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Toward Choosing Energy Mix

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Future picture heavily depends on energy mix

"Basic Energy Plan" without target energy mix

- The Cabinet approved a new Basic Energy Plan in April 2014 after the plan was revised with no quantitative energy mix being depicted.
- The absence of quantitative energy mix picture hinders proper energy investments and causes grave concern regarding sustainable economic growth.
- We would like to appreciate the establishment of the Subcommittee on Long-term Energy Supply-demand Outlook to specify energy mix and deliberate energy supply and demand balance structure in the future.

Long-term strategy is important for resource-poor Japan

- Japan features an extremely low self-sufficiency ratio in energy supply and depends almost fully on imports for fossil fuel supply.
- Japan must build an appropriate long-term energy strategy to maintain a stable society without being shaken by growing international turmoil.

Utilisation both of renewables and of nuclear is essential

- We conducted quantitative analyses of pictures that Japan can strategically select for 2030 with some uncertainties taken into account. Four scenarios are developed with attention paid to a power generation mix influenced strongly by policies.
- All of renewables, nuclear and fossil fuels must be applied in a balanced manner considering comprehensively quantitative impacts on economy, environment and energy security. The *Scenario III*, in which renewables, thermal and nuclear account for 25%, 50% and 25%, respectively, can be regarded as the closest to what to be aimed.

Power generation mix assumptions = scenario driver

- 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.

Promising renewables-based power generation

- Various renewable energy sources are diffusing rapidly. Installed capacity for non-residential solar photovoltaic, though decelerating its present explosive growth, may expand six-to-13-fold from the present level.
- Installation through 2030 will be limited for offshore wind now under demonstration tests and geothermal with a lead time of a decade.

Installed capacity and electricity generation assumptions for renewables

	Capacity (GW)						Electricity generation (TWh)				
	2013		2030				2013	2030			
	Installed	Approved	Scenario I	Scenario II	Scenario III	Scenario IV		Scenario I	Scenario II	Scenario III	Scenario IV
Total	**29**	**69**	**185**	**157**	**121**	**86**	**76**	**315**	**274**	**217**	**163**
(growth from 2013 [times])			(6.3)	(5.4)	(4.1)	(2.9)		(4.1)	(3.6)	(2.9)	(2.1)
Non-residential solar PV	7	63	93	78	65	43	8	98	82	68	45
Residential solar PV	7	3	34	30	20	16	7	36	31	21	17
Onshore wind	3	1	28	23	13	8	5	49	40	23	15
Offshore wind	-	-	6	4	3	1	-	15	9	7	3
Geothermal	1	0	2	2	1	1	3	12	11	9	7
Small and medium hydro	10	0	14	13	12	11	38	54	51	47	42
Biomass	3	2	8	8	7	6	16	51	49	43	34

Reality check | Impacts of renewables-based power generation

- The cost problem may be coupled with a need for massive capacity and personnel expansion and a later reactionary deceleration in installation if renewables' share of power generation is raised hastily.

		2013		2030			
		Installed	Approved	Scenario I	Scenario II	Scenario III	Scenario IV
Non-residential solar PV	Area [Ratio to area of Manhattan] (Ratio to total land area of Japan)	2 times	19 times	29 times (0.4%)	24 times (0.4%)	20 times (0.3%)	13 times (0.2%)
Residential solar PV	Penetration ratio to detached houses (household penetration)	7% (3%)	7% (3%)	34% (16%)	30% (14%)	20% (9%)	16% (7%)
	Annual installation [1,000 houses]	120 (2000-2013)	-	410	340	200	140
Onshore wind	Area [Ratio to area of Manhattan] (Ratio to total land area of Japan)	5 times	2 times	47 times (0.7%)	38 times (0.6%)	22 times (0.3%)	14 times (0.2%)
	Annual installation [MW]	190 (2000-2013)	-	1,480	1,170	600	340
Offshore wind	Annual installation [MW]	-	-	330	210	150	70

Nuclear as "important base-load electricity source"

- No nuclear power plant will be in operation in the *Scenario I*. Plants under construction will not operate.
- Nuclear power plants meeting the regulatory standards will operate for 40 years in the *Scenario II*. Plants passing the special inspection extend their operating periods in the *Scenarios III* and *IV*.

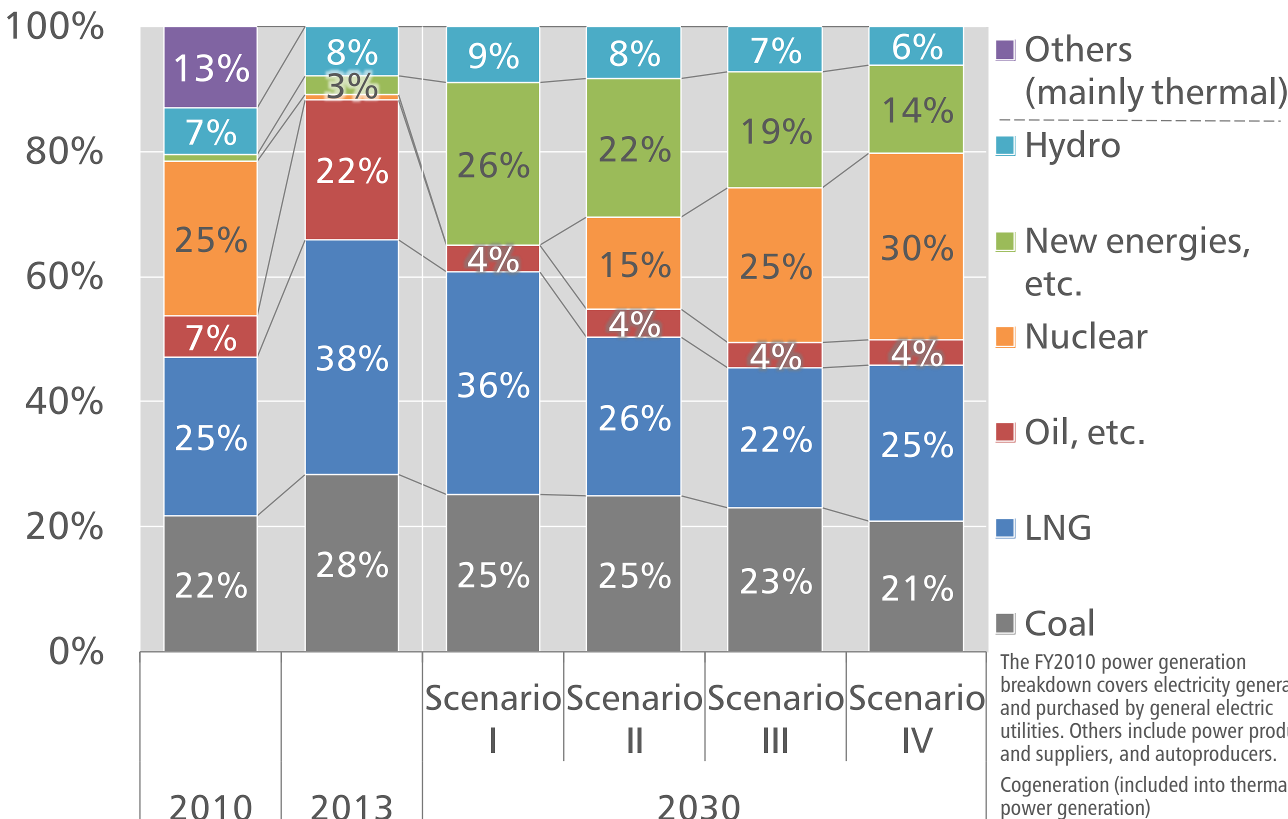
Assumed nuclear power generation shares and image

	2010	2030			
		Scenario I	Scenario II	Scenario III	Scenario IV
Generation share	25%	0%	About 15%	About 25%	About 30%
Electricity generation [TWh]	288	0	169	292	353
Operating periods	-	Immediate shutdown	Decommissioning in 40 years	Decommissioning in 60 years	Decommissioning in 60 years
Capacity factor	67%	-	80%	80%	90%
Construction completion	-	0 unit	2 units	3 units	5 units
Installed capacity [GW]	49	0	24	42	45

