Japan’s Sunshine Project and PV roadmaps

First 1MW PV demonstration site (1986)

Izumi KAIZUKA and Dr. Fukuo Aratani, RTS corporation
RTS Corporation – founded in 1983, 35-year experience

Comprehensive Consultancy on Photovoltaic Power Generation (PV)

Business: Helping establish PV business strategy, “Go to Japanese market”

Clients: Government agencies, utilities, manufacturers (entire value chain of PV) project developers, financial institutes, industry associations, etc.
in JP, US, DE, IT, FR, AT, NR, CHE, AUS, CHN, IND, KOR, Taiwan, Thailand, etc.

Consulting for PV projects

30 year experience

Go to Japanese Market

Japan

World

PV system

PV projects

Deployment

Business models

R & D

Silicon feedstock for solar cell
Contents

• Sunshine and New Sunshine Projects
• Roadmaps of NEDO (PV 2030, PV 2030+, PV challenge)
• What we learned
NEDO’s R&D Programs for Low Cost Solar Cells and Module Production

- Thin Film Silicon Solar Cells (140 JPY/W)
- Low Cost mc-Si Silicon Solar Cells Production Technology (Efficiency = 17.2%, 189 JPY/W)

1974
- “Sunshine” Project initiated
- Establishment of NEDO

1980
- “New Sunshine” Project initiated
- Grid Connected PV System
- Amorphous Silicon Solar Cells
- Crystalline Silicon Solar Cells

1993
- “New Sunshine” Project initiated
- PV System Demonstration
- 1MW Demonstrate PV plant
- Grid Connected PV System
- Amorphous Silicon Solar Cells
- II-VI compound Solar cells
- Crystalline Silicon Solar Cells

1997
- Low Cost mc-Si Solar Cells Production Technology

2000
- 500 KW Pilot Production Line for mc-Si Solar Cells

2005
- Residential PV System Technology

R&D Results

1MW PV Power Plant

Sun Shine & New Sunshine Project

R&D Items

- Hybrid TF-Si Solar Cells
- BIPV module
- CIS solar Cells
- TF-Si Solar Cells
- III-V high eff. Solar cells
Sunshine projects (1974 - 1994)

- Total budget: 500+ Billion Yen
  For PV: ~ 100 Bญ
- Technological development of abundant and clean energy
- Topics
  - Solar Energy (PV, CPV, solar heating, etc.)
  - Geothermal energy
  - Coal (gasification, liquidation)
  - Hydrogen (generation, transportation, application, storage, etc.)
  - Other topics
    - Wind energy, ocean thermal energy, biomass, etc.

- Budget allocation by technologies
  - Solar Energy 22%
  - Geothermal 18%
  - Coal related 53%
  - Wind & Ocean Thermal 4%
  - Other 1%
  - Hydrogen 2%
### R&D topics under the SunShine Project (-1992)

<table>
<thead>
<tr>
<th>Year</th>
<th>1975</th>
<th>1980</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ribbon Si, sc-Si, etc.</strong></td>
<td>Process R&amp;D, 600 kW of PV module production</td>
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<tr>
<td><strong>Crystalline Si</strong></td>
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<td>High-efficiency sc-Si</td>
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<td></td>
<td></td>
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<td></td>
<td>Wafer, larger cell</td>
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<td>Fundamental</td>
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<td>Ultra High efficiency</td>
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<tr>
<td><strong>amorphous Si</strong></td>
<td>Substrate, device structure</td>
<td>Fundamentals (surface, carrier dynamics, deposition, etc.)</td>
<td>Practical use: substrate, deposition, failure mechanism</td>
<td></td>
</tr>
<tr>
<td><strong>III-V</strong></td>
<td></td>
<td></td>
<td>CIGS, Cd, etc.</td>
<td></td>
</tr>
<tr>
<td><strong>BOS</strong></td>
<td>BOS testing, facility</td>
<td></td>
<td>BOS: inverter, support structure, storage</td>
<td></td>
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<tr>
<td><strong>Demonstration</strong></td>
<td>Large-scale grid integration: Shikoku &amp; Kansai EPCOs, CRIPES</td>
<td>Small &amp; middle application</td>
<td></td>
<td>Off-grid</td>
</tr>
</tbody>
</table>
Target & achievement of SunShine Project on PV area

