Energy Transition and the Role of Hydrogen

Presentation at the Session Ⅱ
The 5th IEF-Kapsarc Thought Leaders' Roundtable

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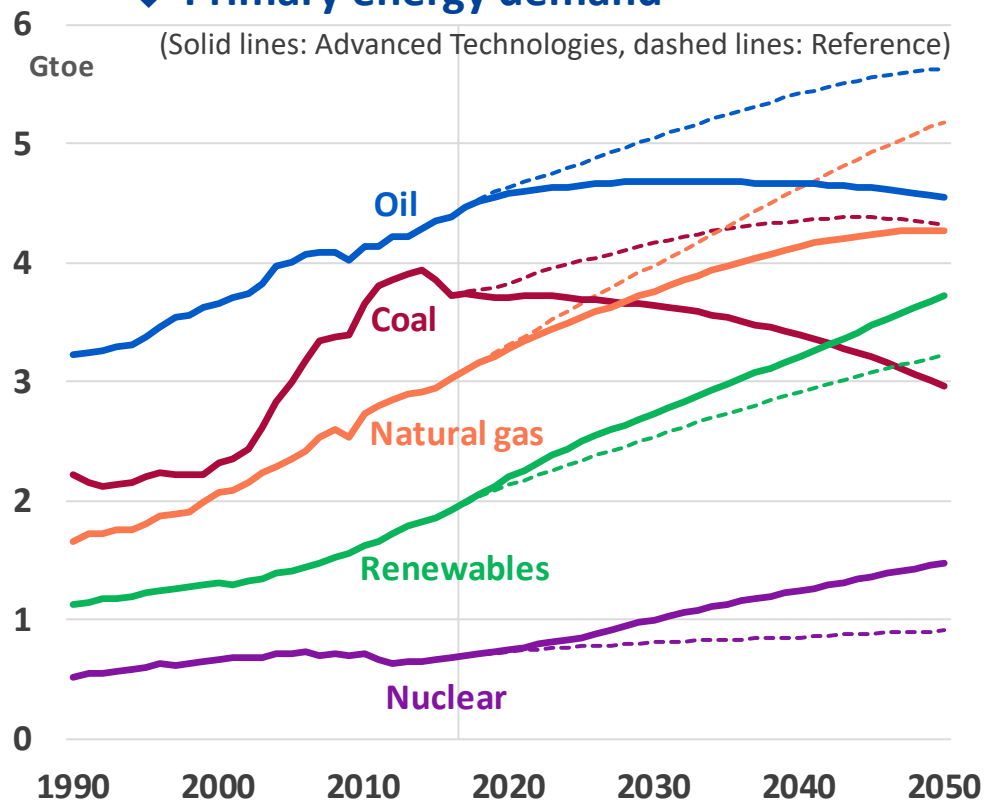
Coal declines while oil hits peak in 2030

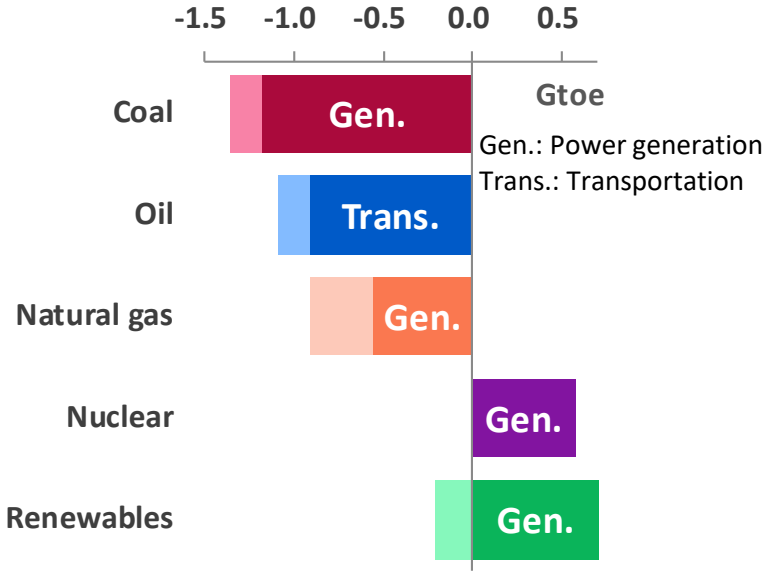
❖ Primary energy demand



● Advanced Technologies Scenario

It is assuming preparation and implementation of more ambitious strategies or programs for energy security, mitigation of climate change and so on.