Power generation mix

- 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

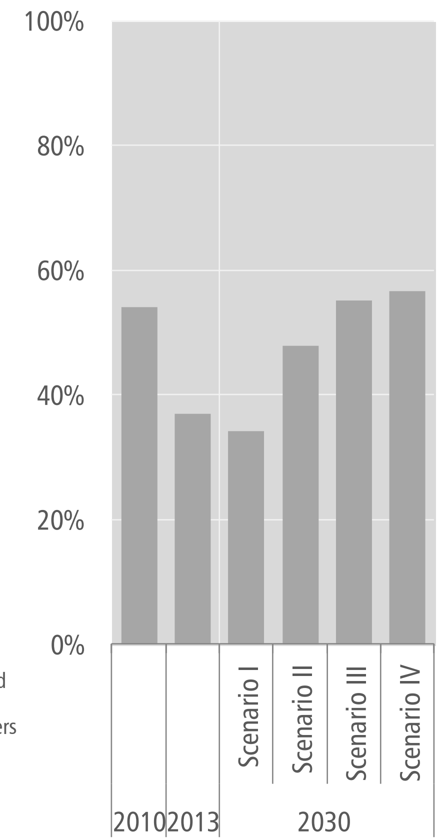
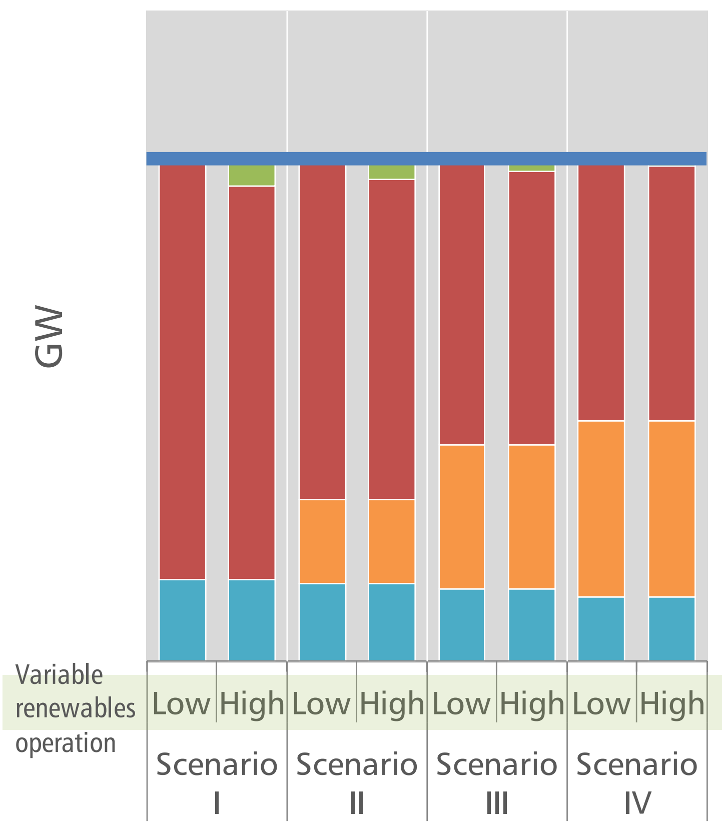


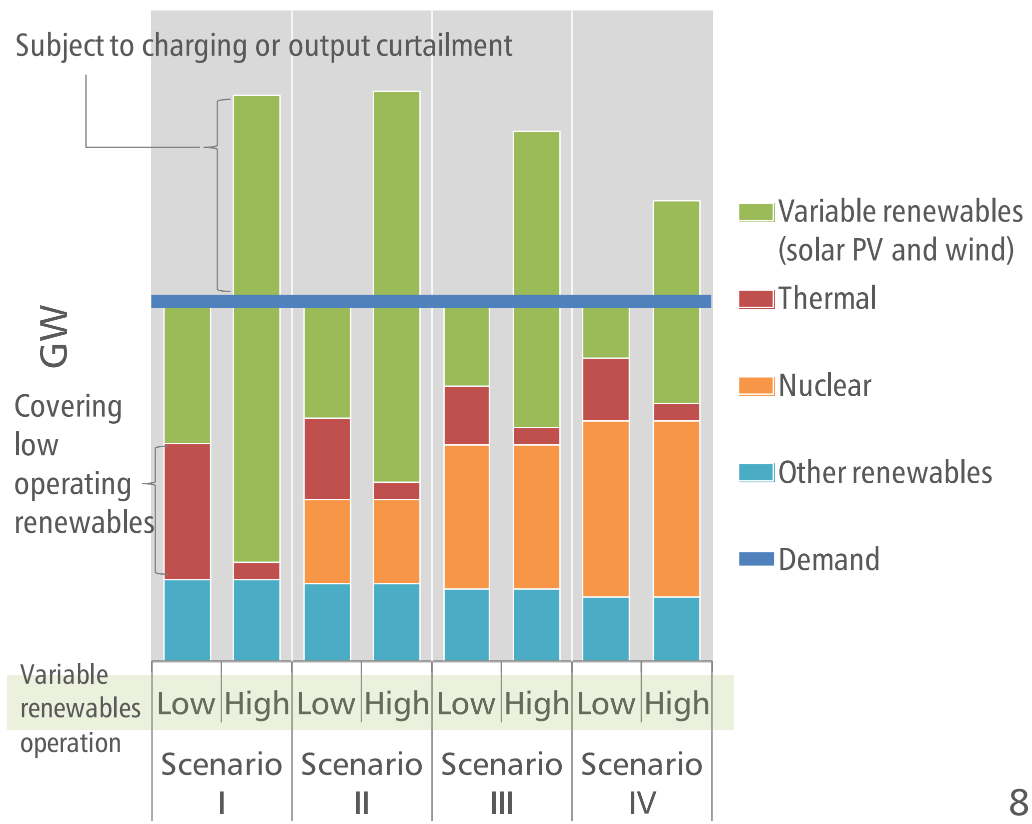
Image of electricity supply and demand balance

- Thermal power generation must make up for supply shortages when generation by variable renewables including solar PV and wind, are low. Those thermal power plants, however, are not utilised efficiently.
- Excessive power supply is also a problem. Adjustment is required when electricity generation by variable renewables is high. It will become more difficult to secure good electricity quality since thermal power generation for such adjustment is reduced.

Balance [night in early autumn]



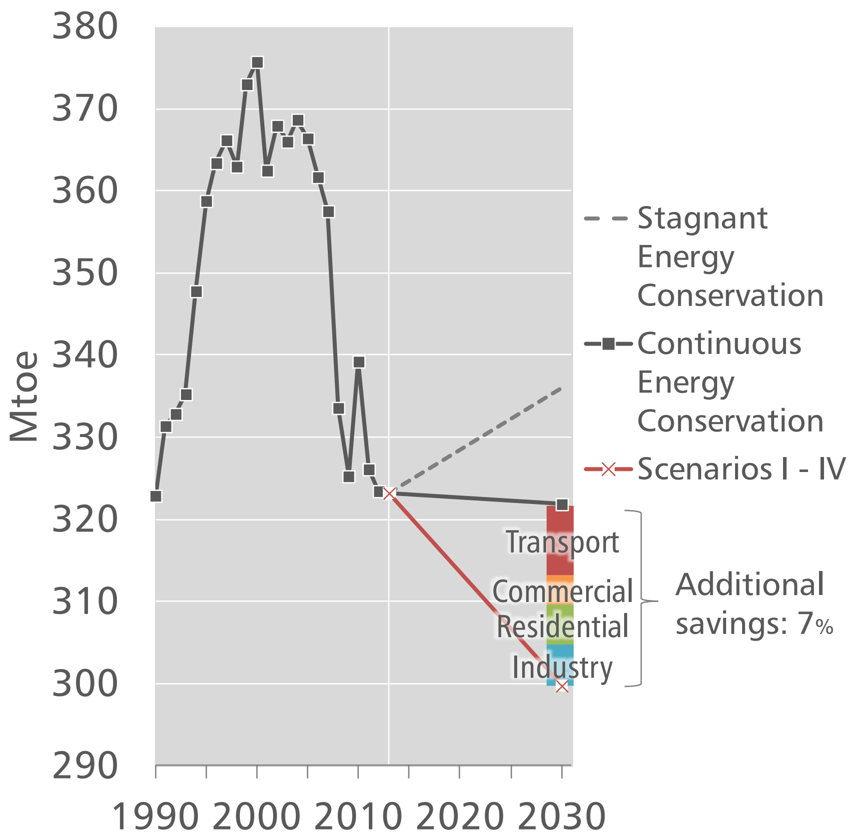
Balance [daytime in spring]



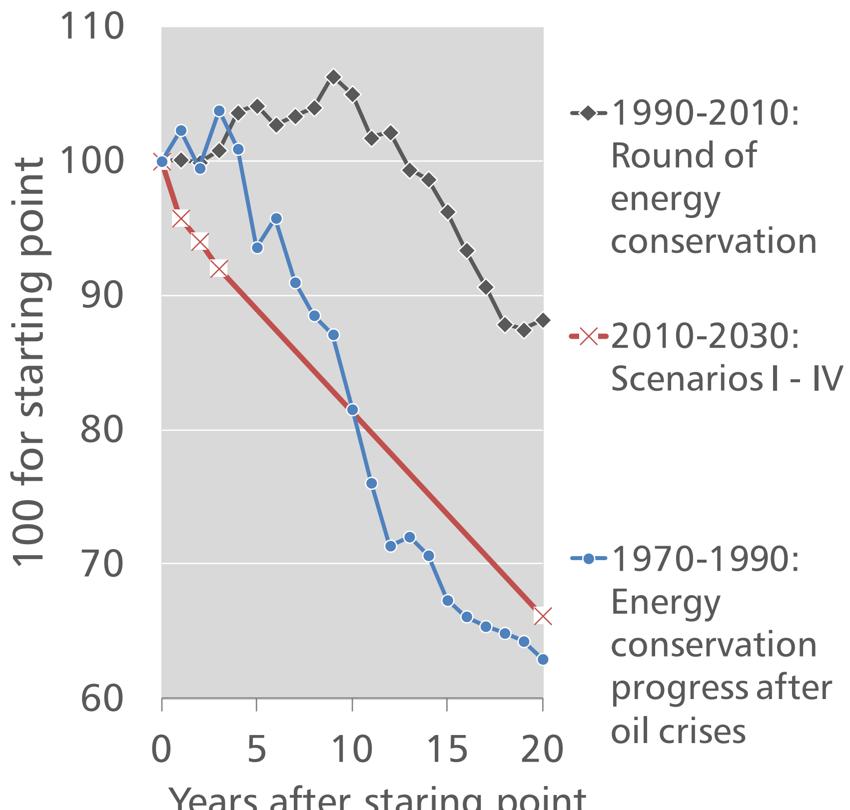
Continuous energy conservation equivalent to that just after the oil crises

- 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.

