ICEF2023 CS3: Innovative Use of Renewables

Towards Sustainable Deployment of Renewable Energies for Carbon Neutrality

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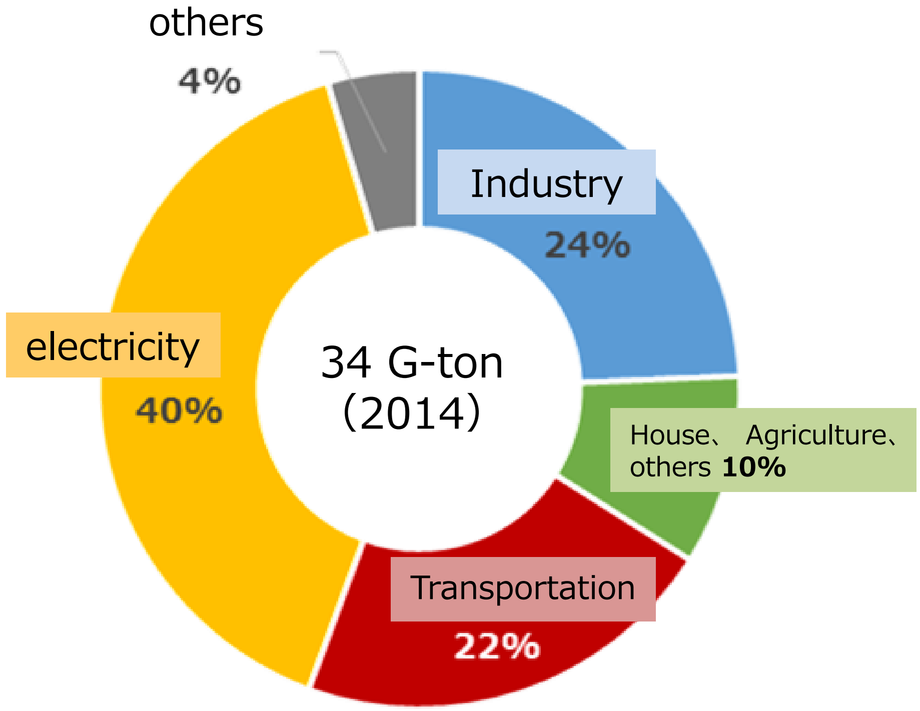
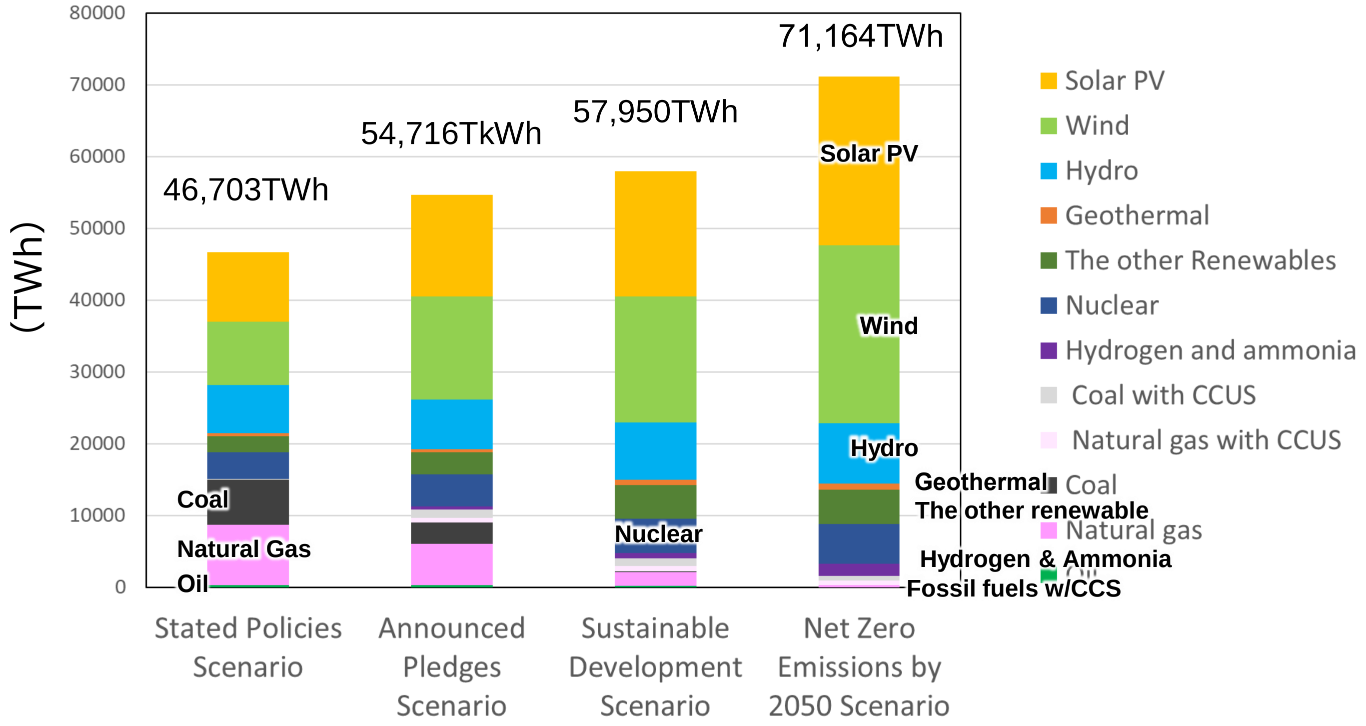
Extended Role of Renewable Energies

- The climate change has been recognized globally as an urgent issue to be solved.
- CO_2 emission in electricity occupies 40% of total CO_2 emission.
- Renewable energy is one of the most effective technologies to reduce CO_2 emission.
- Demonstration of net-zero electricity is mandatory to realize the 2050 carbon neutrality.
- PV and wind have large potentials to reduce CO_2 emissions and expected to play central roles in the future global energy.



