Japan's World-Leading Renewable Energy Development —Review the 50-Year History of the Sunshine Project and Look Into the Future—

1. Japan's Sunshine Project with a Long-Term and Far-Sighted Perspective
2. R&D and Commercialization of Solar Power Generation in Japan That Contributed to the World
3. Expansion of Solar Power and Other Renewable Energy in Japan
4. Let's Talk About the Future!
   Can renewable energy cover the world's energy needs?

Yukinori Kuwano
Former President and CEO of Sanyo Electric Co., Ltd.,
Outside Director of Daiwa House Industry Co., Ltd.
Honorary Advisor of the Photovoltaic Technology Research Association

1-1. The Sunshine Project was planned prior to the oil crisis in 1973

1) At the beginning of 1970, discussions on alternative energy were started in the MITI to respond to concerns about the unstable energy supply at that time.
2) In the wake of the outbreak of the Middle East War in 1973 (50 years ago), the oil crisis occurred, and oil prices rose approximately four-fold.

3) The necessity of developing alternative energy sources was emphasized. With the aim of developing alternative energy, the Sunshine Project was launched in 1974.
(Japan's first national long-term industry-government-university collaboration project)

Outline of the Sunshine Project

1) Solar energy power generation system technology (solar power generation, solar thermal power generation, etc.)
2) Geothermal energy
3) Coal energy (coal liquefaction technology and gasification technology)
4) Hydrogen energy (hydrogen production technology, hydrogen transportation, and storage technology)
5) Wind energy
6) Ocean thermal energy conversion
7) Biomass

Source: Data released by METI

1-2. Two major energy resource wars in the past

PVTEC
Photovoltaic Power Generation Technology Research Association

1) On October 6, 1973 (50 years ago), the fourth Middle East War began. Of the OPEC member oil-producing countries, six Persian Gulf countries decided to raise listed crude oil prices approximately four-fold (from $3.01/barrel to $11.65/barrel).

2) In February 2022, Russia invaded Ukraine.
The G7 countries imposed sanctions, which led to the energy resource war.

Source: each Website.

1-3. Enormous solar energy

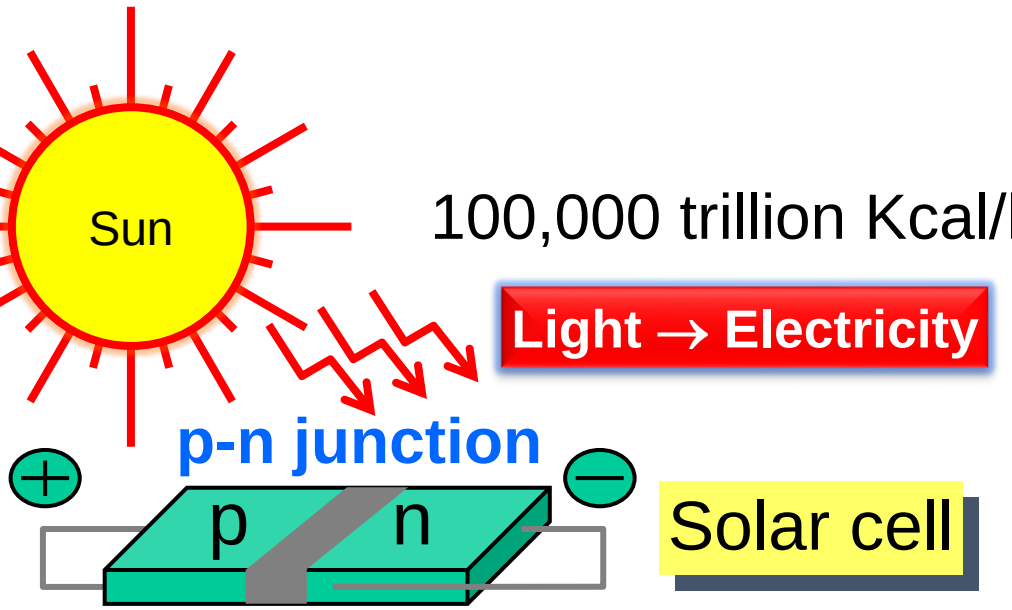
- Inexhaustible
- Clean
- No regionally uneven distribution

Solar energy, which reaches the Earth's surface within just one hour, can provide energy consumption for all human beings in one year.

Hydraulic power

Wind power

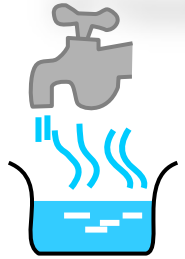
Biomass

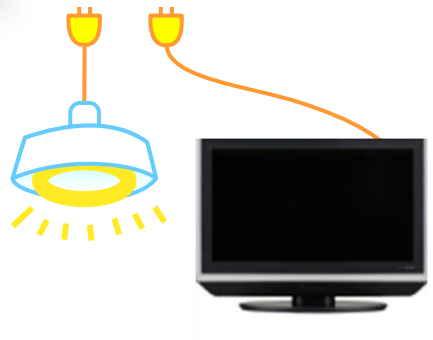


V

Utilization of electricity

Utilization of heat



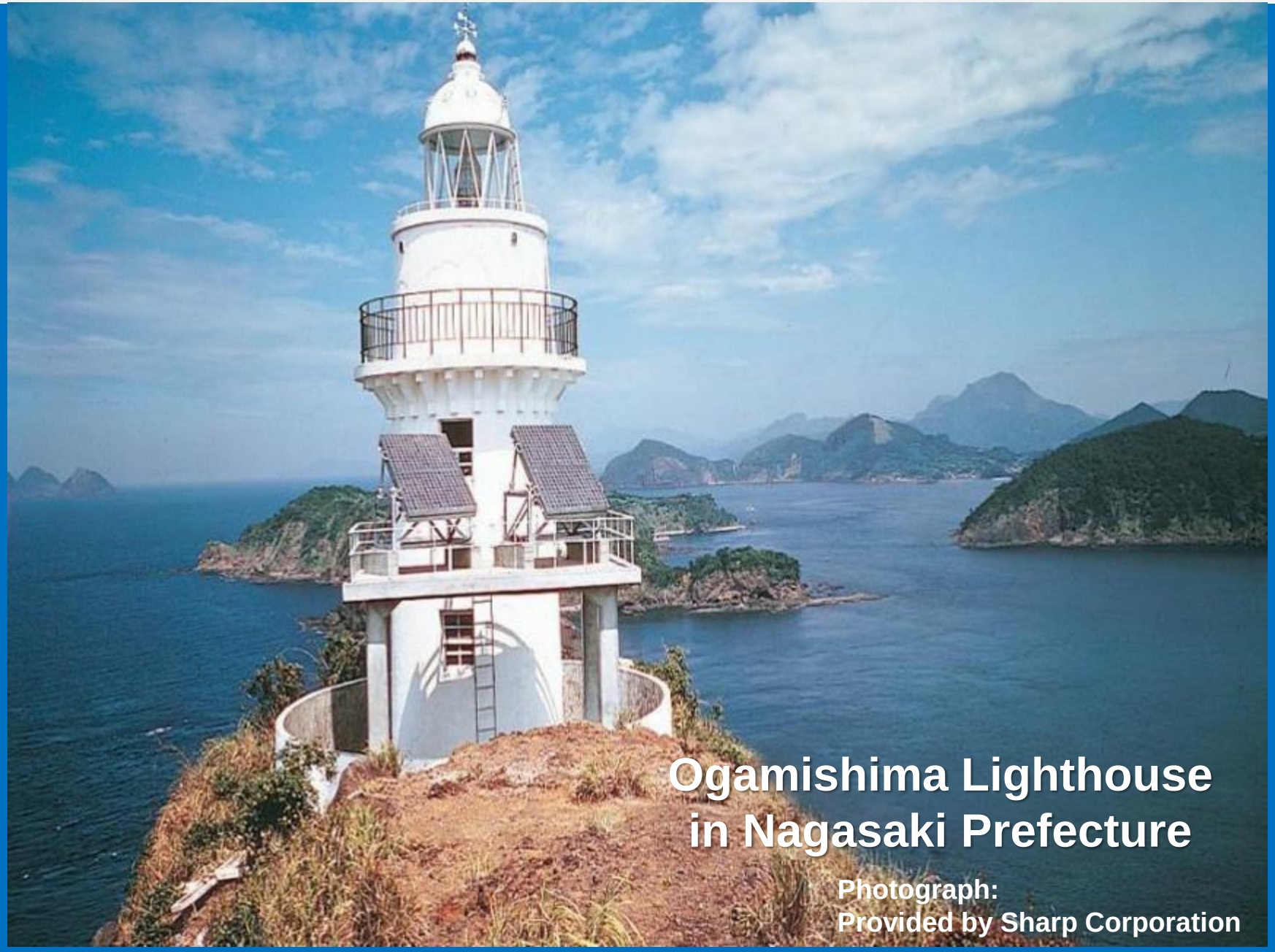


Source: each Website.

1-4. At first, solar cells were used as power sources for satellites

Photograph:
Provided by Alcatel-Lucent
Bell Laboratories

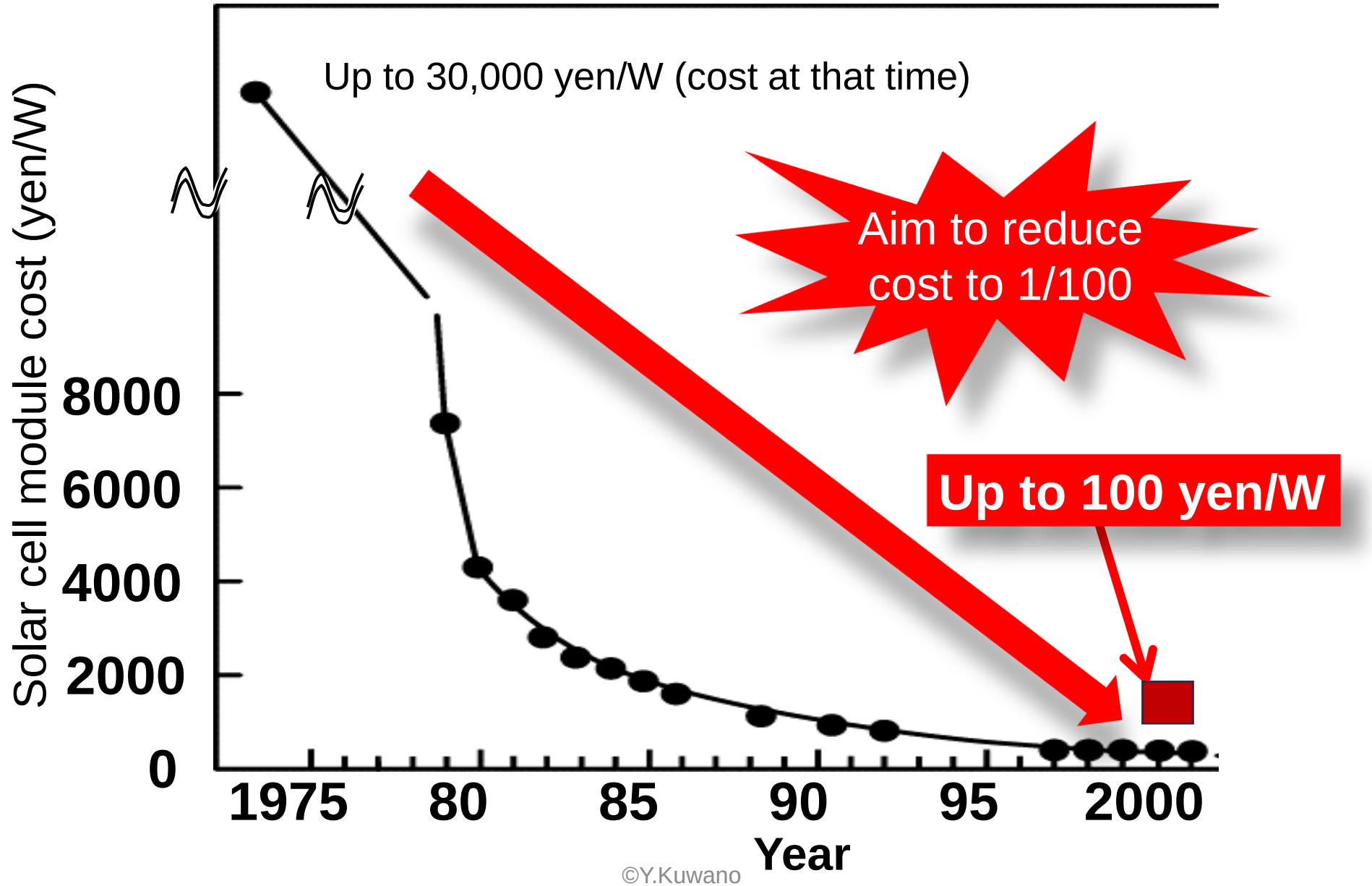
In Japan, solar cells were used as power sources for lighthouses



Ogamishima Lighthouse
in Nagasaki Prefecture

Photograph:
Provided by Sharp Corporation

1-4. Solar cell costs predicted in 1974 (approx. 50 years ago)



1-5. Development of various solar cells

Types of solar cells

1. Crystalline silicon solar cells (monocrystalline Si and polycrystalline Si)
2. Thin-film solar cells
   a) Amorphous Si or other thin-film silicon solar cells
   b) Compound-semiconductor solar cells
   c) Organic solar cells (dye-sensitized, organic semiconductor, and perovskite solar cells)

Crystalline silicon

Thin-film silicon

Compound

Perovskite solar cell

Organic (dye-sensitized)

Source: each Website.