Final energy consumption



Final energy consumption per GDP



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

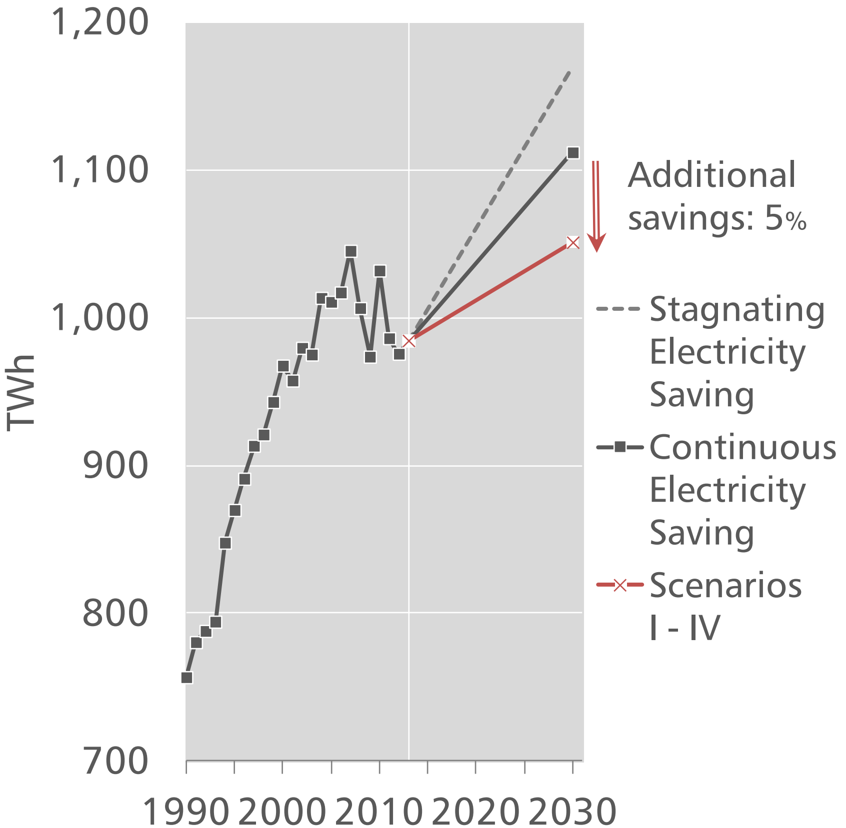
Examples of additional energy conservation measures

		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%

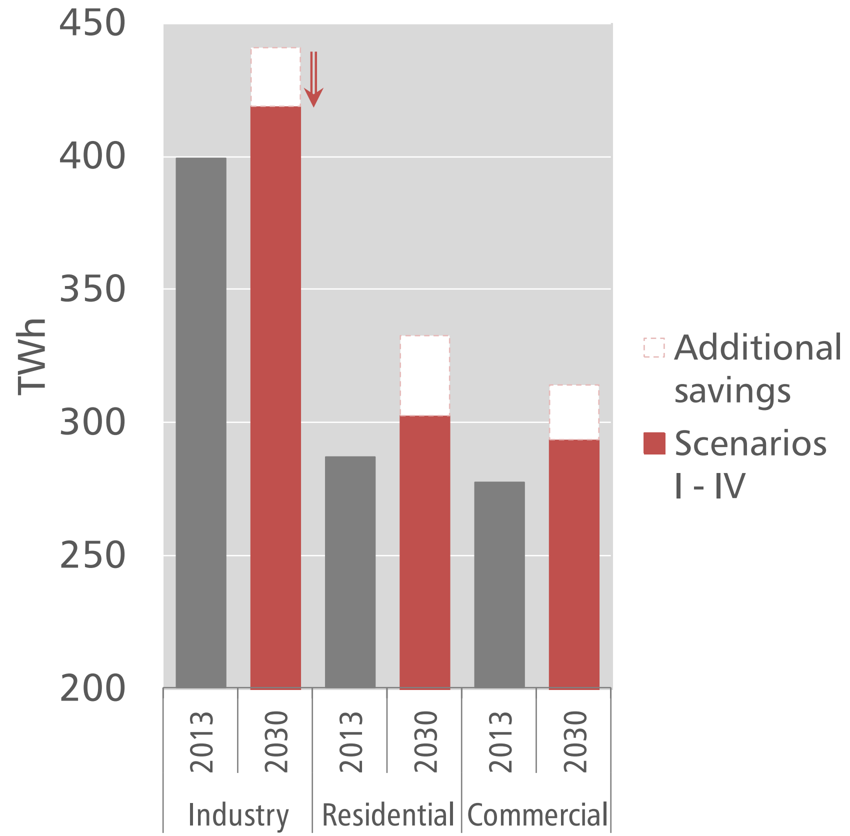
Electrification will make further progress even amid energy conservation efforts

- 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).
- <Memo.> In the New Policies Scenario, the central scenario in the IEA "World Energy Outlook 2014," electricity consumption will increase by some 10% over the period 2012-2030.

Final electricity consumption



Additional electricity saving by sector

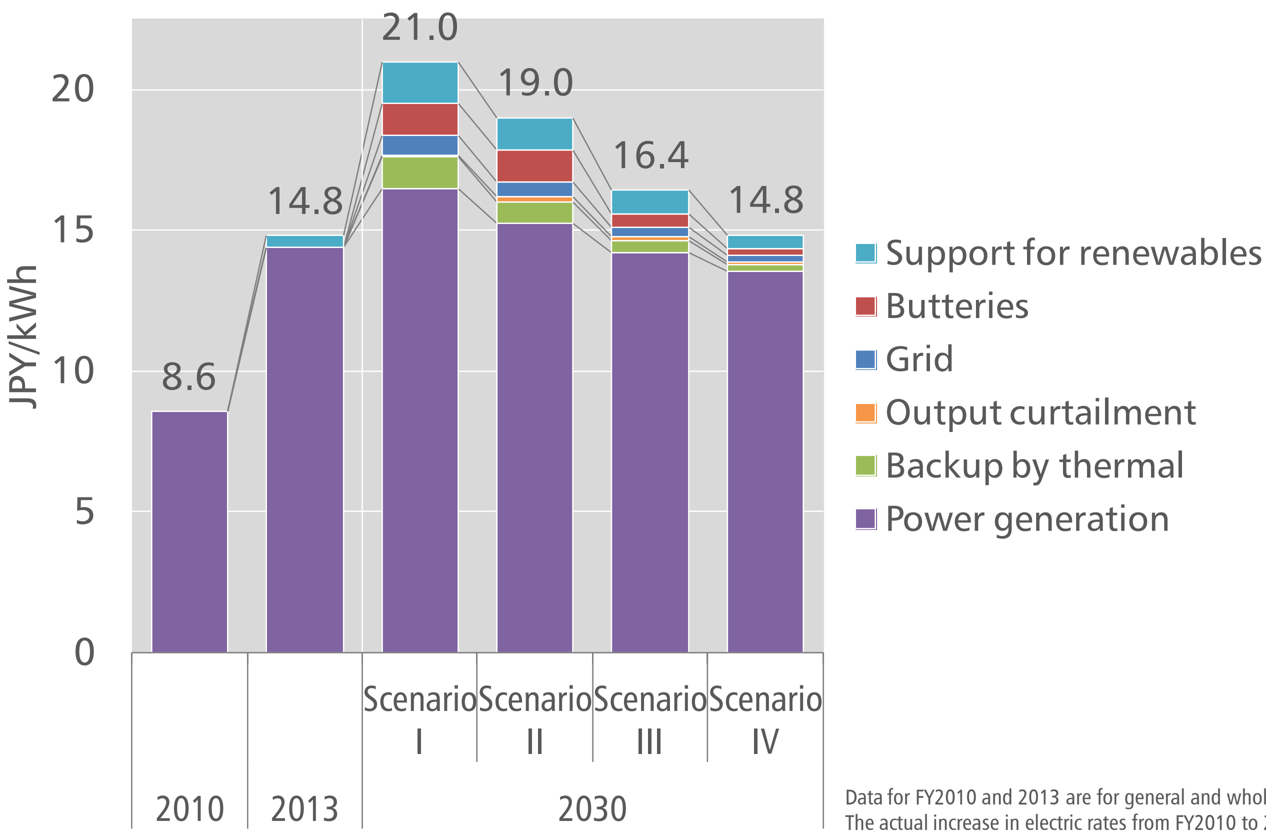


The *Scenarios I – IV* in the figure is represented by the *Scenario I*.