Source：Compiled by NEDO TSC based on
IEA ETP2017、Global Renewables Outlook 2020（IRENA）

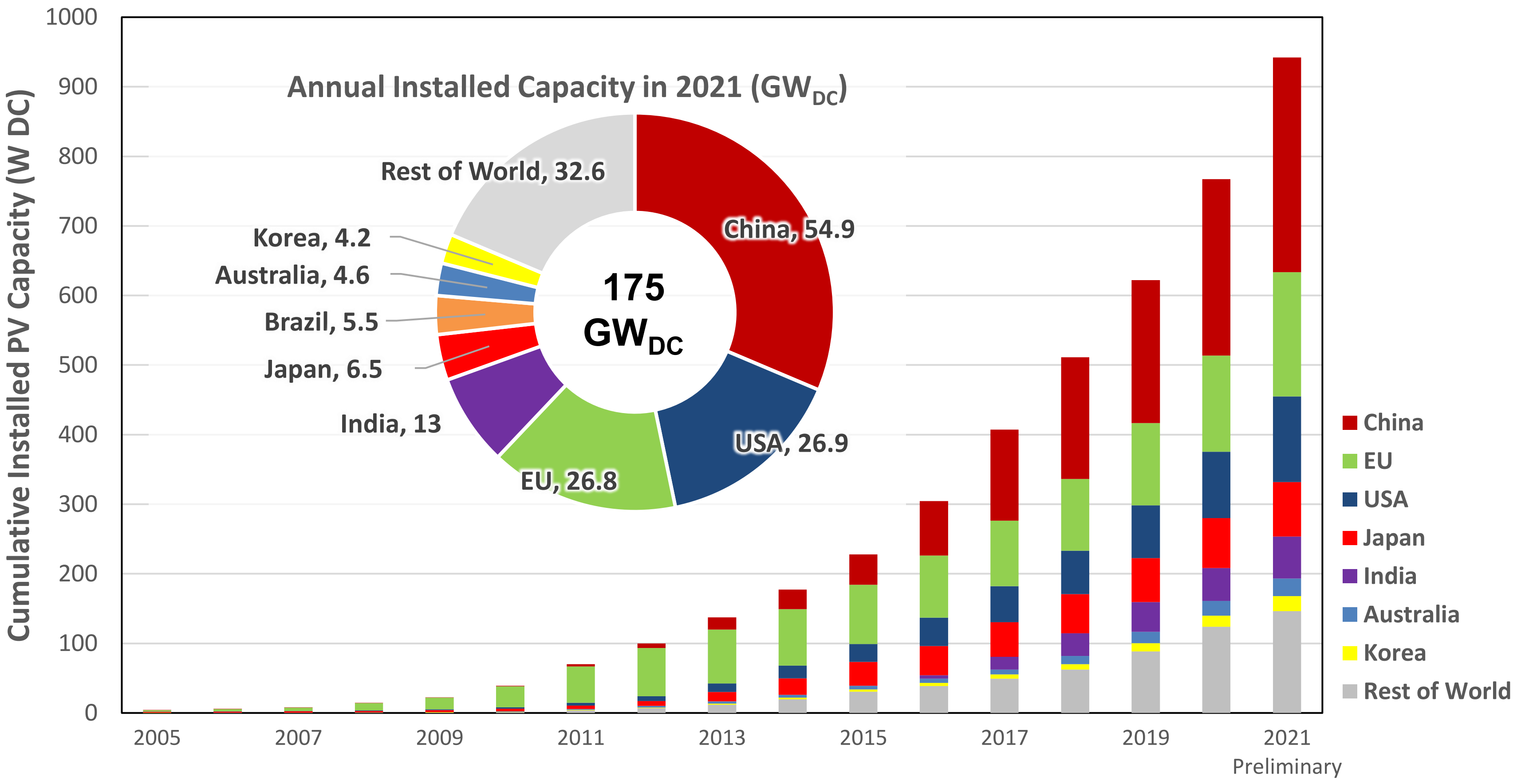
Energy Mix in Electricity at 2050



Source：Compiled by NEDO TSC based on IEA World Energy Outlook 2021

World Cumulative PV Installation

- Cumulative PV installation exceeded 900GW and annual PV installation reached 175GW in 2021, PV becoming one of the primary energies.
- PV reached a big milestone of 1TW in 2022 entering "Terawatt Era".
- PV became the cheapest form of electricity in some regions.



Reference：Compiled by NEDO TSC based on IEA PVPS "Trends in Photovoltaic Applications 2021", "Snapshot of Global PV Markets 2022"

New PV Applications

- The penetration of new PV applications in addition to mega solar and rooftops is expected.
- New applications such as side wall of the buildings, on water, in farmland and on mobility can accelerate the penetration of PV systems further.
- These applications need additional specifications such as very high-efficiency (η>30%), light-weight, flexible, high quality design, long-term stability under special environment, etc.

