Keynote Lecture 2 at Singapore EE Symposium

History and Future Direction of Energy Conservation in Japan's Petrochemical Industry

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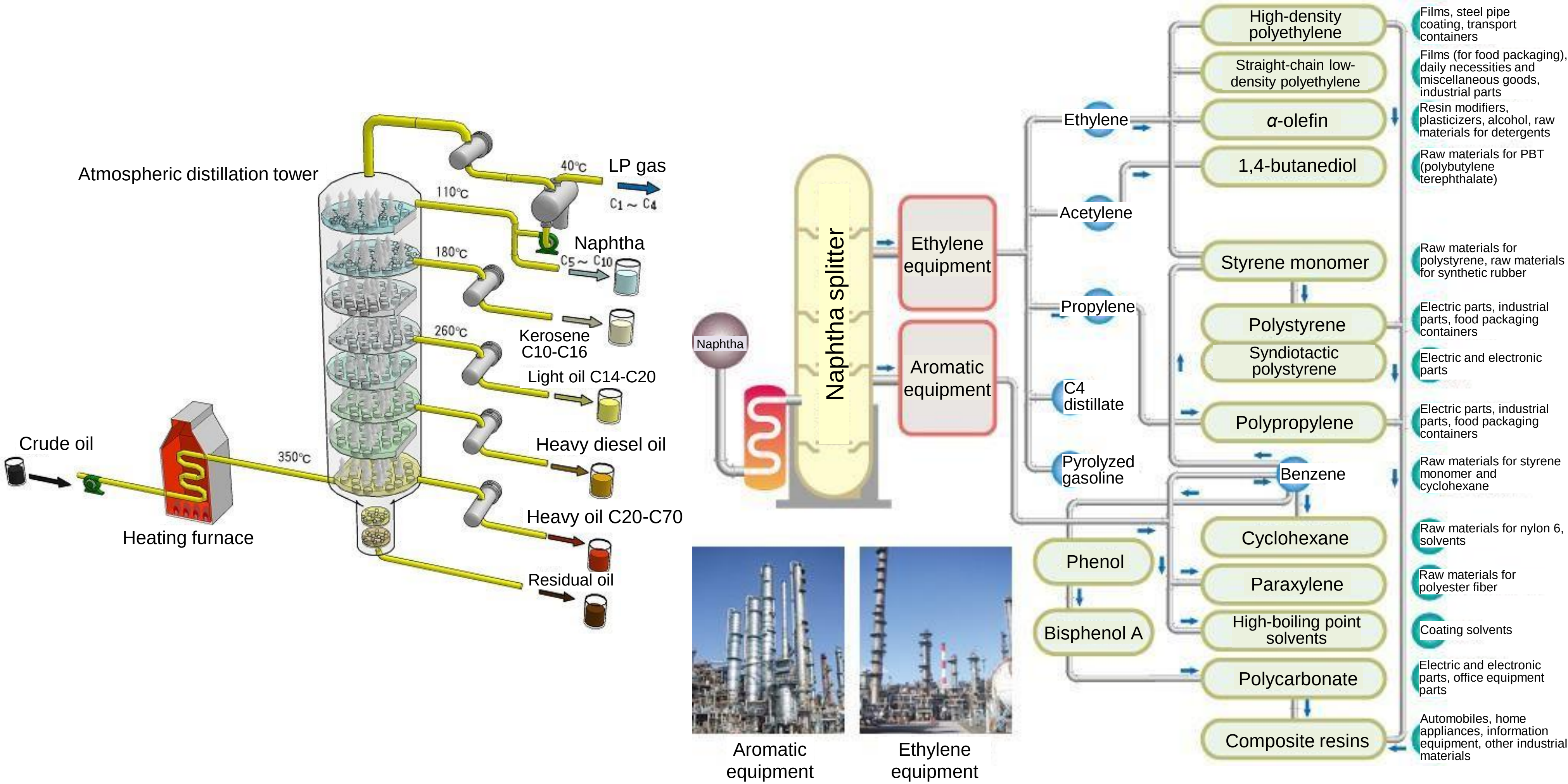
Content

What Is Petrochemical Industry?