❖ Comparison with the Reference



In the Advanced Technologies Scenario…

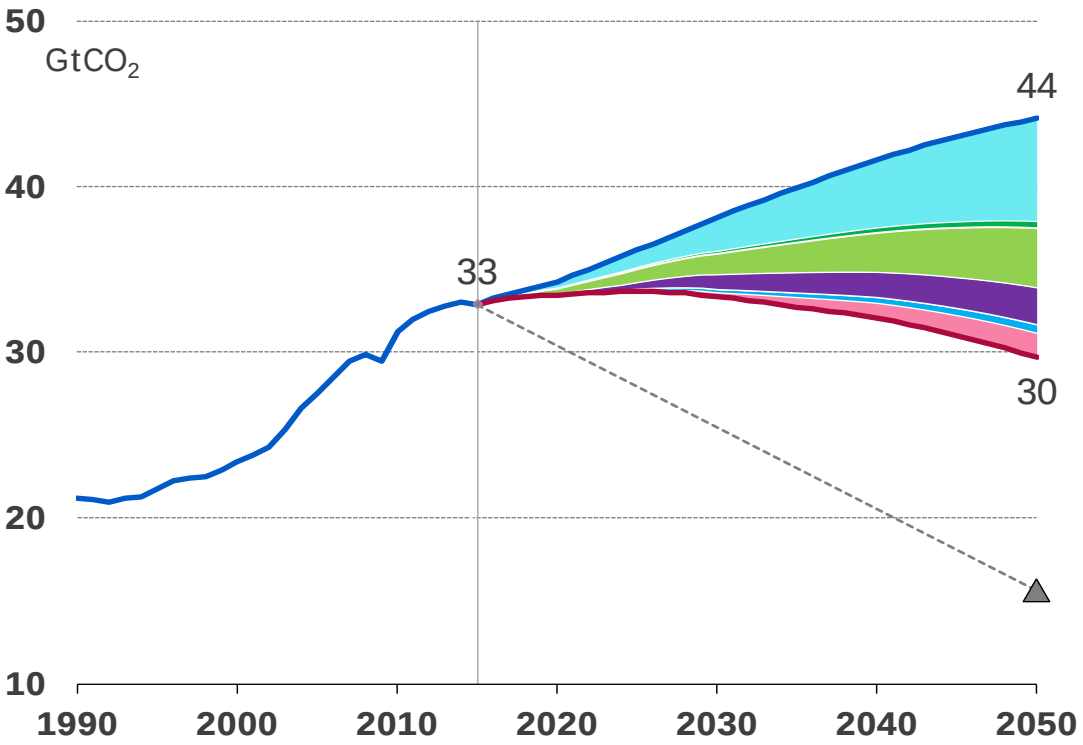
- ◆ Coal consumption will decrease remarkably (especially, for power generation).
- ◆ Oil consumption will decrease after peaking in 2030.
- ◆ Although share of fossil fuel in energy consumption will decrease from 81% to 69% in 2050 (to 79% in the Reference Scenario), high dependency on fossil fuel continues.

Source: "IEEJ Outlook 2019" (IEEJ, October 2018)

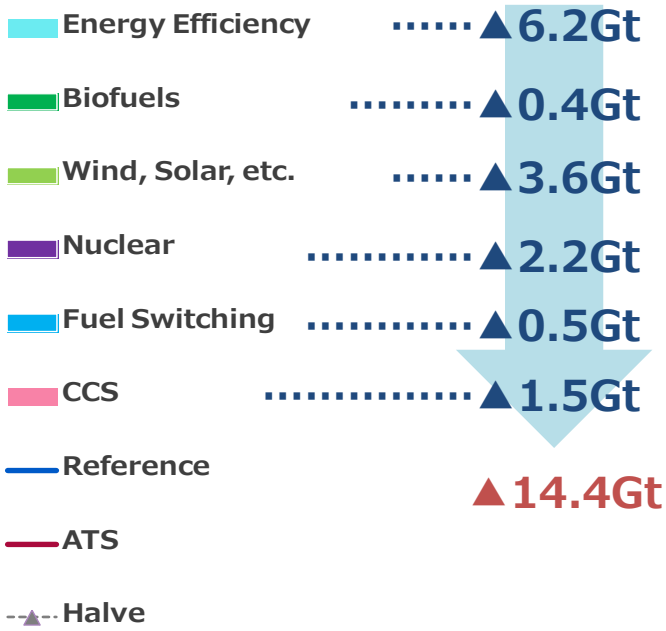
<Advanced Technologies Scenario>

CO_2 emissions peak in the middle of 2020s

❖ Energy-related CO_2 Emissions



❖ Reductions by technology

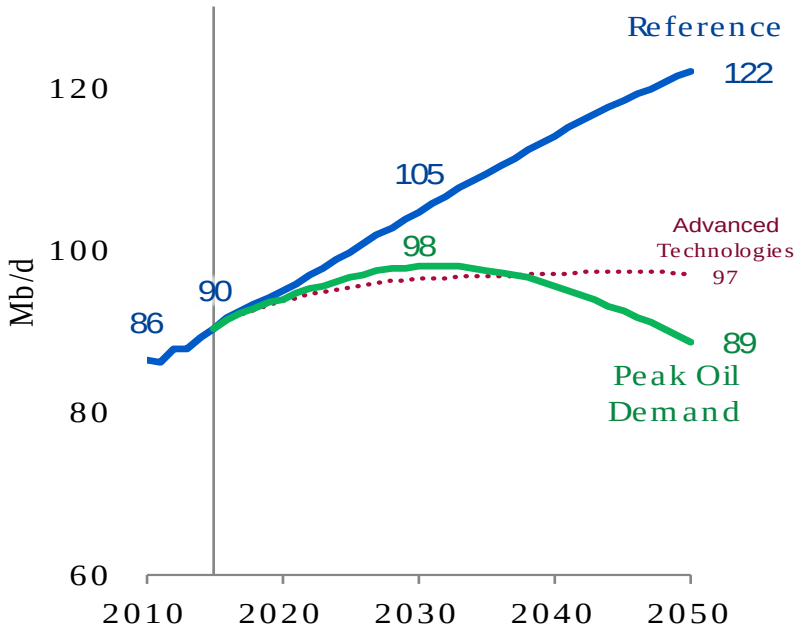


Energy-related CO_2 emissions in ATS decline after the 2020s but are still very far from reaching half of current levels by 2050. Efficiency is the most contributor for CO_2 reductions from the reference. Two-thirds of the total reductions are electricity-related technologies, including non-fossil power, thermal power with CCS and energy efficiency in power supply/demand.