＜Floating＞ reference：Yamakura dam（Kyocera）

＜Farmland＞ 出典：営農型発電設備の現状について（農林水産省,2018）

＜Side wall＞ reference：https://www.taisei.co.jp/about_us/wn/2014/140616_3948.html（大成建設HP）

＜Car＞ Reference：: https://global.toyota/jp/newsroom/corporate/28781301.html?_ga=2.7594312 3.774819704.1599699649-2016341029.1598338298（トヨタHP）

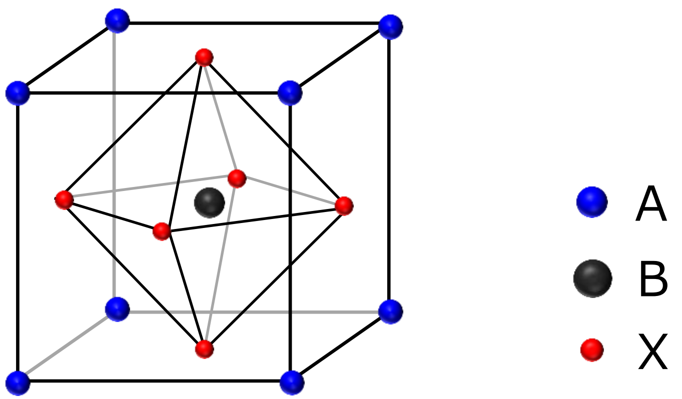
＜HAPS＞（High Altitude Platform Station Pseudo-Satellite）

https://www.softbank.jp/corp/news/press/sbkk/2019/20190425_02/

Emerging Technology: Perovskite Solar Cells

- The R&D of perovskite solar cells started at 2009, and the efficiency increased rapidly up to 26.1%
- Low-cost processes such as printing technology can be used for mass production.
- Japan, EU, US, China and Korea have been investing a lot for the R&D of perovskite technologies.
- Module technology, long-term stability and replacement of Pb are the most important tasks for the commercialization.

Crystal structure of perovskite



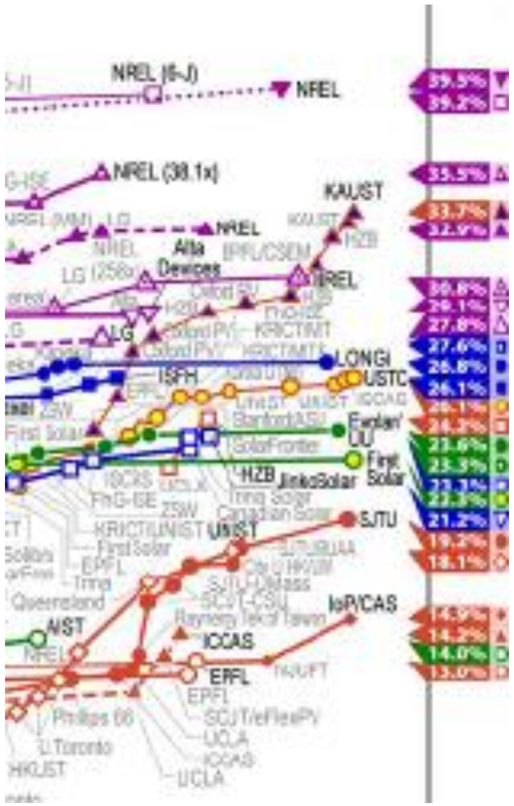
ABX_3

A = $CH_3NH_3^+$, $HC(NH_2)_2^+$, Cs^+, Rb^+, K^+

B = Pb^{2+}, Sn^{2+}

X = I^-, Br^-, Cl^-

Composition of perovskite solar cells



Perovskite/Si Tandem 33.7% (KAUST)

Perovskite cell 26.1% (USTC)

Best Research-Cell Efficiencies (NREL) as of 7/10/2023

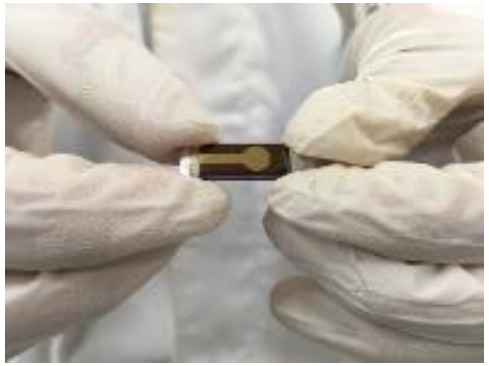
Development of Next-Generation Solar Cells
(Overview of Green Innovation Fund Project)

- In order to expand the installation of solar power, it is necessary to **develop next-generation solar cells (perovskite solar cells)** that can be installed such as walls.
- Japan is in the **top group in the development of perovskite solar cells** (**recording the world's highest conversion efficiency**). Europe, US and China are also accelerating development.
- **Aiming for market launch by FY2030**, the project will develop **basic technologies as well as practical application and demonstrations**.