Power costs

- 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.

Comparing impacts

- 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.

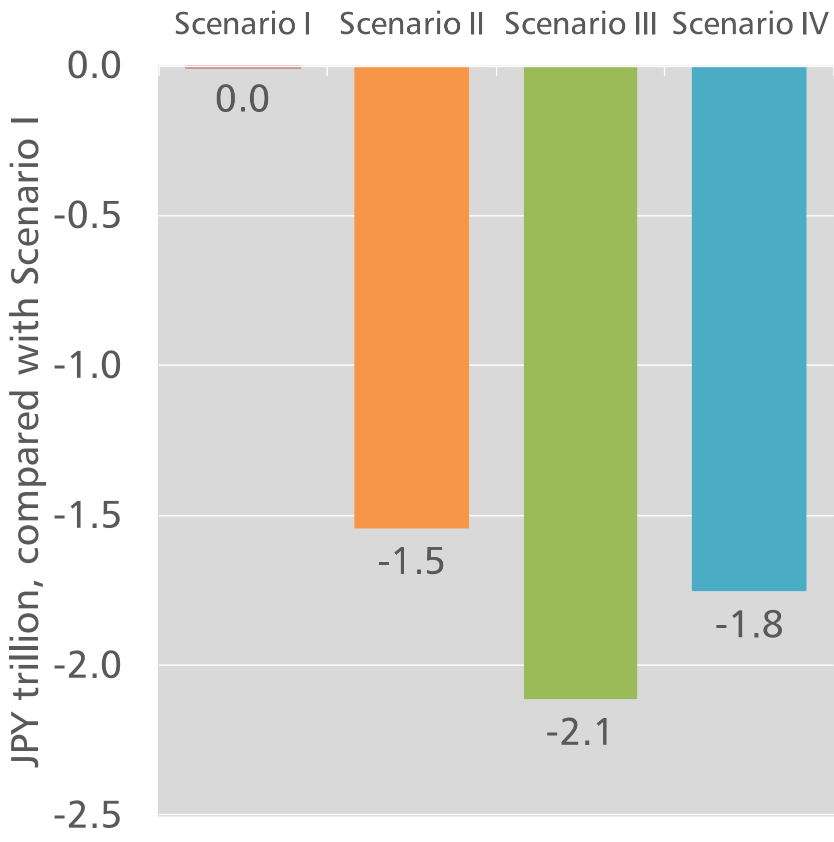
		2010	2013	2030			
				Scenario I	Scenario II	Scenario III	Scenario IV
Economy	Power generation-related cost [JPY/kWh] (JPY2013/kWh)	8.6 (8.3)	14.8 (14.8)	× 21.0 (17.1)	△ 19.0 (15.5)	○ 16.4 (13.4)	◎ 14.8 (12.1)
	Real GDP [JPY2005 trillion]	512	531	× 684	△ 690	○ 693	◎ 694
	Fossil fuel import spending [JPY 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%)
	Electric utilities' NO_x emissions [kt]	170	254	× 136	△ 122	○ 110	◎ 106
Security	Self-sufficiency ratio	18%	7%	× 19%	△ 25%	○ 28%	○ 28%
	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.

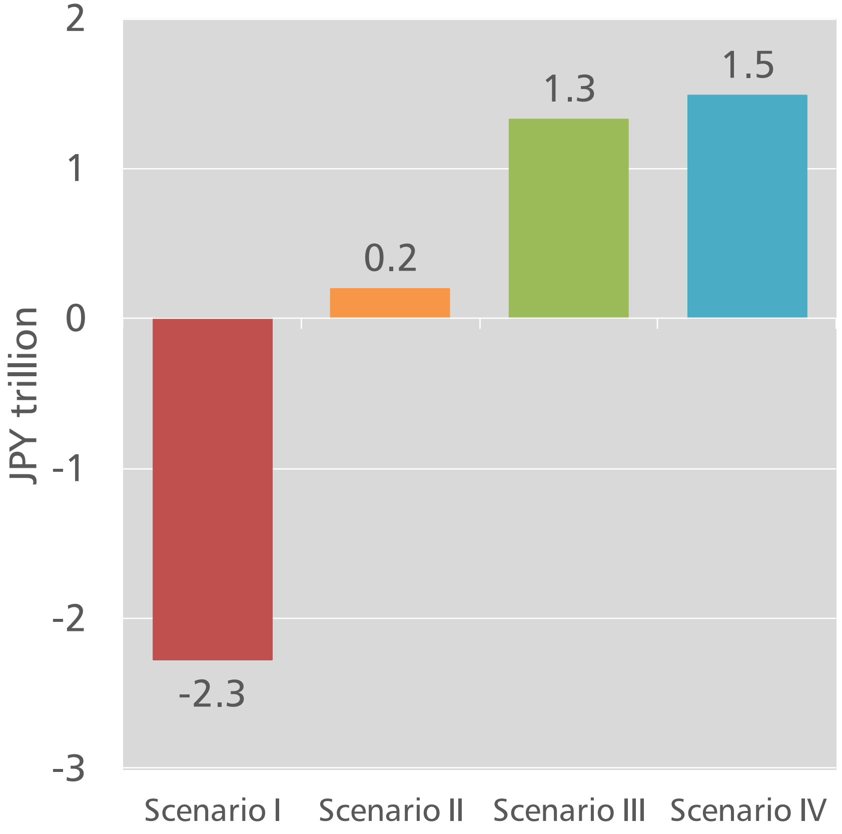
Economy ▷ Fossil fuel imports and trade balance

- 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)



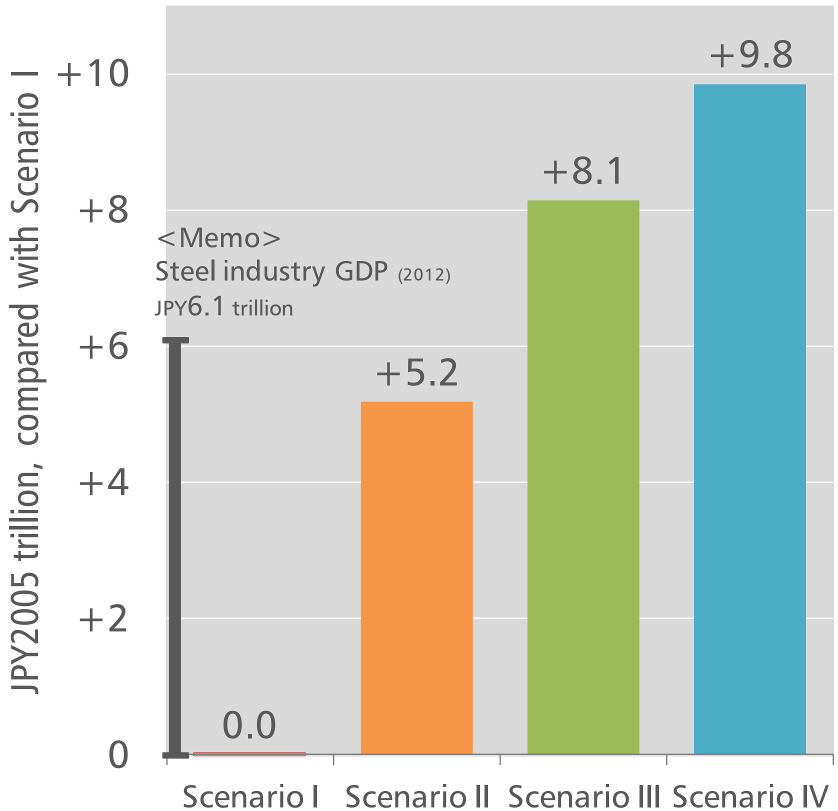
Balance of Trade (2030)