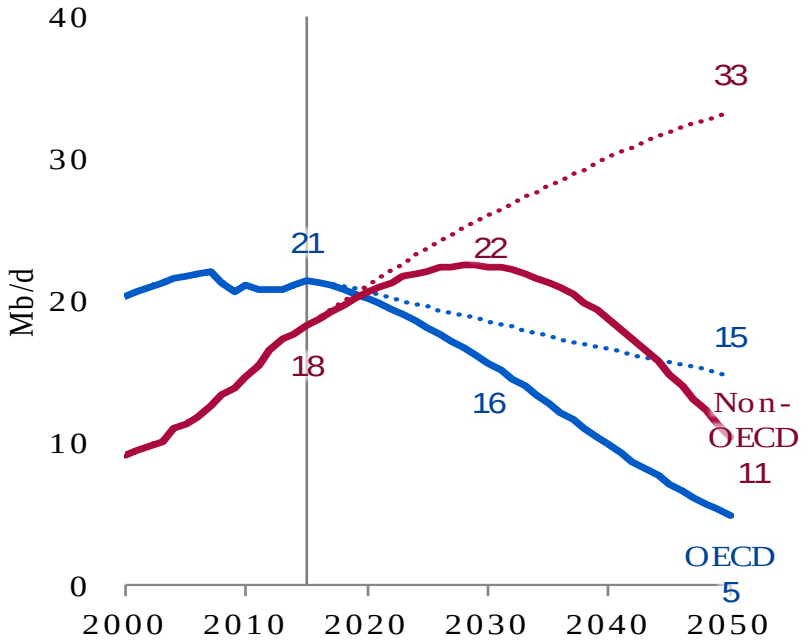
Source: IEEJ "IEEJ Outlook 2018" (Oct. 2017)

Oil Demand Peaks Around 2030 by Rapid ZEV Penetration

Oil consumption



Oil for Road [Peak Oil Demand Case]



Note: Dotted lines are the Reference Scenario

In the Peak Oil Demand Case, oil consumption hits a peak of 98 Mb/d around 2030 then declines. The reduction from the Reference Scenario is 7 Mb/d and 33 Mb/d in 2030 and in 2050, respectively.

Oil consumption by cars in Non-OECD, which continues to increase rapidly in the Reference Scenario, also declines from around 2030. It is as much as one third of the Reference Scenario in 2050.

Source: IEEJ "IEEJ Outlook 2018" (Oct. 2017)

Why Is Hydrogen Important ?

Hydrogen

- Hopes are placed on hydrogen as zero-carbon energy.
- Hydrogen can be produced from various resources (including renewable energy, fossil fuels, nuclear energy and wastes)

Important Role of Hydrogen

- Addressing Climate Change
- Stabilizing fossil fuel rich economies including Middle East in energy transition by de-carbonizing fossil fuels together with CCS (CO_2 Capture and Storage)

Source: IEEJ

Hydrogen: Demand Creation is Required

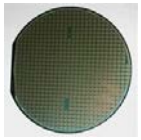
Industrial Use

- Large-scale use
  15 billion Nm^3/y for oil refining, petrochemicals, ammonia, etc. in Japan
- Small-scale use
  300 million Nm^3/y in Japan at present

Stainless steel bright annealing

Glass

Hydrogenated fat, margarine



Semiconductor

Energy Use

- FCV, hydrogen station

800,000 units @2030
: 800 million Nm^3

- Hydrogen burning power generation

1GW=2-3 billion Nm^3

- Industry sector

For steelmaking (hydrogen reduction steelmaking), boilers, burners, etc. in future