〈Image of solar cells development phase〉

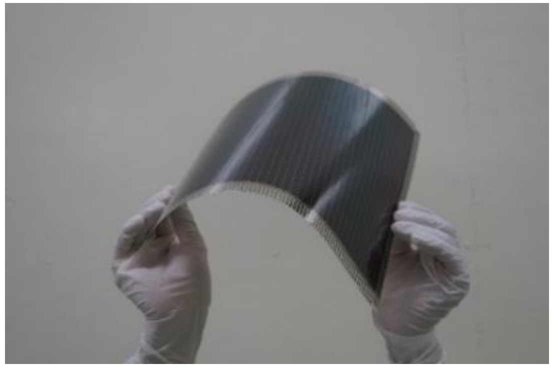
Laboratory level R&D ▶ Upsizing, etc. for commercialization ▶ Demonstration in collaboration with users

Test cell



University of Tokyo

Practical size sample



Toshiba

Wall installation example

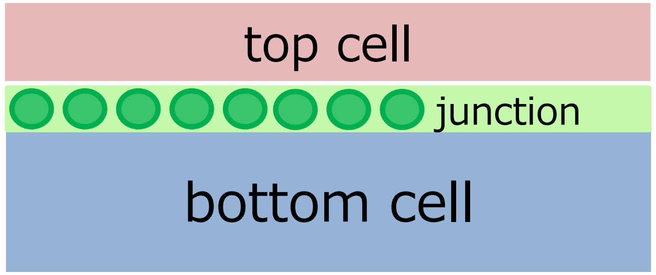
Taisei Corporation

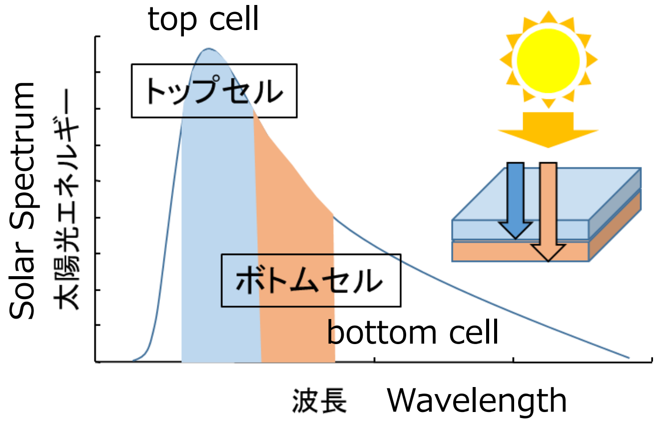
R&D target: Achieve a power generation cost of 14 yen(about 10 cent)/kWh or less under certain conditions (sunshine conditions, etc.) by FY2030

Reference: New Energy Technology Division (NEDO)

Emerging Technology: Next-Generation Tandem Cells

- Certain applications need high efficiencies beyond the theoretical limit of single-junction solar cells.
- For the bottom cell, c-Si and CIGS solar cells can be used with optimization.
- Requirements for the top cell: high efficiency over 20%、long-term stability over 20 years (equivalent to that of bottom cell) with low-cost process.
- Currently, no established top cell technology exists.





Top cell candidates

III-V

advantage
・over 40% efficiency demonstrated
・proven long-term stability

To be solved
・high production cost

Perovskite

advantage
・over 25% efficiency reported
・low production cost

To be solved
・long-term stability
・alternate materials for Pb

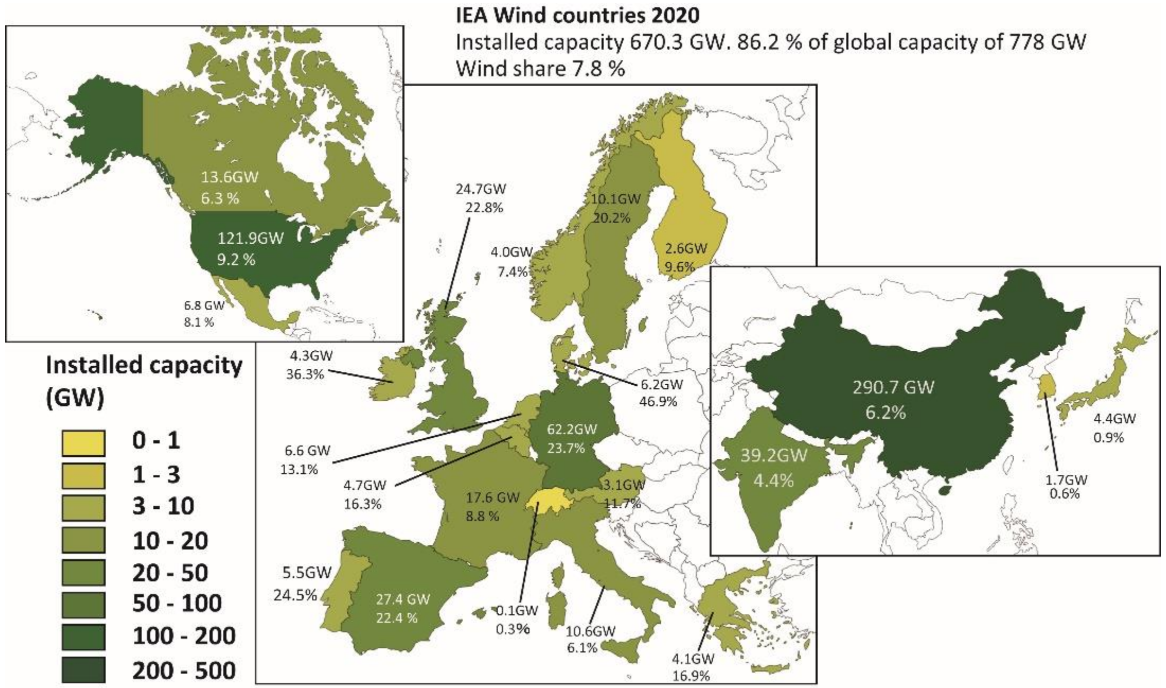
Chalcogenides

advantage
・over 23% efficiency achieved
・low-cost process
・proven long-term stability