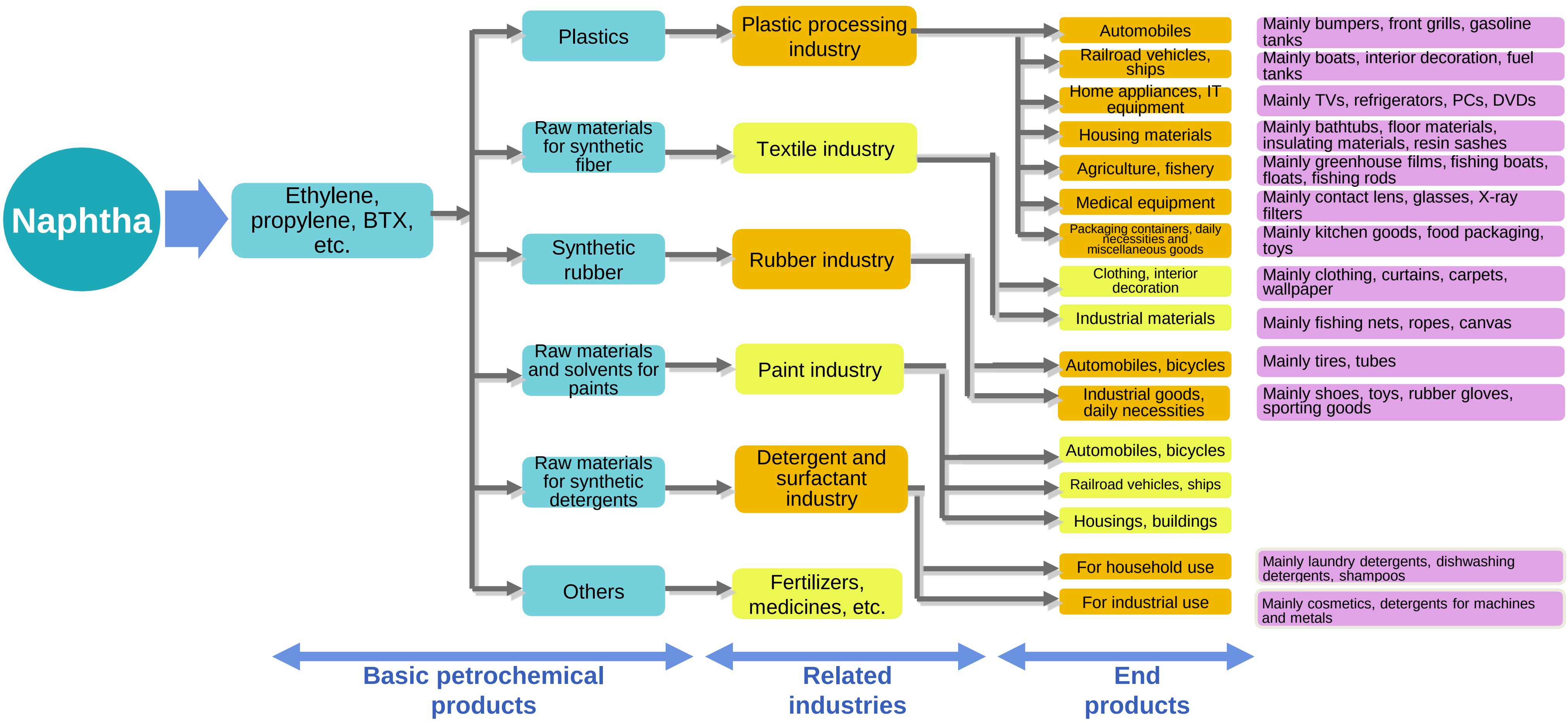
Overview of Petrochemical Industry (Processes and Products)

- **Major semi-finished product is naphtha and primary product is ethylene. Then, they are sorted into the following various secondary products and fainal products, including polyethylene.**



Major Chemical Products after Naphtha

➢ Petrochemical forms wide supply chains as far as end products, but only the related industries are covered this time.



Source: Japan Petrochemical Industry Association

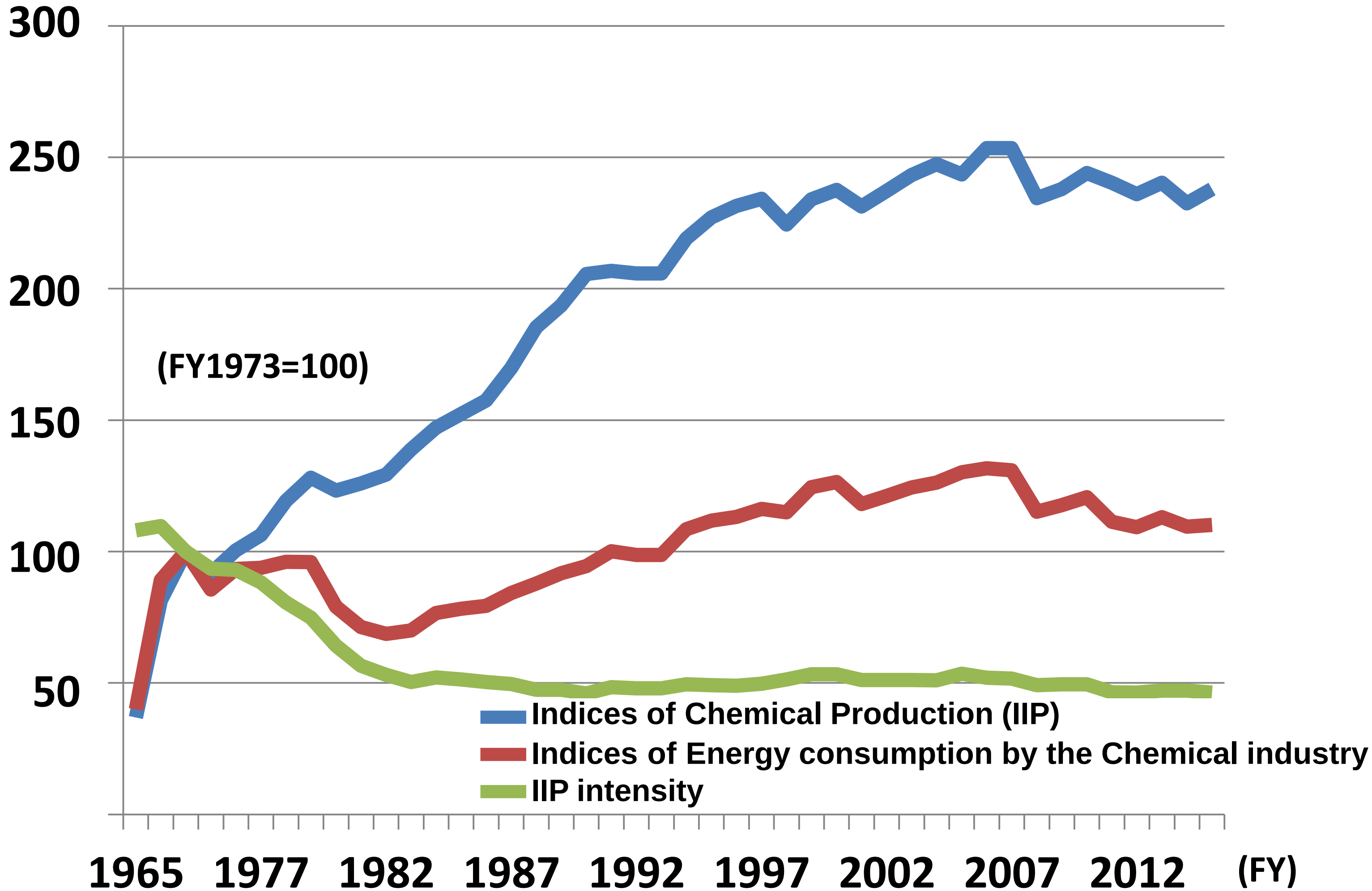
EE&C and GHG Reduction efforts in the past

