Overview of "PV Roadmap Toward 2030" (PV2030)

June 2004

NEW ENERGY AND INDUSTRIAL TECHNOLOGY DEVELOPMENT ORGANIZATION (NEDO)

New Energy Technology Development Department

Overview of “PV Roadmap Toward 2030” (PV2030)

– For realization of mass introduction of PV systems –

1. PV2030 Roadmap as a long-term strategy for PV R&D

Thirty years have passed since research and development (R&D) on photovoltaic (PV) power generation began under the Sunshine Project launched in 1974. Short-term PV R&D projects based on a seeds-driven approach have been revised every 4 - 5 years, and all current national PV R&D projects are scheduled for completion in FY 2005. With technologies developed under the R&D projects and policies supporting introduction of PV power generation, the primary goal of creating the initial market for PV systems is presently being achieved. Furthermore, Japan is now the global leader in both PV production and installed capacity.

As energy resources/global environment issues are emerging domestically and abroad, the importance of PV systems is ever-increasing, and further efforts are required to create a full-scale market for PV systems as well as elevate the status of PV power generation as an established energy-supply technology. In European countries and the United States, PV R&D roadmaps have been established in consideration of competition with Japan. Other Asian countries have also begun production and dissemination of PV systems. It is thus essential to structure a long-term R&D strategy to secure and maintain global competitiveness based on technological advantages.

An investigative committee consisting of key figures from academic, industry and governmental circles was established to study and formulate the “**PV Roadmap toward 2030 (PV2030)**” through six discussion sessions. Based on the expected position of PV power generation as an established energy-supply technology, the committee examined tasks to achieve the position in 2030 with the aim of shifting from existing “seeds-driven R&D” to “market-driven R&D”.

2. Expected position of PV power generation in 2030

The forthcoming 26-year period will serve as the formation stage of the full-scale market for PV systems. To become one of the major energy resources in response to energy resources/global environmental issues, it is crucial that PV power generation gains public awareness and confidence in this period. As shown in Figure 1, mass deployment of PV systems without restriction induced by the grid will be realized with PV R&D. Cumulative introduced capacity in the range of 100GW is achievable by 2030, at which time PV power generation could supply approximately 50% of residential electricity consumption (approximately 10% of total electricity consumption) in Japan.