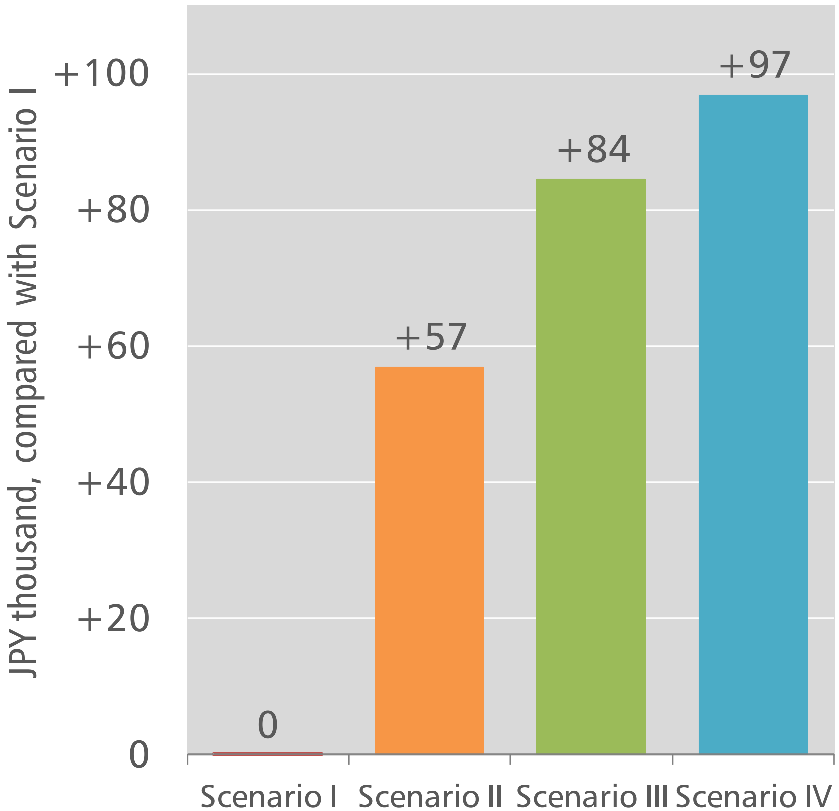
Economy ▷ Real GDP and gross national income

- 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.
- Gross national income (GNI) per capita in the *Scenario I* will be JPY84 thousand less than in the *Scenario III* in 2030. The cumulative gap between the two *Scenarios* through 2030 will reach JPY820 thousand.

Real GDP (2030)



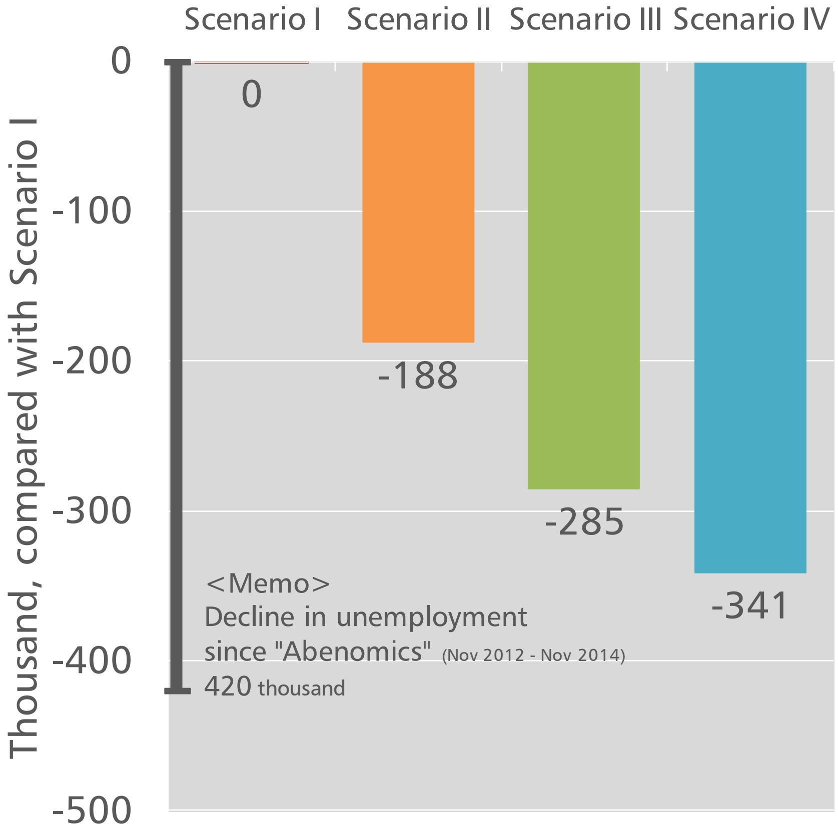
GNI per capita (2030)



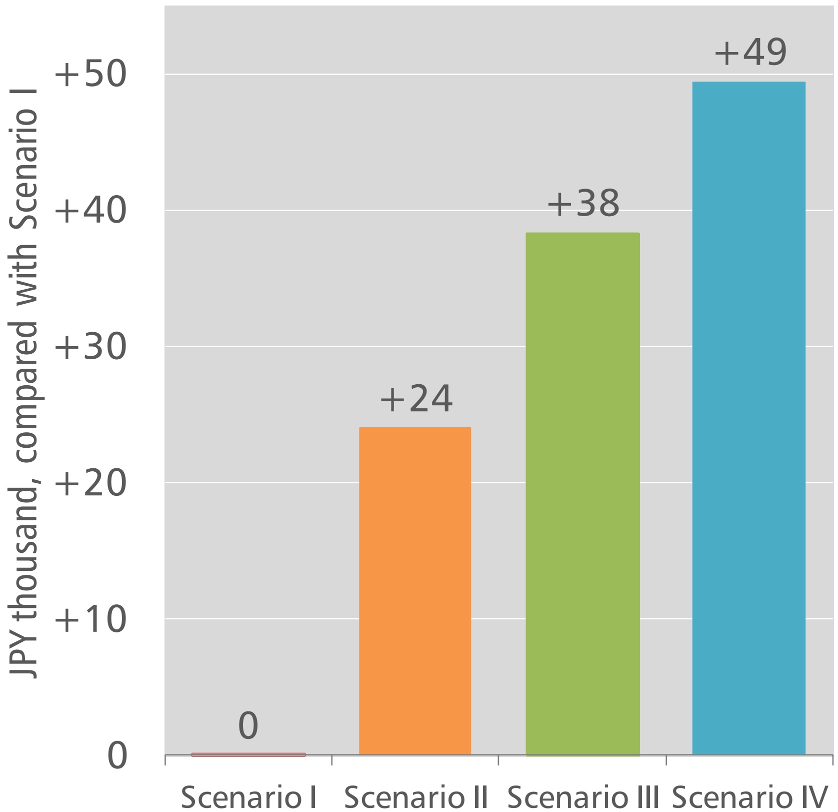
Economy ▷ Employment and labour

- Increased fossil fuel import spending and weaker international competitiveness will deteriorate the employment situation harming the nation's macro economy.
- Workers and households free from unemployment will be affected by lower wages. Coincident rises in electricity rate will exert the greatest pressure on household budgets in the *Scenario I*.

Unemployment (2030)



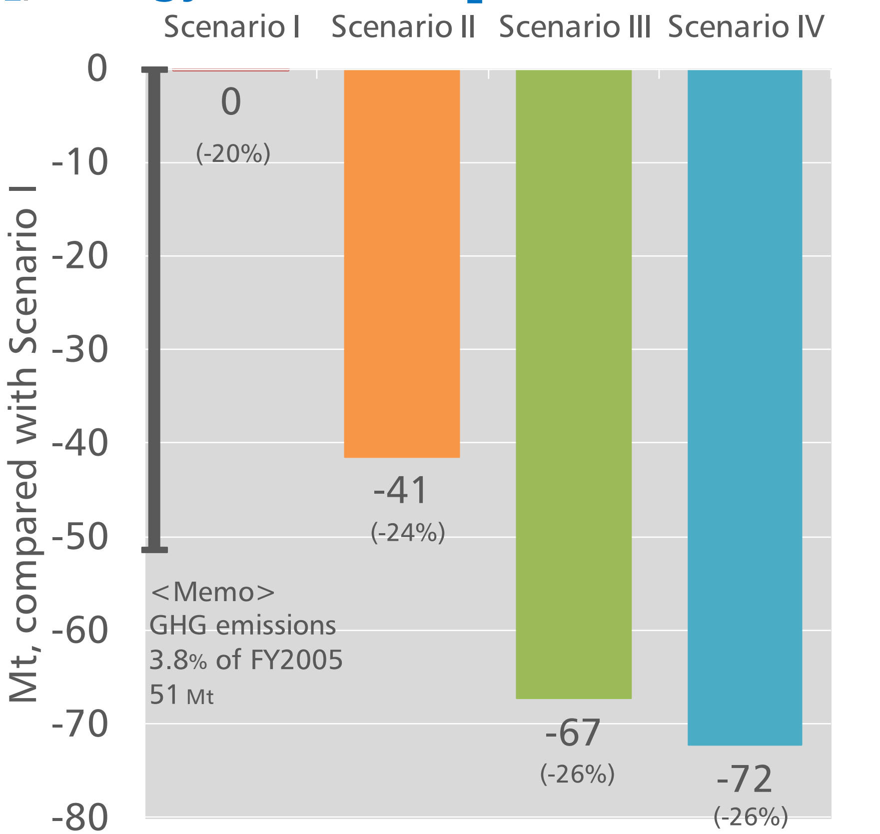
Wages (2030)