1. Japan's Sunshine Project with a Long-Term and Far-Sighted Perspective
2. **R&D and Commercialization of Solar Power Generation in Japan That Contributed to the World**
3. Expansion of Solar Power and Other Renewable Energy in Japan
4. Let's Talk About the Future!
   Can renewable energy cover the world's energy needs?

2-1. History of development and expansion of solar power generation

An industry-university-government collaboration system for R&D and commercialization was established.

Approx. 50 years

1973: The oil crisis began.

1974: The Sunshine Project and other national projects of different countries were launched.

1980: NEDO was established, and solar cells began to be applied to electronic products (e.g., calculators).

Early days of solar cells

1988: The problem of global warming came to the surface.

1992: The system for purchasing surplus electricity from solar power generation was launched, and a private residential PV system with reverse power flow was implemented.

1993: The New Sunshine Project was launched.

1994: The subsidy system for private residential PV systems, field test projects for solar power generation for public facilities, etc., were started.

Between the late 1990s and 2005, Japan boosted the world's largest production of solar cells.

Second phase: Came into use for electric power Growth period

2000: Germany established the feed-in tariff (FIT) system.

2004: NEDO announced the Photovoltaic Roadmap Toward 2030 (PV2030).

2005: The worldwide solar cell production exceeded 1 GW.

2012: The feed-in tariff system was introduced in Japan.

Third phase: Period of global expansion of solar power generation

2015: The UN adopted the Sustainable Development Goals (SDGs).

2015: COP21 (UN Climate Change Conference: Paris Agreement)

2018: The worldwide solar cell production exceeded 110 GW.

2021: The government defined renewable energy as a core energy source in the 6th Basic Energy Plan.

As of 2024, the worldwide solar power generation has reached 1 terawatt.

PVTEC
Photovoltaic Power Generation Technology Research Association

Sunshine Project promoted

In the wake of the oil crisis, the development of renewable energy was promoted as a national project.

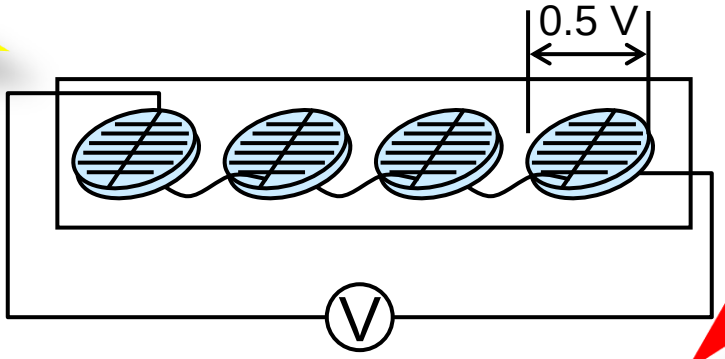
However, solar power generation and other renewable energy were immature as alternative energy sources and could not compete with existing electric power.
In the late 1970s, many domestic and overseas renewable energy developers and manufacturers fell behind in the development of solar cells.

SANYO, Sharp, and other companies decided to use solar cells for electronics.

We aimed to develop new integrated amorphous Si solar cells that were different from conventional solar cells.

Conventional crystalline solar cells were connected in series via a lead wire.

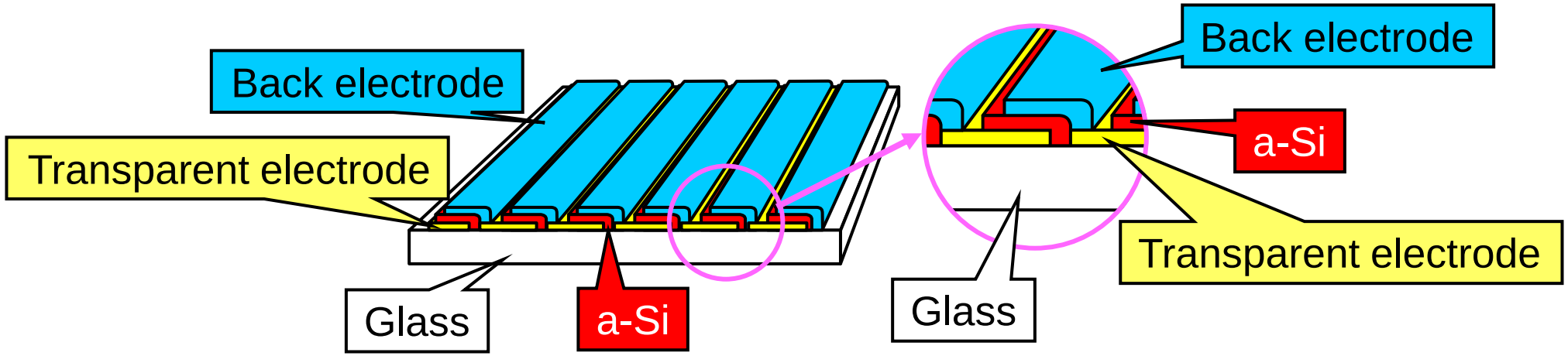
(a) Conventional solar cells



The technology of serially connecting the end faces of thin-film solar cells in this pattern provides the basic structure for thin-film solar cells, which were developed later.

(b) Integrated type

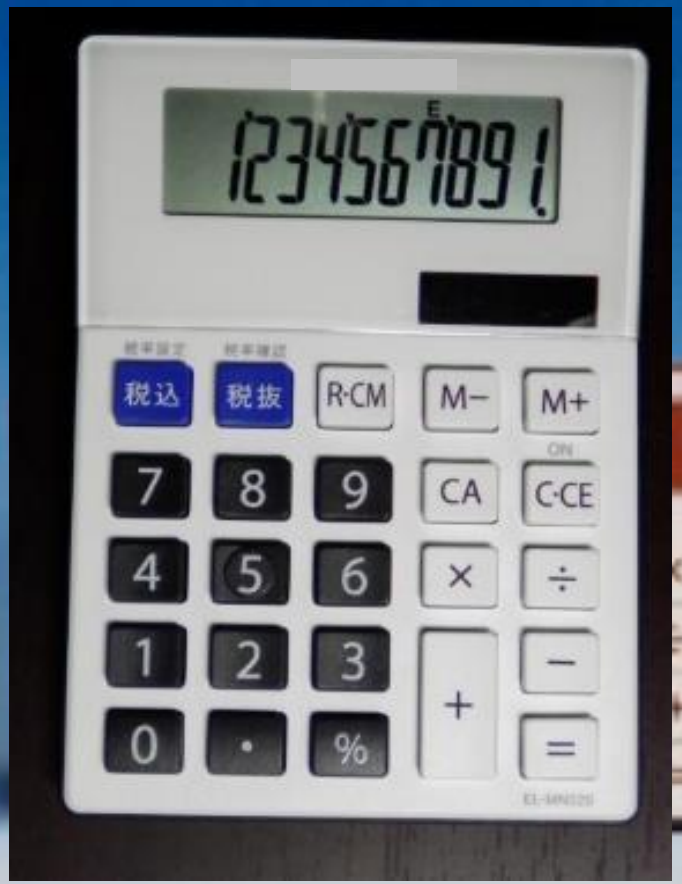
Amorphous Si = a-Si



World's first industrialized amorphous solar cells

PVTEC
Photovoltaic Power Generation

1980
(44years ago)



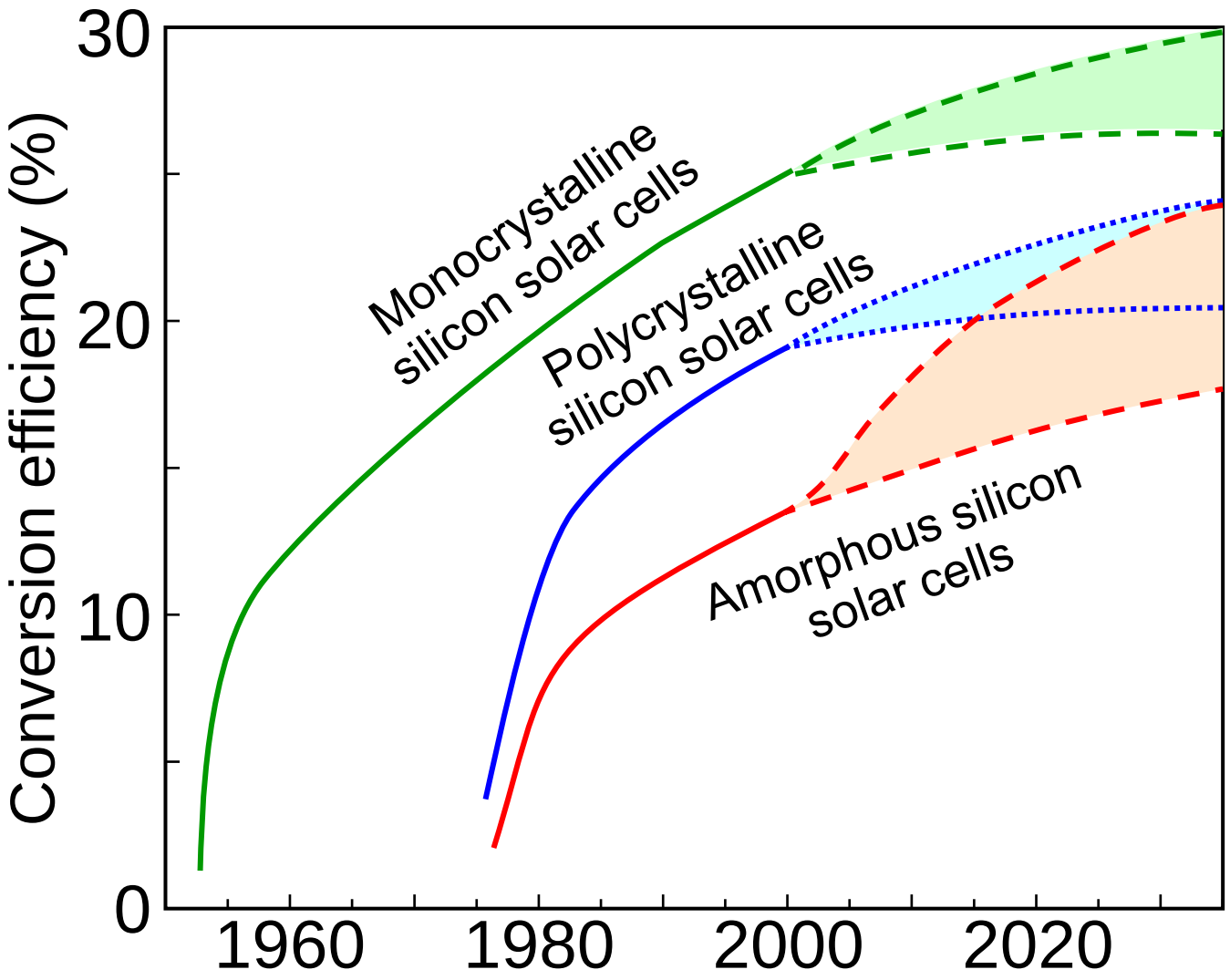
Panasonic Solar Amorton Co., Ltd. still produces solar cells even now

(Kitakata City, Fukushima Prefecture)

Source: Website of Panasonic Solar Amorton Co., Ltd.

2-4. The national project continued

and the conversion efficiency of solar cells began to increase in the late 1990s



2-5. HIT solar cell: A new high conversion efficiency solar cell born out of a preposterous idea

PVTEC
Photovoltaic Power Generation Technology Research Association

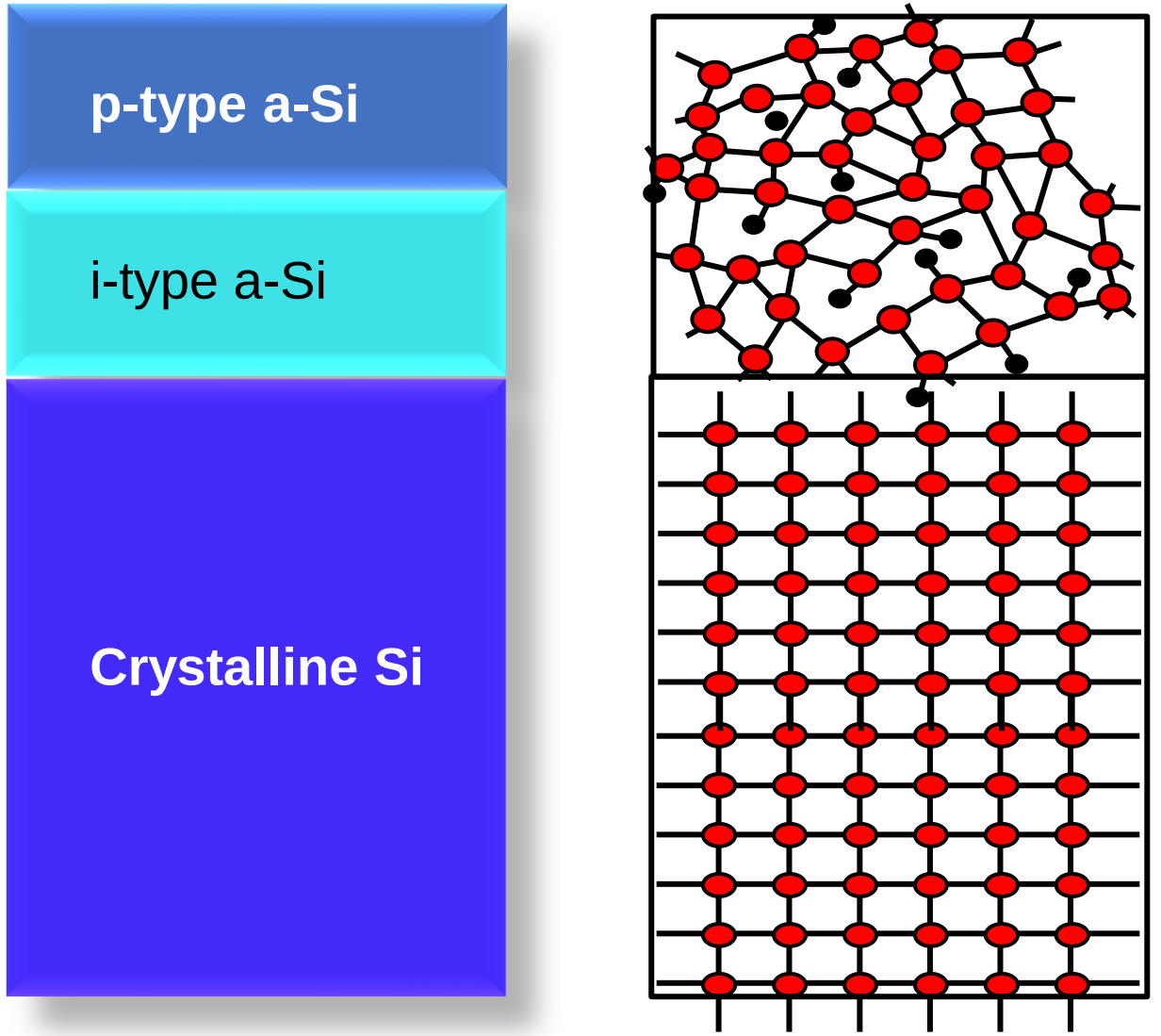
The world's highest conversion efficiency HIT solar cell was developed from a preposterous idea.

