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Energy Business Technology Strategy

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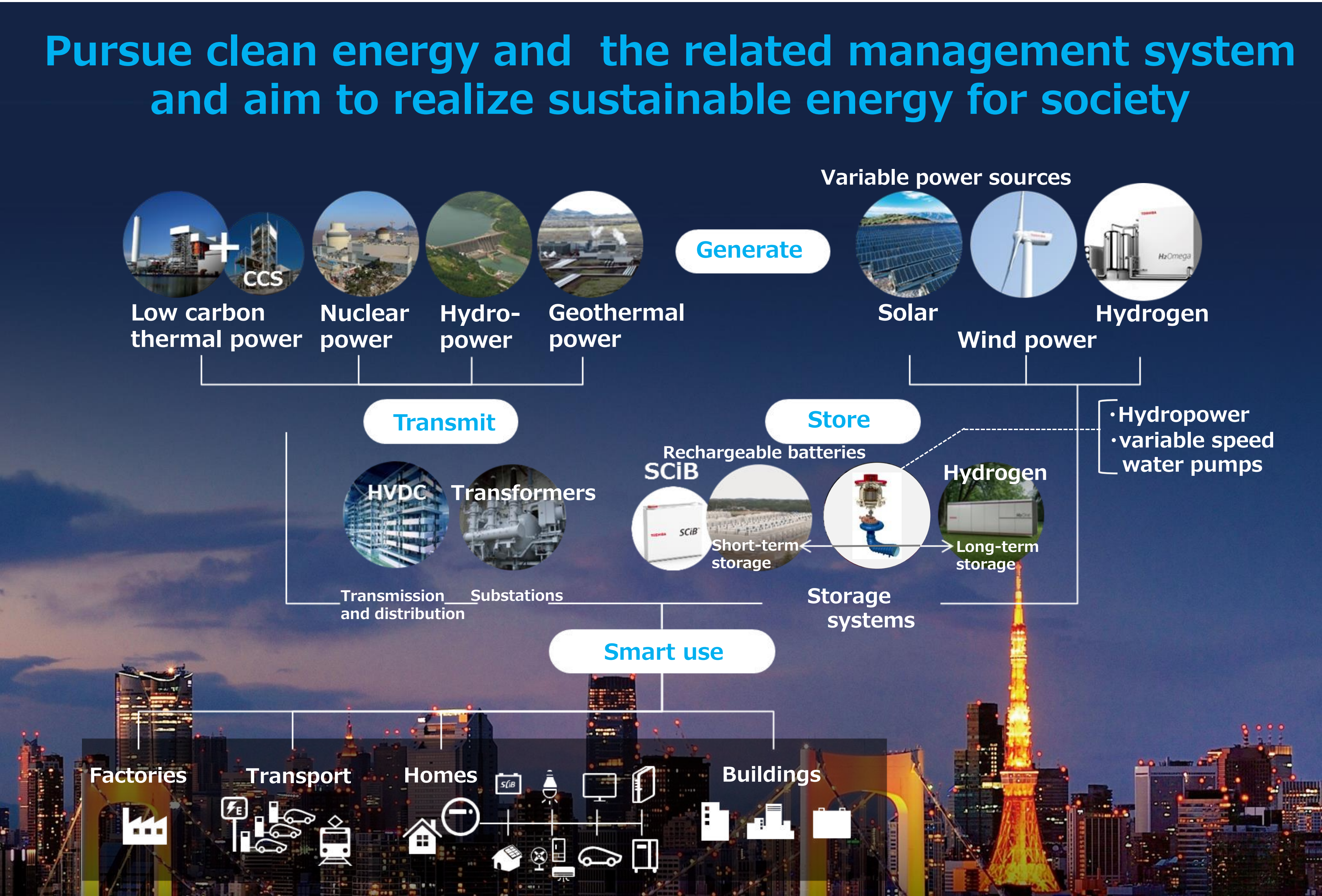
Energy Systems & Solutions Company
Chief Technology Executive
Toshiba Corporation

October 18, 2016

Energy Business Technology Strategy



I. Green energy

- That pursues the world's highest level of safety in nuclear power
- That aims for zero emissions by introducing high efficiency systems and carbon capture technologies in thermal power
- That contributes to the stabilization of the power system with hydropower

II. Energy management

- Use next-generation technologies to pursue optimal control of the supply and demand balance

Ⅲ. Cutting-edge technologies

- Lead the world in cutting-edge technologies

Toshiba Group’s Nuclear Power Plants

Global expansion with two reactors offering the world's highest safety levels

High capacity BWR: **ABWR**

- Dynamic + static safety system (optional)
- Large output (1.35 - 1.65 million kWe)
- Extensive operating experience (four units in service)
- Short construction period track record (37 months)

Innovative PWR: **AP1000™**

- Static (Passive) safety system
- Medium output (1.1 million kWe)
- Under construction (Eight units, in the United States and China)
- Simplified system to reduce maintenance requirements

○ Rigorous measures against severe accidents
○ Measures to withstand aircraft strikes, ensure security and protect against cyber-terrorism
○ Application of the latest construction technologies: modular construction, 6DCAD™ and others

Installation of l
large module

6DCAD™; 3D desingn data + Resources planning + Process of planning + Manpower planning

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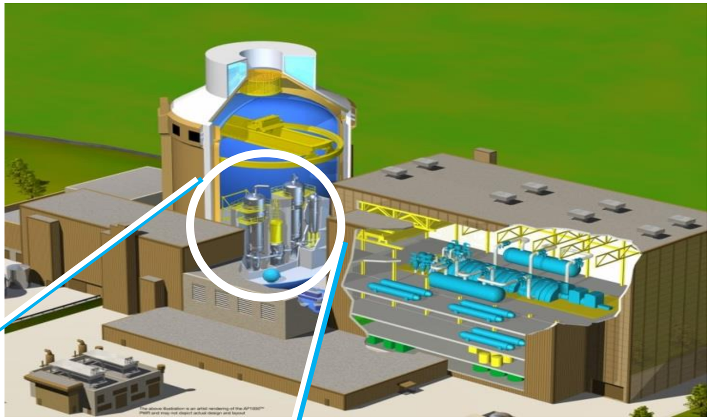
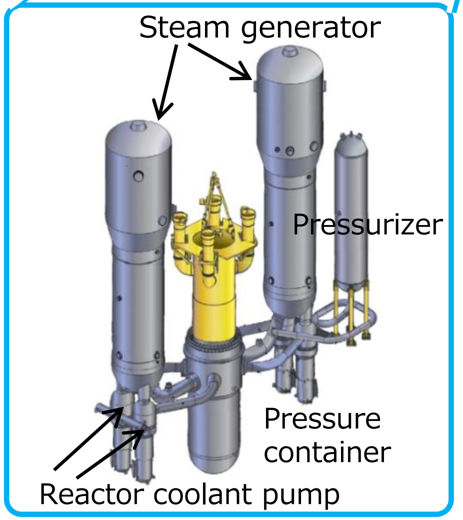
Key Features of the AP1000™

Development based on proven PWR technologies of WEC※1

- **Employs** a Static (Passive) safety system
  - **Gravity-driven water injection cooling**
  - **Core cooling by natural circulation**
- **Adoption of** large steam generator **realizes 2-loop primary system reactor**
- **Adoption of** seal-less RCP※2
- **Application of** state-of-the-art technologies
  - **Full digital instrumentation and control system**
  - **High performance turbine**
- **Adoption of** modular construction





AP1000™ construction underway

※1 WEC: Westinghouse Electrical Company LLC
※2 RCP: reactor coolant pump

Collaboration with WEC in Construction of the AP1000™

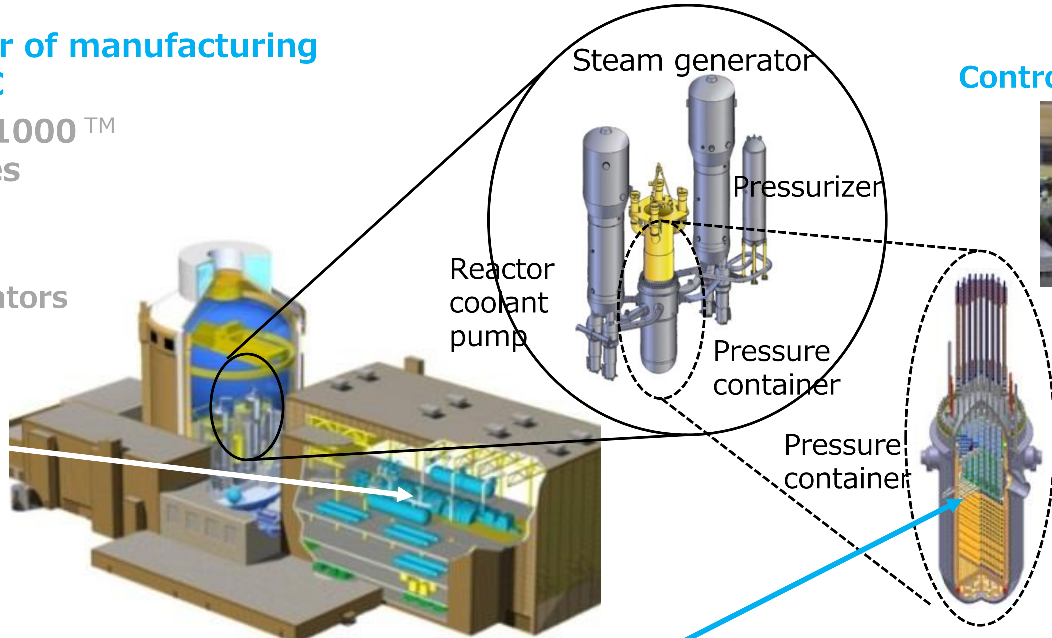
Applying Toshiba's strengths

Completed transfer of manufacturing technology to WEC

Adopted in the AP1000 ™ in the United States

Turbines and generators

Condenser & Heat exchanger



Control rod drive mechanism (CRDM)

