Nuclear Energy : Indispensable for Sustainable Development in Japan

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The Institute of Energy Economics, Japan (IEEJ)

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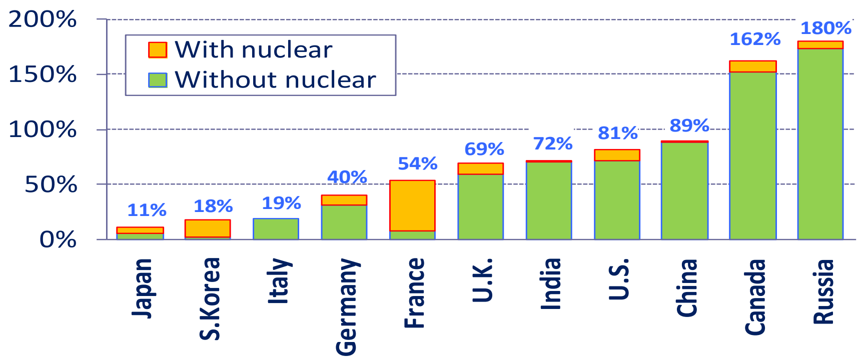
1. Basic Viewpoints for Energy Policy has evolved from「３Ｅ」to「３Ｅ＋Ｓ」

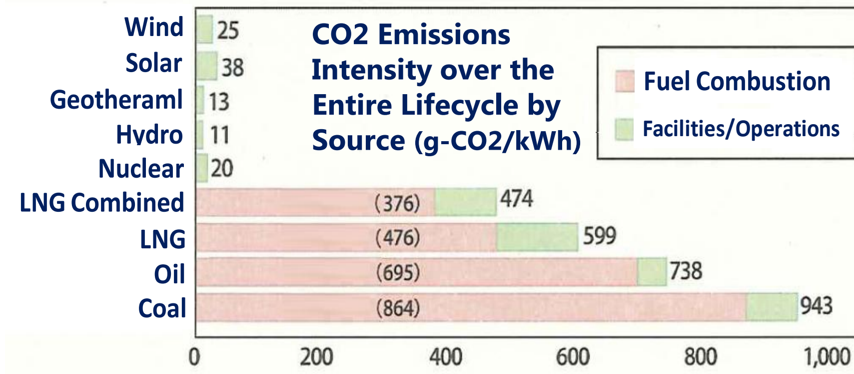
E1 Energy Security

Self sufficiency rate (2011)



Source: OECD/IEA "Energy Balances of OECD, Non-OECD countries"

E2 Environment (Climate Change)



Source: Central Research Institute of Electric Power Industry (CRIEPI) "Evaluation of Life Cycle CO2 Emissions of Power Generation Technologies: Update for State-of-the-art Plants" July, 2010.

E3 Economic efficiency

Power Source	Gneration Cost (Yen/kWh) (Model Plant Case, 2010)	Durable years	Capacity Factor
Nuclear	8.9～	40yrs.	70%
Coal thermal	9.5～ 9.7	40yrs.	80%
LNG thermal	10.7～11.1	40yrs.	80%
Oil thermal	20.8～22.4	40yrs.	80%
Hydro	10.6	40yrs.	45%
Wind power (Onshore)	9.9～17.3	20yrs.	20%
Geo-thermal	9.2～11.6	40yrs.	80%
Photovoltaic (houses)	33.4～38.3	20yrs.	12%

Source: the Energy and Environment Council (National Policy Unit, Cabinet Secretariat) "Report of the Cost Verification Committee" December, 2011.

+ Safety

2. No energy is perfect in light of「3 E + S」

（0） **Energy Saving :** Good from the standpoint of Energy Security (ES) and Environment (Env), but not limitless in terms of Energy Efficiency (EE), namely cost

（1） **Fossil Fuel**

① Oil： Very convenient to handle , but concerns are with ES, Env. and EE

② LNG： Similar concerns with 3E , but less so with ES and Env.

③ Coal： Advantageous with respect to ES and ES , but serious concern with Env.

（2） **Renewable Energy**

① Solar： Superior in terms of ES, Env. , but serious concern with EF, namely cost

② Wind power： Good for ES, and Env. But considerable concern with EF and location

③ Geo thermal： Good for ES and Env. And EF as well , but difficult regarding public acceptance (PA).

（3） **Nuclear :** Good for 3E , but concerns remain with Safety (S)

（4） **Other**

Hydrogen： Good for ES and Env. (with CCS) , but still very expensive (EE) .

3. What has resulted from all the reactors being off line?

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Situation after the Great East Japan Earthquake

Stable supply of energy Energy Security	**1. Increasing dependence on fossil fuels** • 88% of overall electricity output (FY 2012) Higher than the First Oil Shock levels (76%) * ME dependency: oil (83%), natural gas (29%) • Ratio of renewable energy capacity - 1.6% of overall electricity output (excl. hydro) (Public burden for FY 2012 due to the FIT system was 350 billion yen)
Impact on the lives of the public and the economy Economic Efficiency	**2. Increase in fuel costs (for increasing thermal output)** 3.6 trillion yen (30,000 yen per capita, FY 2013) **3. Soaring electricity tariffs** • Average 20% higher than before the earthquake disaster (tariffs for standard households) • Could rise further if nuclear plants are not restarted
Global warming Environment	**4. Increase in CO2 emissions (FY 2012)** • CO2 emissions of general electric utilities increased by 110 million tonnes (compared to FY 2010, equal to 9% of Japan's overall emissions)

