IEEJ Outlook 2018

-Prospects and Challenges toward 2050-

October, 2017

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Overview of the current global energy market

- Although the trend of Asia as leading the global energy market remains unchanged, developments in the US and China, which accounts for 40% of the energy market, must be carefully monitored.

- World coal demand dropped for two years in a row (US and China largely) while oil and gas grew. China's coal consumption declined for the third consecutive year (2016, BP).

- Discussions on Peak Oil (supply) of the 2000s are now changing to Peak Demand. Note the recent movements that aim to ban the sale of internal combustion engine vehicles.

- CO_2 emissions dropped in 2015 but increased again in 2016. India and ASEAN showed big increases despite the declined observed in the US and China.

- Paris Agreement calls for "Long-term low greenhouse gas emission development strategies" by 2020. This Outlook expands its estimation period to 2050.

Scenarios in this Outlook

< Energy Model Analysis>

Reference Scenario

Reflects past trends with current energy and environment policies. Does not reflect any aggressive policies for low-carbon measures.

Advanced Technologies Scenario

Assumes the introduction of powerful policies to enhance energy security and address climate change issues. It promotes utmost penetration of low-carbon technologies.

Oil Demand Peak Case

Assumes a more rapid introduction of electric drive vehicles than in the reference scenario, to analyze the possibilities of oil demand peak.

❖Examples for Technology

		Reference	Advanced Technologies	Peak Oil Demand
Energy efficiency	Vehicle technology (ZEV[*1] sales share)	9% in 2030 20□ in 2050	21□ 43□	30□ 100□
	Coal-fired power generation (CCT[*2] share in newly installed capacity)	30□ in 2030 90□ in 2050	70□ 100□	Same as Reference
Carbon free technology	Installed capacity PV Wind Nuclear	(2015 to 2050) 0.2 to 1.5 TW 0.4 to 1.9 TW 0.4 to 0.6 TW	(2050) 2.5 TW 3.0 TW 1.0 TW	
Thermal power generation with CCS (Only countries and regions with CO_2 storage potential excluding aquifers)		none	Newly installed after 2030	

*1 ZEV: battery electric vehicles, plug-in hybrid electric vehicles and fuel cell battery vehicles
*2 CCT: ultra super critical, advanced-USC and integrated coal gasification combined cycle

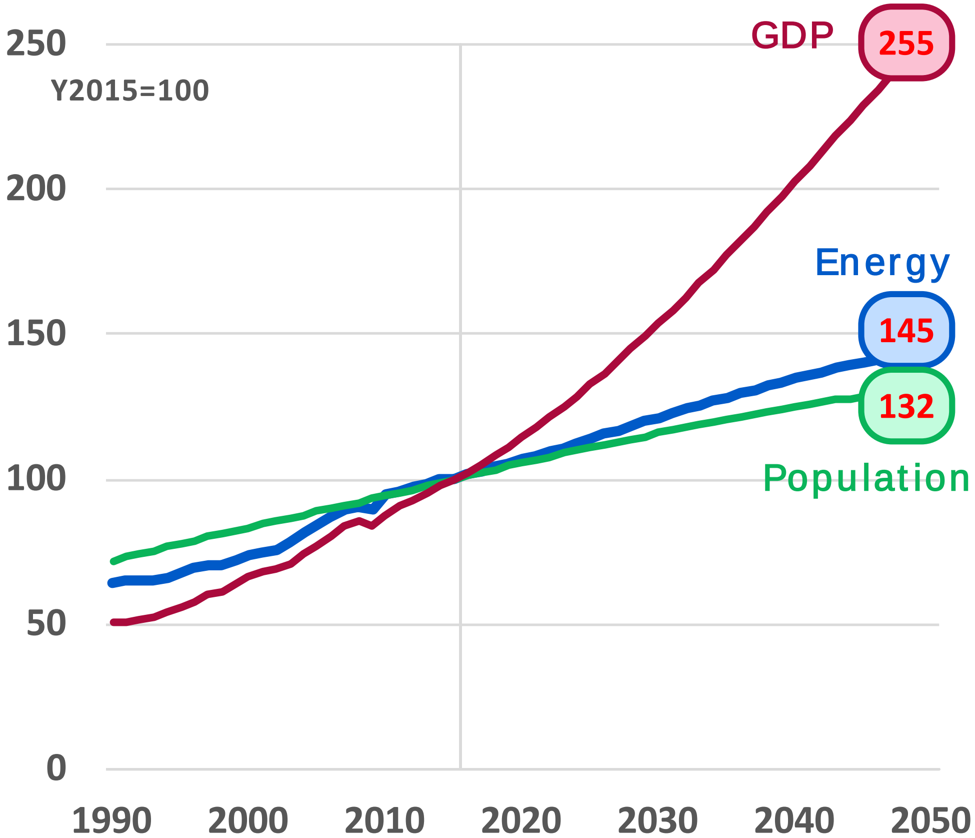
< Climate Model Analysis>

Reference: Emissions path with continuing past trends
Minimizing Cost: Emissions path with minimizing total cost
Halving Emissions by 2050: Emissions path reflected RCP2.6 in AR5 by IPCC