<summary>

1) Before the oil shock occurred in 1970's, energy costs were so low that the equipment investment tended to be energy intensive. In addition, since there was not so strong demand for strict energy management at site at that time, a small improvement in operation management resulted in rather significant energy saving effect.
2) As a result, in 1970's and 1980's saved energy was 7.3% by oil refinery and 9.3% by petrochemicals, in both of which 80% was due to operational improvement and 20% was due to facility improvement.
3) This situation has changed significantly due to the soaring crude oil prices associated with the oil shock.
4) The balance point between equipment cost and energy cost has greatly influenced for then engineer to feel more inclined to energy-saving oriented investment.

Production, Energy Consumption and Energy Consumption Intensity Chemical Industry

➢ **Energy efficiency had improved greatly by the 1980s and has been leveling off since then.**



Source: Institute of Energy Economics, Japan “Handbook of Energy & Economic Statistics”

Features of EE&C Measures in Chemical Plants

1	Longer process to turn raw materials into products, compared with steel making, cement and paper making.
2	Raw materials and products mostly fluid. 24-hour continuous operation. Outdoor facilities.
3	High consumption of electric power and steam. Large-scale cogeneration facilities installed for this reason.
4	Major fuel consuming equipments are the heating furnace and the boiler.
5	Main process is reaction control, accompanied by many heating and cooling processes before and after that.
6	Less operation processes and less energy conservation measures.
7	Long processes and small-scale distributed energy conservation measures. Large-scale distributed ones in the case of steel making and cement.
8	EE&C measures tend to be the one related to each operation system and the one covering process
9	Optimum operating conditions (pressure, temperature) change depending on the type and volume of raw material and product, and energy cost.
10	Accordingly, operation management is necessary by continuous check of the operating conditions to ensure optimum energy consumption.
11	Improvement of facilities is necessary in case the optimum operating conditions cannot be attained by management of the operating conditions alone.
12	Advanced elemental technology allows updating to the high-performance equipment to contribute to energy conservation. Particularly the process control system.

Specific Viewpoints in EE&C Measures by Process

Process	Viewpoint in EE&C Measure
Reaction	Possible to lower the temperature and the pressure? Are they not higher than necessary? Possible to lower the operating temperature by changing a catalyst? Are the frequencies of reproduction and replacement proper?
Distillation, absorption	Possible to lower the temperature and the pressure? Are they not higher than necessary? Possible to lower a reflux volume? Are the product specifications proper? Not too strict?
Heat exchanger	Heat transfer not lowered by contamination? Possible to increase a heat recovery volume by extension?
Cooler	Cooler inlet temperature not high? Possible to recover more heat upstream? In the case of air cooling, is the fan speed controlled according to the outdoor temperature?
Heating furnace, boiler	Exhaust gas temperature not high? No improvement for heat recovery? Not too much air?
Rotating machine	Possible to employ rpm control? Valve control of flow rate is an energy loss.
Heat retention	Is heat retention of the tank sufficient? Is heat retention of the piping, valves and joints proper?
Power generation, steam generation	Is the steam pressure condition proper? Any steam losses of the steam trap?
Process	Possible to increase heat recovery by changing a process flow? Possible to recover pressure energy by a turbine?

Major EE&C Measures, Improvement of Operation Management and Facilities

Operation management improvement	Facility improvement
(1) Excess air control of the heating furnace and the boiler(heat loss reduction)	(1) Installation of an air preheater, feed water heater, steam heater for the heating furnace(heat recovery)
(2) Lower reflux ratio of the distillation tower (reboiler heat reduction)	(2) Change of the heating furnace's burner to the low excess air type (Lower heat losses)
(3) Lower blow-in steam volume for the diffusion tower(steam consumption reduction)	(3) Change of the distillation tower trays and the filler to the low pressure loss type (Lower power losses)
(4) Lower hydrogen-hydrocarbon ratio of the Reactor(hydrogen usage reduction)	(4) Extension of the heat recovery heat exchanger (heat recovery)
(5) Repair and replacement of the furnace wall and the heat retaining material of the piping(Reduction of heat dissipation loss)	(5) Installation and extension of the exhaust heat recovery boiler(heat recovery)
(6) Cleaning and replacement of the heat exchanger(Reduction of heat transfer resistance due to dirt)	(6) Water heater / steam heater installed in heating furnace (heat recovery)
(7) Reduced pump impellers (power loss reduction)	(7) Utilization of a flare gas as a fuel(effective use of energy)
(8) Expanded computer control(prompt follow-up to disturbances caused by various changes)	(8) Utilization of the heat mutually between the equipment(heat integration, heat ross reduction)
(9) Optimization of the power generation steam pressure(Optimal cogeneration system operation)	(9) Recovery of the power from pressure energy(power recovery)
(10) Stricter operation management target values(Suppressing excessive specifications)	(10)Employment of cogeneration(EE improvement)

Major Future EE&C themes and corresponding viewpoints

<summary>

1) After the oil shock energy-saving investment was required to have a return on investment within several years. On top of it the construction period was limited due to the busy situation.
2) Currently, not only from the viewpoint of cost-effectiveness, but also curbing greenhouse gas emissions, capital investment with a longer payback period than the 1980s has become acceptable..
3) Energy savings through equipment improvements have since been centered on technology associated with unit operations. Content-wise 80% was effective use of heat energy with the rest of it being recovery of materials such as off-gas and steam condensate, and recovery of pressure energy after turbine process.
4) In future EE&C measures, not only the technology associated with unit operations, but also engineering-oriented measures including process transformation will play a greater role.
5) Another aspect is more stress on the items such as IT based energy management including digitalization technology, area-wise cooperation among near-by factories etc.

