The Challenges for Petroleum in a Carbon Constrained World

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The Institute of Energy Economics, Japan

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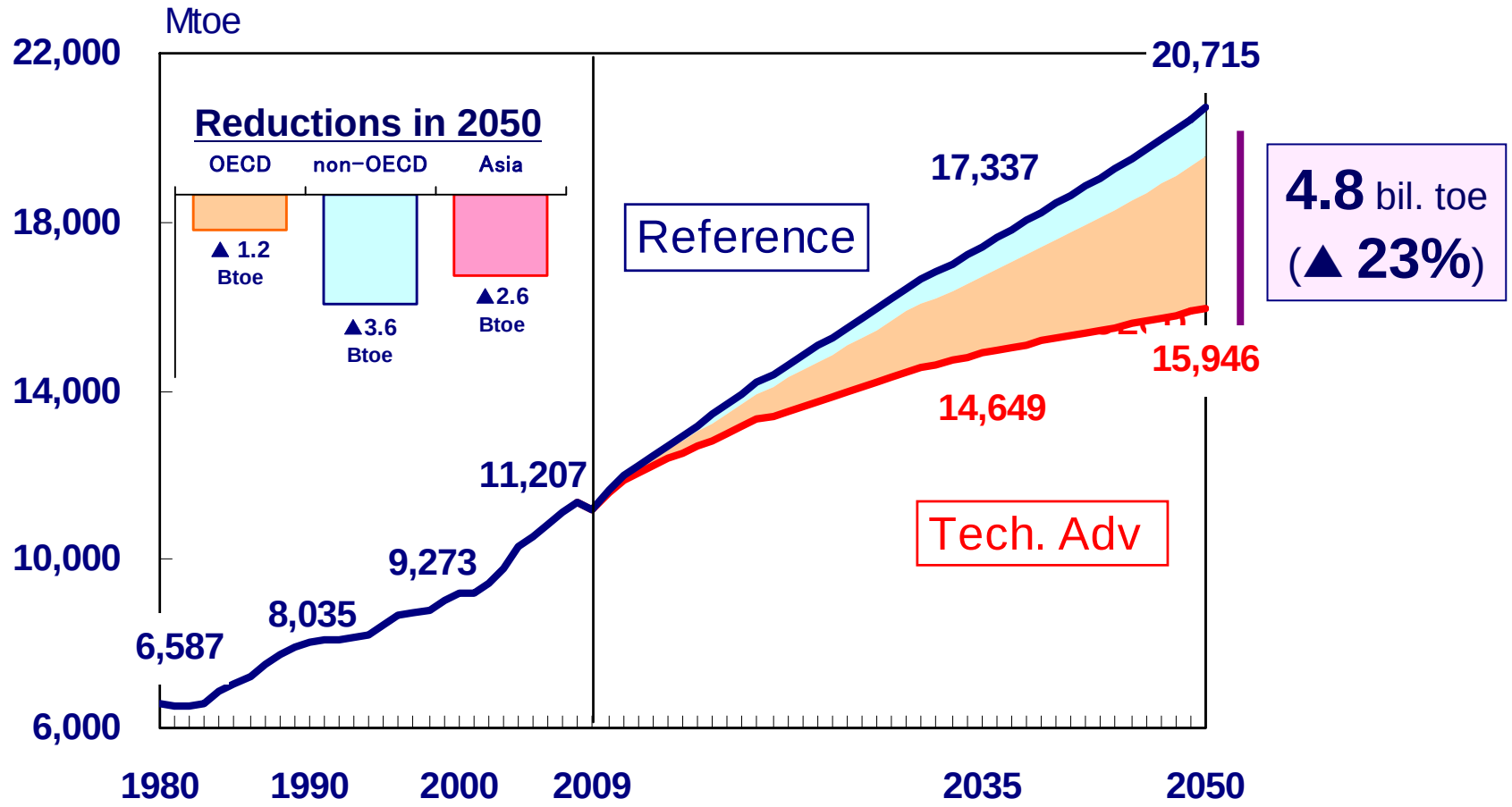
(4) Petroleum as convenient fuel for vehicles

(5) Petroleum as convenient fuel even for electricity generation and industrial use

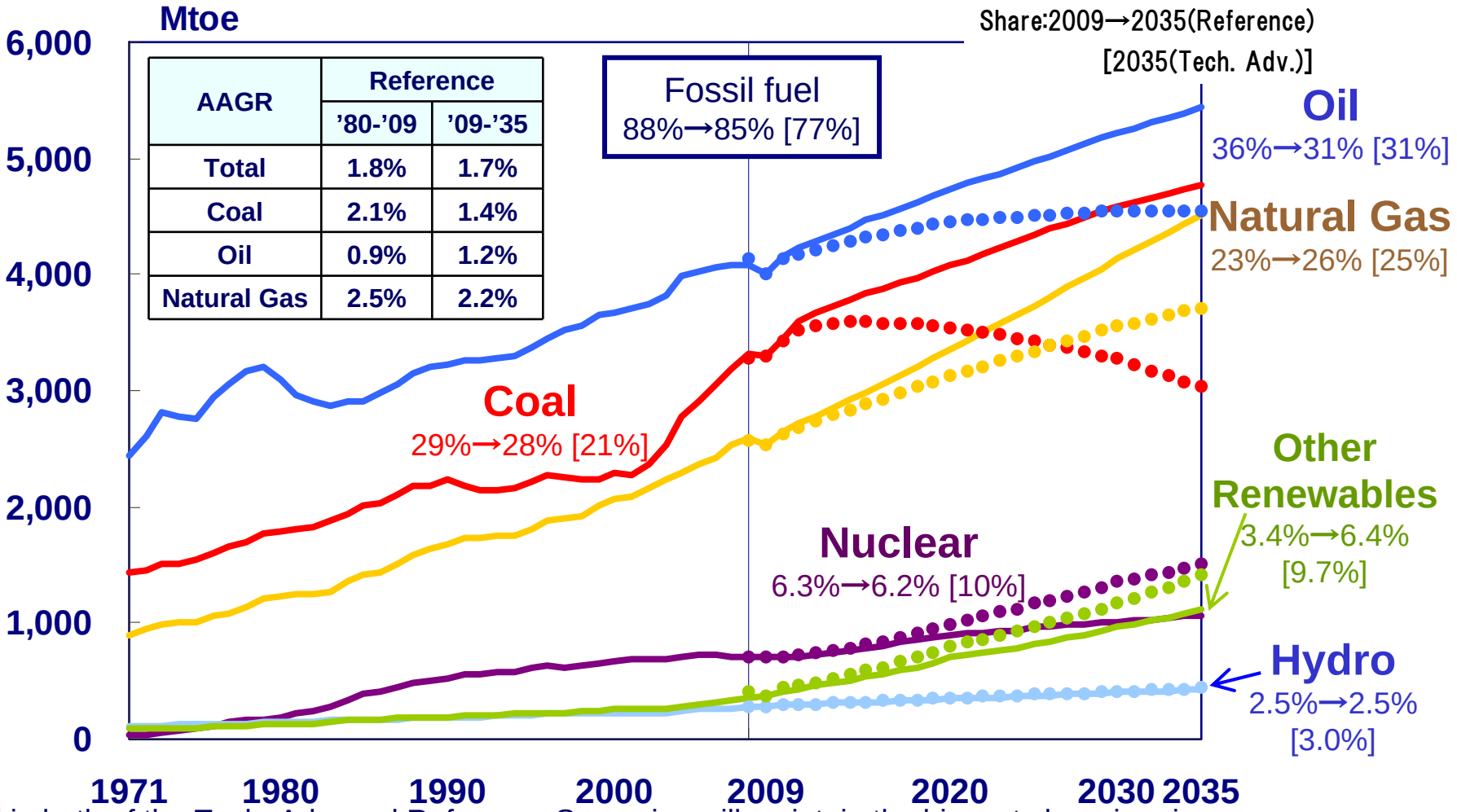
(1)World outlook for primary energy consumption toward 2050



●The world primary energy demand will peak out around 2050 in the Tech. Adv. Scenario.