1. There had been little progress in improving conversion efficiency.
2. There seemed to be nothing that could be done any longer.
3. The reverse idea of the HIT structure was conceived.
4. Incredibly high conversion efficiency was realized.
5. Conversion efficiency has continued to increase.

Around 1989, the Heterojunction with Intrinsic Thin-layer (HIT) solar cell, a new solar cell that combines the merits of amorphous SI and crystalline silicon, was developed.

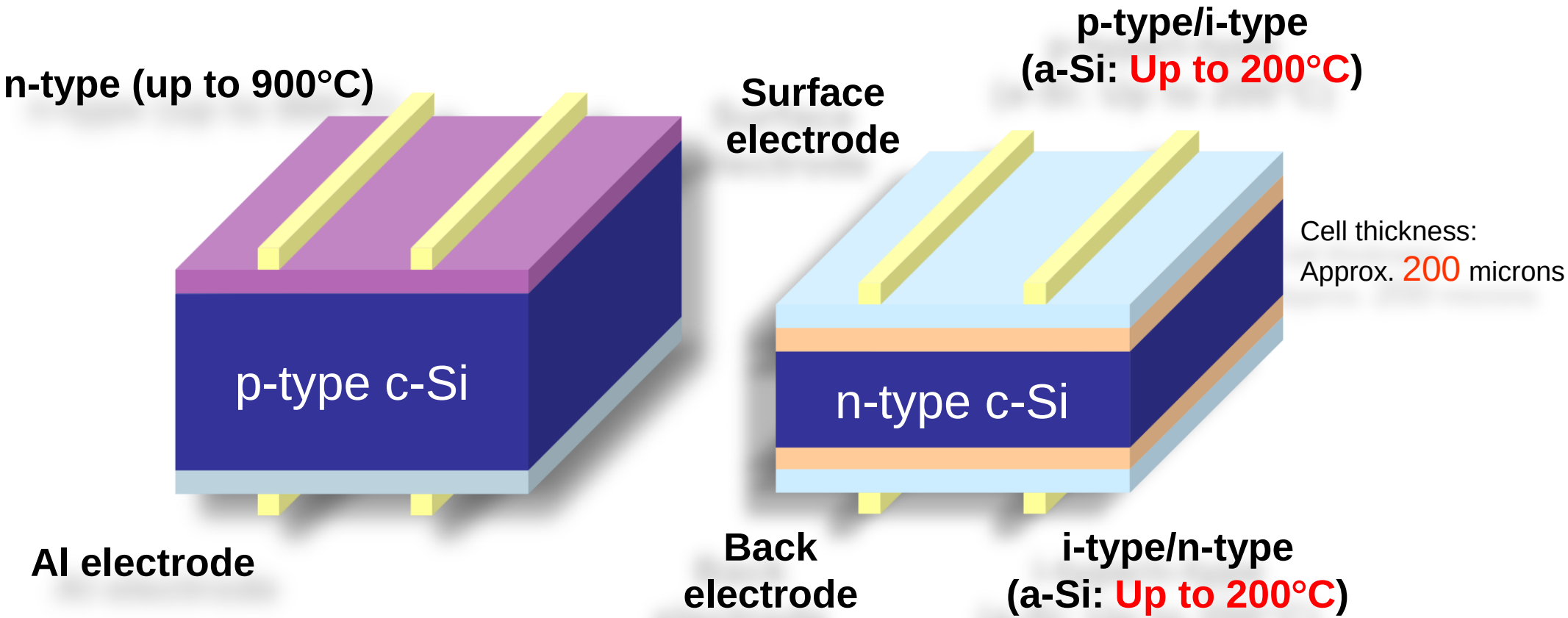
The HIT structure consists of amorphous Si stacked on crystalline Si

(similar to grafting bamboo onto a tree)



Structure of the new high conversion efficiency HIT solar cell

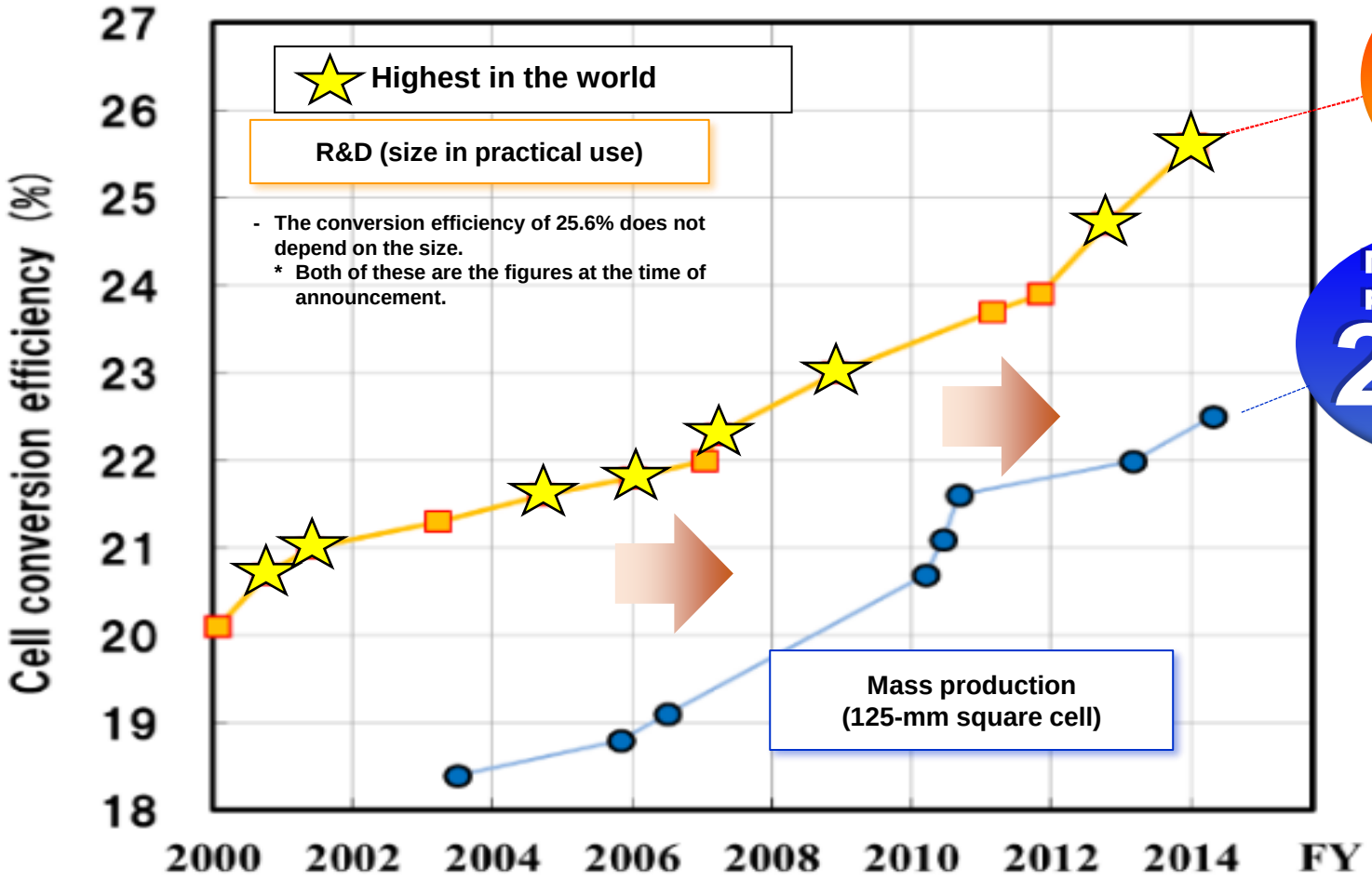
(HIT: Heterojunction with Intrinsic Thin-layer Solar Cell)



Characteristics of HIT®: High conversion efficiency

PVTEC
Photovoltaic Power Generation Technology Research Association

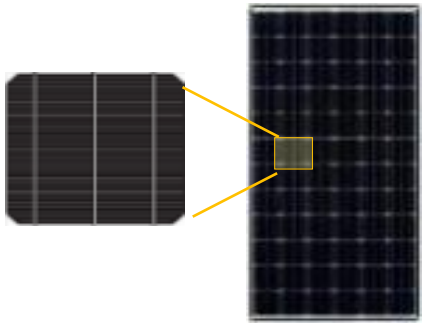
World's highest level of conversion efficiency



R&D
25.6%

Mass production
22.5%

World's highest level



2-6. The challenge of private residential photovoltaic system with reverse power flow

Between the late 1980s and the beginning of the 1990s,
the efficiency of solar cell modules exceeded 10%.

1) **At that time, private residential photovoltaic system (PV) was not allowed to connect power lines.**

2) **Next, approach to MITI and electric power companies**
The solar cell industry has lobbied power companies to connect PV systems to the power grid and to purchase surplus electricity from solar power generation.

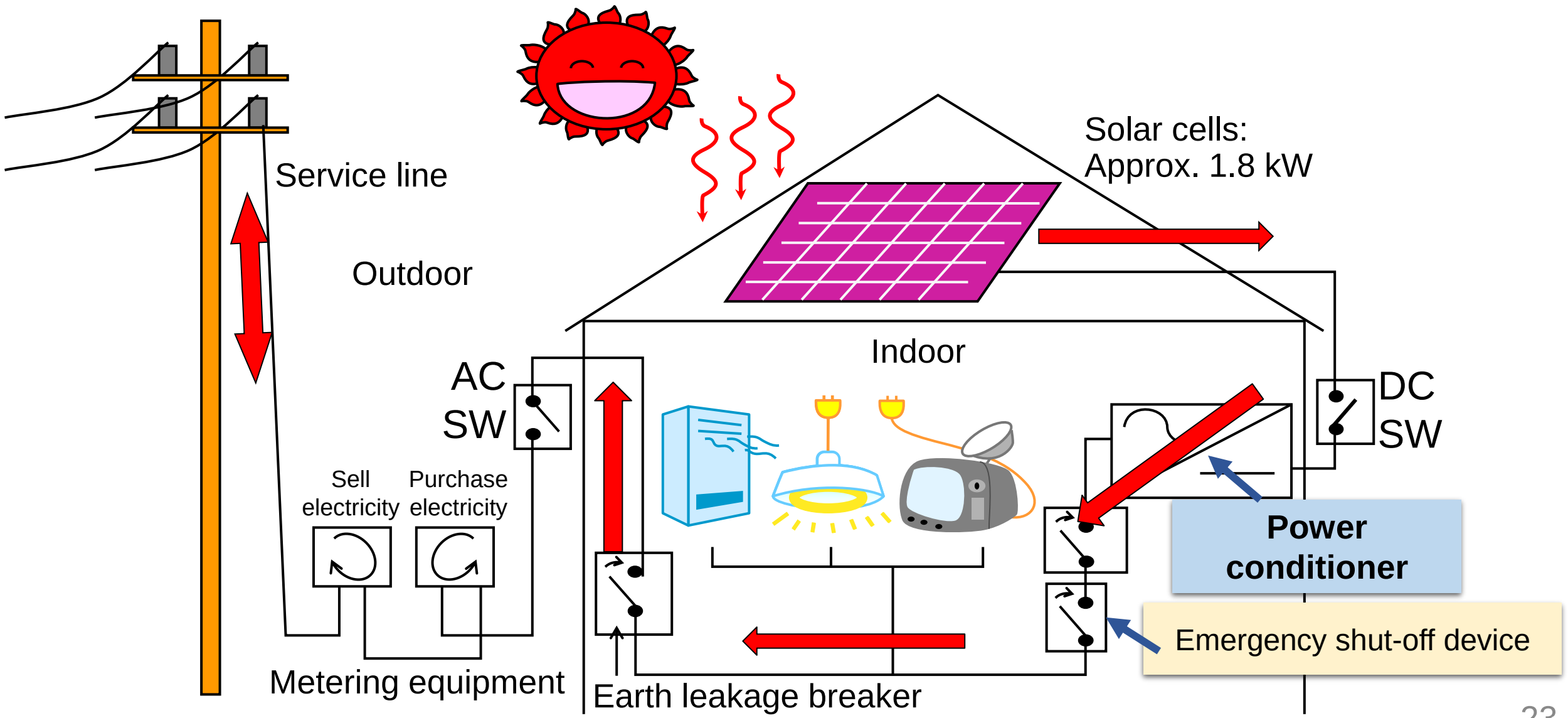
3) **In 1992, the power industry decided to allow interconnection between these systems, thereby establishing a system under which electric power companies purchase surplus electricity from solar cells.**