Major Future EE&C Themes

1. Themes associated with an introduction of new elemental technologies
2. Themes associated with an introduction of advanced IT system technology
3. Themes related to advanced equipment management
4. Themes related to conversion of raw material and auxiliary material
5. Themes related to utilizing high performance catalyst
6. Themes related to area-wise cooperation
7. Themes ignored in the past due to low economical merit

Operation management improvement	Facility improvement
(1) Utilization of an advanced computer	(1) Utilization of elevated temperature by heat pump for low-temperature exhaust heat
(2) Use of a high-function heat-retaining material	(2) Recovery and utilization of small temperature difference heat with plate heat exchanger
(3) Optimization of a maintenance cycle	(3) Conversion to energy-saving unit operations such as membrane separation
(4) Expanded utilization of the heat pump	(4) Conversion of raw materials and auxiliary materials
(5) Recovery of the low-temperature exhaust heat	(5) Adoption of low temperature operation type catalytic reactor
(6) Higher-efficiency private power generation equipment	(6) Use of a continuous catalyst reproduction system
(7) Promotion of enhanced operation optimization	(7) Utilization of recovered process fluid pressure through an expansion turbine and a hydraulic turbine
(8) More introduction of cogeneration system	(8) Adopting high-efficiency distributed power generation systems such as fuel cells
(9) Optimum storage temperature of raw materials and products	(9) Expanded utilization of a gas turbine
(10) Reduction of heat loss in steam trap	(10) Joint use of energy with neighboring factories

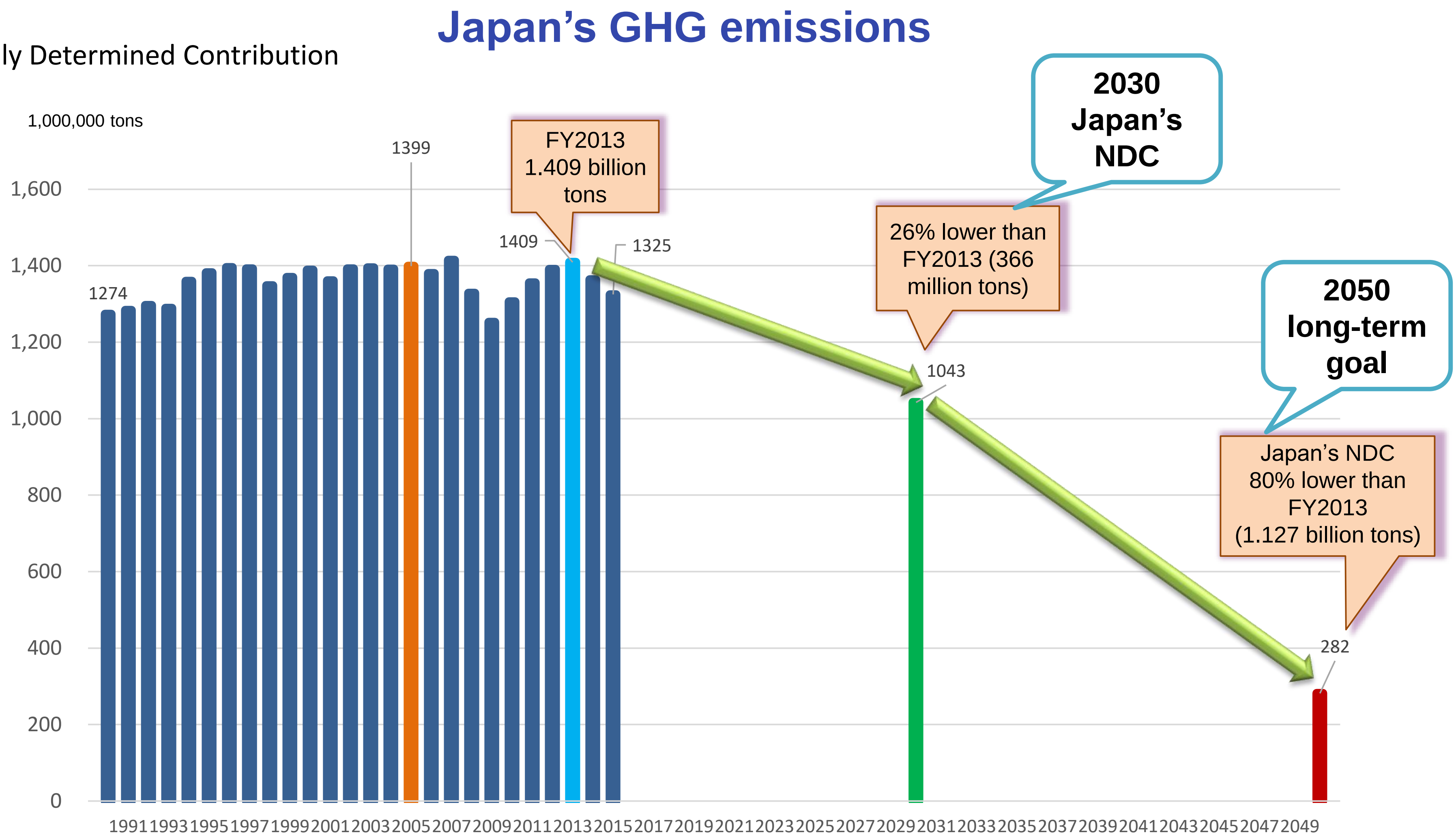
Efforts for Realizing Low-carbon Society

<summary>

1) Japan's long-term GHG reduction target in line with the Paris Agreement is to reduce by 26% in 2030 from 2013 and 80% in 2050.
2) The Japanese government formulated a detailed plan in line with this goal in the 5th Basic Energy Plan in 2018.
3) In industry, since the Keidanren(Japan Business federation) Environmental Voluntary Action Plan was announced in 1997, each industry has voluntarily set and promoted GHG reduction targets.
4)The chemical industry has formulated a plan named "what it should be as a chemical industry that provides solutions to global warming issues".
5)Today, I would like to explain three points regarding specific efforts to achieve this plan.

