan Wushantou Dam**

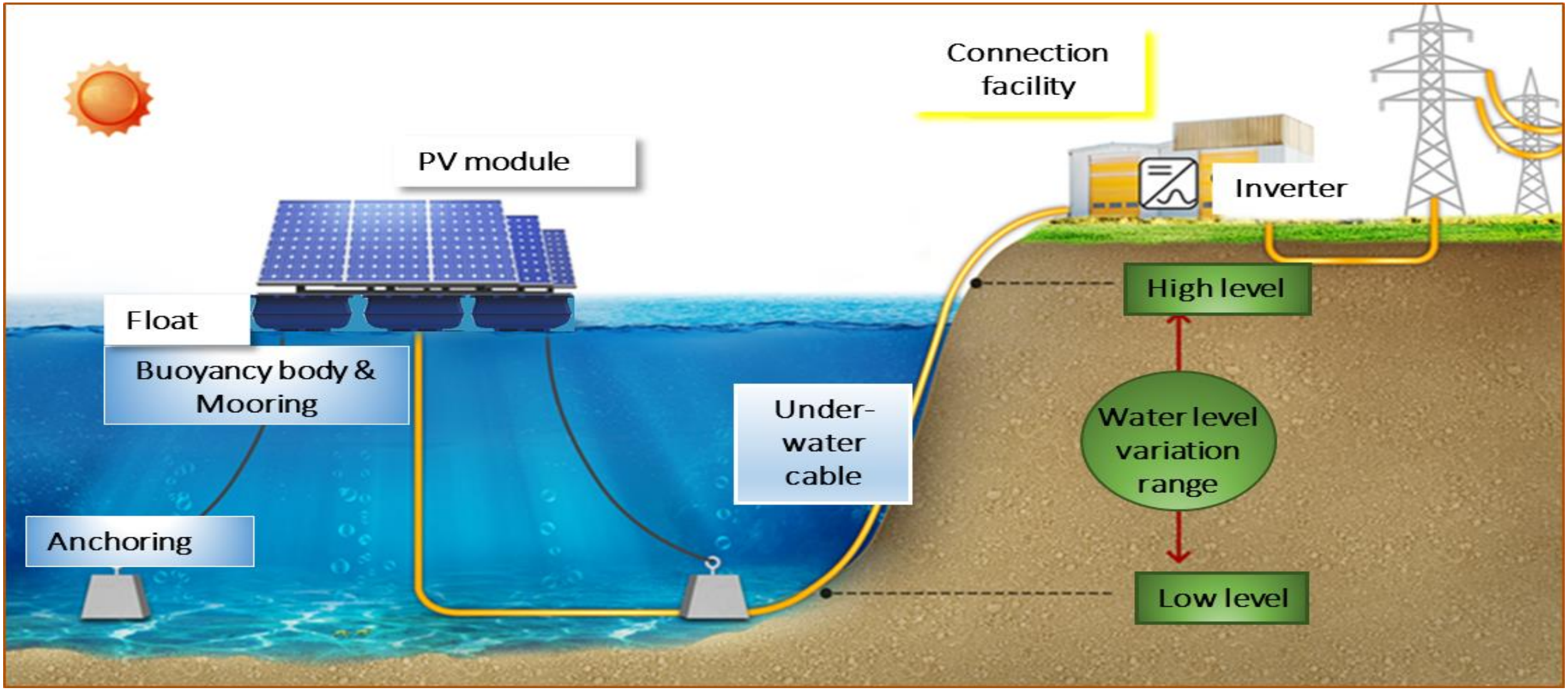
1. About SCOTRA

Hapcheon Dam / 41MW / 2021

2.0 Floating PV Systems : Introduction

CNBC released a floating PV System in December, 2011.