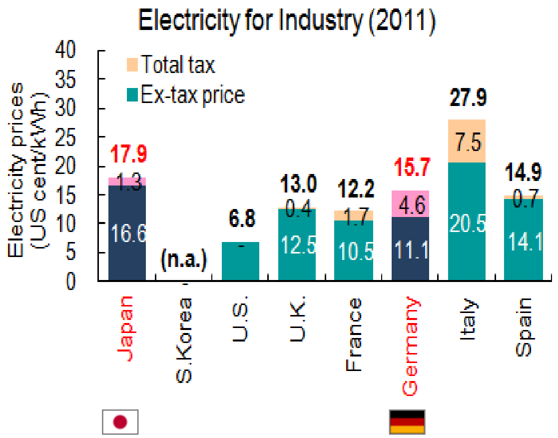
2

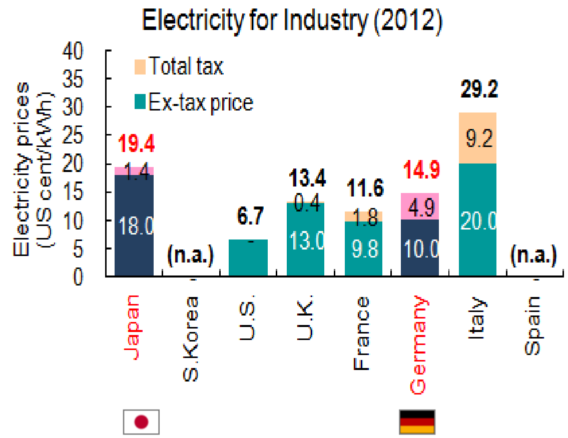
\+ **Safety**

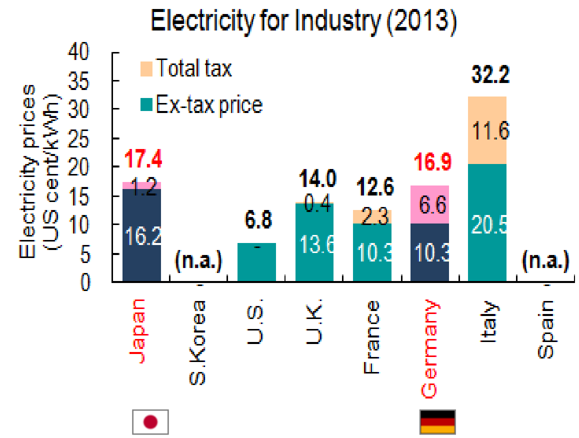
\+ **Macro economic impact**

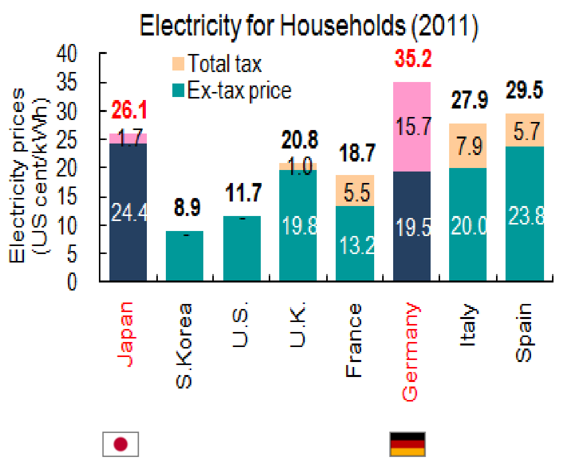
Source: ANRE "Handout", Second Follow-up Meeting (energy) for the Competitiveness Council, December 20, 2013

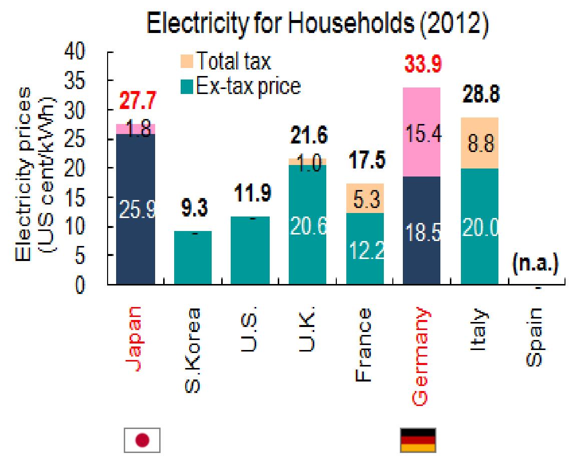
International Comparison of Electricity Tariffs (2011~13)

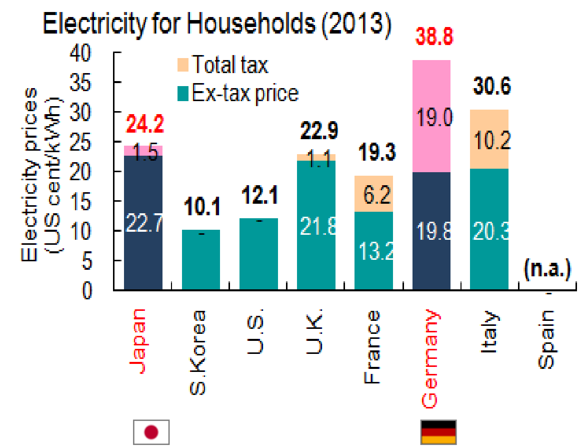










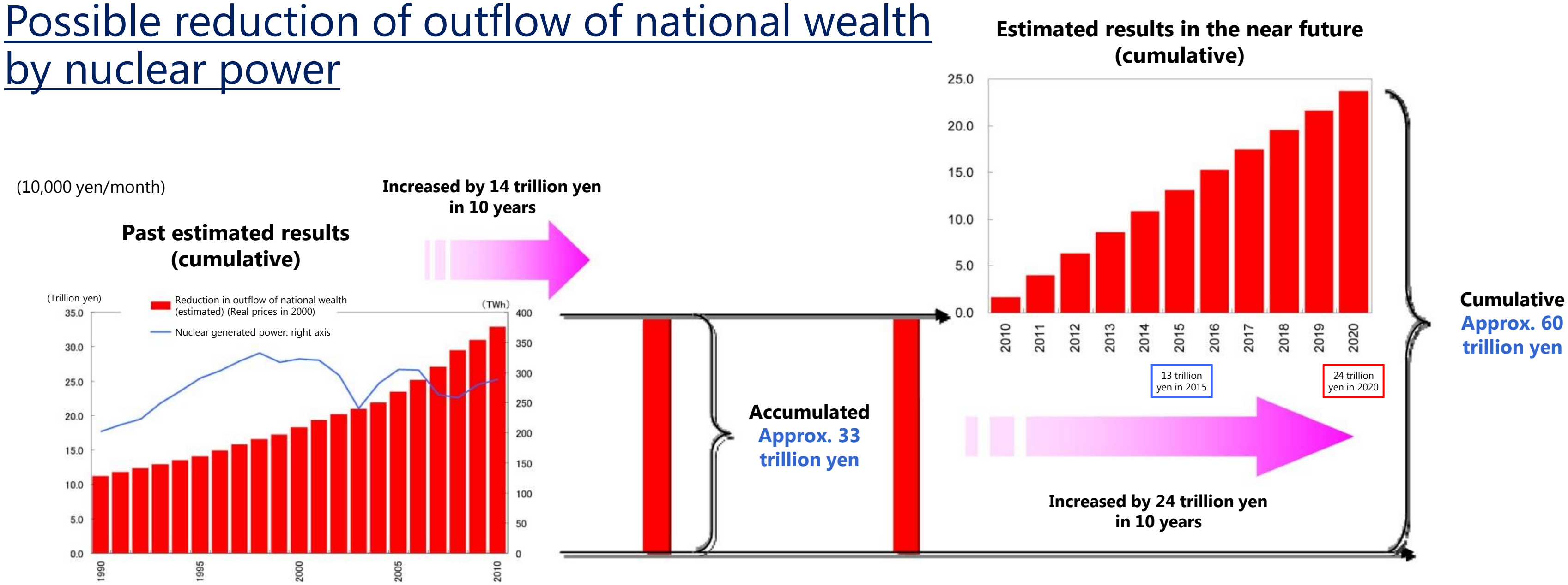


(Note 1) n.a. (no data available) for [Industrial] S. Korea for 2011-13 and Spain for 2012-13, [Residential] Spain for 2012-13
(Note 2) For S. Korea and the US, the ratio of electricity price and tax in the tariffs is not available.
(Note 3) Totals may not match due to rounding.