Japan’s NDC in Paris Agreement and Long-term Reduction Goal

*NDC:
Nationally Determined Contribution



Planned Actions

1. Chemical industry focuses all the efforts to formulate the program for technical development by joint movement of industry, government and academia.

2. In order to connect to overseas great GHG reduction activity, Chemical industry propose technological strong points in it to advance the world movement to build up the systems with economical rationality

3. Chemical industry builds a cooperation system beyond an industrial frame for launching social innovation all over the value chain eventually to propose a new social system.

Efforts for realization of Planned Actions (1)

- Technical development across the industry, government and academia.

They proposed "Must to do" in the following occasions to the Ministry of Economy, Trade and Industry, Japan Business Federation and other relevant organizations.

- At public comment meeting on the 5th basic energy strategy (Ministry of Economy, Trade and Industry), June 2018
- At the time of formulation of the roadmap for the hydrogen and fuel cells strategy (Ministry of Economy, Trade and Industry), June 2019
- At the time of formulation of the roadmap for carbon recycling (Ministry of Economy, Trade and Industry), June 2019

↓

Reflected on "Long-term Growth Strategy Based on Paris Agreement" published at G20 (Osaka, June 2019)

Efforts for realization of Planned Actions (2)

➢ Proposal of our technological strong points to an international organization with economical rationality

Participation in the activities of the Japan Business Federation

◆ **Preparation of "GVC Concept Book"**

- ➢ Summarized the cLCA (carbon life time analysis) Best Practices in the industrial sector and publicized it at the COP24 (Katowice, Poland).
- ➢ Described 3 leading cases accepted globally as higher-impact practices
  - **(1) Seawater desalination plant by the RO* membrane method(*Reverse osmosis membrane)**
  - **(2) Hall elements, Hall ICs (magnetic sensors for inverter air-conditioners)**
  - **(3) Aircraft materials (carbon fiber composite materials)**

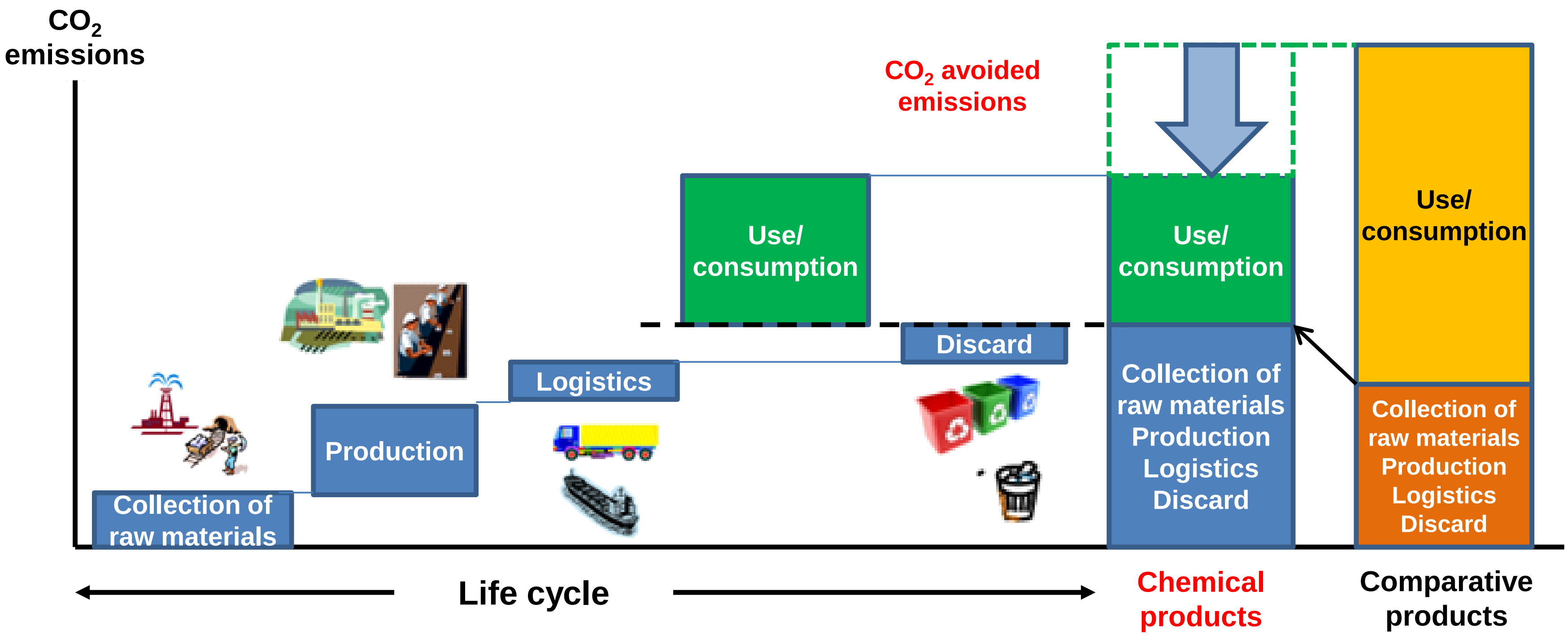
GVC Concept Book

(Japan Business Federation, published in December 2018)

GVC: Global Value Chain Contribution

Efforts for realization of Planned Actions (3)

➢ Contribution in Reduced CO_2 Emissions (cLCA)



CO_2 is emitted in the product life cycle ranging from raw materials to production, logistics, use and discard. Emission in the phase of use is relatively high. For reduction of an absolute volume, an overall optimization viewpoint, which covers overall product life cycle, is more important than a partial optimization viewpoint which looks at only the production phase.