- Natural gas pipeline

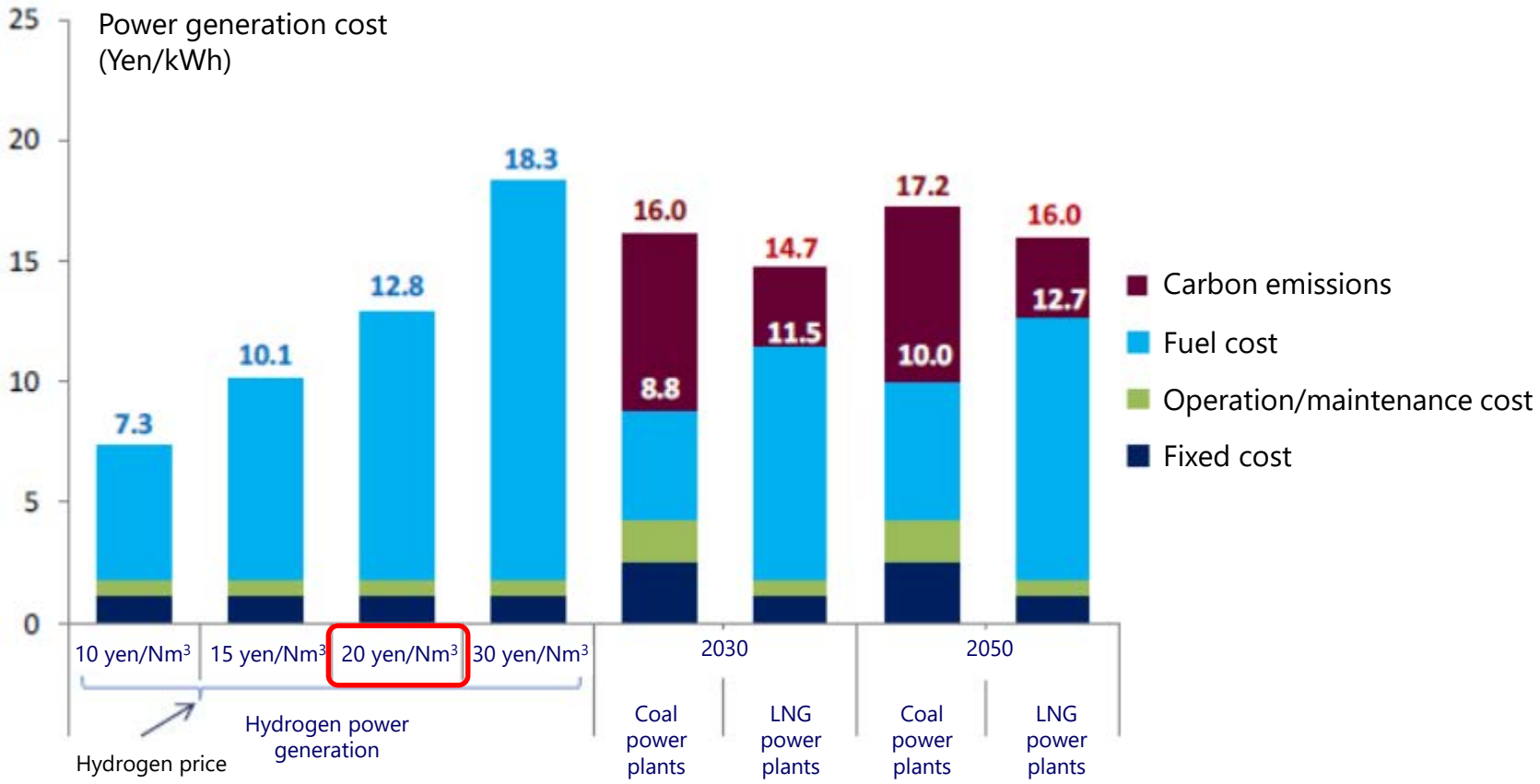
Hurdles are lower for synthetic methane

- Buildings sector

Future hydrogen town?

Hydrogen: Cost reduction is required

- Given Japan's hydrogen use for power generation, the desirable hydrogen CIF import price is 20 yen /Nm^3 or less.
  The Japanese government has set its target at 30 yen /Nm^3.



Source: IEEJ

Viewpoint for Resource-rich Countries

- An oil demand decline amounting to a loss of gasoline consumption by 100 million gasoline vehicles can be offset by demand for hydrogen for 100 million FCVs and 30 GW in hydrogen power generation.

100 million gasoline vehicles

900,000 b/d

=

100 million FCVs

500,000 b/d
(Hydrogen production from oil)

+

30 GW in hydrogen-only power generation

400,000 b/d
(Hydrogen production from oil)

<Assumptions>
- About 550 Nm^3 (50kg) in hydrogen can be made from 1 barrel in crude oil.
- 1 million b/d ➔ 550 million Nm^3-H_2/d≒200 billion Nm^3-H_2/y
  ➔ equivalent to hydrogen consumption for 80 GW in hydrogen-only power generation or 200 million FCVs
  - A 1 GW hydrogen-only power generator consumes 2.5 billion Nm^3-H_2 annually.
  - An FCV consumes 1,000Nm^3-H_2 annually.
- 1 million b/d ➔ covering gasoline consumption by about 110 million gasoline vehicles
  - A gasoline vehicle consumes 500 liters or 3.3. barrels of gasoline annually.

Conclusion

- **Hydrogen can play important roles** in energy transition
  - **1)** To address Climate Change
  - **2)** To stabilize fossil fuel rich economies

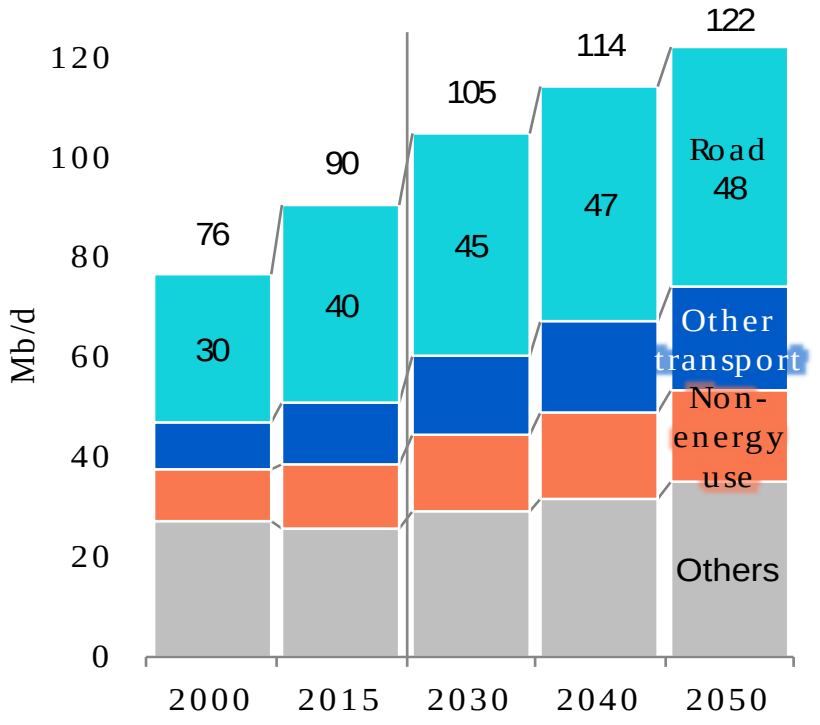
- **Two possible ways to produce zero carbon hydrogen**
  - **a)** To produce hydrogen form fossil fuels in combination with CCS
  - **b)** To produce hydrogen through electrolysis