Reactor internal structure

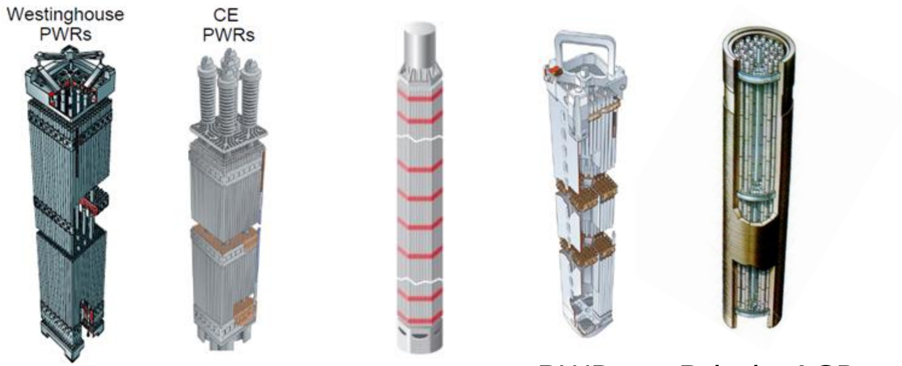
Guide tubes

Core barrel

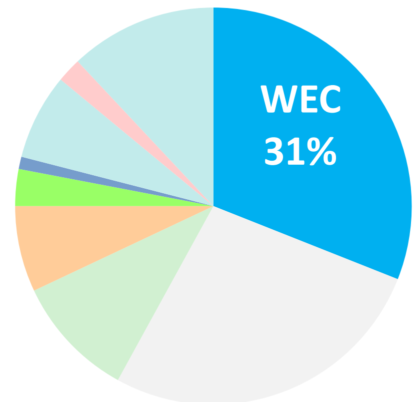
AP1000™
Earthquake resistant options
(currently under review by NRC)

Features of Toshiba Group's Fuel Technology

The world No. 1 share, won by an extensive line-up and reliability

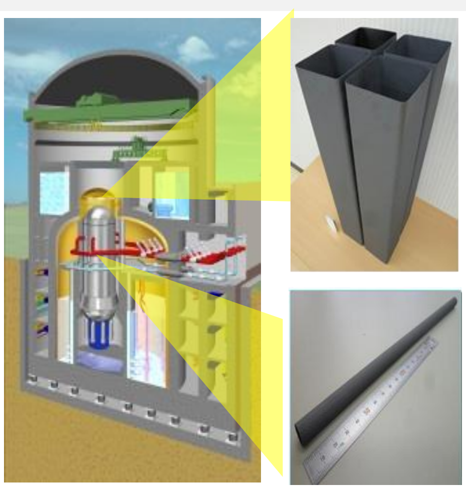


PWR VVER BWR Britain AGR



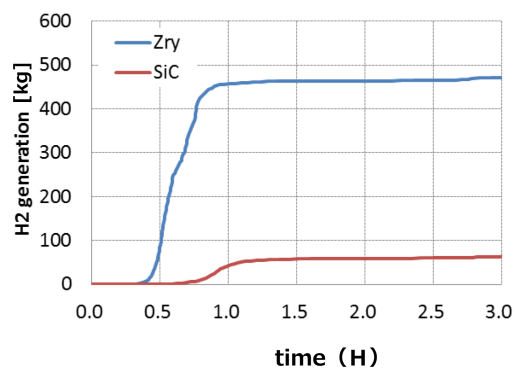
Fuel share for light-water reactors
(2011 - 2013 average)

Accident-resistant fuel – SiC* reactor core material



Channel Box (SiCf-SiC)

Cladding tube (SiCf-SiC)



Severe accident behaviour analysis example

Suppression of hydrogen generation in the event of severe accident

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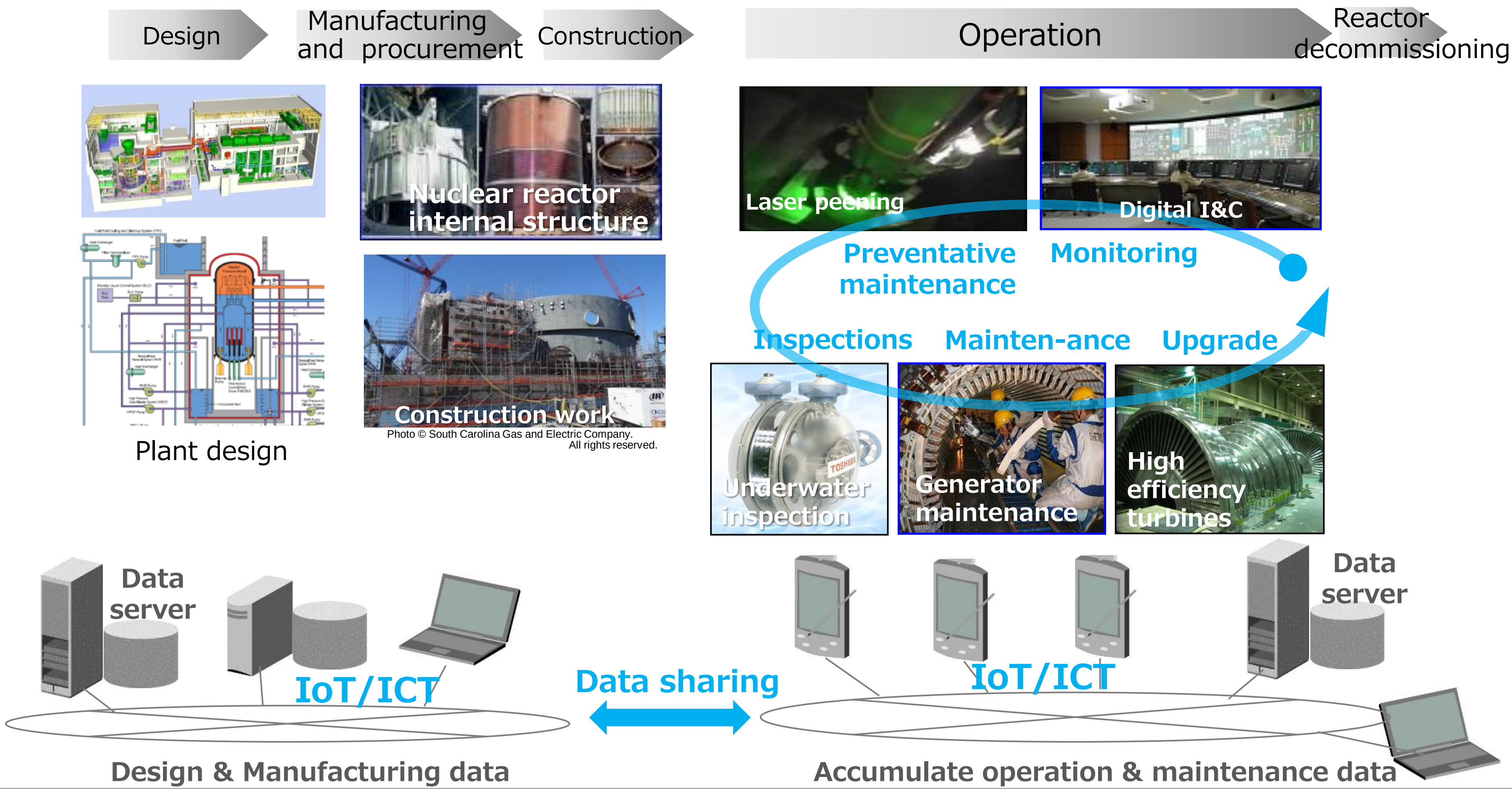
*** SiC: Silicon Carbide**

Maintenance over the life of the nuclear power plant from construction → operation → reactor decommissioning



① Contributions at Fukushima Daiichi
② Decommissioning Technologies For Nuclear Facilities

①Developing technologies for stabilization of site condition and reactor decommissioning