- Cost target: Lowering PV system price to 1/100 by around 1990
  - ✓ PV module price: 20,000 - 30,000 Yen/W → 996 Yen/W (1992)

- Target installed capacity: 3,000 MW by 2000
  - ✓ Reched 10 years later
Lesson learned

• Year 2000 target installed capacity
  – Shift to PV did not happen.
  – When the target was set, more significant rise of crude oil was expected

• No strong link between R&D and dissemination

• Cost target could not reach 1/100
  – Invested various technologies
  – In early stage, it was difficult to select and focus promising technologies
Key Achievement of Sunshine project

• Commercialization and performance improvement of mc-Si PV cell/modules

• Investment for amorphous Si resulted in high efficiency HJT PV (Panasonic & Kaneka)

• Establishment and demonstration grid connection

• Continuous R&D encouraged investment for PV module manufacturing
  – No1 manufacturing country from 1999 to 2007
  – 4 Japanese PV companies ranked in top 10
New SunShine Project Target (1993) & Achievement in 2000

Assumed performance ratio: 12%
Assumed manufacturing capacity: 100MW/year
Assumed PV system application: 3kW, residential PV system

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<tr>
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<tbody>
<tr>
<td>Assumed technology</td>
<td></td>
<td>Crystalline Si (mc-Si)</td>
<td>a-Si, CdTe (BIPV)</td>
<td>a-Si, CdTe, CIGS</td>
</tr>
<tr>
<td>PV System cost</td>
<td>450 Yen/W</td>
<td>320</td>
<td>260</td>
<td>220</td>
</tr>
<tr>
<td>PV module cost</td>
<td>330 Yen/W</td>
<td>210</td>
<td>170</td>
<td>150</td>
</tr>
<tr>
<td>BOS cost (Non-PV module)</td>
<td>120 Yen/W</td>
<td>110</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>Domestic PV production (MW)</td>
<td>18.8MW</td>
<td>100 MW</td>
<td></td>
<td>136 MW</td>
</tr>
</tbody>
</table>

Source: RTS Corporation, Kazuo Yoshino, JPEA, “History of Photovoltaics”, IEA PVPS National Survey Report, etc.
The Path to the 1-GW PV Capacity: The first half of early 1990s

<Policy and Measures>

1992

R&D of PV for practical application based on Sunshine Project

1995

R&D of PV for practical application based on New Sunshine Project

Net billing of PV electricity at the retail price by electric utilities

PV System Field Test Project for Public Facilities (- 1997)

Guideline of PV grid connection

Establishment of target PV capacity: 4,600 MW by 2010 by Basic Guidelines for New Energy Introduction

Residential PV System Monitor Project

<Major application of the PV Market>

PV project by utilities

Cumulative PV capacity 30 MW level

PV System for Field Test

Roadmaps of NEDO

• 2004: PV 2030 roadmap
  – compiled to make “PV power generation as one of major energy by 2030”

• 2009: PV 2030 was reviewed and revised as “PV 2030+”
  – Considering the change of PV market (shifting to Europe) and industry (new countries emerged)

• 2014: NEDO PV Challenges (Strategies for PV R&D) compiled
  – Considering global trends
    • Significant reduction of PV module price
    • Increased production share by new countries, etc.
Cost-down Scenario: PV2030

Electricity Cost

~50 Yen/kWh

2002 2007 2010 2020 2030

30 kWh/Yen

Battery Backed-up

23 Yen/kWh

Grid-Connected PV with Higher Degree of Autonomy

14 Yen/kWh

Large System Long Life BOS

7 Yen/kWh

New Material Entering

<<Cell Technology>>
Cost Reduction by Technology Generation Change

<<System Technology>>
Less-dependent on Grid from Individual to Clustered

[ PV System Deployment Images ] (Examples)