Environment ▷ Climate change and air pollution

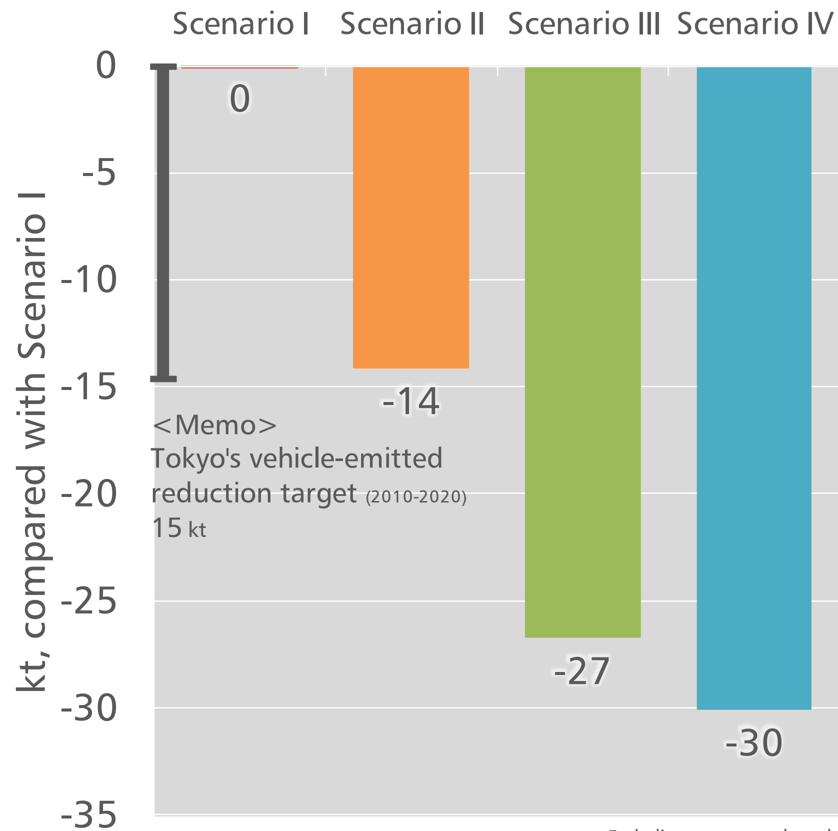
- CO_2 and local pollutants emissions in the *Scenario IV*, in which coal is reduced, are less than in the *Scenario III* despite of the same non-thermal power generation share of 50%.
- Economic costs will increase if carbon prices are imposed to hold down the greater CO_2 emissions in the *Scenario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

Energy-related CO_2 emissions (2030)



Numbers in parentheses are changes from FY2005

Electric utilities' NO_x emissions (2030)

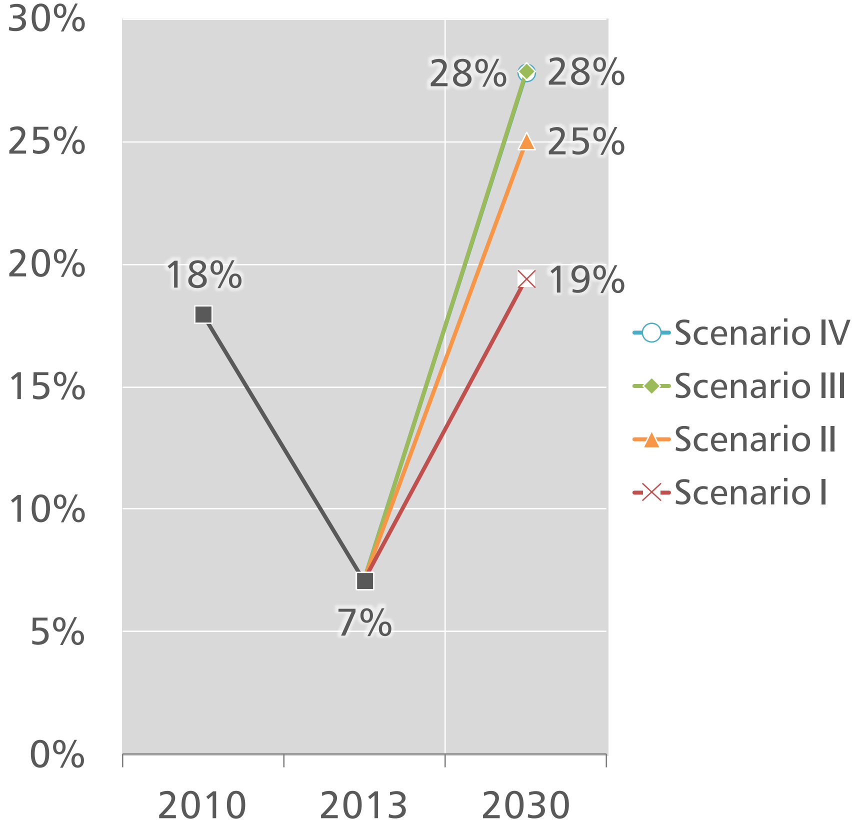


Excluding power purchased

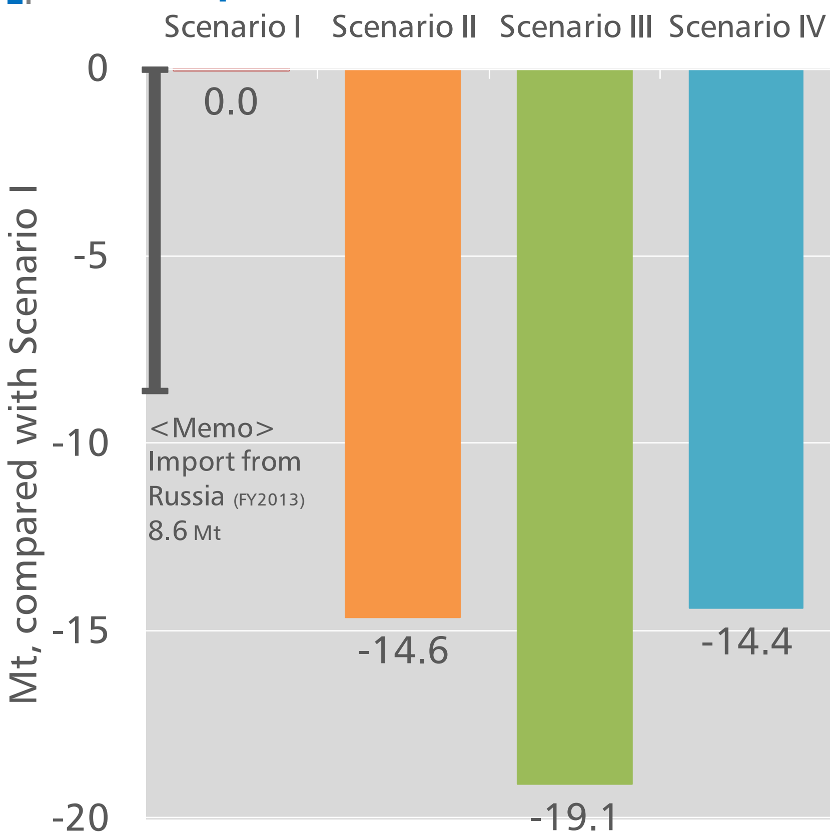
Energy security ▷ Self-sufficiency ratio and LNG imports