Source: OECD/IEA "Energy Prices & Taxes," 2nd Quarter 2014

Impact on the Macro Economy: Outflow of National Wealth and Current-account Balance

Possible reduction of outflow of national wealth by nuclear power



Note: As renewable energies are expected to grow towards 2030, already 30% of PV is imported. Replacing nuclear with renewables could raise the ratio of cheaper imports from overseas, resulting in a further outflow of national wealth.

- Historically, if Japan had used fossil fuel instead of nuclear, an additional 33 trillion yen (1965-2010 cumulative) would have been needed. (Fossil fuel cost minus nuclear fuel cost).
- If the "no nuclear" situation continues, an additional 13 trillion yen by 2015 and 24 trillion yen by 2020 will be needed.

Source: Prepared by IEEJ based on the trade statistics

4. Is nuclear tolerable with respect to「S」?

: Comments from Accident Investigation Committees

A. The Japanese Government's Nuclear Incident Investigation and Verification Committee

(1) Safety measures/emergency response measures
- **Introducing new techniques and findings covering complex disasters.**

(2) Safety measures taken in the nuclear power generation system
- **Severe accident measures**

(3) Preparation for nuclear disasters
- **Risk management system in case of a nuclear disaster**

(4) Measures to prevent/mitigate damages
- **Activities to disseminate risk information, monitoring, evacuation of residents, etc.**

(5) International consistency
- **Consistency with international criteria including IAEA standards, etc.**

(6) Ideal status of related organizations
- **Independence of nuclear safety organizations**

(7) Continuous investigation
- **Continuation of investigation activities, etc.**

B. The National Diet of Japan, Fukushima Nuclear Accident Independent Investigation Commission

(1) Supervision of regulatory authority by National Diet
- **Establishment of a permanent committee**

(2) Review of the government's risk management regime
- **Operators shall have primary responsibility on site**

(3) Response of the government to disaster victims
- **Information disclosure, prevention of escalation of contamination**

(4) Supervision of the electric utilities
- **Preventing operators from putting undue pressure on regulatory authority**

(5) Requirements of the new regulatory organization
- **Independence, high transparency, expertise, etc.**

(6) Review of nuclear regulation laws
- **Review and backfit based on the world's latest technologies**

(7) Utilization of independent investigation committee
- **Establishment of a third-party committee in the Diet**

(Note) Red and/or underlined numbers indicate that the accident could have been prevented by complying with the IAEA's 10 fundamental safety principles.

What can be International Standards

10 fundamental safety principles set out by the IAEA

Principle 1: The prime responsibility for safety rests with the licensees.

Principle 2: An effective framework for safety, including an independent regulatory body, must be established and sustained by the governments.

Principle 3: Leadership in safety matters has to be demonstrated at the highest levels in an organization.

Principle 4: Only those facilities and activities whose benefits exceed radiation risks should be justified.

Principle 5: Protection shall be optimized to provide the highest level of safety and it shall be reviewed regularly.

Principle 6: Individual risk shall be controlled within the prescribed limits.

Principle 7: People and environment, present and future, must be protected against radiation risks.

Principle 8: Primary means of the prevention and mitigation of accident consequences are "defense in depth". Good design and engineering features providing safety margins, and diversity and redundancy must be introduced.

Principle 9: Emergency preparedness and response should be established.

Principle 10: Protective actions to reduce radiation risk must be justified and optimized.

Comparison of radiation dose

From the standpoint of medical science …

Dental X-ray 135g of brazil nuts	0.005 mSv
Transatlantic flight	0.07 mSv
Average annual dose (UK)	2.7 mSv
CT scan (whole body)	9 mSv
Av dose 6M Chernobyl residents	10 mSv
Annual exposure to average smoker	13 mSv
Radiotherapy for breast cancer	50 Sv

Source: Professor Gerry Thomas, Molecular Pathology, Imperial College London "Communicating Health Risks from Nuclear Accidents"
(The 80th IEEJ Energy Seminar, March, 2015, presentation material)

5. 「M」in addition to 「3E+S」is also essential in determining appropriate energy mix

5-1) The role of respective energy by the New Basic Energy Plan(IV), *Primary energies*

1. Primary energies	
(1) Renewable energies	Despite various issues in terms of supply stability and cost, renewables are a **promising, diverse and important low-carbon domestic energy source with no GHG emissions**.
(2) Nuclear	Nuclear is a low-carbon quasi-domestic energy with excellent supply stability and efficiency which will continue to contribute to supply stability, premised strictly on safety, as an **important base load source of electricity.**
(3) Coal	Coal is an **important base load source of electricity with** low geopolitical risk and price per calorie, which will continue to be used while efforts are made to reduce its environmental impact.
(4) Natural gas	Accounting for 40% of electricity sources and playing a central role among intermediate power sources, natural gas is an **important energy source** whose role will grow as the shift to natural gas accelerates.
(5) Oil	Accounts for slightly over 40% of the primary energies with the highest geopolitical risk, high portability and abundant stockpiles; an **important energy source** that will continue to be used.
(6) LPG	Is a **distributed-type and clean gaseous energy source** that can be used as an intermediate power source, with relatively low GHG emissions and a closely-integrated supply and storage infrastructure, which will be useful in case of emergency.

Source: METI, Basic Energy Plan, April 2014, pp.19-24

5. 「M」in addition to 「3 E + S 」is also essential in determining appropriate energy mix

5-2) The role of respective energy by the New Basic Energy Plan(IV), *Secondary energies*

2. Secondary energies

(1) Electricity	***will continue to play the central role in the secondary energy structure.*** *Energy structure…inexpensive and stable base load electricity sources should be secured at a level that compares favorably with the international level…* ***focus should be placed on achieving a balanced energy structure.***
(2) Heat utilization *Promoting the use of CHP * and renewable heat*	***The use of co-generation, which combines heat and electricity, must be expanded not only in single buildings, factories and houses, but also for entire districts including peripheral areas.*** ***Further, efficient use of river heat, sewer heat, geothermal heat, solar heat and snow and ice cooling will be sought, to make good use of the heat sources that exist in the region.***
(3) Hydrogen *Achieving a "hydrogen society"*	Hydrogen will play a central role, in addition to electricity and heat. **Systems and infrastructure will be built strategically** by promoting diverse technological development and lowering costs.