Contaminated water treatment technology

Multi-nuclide removal equipment

Remote decontamination technology for buildings

High altitude dry-ice blasting decontamination equipment*

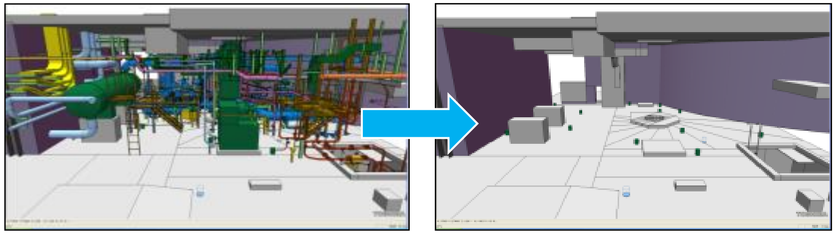
Robots for high dose areas

Robot for examination containment vessel interior*

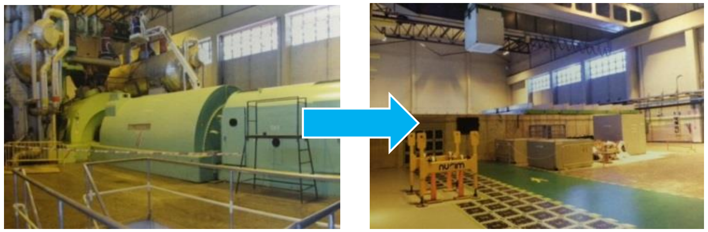
Spent fuel removal

Fuel handling system

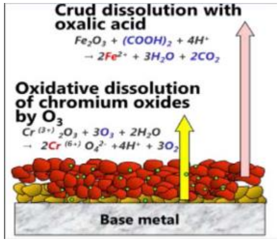
② Extensive experience in developing basic technologies and planning management, in Japan and overseas



Simulation-based planning



Removal of unwanted substances (Zorita, Spain)



System decontamination technology (T-OZON™)

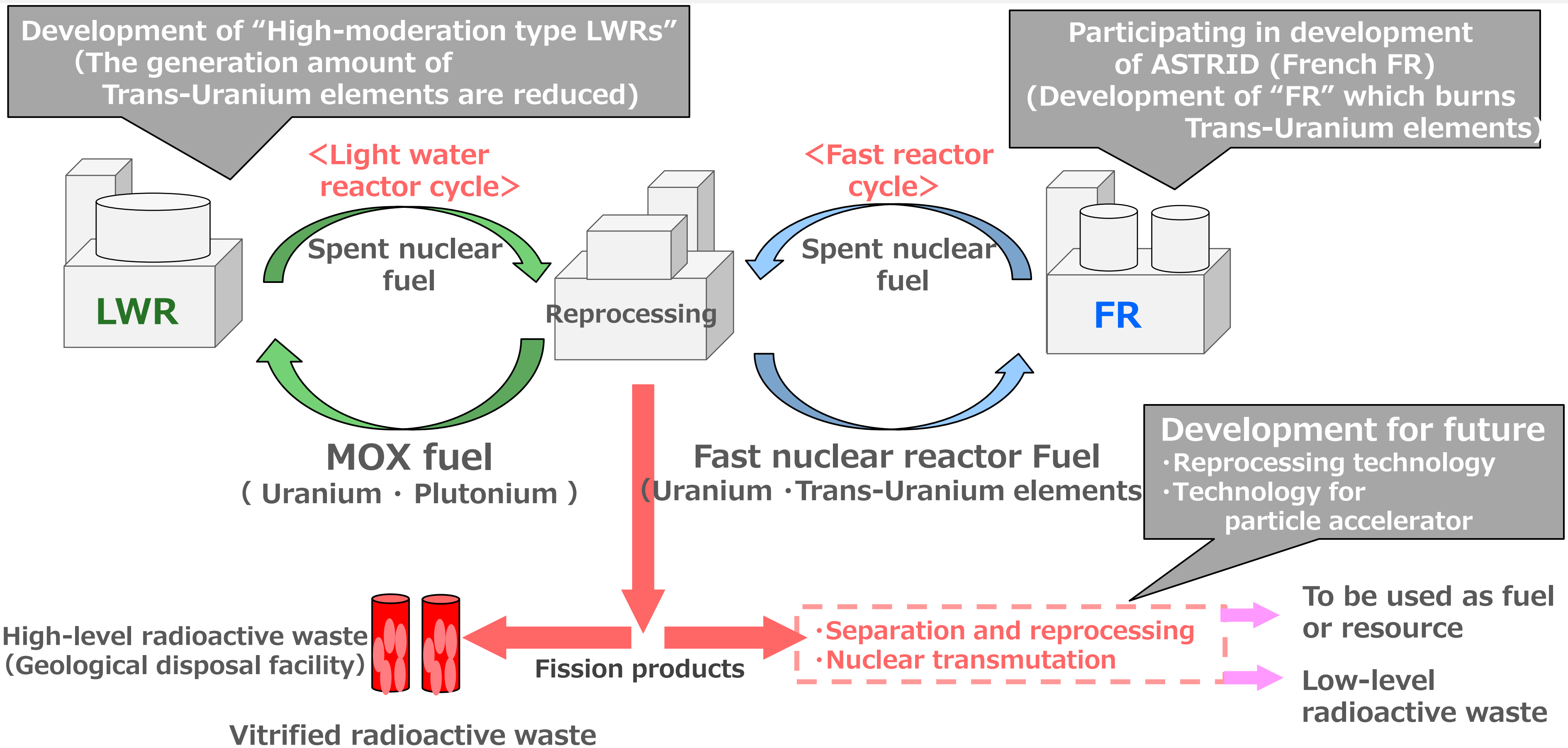
Plan → Disassembly preparation → Equipment removal → Building demolition

Waste treatment, waste disposal (cutting technology, decontamination technology, inspection technology)

*: Developed with FY2013 supplementary budget "Reactor decommissioning and contaminated water countermeasure project cost grant (IRID／Toshiba)

Future nuclear fuel cycle

Concept of nuclear reactor and fuel cycle system to reduce environmental impact



We actively participate in national projects to reduce high-level radioactive waste

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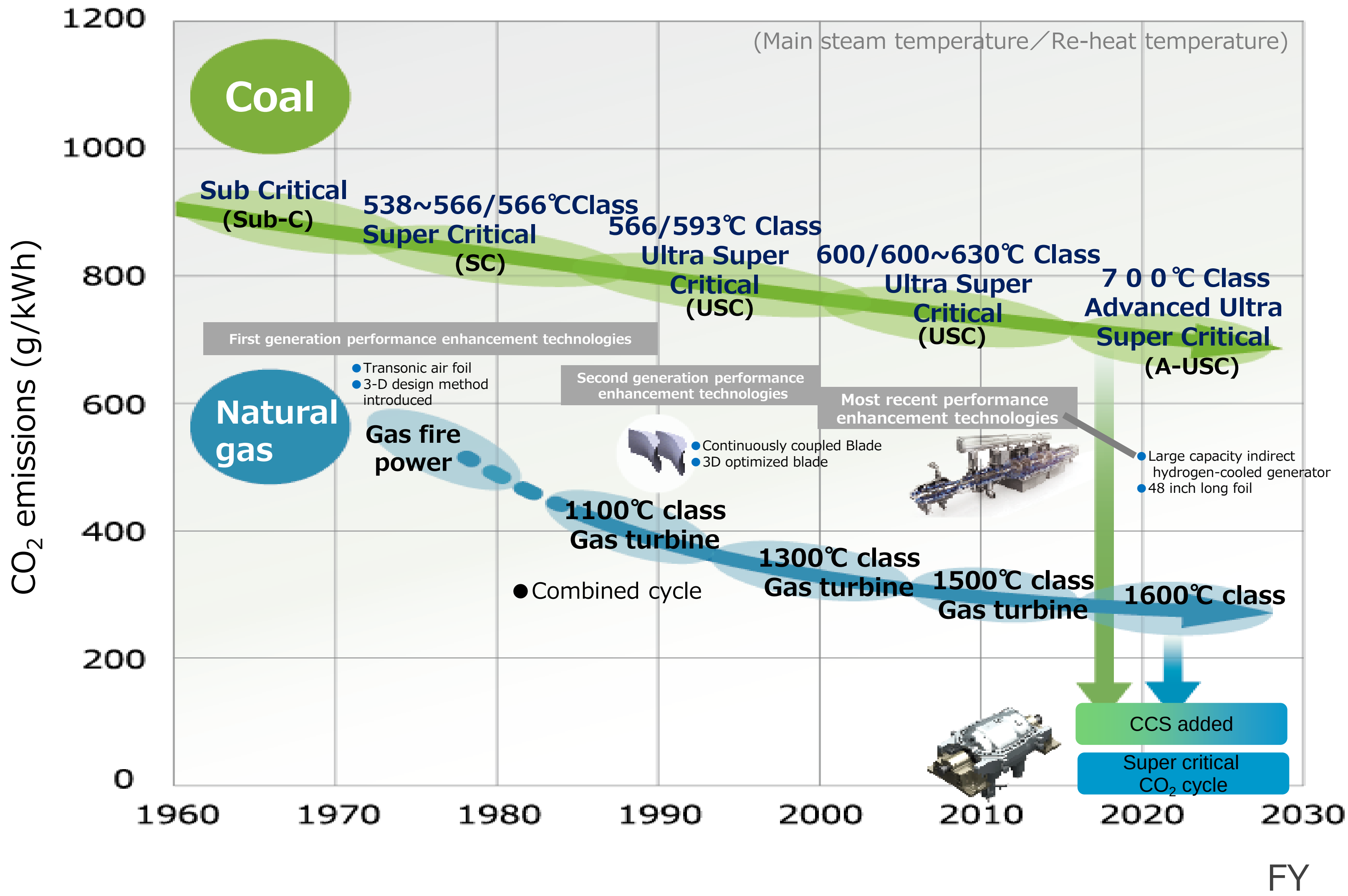
Advancing CO_2 Emission Reductions at Thermal Power Plants