● In 2050, world primary energy demand in the Tech. Adv. Scenario will be decreased by 4.8 Btoe in comparison with the Reference Scenario. The demand by OECD and non-OECD will be decreased by 1.2 Btoe and 3.6 Btoe, respectively. The demand by non-OECD and Asian countries will be largely decreased because of diffusing innovative technologies.

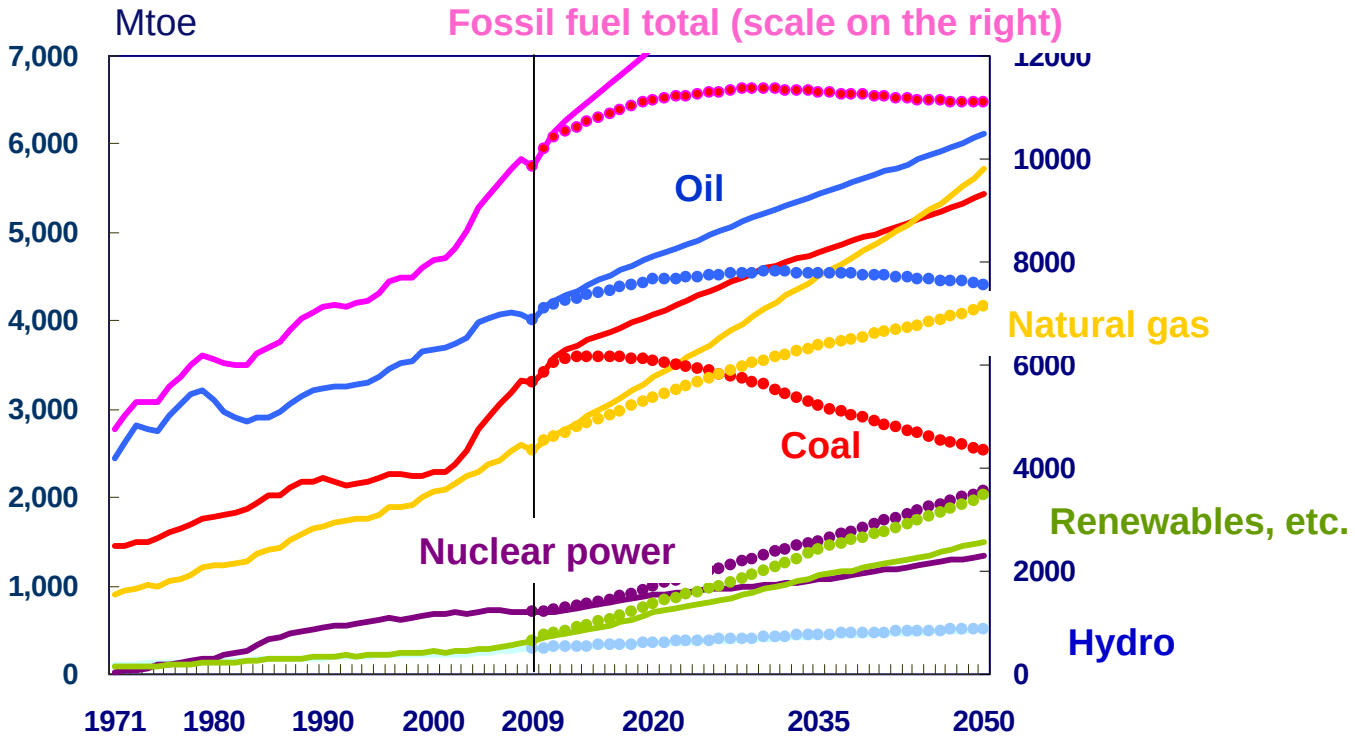
(2)World Outlook for Petroleum and other energy
① Toward 2035



- Oil in both of the Tech. Adv. and Reference Scenarios will maintain the biggest share in primary energy mix by 2035. In the Tech. Adv. Scenario, oil demand will peak in 2030.
- Fossil fuels will continue to account for the largest share by 2035, though its share will slightly decrease from 88% in 2009 to 85% in the Reference Scenario in2035 or to 77% in the Tech. Adv. scenario
- Natural gas in the Tech. Adv. scenario will continue to grow with its future extensive use in various sectors.

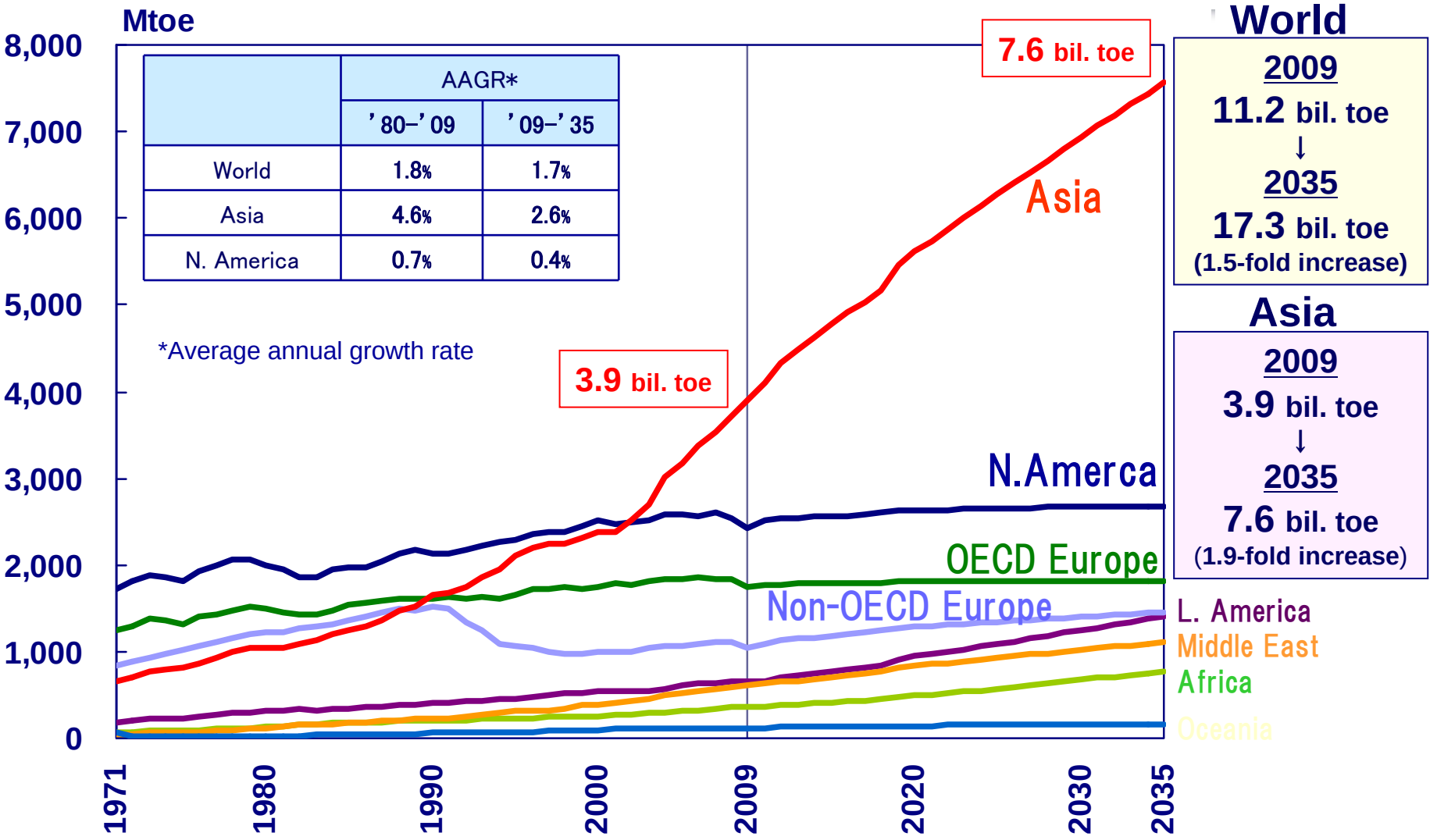
(2) World Outlook for Petroleum and other energy ②Toward 2050

- In the reference case, the demand for petroleum will still be growing even in 2050.
- In the technologically advanced case, the demand for petroleum will peak around 2030. Petroleum and natural gas will have almost equal shares in 2050.
- In the technologically advanced case, GHG emissions will decrease by 29% from 2005 level, not by half. Halving GHG emissions will require extra efforts, which may make natural gas have a greater share than petroleum.