*** Combined heat and power (CHP), also known as "co-generation"**

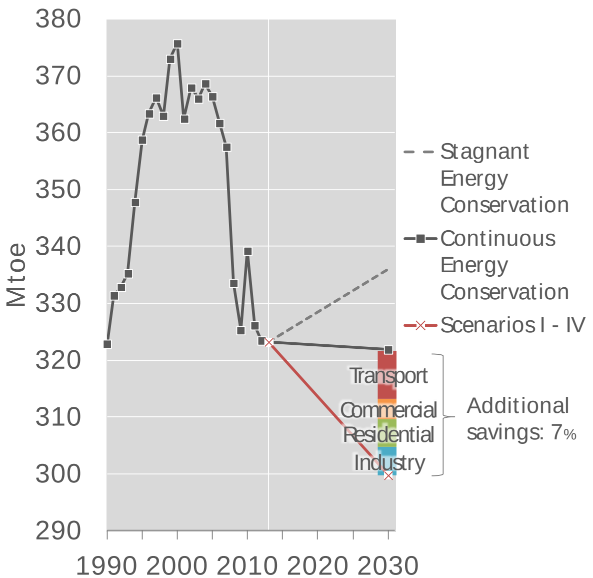
Source: METI, Basic Energy Plan, April 2014, pp.24-26

5. 「M」in addition to 「3 E + S 」is also essential in determining appropriate energy mix

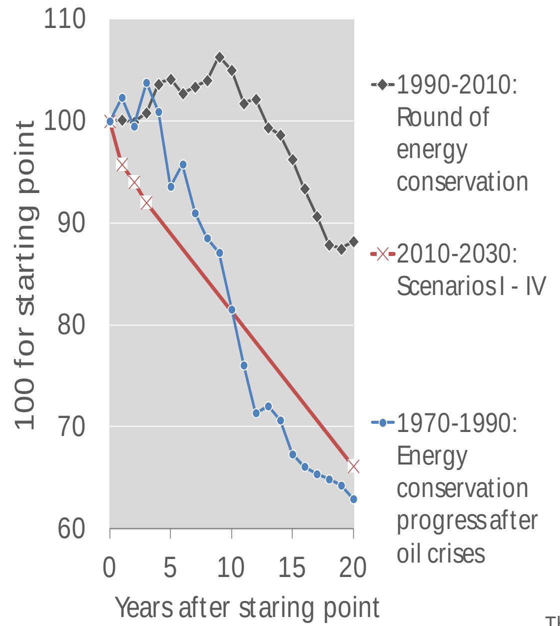
5-3) Energy conservation is desirable in many aspects but cost matters

- Each sector is assumed to promote steadily powerful energy conservation to save energy by an additional 7% (or 11% from the Stagnant Energy Conservation).
- Energy efficiency is assumed to reverse the trend for the past two decades and continuously improve at a pace comparable to that just after the oil crises.
- While the economic size will expand 30% from 2013 to 2030, additional electricity saving measures will limit electricity consumption growth to 7% (or 2% from 2010).

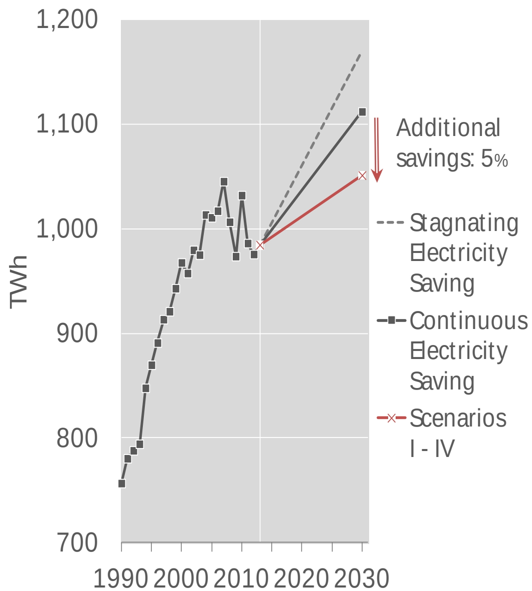
Final energy consumption



Final energy consumption per GDP



Final electricity consumption



The *Scenarios I – IV* in the figure is represented by the *Scenario I*.

Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Examples of additional measures for energy conservation

		Present	2030 Before additional energy conservation	2030 After additional energy conservation
Industry	Energy efficiency		Trendy improvement	Best available technology penetration rate at 50%
Residential	Electrical appliance efficiency (in stock basis)		Top runner compliance Equivalent to a 10% improvement from present levels	Best levels at present Equivalent to a 30% improvement from present levels
	Housing insulation (new housing)	50-60% attain standards	All attain standards	All attain 10% excess over standards
	High-efficiency water heater (household penetration rate)	20%	60%	90%
	LED lighting (penetration rate)	15%	75%	90%
	Home energy management systems (new housing penetration rate)	Little	Little	10%
Commercial	Building performance (new buildings)	90% attain standards	All attain standards	All attain 10% excess over standards
	LED lighting (penetration rate)	2%	30%	90%
	Building energy management systems (new buildings penetration rate)	60%	60% 100% for large buildings	70% 100% for large buildings
Transport	Next-generation vehicles (share in new vehicle sales)	17%	49%	84%

Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

5. 「M」in addition to 「3 E + S 」is also essential in determining appropriate energy mix

5-4) 4 possible scenarios for energy mix in Japan (assumed by IEEJ)

- Developing four scenarios according to power generation mix assumptions for 2030.
- Assessing impacts of power generation mix assumptions on not only electricity supply but also overall energy supply and demand, economy and environment.

Scenarios and power generation mix pictures (2030)

	Scenario I	Scenario II	Scenario III	Scenario IV
Renewables (of which: variable power sources)	35% (17%)	30% (14%)	25% (10%)	20% (7%)
Thermal	65%	55%	50%	50%
Nuclear	0%	15%	25%	30%
Total electricity generation [PWh]	1.1	1.2	1.2	1.2