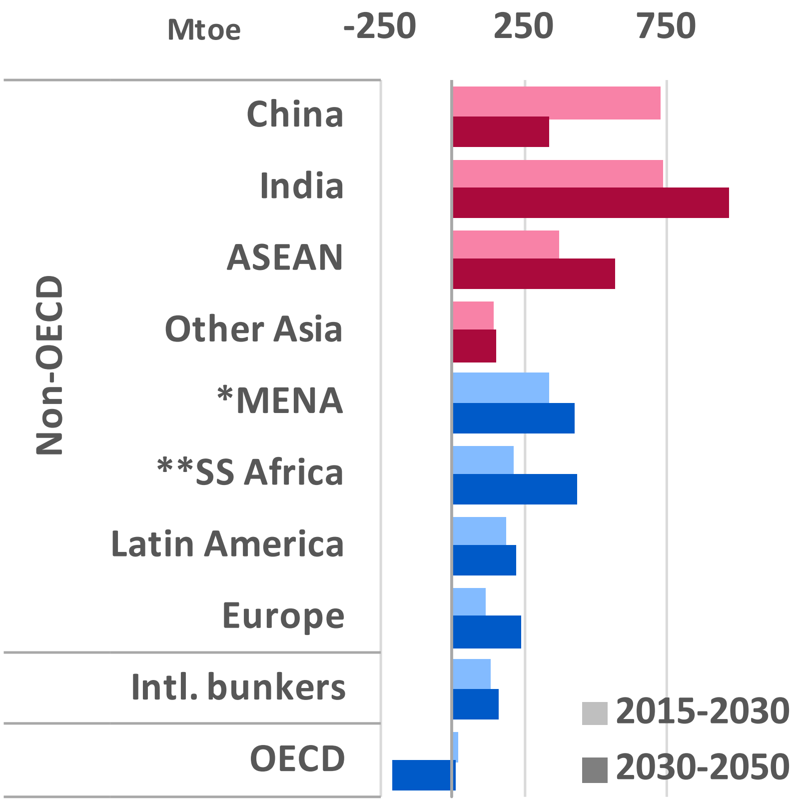
Energy Outlook up to 2050

Energy market shifting to southern Asia

❖ Global Population, GDP and Energy



❖ Growth in Primary Energy

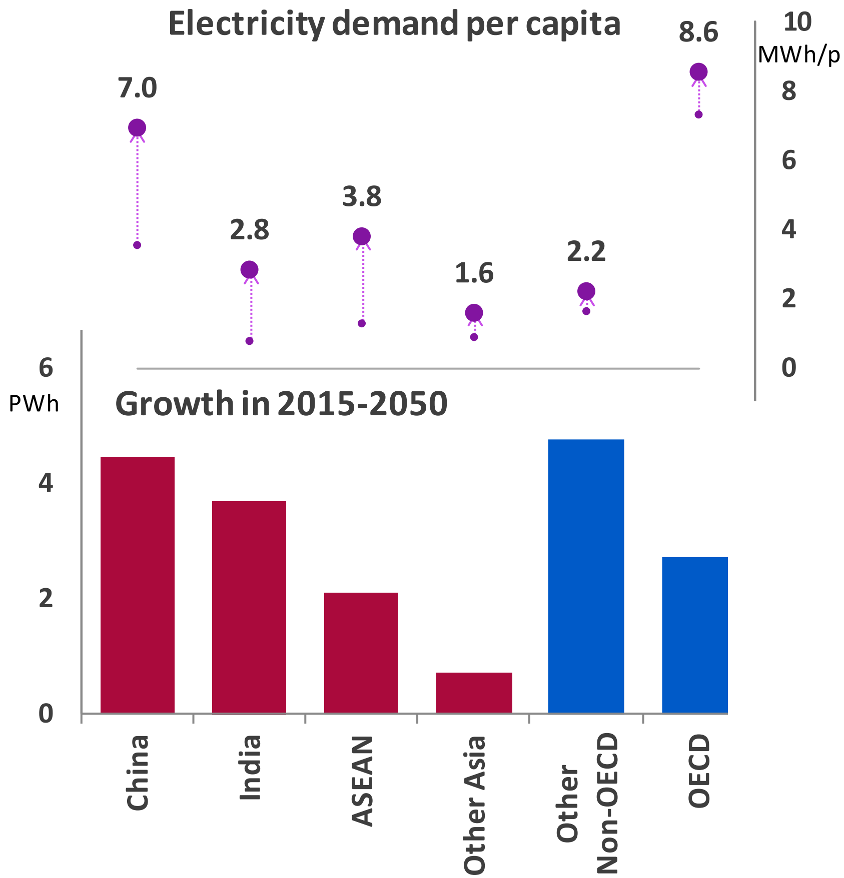


* Middle East and North Africa, ** Sub-Saharan Africa

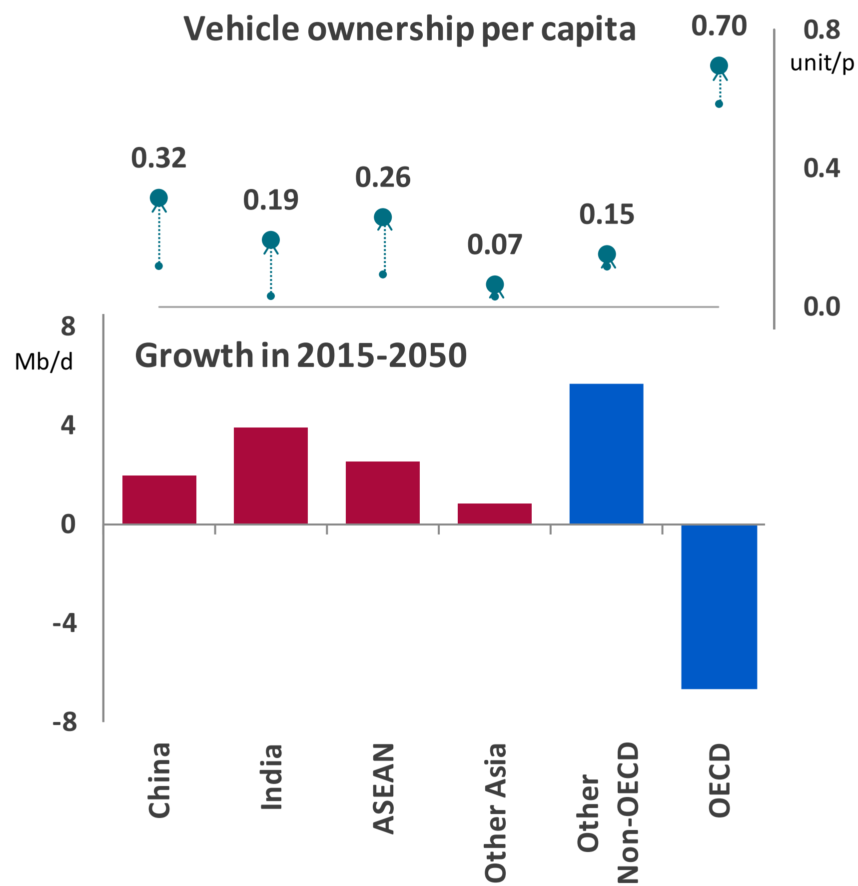
Despite large improvements in energy efficiency/intensity, global energy demand continues to increase. Two thirds of the energy growth comes from non-OECD Asia. As China peaks during the 2040s, the center of gravity of the market shifts within Asia towards the south.

Demand led by fuels for Generation & Transport

❖ Electricity



❖ Oil fuels for vehicles



Three quarters of the growth until 2050 are for fuels for power generation and transportation. The economic development and improvements in living standards of the relatively poor and populous areas - non-OECD Asia - contribute to the global energy expansion.