Advancing Improved Efficiency in Thermal Power Plants

Further efficiency improvements with steam in excess of 700°C

Coal-fired thermal power

USC maximum efficiency: about 42% (transmission end HHV)
Main steam pressure: 25Mpa
Main steam temperature / reheat steam temperature: 600/600℃

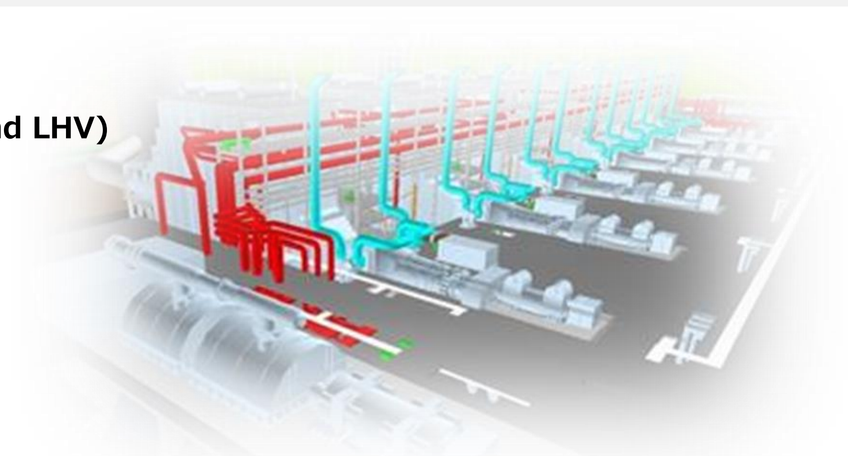
A-USC efficiency: a further 10% improvement
Main steam pressure: 35Mpa
Main steam temperature / reheat steam temperature: 700/720/720℃

Realize extremely high efficiency through a combination of gas and steam (combined cycle)

Gas-fired thermal power

Maximum efficiency: about 62% (generation end LHV)
1600℃ gas turbine + latest steam turbine cycle

Even higher efficiency with cycle improvements



Capturing CO_2 from all emission sources

Technology features

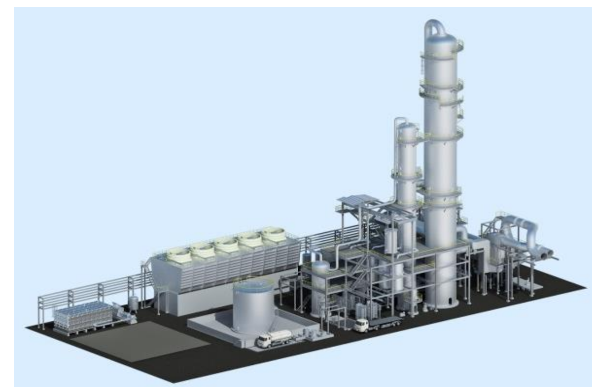
- Capture CO_2 at high purity
- Flexible design :amount of CO_2 captured; can be integrated into operating plants
- Track record in coal-fired power plants—10,264 operating hours

(October 10, 2016)

Case Studies

Mikawa※1 pilot plant
From September 2009
Captures 10t / day from coal-fired thermal power flue gas

Saga CCU plant
From September 2016
Captures and utilizes 10t / day by cleaning factory flue gas



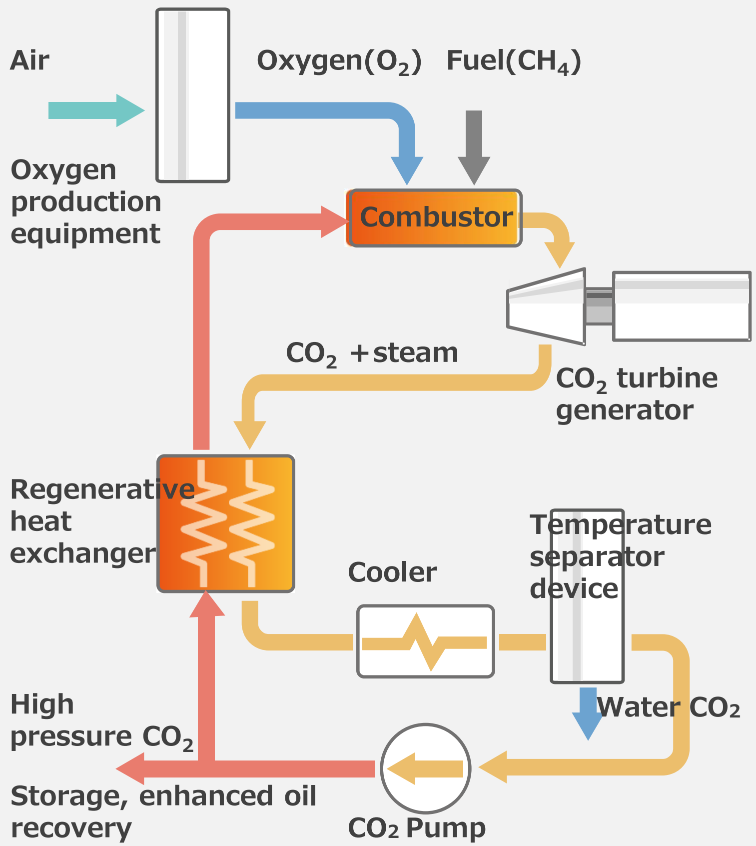
Mikawa Ministry of the Environment PJ demo plant
2020 (scheduled)
Will capture over 500t / day from coal-fired thermal power flue gas

※1 Mikawa : Incorporated company Sigma power Ariake Mikawa power plant

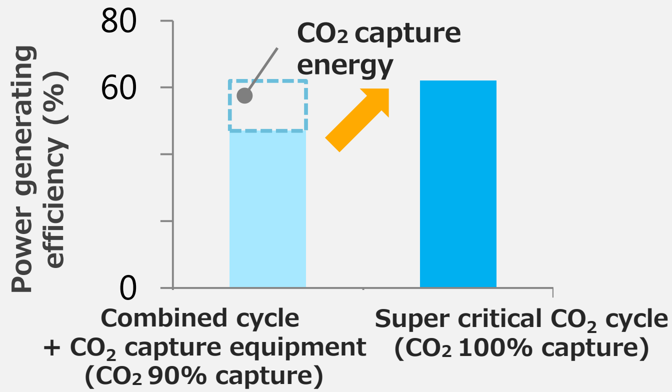
Supercritical CO_2 Cycle Power Generation