- **Challenges are;**
  - **i)** To reduce the cost of zero-carbon hydrogen
  - **ii)** To diversify the use of hydrogen;
    not only for transportation use but for power generation and industry

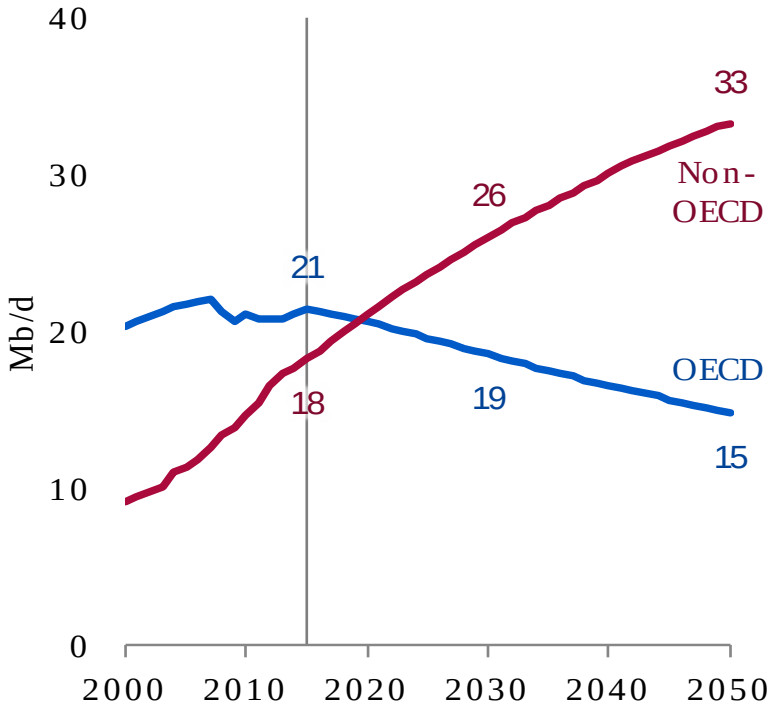
  Therefore;
  - **iii)** **International collaboration** is essential for speeding up this process

Transportation, Especially Cars, Drives Oil Demand

Oil consumption [Reference Scenario]



Oil for Road [Reference Scenario]



About 70% of the increase in oil consumption until 2050 is by transportation and for petrochemical feedstocks. In particular, road transport may decide where demand goes.

However, oil consumption by cars in OECD is decreasing, and it will be less than in non-OECD around 2020. Non-OECD accounts for all future increases.

Source: IEEJ "IEEJ Outlook 2018" (Oct. 2017)

The time for car electrification has come?

Germany

A resolution to ban conventional car sales in the European Union by 2030 was passed by the Bundesrat of Germany (2016)

Norway

The ruling and opposition parties proposed the abolition of conventional vehicles by 2025 (2016)

France

The Government announced that it would ban conventional car sales by 2040 (2017)

United Kingdom

The Government announced that it would ban conventional car sales by 2040 (2017)

India

Minister said that all new car sales after 2030 would be electric vehicles (2017) → **Canceled later**

China

Deputy Minister mentioned that the ban on the sale of conventional vehicles was under investigation (2017)

Toyota

The target for EV/FCV sales is more than 1 million and total electrified vehicles sales at 5.5 million in 2030 (2017).

Volkswagen

Announced the strategy to increase EV share in its total sales to 25% with more than 80 models of ZEVs by 2025 (2017)

Renault-Nissan

Introducing 12 models of EVs by 2022. The target of 30% of its total sales as EVs (2017)

Hyundai

The plan to prepare EVs at all line up by 2020 (2015).

Introducing 14 EV models by 2025 (2017).

Ford

Introducing 13 new models of EVs by 2022 with new investment of 11 billion USD (2017).