< Reference>

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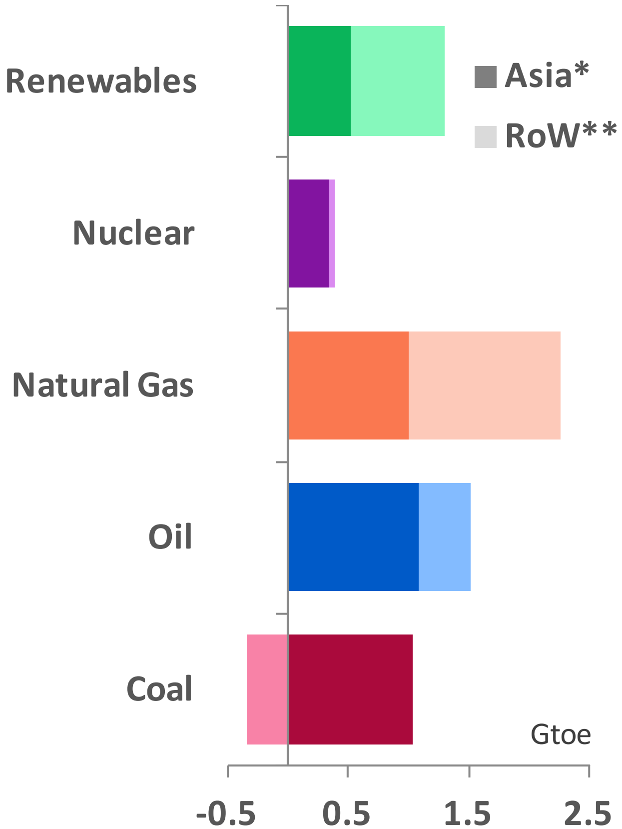
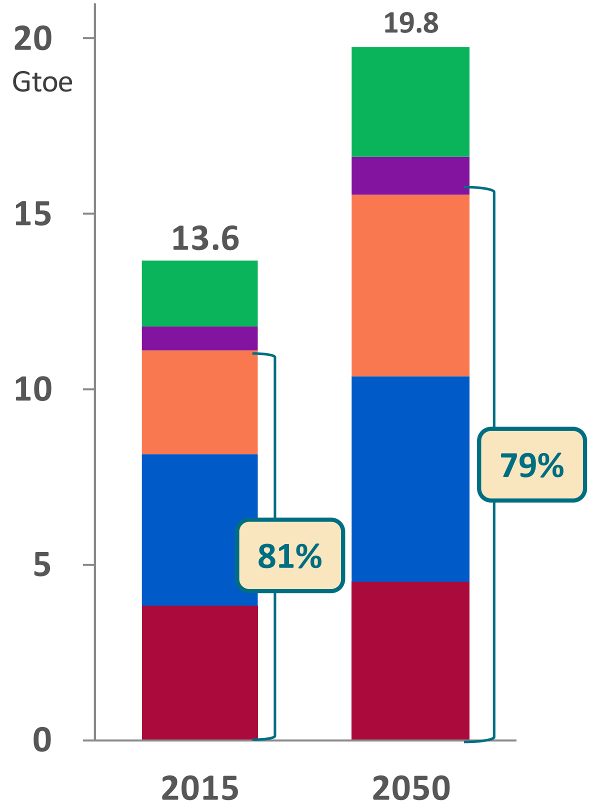
High dependence on fossil fuels continues