Source: Asia / World Energy Outlook 2011 (IEEJ)

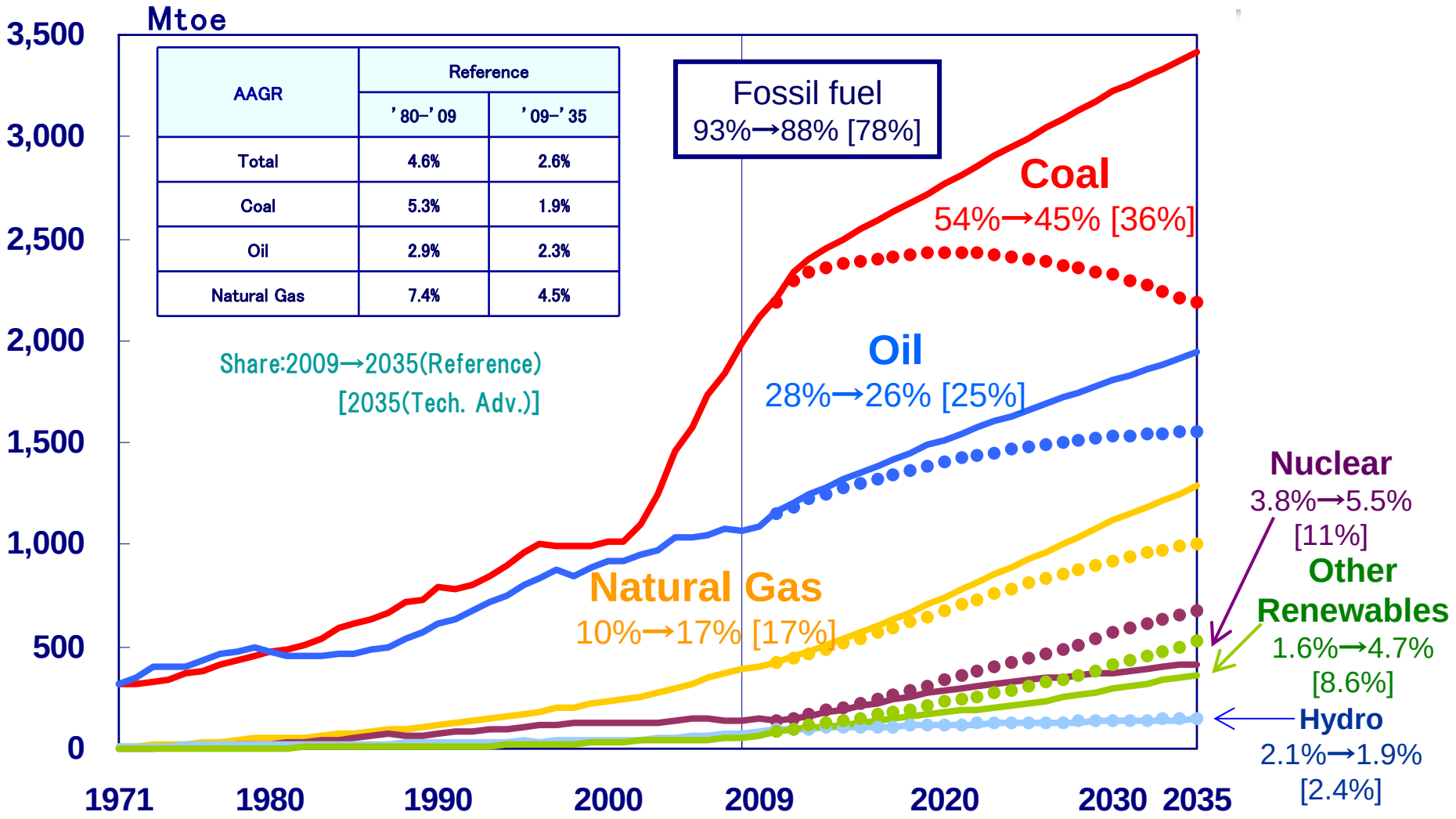
(3) Asia as the center for Energy/Petroleum Consumption
①Regional comparison



●By 2035, primary energy demand of Asia will double from the current level, reflecting high economic growth; 3.9 billion toe(2009) → 7.6 billion toe(2035).

●Non-OECD will represent 90% of incremental growth of global energy demand toward 2035.

(3) Asia as the Center for Energy /Petroleum Consumption
②　Sectoral Comparison in Asia

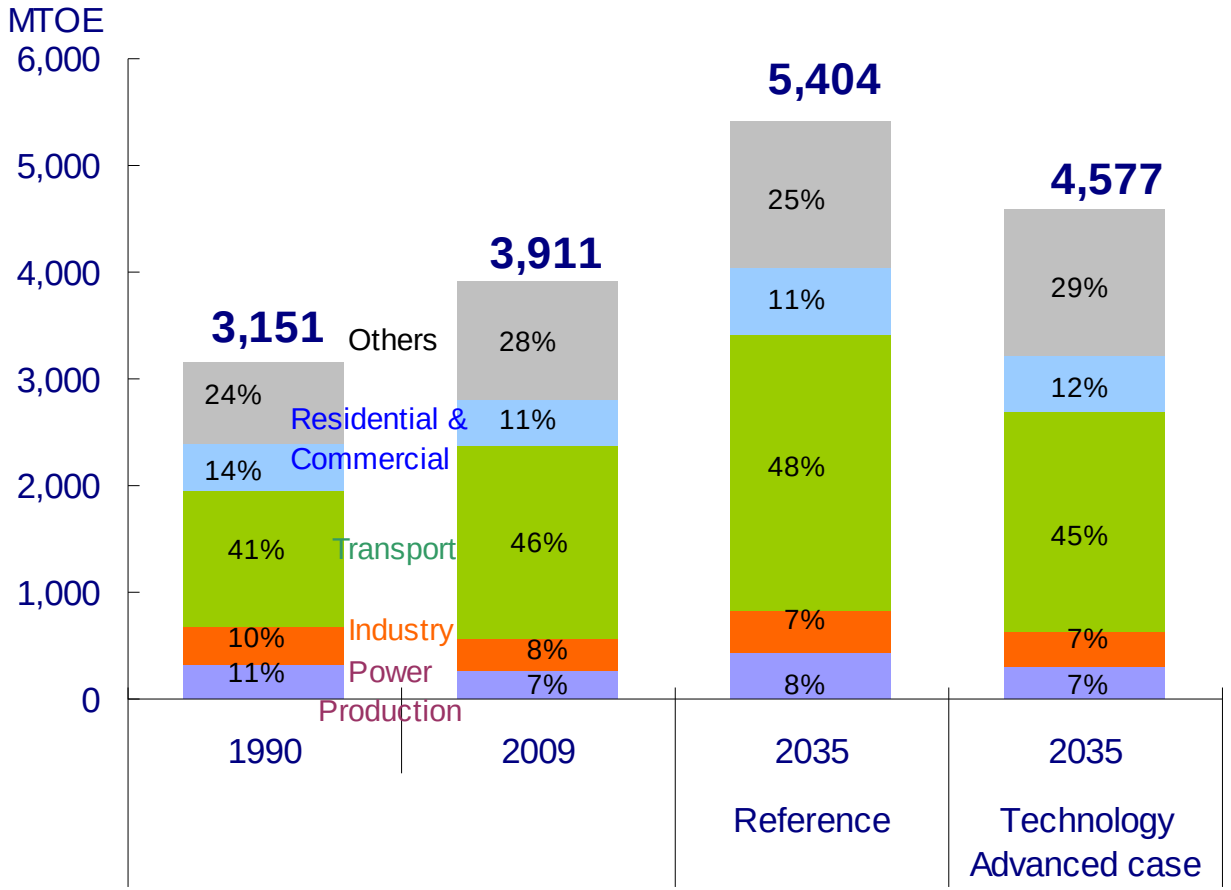


●Coal and oil will continue to maintain the dominant share in Asian energy demand through 2035. The share of natural gas will increase substantially reaching 17% by 2035, driven mainly by power generation.