1. About Floating PV Systems : major component

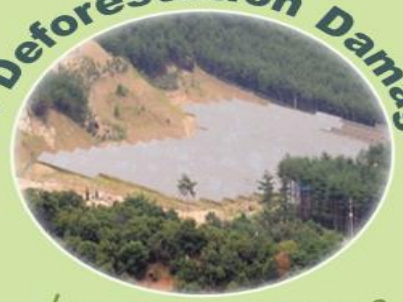


1. About Floating PV Systems : Benefits

Business

Conservation of Forest & Farmland

No Deforestation Damage



by green system

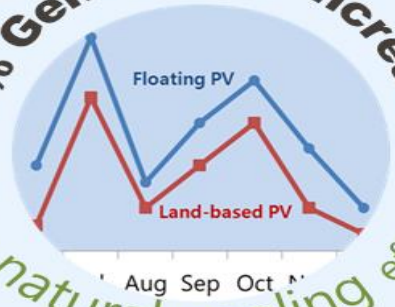
Use of Water Surface

The Efficient Use of Land

by eco-friendly system

High Efficiency

10% Generation Increase



by natural cooling effect

Environment

Preventing Green Tide

Green tide can be controlled

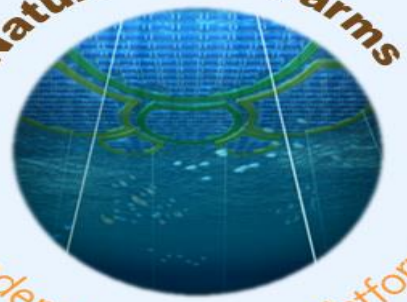
by blocking sunlight

Saving the Water Resources

by blocking sunlight

Eco-friendly System

Natural Fish Farms

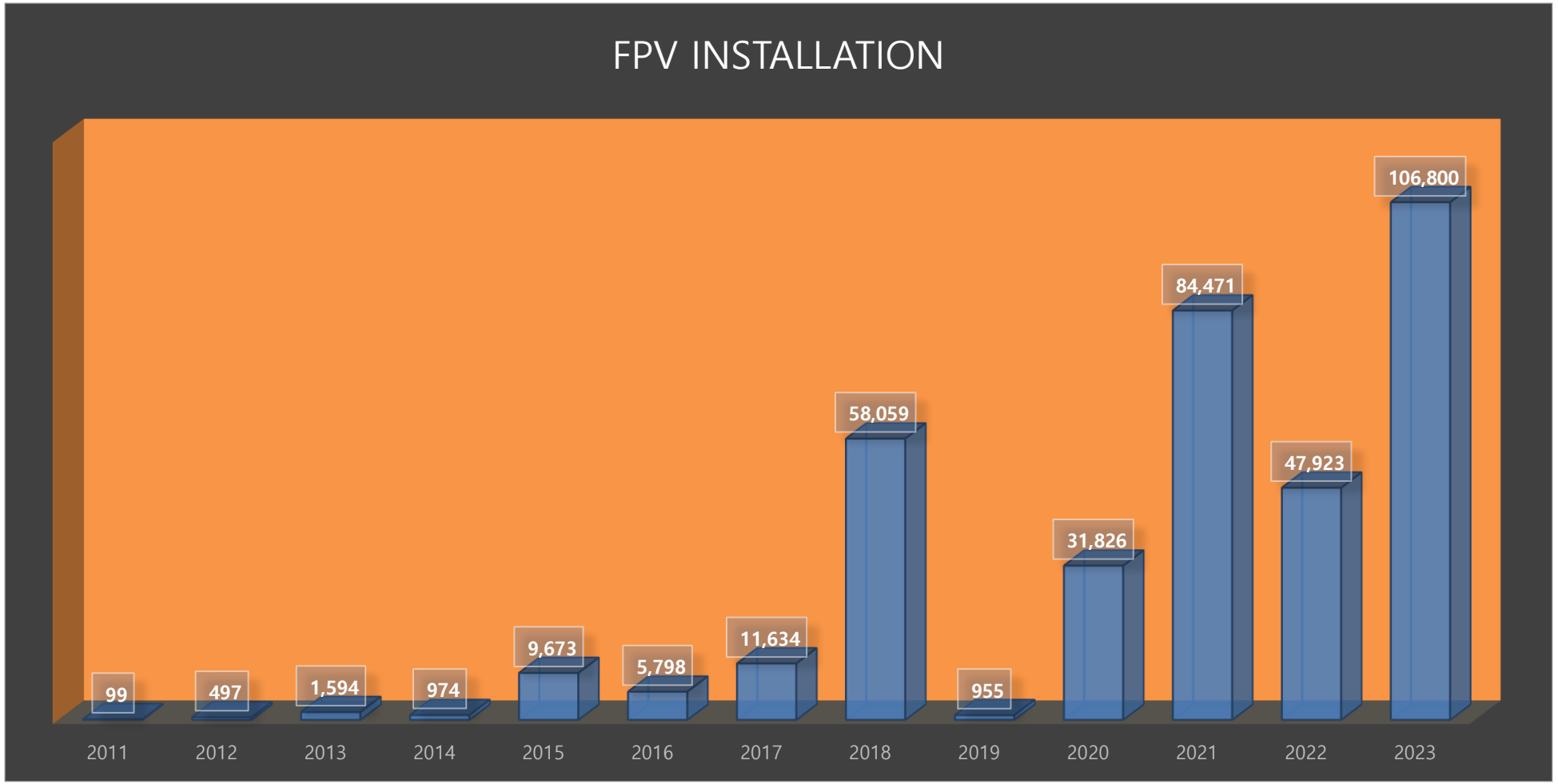


under the floating platform

2. Korea Economy FPV Market : Cumulative FPV Installation

A 99kW FPV system was installed in the fall of 2011. As of 2023, 107MW has been installed , and the total cumulative installed volume reaches 360MW.

Unit : [kW]



2. Korea Economy FPV Market : FPV category

Electrical generation Dam : 11 system, 61MW

Agricultural reservoir : 65 system, 60MW

Reclaimed lake : 4 system, 216MW

Industrial reservoir: 3 system 23MW

2. Korea FPV Market : FPV Business environment

REC weighting scheme

category	REC weighting	Energy source and criteria	
		Facility type	Criteria
Solar PV	1.2	Facility installed on general site	Less than 100kW
	1.0		More than 100kW
	0.7		More than 3,000kW
	1.5	Facility installed on existing buildings	Less than 3,000kW
	1.0		More than 3,000kW
	1.5	Facilities floating on the water	

1. Korea Economy supports renewable energy by implementing the RPS system. In the case of FPV, the RPS support weight is 1 to 1.5 times higher than that of land-based PV.

2. Korea Economy has an established permitting process for floating solar power projects. However, the public is very interested in conserving the natural environment, and the permitting process includes a procedure to obtain consent from residents.

3. In Korea, it is mandatory for floating photovoltaic systems to use dedicated solar modules suitable for the water environment. This defines product performance in KS, a national standard.