Construction of first private residential PV system with reverse power flow

First private residential PV system with reverse power flower

PVTEC
Photovoltaic Power Generation Technology Research Association

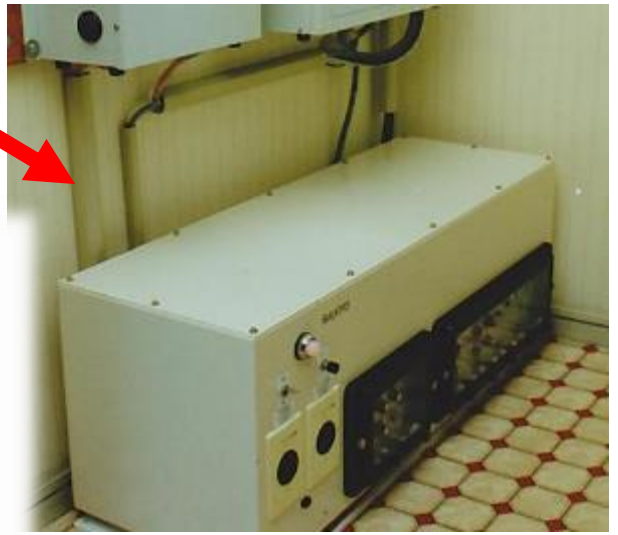
Diagram of the PV system using reverse power flow.



2-7. Relaxation of the regulations on residential PV systems

Because this was the first PV plant with reverse power flow in private residence. They had to follow almost the same procedure and protection measures as when an electric power company constructed a power station.

(1) Since it is treated as a general power plant, individual permission is required for each PV systems
(2) A special large emergency shut-off device designed to shut off the system in case of unexpected circumstances had to be installed.
(3) Appointment of a chief electrical engineer for constant monitoring is required.



Based on the idea that these regulations had prevented the PV system from spreading among general households, the whole PV industry encouraged the government to change the system again. As a result, the regulations were relaxed as follows.

(1) Individual approval applications are now only required to apply for model approval for standard electric products (they no longer need to apply for a license on an individual basis).
(2) They are no longer required to install a large shut-off device since they can instead use a small power shut-off device built into a power conditioner.
(3) Appointment of a chief electrical engineer for constant monitoring no longer needs since the system's safety was confirmed.

These new standards spread around the world.

20th anniversary in 2012 (stable PV system with no accident)

Ceremony for
25th and 30th anniversaries of
Kuwano's Solar Power Station

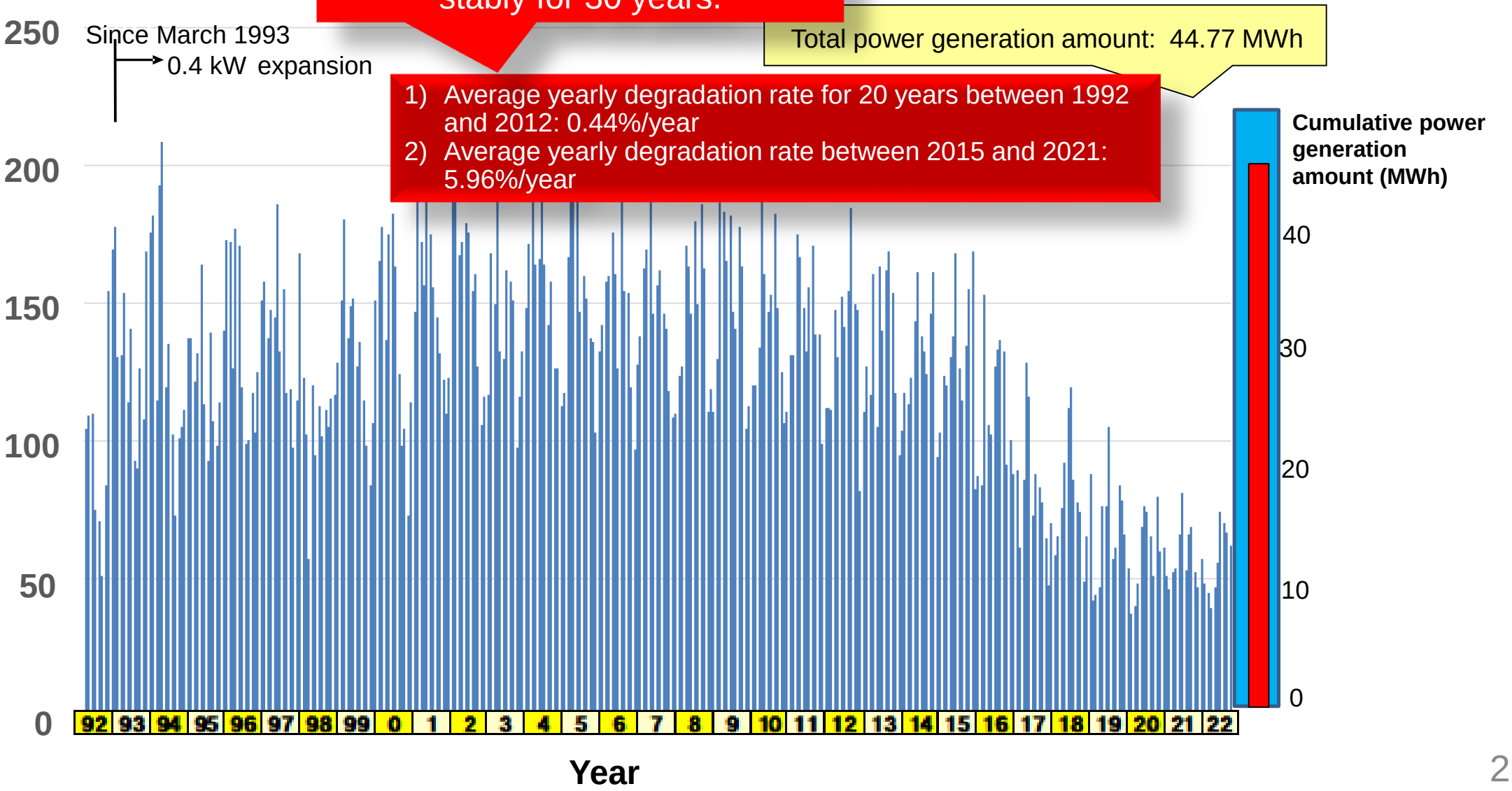
Kuwano’s PV Station marked its 30th anniversary

©Y.Kuwano

Records of the PV Station for the past 30 years

PVTEC
Photovoltaic Power Generation Technology Research Association

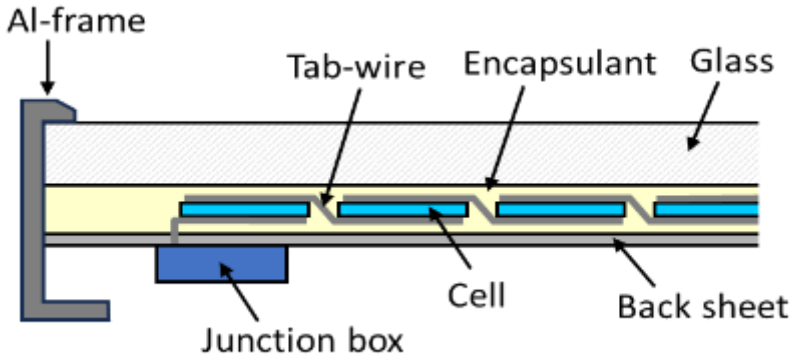
It was confirmed that solar power generation has generated power stably for 30 years.



Efficiency change of 38 solar cell modules after 30 years

PVTEC
Photovoltaic Power Generation Technology Research Association

After 30 years　　Initial state



Cross-section view of a module

1) The a-Si solar cell modules showed less degradation, with a retention rate of approximately 80%, partly due to the low initial efficiency.

2) The degradation characteristics of the polycrystalline Si solar cell modules
(1) one of them maintained an output retention rate of up to 93%.
(2) eight out of 24 panels were able to maintain output exceeding 80% of the initial value.
(3) the average output of all modules was about 68%.

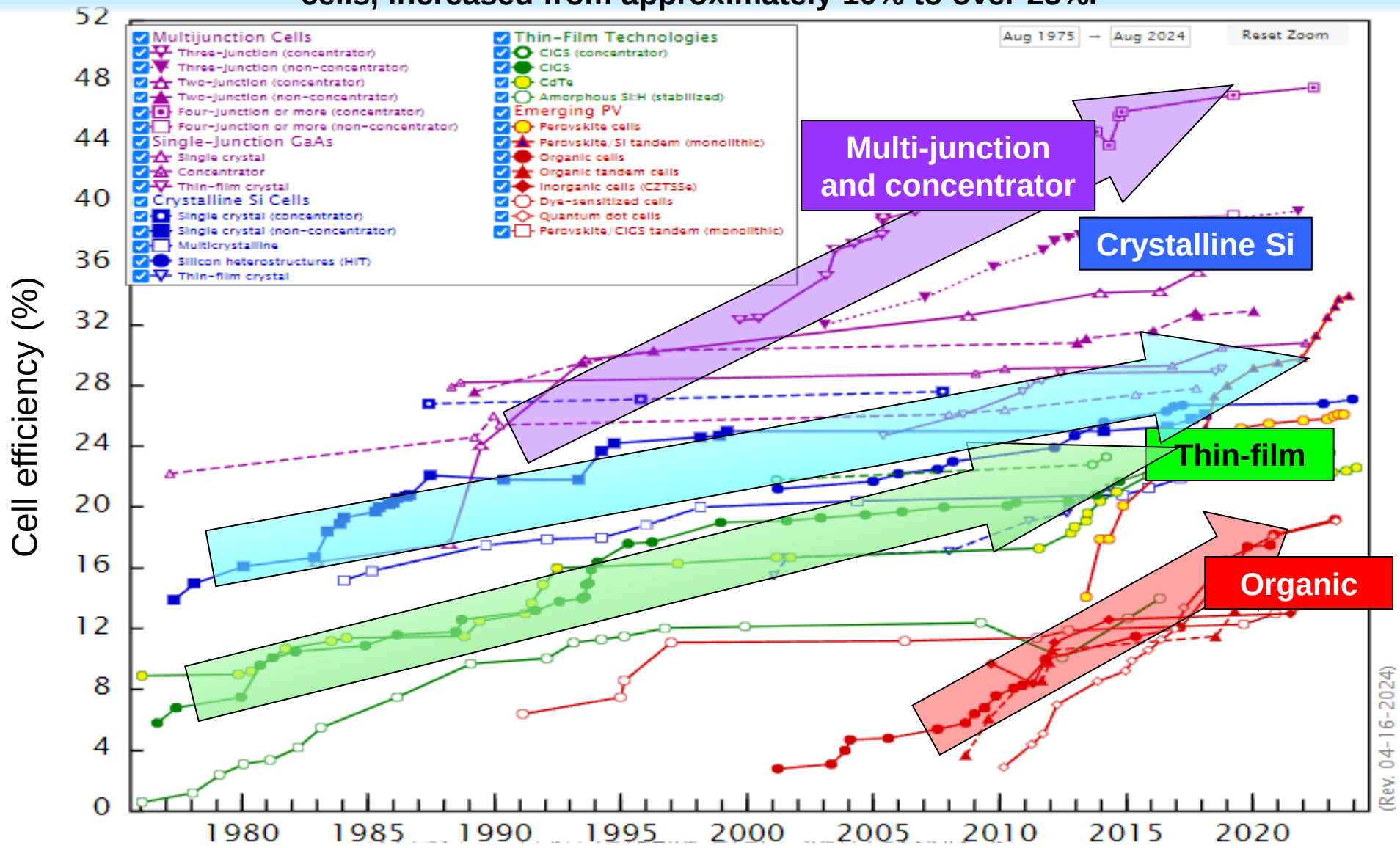
Refer to the Journal of the Solar Energy Society : https://doi.org/10.24632/jses.50.2._75

	Min.	Ave.	Max.
AMP-06S2 (a-Si): 7 modules	74.7%	80.3%	87.7%
CPS-4516 (AR:ITO): 12 modules	39.4%	51.3%	65.3%
CSP-4516M (AR:SiN): 24 modules	1.5%	67.9%	93.0%
CSP-4533M (AR:ITO): 6 modules	62.0%	70.0%	77.9%

1. Japan’s Sunshine Project with a Long-Term and Far-Sighted Perspective
2. R&D and Commercialization of Solar Power Generation in Japan That Contributed to the World
3. **The world is moving towards greater use of renewable energy**
4. Let’s Talk About the Future!
   Can renewable energy cover the world’s energy needs?

3-1. Improvements in the efficiency of various solar cells over 50 years

The conversion efficiency of crystalline Si solar cells, which constitute a main part of commercially available solar cells, increased from approximately 10% to over 25%.