Capture 100% of CO_2 without energy consumption by carbon capture system

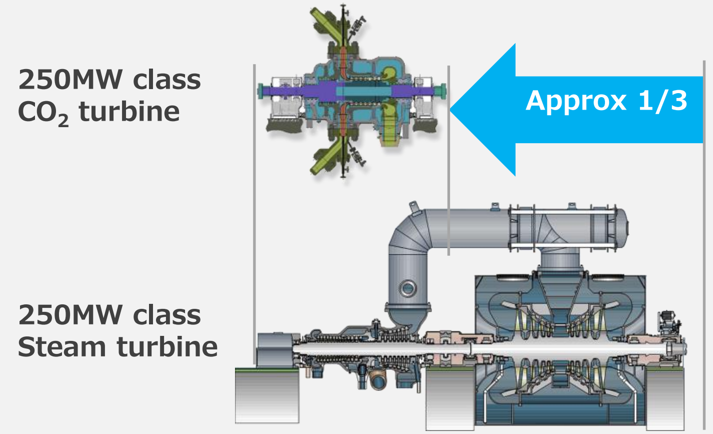
Supercritical CO_2 circulation cycle



Efficiency compared with combined cycle



Size comparison with conventional turbine



Advancing Toward a Society Supported by Sustainable Energy

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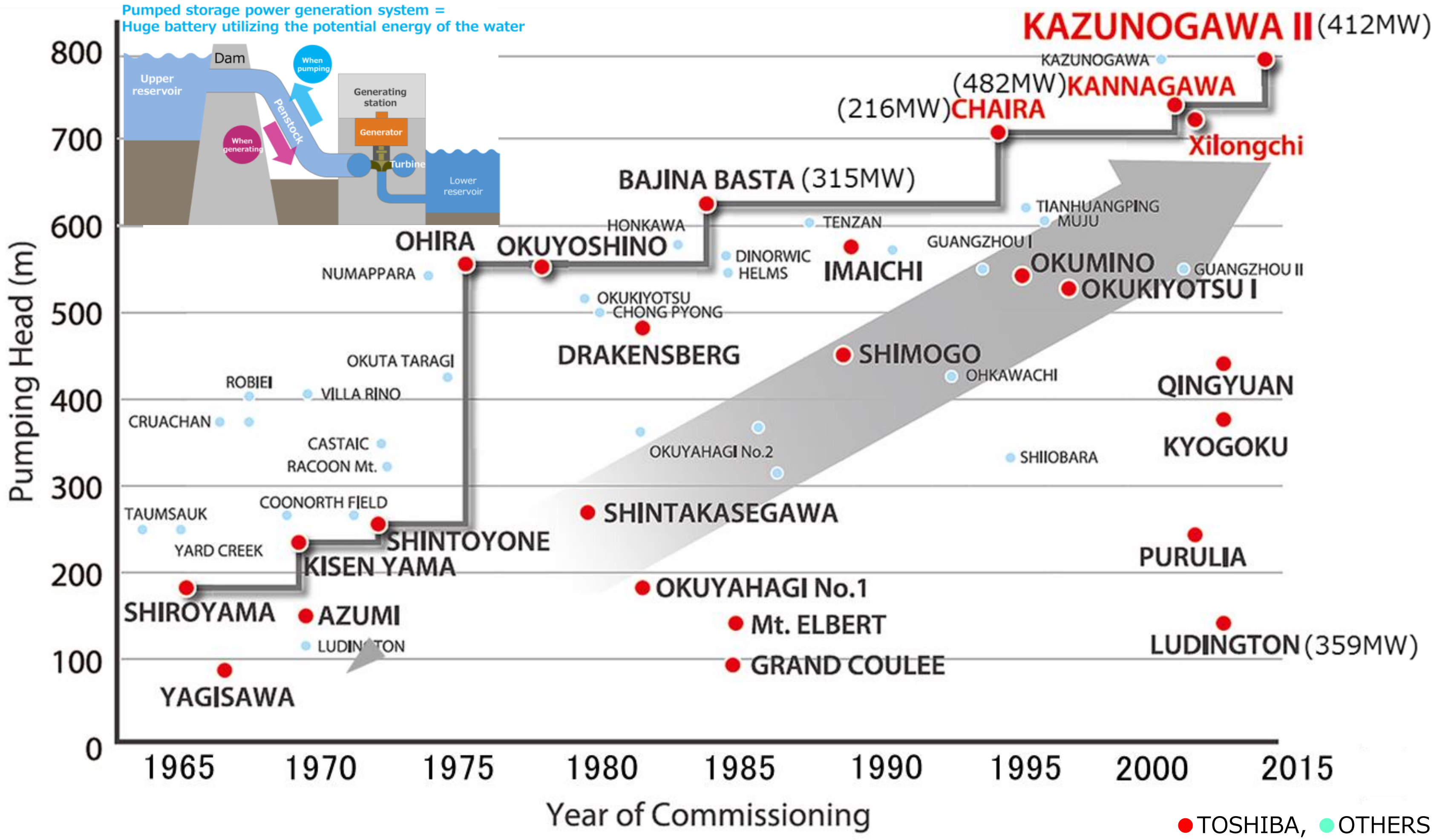
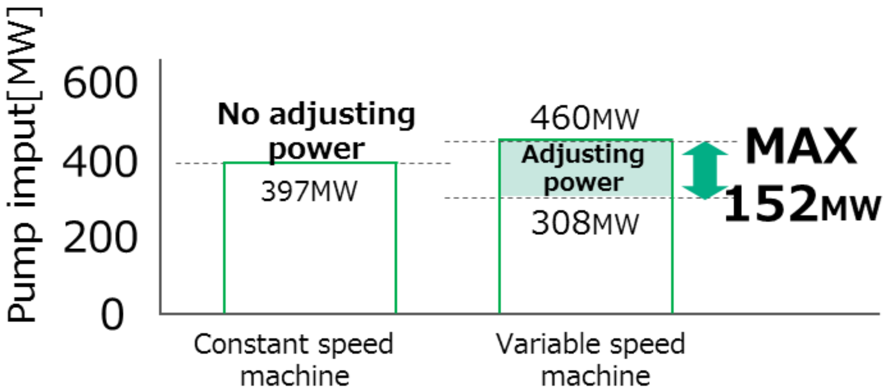
Ascending Size of Pumping Head

Toshiba sets new world record for pump turbines

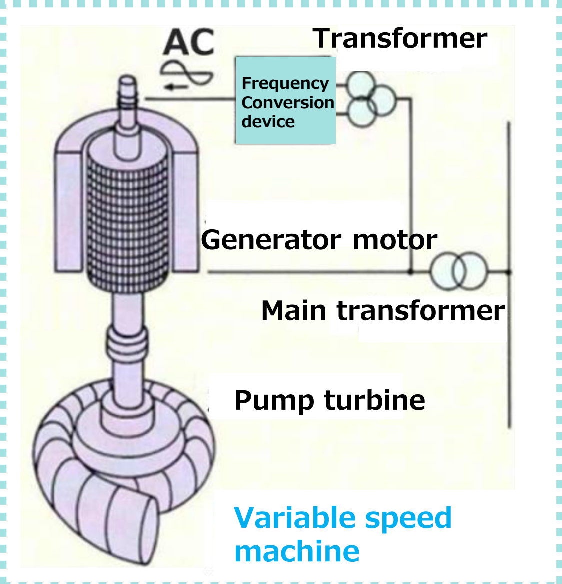


Variable Speed Pumped Storage Power Generation

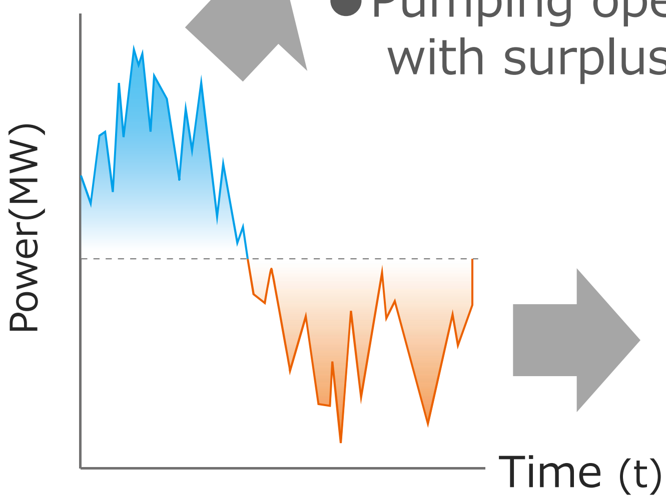
Approximately double the output adjustment capability of constant speed equipment



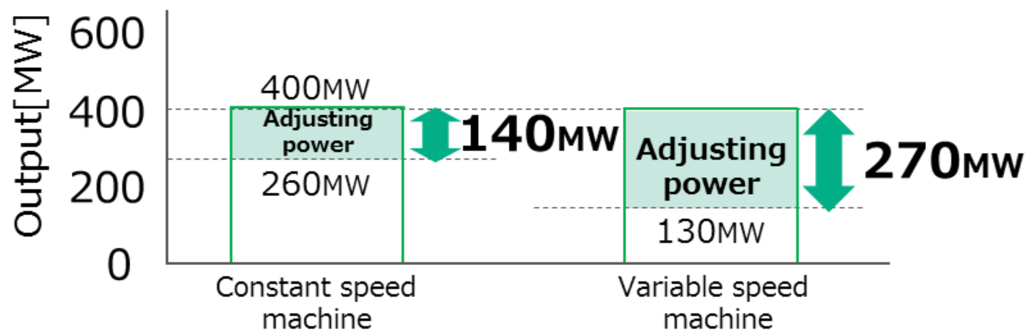
Pumping operation



● Pumping operation with surplus electric power



Graph of power generation volumes (Example)



Power-generating operation

● Power-generation operation during insufficient power supply

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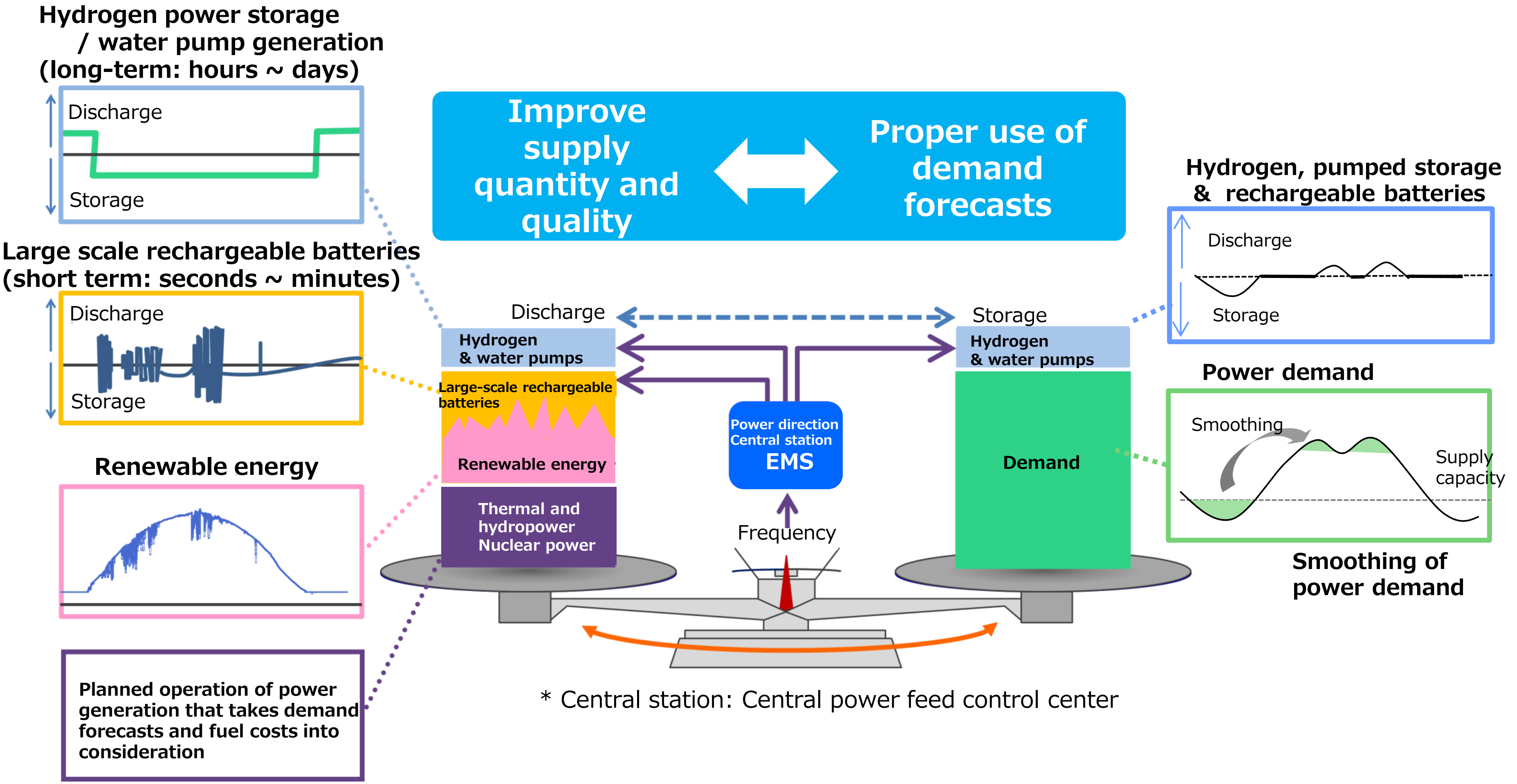
Energy Management System (EMS)