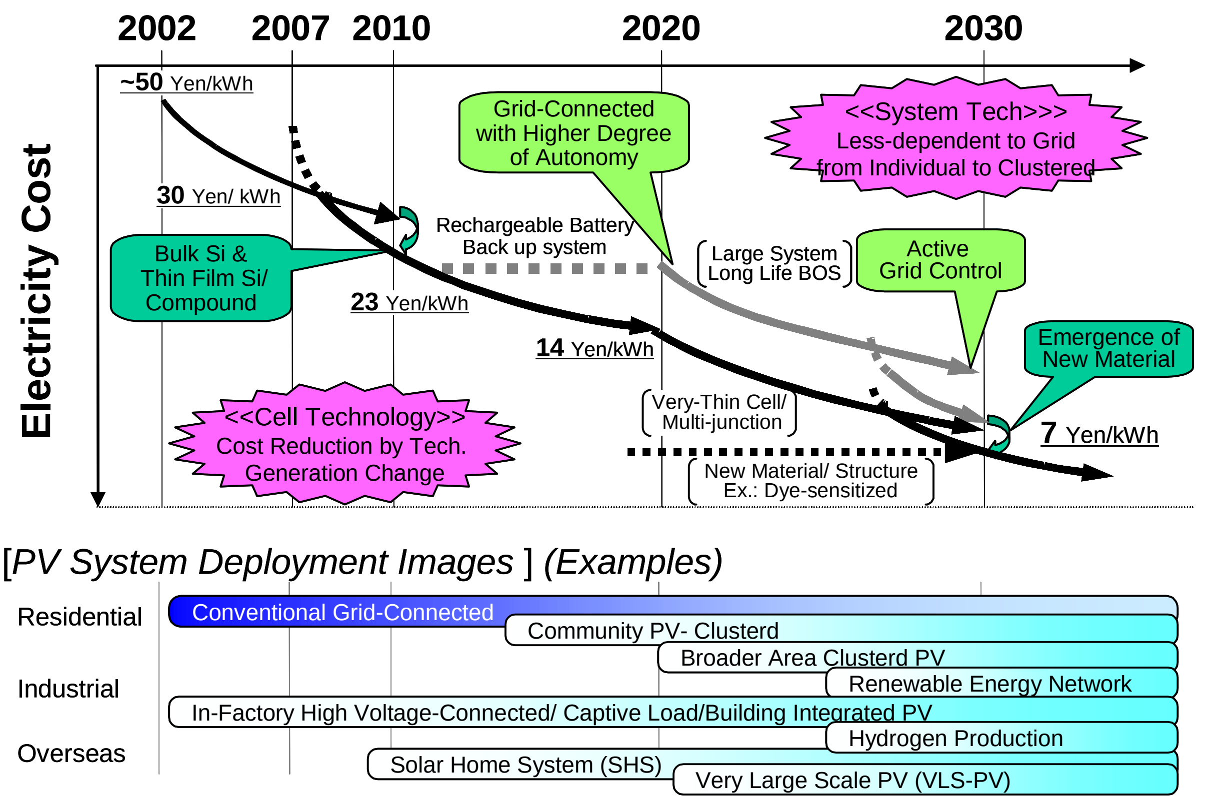


Figure 1. Scenario for improving the economic efficiency of PV power generation

1. Improvement of economic efficiency

PV power generation will be competitive with other energy resources by achieving a similar cost level as that for industrial use (approximately 7 Yen/kWh) by 2030.

2. Enlargement of PV application areas

PV system applications will be shifted from conventional grid-connected systems to new system configurations that do not overload the grid. Application areas will be enlarged and increased utilization of PV systems will be realized in terms of both installation sites and conditions by R&D *of PV systems for diverse uses and purposes.*

In the global marketplace, competitiveness in the PV industry will be secured via the technological advantages established by the R&D mentioned above.

3. Tasks and targets of PV R&D

With regards to the improvement of economic efficiency, milestones to achieve the targeted electricity costs are as follows: 1) equivalent to the electricity charge for residential use (approximately 23 Yen/kWh) by 2010; 2) equivalent to that for business use (approximately 14 Yen/kWh) by 2020; and 3) equivalent to that for industrial use (approximately 7 Yen/kWh) by 2030. Achieving PV module cost reduction through cell efficiency improvement as well as through technological innovations in the manufacturing process is crucial. Reducing the balance of system/installation costs, along with improving the durability (longer service life) of system components, etc., are also important. Table 1 illustrates the technological targets toward 2030. To improve economic efficiency, reduction of module manufacturing cost is assigned top priority. It is essential to challenge technological innovations beyond the augmentation of existing technologies including via drastic improvement of solar cell performance and to develop revolutionary solar cells, etc.

Table 1. Technological targets toward 2030

Item	Target by 2010 - 2030
Production cost of PV module	100 Yen/W (by 2010), 75 Yen/W (by 2020), < 50 Yen/W (by 2030)
Conversion-efficiency of PV module	
Durability of PV module	Service life: 30 Years (by 2020)
Silicon feedstock consumption:	1 g/W (by 2030)
Inverter (power conditioner unit)	15,000 Yen/kW (by 2020)
Accumulator battery	10 Yen/Wh (by 2020)

PV module conversion efficiency (%)* target	2010	2020	2030
Crystalline silicon solar cell	16 *(20)*	19 *(25)*	22 *(25)*
Thin-film silicon solar cell	12 *(15)*	14 *(18)*	18 *(20)*
“CuInSe” solar cell	13 *(19)*	18 *(25)*	22 *(25)*
“III –V” solar cell	28 *(40)*	35 *(45)*	40 *(50)*
Dye-sensitized solar cell	6 *(10)*	10 *(15)*	15 *(18)*

* Figures inside the parentheses indicate solar cell conversion efficiencies.