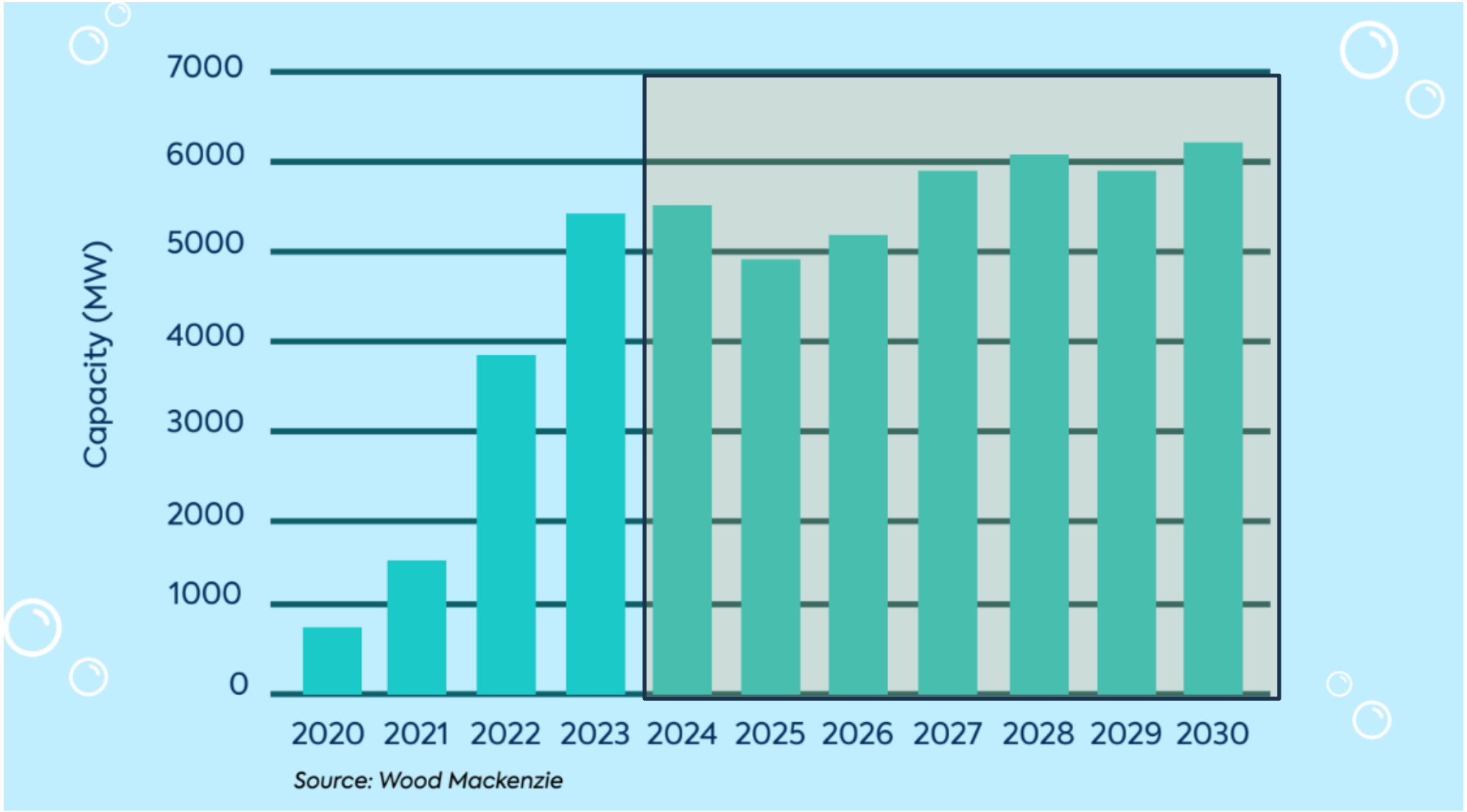
2. Korea FPV Market : FPV Photovoltaic Module

1. In Korea, when installing a floating Photovoltaic generation system, it is required that a dedicated floating Photovoltaic module must be used.

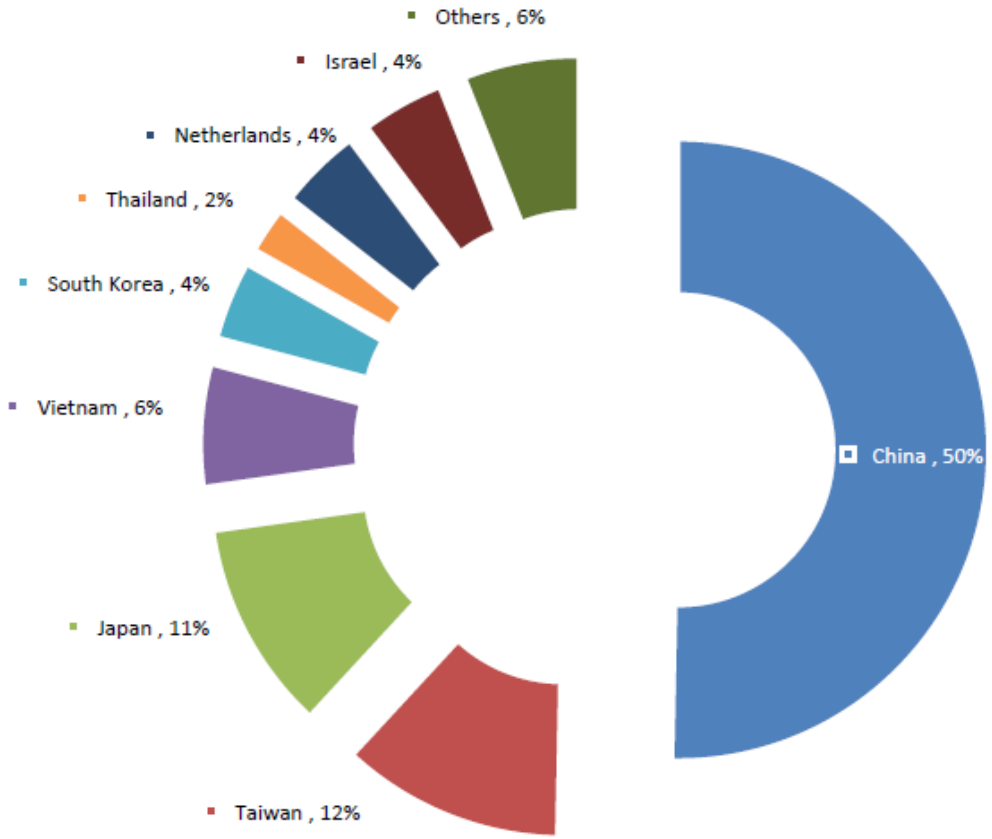
2. The KS C 8561 Crystalline silicone photovoltaic(PV) module (performance) regulation used in Korea includes the required performance and test methods for modules for installing solar power generation on water.

3. The performance test of the water module has three characteristics : 3000h damp heat test, mechanical load test including dynamic load, and restriction on the use of heavy metals.