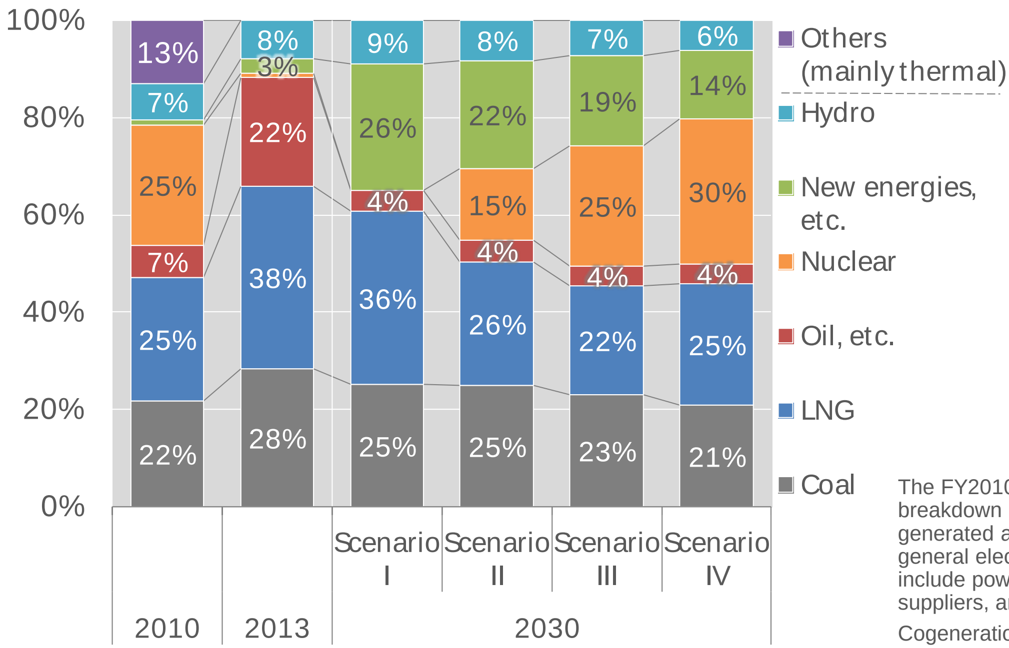
All estimates are rounded.
Variable electricity sources represent solar photovoltaics and wind.
Total power generation covers electric utilities and autoproducers of electricity.

Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Composition of power generation by 4 scenarios (assumed by IEEJ)

- The thermal power generation share decline toward 2030 in all of the Scenarios from 90% following the Earthquake. The LNG-fired power generation share, however, remain unchanged from 2013 in the *Scenario I*.
- The zero-emission power generation share will be one-third, slipping below the 2010 level in the *Scenario I*. CO_2-free energy sources will account for 50% of total electricity generation in the *Scenarios III* and *IV*.

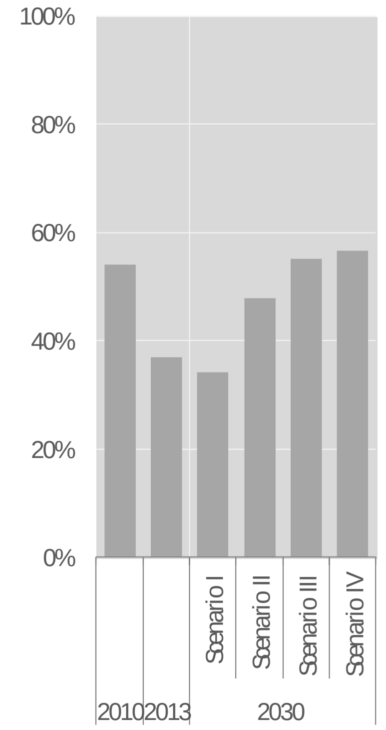
Power generation mix [electric utilities and autoproducers]



The FY2010 power generation breakdown covers electricity generated and purchased by general electric utilities. Others include power producers and suppliers, and autoproducers.

Cogeneration (included into thermal power generation)
FY2013: 4%
FY2030: 15% (common to all scenarios)

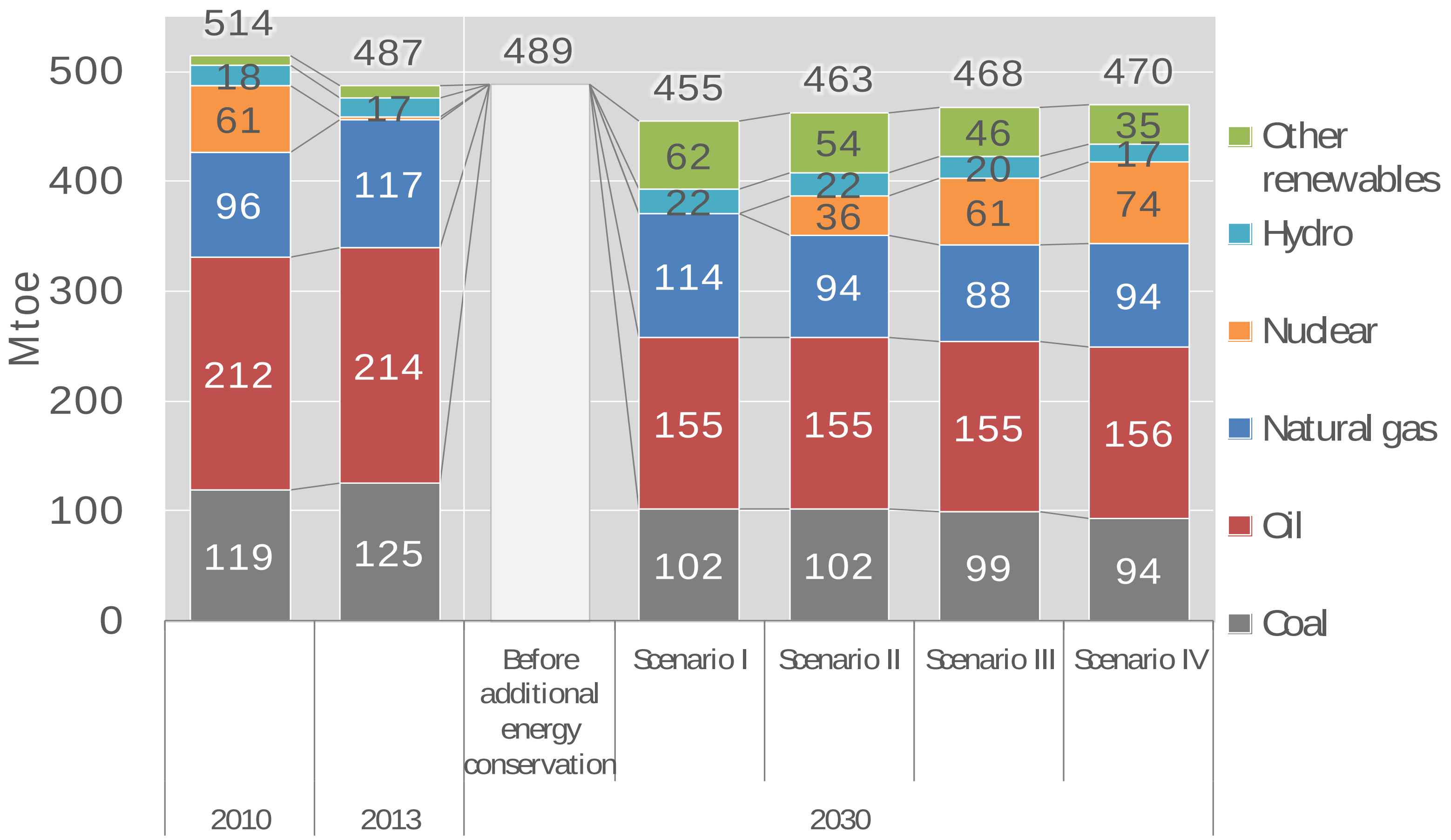
Base load power source



Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Compositions of primary energy by 4 scenarios (estimated by IEEJ)