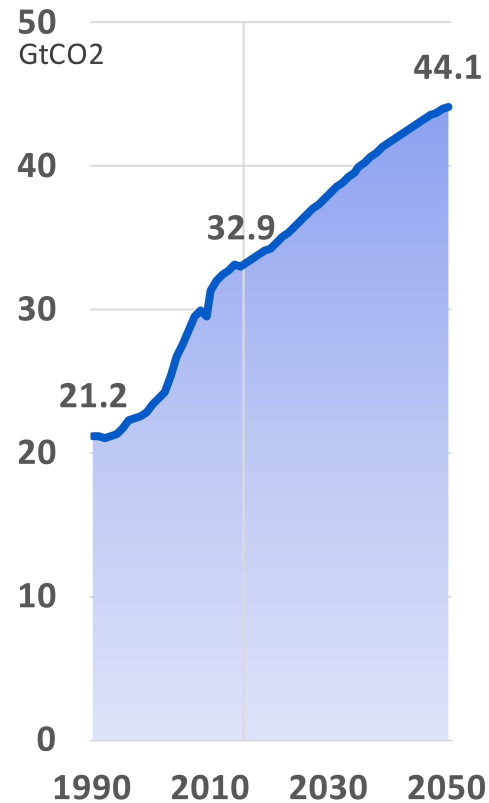
❖ Growth in Primary Energy



❖ Energy Mix



❖ Energy-related CO_2

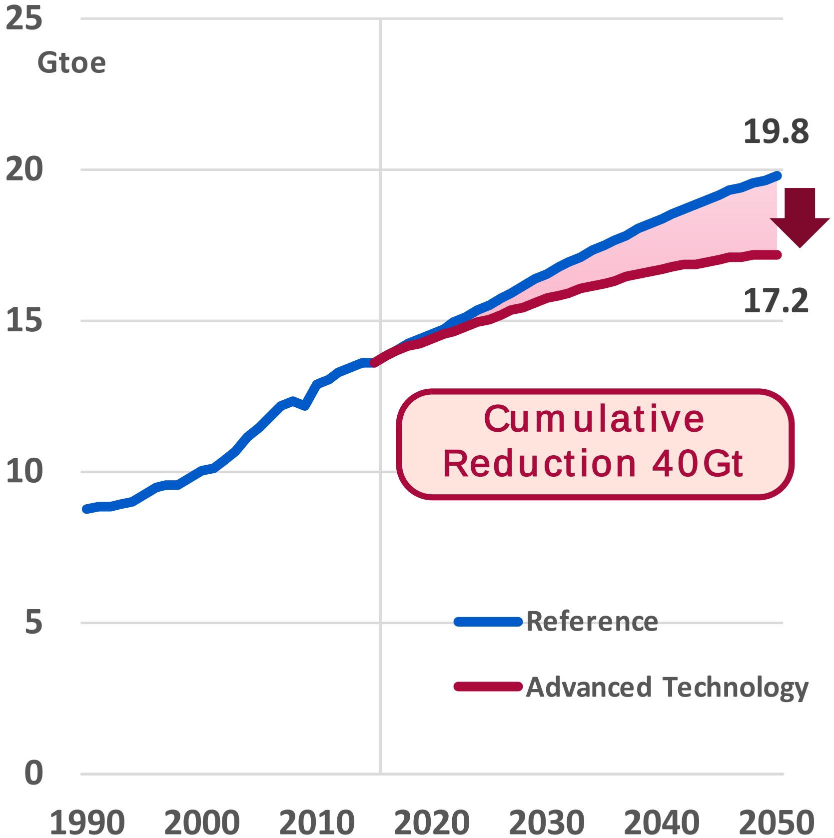


* Non-OECD Asia, ** Rest of the world

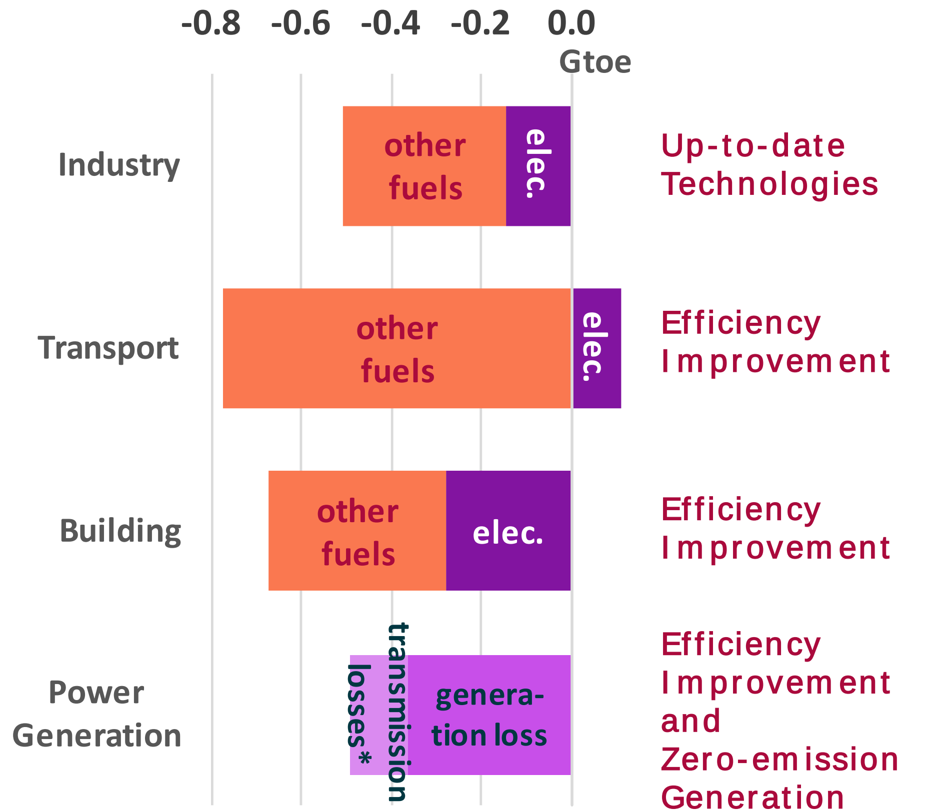
Sixty percent of the growth in electricity demand will be met by thermal power generation, especially natural gas. Asia leads the large global increase in fossil fuels required for power generation as well as for transportation. The high dependence on fossil fuels remains unchanged and energy related CO_2 emissions increase by 34% by 2050.

Drawing another path – Advanced Technologies Scenario

❖ Global Primary Energy



❖ Reduction Effects by ATS in 2050

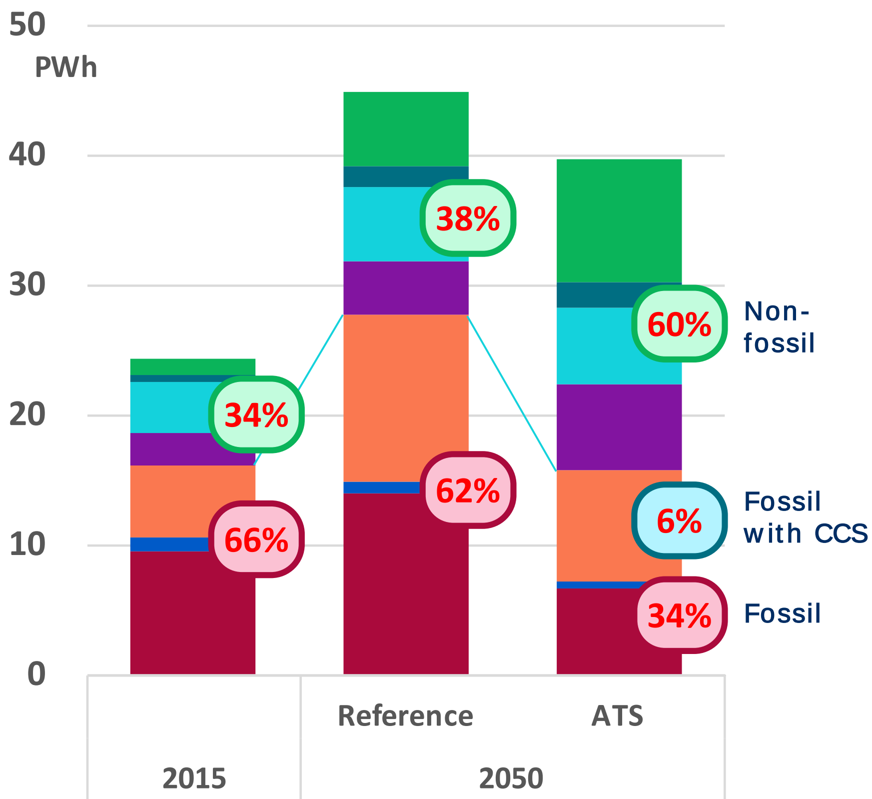


* Including station service power

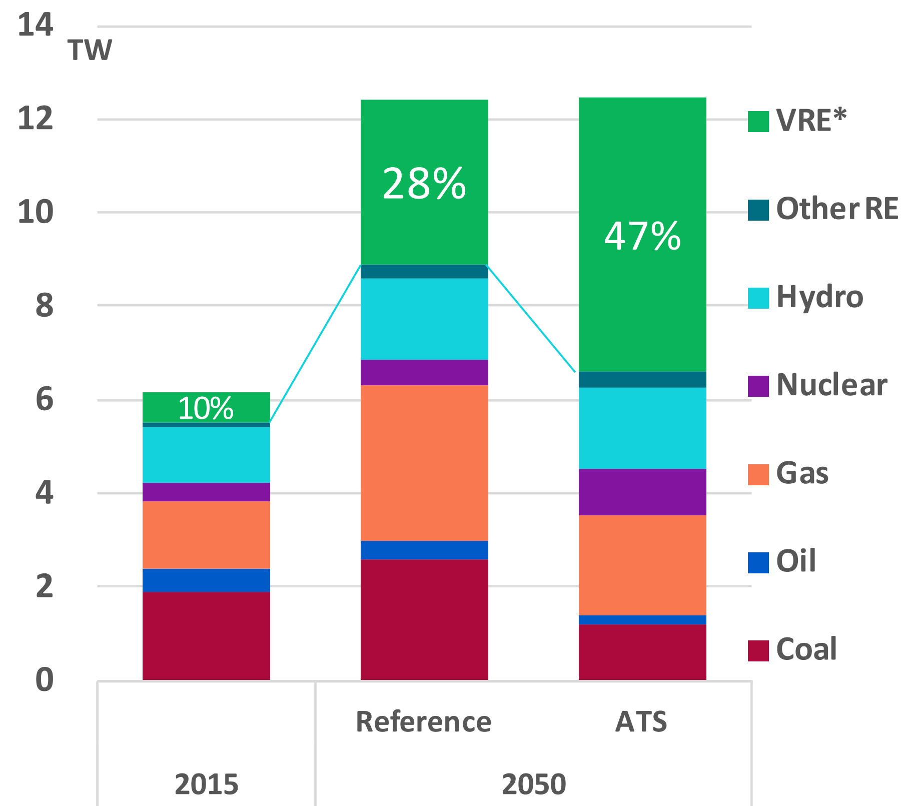
With the maximum installation of low-carbon technologies, the Advanced Technologies Scenario can reduce energy consumption by 13% in 2050. Energy efficiency in power supply/demand technologies would account for 30% of the total reduction. The energy conservation in the transport sector is quite large due introduction of HEVs, EVs, etc.