3. Global FPV Market : Size Forecast



3. Global FPV Market : Major Economy



Continent	Country	Installed Capacity (kWp)	Number of projects
Asia	China	1,327,230	45
	Taiwan	305,266	51
	Japan	287,729	186
	Vietnam	167,530	5
	South Korea	106,947	44
	Thailand	61,982	44
Europe	Netherlands	111,123	36
	Israel	112,136	NA
Mixed	Others	158,259	159
	TOTAL	**2,638,202**	**578**

Source : SERIS

3. Global FPV Market : FPV Potential

Continent	Total surface area available (km²)	Number of water bodies assessed	FPV potential (GWp)			Possible annual energy generation (GWh/year)		
			Percentage of total surface area used			Percentage of total surface area used		
			1%	5%	10%	1%	5%	10%
Africa	101,130	724	101	506	1,011	167,165	835,824	1,671,648
Middle East and Asia	115,621	2,041	116	578	1,156	128,691	643,456	1,286,911
Europe	20,424	1,082	20	102	204	19,574	97,868	195,736
North America	126,017	2,248	126	630	1,260	140,815	704,076	1,408,153
Australia and Oceania	4,991	254	5	25	50	6,713	33,565	67,131
South America	36,271	299	36	181	363	58,151	290,753	581,507
Total	**404,454**	**6,648**	**404**	**2,022**	**4,044**	**521,109**	**2,605,542**	**5,211,086**

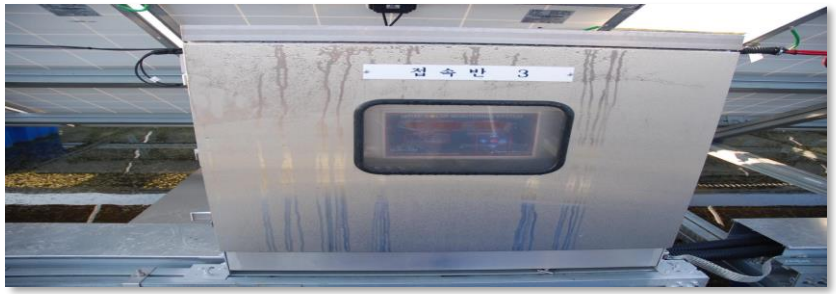
Source: SERIS calculations based on the Global Solar Atlas © World Bank Group (2019) and the GRanD database, © Global Water System Project (2011).

Note: GWh = gigawatt-hour; GWp = gigawatt-peak; km² = square kilometers; PV = photovoltaic.

4. FPV Module Research : FPV site Environment

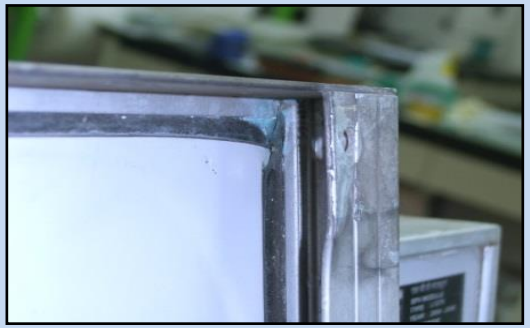
The environment of dams and reservoirs in which water-based photovoltaic systems are installed is very humid and covered with fog in the early hours of the morning, and when the fog clears, there is considerable moisture on the surface of the module.

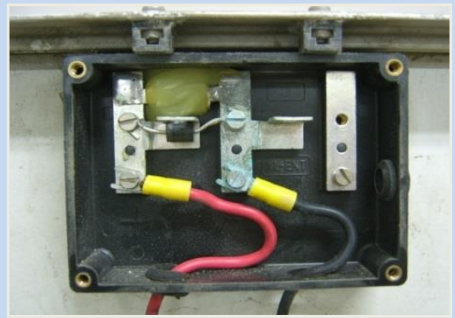
Site name : Dea-do reservoir
Site coordinate : **35°04'06.5"N, 126°37'14.1"E**
Inst Capacity: 500kW
Installation Date : Sept 2015
Water Depth : 3~7m
Module Type : c-Silicon

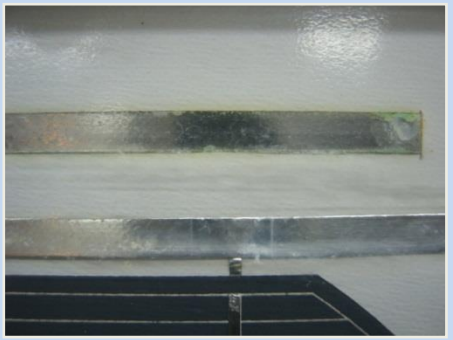


4. FPV Module Research : Reference PV module for Research

For the development of floating PV modules, we refer to two modules. One is a module installed on the island 20 years ago, and the other is one on a buoy that is replaced every five years.







4. FPV Module Research : FPV module Specifications

Eco-friendly Customized PV Module

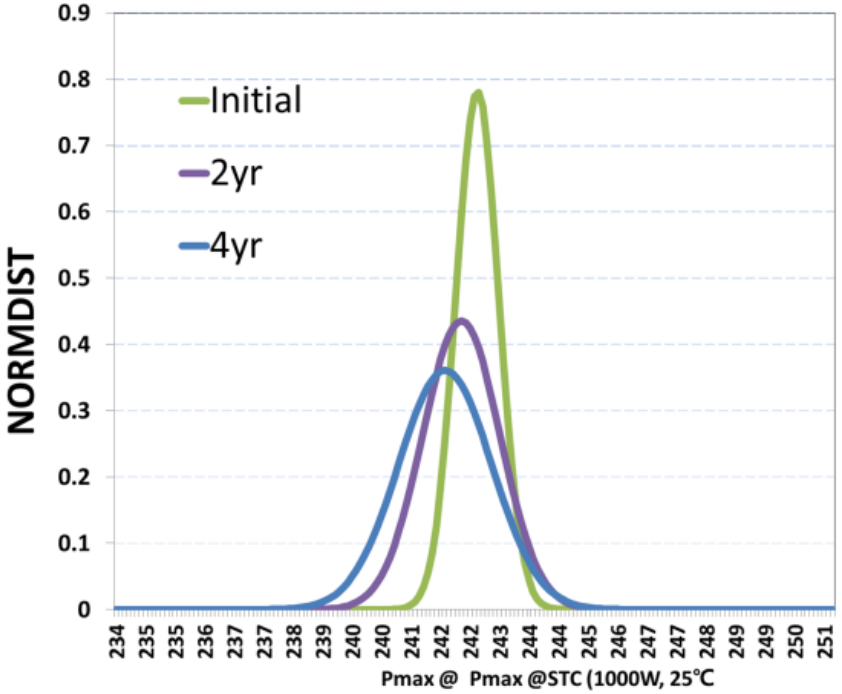
Special Features	Customized PV Module	Conventional PV Module
Applicable Installation Site	Reservoir, Dam Lake, etc.	Building Rooftop, Land
IP Class	IP67	IP64
Humidity	High	Normal
PID	PID Free	PID Free or Non-PID
Encapsulant	Polyolefin Elastomer(POE)	Ethylene vinyl acetate(EVA)
Material of Ribbon	Lead(Pb) Free	Lead(Pb) used