To be solved
・high-efficiency at E_g=1.6-1.8eV
・ alternate materials

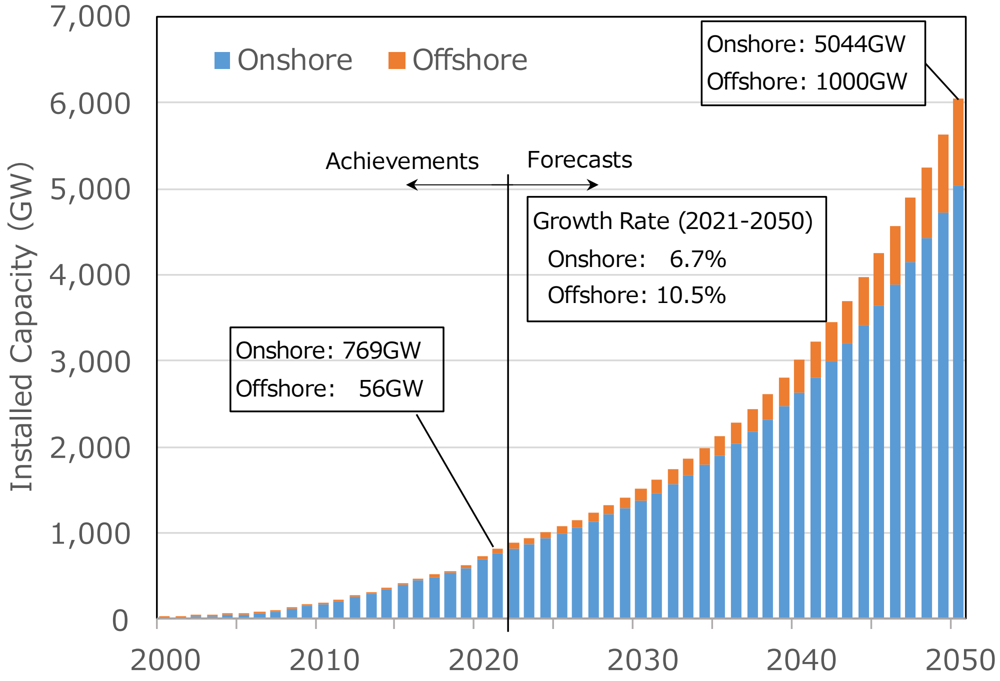
Current Status and Outlook of Wind Power Generation

- World cumulative installation of wind power reached 778GW including 35GW of offshore wind power in 2020.
- IRENA estimated the expansion of wind power installation up to 5,044GW (onshore) and 1,000GW (offshore) in 2050.



Total Installed Wind Power System by 2020

Source：Compiled by NEDO TSC based on IEA Wind TCP Annual report 2020



Cumulative Wind Power Installation

Source：Summarized by NEDO TSC from IRENA Renewable Capacity Statistics 2022 and Future of Wind (2019)

Technology Strategy and Future Goals

- Wind power gains competitiveness as a main power supply, and contributes significantly to the carbon neutrality by 2050.
- Five key issues as shown below have to be established in order to make the wind power reliable and sustainable for a long time.

Future Goals

Cost-Competitive Floating Offshore Wind	・Upsizing of the wind turbine ・Extended areas for installing floating wind
Further Penetration of Fixed-Bottom Offshore Wind	・Upscaling of the wind farms ・Establishment of multi-terminal interconnections
Repowering of Onshore Wind Improved Social Acceptance	・Improvement in social acceptance ・Use as incubation sites
Circular Economy in Wind Power	・Reduction of material usage and recycling ・Extended lifetime of facilities
Extended Usage of Wind Power	・Sector coupling with hydrogen, etc.

Importance of Offshore Wind Power in Japan

- The offshore wind power has a lot of potential in Japan.
- The floating type offshore wind is very important in Japan, and is still under development and competition worldwide.
- The Green Innovation Fund Project will develop the offshore wind power technologies suitable for weather and sea conditions of Asia, and it aims for the development of the cost competitive integrated design of floating offshore wind including wind turbines, floating bodies, cables, etc.