Zero-emission Generation occupies two thirds

❖ Global Power Generation



❖ Global Power Capacity

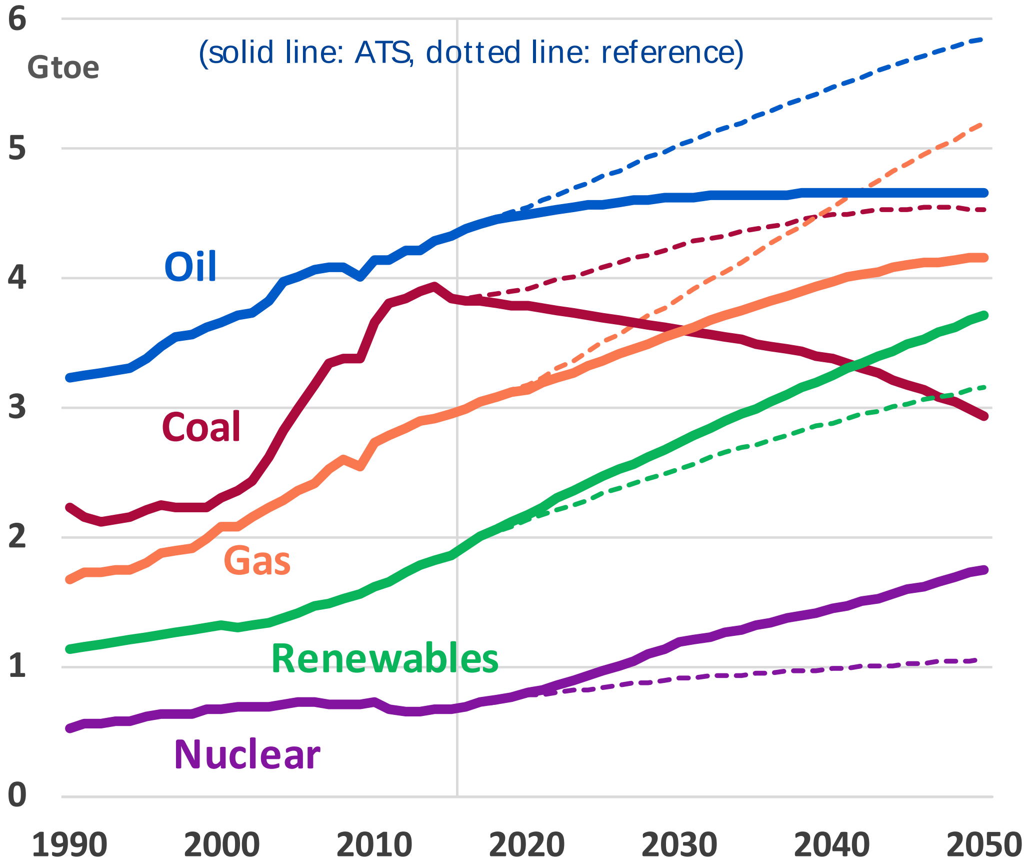


* Variable Renewable Energy includes PV, CSP, wind and marine.

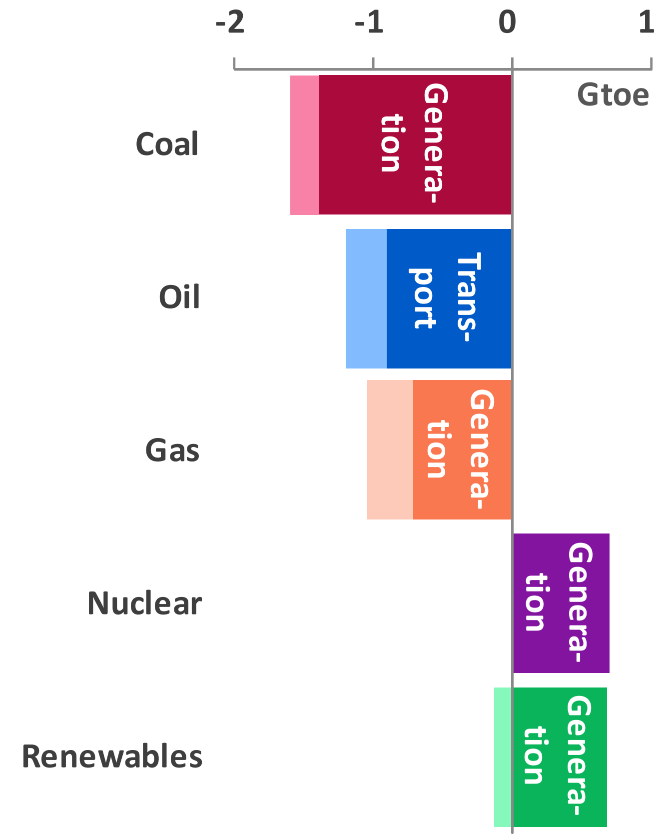
ATS slows the growth in electricity demand from 1.8 times in the reference, down to 1.6 times. In ATS, non-fossil power generation accounts for 60% and zero-emission generation, including thermal generation with CCS represents two thirds (that's half today's CO_2 emissions per unit of generation). Half of the total power capacity will be comprised of intermittent renewable energy, which needs to further reduce costs and enhance grid stability.