●Coal share in the Tech. Adv. Scenario will significantly decrease, but will maintain the largest share (36% of total) in primary energy mix by 2035.

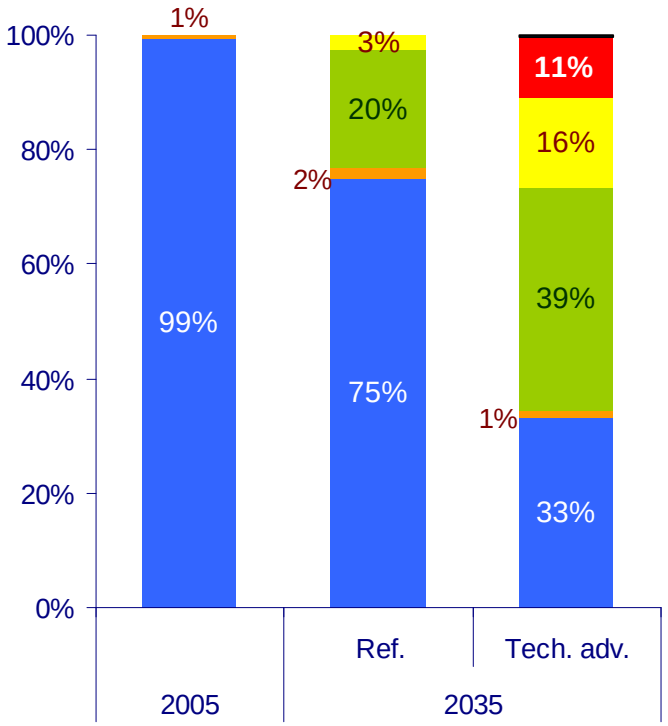
(4) Petroleum as convenient fuel for vehicles ①Petroleum consumption by sector

- In the reference case, the demand for petroleum grows by 1.4 fold (2009 ➔2035). The growth of share of transport sector is the largest (46%➔48%).
- In the technologically advanced case, the demand growth is constrained 1.2 fold. The share of sector remains approximately same as of 2009

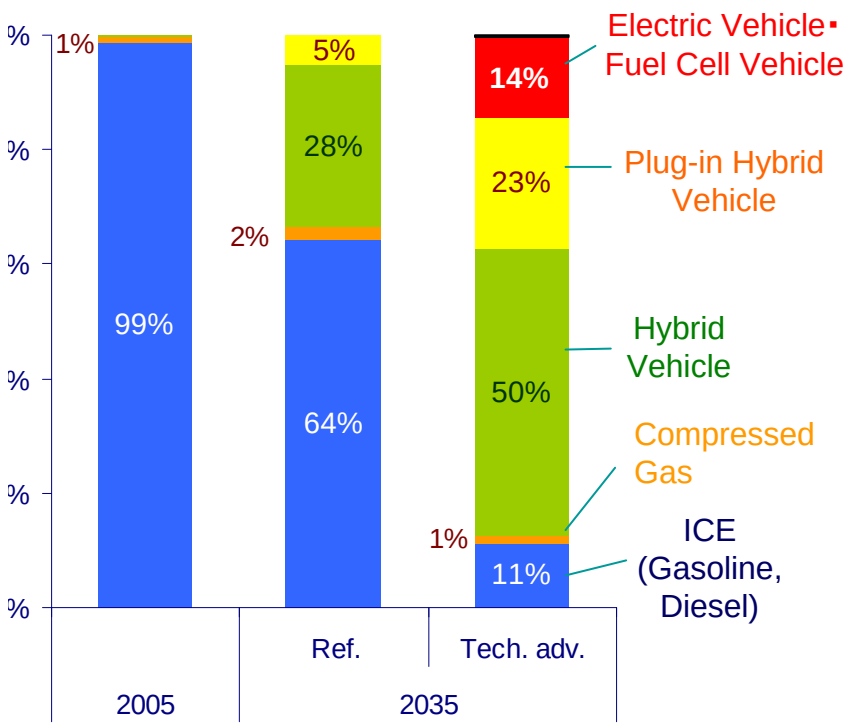


(4) Petroleum as Convenient Fuels for vehicles
② Trend of Shares by Vehicle Type Toward 2035

【The Share of Vehicle Stocks by Type (World)】



【The Share of Vehicles' Annual Sales by Type (World)】



Share of clean energy vehicles in total stocks (2035)

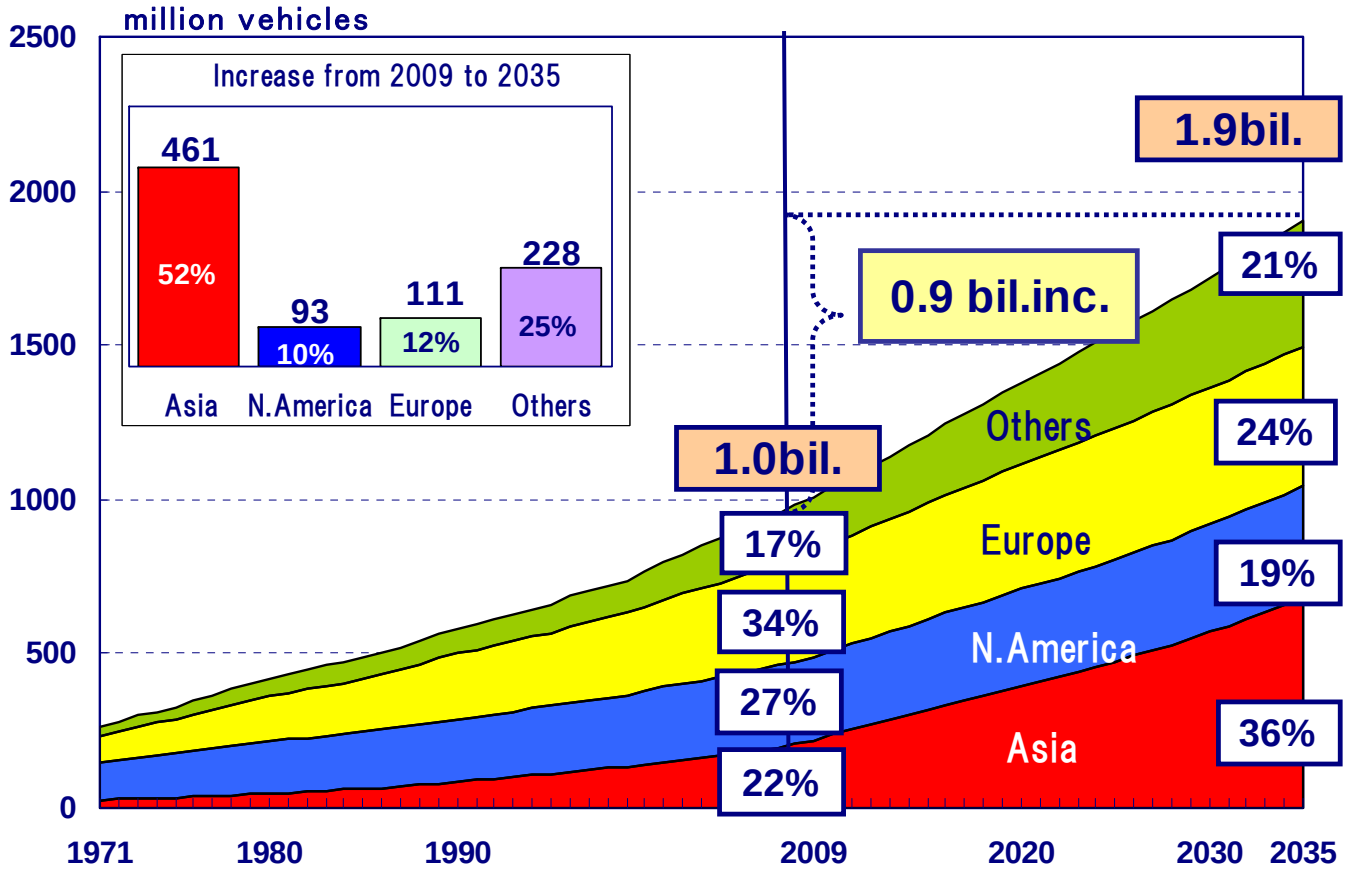
Reference **25 %**
Tech. Adv. **67 %**

Share of clean energy vehicles in annual sales (2035)

Reference **36 %**
Tech. Adv. **89 %**

●In Tech. Adv. Scenario, the clean energy vehicles will account for approximately 67% of total stocks in 2035.