Optimal control of supply and demand balance through utilization of pumped storage, storage batteries and hydrogen



Advancing EMS Solutions

Take full advantage of smart grid development simulator to pursue solutions

Smart grid research facilities (started operation in 2012)

- Research and development facility that provides coordination from power systems through to customers
- Utilized for technology development, product testing, and validation of effects of equipment introduction

Smart grid development simulator

Real time simulation that allows system conditions to be set freely

Application example: Control study utilizing the features of SCiB™

Objectives

- **Reduce power supply and demand gap, stabilize system frequency**
- **Demand response, ancillary services, realization of virtual power plant**

Over 40,000 charge-discharge cycles

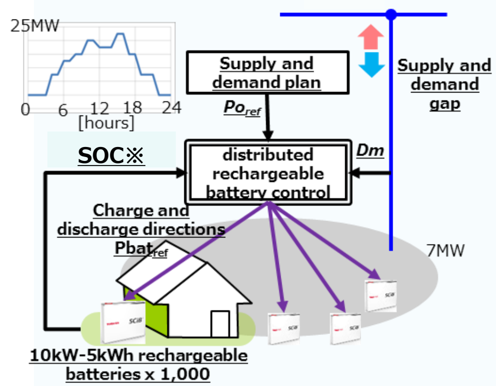
±3% error SOC* estimate

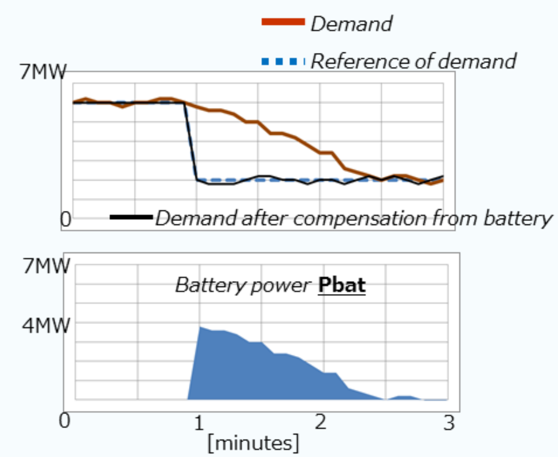
Fast response within 0.25sec

Features of SCiB™ power storage system

Evaluation results example

Supply and demand planning and distributed rechargeable battery control





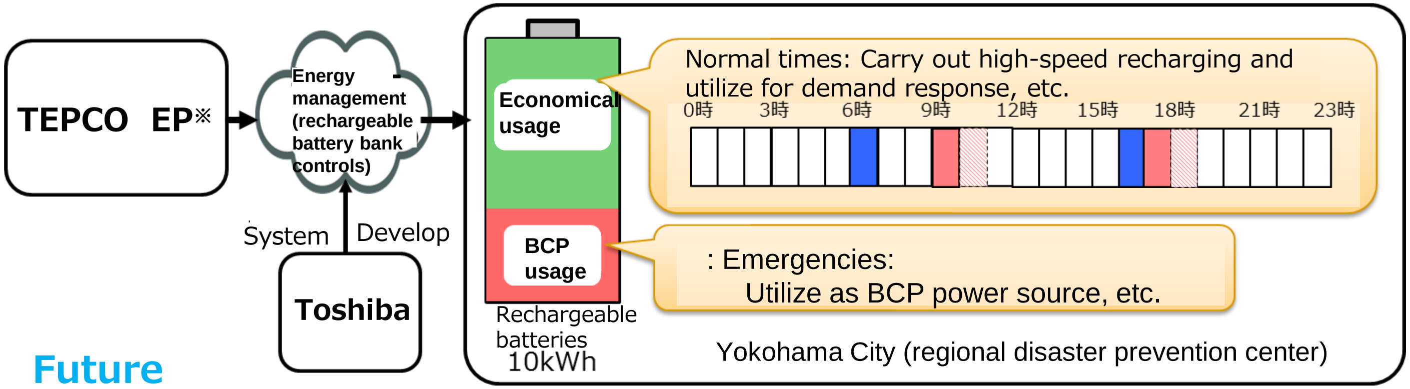
① **Possible to use SCiB™ characteristics to estimate life span**
② **Estimate supply and demand gap to within 3% with battery group charging and discharging**

* SOC: State of Charge

Smart Resilience & Virtual Power Plant Construction Business

Yokohama City, TEPCO EP※ & Toshiba have entered into an agreement

Business Activity Install rechargeable batteries in elementary and junior high schools within the city (18 schools planned) (Period: 6/5/2016 ~ 31/3/2018)

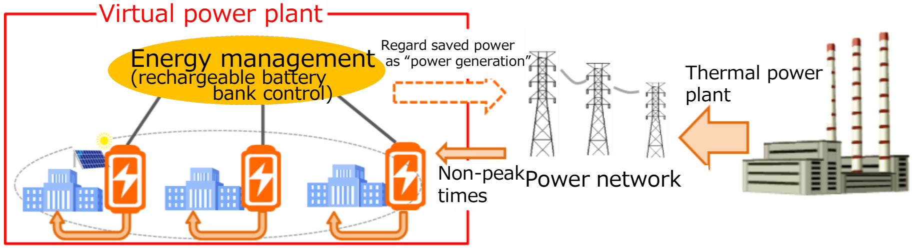


Basic agreement signed on July 6, 2016

(BCP ; Business Continuity Plan)

Future development

Construction and deployment of "smart resilience and energy services" with consideration for electricity liberalization



① Improvement of disaster prevention features that take environmental friendliness into consideration
② Establish both effective utilization of renewable energy and power stabilization
③ Establish a new energy service provider business that makes use of storage battery equipment

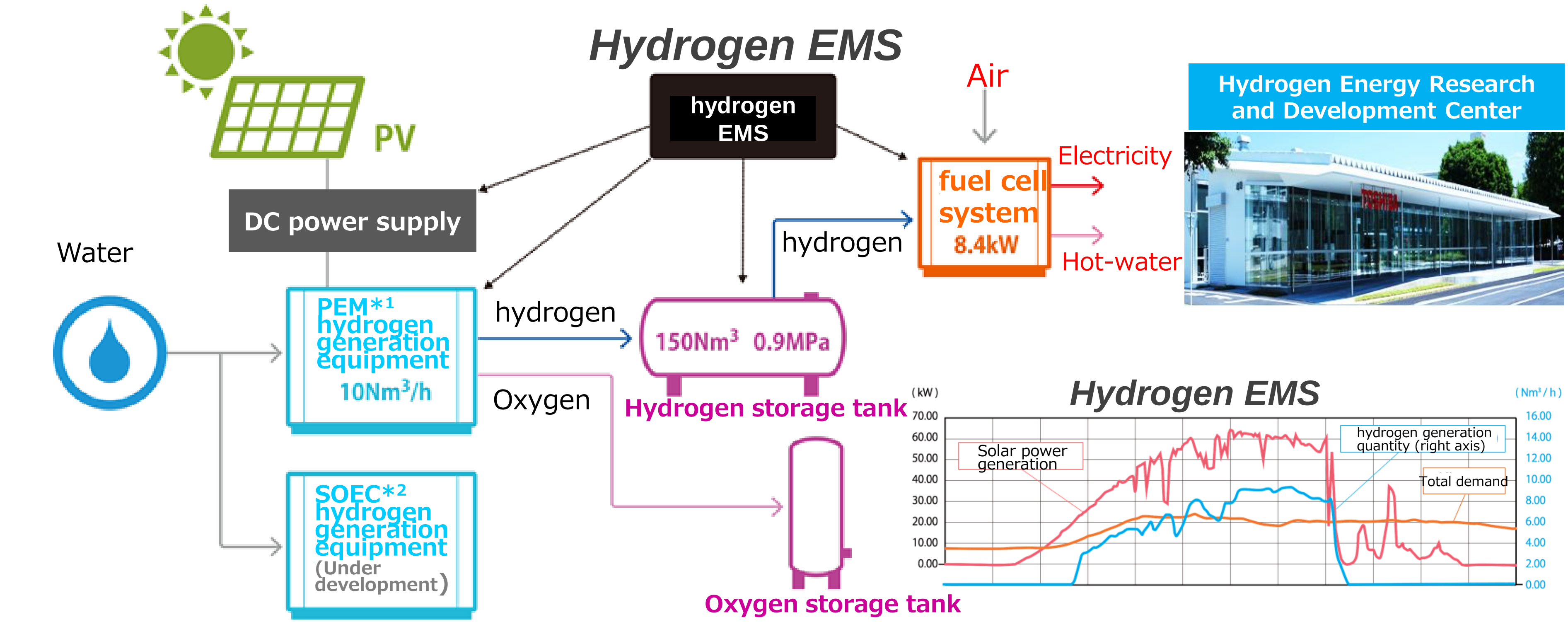
Disaster prevention features, environmental friendliness (energy conservation, & renewable energy expansion), economic efficiency (new services) improvements

※ TEPCO EP :Tokyo Electric Power energy partner Co., Inc.