Coal falls significantly and below renewables

❖ Primary Energy



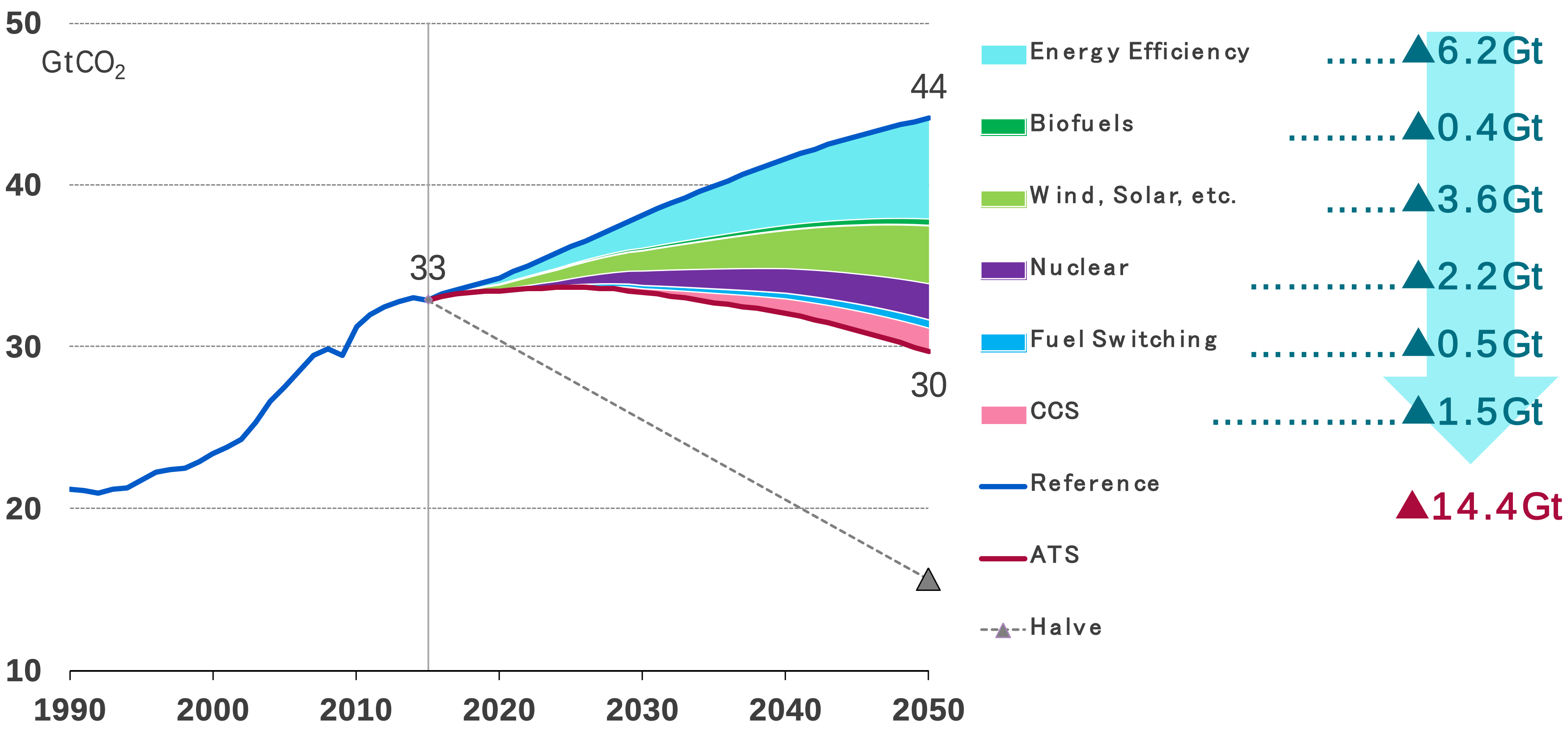
❖ Effects by ATS in 2050



In ATS, coal starts to decline from now and is surpassed by renewables around 2040, due mainly to energy efficiency and the elimination of emissions in the power supply/demand sectors. Despite large decline in transportation fuels, oil does not reach a peak. Fossil fuels share of the total in 2050 is reduced to 68%, from 79% in the reference case. It is still a high level of dependence.

CO2 emissions peak in the middle of 2020s

❖ Energy-related CO_2 Emissions ❖ Reductions by technology



Energy-related CO_2 emissions in ATS decline after 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.

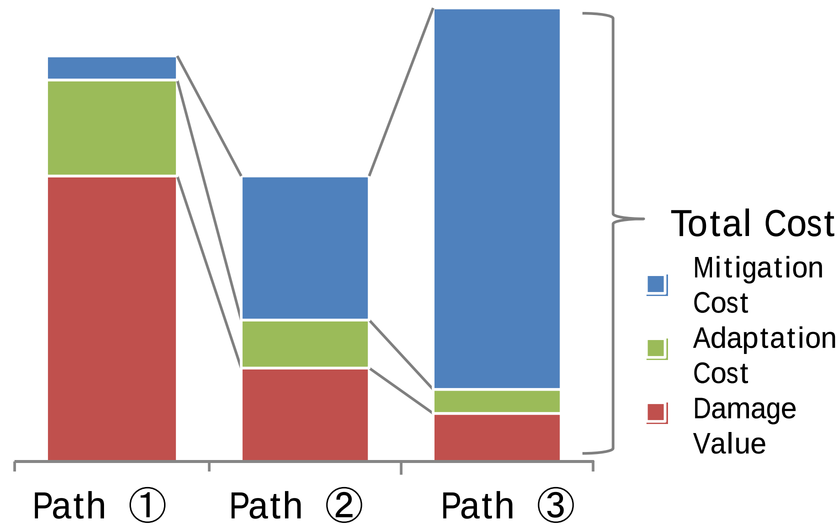
Ultra-long-term Climate Analysis

Rule for ultra long-term: Reduce the total cost

❖ Mitigation+ Adaptation+ Damage= Total Cost

Mitigation	•Typical measures are GHG emissions reduction via energy efficiency and non-fossil energy use. • Includes reduction of GHG release to the atmosphere via CCS • These measures **mitigate** climate change.
Adaptation	•Temperature rise may cause sea-level rise, agricultural crop drought, disease pandemic, etc. • **Adaptation** includes counter measures such as building banks/reservoir, agricultural research and disease preventive actions.
Damage	If mitigation and adaptation cannot reduce the climate change effects enough to stop sea-level rise, draught and pandemics, **damage** will take place.