(4) Petroleum as Convenient Fuels for vehicles
③ Asia as Growth Center for Vehicles



World

2009
1.0 bil.
↓
2035
1.9 bil.
(**1.9**-fold inc.)

Asia

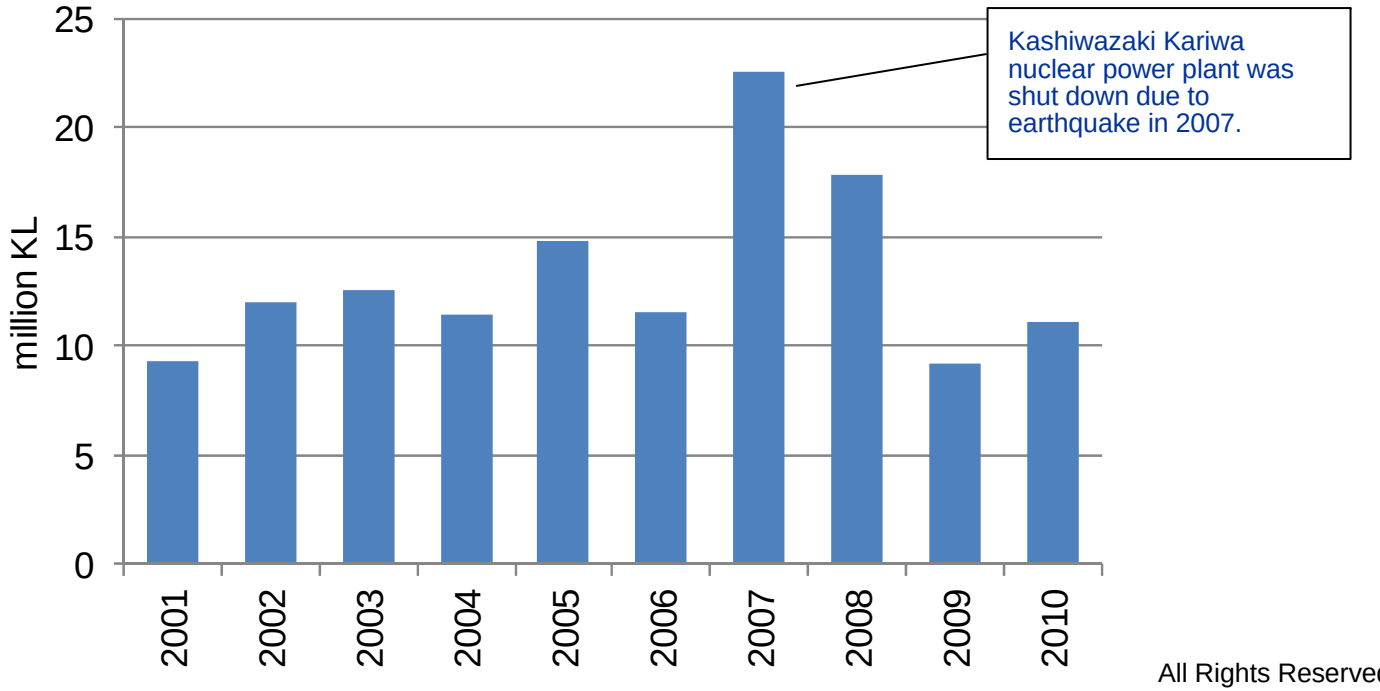
2009
0.22 bil.
↓
2035
0.7 bil.
(**3.0**-fold inc.)

- Approximately 36% of the world vehicle stocks concentrates in Asia.
- The share of vehicle stocks in OECD will decline from 69% in 2009 to 47% in 2035.The stock in Non-OECD will surpass that of OECD by 2035.

(5) Petroleum as convenient fuel even for electricity generation and industrial use

- Oil fired power plant have been the “last resort” for Japanese power supply.
  - Oil fired power plants have made up for the lost nuclear power supply every time nuclear power plants were unexpectedly shut down.
  - Flexibility of oil supply is unrivaled, especially in case of emergency.
- Oil fired power generation owned by steel mills or refineries played an important role to avoid power shortage this summer.

Oil consumption by Japanese power companies



2. Specific Measures to Cope with Carbon Constraint

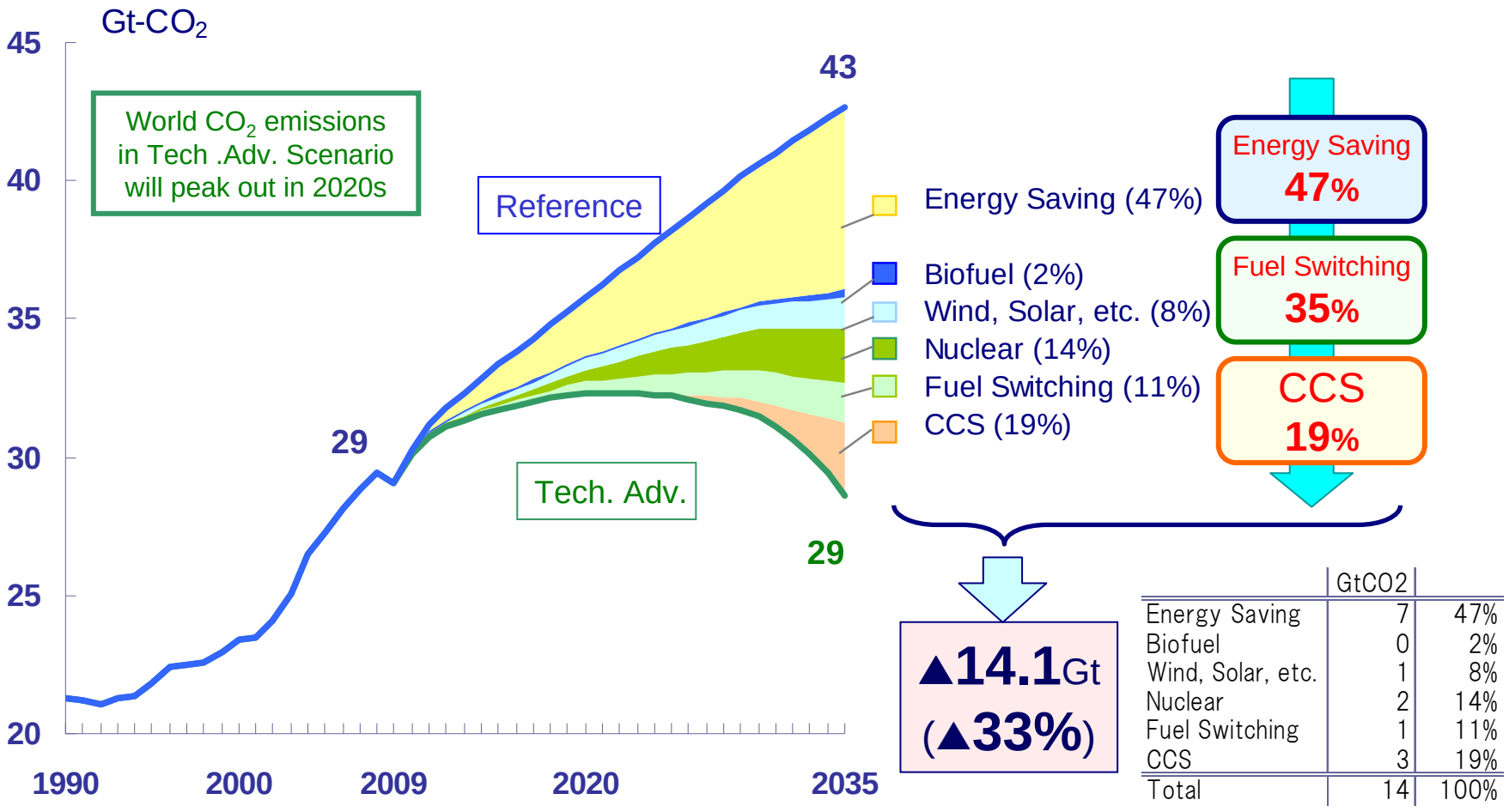
(1) Emission reduction by various technologies
- ① Toward 2035
- ② Toward 2050
- ③ Impact of low or zero nuclear power scenario