- 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



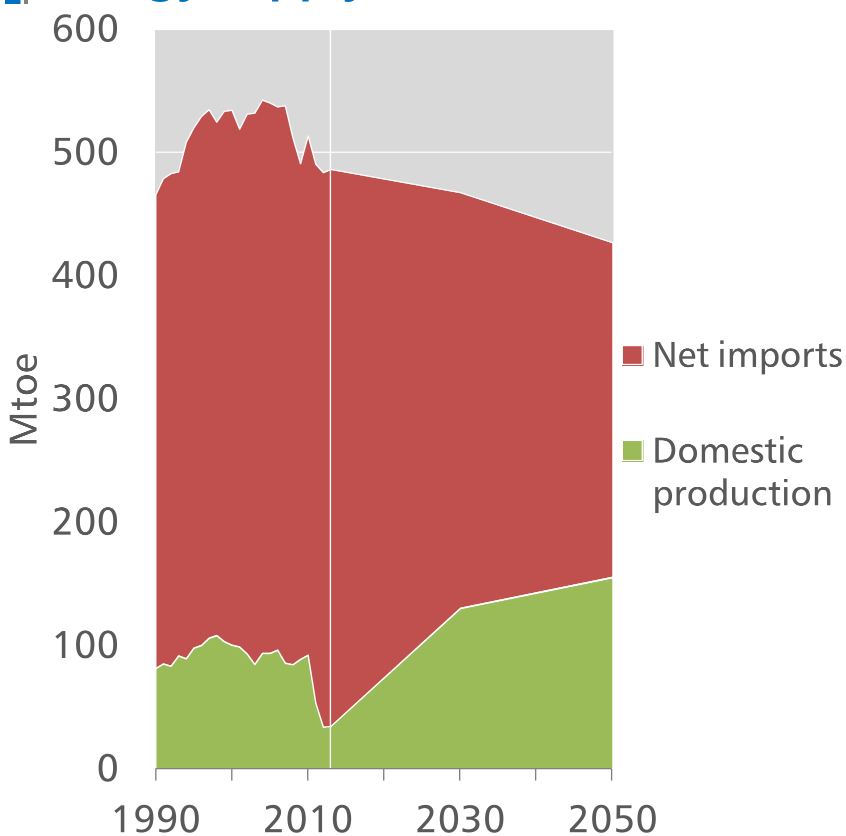
LNG import volume



Beyond scenarios through 2030

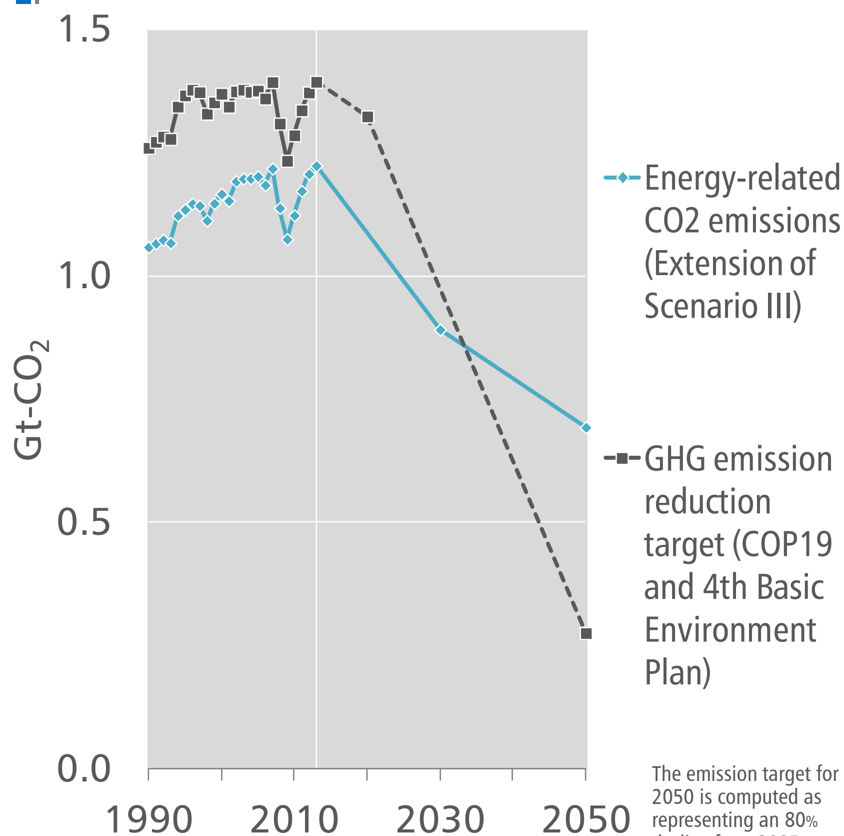
- While energy consumption and imports will decline gradually, ensuring physically and economically secure energy supply will remain a challenge.
- New technology developments such as artificial photosynthesis are indispensable for attaining the Basic Environment Plan based on an ambitious GHG emission reduction target (reductions by 80% in 2050).

Energy supply



Extending the *Scenario III*

GHG emissions



The emission target for 2050 is computed as representing an 80% decline from 2005.

Methane hydrate | Attention-attracting domestic resource

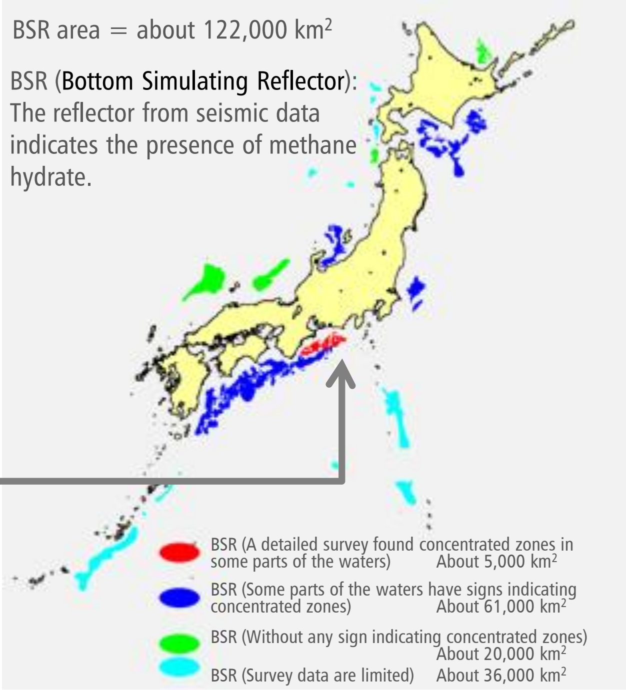
- Methane hydrate contains methane as a main component of natural gas.
- Methane hydrate exists in a low-temperature and high-pressure environment. There are two types of methane hydrate in offshore of Japan: shallow-type and pore-filling sand-layer type.

Eastern Nankai Trough
(From waters off Shizuoka Prefecture to those off Wakayama Prefecture)

Concentrated zones (767 km²): 573.9 billion m³ (20 Tcf)

Other zones (3,920 km²): 567.6 billion m³ (20 Tcf)

Total: 1,141.5 billion m³ (40 Tcf), equivalent to Japan's natural gas consumption for about ten years



- Test production through the decompression procedure* took place at a depth of 857-1,405 m in waters 70-80 km south-southeast of the Atsumi Peninsula in March 2013. Gas output over some six days totalled about 120,000 m³.

* The procedure reduces pressure within layers to decompose methane hydrate into water and gas.

- Reconnaissance geological surveys for shallow methane hydrate was conducted between April and June 2014 in the offshore areas around the Oki Islands, the Joetsu region, the Akita and Yamagata prefectures, and the Hidaka region. These surveys revealed 746 newly discovered gas chimney structures which are potential sites for methane hydrate accumulation. The number of gas chimney structures which have been confirmed over the past two years totals 971.

Source: Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium)

Methane hydrate production should follow suit of shale revolution

"Basic Energy Plan" (April 2014)

The government will develop technology to realise commercial methane hydrate production by FY2018. While watching the international situation, the government will promote technology development so as to allow a private sector-led project for commercial methane hydrate production to start between 2023 and 2027.

Advantages

- Drilling costs and time are limited as methane hydrate layers are shallow.
- Given that methane hydrate resource locations are close to consumption areas, gas may be supplied via pipelines if they can be laid.
- Natural gas supply sources can be dispersed.

Challenges

- While oil and natural gas flow automatically, a process is required to decompose methane hydrate into water and gas.
- Daily methane gas production through the decompression procedure is limited to some 50,000 m^3, one digit less than natural gas field output (more than several hundreds of thousands of cubic metres on average).
- As decomposition represents endoergic reaction, prolonged production may lower layer temperatures, resulting in declining production. Well drilling costs will increase as a large number of wells are required.
- Sand inflow may be serious as methane hydrate exists in loose layers frequently. Earth slides could occur to affect production.

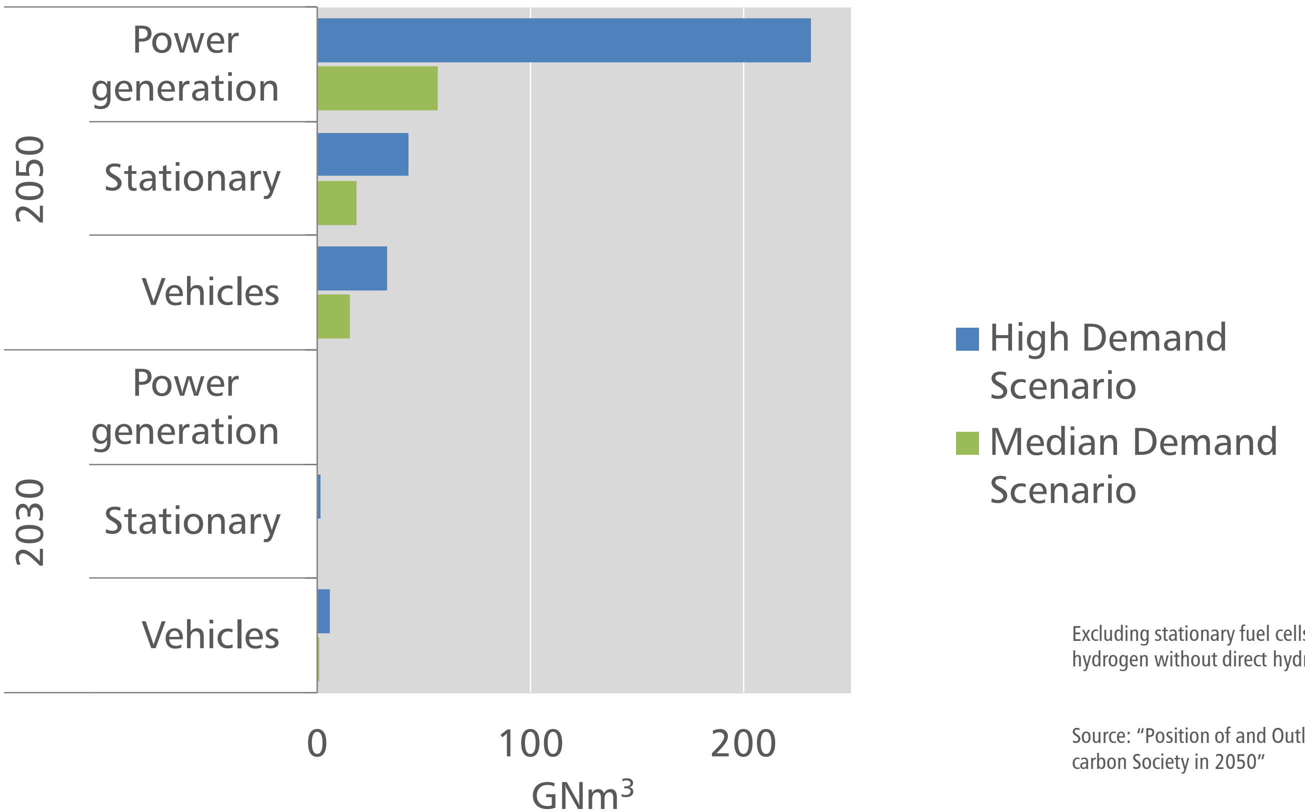
Methane hydrate production technology is still under development. Given a long period of time required for establishing technology, securing economic efficiency, constructing pipelines and other shipment facilities and gaining users' understanding, commercial methane hydrate production in full scale is expected to come in the 2030s.