Primary energy supply

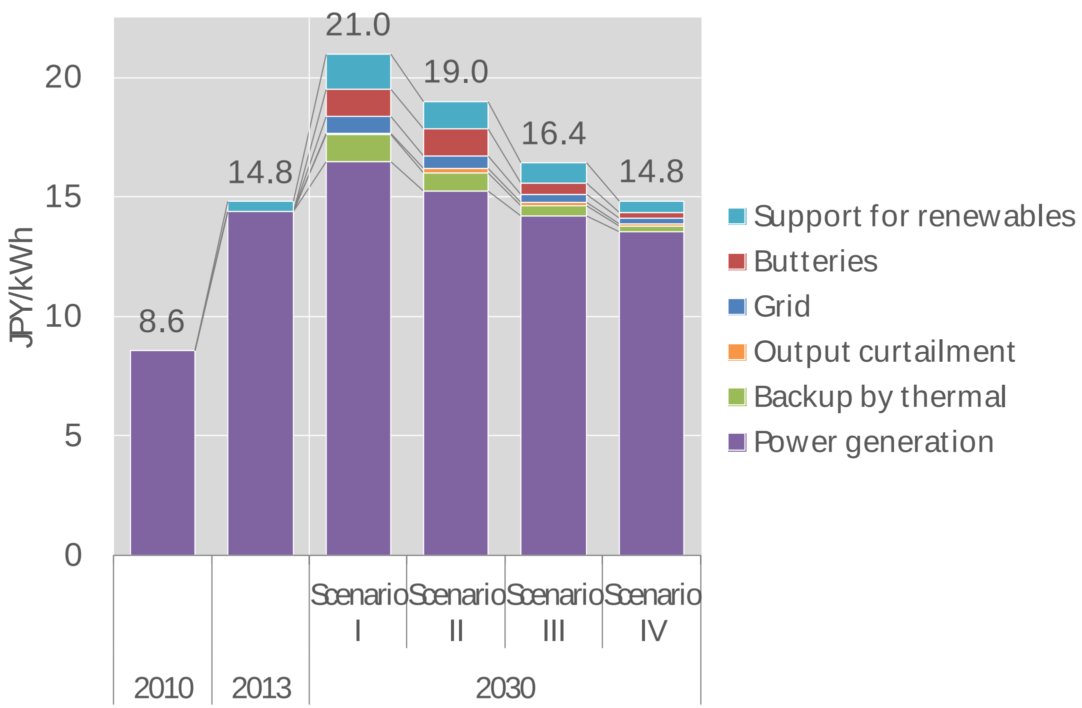


Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Power generation cost by 4 scenarios (estimated by IEEJ)

- As high-cost renewables-based power generation expands its share of total electricity generation, average power generation cost, support for renewables and grid adjustment costs increase.
- Whilst power cost rises by JPY1.6/kWh from FY2013 in the *Scenario III*, the cost rises by JPY6.2/kWh to JPY21.0/kWh in the *Scenario I*.

Power generation-related costs



Data for FY2010 and 2013 are for general and wholesale electric utilities.
The actual increase in electric rates from FY2010 to 2013 was JPY3.9/kWh.

Assumptions (2030)

Fossil fuel import prices [$2013]

- Oil: $175/bbl [$123/bbl]
- Natural gas: $1,035/t [$844/t]
- Steam coal: $194/t [$158/t]

Renewables

- Output curtailment and storage batteries are assumed to deal with surplus electricity.
- Backup thermal generation cost represents an increase in fuel input accompanying a power generation efficiency decline through a drop in the capacity factor.
- The fixed feed-in tariff system is assumed to remain until 2030. For solar photovoltaics and wind, feed-in tariff drops through system prices decline accompanying learning effects are taken into account.

Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Macroeconomic impacts by 4 scenarios (estimated by IEEJ)

- The *Scenario III* (renewables: 25%, thermal: 50% and nuclear 25%) can be regarded as the closest to what should be aimed considering comprehensively economy, environment, energy security and hurdles to overcome.

		2010	2013	2030 Scenario I	2030 Scenario II	2030 Scenario III	2030 Scenario IV
Economy	Power generation-related cost [JPY/kWh] (JPY2013/kWh)	8.6 (8.3)	14.8 (14.8)	✕ 21.0 (17.1)	△ 19.0 (15.5)	○ 16.4 (13.4)	◎ 14.8 (12.1)
Economy	Real GDP [JPY2005 trillion]	512	531	✕ 684	△ 690	○ 693	◎ 694
Economy	Fossil fuel import spending [JPY trillion]	17.8	28.1	✕ 33.7	△ 32.2	◎ 31.6	○ 32.0
Environment	Energy-related CO_2 emissions [Mt] (compared with FY2005)	1,123 (-7%)	1,224 (2%)	✕ 959 (-20%)	△ 917 (-24%)	○ 892 (-26%)	◎ 887 (-26%)
Environment	Electric utilities' NO_x emissions [kt]	170	254	✕ 136	△ 122	○ 110	◎ 106
Security	Self-sufficiency ratio	18%	7%	✕ 19%	△ 25%	○ 28%	○ 28%
Security	LNG import volume [Mt]	70.6	87.7	✕ 84.4	○ 69.7	◎ 65.3	△ 70.0
Waste	Cumulative nuclear fuel consumption [ktU]	25	26	◎ 26	○ 34	△ 37	✕ 39

FY2010 and 2013 power generation costs are for general electric utilities and wholesale electric utilities.
Electric utilities' NO_x emissions exclude those for electricity purchased.

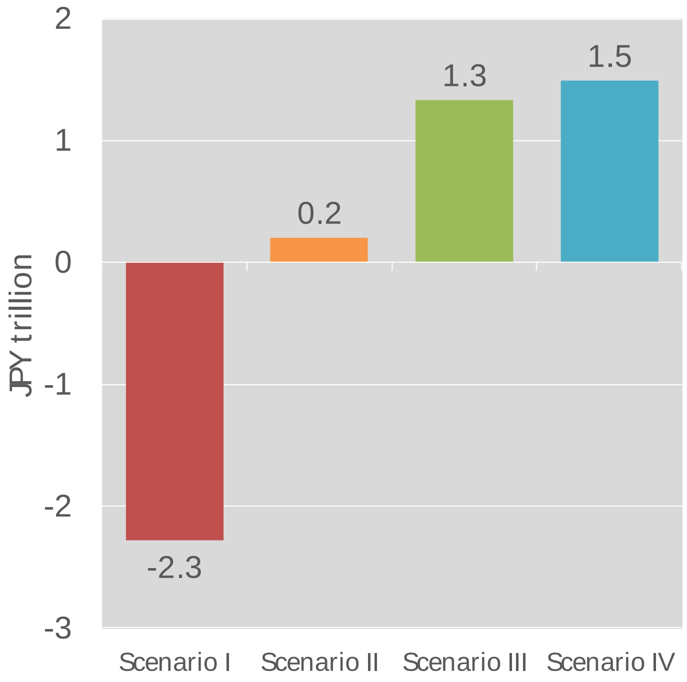
Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Economy ▷ Fossil fuel imports and trade balance (estimated by IEEJ)

- Fossil fuel import spending in the *Scenario III* will be JPY2.1 trillion less than in the *Scenario I*. The spending in 2030 will increase by JPY6 trillion to JPY34 trillion in the *Scenario I*.
- In the *Scenarios II*, *III* and *IV*, a decline in fossil fuel imports and an increase in exports will eliminate a trade deficit.