(2) Specific Measures for Petroleum
- ①CCS
- ②CCU
- ③Production of hydrogen

(3) next generation Vehicles

(1) Emission Reduction by Various Technologies

① Toward 2035

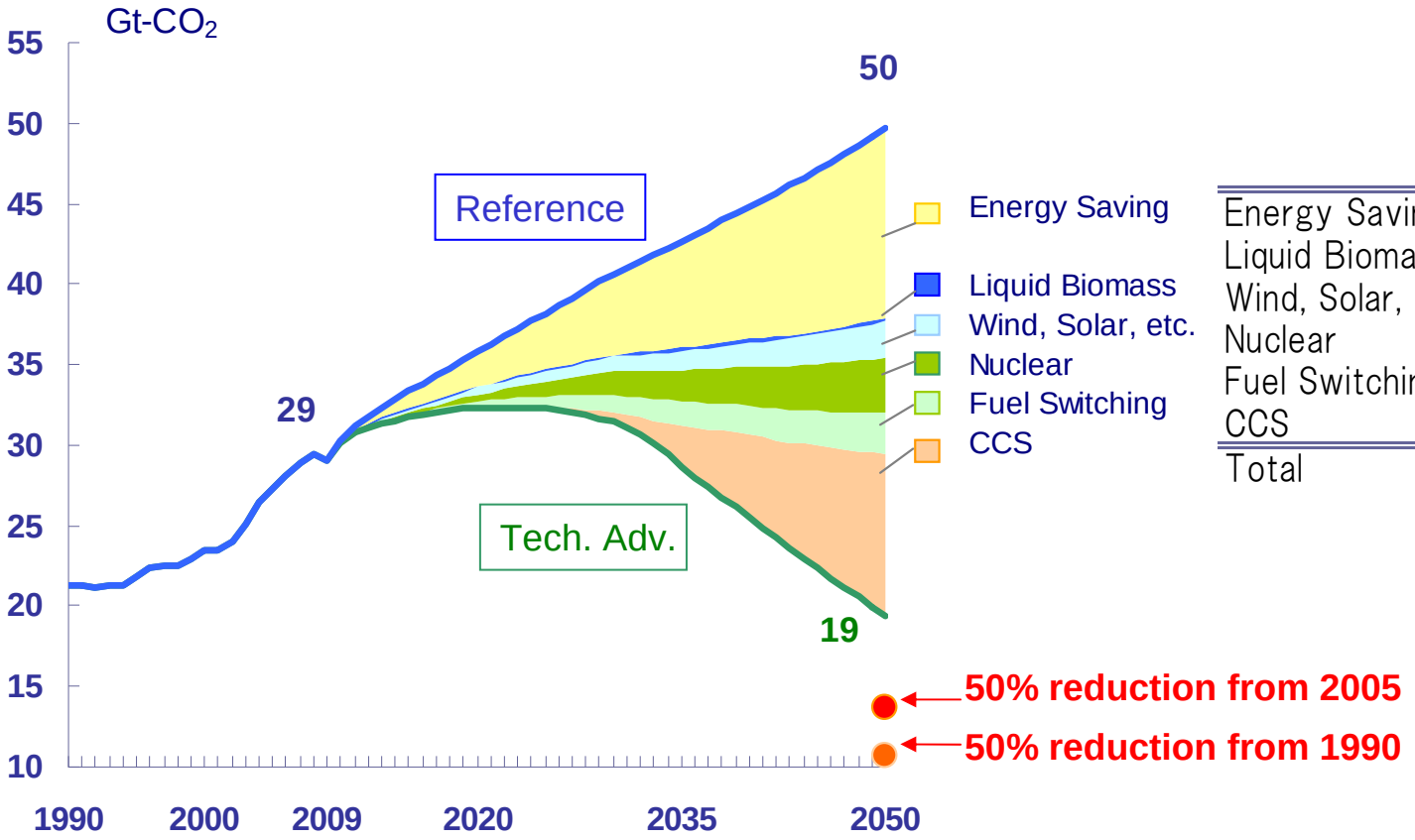


	GtCO2	
Energy Saving	7	47%
Biofuel	0	2%
Wind, Solar, etc.	1	8%
Nuclear	2	14%
Fuel Switching	1	11%
CCS	3	19%
Total	14	100%

■ In the Tech. Adv. Scenario, between 2005 and 2020 the world CO_2 emissions will increase by 5.1 Gt-CO_2 (or 19% up from the 2005 level), while the CO_2 emissions will reach its peak during 2020s with the introduction of advanced energy and environmental technologies.

■ Various technological options, including energy saving, enhancement of power generation efficiency, renewables, nuclear, and CCS altogether contribute to massive CO_2 emissions reduction.

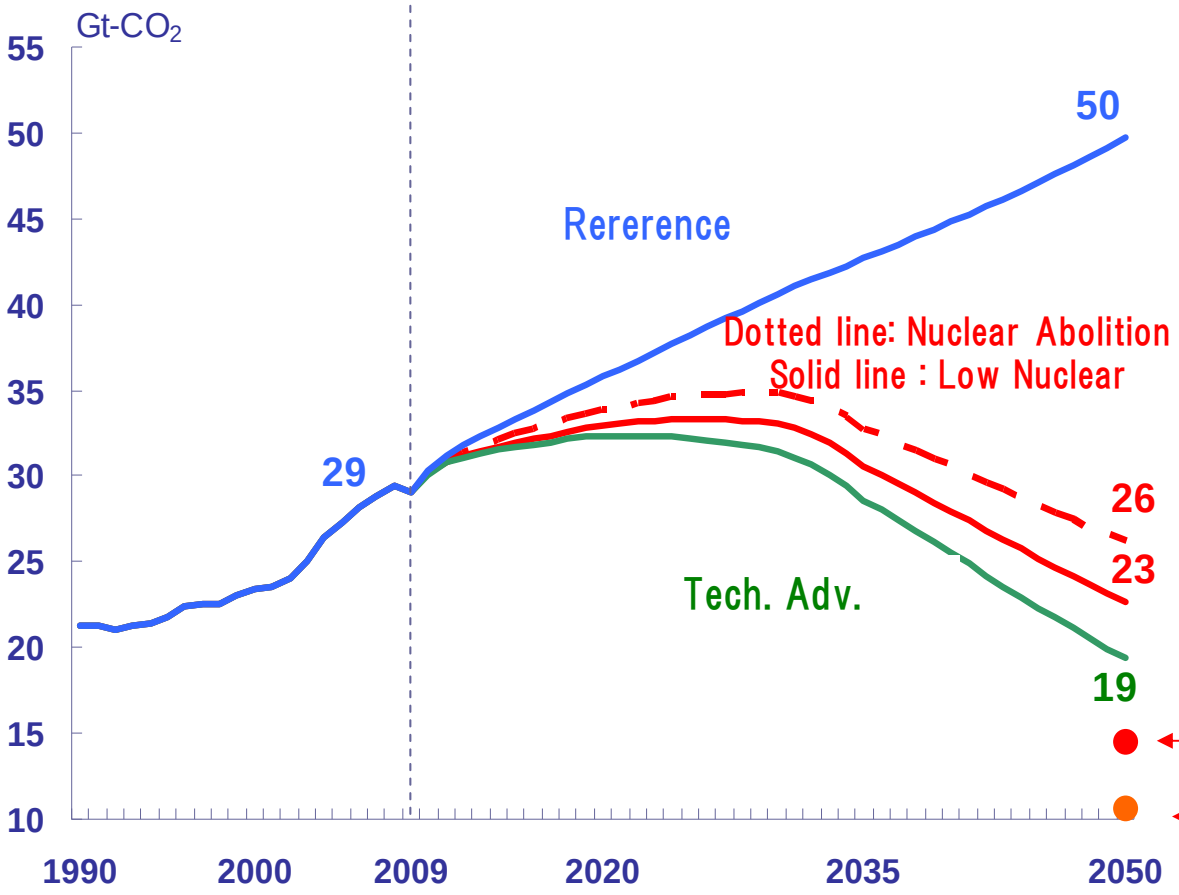
(1) Emission Reduction by Various Technologies
②　Toward 2050



	Gt	
Energy Saving	12	39%
Liquid Biomass	0.2	1%
Wind, Solar, etc.	2	8%
Nuclear	3	11%
Fuel Switching	3	8%
CCS	10	33%
Total	30	100%

●Energy saving technology principally contributes to the world CO_2 reduction in 2050. Fuel switching and CCS will substantially mitigate global emissions as well.
●In order to halving world CO_2 emissions, further policy and technological measures are required, such as progressive R&D, and development of low-carbon-emitting cities.

