Renewable Energy Technology:
Current Status of Technology Penetration and Its Challenge
Nov. 28th, 2018
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3. Research and Development of RE Technologies, AIST
4. Progress and Problems of Renewable Energy Deployment in Japan
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Current Status of Energy-Related Issues in Japan
After the Great East Japan Earthquake in March 2011,
1. Self-sufficiency ratio in the primary energy supply dropped from ~20% in 2010 to ~6% in 2013.
2. CO₂ emissions increased significantly (2013 was the worst ever).

Japanese Energy Policy for 2030
3E+S
- Energy Security
- Economic Efficiency
- Environment with securing Safety

Target
- energy self-sufficiency: 6%→24.3%@2030
- electricity cost: less than the current cost
- CO₂ reduction target: 26% reduction from 2013 value @2030

Energy Mix for 2030 under Long-Term Energy Supply-Demand Outlook
(Agency for Natural Resources and Energy: June 2015)

How to improve the energy self-sufficiency ratio in the primary energy supply?

Trend in energy self-sufficiency
- FY2010:19.9%, FY2011:11.2%, FY2012:6.3%, FY2013:6.0%
- Goals set to be 24.3% at FY2030
- Renewable Energy: 13-14%, Nuclear: 11-10%

Fundamental plan of action
- Maximum cutdown of energy usage
- Maximum introduction of renewable energies
- Improve in efficiency for thermal power plant

Reduce the dependence on Nuclear
RE: maximum introduction with suppressed cost
Role of RE has to be expanded.

- RE: 10.7% (2013), 13.3% (2016) in total electricity → 22-24% (2030)
- RE except for hydro power: from 2.2% (2013) to 13-15% (2030)

Energy Mix for 2030 under Long-Term Energy Supply-Demand Outlook
(Agency for Natural Resources and Energy: June 2015)

Mission: Promotion of “Green Innovation”,
- energy generation: increased use of alternative energies such as renewable energies that can reduce greenhouse gas emissions
- energy storage: high-density storage of energy
- energy saving: highly efficient conversion and use of energy and effective utilization of fossil energy resources
- environmental risk management: evaluation and reduction of environmental risks for industrial promotion.
3. Research and Development of RE Technologies

1. World cumulative PV installation exceeded 400GW, PV becoming a very important energy resource.

2. c-Si technology is still dominant with a share of ~90%, and thin film technologies such as CdTe and CIGS are competitive. The perovskite solar cells are emerging.

3. PV market shifted from Europe to Asia and USA to more severe climates.

4. Japanese share of world annual PV production dropped From 50% at 2005 to ~2.9% at 2017.

5. New Japanese PV roadmap (NEDO PV CHALLENGES) was announced, and cost goals are set to be 14 JPY/kWh for 2020 and 7 JPY/kWh for 2030.
PV technologies at AIST

Renewable Energy Research Center (Fukushima)
- crystalline Si, energy rating
- energy network

Research Center for Photovoltaics (Tsukuba and Kyushu center)
1) Improvement in cell and module performance:
   - CIGS, CZTS, thin-film Si, Organic TFs, Perovskite, etc.
2) Innovative solar cells:
   - Multijunction, quantum-dot, plasmonics, etc.,
3) Module reliability and robust modules:
4) Calibration, measurement, PV system safety, maintenance, and diagnosis:

Effective and Sustainable Use of Geothermal Energy

Japan is estimated to have the world 3rd largest potential of hydrothermal resources, though the resources have not been used effectively.

Obstructive factors in Japan
1. National Parks: 80% of the geothermal energy in Japan exist inside national parks where no exploitation had been allowed.
2. Coexistence with hot springs: Some of the owners of hot springs make strong campaign against geothermal development in afraid of degradation of the hot springs.
3. Cost: High initial cost and long lead time prevent private sectors to invest to the geothermal developments.
4. Size of hydrothermal systems: Power generation around 20-30 MW is the most suitable from sustainability (~30 years) point of view in Japan.
5. Reservoir management: Some of the operators find difficulties in prevention of scale deposition, maintenance of sustainability and treatment of acid fluid.

Potential of geothermal power generation

Electricity produced by geothermal power plant

EGS project at Yanaizu-Nishiyama, Fukushima

EGS: Enhanced (Engineered) Geothermal System
Location: Fukushima Prefecture
Operator:
(Power generator) Tohoku Electric Power Co., Inc.
(Steam supplier) Okuaizu Geothermal Co., Ltd
Installed Capacity: 65 MW
Operation start: May 1995

Produced Energy (MWh)

Background: Steam production has dropped significantly at Yanaizu-Nishiyama because of insufficient natural re-charging of water to the reservoir.

Water supply and monitor their effects
New Geothermal Resources with Potentials of GWs

Development of new technologies and control of new geothermal resources

<table>
<thead>
<tr>
<th>Size of rock body: 10-20 km (DIA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top depth of rock body: 4-6 km</td>
</tr>
<tr>
<td>Temperature: 500 deg-C</td>
</tr>
<tr>
<td>Phase: Supercritical</td>
</tr>
<tr>
<td>Chemical contents: $H_2S$, $HCl$, $SiO_2$, $NaCl$,…</td>
</tr>
<tr>
<td>Pressure: 60-80 MPa</td>
</tr>
</tbody>
</table>

Potential map of ground-source heat pump system prepared by FREA (Image figure)

GSHP Systems for East and Southeast Asia


GSHP is in operation at President house at Chulalongkorn University.