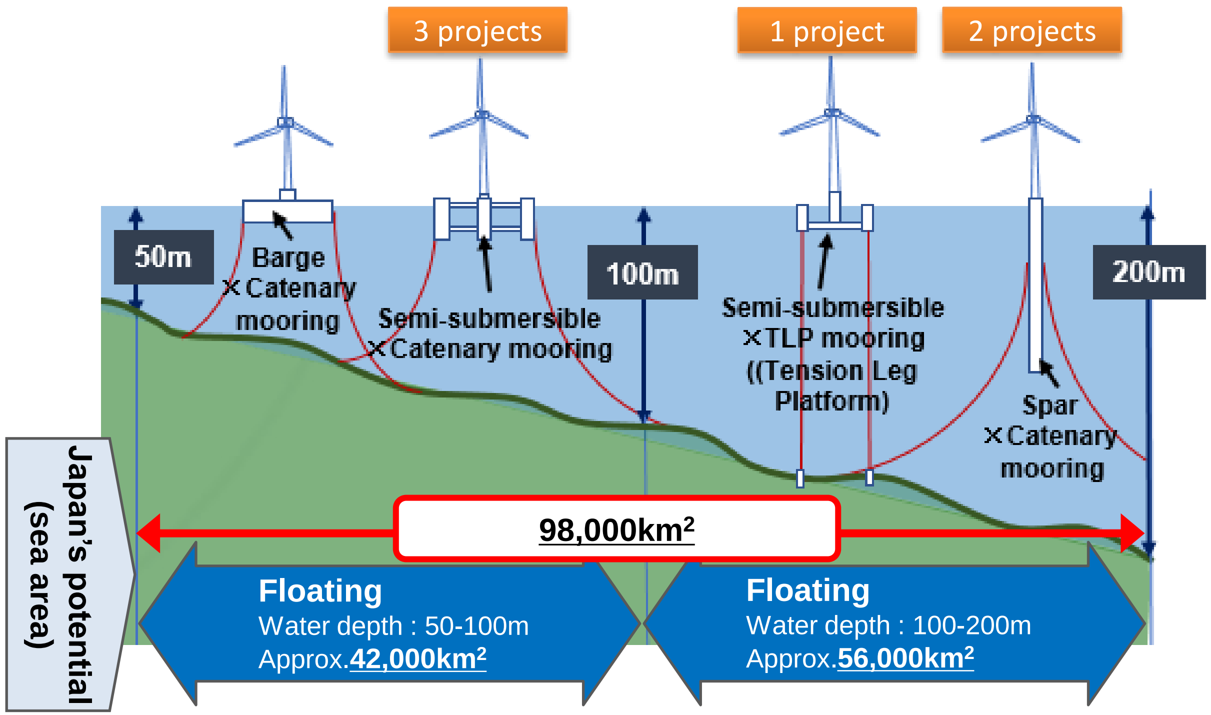
Phase 1:Technology development

Development issues:
- Low-cost steel alternative materials
- Wind turbine which responds to the natural environment of Asia
- Improved durability of mooring cables
- Failure prediction using AI and big data

Phase 2: Demonstration

Development issues:
- Design and cost reduction of the entire system integrating wind turbine, floating body, and cables.

R&D target: A level at which power generation costs of Bottom-mounted type can be forecast at 8 to 9 yen/kWh under certain conditions by 2030



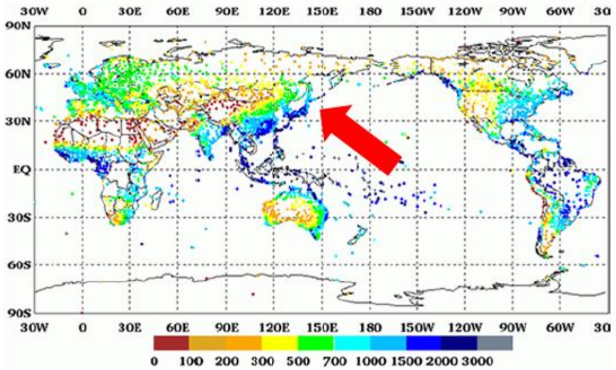
※1 The sea area is estimated based on the offshore distance of less than 30km, excluding social constraints, and an annual average wind speed of 7m/s or higher.
※2 The position shown in the figure for the floating type is not the applicable range or the optimal water depth.

Extension of Lifetime, Reduction of O&M Cost: Erosion of Wind Turbine Blades

- Leading-edge erosion takes place on the surface of high-speed rotating blades by hydrometeor impact.
- Substantial impact on cost of energy and unpredictability of business risks especially for large offshore turbine in the Asian Monsoon region.
- Countermeasures including leading-edge protection devices, inspection and maintenance methods, and new turbine control are under development.
- International collaborative R&D framework has been formed in IEA Wind TCP Task46 to better understand the key technical challenges in the blade erosion.

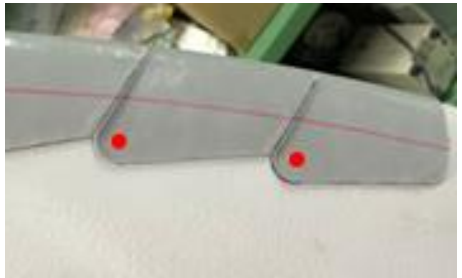
Eroded leading edge

Global annual precipitation

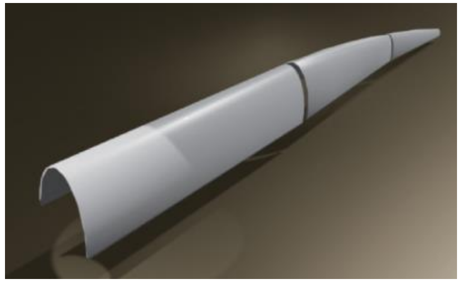


https://www.data.jma.go.jp/gmd/cpd/monitor/climfig/?tm=monthly&el=TanmMIn

Devices for erosion protection



https://www.fujikuracomposites.jp/satellite/denzai/products/bladeprotectivesheet/ブレード保護シート.pdf



https://www.asahi-rubber.co.jp/products/products-for-windmill-blades/index.html

Task46 work packages

- Climatic conditions driving erosion (wp2)
- Wind turbine operations with erosion (wp3)
- Laboratory testing of erosion (wp4)
- Erosion mechanics & material properties (wp5)