Fossil fuel import spending (2030)

Balance of Trade (2030)

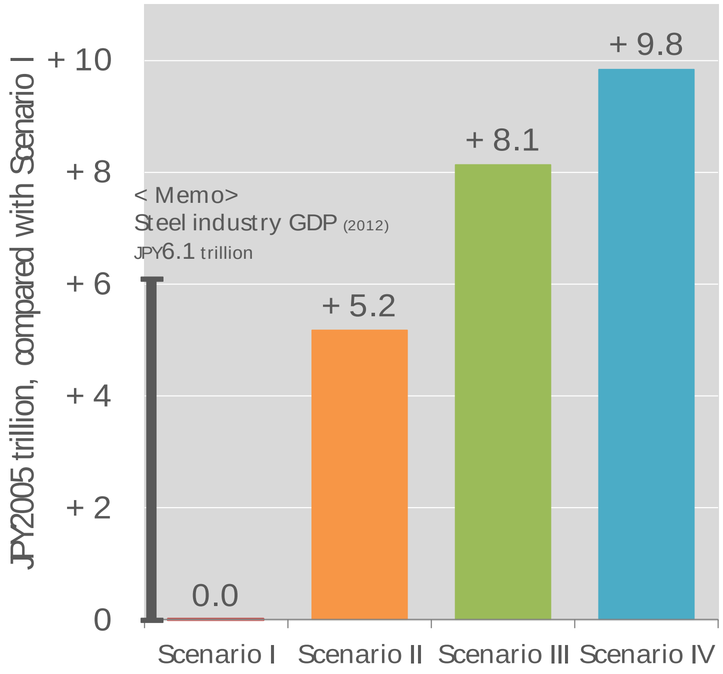


Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Economy ▷ Real GDP and gross national income (estimated by IEEJ)

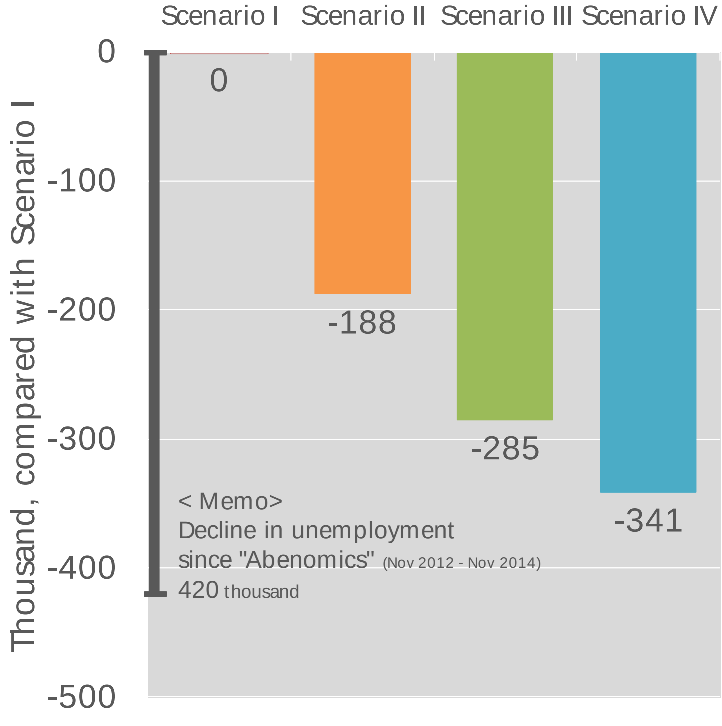
- Increases in energy import spending and electric rate will bring about the maximum real GDP gap of JPY10 trillion between the *Scenarios*. In the *Scenario I*, 5% of economic growth in the *Scenario III* will be lost.

Real GDP (2030)



- Increased fossil fuel import spending and weaker international competitiveness will deteriorate the employment situation harming the nation's macro economy.

Unemployment (2030)

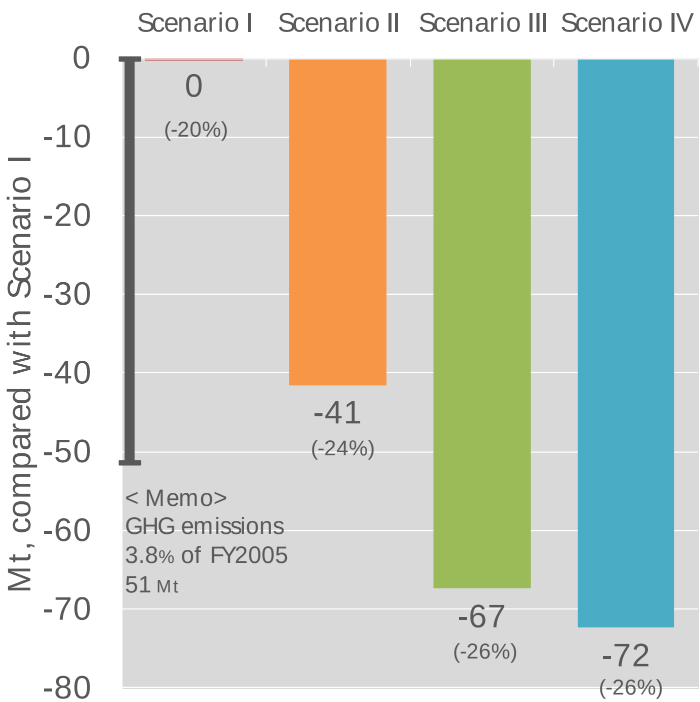


Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Environment ▷ Climate change and air pollution (estimated by IEEJ)