❖ Illustration of Total Cost for Each Path



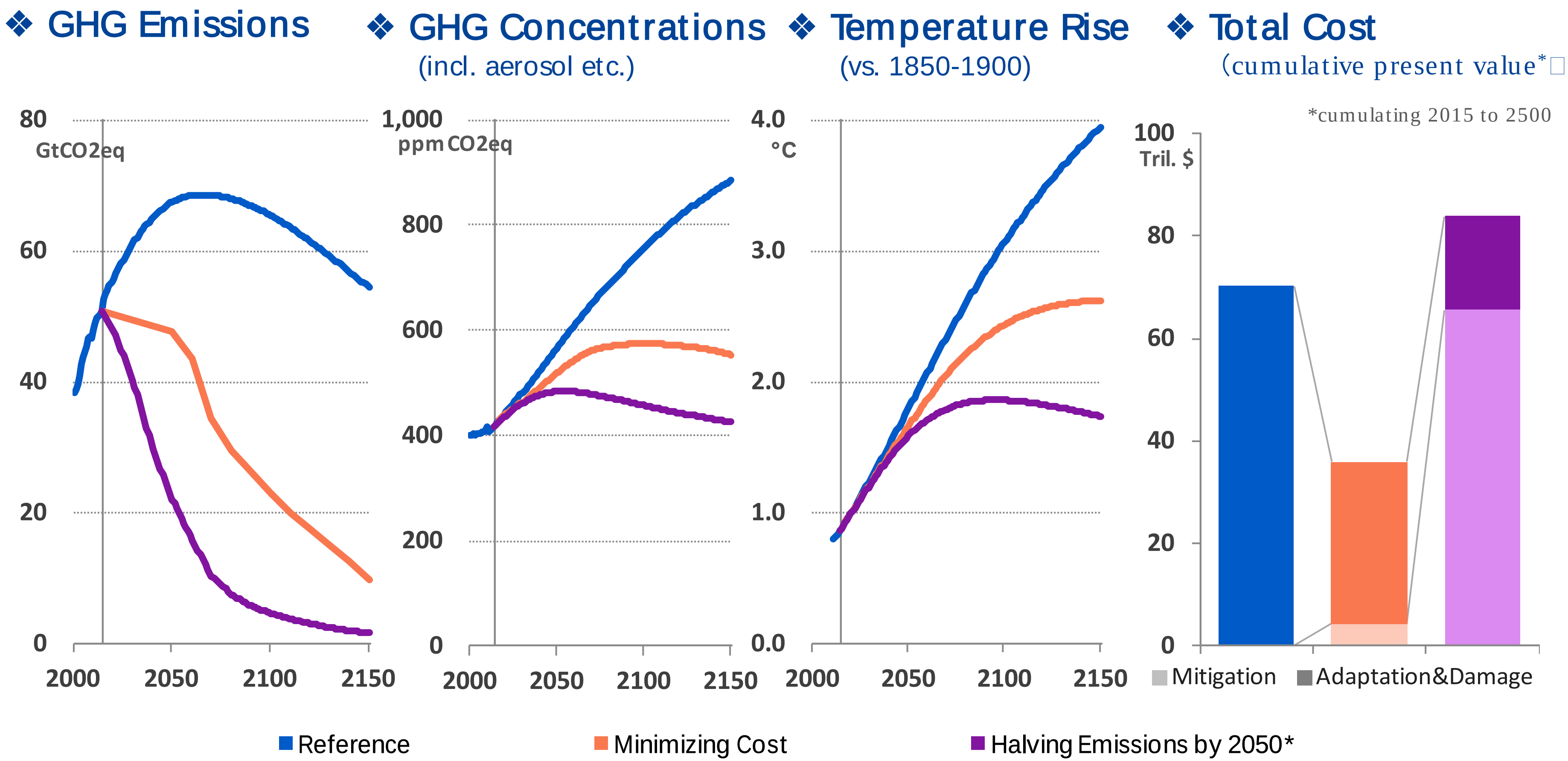
Path ①	Path ②	Path ③	
Too Small	Reasonable	Too Big	**Mitigation**
Big	Medium	Small	**Adaptation**
Big	Medium	Small	**Damage**

Without measures against climate change, the mitigation cost is small, while the adaptation and damage costs become substantial. Aggressive mitigation measures on the other hand, would reduce the adaptation and damage costs but the mitigation costs would be notably colossal.

The climate change issue is a long-term challenge influencing vast areas over many generations. As such, and from a sustainability point of view, the combination (or the mix) of different approaches to reduce the total cost of mitigation, adaptation and damage is important.

Minimizing Total Cost in IAM*

*Integrated Assessment Model

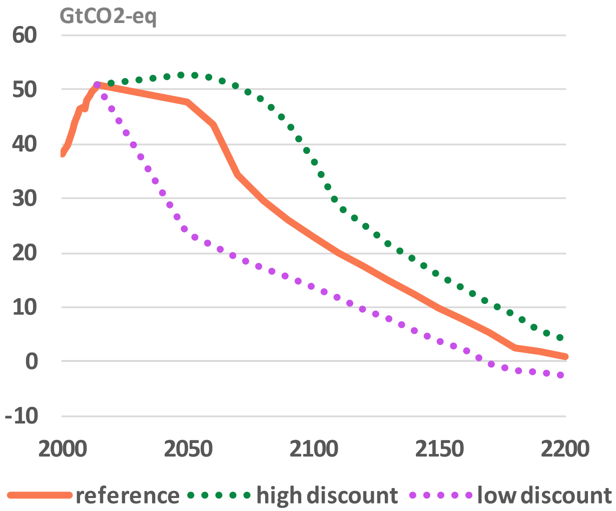


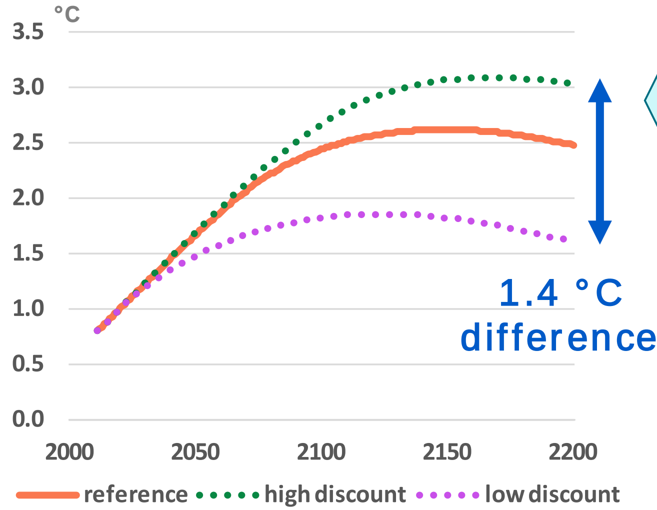
Total cost of "Minimizing Cost" is half of the reference. In 2150, GHG emissions decrease by 80% from now and temperature rises by 2.6 °centigrade from the late 19th century. In "Halving Emissions by 2050", temperature peaks at 2100, resulting in 1.7 °C in 2150. However, total cost is 20% higher than the reference and double of the "Minimizing Cost" path.

*Emissions path reflected "RCP 2.6" in the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC).

