Lesson 1

Current Status and Issues of Electric Power Generation

February 2013

For Elementary School
Introduction of Japan Aerospace Exploration Agency (JAXA)

JAXA makes research and development in two fields; space and aeronautics. The activities in the field of space are shown in general below;

Launch satellites and spacecraft

to study the universe

“HAYABUSA” etc

to utilize the space for humans

“International Space Station” etc
“Electricity” is very important in our daily life.

- **Manufacturing plant**
- **School lighting**
- **Electric car**
- **Railway power source**
- **Household electric appliance**
- **City Illumination**
How to generate electricity?

Motor is driven by electricity.

Electricity from battery.

Motor is driven by some external force.

Electricity is generated.

Electric power generation
Examples of Electricity Generator

Generator for bicycle light  Hand-working light
Power Generation and Consumption

Power Station

- Hydroelectric power plant
- Thermal power plant
- Nuclear power plant

Transmission network

Power Consumption

- Factories
- Transportation
- Homes

Before Fukushima Disaster (in Japan)
Hydroelectric Power Plant and Dam

http://www.info-toyama.com/spot/31038/
Mechanism of Hydroelectric Power Plant

Energy of falling water is used to rotate the power generator.

http://www.sbenergy.jp/study/illust/water/
Thermal Power Plant

http://gazone.morrie.biz/keizai/kkt/sin_kokura_hatudensyo.html
Mechanism of Thermal Power Plant

Steam

Steam Flow

Turbine

Rotating Generator

Steam Condenser

Combustion of Coal, Petroleum, Natural gas. Fuel is burned with atmospheric oxygen.

Steam is generated when water is boiled.

http://www.fepc.or.jp/enterprise/hatsuden/fire/
Nuclear Power Plant

Fukushima Daini Nuclear Power Station

http://www.tepco.co.jp/nu/f2-np/index-j.html
Mechanism of Nuclear Power Plant

Steam is generated when water is boiled.

Boiler

- Steam
- Water
- Nuclear fission

Electricity

- Generator
- Steam flow
- Condenser
- Sea water

Nuclear fission

Water is boiled by heat of nuclear fission.

http://www.chuden.co.jp/kids/kids_denki/tsukuru/tsu_nuclear//
Disaster of Fukushima Daiichi Nuclear Power Station
March 2011

http://www.tepco.co.jp/decommision/accident/index-j.html

Nuclear power stations will be re-operated after the safety is fully confirmed by the new government requirements.

However, since many people are seriously concerned about the safety of nuclear power station, nuclear power station will not be used as many as before.
**Current Situation of Power Generation**

**Power Station**

- **Hydroelectric power plant**
- **Thermal power plant**
- **Nuclear power plant**

**Transmission network**

- **Factories**
- **Transportation**
- **Homes**

- Nearly zero after Fukushima Disaster In Japan
  (about 20% was supplied before the disaster)
Power Saving!

Pictures:
http://www.city.iruma.saitama.jp/blog/16kaneko/2011/05/post-76.html
In reality, we will face electricity shortage in future even if we had not the Fukushima disaster.

We need new type of power plant, because the power capability of the current plants will not be increased or even reduced in future, while electric power demand will be certainly increased.
Increase of Electric Power Demand

Population Statistics by the U.N. (1950-2050)

Population Increase

Power Demand Increase
Future of Power Plants Currently in Operation

- **Hydroelectric power plant**: Available lands for hydroelectric power plants are limited. It will be difficult to construct them much more. A sustainable solution for future, but we cannot depend on them so much.

- **Thermal power plant**: Fossil fuel resources will be depleted. Burning fossil fuels increases CO$_2$ emission and causes global environmental degradation. We will be unable to maintain the thermal power plants as many as we have. Not a sustainable solution for future.

- **Nuclear power plant**: There is a big concern about the safety of the nuclear plant and nuclear waste. Uranium will be depleted in future. Not a sustainable solution for future.
Reserves of Oil, Coal, Natural Gas, and Uranium

People around the world are heavily dependent on the fossil fuel, more than 80 %, but the fossil resources are limited.
Balance of $CO_2$ and $O_2$

$CO_2$ generated at the thermal power plants is converted into $O_2$ by plants by using the energy of sunlight.

Burning fossil fuel generates $CO_2$ emissions.

$C + O_2 \rightarrow CO_2 + Energy$

Emitting $CO_2$ more than absorption by plants and others results in more $CO_2$ concentration in the atmosphere.
Relation between CO$_2$ Concentration and CO$_2$ Emissions

The Issue of Global Warming

Sea level rises as the atmospheric temperature rises?

Global warming causes more desertification?

Note: IPCC established by the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) predicts global warming. However, some climate scientists are insisting that we are headed into a period of global cooling. In any case, the artificial increase of CO₂ concentration will give adverse effects on the global environment.
What should we do?