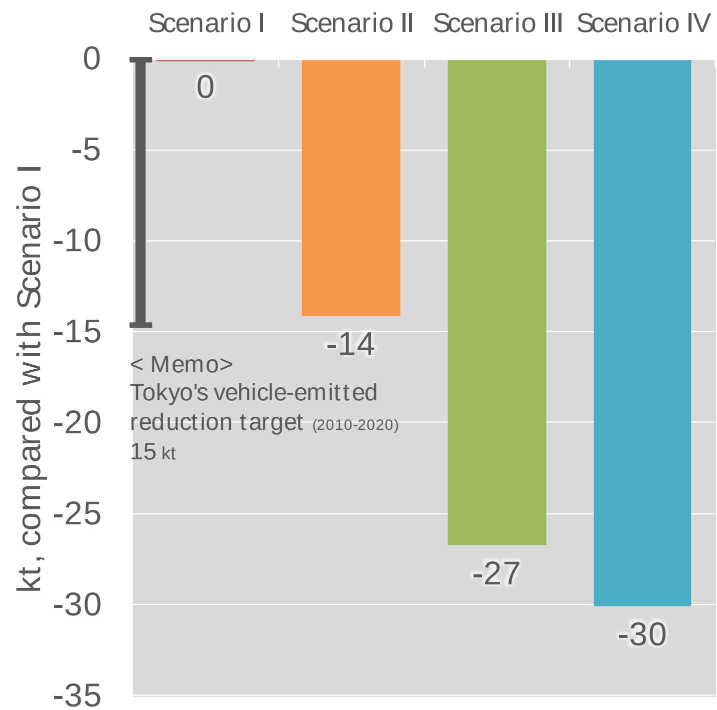
- CO_2 and local pollutants emissions in the *Scenario IV*, in which coal is reduced, are less than in the *Scenario III* despite of the same non-thermal power generation share of 50%.
- Economic costs will increase if carbon prices are imposed to hold down the greater CO_2 emissions in the *Scenario I*.

Energy-related CO_2 emissions (2030)



Numbers in parentheses are changes from FY2005

Electric utilities' NO_x emissions (2030)



Excluding power purchased

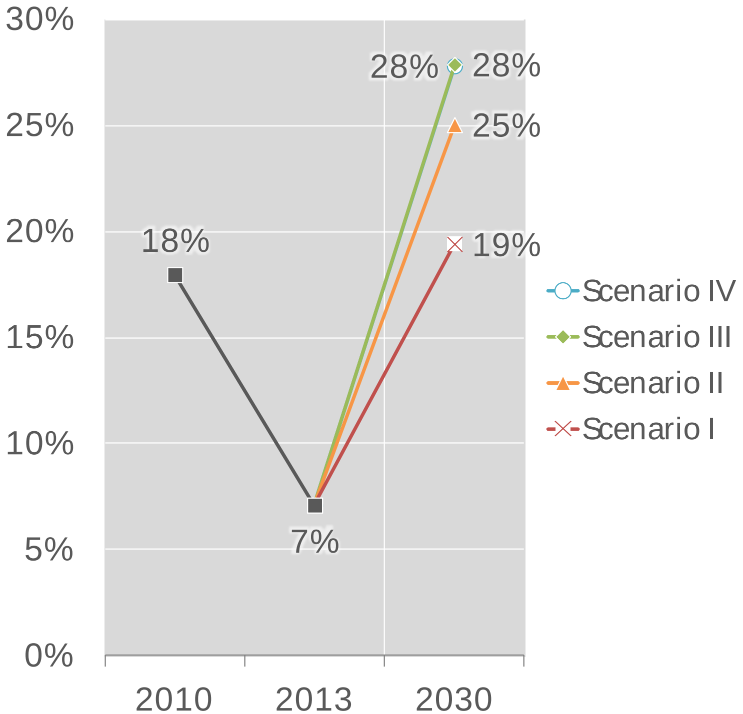
Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

Energy security ▷ Self-sufficiency ratio and LNG imports

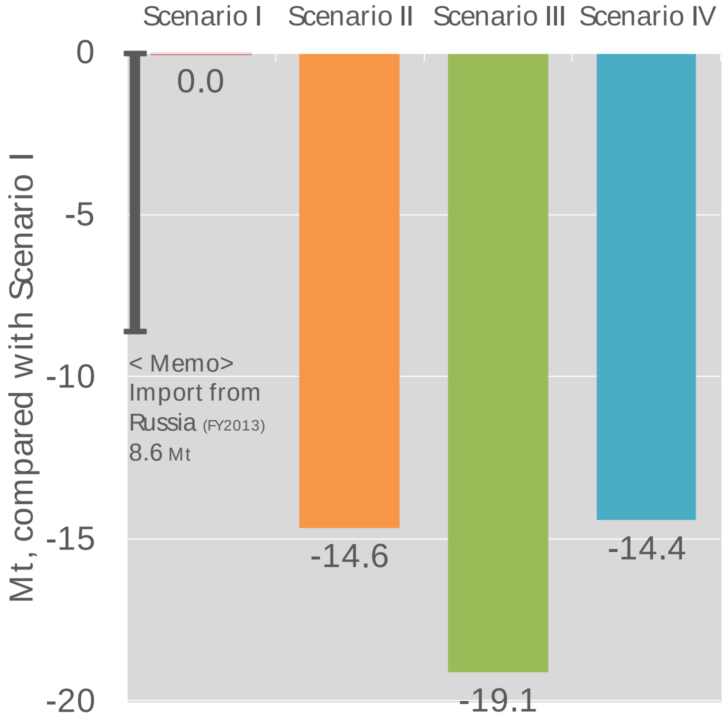
(estimated by IEEJ)

- The energy self-sufficiency ratio will improve most in the *Scenarios III* and *IV* where the collective share for renewables and nuclear deemed (quasi-) domestic energy sources will be the highest.
- LNG imports will decrease in all of the *Scenarios* where the dependence on thermal power generation will decline. LNG imports in the *Scenario I*, however, will be 14 Mt more than before the Great East Japan Earthquake.

Energy self-sufficiency ratio



LNG import volume



Source: IEEJ, Toward Choosing Energy Mix (The 419th Forum on Research Work), January 2015

6. Conclusion: Nuclear energy is not perfect, but indispensable in terms of sustainable development

1. Basic Viewpoints for Energy Policy has evolved from 「３Ｅ」to 「３Ｅ＋Ｓ」after nuclear accident in Fukushima.

2. No energy is perfect in light of 「３Ｅ＋Ｓ」

3. Because of all the nuclear reactors being off line ,「３Ｅ＋Ｓ 」is not satisfied in Japan. Sustainable development is endangered.

4. Nuclear is not free from safety risk. But the risk can be reduced to the tolerable level under the new safety regime in line with international standards. Naturally , we need prepare for the even remote possibility .

5. Determining an appropriate new energy mix is something like solving a simultaneous equation with many variables. 「M」in addition to 「３Ｅ＋Ｓ」would play a determinant role. Then nuclear energy of around 25% out of total power generation is essential for healthy economic development meeting 「３Ｅ＋Ｓ」in Japan.

6. Nuclear energy is not perfect , but indispensable for Japan's sustainable development.

Thank you for your attention.

IEEJ Website> http://eneken.ieej.or.jp/en/