Toshiba’s Hydrogen Utilization Technology

Use Hydrogen EMS to maximize utilization of renewable energy

System overview of Hydrogen Energy Research And Development Center



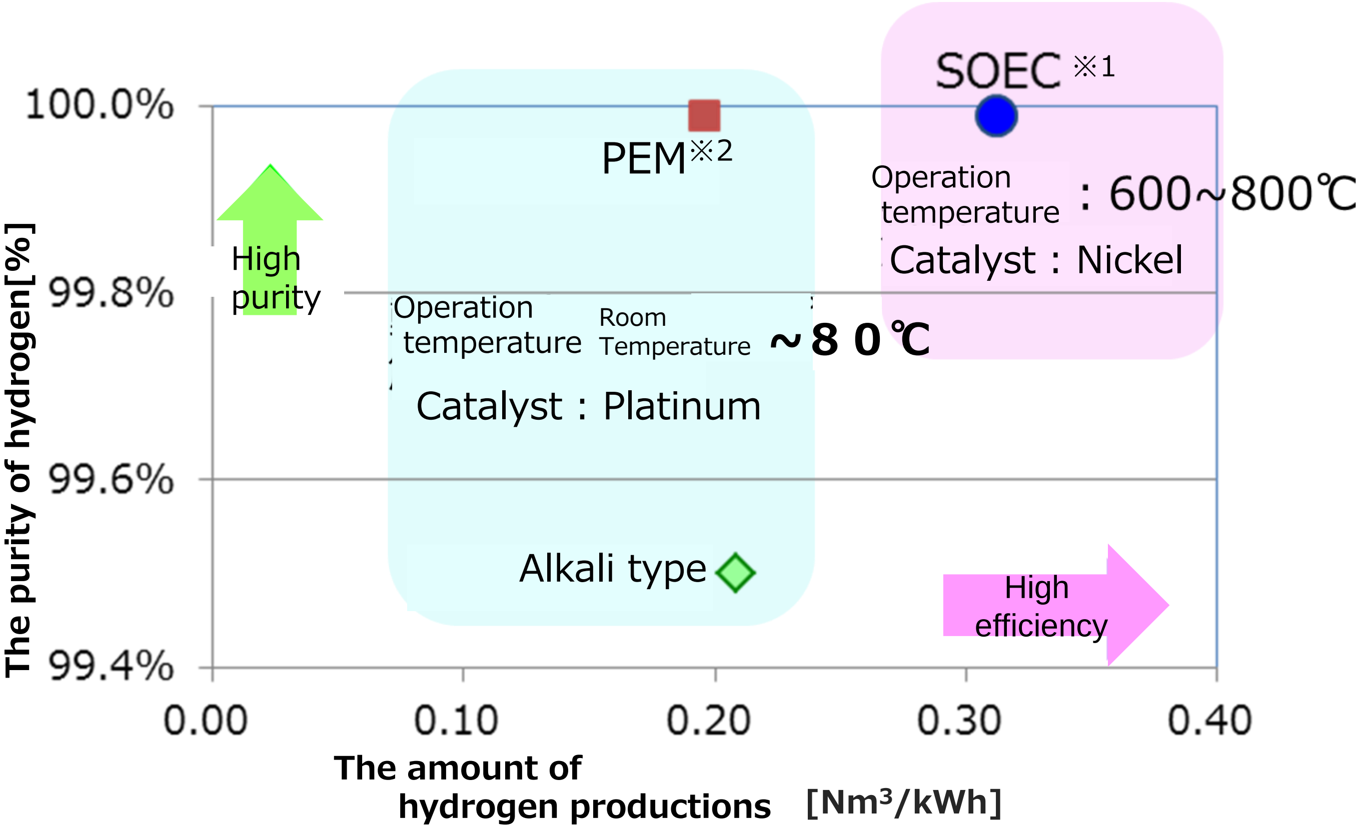
- Utilize renewable energy output that can be used to meet load demand, and use surplus power for generation and storage of hydrogen
- Utilize stored hydrogen in fuel cell power generation to compensate for power shortfalls from renewable energy
- Realize energy management over a long period of time by linking with weather data and accumulating know-how

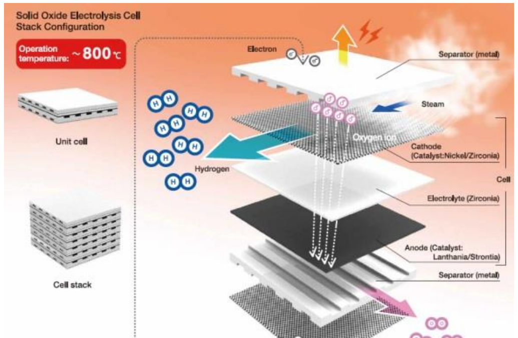
TOSHIBA Leading Innovation

*1 PEM: Proton Exchange Membrane
*2 SOEC: Solid Oxide Electrolyte Cell

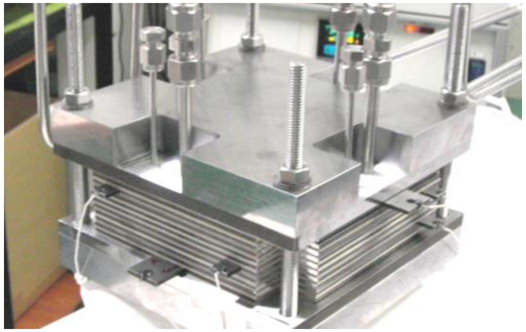
Hydrogen Production: High-efficiency Water Electrolysis Technology

SOEC* achieves a 30% cut in input power during hydrogen production





SOEC cell stack construction



SOEC appearance

- Since the SOEC operates at 600~800℃ high temperature and thermal energy can also be utilized for water electrolysis besides electric power, a more efficient hydrogen production system is realizable.

※1 SOEC: Solid Oxide Electrolyte Cell
※2 PEM: Proton Exchange Membrane

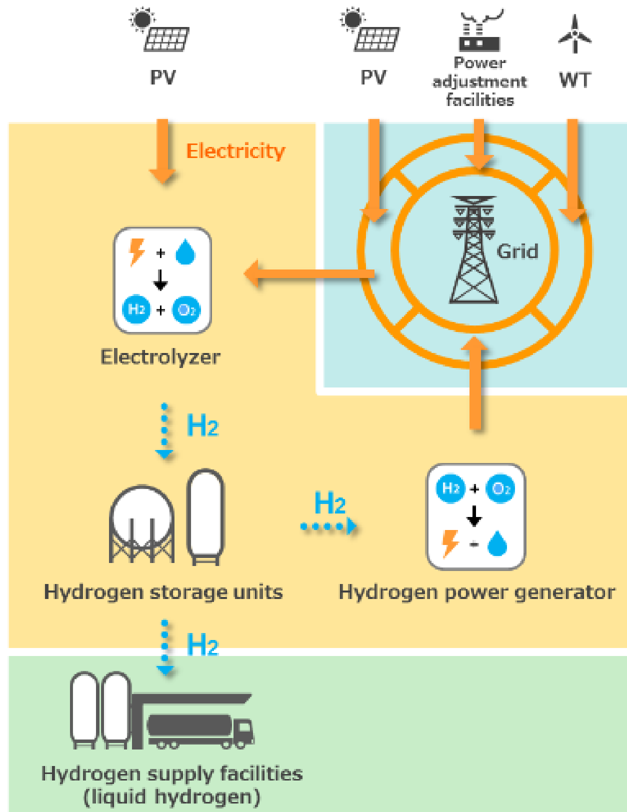
Deployment of H_2One^{TM}

Hydrogen-based Autonomous Energy Supply System H_2One^{TM}

World's Largest Hydrogen Energy System

(Fund by Japan's New Energy and Industrial Technology Development Organization (NEDO).)

- **The system will be deployed in Fukushima prefecture, in Tohoku.**
- **Business feasibility will be examined over the next year and a report produced by September 2017.**



Tohoku Electric Power Co., Inc.