Source: Research Consortium for Methane Hydrate Resources in Japan (MH21 Research Consortium)

Hydrogen | Key future option

- Japan launched stationary fuel cells for household in 2011 for the first time in the world. Fuel cell vehicles have been put on sale in 2014. Large-scale hydrogen-fired power generation will start in 2015.
- The use of hydrogen will be limited due to infrastructure, technological, cost and other problems. From the long-term viewpoint, however, hydrogen could become one of the key energy sources.

Example of hydrogen demand projections



Excluding stationary fuel cells that reform oil or city gas to extract hydrogen without direct hydrogen supply.

Source: "Position of and Outlook for Hydrogen Energy toward a Low-carbon Society in 2050"

Requirements for energy policy

■ Desirable energy mix

- An energy mix set by the government is requested to be a target backed by policy measures.
- The government should work out a feasible energy mix by taking into account long lead times and lifetimes peculiar to energy and environment technologies, technological innovation, and physical, social and political constraints on the introduction of these technologies.
- The government should regularly review policy progress and timely revise the target energy mix in consideration of domestic and global energy, economic and environmental situations.

■ Direction required for energy policy

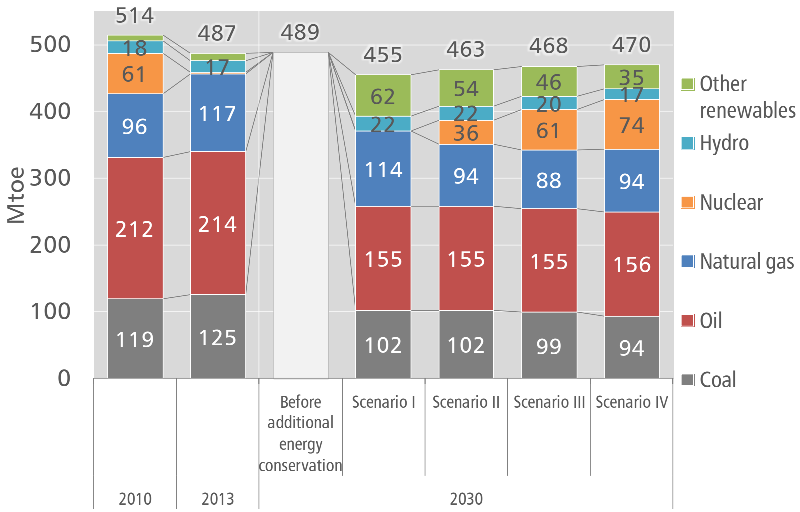
- The principle of "Three Es and S" (energy security, environment, economic efficiency and safety) for energy policy is an everlasting evaluation standard.
- Energy security and climate change measures should be continuously enhanced. Fossil fuel conservation and the expansion of the self-motivating energy ratio will be indispensable.
- The government should timely implement an appropriate policy for achieving goals in a manner to minimise burdens on society.



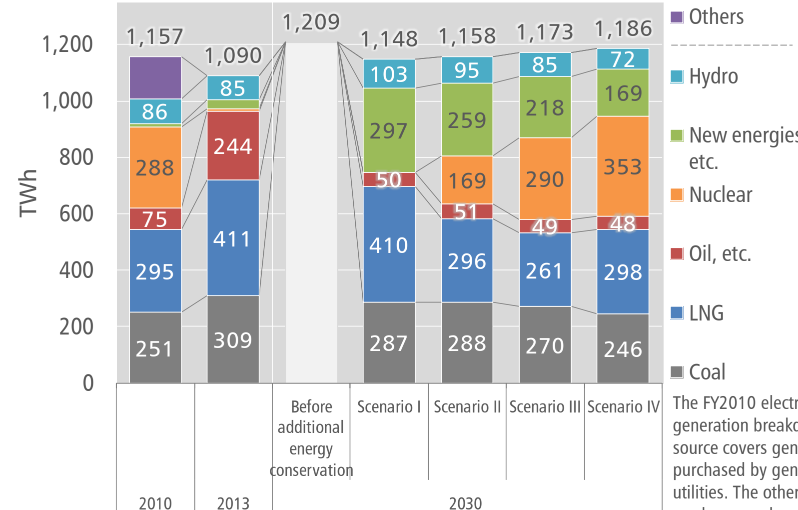


Annex | Major indicators

Primary energy supply

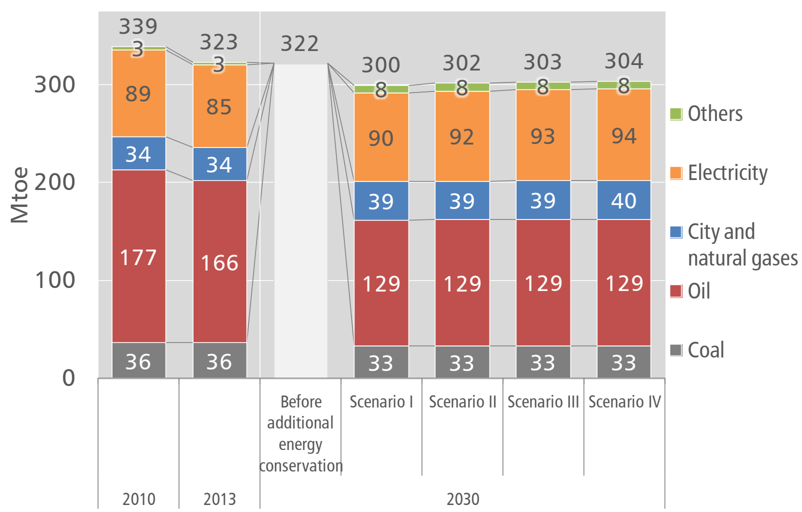


Electricity generation mix

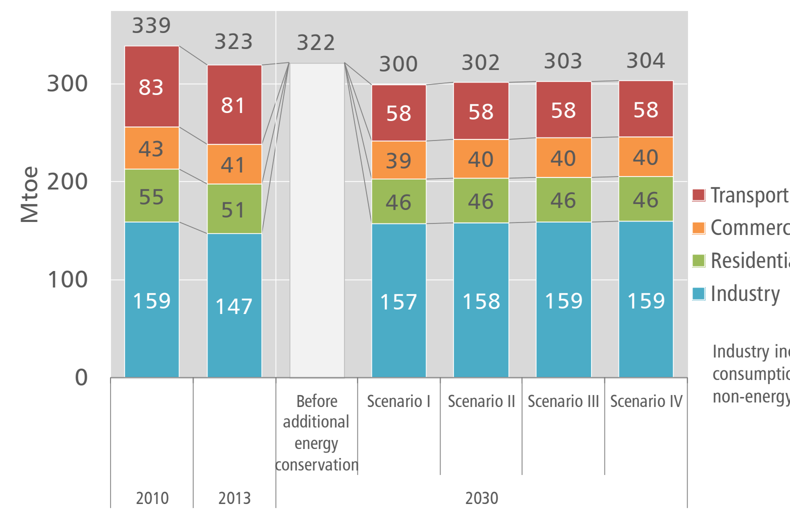


The FY2010 electricity generation breakdown by source covers generated and purchased by general electric utilities. The others cover power producers and suppliers, and autoproducers.

Final consumption by energy source



Final consumption by sector



Industry includes consumption for non-energy use.