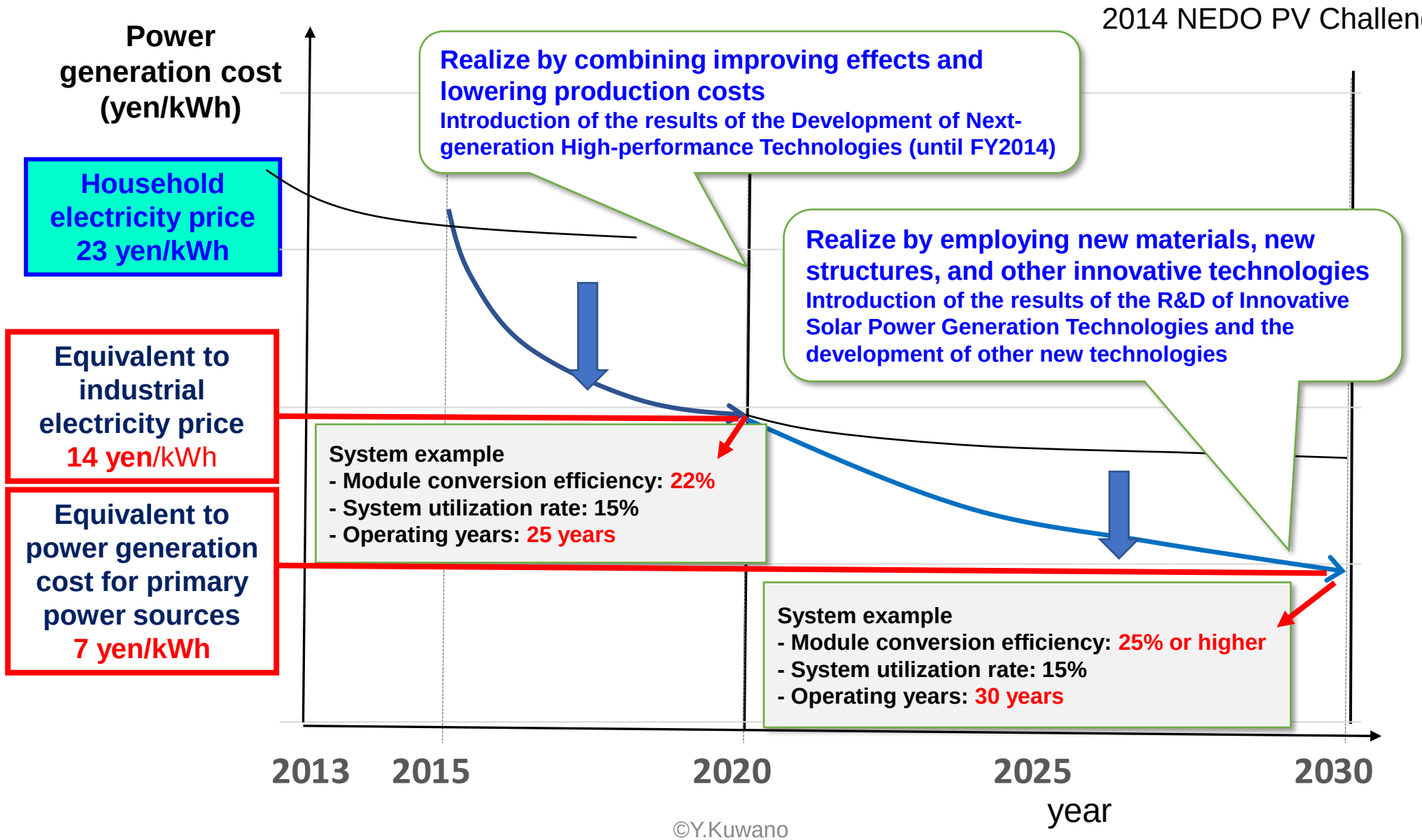


Graph of the maximum conversion efficiency of cells for research based on various solar power generation technologies confirmed in the period from 1976 up to today

This graph shows the conversion efficiency records of cells for research based on five major technologies: crystalline silicon cells, single-junction gallium arsenide cells, multi-junction cells, thin-film solar cells, and emerging solar cells. The conversion efficiency of all the technologies has increased over the past 50 years.

Source: ENREL

3-2. NEDO PV Challenges
New departure for the development of even lower-cost solar cells



3-3. Government support for the expansion of PV system

1) In 1993, Japan's first subsidy scheme for the residential PV system was introduced (3.7 million yen/1kW).
2) In 2009, the surplus electricity purchase system was implemented, subsidies were reinstated, and the PV system became even more widespread.

Example of solar power generation in a group of stand-alone houses
Total: 2,130 kW, 553 households (3.85 kW/household on average) *(Ota City, Gunma Prefecture)*
Source: Photograph provided by Ota City Land Development Corporation

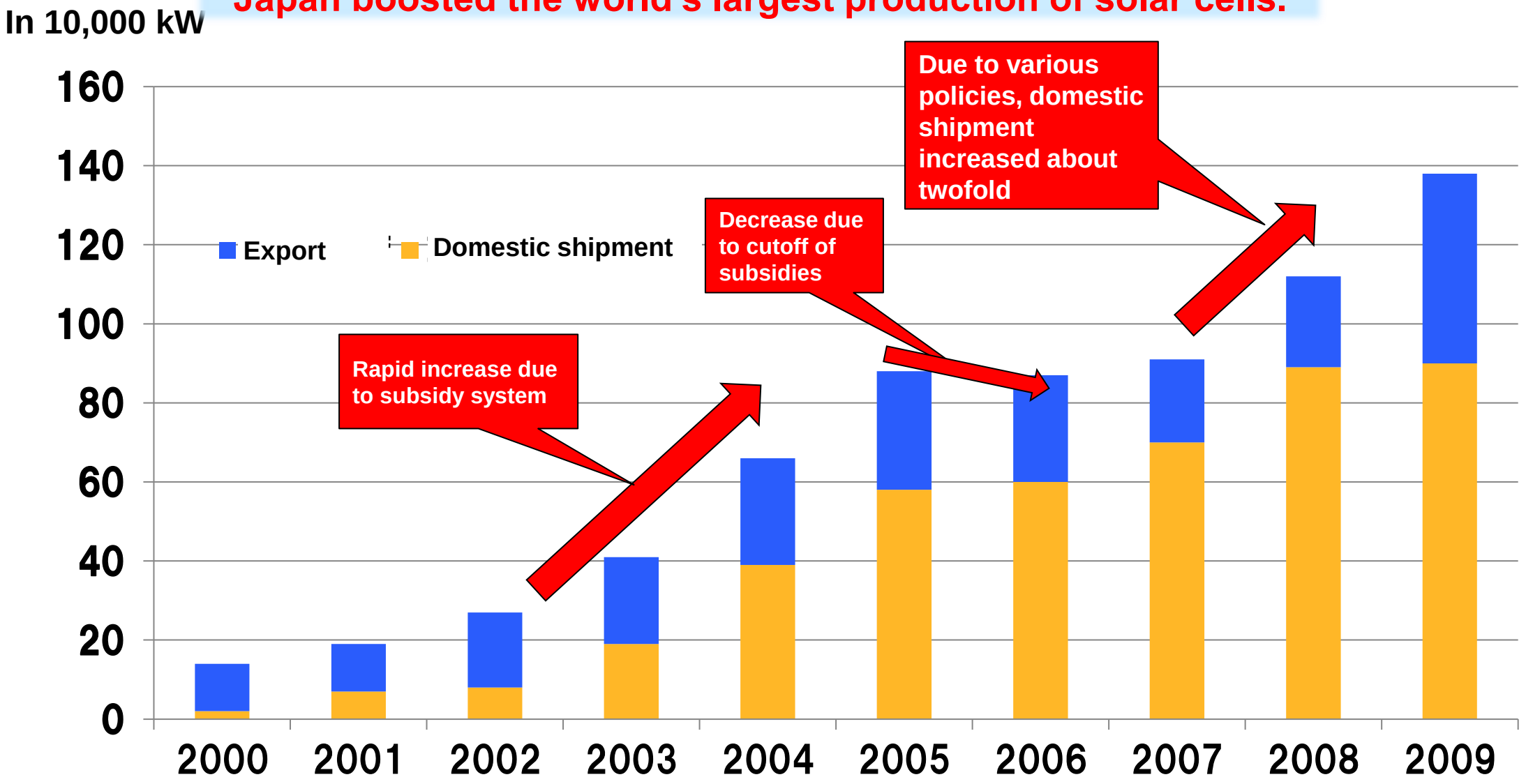
Mega-solar system in Hokuto City, Yamanashi Prefecture (demonstration experiment by NEDO)

Salamanca - Spain

Source: Photograph provided by Kyocera

3-4. Japan became the world's largest producer of solar cells

Between the late 1990s and 2005,
Japan boosted the world's largest production of solar cells.



Source: JPEA

3-5. The German Renewable Energy Act was enacted in 2000

1) In Germany, the Renewable Energy Act was enacted to limit global warming. The feed-in tariff (FIT) system, which involves purchasing electric power from PV system at three times the normal price, was established.

2) This system is intended to promote widespread use of renewable energy by allowing all people to increase their electricity rates rather than relying on government subsidies.

This system spread across the world.

©Y.Kuwano

Source: each Website

Gujarat Solar Park (1,600 MW) in India

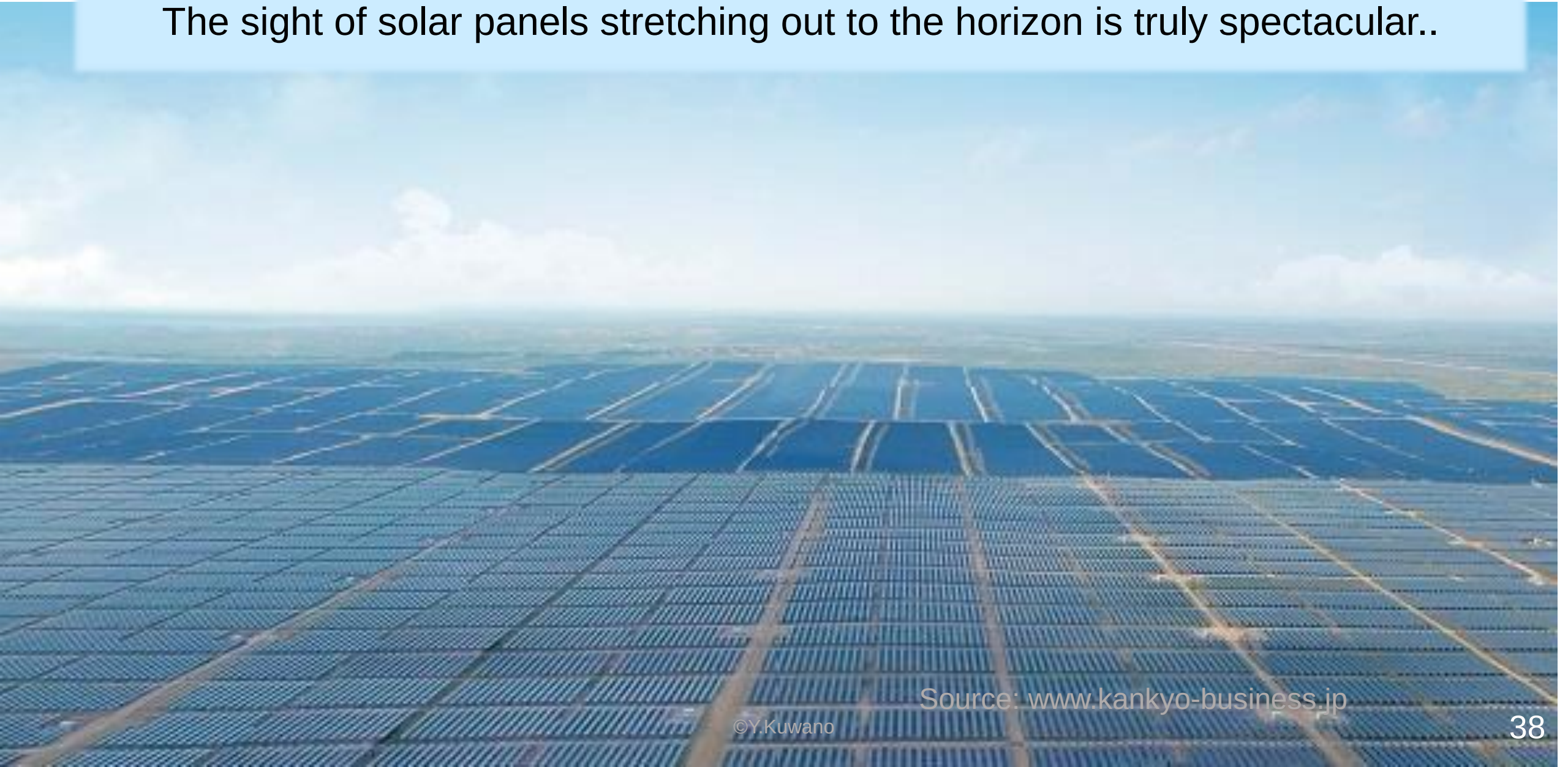
PVTEC
Photovoltaic Power Generation Technology Research Association

Source: Website.

the World's largest class solar power generation capacity of 1 GW in China

PVTEC
Photovoltaic Power Generation Technology Research Association

The sight of solar panels stretching out to the horizon is truly spectacular..