Task46 participants

Reference: Dr. M. Tanaka (AIST, FREA)

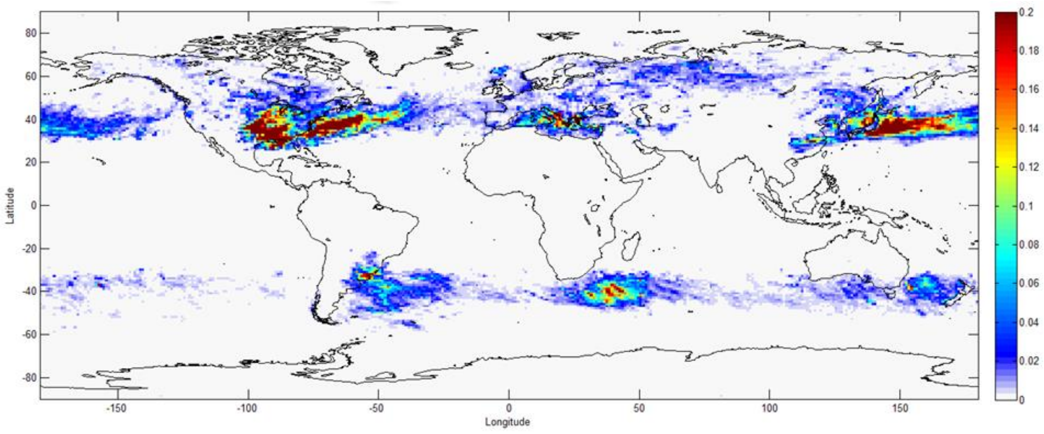
Extension of Lifetime, Reduction of O&M Cost: Severe lightning strikes

・The lightning strike is one of the major causes of wind turbine failure, and the counter measures are especially important in Japan and Southeast Asian countries.
・The lightning failure leads to additional costs such as repair and protection, inspection and monitoring, etc.
・Robust diverter strips which are effective for lightning protection have been developed under NEDO projects.

Blade failure by lightning

<https://www.meti.go.jp/shingikai/sankoshin/hoan_shohi/denryoku_anzen/newenergy_hatsuden_wg/pdf/024_03_00.pdf>

Global distribution of winter lightning



https://nhess.copernicus.org/preprints/nhess-2015-302/nhess-2015-302.pdf

Diverter strips applied in a field

https://www.nedo.go.jp/content/100964528.pdf

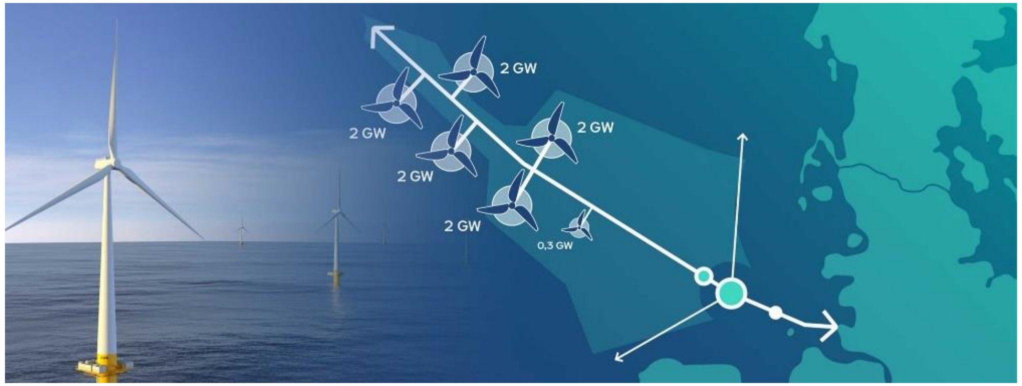
Reference: Dr. M. Tanaka (AIST, FREA)

Emerging Technologies: Hydrogen Production Using Wind Power

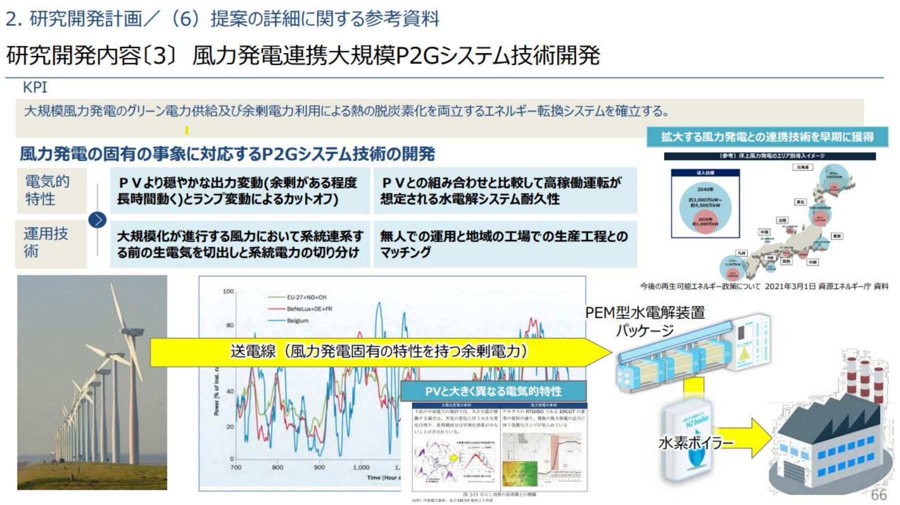
- We face the issues of synchronization between generation and consumption when we use variable renewables .
- Green hydrogen is one of the solutions not only avoiding the grid bottlenecks but also decarbonizing industrial sectors by replacing the fossil fuel.
- Some projects have been demonstrated in Europe, for example the AquaVentus project on the North Sea. Also in Japan, hydrogen production through water electrolysis using renewables have been investigated under another Green Innovation Fund Project.