Residential

Conventional Grid-Connected
Community PV - Clustered
Broader Area Clustered PV
Renewable Energy Network

Industrial

In-Factory High Voltage-Connected/ Captive Load/ Building Integrated PV
Solar Home System (SHS)

Overseas

Very Large Scale PV (VLS-PV)
Scenario by “PV2030+“ Roadmap

~50 JPY/kWh

30 JPY/kWh

Battery Backed-up

Grid-Connected PV with Higher Degree of Autonomy

23 JPY/kWh

Larger System


Long Life BOS

30 JPY/kWh

<<Cell Tech>>

Cost Reduction by Tech. Generation Change

<<System Tech>>

Less-dependent on Grid; HEMS/BEMS to Clustered; PhV/EV

New Material/Structure

η ≥ 40%

Entering A variety of devices & applications

7 JPY/kWh

7 JPY/kWh or Less

innovative R&D

New Material/ Structure

~50 JPY/kWh


Very-Thin Cell/ Multi-junction Higher η

Accelerated R&D

7 JPY/kWh

Wafer Si & Thin Film Si/ CIS mass-pro, quality

Entering A variety of devices & applications

η ≥ 40%

<<Cell Tech>>

Cost Reduction by Tech. Generation Change

<<System Tech>>

Less-dependent on Grid; HEMS/BEMS to Clustered; PhV/EV

New Material/Structure

7 JPY/kWh

7 JPY/kWh or Less

innovative R&D

New Material/ Structure

~50 JPY/kWh

NEDO PV Challenges: LCOE targets

Levelized cost of energy [Yen/kWh]

- 23 yen/kWh
- 14 yen/kWh
- 7 yen/kWh

Comparative to business electricity price
Comparative to levelized cost of energy by conventional thermal power

Improvement of efficiency and reduction of production costs

Innovative technology such as new material, new structure

Technology Development Examples and Targets Aiming at the Realization of LCOE of 7 yen/kWh in 2030.

- Module efficiency: 22%
- Capacity factor: 15%
- Operation period: 25 years

- Module efficiency: 25% or higher
- Capacity factor: 15%
- Operation period: 30 years
### Target and achievement

<table>
<thead>
<tr>
<th>Target generation cost</th>
<th>2017 status for 2020 target</th>
<th>2017 status for 2030 target</th>
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</thead>
<tbody>
<tr>
<td>PV module manufacturing cost (Yen/W)</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Cell efficiency (%), laboratory level</td>
<td>25</td>
<td>(30)</td>
</tr>
<tr>
<td>Commercial PV module efficiency (%)</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>PV module lifetime (years)</td>
<td>30</td>
<td>30 (40)</td>
</tr>
<tr>
<td>Silicon consumption unit (g/W)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Inverter price (Yen/kW)</td>
<td>15,000</td>
<td></td>
</tr>
<tr>
<td>Storage batteries (Yen/Wh)</td>
<td>10</td>
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</tbody>
</table>

- **Achieved**
- **Good prospect to achieve**
- **Not yet**
National Target 64 GW will be achieved around 2020

- With the pipeline of the PV projects under the FIT, 64 GW target will be achieved in around 2020

Source: IEA PVPS Trends Report 2017, RTS Corporation
What we learned so far or what we could not predict

• Recent development of PV was beyond assumption

• Turnkey production equipment lowered the barrier for new entrants (Long-term R&D is not required) for the entire value chain → imported PV modules contributed in lowering cost (especially in non-residential & utility scale application)

• FIT program and its impact was also beyond assumption
Acknowledgement for the support of PVPS activities

Contact: Izumi KAIZUKA, RTS Corporation, kaizuka@rts-pv.com

Jun 15, 2018 from 8:30 AM to 10:00 AM
K. Sugibuchi, RTS Corporation
150GW by 2030: PV Market Outlook for Japan
"PV150": the new target proposal for PV in Japan