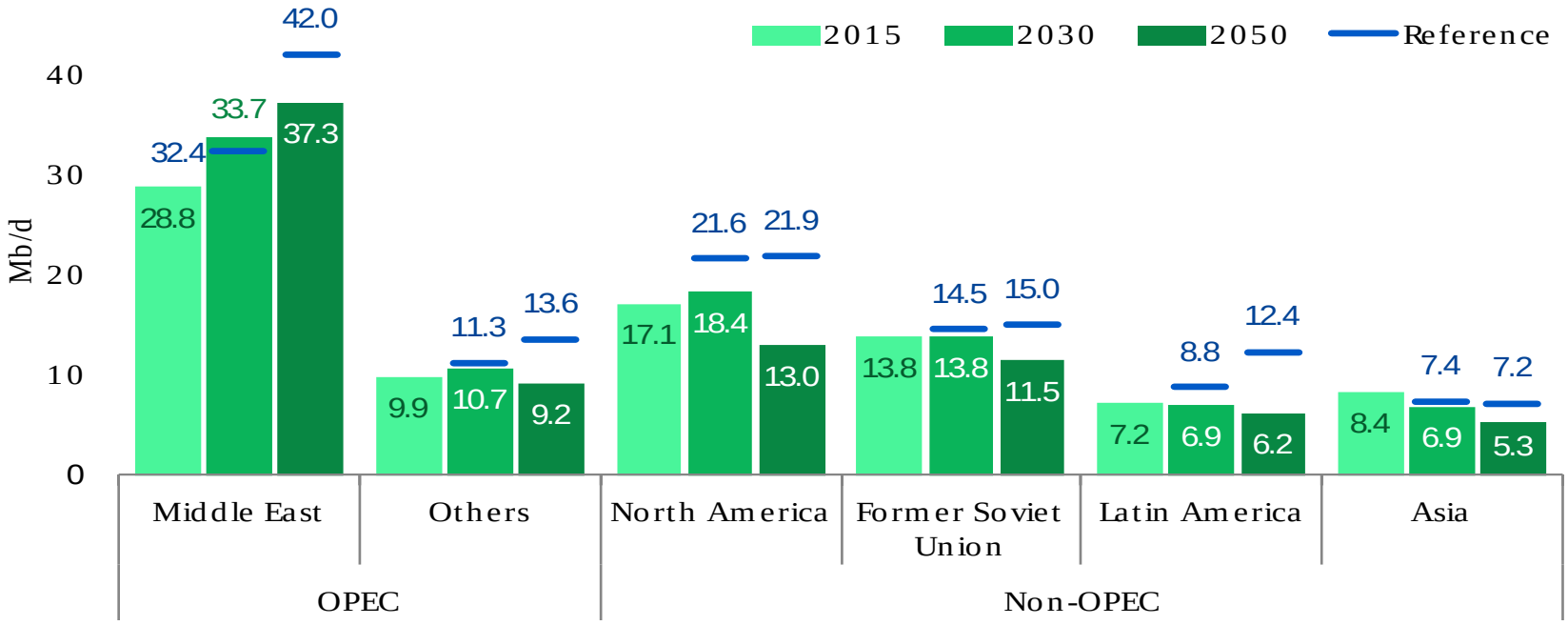
Honda

In 2030, two-thirds of automobile sales will be electrified. EVs will be released in China in 2018 (2017).

Source: "IEEJ Outlook 2018" (IEEJ, October 2017)

Crude Oil Production Shifts to Low-cost Regions …

Crude oil production [Peak Oil Demand Case]