Recommendations to Petrochemical Industry in Singapore

<summary>

1)This section gives an overview of Singapore's energy situation and GHG emissions.

2) At the same time, Singapore is positioned in Japan as an excellent example of an oil refining and petrochemical cluster, which is categorized as has production resources and their infrastructure, presence of the buyer, aggregation of supply and related industries and existence of competitive environment.

3) In Singapore, EDB started developing a chemical island on Jurong Island from the 1990s based on the cluster strategy. Currently, a production system of 4 million tons of ethylene has been established. Despite the handicap of land and labor costs, it has achieved global competitiveness.

4) Next, I would like to present two types of ideas that can be proposed from Japan. One is related to the activity of RING (Research association of refinery Integration for Group operation).

5) In addition, we propose candidates for future energy conservation measures from the perspective of individual companies. A list of technologies that have been used in Japan.

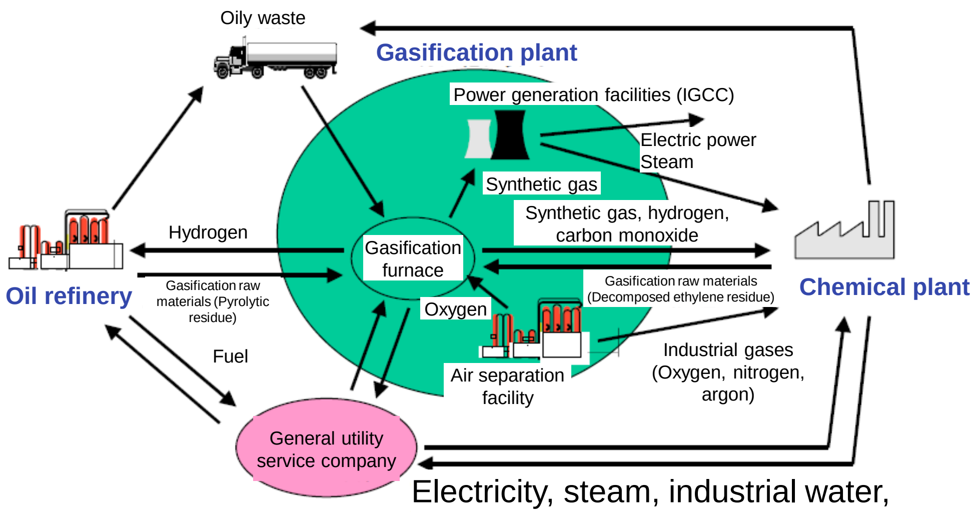
Energy Situation in Singapore

- Being a successful case of chemical cluster strategy, Singapore achieved annual production of 4,000,000 tons of ethylene in the early 2010s.
- Concerning the most basic energy for the chemical industry, electric power is generated by the IGCC(Integrated coal Gasification Combined Cycle) utilizing the residue at an oil refinery and shared as a network. Other utilities & raw materials are in the same situation as electricity.

	as of	Singapore	Japan
Population (million people)	1973	2.2	108
	2014	5.5	127
GDP (billion dollars)	1973	19	2,294
	2014	281	5,643
primary energy consumption (Mtoe)	1990	12	439
	2014	28	442
	2030E	32	453
	2050E	33	429
CO2emission (Mt-Co2)	1990	29	1,071
	2014	57	1,201
	2030E	63	1,075
	2050E	66	1,007
ethylene production capacity (Mt)	2018	3.96	6.16

Data source: IEA "Energy Balances" + EDMC(IEEJ)estimation

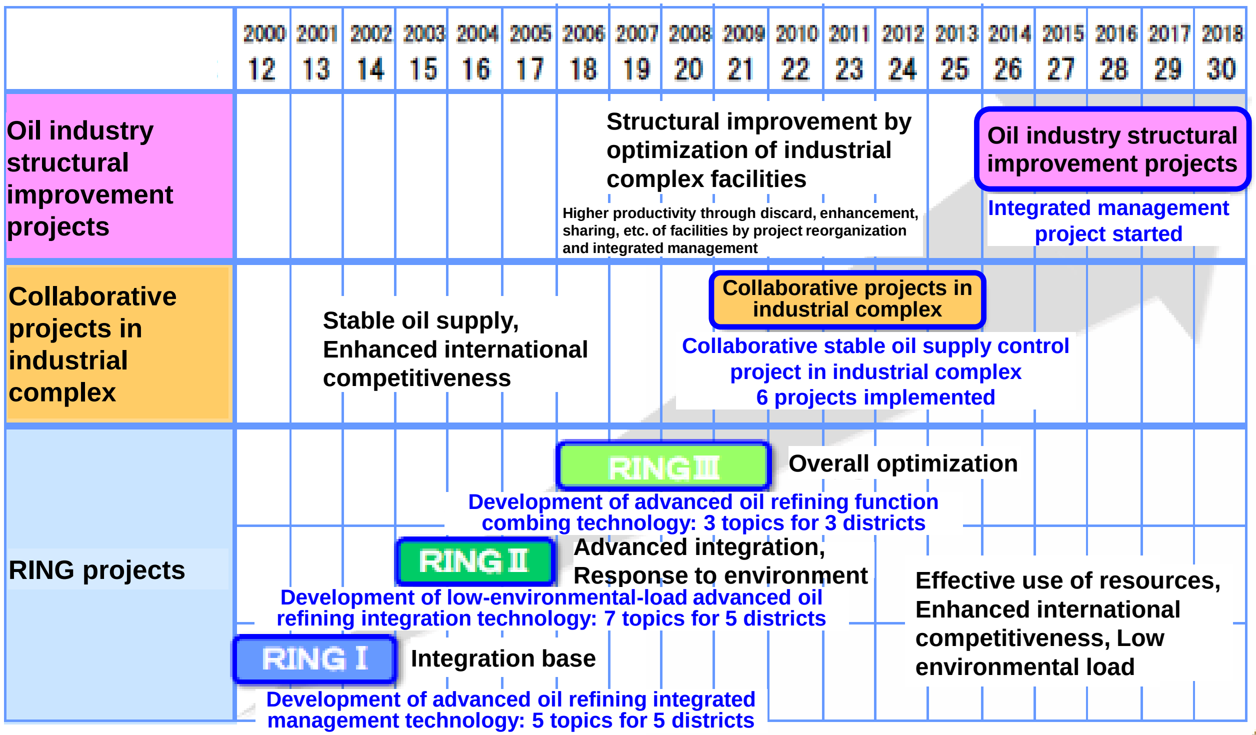
Formation of Energy Utility Hub on Jurong Island
– Best Practice of Composite Energy Value Chain –