(1) Emission Reduction by Various Technology
③ Impact of Low or Zero Nuclear Power Scenario

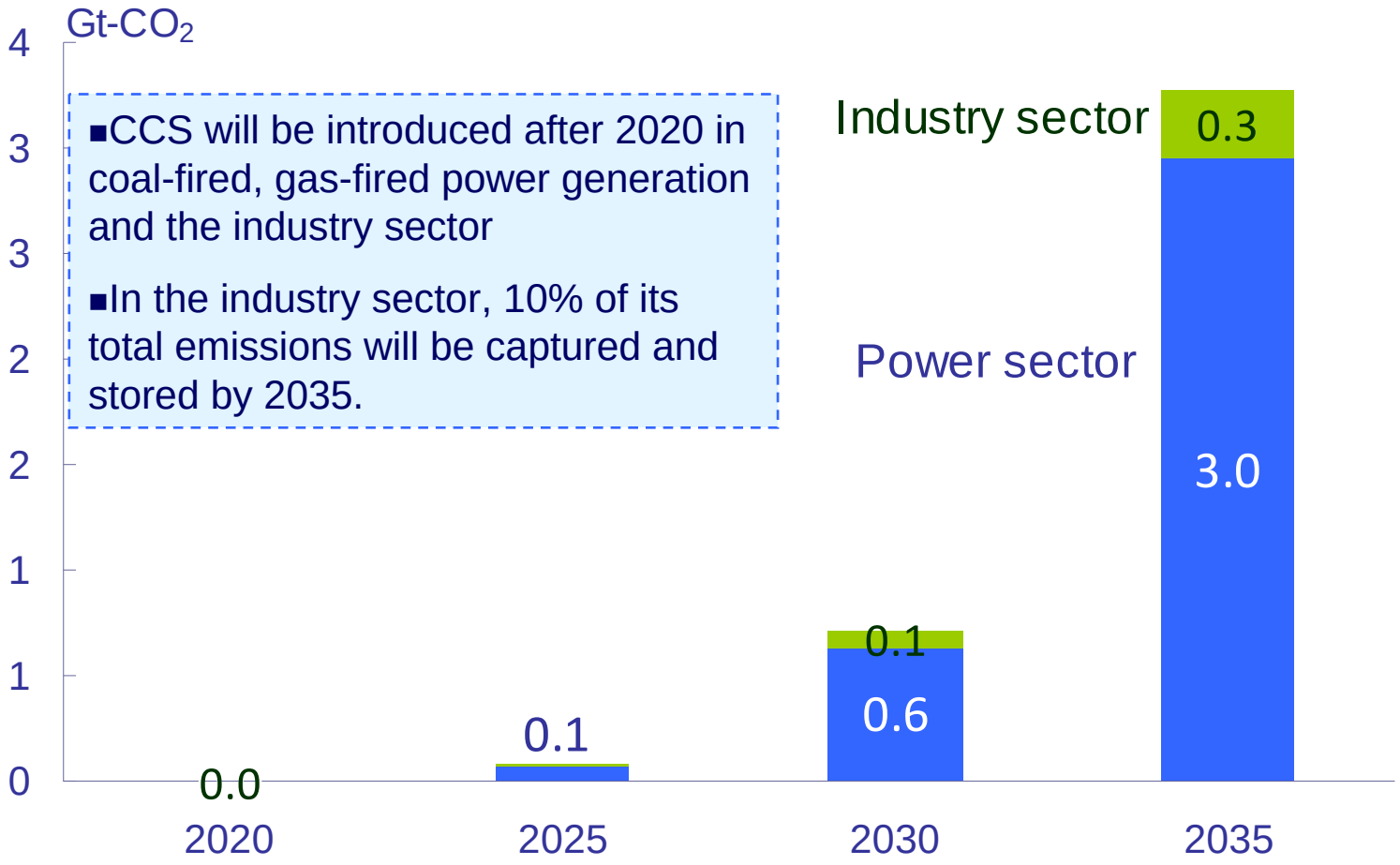


World CO_2 emission in 2050

	from 1990	from 2005
Tech.Adv.	-9%	-29%
Low Nuclear	+7%	-17%
Nuclear Abolition	+23%	-4%

● In the Low Nuclear or Zero Nuclear Scenario (replaced by fossil-fuel fired), CO_2 emission in 2050 will become larger than that in the Tech. Adv. Scenario by 4Gt(18% or 36%).

(2)① CCS (Carbon Capture and Storage)
a. Prospect of CCS



●Cumulative captured and stored CO_2 from 2020 to 2035 will reach 12 Gt. Theoretical potential of CCS in geological structures is estimated at 10 trillion tons, and that of combined total of depleted gas field, oil field and coal field, is estimated to reach1 trillion ton, suggesting that projected CO_2 emissions reduction from the CCS in the Tech. Adv. Scenario can be accommodated.

(2) ②CCS (Carbon Capture and Storage)
b. Petroleum consumption vs. cost of CCS

1) By how much can the cost be reduced?
   a. Cost of capture
   b. Cost of storage
   c. Cost of transportation

2) By how much can the cost be compensated by the benefits of enhancing the productivity of oil and gas?

3) Consuming countries may have to reduce petroleum use more rapidly if CCS cost remains high.

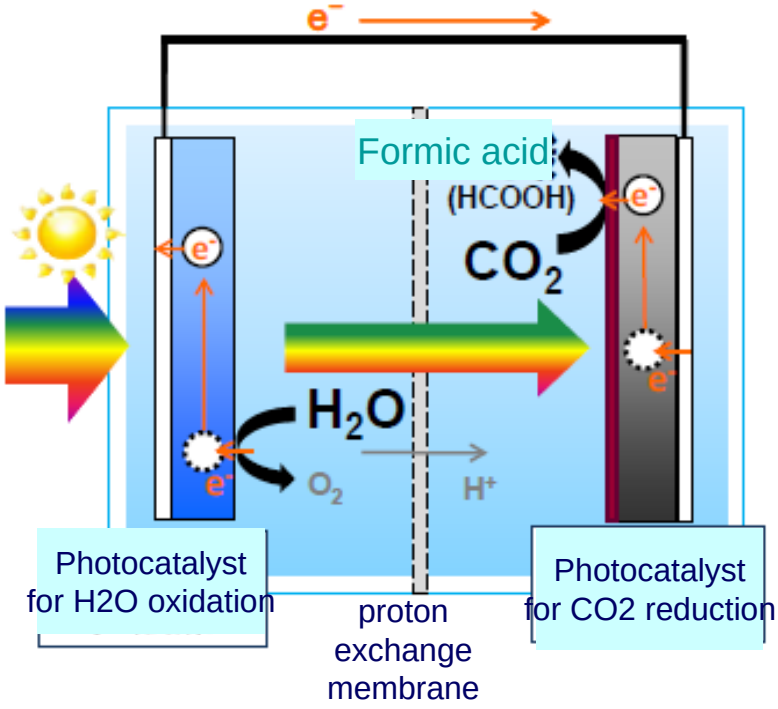
(3) ②CCU(Carbon Capture and Use)
ａ. What is CCU?

- CCU is a technology for using carbon to produce chemical materials by, for instance, artificial photosynthesis.
  Dr. Eiichi Negishi, Nobel Prize Laureate for Chemistry in 2010, is one of the most prominent advocators of CCU technology.