SCADA / EMS

Toshiba Corporation

Hydrogen energy management system

Iwatani Corporation

Liquid hydrogen demand and supply forecasting system

* A joint proposal by Toshiba Corporation, Tohoku Electric Power Co., Inc. and Iwatani Corporation on the development of technologies for hydrogen energy systems was selected for funding by Japan's New Energy and Industrial Technology Development Organization (NEDO) on 29 Sep, 2016.

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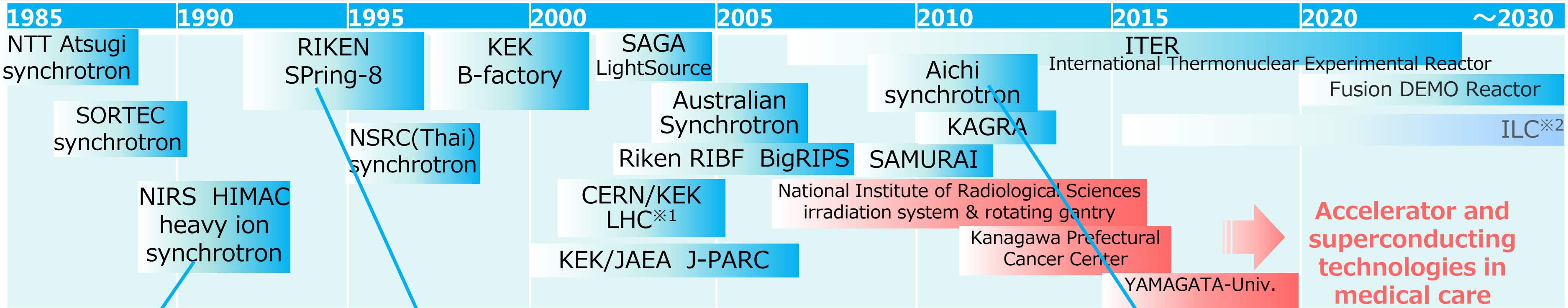
Toshiba's Contributions to Advanced Technologies (1/2)

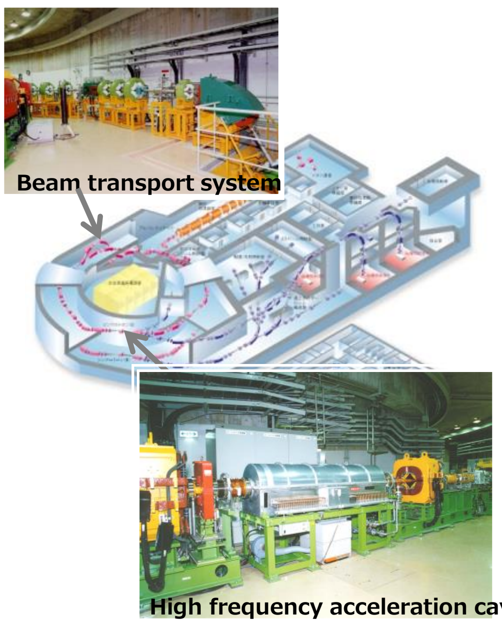
Application of accelerator and superconducting technologies in the medical field



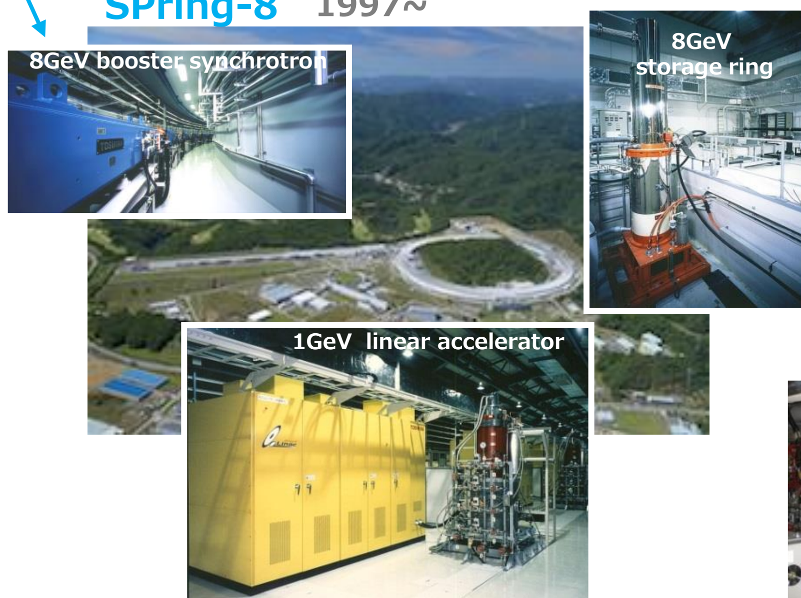
※1 Large Hadron Collider

※2International Linear Collider

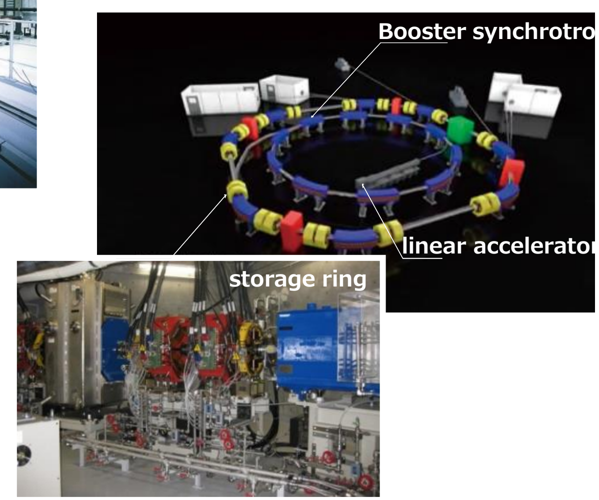
HIMAC 1993~



SPring-8 1997~



Aichi Synchrotron Radiation Center 2013~



National Institutes for Quantum and Radiological Sciences and Technology　Institute of Physical and Chemical Research

Toshiba's Contributions to Advanced Technologies (2/2)

Superconducting technologies supporting advanced science

Toshiba's technology was applied to the ATLAS detector at the LHC ※1

Nobel Prize in Physics 2013 Peter W. Higgs

- ✓ The magnets generate magnetic fields, essential for the particle identification.
- ✓ The magnets focuses proton beams into a single point for effective collisions.

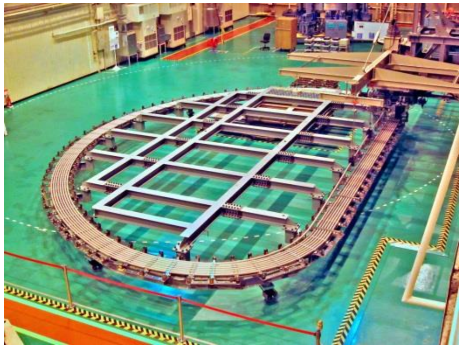
(C)CERN/KEK ※1 Large Hadron Collider

Supplying cryostats for the Gravitational Wave Telescope(KAGRA)

Cryostats to cool and keep the mirrors at -253 degrees.

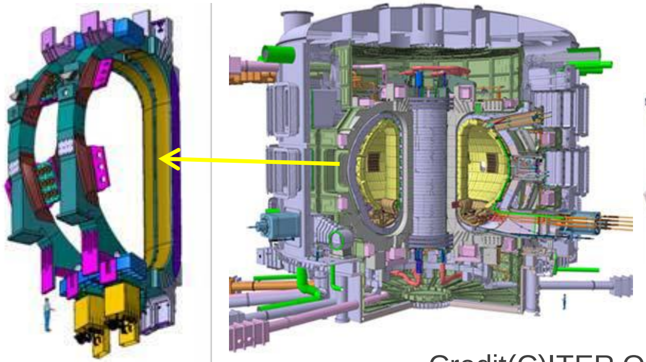
(C)ICRR/KEK

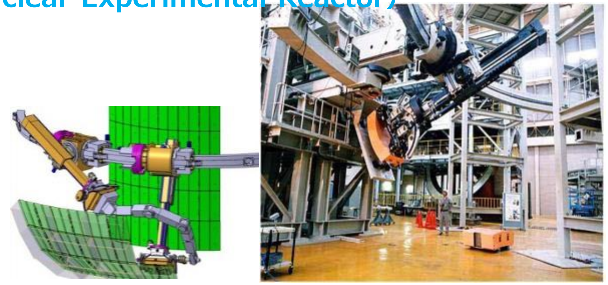
Energy of the future – nuclear fission



Toroidal Field (TF)Coil

ITER (International Thermonuclear Experimental Reactor)





Remote maintenance system

Credit(C)ITER Organization, http://www.iter.org/

Advancing Society's Realization of Sustainable Energy

In nuclear power, we are committed to site stabilization at Fukushima Daiichi, and through synergies with WEC, we pursue the world's highest levels of safety.

We aim to achieve "green energy." In thermal power, still the main source of electricity, we are pursuing further efficiency improvements and deploying carbon capture technologies to realize zero emissions. We are also promoting renewable energy sources: hydro, geothermal, solar and wind power.

Through energy storage technologies that take advantage of the characteristics of pumped storage power generation, rechargeable batteries, hydrogen production and other systems, and by promoting advanced energy management technologies and high-efficiency power distribution systems, we will continue to contribute to increased adoption of renewable energy and stabilization of the power system.

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