In shifting to a new PV system that exerts less load on the grid, it is essential to improve the stand-alone capabilities of PV system technologies with electricity storage functions and to develop community-based, clustered PV systems with energy control technologies such as active grid control technology using multi-functional inverters. With such R&D, it is also necessary to establish new types of energy systems such as community-scale/wide-area energy networks combining different types of new and renewable energy systems or a large-scale energy system based on hydrogen generation.

In addition, it is important to develop a wider variety of PV modules applicable to various locations, patterns of use and purposes (light-weight, flexible, bifacial, inverter-integrated, etc.). The development of value-added PV modules with diverse functions such as sound and heat insulation and anti-reflection for raising the incentive for users, and integration of PV modules with building materials and components to increases the value-added of PV systems, is also required.

In addition to the items indicated above, peripheral industrial technologies for mass production such as technologies for a stable supply of high-purity silicon feedstock and fundamental technological infrastructure such as evaluation technologies for PV system performance, estimation technology of power generation output and recycling and reuse technology of PV systems, etc. should be emphasized in order to contribute to sustainable development of the PV market.

<u>4. Measures to achieve the targets</u>

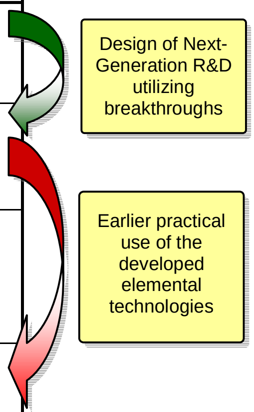
Future PV R&D will shift from "national government-directed R&D to create the initial market for PV systems" to "full-scale PV system market creation R&D based on role-sharing and collaboration among academic, business and governmental circles". The activities of the national government will focus on high-risk R&D that is required for development of energy-supply technology and on establishment of the highly public fundamental technological infrastructure. Responsibility for R&D closer to practical applications will be gradually shifted to the industrial sector.

In R&D toward 2030, it is essential to challenge technological innovations beyond the augmentation of existing technologies including drastic improvement of solar cell performance, manufacturing process innovation and qualitative changes in the concept of PV systems. For this reason, PV R&D will be implemented in accordance with the scheme depicted in Table 2. The "Next-Generation R&D" will be established in this scheme and the development of elemental technology necessary to achieve the 2020 target will be conducted as a step toward 2030.

Under existing circumstances, R&D for various types of solar cells necessitates parallel implementation. However, in order to select and focus on core R&D after 2010 through a selection and concentration process, developed technologies will be evaluated and the PV2030 Roadmap will be reviewed in FY 2009.

Table 2. Scheme of PV research and development (R&D)

Category of PV R&D		Concept	Targeted cost
Development of Fundamental Technology (entrusted research)	Seeds Search	- Search to discover technological innovation breakthroughs for PV power generation toward 2030	50 Yen/W
	Next-Generation R&D	- Development of elemental technologies to achieve the target for 2020 (Electricity cost: 14 Yen/kWh)	75 Yen/W
	R&D for Common Infrastructure	- R&D of technologies necessary for all aspects of PV power generation and technologies of a highly public nature	-
R&D for Practical Use (cost-sharing research)		- R&D for commercialization utilizing the outcome and for practical application, demonstrative research of novel PV systems, etc.	100 Yen/W



5. PV R&D toward 2010

PV R&D toward 2010 consists of two pillars: 1) R&D toward the target for 2010 (482 GW of cumulative PV system introduction volume) (short-term task) and 2) R&D for progress after 2010 (mid- to long-term task).

"R&D toward the target for 2010 (short-term task)" focuses on the ongoing R&D and its practical application. R&D on elemental technologies such as thin-film silicon solar cells and $CuInSe_2$ thin-film solar cells will be completed by 2005 in order to achieve earlier commercialization at 100 Yen/W module manufacturing cost. R&D for fundamental technological infrastructure such as evaluation technologies for PV system performance, power generation output estimation technology and recycling/reuse technology of PV modules will be promoted while R&D for Practical Uses, such as technologies for a stable supply of high-purity silicon feedstock and diversification of modules, will be enhanced for mass production and mass deployment.