Two more systems have been installed in Thailand.

CCOP-GSJ/AIST Groundwater Phase III Sub-Project Meeting, June 10, 2015

Japan: AIST, Akita Univ.

Japanese embassy Thailand: Chulalongkorn Univ., DMR, DGR, Kasetsart Univ.

Where? and How Deep?

Potential of ground-source heat pump systems based on hydro-geological modeling

GSHP system exchanges temperature between in-room and underground.

Excess heat to underground for cooling and intake underground heat to the room for heating.

20-100m in depth

Hydrogen Carrier Production/Storage/Utilization

- Hydrogen production from PV and wind turbine output
- Conversion to hydrogen energy carrier (liquid at room temp.), large scale storage at a high density (MCH: 500 litter $H_2$ gas, $NH_3$: 1300 litter $H_2$ gas, HCOOH(formic acid): 400 litter $H_2$ gas @RT, 1atm,
- $3H_2 + C_6H_5CH_3$ (toluene) $\rightarrow$ $C_6H_{11}CH_3$ (MCH: methylcyclohexane)
- Hydrogenation/dehydrogenation by catalytic reaction
- Combined heat and power application by engines, fuel cells, etc.
High Efficiency H₂-Diesel Dual Fuel Engine Technology Using Exhaust Heat Recovery

Dehydrate process from MCH is endothermic reaction.
C₆H₁₁CH₃ (MCH: methylcyclohexane) → 3H₂ + C₆H₅CH₃ (toluene)

Use of dehydrated H₂ from MCH as a H₂ carrier using co-generation system with engine:
60% - H₂ at thermal efficiency of over 40% was demonstrated
→ next target: H₂% > 80%

Efficiency improved with increasing H₂%

Efficiency maintained high output by controlling the timing

Dehydrate process from MCH is endothermic reaction.

PV Deployment in Japan (1)

- The main driver shifted to RPS (Renewables Portfolio Standard) in 2003, Residential Surplus Electricity purchasing in 2009, then to FIT in 2012.
- 26% annual increase after the introduction of FIT in 2012
- Since the start of FIT in 2012, more than 35 GW already installed and ~80 GW of proposals approved by METI (as of March 2017)
- The deployment goal of 64 GW for 2030 is expected to be demonstrated even before 2020.

Cumulative installation

Policy and Deployment of RE

Reference: METI
Tariff for large-scale PV systems set at 40 JPY/kWh (excluding tax) two times higher than European countries such as Germany and Spain. Market expanded rapidly much faster than the original long-term deployment plan of around 2~3GWp/year until year 2020.

Comparison of tariff levels for PV (>1MW, ground-mounted)

<table>
<thead>
<tr>
<th>Tariff (JPY/kWh)</th>
<th>Change of Tariff (JPY/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>2016</td>
</tr>
<tr>
<td>10kW or more</td>
<td>40</td>
</tr>
<tr>
<td>less than 10kW</td>
<td>42</td>
</tr>
</tbody>
</table>

Reference: METI

In view of drastically reduced PV costs, cumulative global installations in excess of 3 TW are anticipated by 2050, continuing current R&D and investment paths. To provide a major contribution to global climate goals, total installations on the order of 20 TW will be needed by 2040. This will require continued investment in worldwide R&D to reduce production costs, increase efficiency and improve reliability. An increasingly flexible electricity grid, increased availability of low-cost energy storage and demand side management will also play key roles in enabling accelerated PV deployment.

Press release from AIST, FhG and NREL on March 30, 2016

"Terawatt-scale photovoltaics: Trajectories and challenges" Science 356 (6334), 141-143

Worldwide gathering of 70 experts from Germany, Japan, the United States and elsewhere to discuss the future of PV. (research institute, academy, industry, governmental funding organization, finance, etc.)

"Statement (extracts)"

Cumulative PV deployment in the world will reach 1 TW by 2023 or sooner. The current trajectory suggests total global installation of ~ 7 TW by 2030. A range of scenarios from 5-10 TW by 2030 and 60-80 TW by 2050 discussed. Solar will become the lowest cost form of electricity around the globe and a central feature of a future sustainable energy economy. Solar PV is on a trajectory to provide a majority of the world’s electricity, reaching generating capacity at multi-terawatt scale, and address broader global needs for clean air, defossilization and economic development. PV in combination with high power electronic will play a critical role in stabilizing the grid by providing frequency regulation, voltage support and local power when the grid is down. A key element of solar’s success will be a partnership with wind, hydropower and bioenergy and a range of storage and load-shifting technologies. Fully integrated research programs among institutes, universities and industry, spanning both near- and long-term needs, can address challenges to further reduce cost of solar electricity and enable solar’s enhanced roles in stabilizing the grid and powering other sectors of energy demand.