Electricity, steam, industrial water, seawater, pure water, cooling water, fire extinguishing water, process drainage treatment, process waste disposal, pipeline management, raw materials, product logistics management

Possible Future Direction of EE&C activities Based on Japanese Experiences − From a Viewpoint of Industrial Complexes −

- Since 2000, the Japanese industrial complexes aim at consolidation for advanced integrated management between oil refineries and different categories of business such as petrochemical, beyond the industry framework and enterprises under the leadership of RING *(www.ring.or.jp)
- To date optimization of the entire complex has been pursued by RING in the following fields.
  - Effective use of unused resources
  - Reduce procurement costs through shared use of raw materials
  - Improvement of energy efficiency and high added value of products



*RING: Research association of refinery Integration for Group operation

RING I: Development of the basic technology for integrated management such as a transfer system and an integrated control system between multiple oil refineries/different categories of business

RING II: Development of the integrated technology focusing on advanced by-products, promotion of optimum utilization of energy (utilization of the cold heat, improvement and reduction of carbon dioxide), etc.

RING III: Independently unachievable high-efficiency production, manufacture of high-value-added chemical raw materials and efficient environmentally-friendly utilization of energy by combining advanced oil refining functions

Possible Future Direction of EE&C activities Based on Japanese Experiences − From a Viewpoints of Individual Companies −

- The following lists EE&C countermeasure candidates for the petrochemical industry in Singapore, based on the Japanese experiences; ◎ very often employed in Japan, ○ often employed and △ employed to some extent

Facility	Improvement of facility			Improvement of operation management		
	Addition/change of equipment	Process flow change	Facility maintenance	Improvement of control system	Improvement of operation guidelines	Improvement of production management
Boiler Heating furnace Flare stack	◎ **Installation of air preheater** △ Employment of split flow (split a fluid flow to recover heat from combustion) ◎ **Change to low excess air burner** ○ Installation of soot blower ○ Improvement of operability of duct damper ○ Change of heating tube (from bare tube to fin stud) ○ Ceramic lining of furnace internal caster ◎ **Installation of oxygen meter for control** △ Installation of air inlet damper ○ Replacement of heat retaining material, addition of heat retaining thickness △ Utilization of product cooling air for combustion	○ Installation of economizer ○ Installation of waste heat boiler ○ Installation of steam superheater ○ Installation of boiler feed water preheater △ Process fluid heating by waste heat △ Fuel preheat by waste heat ◎ Recovery of hydrocarbon from flare gas ◎ **Utilization of flare gas for fuel**	◎ Removal of adhered dust △ Prevention of air leak from furnace wall △ Maintenance of fire-resistant material	◎ Introduction of excess air control system	◎ Stricter target value of exhaust gas oxygen concentration ◎ Lower spray steam (volume, pressure) △ Proper utilization of fuel additive △ Smoothed calorie of gas fuel ◎ Optimum opening of register and damper △ Optimum heavy oil steam trace	△ Optimum maintenance cycle ◎ Optimum fuel used
Distillation tower Diffusion tower Extraction tower Absorption tower	◎ **Change to low-pressure-loss tray** ○ Optimization of raw material supply step △ Improvement of feed distributor △ Extension of intermediate reboiler and side reflux ○ Enhanced heat retention (thickness, material, scope) △ Installation of feed step overflash monitor	◎ **Employment of hot charge** ○ Utilization of waste heat for reboiler heat source ○ Utilization of steam latent heat of distillation tower for reboiler heat source △ Optimum reboiler heat source steam pressure ○ Utilization of latent heat of tower top steam by heat pump △ Utilization of pressure rising heat of low-pressure steam by ejector	◎ Removal of contamination of tray and filler	△ Introduction of internal reflex control	◎ Lower reflux volume ○ Optimum operation pressure ◎ Reduced stripping steam ◎ Reduced absorbent and extractent △ Reduced overflash volume	△ Optimum product configuration △ Optimum product specifications △ Optimum maintenance cycle ○ Optimum absorbent ○ Optimum extractant

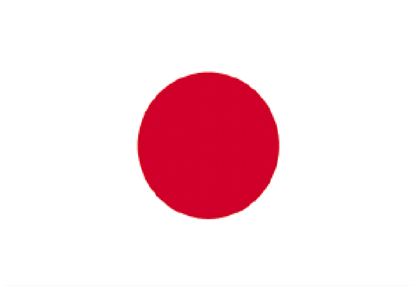
Possible Future Direction of EE&C activities Based on Japanese Experiences – From a Viewpoints of Individual Companies –