"R&D for progress after 2010 (mid- to long-term task)" is Next-Generation R&D to achieve the targeted cost reduction by 2020 (14 Yen/kWh for electricity cost and 75 Yen/W for PV module cost) as a step toward 2030 and Seeds Search on a long-term basis. For Next-Generation R&D, based on the outcomes of the Seeds Search, the direction of R&D will be discussed. Promising technologies will be selected and the Next-Generation R&D on core technologies will be implemented aiming at a shift to R&D for Practical Uses around 2010. Furthermore, the Seeds Search will be continued on a long-term basis, for technologies not included in the issues of Next-Generation R&D as mentioned above.

(Review of PV2030 Roadmap)

From the perspective of the latest trends in PV technologies and R&D as well as general conditions both domestically and abroad, the PV2030 Roadmap will be reviewed regularly. The first review of the PV2030 Roadmap is scheduled for FY 2009.

Overview of “PV Roadmap Toward 2030” (PV2030)

ーReference Materialsー

Background/Perspectives on Roadmap Deliberations

Present Status and Issues of PV Power Generation

＜Present Status＞

- 30 years since the Sunshine Project was launched.
- Achieved drastic improvements in solar cell performance and cost reduction.
- Created the initial market

—Subjects—

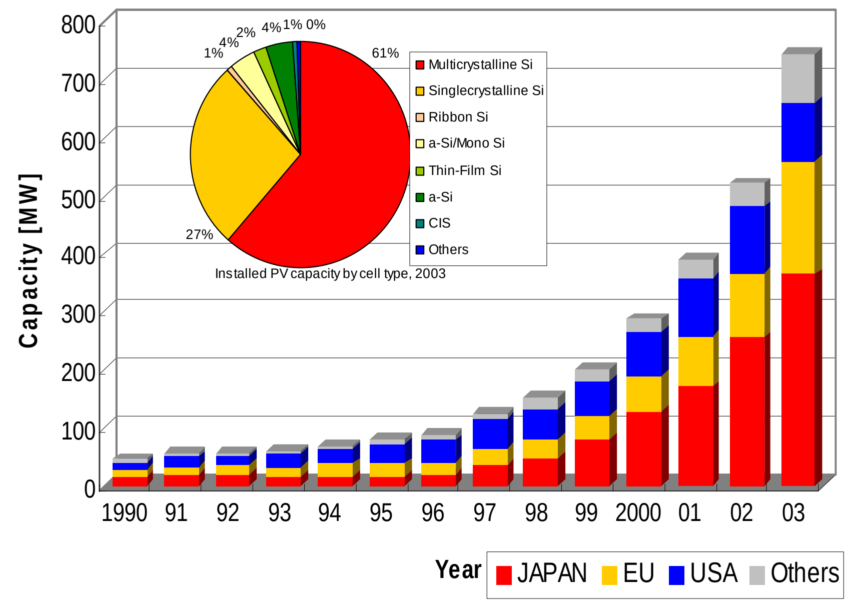
Further improvement of economic efficiency is required to compete with power grid

Limited capacity of PV installation apparent in interconnection to power grid

＜Issues＞

- Energy resources and Environmental issues:
  - —Response to increasing global population, energy consumption and global warming
  - —Rise of importance in PV power generation for energy supply
- Formulation of R&D strategies in Europe and the USA

Cumulative Installed PV System Capacity (Global)



Perspectives on the Roadmap

Investigation into the long-term R&D strategy toward 2030

- **Formulation of a long-term R&D strategy to the expected position**
- **Realization of mass introduction of PV systems without restriction**
- **Establishment of study and formation stage of the full-scale market for PV systems**
- **Securement and maintenance of global competitiveness based on technological advantages**

Investigative Committee for Roadmap

This Roadmap was investigated through six discussion sessions.