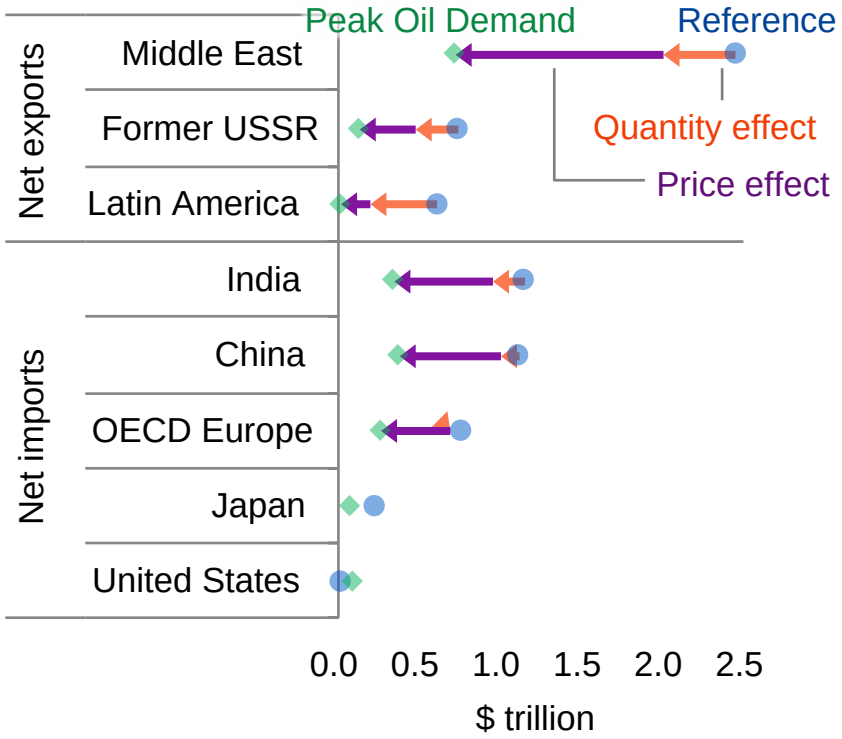


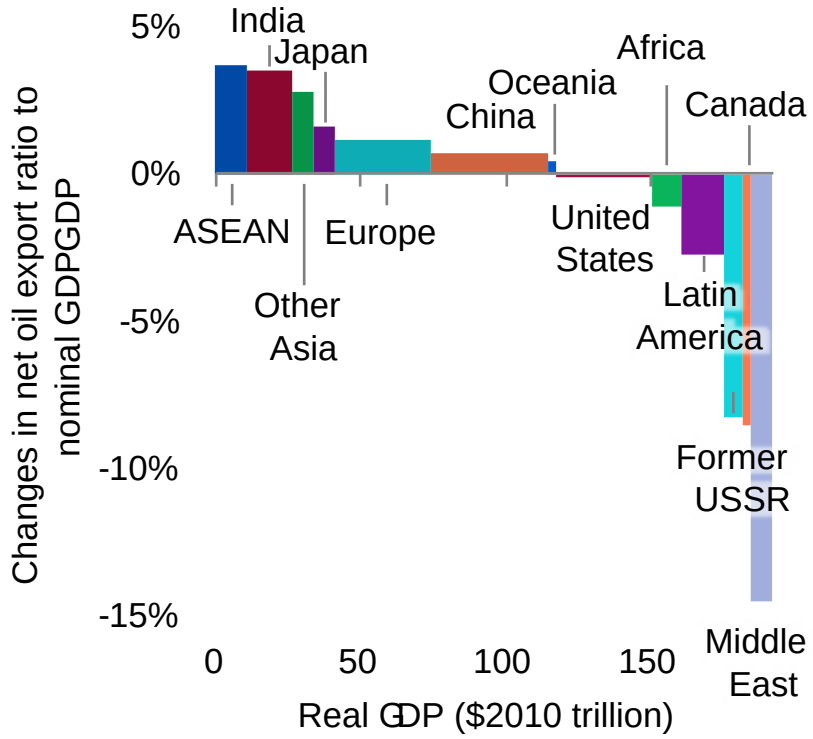
Oil price falls due to the change in supply and demand pressure and market sentiment – $65/bbl and $50/bbl in 2030 and in 2050, respectively, compared to $95/bbl and $125/bbl in 2030 and in 2050, respectively, in the Reference Scenario (in $2016). Given this drastic price decrease, superiority of lower production costs-regions increases, and only the Middle East produces more in 2050 than today. North America decreases by 40% from the Reference Scenario to 13 Mb/d.

Source: IEEJ "IEEJ Outlook 2018" (Oct. 2017)

Economic impacts of peak oil demand

Changes in net oil exports/imports and ratios to nominal GDP [2050]





Note: Europe excludes the former Soviet Union

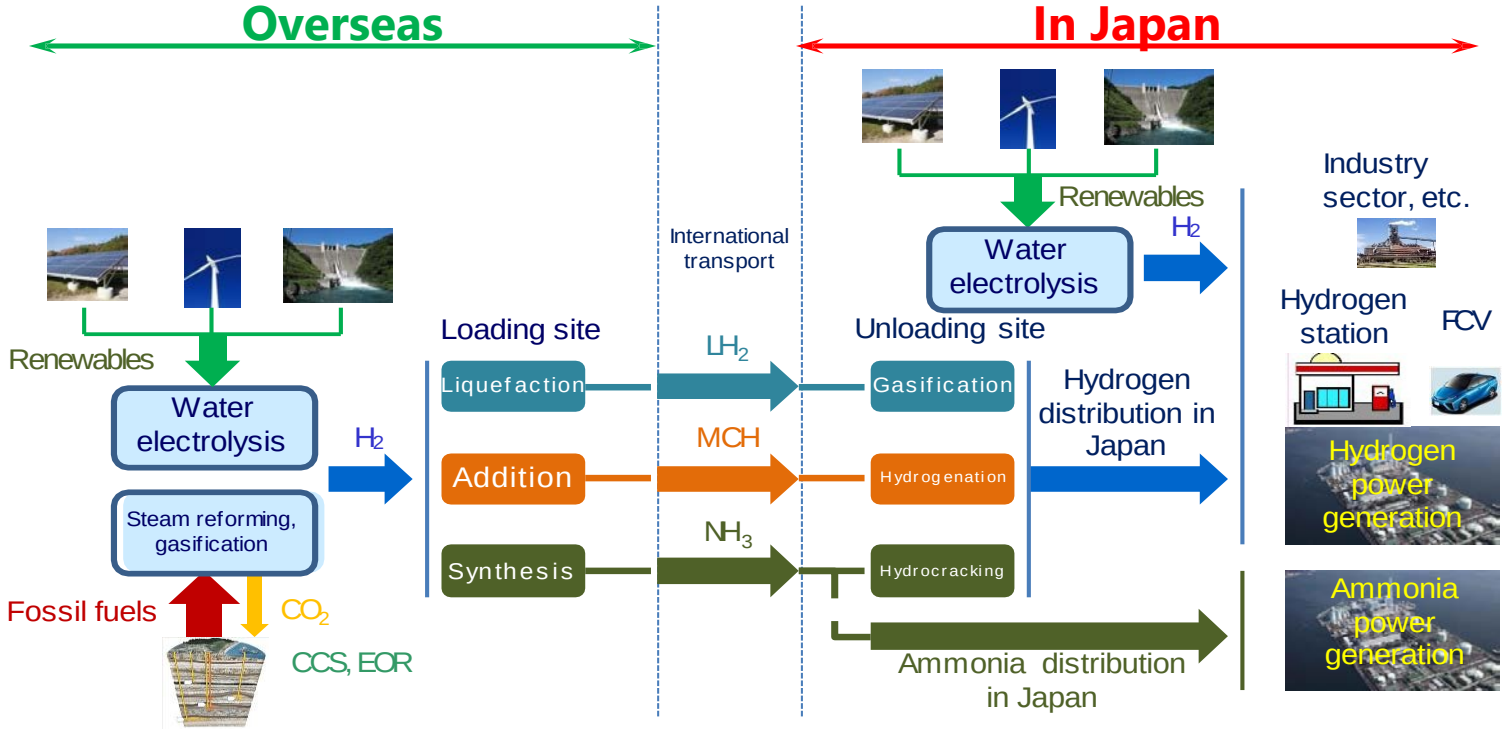
Although the Middle East obtains the relative gain, its net oil export decreases of $1.6 trillion or 13% of nominal GDP is significant.