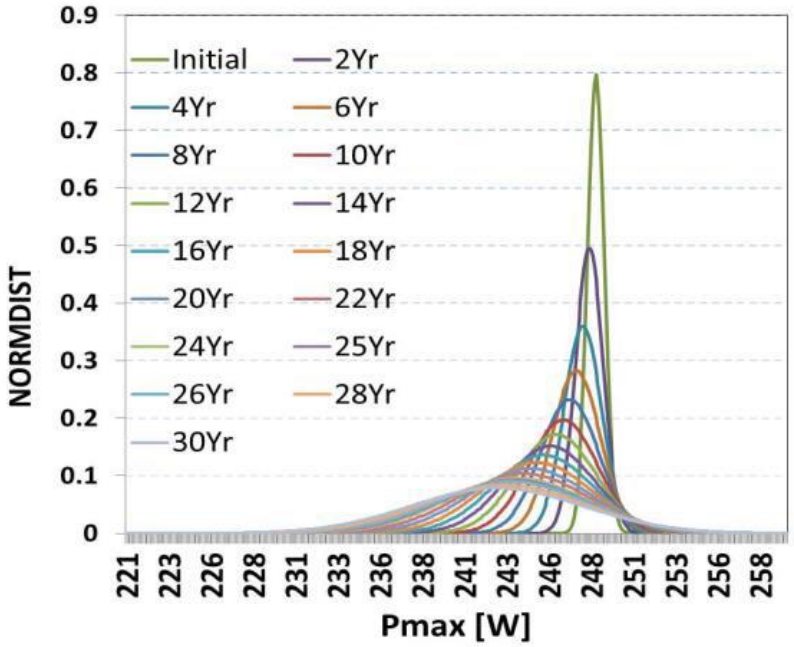
- PID : Potential Induced Degradation

4. FPV Module Research : Power Degradation

The 100 sample for floating pv modules were tested under STC conditions every two years, resulting in an average power reduction of 0.07%. The standard deviation increased by 0.59% over four years. If you predict a 25 year output degradation, We expect a decrease of 13.5%

FLOATING	Yearly PV (@STC)		
YEAR	Yr 0	Yr 2	Yr 4
PVM [W]	242.57	242.19	241.81
STDEV(%)	0.5106	0.9163	1.1065