Chair: Kosuke Kurokawa (Professor, Tokyo University of Agriculture and Technology)

Members: JPEA, Sharp Corp., Kaneka Corp., Sekisui Chemical Co. Ltd., Kajima Corp., Nikkei Science, Tokyo Institute of Technology, Toyota Technological Institute, AIST, NEF, PVTEC

Observer: Ministry of Economy, Trade and Industry

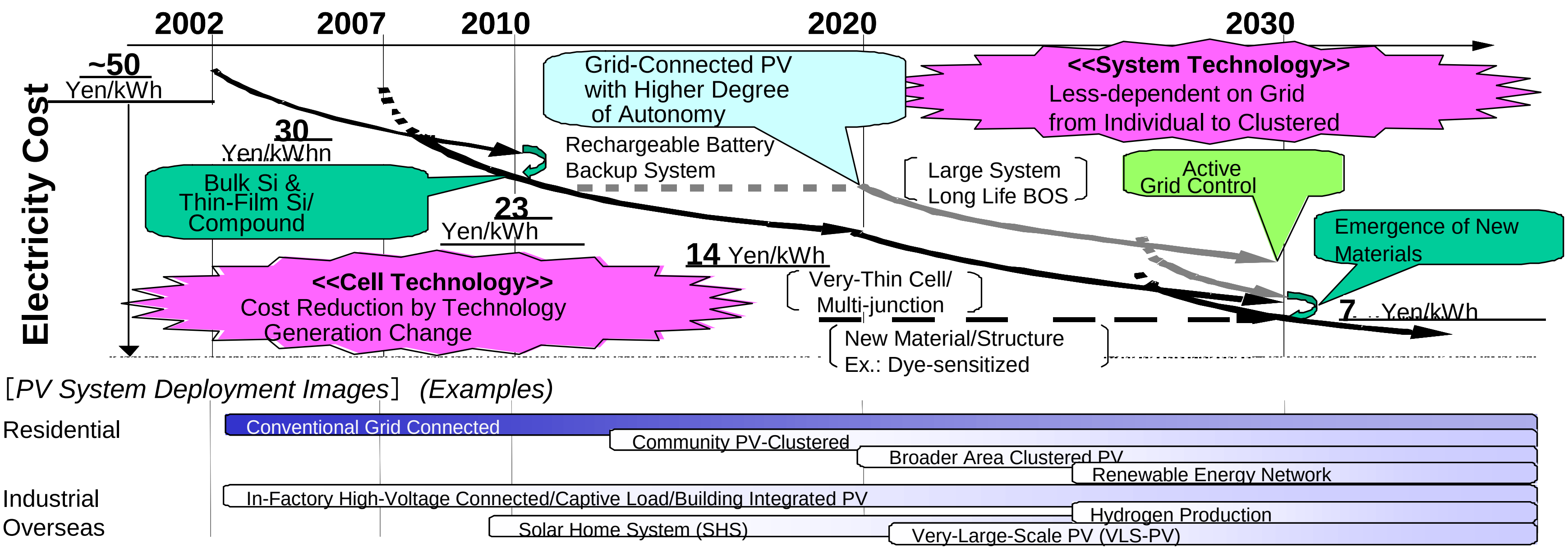
Expected Position of PV Power Generation in 2030(1)

(PV2030)

"Unrestricted mass introduction of PV systems"

- Attain economic efficiency (level of industrial use cost)
- Stand-alone capabilities of PV systems from grid-connected systems and enlargement for various utilization purposes

● Cost Reduction Scenario



● Future PV Power Generation

Item	Present Status		2030 Status	Notes
Generation price	High (twice)	⟶	Industrial-use level	Low-cost, high-efficiency
Reliability of electricity	Reliance on climate	⟶	Stable power supply	Storage functions, Grid-connected PV with higher degree of autonomy
Equipment life	20 years	⟶	Over 30 years	Material research, Structural improvement
Installation pattern	Individual installation	⟶	Community-scale/wide-area installation	Community-PV, Active grid control system
Necessary area/kW	Large	⟶	Small	High-efficiency
Electricity share	Below 0.1%	⟶	~ 10%	Residential, Industrial, Public facilities, Others
Plans	~	⟶	Hydrogen production power supply, Very-large- scale PV generation	Unused lands, Very-large-scale systems