Source: www.kankyo-business.jp

3-6. Occurrence of the Great East Japan Earthquake in 2011

In the wake of this devastating earthquake, Japan's new renewable energy feed-in-tariff (FIT) system, which involved purchasing electric power generated from renewable energy at high prices, was established in July 2012. This rapidly spread solar cells across Japan.

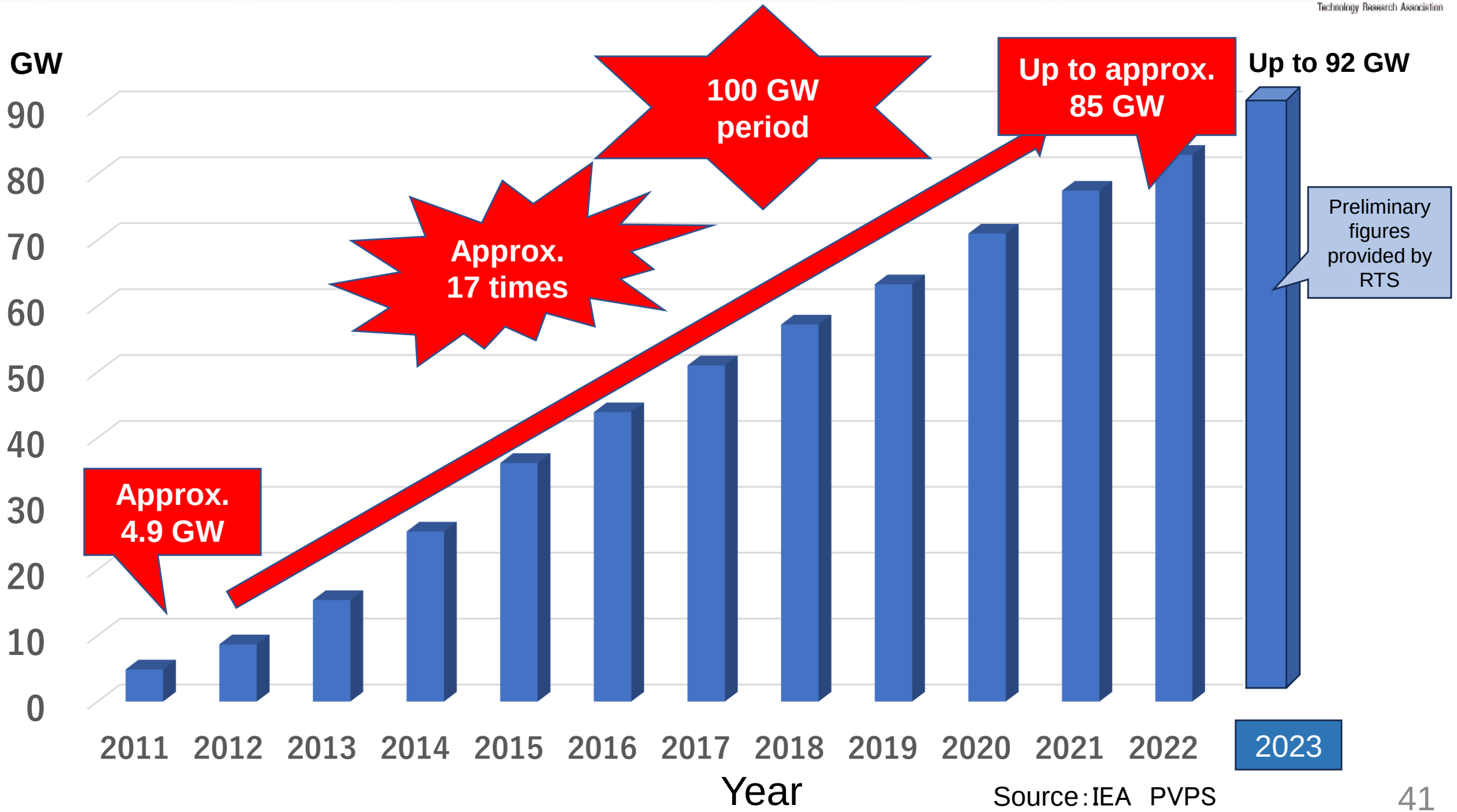
Source: http://www.su-gomori.com/2011/04/fukushima.html

3-7. The cumulative capacity of PV systems installed in the world exceeded 1 TW (1,000 GW) in 2022

PVTEC
Photovoltaic Power Generation Technology Research Association

出典: 各HP

3-8. Changes in the cumulative capacity of PV systems installed in Japan



Source：IEA PVPS

PVTEC
Photovoltaic Power Generation Technology Research Association

Effects of the PV systems of 80 GW

1. According to this output:
   1) Peak power: Approx. 64 million kW (80 GW × 0.8)
   2) Electric power from 80 GW: 8.5 billion kWh

2. The current situation of electric power in Japan (2022) is as follows.
   1) Peak power: 166 million kW[1)]
   2) Total domestic power demand: Approx. 1 trillion kWh[2)]

The peak PV systems is equivalent to 38% of Japan's peak power.

Equivalent to approx. 9.9% of the total power demand[3)]

1) 2022 data released by the Organization for Cross-regional Coordination of Transmission Operators
2) Data released by the METI (2022 data)
3) https://www.isep.or.jp/archives/library/14364: 2022 data

Crude oil imports reduced by the PV systems of 100 GW

Capacity of PV systems installed	100 GW (120 billion kWh)
Reduction in crude oil	30 million KL
Amount of money saved by reduction	Approx. 700 billion yen

PV systems require no fuel cost and can operate for over20 years.
700 billion yen × 20 years = <u>Crude oil import cost of approx. 14 trillion yen can be saved</u>

Source: Data provided by JPEA

3-8. Actions to be taken by Japan in the future

Global issues toward realizing a sustainable society

1) **In September 2015, the UN Sustainable Development Goals (SDGs) were adopted.**
To realize a sustainable society worldwide, 17 goals and 169 targets were set to achieve goals such as health and well-being, energy, climate change, and peaceful society. They are to be completed over 15 years, from 2016 to 2030.

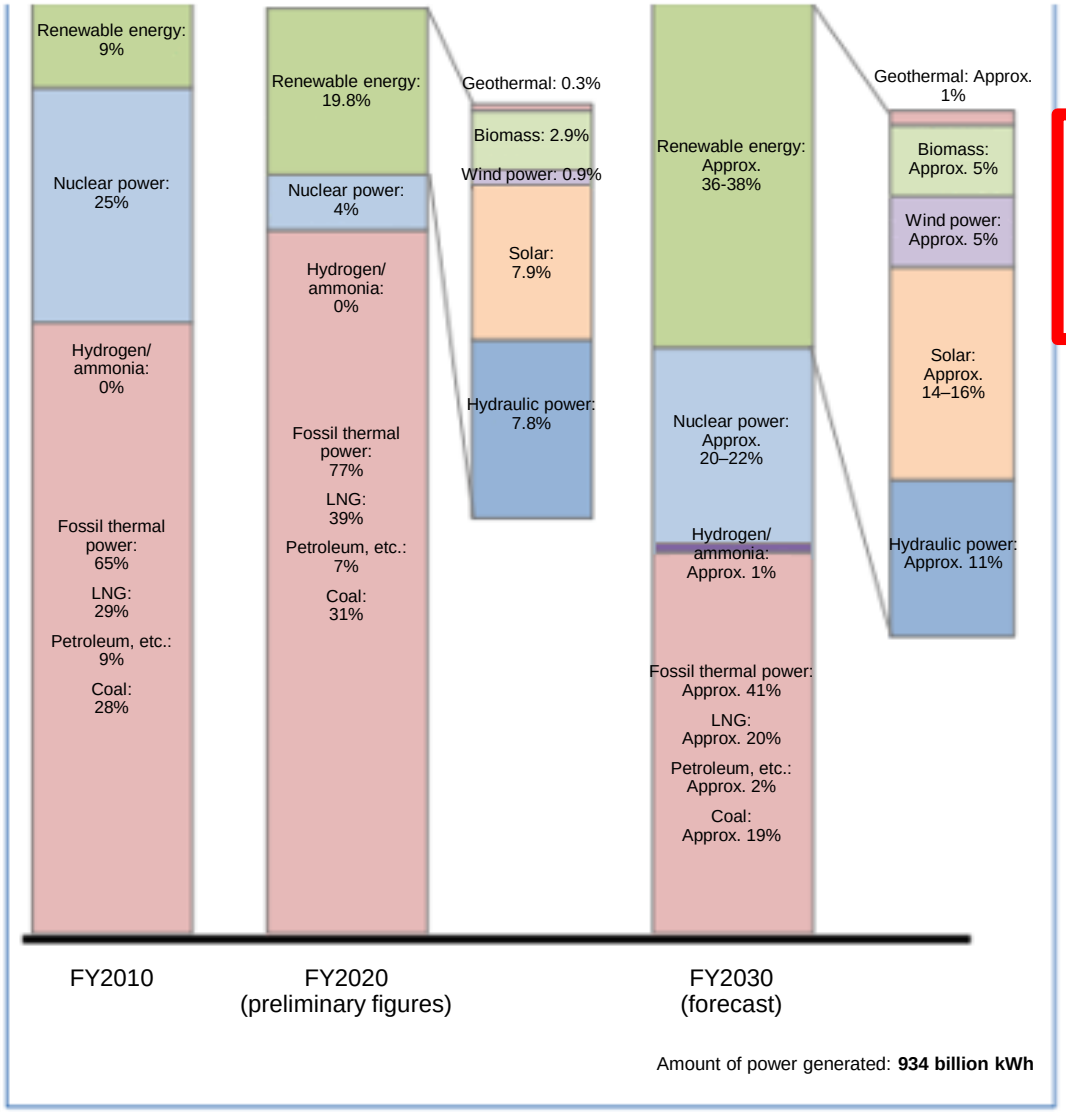
2) **Decisions made in COP26 (held in England in 2012)**
   (1) **Limit global average temperature increase to less than 1.5 degrees above pre-industrial levels.**
   (2) **Achieve net-zero GHG emissions due to human activities globally in the second half of this century (carbon neutrality).**
   *** Japan's targets: By FY2030, Japan aims to reduce GHG emissions by 46% compared to FY2013 and further strives to reduce them by as high as 50%. Achieve carbon neutrality by 2050 (energy transformation [EX])**

Carbon-neutral declaration made by Prime Minister Suga in the extraordinary Diet session in October 2020

1) Carbon neutral declaration
In his policy speech in October 2020, Prime Minister Suga declared that Japan would, as a nation, achieve zero GHG emissions by 2050 or aim to realize a carbon-neutral decarbonized society by 2050.

2) 2) Based on the 2021 "6th Basic Energy Plan" and the "Global Warming Countermeasures Plan," the goal is to increase the proportion of renewable energy to 36% to 38% by 2030.

Targets to be achieved by the 6th Basic Energy Plan



(GW)	Capacity level (Sept. 2021)	Capacity before FIT + FIT-certified capacity (Sept. 2021)	Mix (FY2030)	Introduction progress ratio to mix
Solar	63.8	81.6	103.5–117.6	Approx. 58%
Wind power (Upper: onshore / Lower: offshore)	4.6 –	15.3 0.7	17.9 5.7	Approx. 19%
Geo-thermal	0.7	0.7	1.5	Approx. 41%
Small/ medium-scale hydraulic power	9.8	10.0	10.4	Approx. 94%
Biomass	5.3	10.3	8.0	Approx. 66%

* The figures for biomass factor in the ratios of biomass.
* The figures factor in the capacity expired by the revised FIT Act (capacity confirmed as of September 2021).
* The progress ratio to mix for solar power is the progress in capacity from the intermediate value for the value range indicated as the mix.