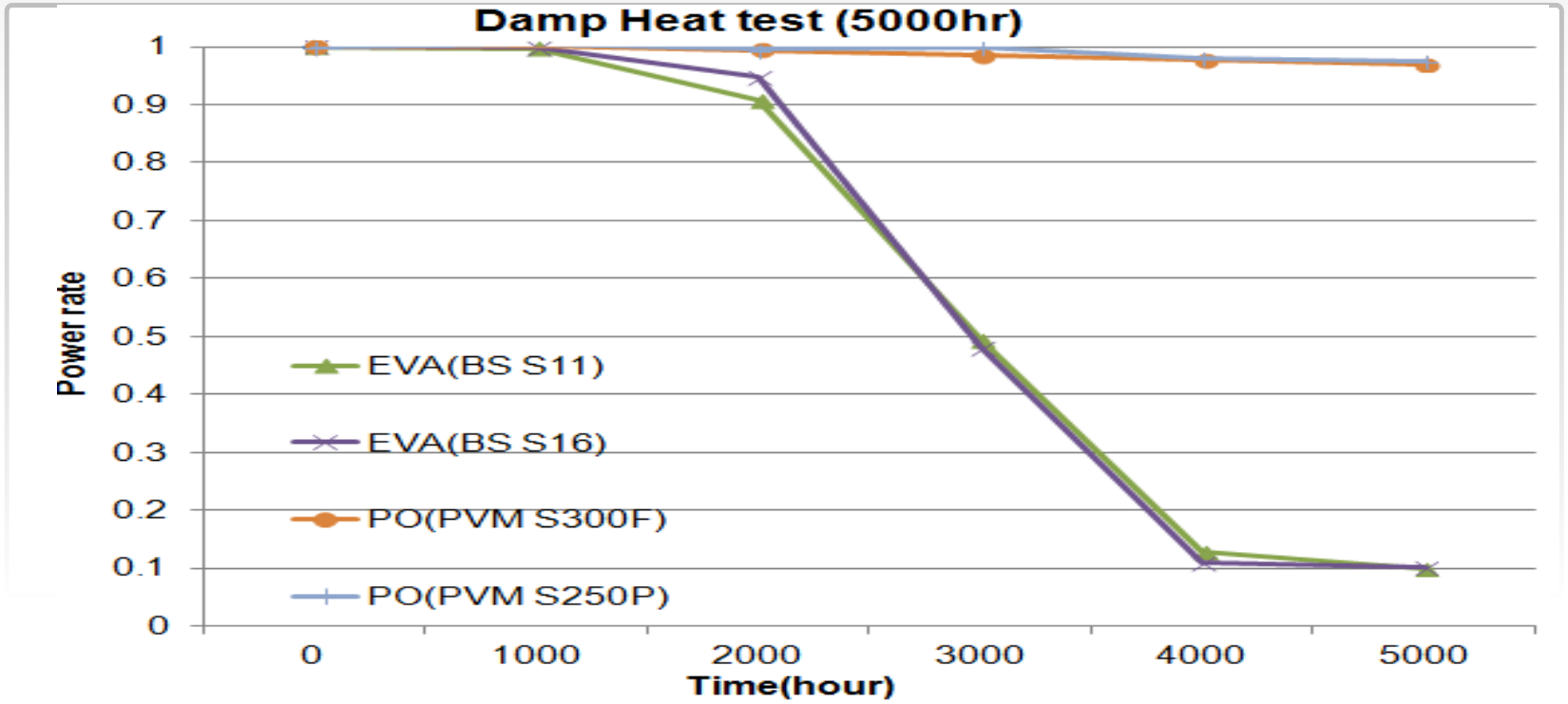




4. FPV Module Research : Anti Moisture Characteristics

5000 hours Damp Heat Test

- 5,000 hours long test for water installation with hard condition.
- Condition: Damp Heat(85℃, RH 85%), 5000hours by KTL



Time(hr)		0	1000	2000	3000	4000	5000
EVA	BS S11	100.0%	99.7%	90.9%	49.4%	12.8%	9.9%
	BS S16	100.0%	100.0%	94.8%	48.1%	10.8%	10.2%
Poly olefin	PVM S300F	100.0%	100.1%	99.5%	98.4%	97.8%	97.0%
	PVM S250P	100.0%	100.4%	99.5%	99.9%	98.1%	97.5%

5. FPV System Research : FPV Installation site

	Agricultural reservoir	Electrical generation Dam
Fresh water		
	Reclaimed lake	**Off-shore**
Salt water		

5. FPV System Research : FPV test bed

■ Agricultural reservoir

■ Electrical generation Dam

■ Terrace land on the river

■ Reclaimed lake

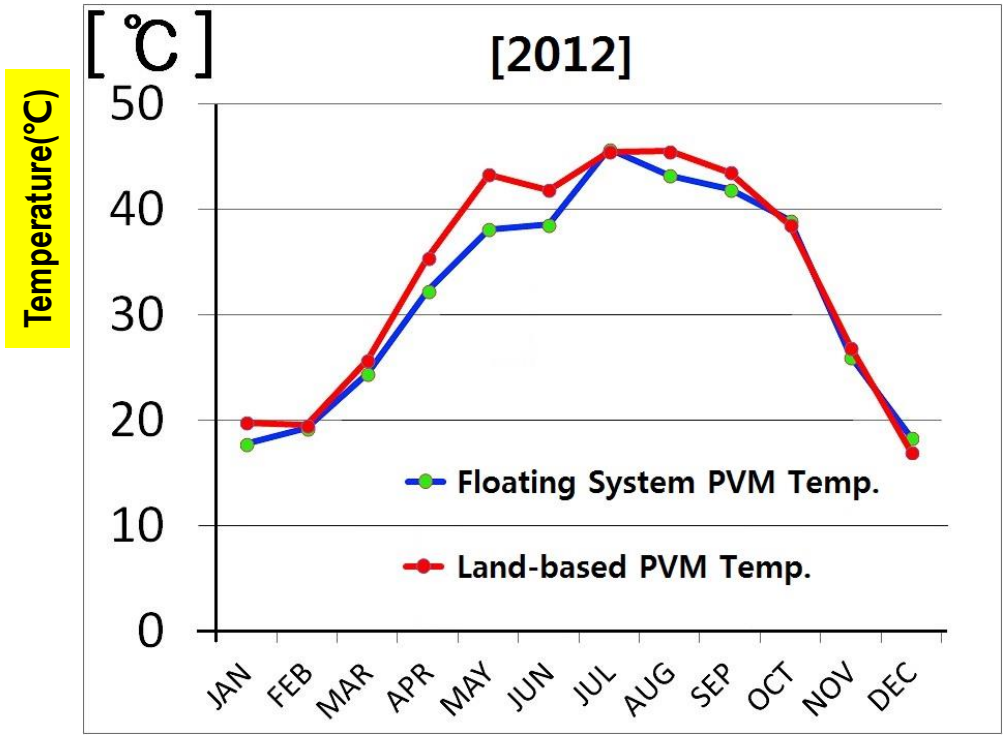
■ Off-shore

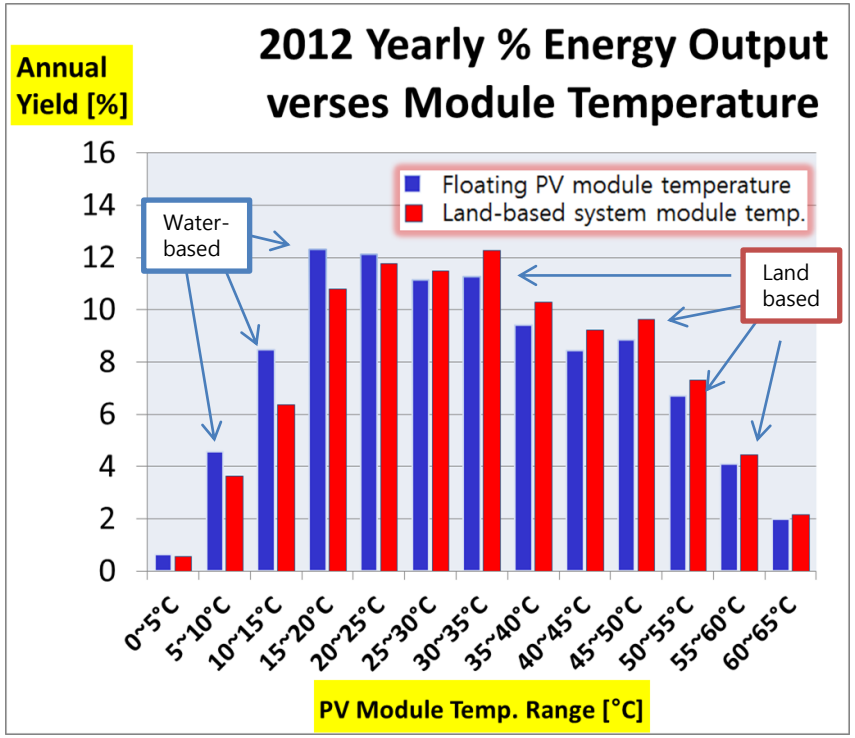
■ Port

5. FPV System Research : Cooling Effect

Floating System vs. Rooftop Temperature Characteristics

- Floating PV module op. temp. 5°C~10°C lower based on annual and monthly averages
- **Higher Yield distribution** & **System Operation time** at corresponding low module temperature ranges