1. Use the power system that can be operated over a long time in future, not requiring limited natural resources.

2. Generate electricity using clean and safe power system.

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Power Source</th>
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<tbody>
<tr>
<td><strong>Renewable Energy</strong></td>
<td>Photovoltaic power generation on ground</td>
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<tr>
<td></td>
<td>Wind power generation</td>
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<td>Wave power generation</td>
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<td></td>
<td>Geothermal power generation</td>
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<tr>
<td></td>
<td>Photovoltaic power generation in space</td>
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<tr>
<td><strong>New Nuclear Energy</strong></td>
<td>Nuclear fusion</td>
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</table>
Lesson 2

Renewable Energy Systems and New Energy Systems in Future
Power Generation by Solar Photovoltaic cell

Photovoltaic Cell

Light

Photovoltaic Cell

Electricity

This method does not need any fuel, water, or air.

Pocket calculator  Solar watch
Example of Photovoltaic Power Plant

80MW Power Plant in Canada (World largest, 2010, 1km² approx.)

70 MW Power Plant in Kagoshima, Japan

One plant can supply power to approximately 20,000 – 30,000 households
Principle of Wind Power Generation

Blade

Speed-increasing gear

Power generator

Miniature model of wind-power generator for children
Wind Power Generation

Wave Power Generation

Power generation turbine is rotated by the force of sea surface wave motion, up and down.

http://www.jamstec.go.jp/j/kids/tazunete/022/

Geothermal Power Generation

Power generation turbine is rotated by geothermal steam.

Two Types of Reaction for Nuclear Energy Release: Nuclear Fission and Nuclear Fusion

**Nuclear Fission**

- Fuel: Uranium (limited resource)
- Heavy atomic nucleus (Uranium, etc.)
- Neutron

**Nuclear Fission Power Plant**
There are problems related to safety and nuclear waste.

**Nuclear Fusion**

- Fuel: deuterium (available in seawater)
- Light atomic nucleus (H, etc.)
- Heavier atomic nucleus (He, etc.)
- Energetic Particles Neutrons, Protons

**Nuclear Fusion Power Plant**
High level safety could be realized, not certain yet.

Nuclear fusion is the same process as that at the core of our sun.
Research for Nuclear Fusion

The project is funded and run by seven member entities — Japan, European Union, India, China, Russia, South Korea, and United States. It is believed it takes another 20-30 years to realize the commercial nuclear fusion plant.

International Thermonuclear Experimental Reactor (ITER)

Transportation of the plant subsystem to space by reusable rockets

Assembly of subsystems into Solar Power Satellite in space
Advantages of Solar Power Satellite (SPS)

**Solar Power Plant on Ground**
- Rainy and cloudy days
- Night
- Land problem

**Solar Power Plant in Space**
- No rainy or cloudy day
- No night (depending on the orbit)
- No land problem

**Contrast**
Experience using an experimenting apparatus

**Image of Solar Power Satellite**

Power is transmitted to the ground using microwave or laser (wireless power transmission).

**Microwaves in daily life**

- Rectenna site in the sea near the shore (an example)
Image of Solar Power Satellite

- Solar Power Satellite
- Microwave
- Pilot beam
- Rectenna
- Power receiving site
- Power network
- Submarine cable
Representative SPS Model Designed in Japan

- **Basic Mode**
  (USEF Tether-SPS)

- **Advanced Model**
  (JAXA M-SPS)
Research Subjects Necessary to Realize SPS

1. Large power generation \((10^9 \text{ W class})\) using a large solar panel \((\text{km size})\) in space.

2. Long-range wireless power transmission to the ground, typically 36,000 km or more.

3. Long life power plant more than 30 years in space environment.
1. Demonstration experiment to extend a large panel in orbit

Two-dimensional deployment of a large panel

Laboratory deployment test

CG showing a deployment procedure

Laboratory test using shape memory alloy as actuator devices
2. Demonstration experiment on microwave power transmission

Microwave Power Transmission
- 1.6 kW power
- 50 m range
- 3° sharp beam
- 0.5° pointing accuracy

Objectives
- to demonstrate technologies to control a microwave power beam and to prepare for the space experiment in the near future.
3. Research for Long-life Structure in Space Environment

There are a lot of space junks or debris in orbit.

In practice, it is impossible to avoid the collision of the debris to the SPS large structure.

We need to find the structure and component to minimize the collision damage.
History and Global Trend of SPS Research

Japan is currently the leading country in the research of SPS.
SPS Demonstration Experiment in Space

Video
**Research Required for New Energy System**

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<th>Necessary research</th>
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<td>Renewable energy</td>
<td>Solar power on ground</td>
<td>Already in practical use, but needs research for low cost implementation.</td>
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Summary

Electric Power Demand/Supply

Power saving

Cost reduction of renewable energy system for currently available system

Development of innovative energy system (SPS, nuclear fusion)

now

Near future

Long future

Solar power plant on ground

SPS (Solar power plant in space)