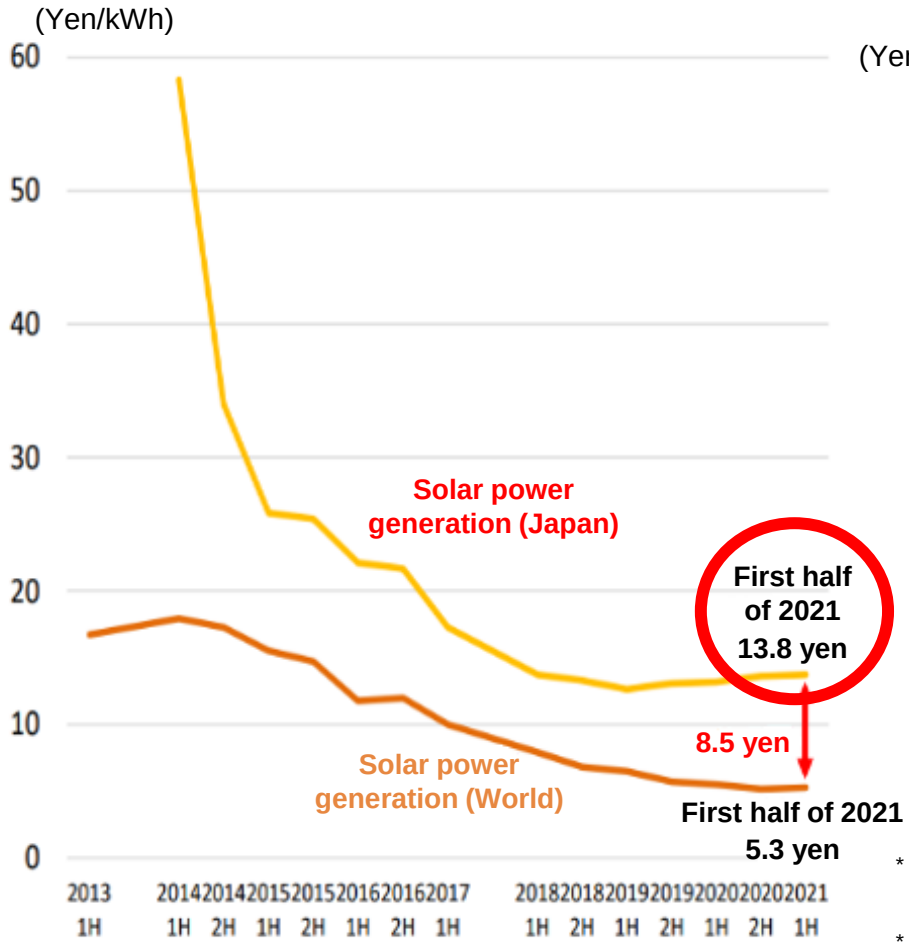
Source: Created by the Agency for Natural Resources and Energy based on comprehensive energy statistics (preliminary figures for FY2020)

In Japan, solar power generation costs became lower than those for commercial power sources

PVTEC Photovoltaic Power Generation Technology Research Association

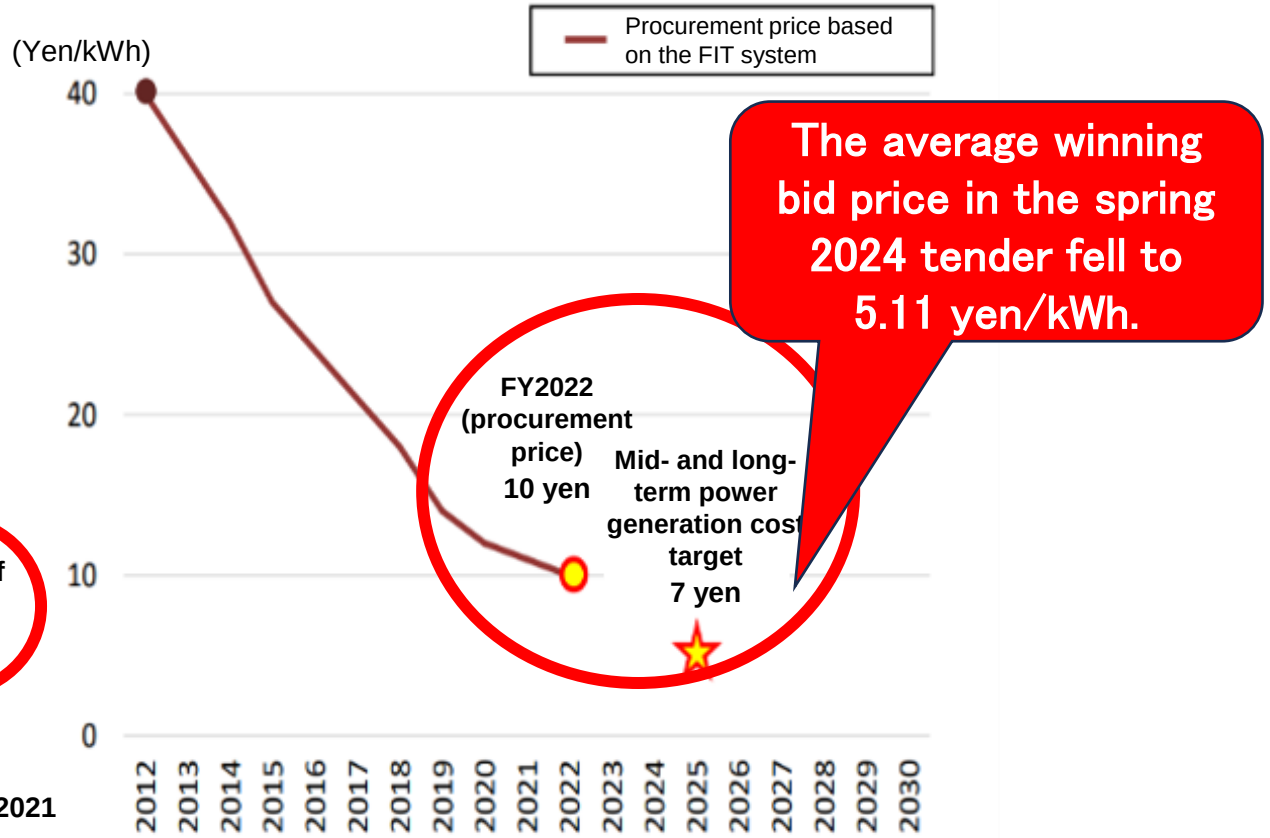
Data released by METI

Changes in solar power generation costs in Japan and the rest of the world



* Created by the Agency for Natural Resources and Energy based on data provided by BloombergNEF. Calculated based on the exchange rate of 100 yen to the dollar.s

Image of the price target for solar power for businesses



* The line graph shows the procurement prices determined by METI every fiscal year based on the opinions of the Calculation Committee for Procurement Prices, etc.
The figure for FY2022 is the procurement price for more than 50 kW of the above.
* The mid- and long-term power production cost target refers to the average power generation cost for projects to be put into operation in 2025, which is set at 7 yen/kWh. This cost is factored into the discount rate, which considers funding costs only (3%).
* It is equivalent to the procurement price of 8.5 yen/kWh (internal rate of return (IRR): 5%).

Source: Data released by METI

Review the Sunshine Project and consider the significance of the national project

PVTEC
Photovoltaic Power Generation Technology Research Association

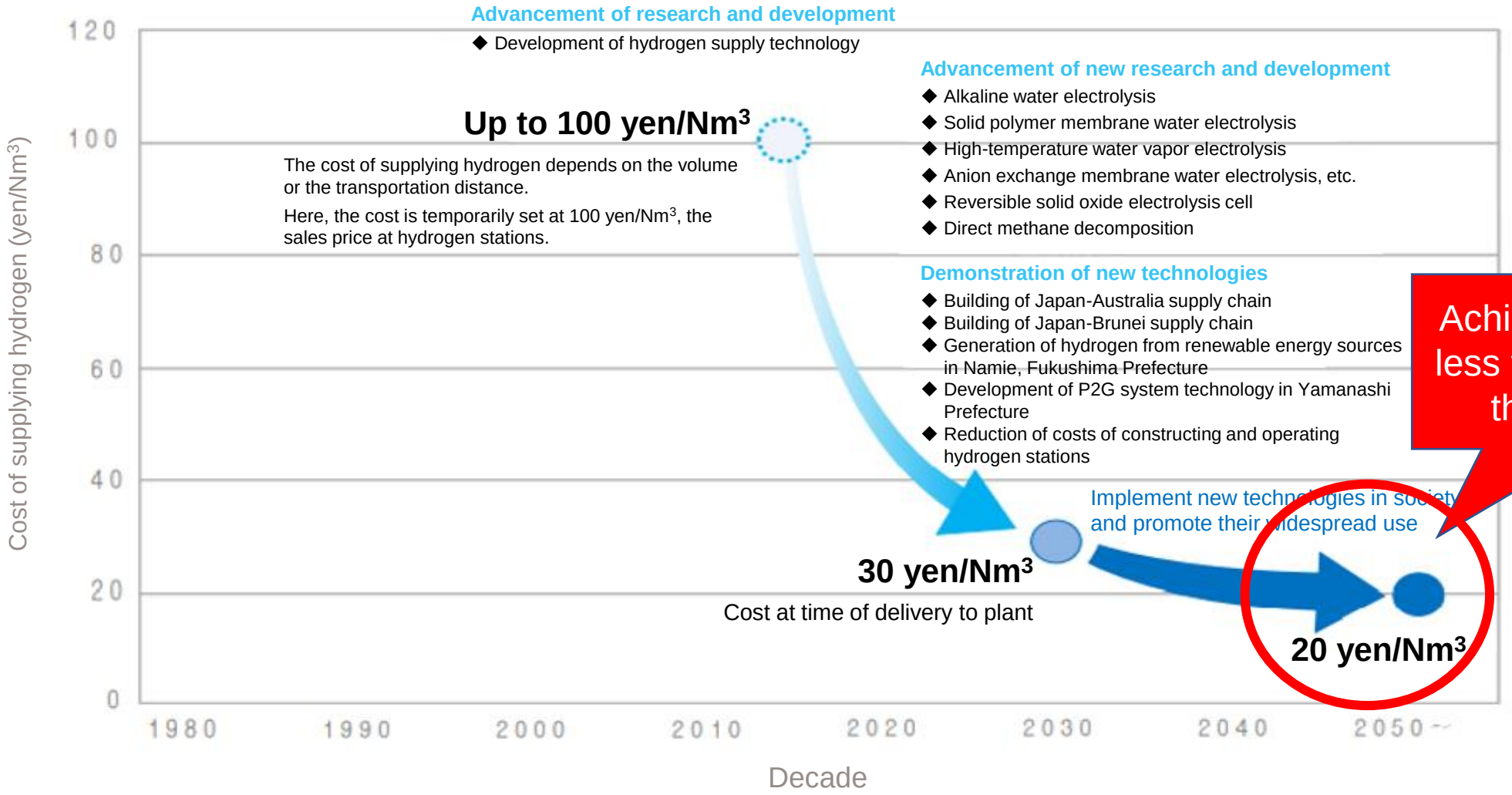
1) The Sunshine Project, which was developed 50 years ago, achieved its goals and produced significant results.
   This was Japan's first industry-government-university collaboration project (involving the industry sector, national research institutes, and universities).
   Japan developed and commercialized solar power generation and other renewable energy.
   These efforts enabled us to take steps to cope with rising fossil fuel prices and prevent global warming.

2) These results have been deployed together with the development results in other countries across the world, contributing significantly to realizing global carbon neutrality.

3) Toward the era of carbon neutrality, new national goals were set and efforts to move R&D and commercialization forward were started.

Building supply chains that reduce the hydrogen cost to 1/5 through innovation

Take advantage of innovative technologies to reduce the cost of supplying hydrogen to the same level as other existing energy by 2050 and use lower-cost hydrogen to produce ammonia fuel



Cost at time of delivery to plant

Reduce the cost of producing hydrogen to less than one-tenth or the levels equivalent to the costs for existing energy sources.

1) These figures assume the advantage of scale following the smooth implementation of new technologies in society, significant reductions in renewable energy prices, and the creation of a market with a good demand and supply balance.
2) It is necessary to keep in mind changes in the costs of competing technologies.

1. Japan’s Sunshine Project with a Long-Term and Far-Sighted Perspective
2. R&D and Commercialization of Solar Power Generation in Japan That Contributed to the World
3. Expansion of Solar Power and Other Renewable Energy in Japan
4. **Let’s Talk About the Future!**
   Can renewable energy cover the world’s energy needs?

4. Let's Talk About the Future!

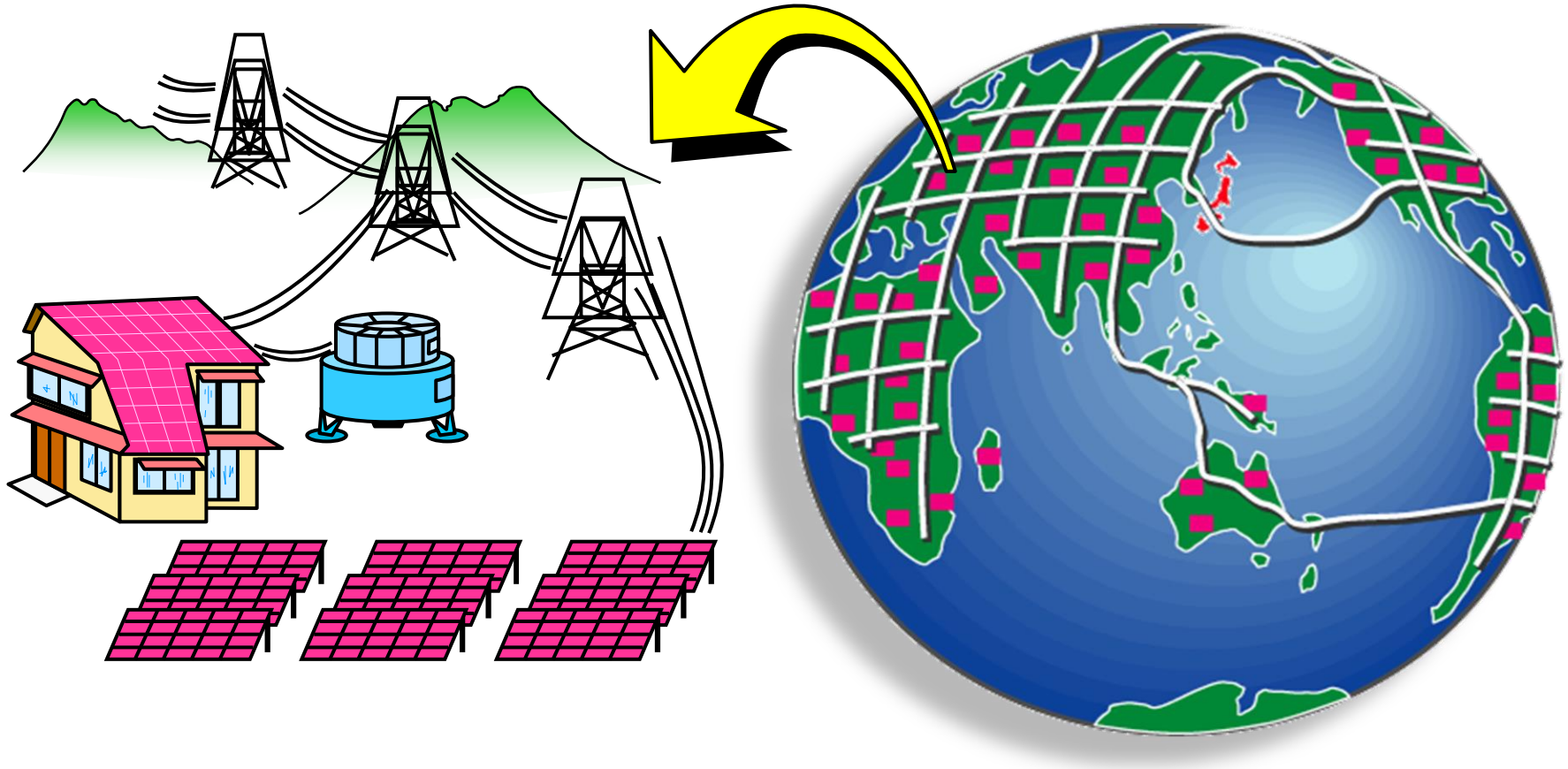
Can renewable energy cover the world's energy needs?