5. FPV System Research : Corrosion

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m²	Thickness loss µm	Mass loss g/m²	Thickness loss µm		
C1 very low	⩽ 10	⩽ 1,3	⩽ 0,7	⩽ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I very high (industrial)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

NOTES

1 The loss values used for the corrosivity categories are identical to those given in ISO 9223.

2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.

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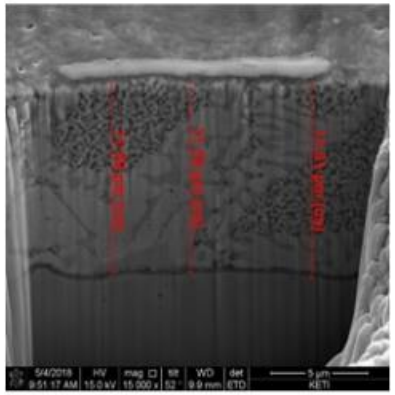	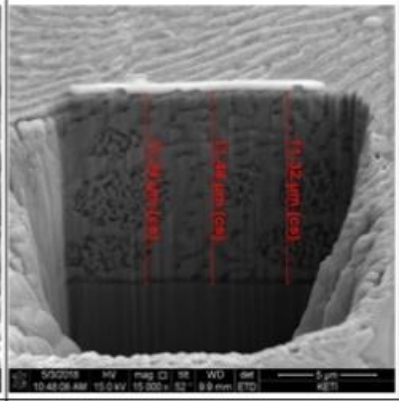	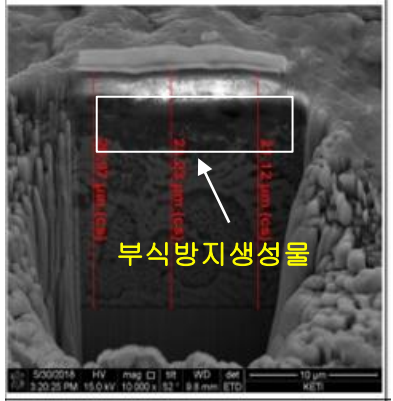
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5. FPV System Research : conservation of nature

☐ Service Organization : Korea Environment Institute(KEI)

☐ (service fee, Period) $130,000/year,2011.~2016.

☐ (Service Contents)

o Establish guidelines and environmental monitoring

o Conduct environmental monitoring for conservation of nature

o Verification and sharing of environmental safety through governance operation

☐ Environmental monitoring

Item	Cycle	Sampling point
Water quality /Phytoplankton	1 times / Month	4 point
Fishes	1 times / Month	2 point
Deep water invertebrate	1 times / Month	6 point
sediment	1 times / Quater	6 point
birds	1 times / Quater	1 point

☐ Result

o Monitoring does not have negative environmental impact

o Does not affect water quality in terms of chemistry

No impact on surrounding ecosystem environment

Water quality
- No possibility influence by facilities

Fishes
- No possibility influence by facilities

Phytoplankton
- No possibility influence by facilities

Deep Water Invertebrate
- No possibility influence by facilities

Sediment
- Lower than the reference value

Dissoving test for water equipment
- Fits standards

Birds
- No association with avoidance, reduction of population

Anaerobic
- No possibility influence by facilities

Surface Water flow
- No possibility influence by facilities

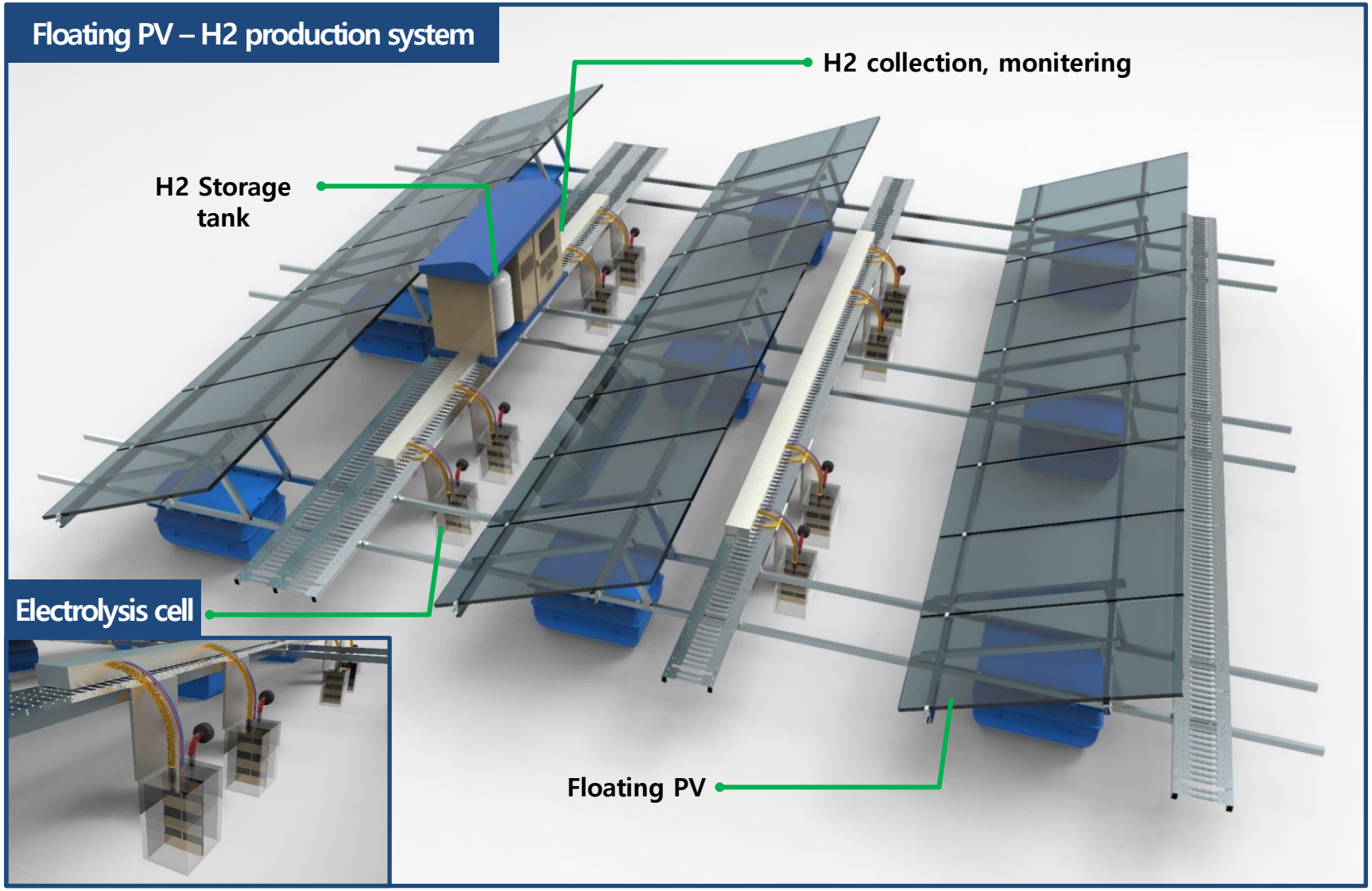
5. FPV System Research : Reclaimed lake FPV Testbed