- Dr. Negishi stated:
  - We can produce carbohydrate by recreating the function of plants through artificial photosynthesis using special metals as a catalyst.
  - This carbohydrate based on artificial photosynthesis could be used as a material for producing ethanol and even foodstuffs.
  - This would solve both global warming and food shortages, which are two of the biggest challenges facing humankind.
  - CCU would be more efficient for addressing climate change than the current measures or policies by major governments.

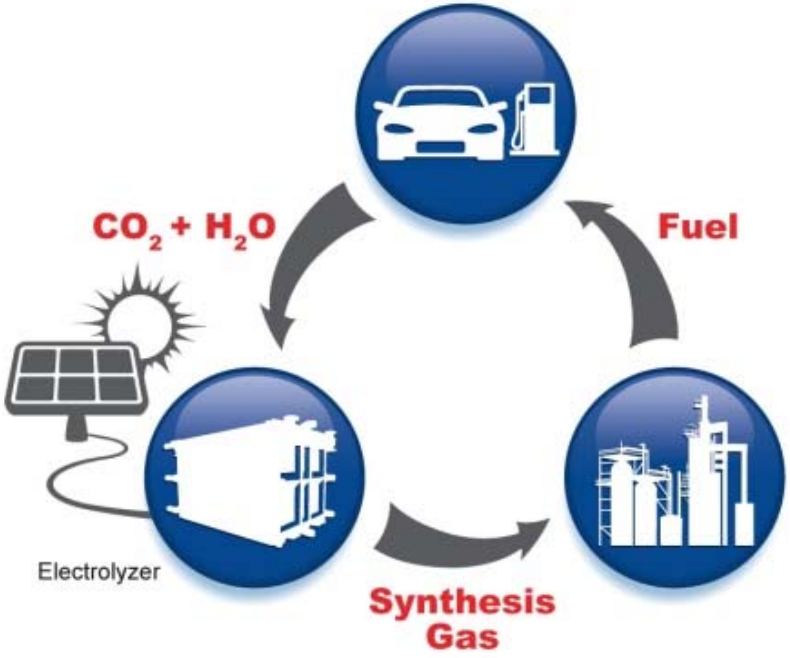
2) ②CCU(Carbon Capture and Use)
b. Example

●An experimental trail succeeded in realizing artificial photosynthesis in Sept.2011 by using water, CO2 and sunshine.



Artificial Photosynthesis

Source: Toyota Central R&D Labs., INC.



Artificial Photosynthesis

Source: http://www.tgdaily.com/

Note: Conversion rate is 0.04, which is one fifth of natural photosynthesis. The conversion rate needs to be improved further.

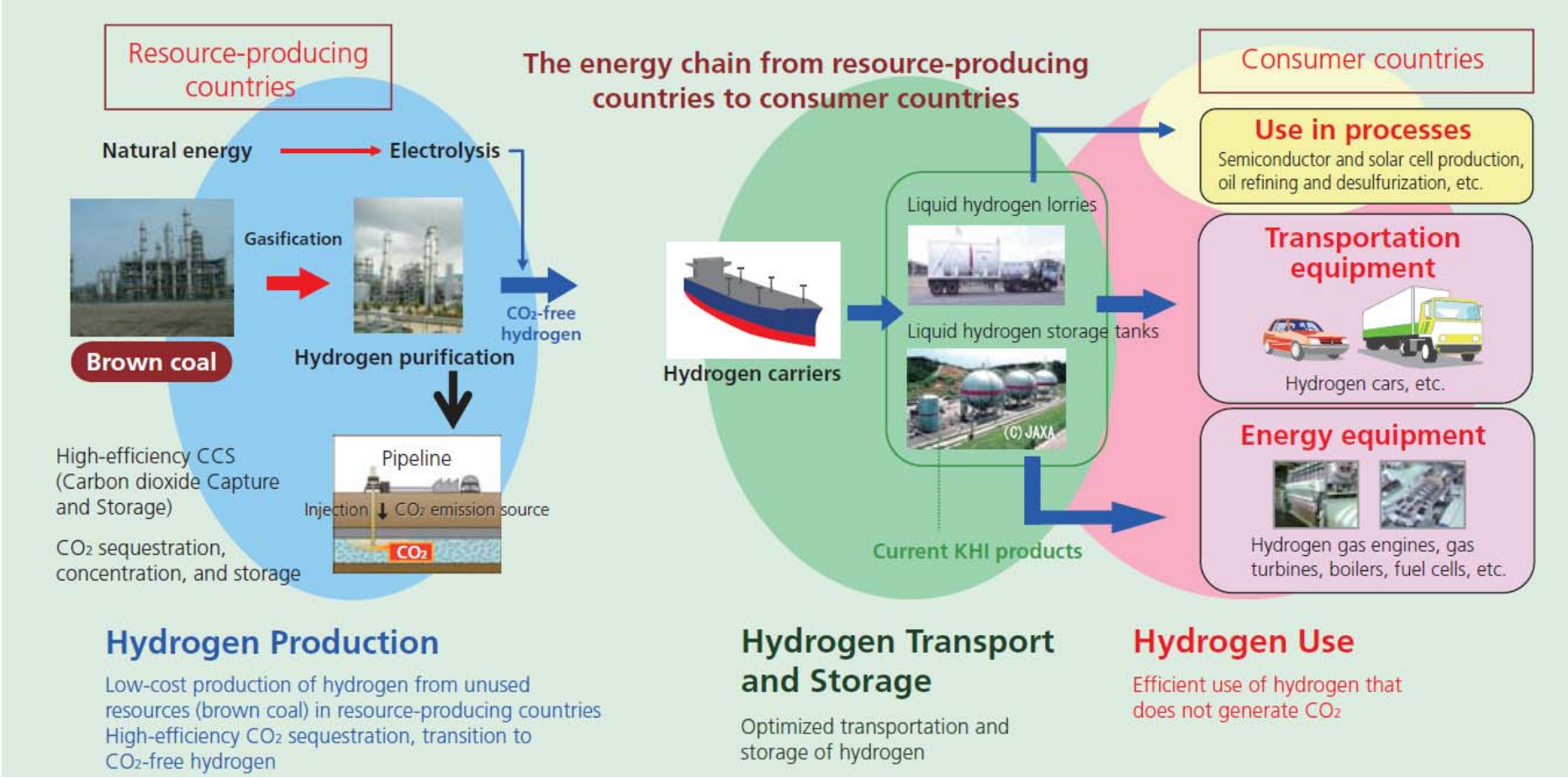
(4) ③Production of Hydrogen
a. Important implications

- The cheapest process for producing hydrogen is through chemical conversion from petroleum, but CO2 is emitted. If hydrogen can be produced and CO2 can be captured and stored in the oil-producing site, CO2 emissions would be eliminated.

- This would enable liquid hydrogen to be traded like LNG.
  If this hydrogen can be used for vehicles and other uses instead of petroleum, it would be of great help for oil-consuming countries which are running short of appropriate CCS sites.

(4) Production of Hydrogen ②Example

KHI's CO2-free hydrogen concept



(3) Next-Generation Vehicles

- There are still various options for next-generation vehicles that address the carbon constraint. Candidates include:
  - Electric vehicles
  - HB/PHB vehicles
  - Hydrogen engine vehicles
  - Fuel cell vehicles

- If hydrogen can be produced cheaply without CO2 emissions, it will greatly expand the scope of petroleum use for transportation.

4. Conclusions

① Petroleum is probably the most convenient fuel, but carbon constraints could greatly reduce the demand for petroleum. In this The future of petroleum demand depends much on the development of:
A) Asian market; B) Measures to cope with carbon constraint.

② The key to coping with carbon constraints is technology. Although various technologies are being developed, all of them have their merits and demerits. International cooperation is needed to accelerate technological development. Japan has both the motivation and capability to develop these technologies.

③ CCS is important but has its limits. CCU is being developed and has huge potential.

④ Fuel cell and hydrogen engine vehicles would be the most CO2-free and the most economic if hydrogen can be produced cheaply without emitting CO2.

Thank you very much !

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