AquaVentus project on the North Sea

One million tons of green hydrogen per year, produced from wind energy on the North Sea and transported on land by pipeline - that is the vision of AquaVentus.
More than 100 companies, organizations and research institutes along the entire value chain collaborating as broad-based project family in realizing 10GW of generation capacity by 2035.



Source: https://aquaventus.org/en/



Hydrogen production through water electrolysis using power from renewables project in Japan

R&D takes place on technology for efficient system operation methods to replace fossil fuels and raw materials with hydrogen in industrial processes that use water electrolysers, and so on.

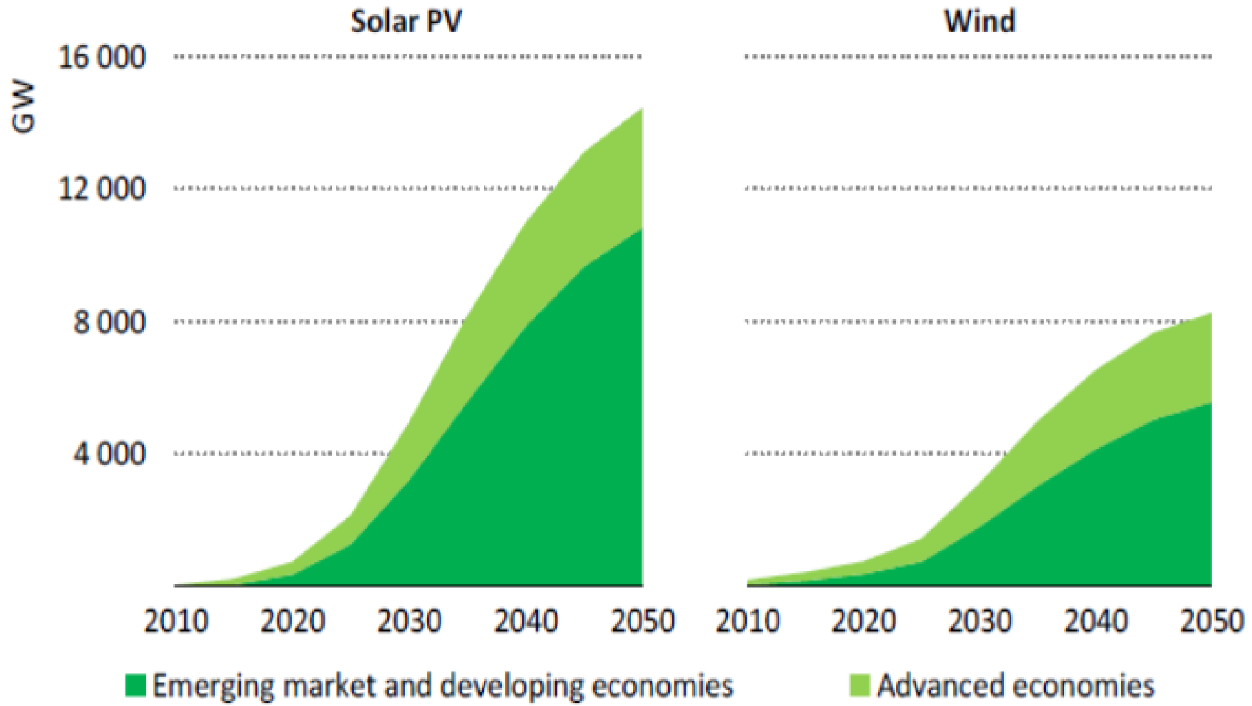
High Expectations to Photovoltaics and Wind Power for Carbon Neutrality

- Photovoltaics and wind power are expected to play a central role for achieving the carbon neutrality by 2050.
- IEA NZE scenario indicated 15TW of PV and 8TW of wind power deployment by 2050.
- Risks in material supply and mass disposal of equipments and facilities from renewables will become critical issues to be solved for further penetration of renewables.

- Sustainability throughout the whole lifecycle has to be achieved when we make renewables as reliable energy sources well into the future.
- Storage, demand response, digitalization, infrastructures, etc. are also key issues to be addressed for further penetration of variable renewable energies.

Maximum energy with minimum resources!!

Outloook of the installation of PV and wind by 2050



reference : IEA Net Zero by 2050

Acknowledgments

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- I also would like to thank to Dr. T. Sugaya (AIST), Dr. M. Chikamatsu (AIST), Dr. Y. Shoji (AIST) and Dr. M. Tanaka (AIST) for supplying valuable information.

ご清聴ありがとうございました。

Thank you for your attention!!