(PV2030)

Technological Issues of PV Power Generation Toward 2030

Economic Efficiency Improvement of PV Power Generation

(Realization of Electricity cost at 7 yen/W)

① **Improvement of PV Module Conversion Efficiency**
- Further enlargement of PV applications for housing complexes
- Manufacturing cost reduction

② **Manufacturing Process Revolutions**
- Cost reduction for materials, production, and facilities
- Productivity improvement

③ **Durability Increase**
- Long-lasting PV modules and inverters to match durability of houses
- Electricity cost reduction

For realization of "unrestricted mass introduction of PV systems"

Enlargement of PV System Application Area

(formulation of new system configurations that do not overload the grid)

①**Stand-alone capabilities of PV systems**

Lower effect on power grid; interconnection restriction elimination

②**Active Grid Control Technology**

Formulation of interconnections with other types of energy systems such as via regional energy networks

③**Development of PV systems in response to utilization and purposes**

Mass introduction of PV modules and systems in response to various patterns of use and purposes for factories, building walls, etc.

Securement of Raw Material Supply

(Silicon, Indium, etc.)

Securement of high-purity silicon feedstock supply and reducing consumption of less common materials (e.g. Indium) to remove obstacles to mass production

Industrial Infrastructure Enhancement

- General improvement of installation incentive for users
- Response to overseas markets

Targets of PV R&D

(PV2030)

R&D Targets

Improvement of economic efficiency: Realization of similar cost as that for industrial use (7 yen/kWh)
(Milestones) 2010: 23 yen/kWh; 2020: 14 yen/kWh; 2030: <7 yen/kWh

Enlargement of PV application area: Cost reduction and stand-alone capabilities of PV systems for inverter and accumulator battery

Technological Targets Toward 2030

Item	Present Status	Target by 2010 - 2030
Production cost of PV module	Production: 250 yen/W (2003) Expected development: 14 yen/W (2007)	100 yen/W (2010) 75 yen/W (2020) <50 yen/W (2030)
Conversion-efficiency of PV module		
Durability of PV module	20 years	Service life 30 years (2020)
Silicon feedstock consumption	10～13 g/W	1 g/W (2030)
Inverter (power conditioner unit)	～30,000 yen/kW	15,000 yen/kW (2020)
Accumulator battery	～10 yen/Wh (for automobile)	10 yen/Wh (2020) Durability: 10 years