5. FPV System Research : off-shore FPV Testbed

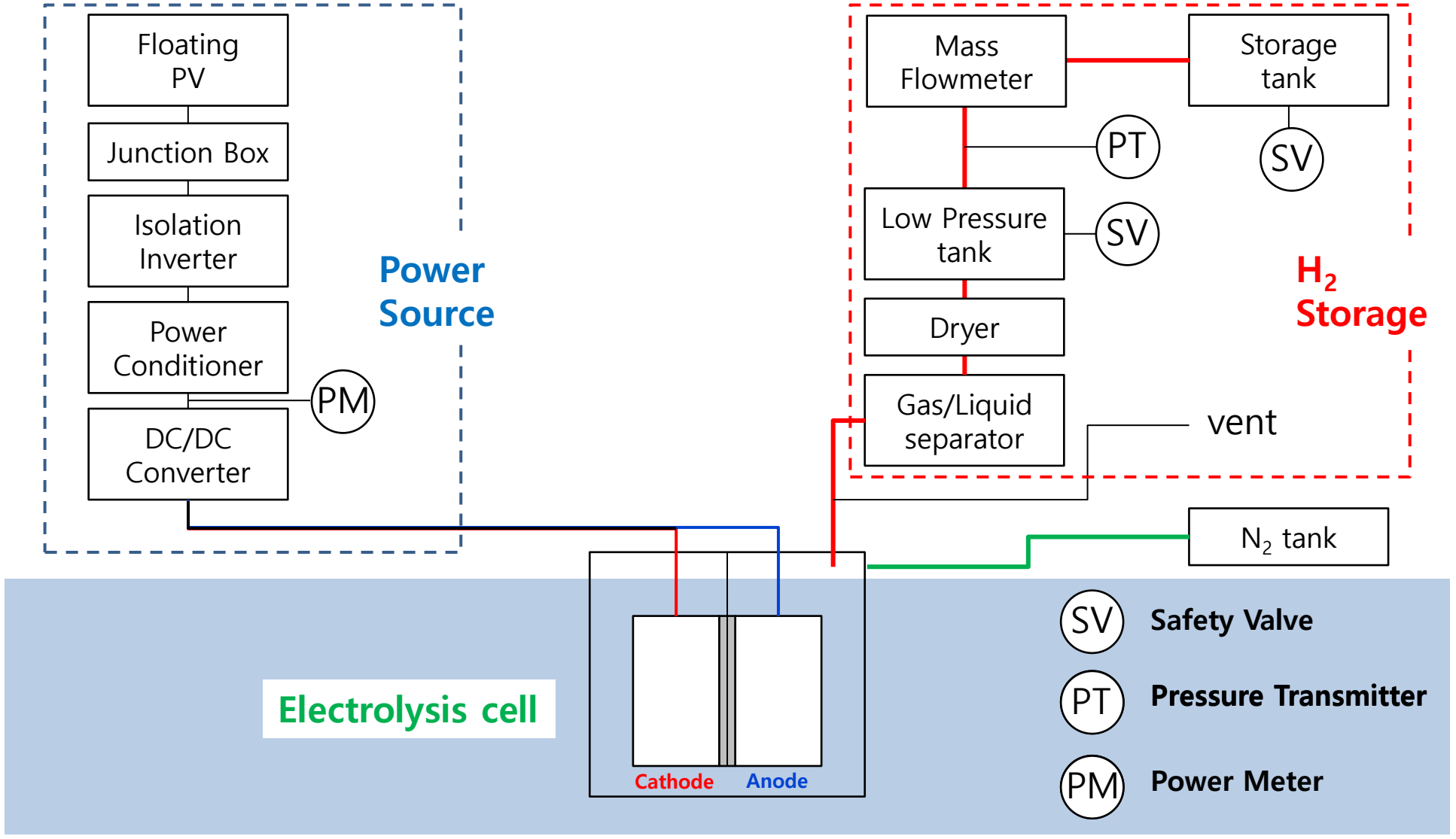
6. Future work : Bird soiling

6 Future work : ship wave (small wave-fatigue failure)

6. Future work : Energy transfer - Floating PV – H2 production system



6. Future work : Energy transfer - Floating PV – H2 production system



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Thank you

for your attention