On the other hand, the most benefiting country from net oil import decreases is India, the second largest oil consumer, followed by China, which has more car fleet than in any other countries. The United States has little impact despite of its consumption scale since it is almost oil self-sufficient.

Source: “IEEJ Outlook 2018” (IEEJ, October 2017)

Technology Options

- Production technology has been almost established.
- Production from fossil fuels with CCS and Electrolysis with surplus of VRE
  -> Three options exist for transportation (energy carriers): under demonstration
- The economically rational realization of CCS is the initial key to hydrogen or ammonia production from fossil fuels: Still in the demonstration stage.



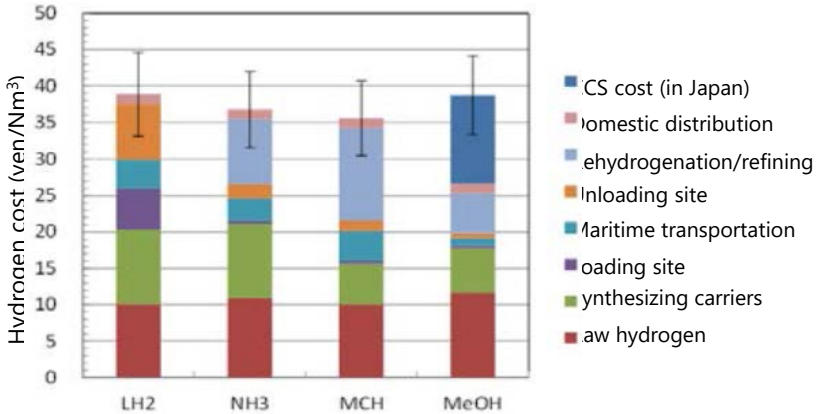
Note: LH2 stands for liquefied hydrogen and MCH stands for methylcyclohexane.

Source: IEEJ

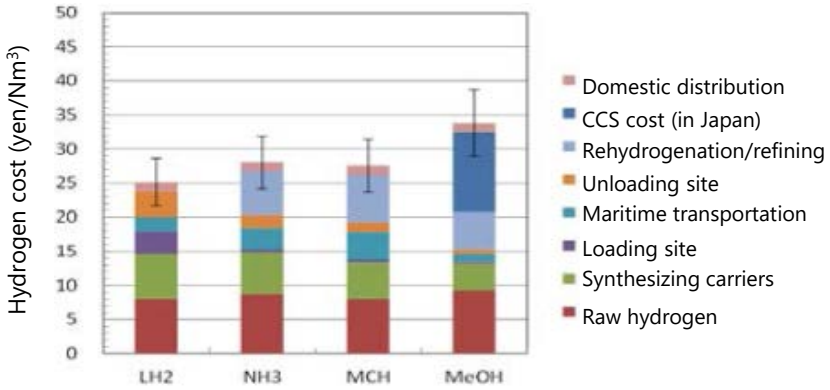
Hydrogen Import Cost Estimation

- Although cost estimates differ depending on energy carrier and technological advancement assumptions, raw material and equipment costs must be substantially reduced.

(Research and development case)

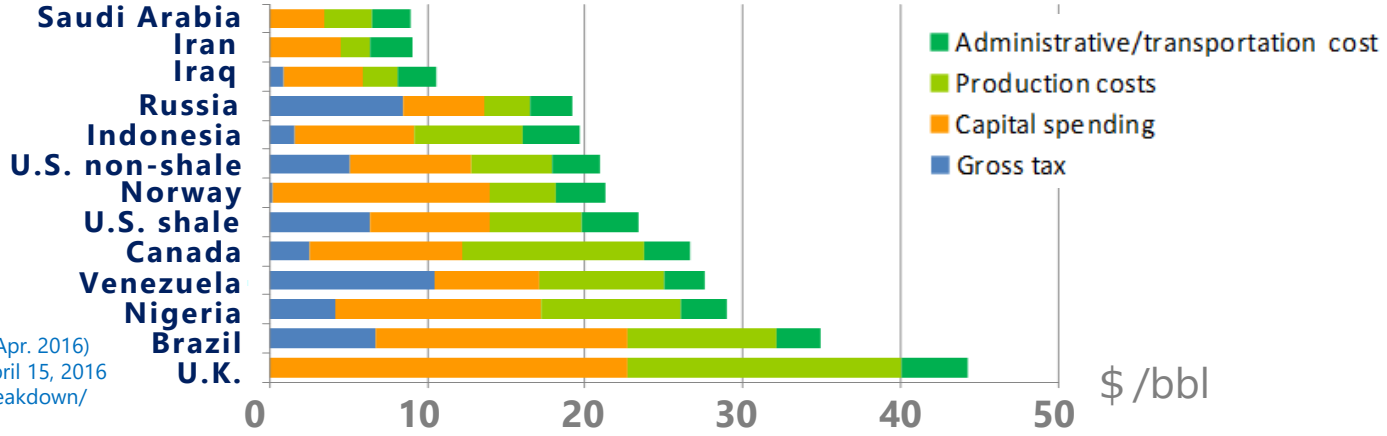


(Maximum expansion case)



Source: Energy carrier system survey and research – assessment of energy carrier systems' economic efficiency and analysis of their characteristics under a leading hydrogen use research and development project, by the Institute of Applied Energy under contract from the New Energy and Industrial Technology Development Organization

Oil and Gas Production Costs



Source: Rystad Energy, Ucube (as of Apr. 2016)
The Wall Street Journal, Published April 15, 2016
http://graphics.wsj.com/oil-barrel-breakdown/