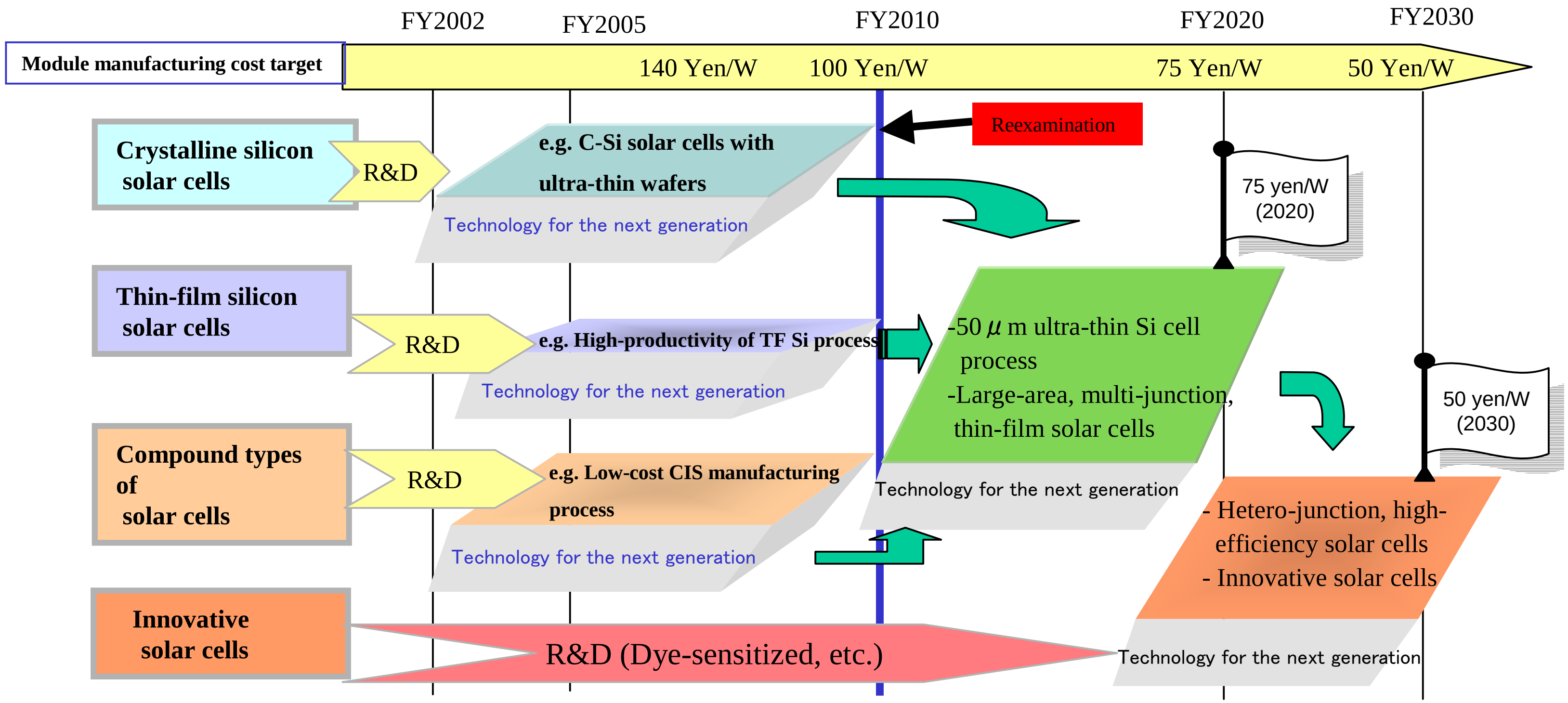
High Efficiency

PV module conversion efficiency targets *(cell efficiency targets)*

Solar Cell Type	Present Status	Conversion efficiency target (%)		
		2010	2020	2030
Crystalline silicon solar cell	13～14.8 *(18.4)*	16 *(20)*	19 *(25)*	22 *(25)*
Thin-film silicon solar cell	10 *(14.7)*	12 *(15)*	14 *(18)*	18 *(20)*
"CuInSe" solar cell	10～12 *(18.9)*	13 *(19)*	18 *(25)*	22 *(25)*
"III-V" solar cell	Concentrator *(38.9)*	28 *(40)*	35 *(45)*	40 *(50)*
Dye-sensitized solar cell	*(10.5)*	6 *(10)*	10 *(15)*	15 *(18)*

(PV2030)

Future PV Research and Technological Development (1)



PV Research and Development (R&D) Scheme

PV R&D Category		Concept	Targeted Cost
Development of Fundamental Technology (entrusted research)	Seeds Search	Search to discover technological innovation breakthroughs for PV power generation toward 2030	50 Yen/W
	Next-Generation R&D	Development of elemental technologies to achieve the 2020 target (Electricity cost: 14 yen/kWh)	75 Yen/W
	R&D for Common Infrastructure	R&D of technologies necessary for all aspects of PV power generation and technologies of a highly public nature	
R&D for Practical Use (cost-sharing research)		R&D for commercialization utilizing the outcomes and for practical application, demonstrative research of novel PV systems, etc.	100 Yen/W

Design of Next-Generation R&D utilizing breakthroughs

Earlier practical use of the developed elemental technologies

(PV2030)

Future PV Research and Technological Development (2)