4-1. The global solar power generation system of solar cells and superconducting cables covers the world's energy needs with PV system

35 years ago — **Announced in 1989**

GENESIS

(Global Energy Network Equipped with Solar Cells and International Superconductor Grids)



4-2. Worldwide energy consumption estimates and areas to be carpeted with solar cell systems

PVTEC
Photovoltaic Power Generation Technology Research Association

By carpeting an area equivalent to only 4% of the global desert area with solar cells, the energy necessary for all human beings can be covered.

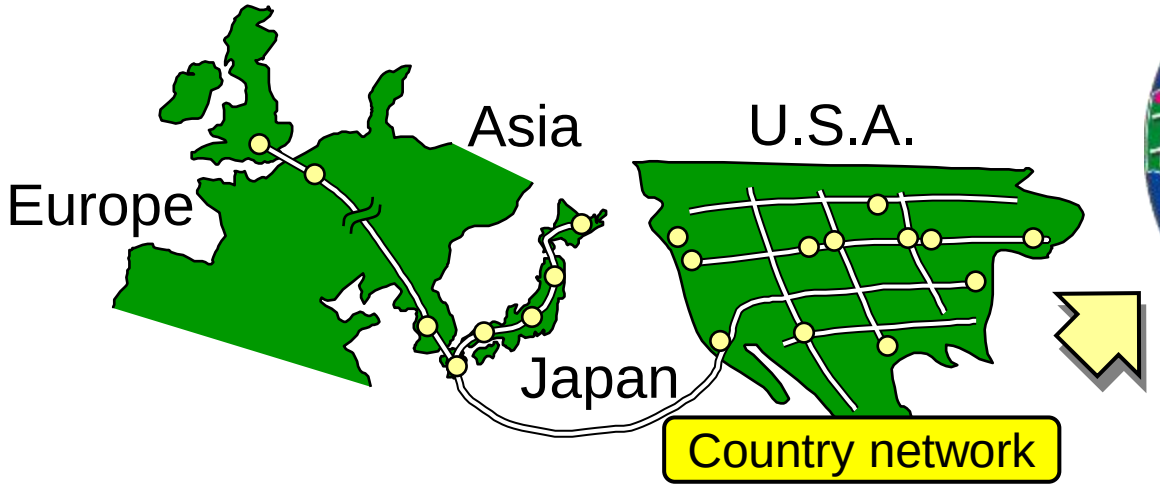
	2000	2010	2050	2100
Worldwide energy consumption estimate (crude oil equivalent × 100 million kl/year)	1			1,110
Conversion efficiency of solar cell systems (%)	10	**10**	15	15
Area to be carpeted with solar cell systems (km^2)	729	**802 (4% of entire desert area)**	1,030	1,850

4% of global desert area

54

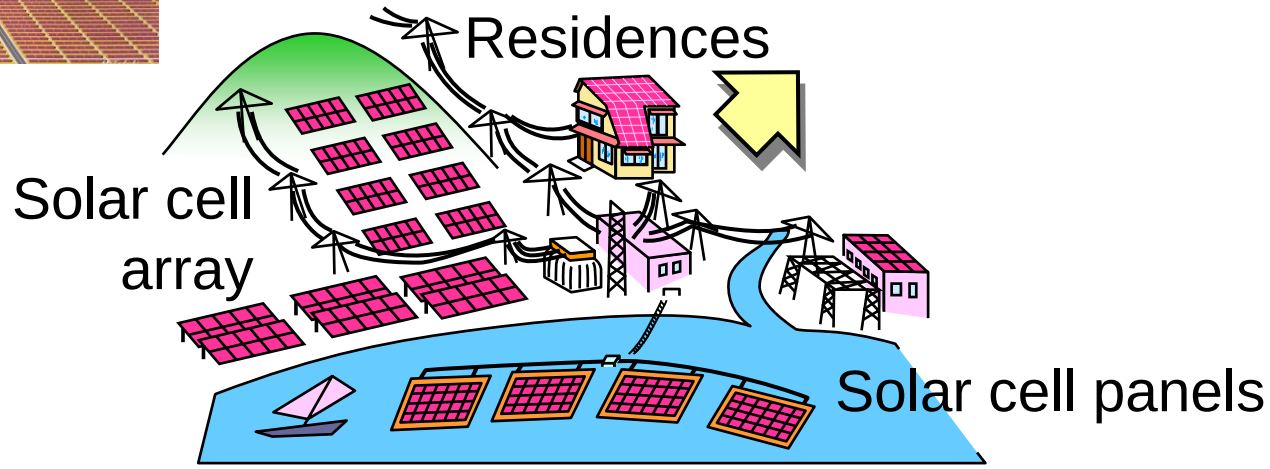
4-3. Step in the GENESIS Project

The GENESIS Plan is based on the idea that by installing PV systems on the roofs of households, buildings, and factories one after another until an area equivalent to only 4% of the global desert area is carpeted with solar cells, the energy necessary for all human beings can be covered.



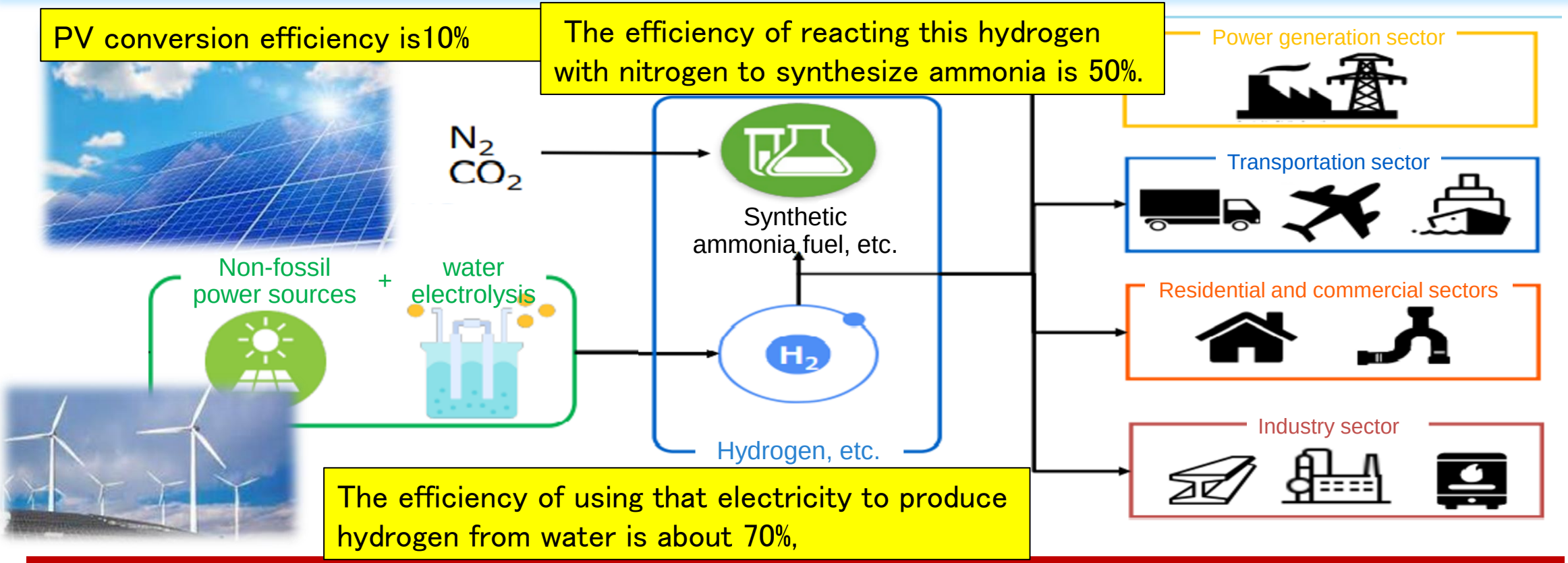
Global network

GENESIS

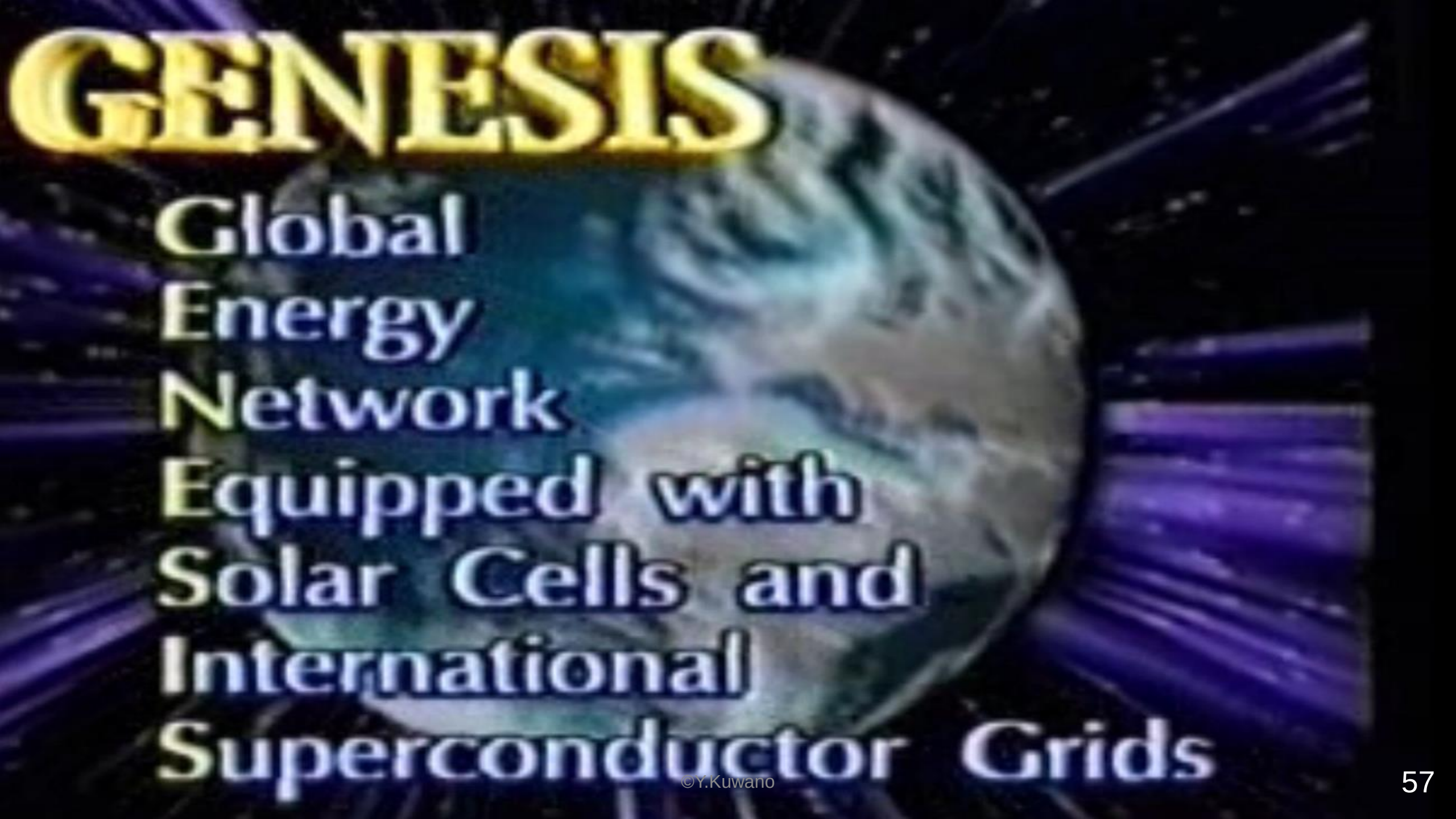


4-4. Ultimate energy for human beings

1) Using electricity generated from PV systems or other renewable energy sources, water is electrolyzed to produce hydrogen, which is then reacted with nitrogen in the air to produce ammonia (NH3), which can be used as liquid fuel.
2) Based on calculations in the Genesis Project, it is predicted that the electricity conversion efficiency from sunlight is about 10%, the conversion efficiency of using that electricity to produce hydrogen from water is about 70%, and the efficiency of reacting this hydrogen with nitrogen to synthesize ammonia is 50%.



The area of solar power generation needed to produce the energy needed to manufacture ammonia, a new fuel that would meet all of the energy needs of all of humanity, would be the size of about 12% of the world's desert, which is feasible.


GENESIS
Global
Energy
Network
Equipped with
Solar Cells and
International
Superconductor Grids