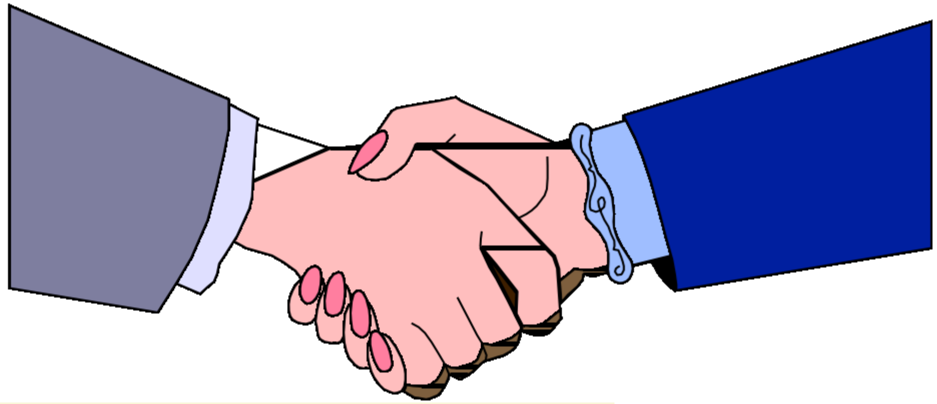
Facility	Improvement of facility			Improvement of operation management		
	Addition/change of equipment	**Process flow change**	**Facility maintenance**	Improvement of control system	Improvement of operation guidelines	Improvement of production management
Reactor	○ Optimum type and steps of reactor ○ Enhanced heat retention (thickness, material, scope) ◎ **Change to low-temperature working catalyst**	○ **Employment of continuous catalyst reproduction** ○ Utilization of waste heat of catalyst reproduction gas	△ Removal of contamination of adhered carbon	△ Introduction of reactive condition optimum control system	◎ Lower recycled gas ratio ○ Optimum reaction temperature and pressure △ Optimum catalyst volume	○ Selection of proper catalyst △ Optimum specification conditions for reaction product ◎ Optimum catalyst reproduction cycle
Heat exchanger Cooler	◎ **Installation/extension of heat recovery heat exchanger** ◎ Change of tube type (from bare tube to fin stud) △ Shorter tube pitch ○ Change of tube layout (from □ to △) ○ Change of baffle (employment of long baffle) ◎ **Employment of plate heat exchanger** ○ Enhanced heat retention (thickness, material, scope)	○ Employment of heat integration ◎ Change of heat recovery combination △ Series utilization of cooling water	◎ Removal of contamination of heat transfer piping ○ Employment of on-stream maintenance	◎ Optimum heat recovery system flow rate distribution ○ Introduction of heat recovery optimum control system ◎ Introduction of automatic control for air-cooled cooler (variable pitch)	○ Proper utilization of contamination inhibitor ○ Optimum cooling water outlet temperature ○ Optimum process fluid outlet temperature △ Optimum air-cooled cooler fan pitch ○ Optimum air-cooled cooler louver opening △ Optimum cooling tower outlet temperature	△ Optimum maintenance cycle
Rotating equipment	◎ Reduced pump impellers △ Optimum pump type ◎ **Employment of variable drive motor** ○ Employment of fluid clutch	◎ Power energy recovery by hydraulic turbine ○ Pressure energy recovery by expansion turbine ◎ Change of rotating equipment drive medium (motor <-> turbine)		◎ Introduction of rpm control ◎ Introduction of automatic operating units control system	○ Optimum compressor operating conditions (temperature, pressure, flow rate) △ Optimum turbine speed ◎ Optimum number of operating units	

Possible Future Direction of EE&C activities Based on Japanese Experiences – From a Viewpoints of Individual Companies –

Facility	Improvement of facility			Improvement of operation management		
	Addition/change of equipment	**Process flow change**	**Facility maintenance**	**Improvement of control system**	**Improvement of operation guidelines**	**Improvement of production management**
Vacuum facility	◎ Optimum vacuum system (vacuum pump <-> ejector) △ Change of capacitor (surface capacitor <-> barometric capacitor) ◎ Split number of ejectors △ Optimum ejector steps		◎ Removal of contamination of surface capacitor ◎ Prevention of air leak from surface capacitor ◎ Cleaning of ejector		◎ Optimum ejector steam (temperature, pressure) ◎ Optimum operating pressure	
Utility facility	◎ Employment of cogeneration system △ Employment of low-pressure steam turbine △ Employment of microgas turbine power generation △ Employment of absorption chiller △ Employment of fuel cells	○ Recovery of boiler feed water from steam condensate ◎ Reutilization of process drainage △ Utilization of pressure rise of low-pressure steam	◎ Inspection and maintenance of heat retaining state ◎ Inspection and maintenance of steam trap		○ Optimum utility balance (non-utility power generation, power purchase, high-pressure steam, medium-pressure steam, low-pressure steam) ◎ Optimum lighting control (scope, illuminance) ○ Reduced vent steam ◎ Optimum piping steam trace	◎ Optimum facility operating rate
Miscella-neous	△ Optimum turbine type (back pressure <-> condensation) ◎ Enhanced tank, duct and piping heat retention (scope, heat retaining material, thickness) ○ Employment of temperature regulation steam trap △ Employment of steam accumulator				○ Optimum tank retaining temperature △ Optimum number of operating boilers △ Optimum turbine back pressure (steam extraction pressure)	

Thank You Very Much





For More Information;
The Energy Conservation Center, Japan
https://www.eccj.or.jp <from 1996>
Asia Energy Efficiency and Conservation Collaboration Center
(Established in April 2007)
https://www.asiaeec-col.eccj.or.jp
Japanese Business alliance for Smart Energy-Worldwide
(Established in October 2008)
https://www.jase-w.org/
SEforALL(Sustainable Energy for All)
(Established in September 2015)
https://seforallateccj.org/

The Energy Conservation Center, Japan
Since 1978

省エネのシンボルです
SMART CLOVER

The Symbol of Energy Conservation
Since 2005ECCJ has been spread the symbol mark with the visual image of a flour-leaf clover which is thought to bring happiness named as “SMART CLOVER”, representing everyone’s energy conservation activities.

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