Still large uncertainties in the climate analysis

❖ GHG emissions and temperature rise using different discount rates (minimizing cost)





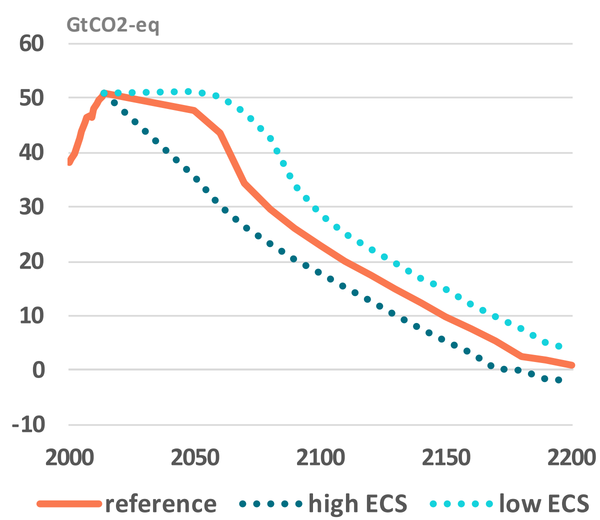
Discount rate
This model uses 2.5%. There are a range of 1.1 to 4.1% summarized by AR5.

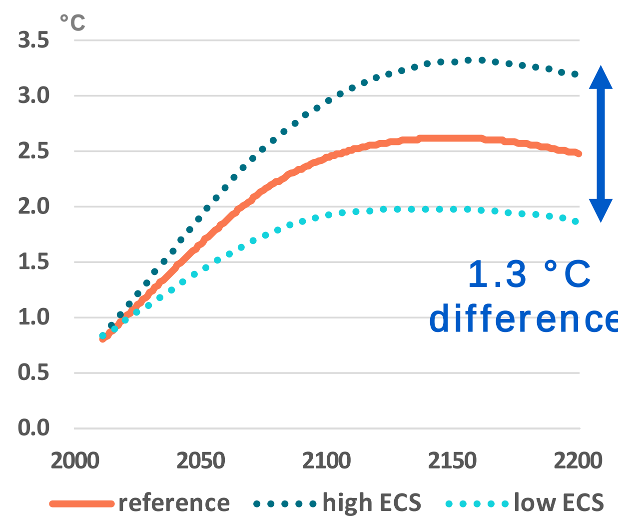
Note: The value used when converting future value (income and expenditure) into current value. The lower discount rate tends to raise emphasis of adaptation and damage, and strengthen the latest GHG reduction. The higher discount rate raises emphasis of mitigation costs and delays GHG reduction efforts.
Although it changes every year in the model analysis, it is represented by the average value in 2015 to 2300 here.

❖ GHG emissions and temperature rise using different ECS (minimizing cost)

Equilibrium Climate Sensitivity (ECS)
This model uses 3 degree.
According to AR5, high possibility that ECS is between 1.9 and 4.5 degree.

Note: A parameter indicating how many degrees centigrade the temperature will rise when the atmospheric greenhouse gas concentration (CO2 equivalent concentration) doubles.





Another path to “2 °C target”

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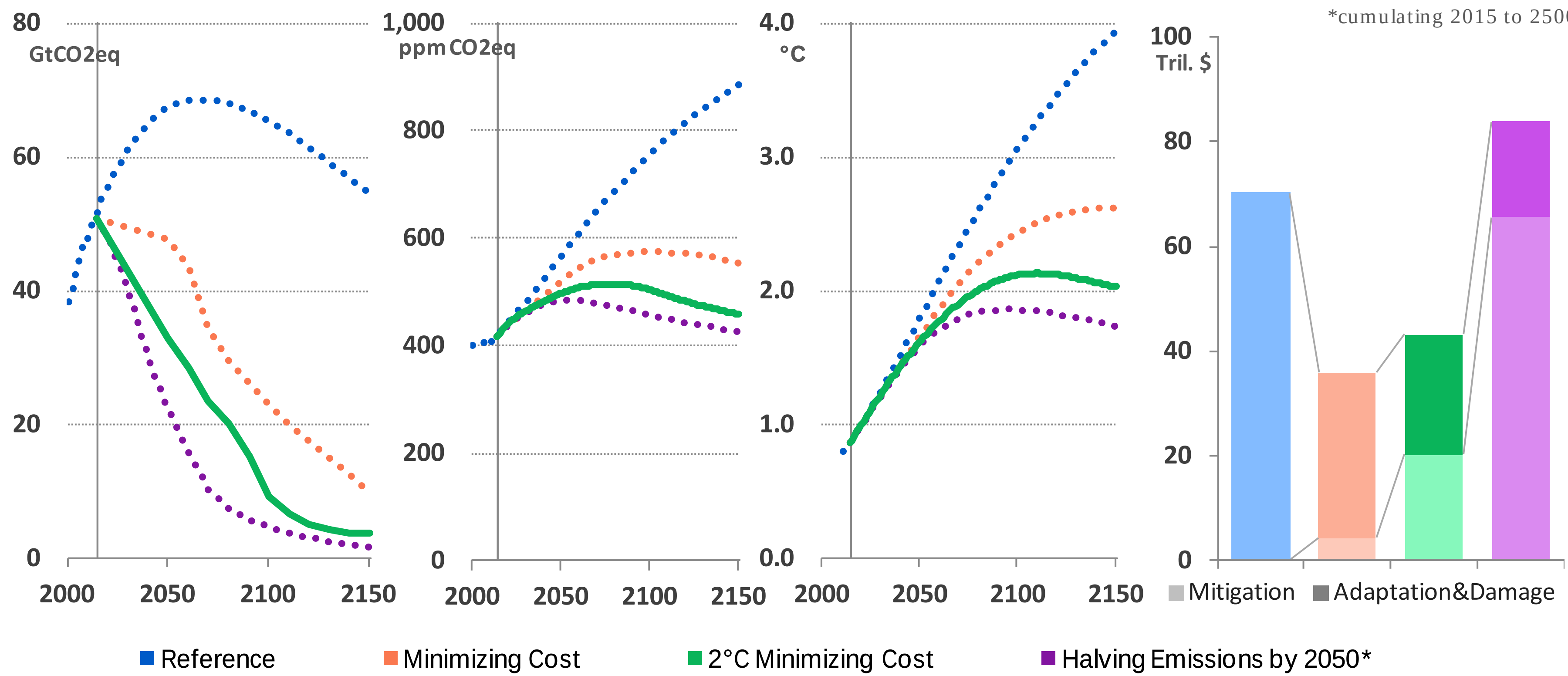
❖ GHG Emissions ❖ GHG Concentrations (incl. aerosol etc.) ❖ Temperature Rise (vs. 1850-1900) ❖ Total Cost (cumulative present value*)



“2°C Minimizing Cost, for example, is a path that minimize total cost under the condition of 2 degree temperature rise in 2150. Its total cost is 20% higher than “Minimizing Cost” without the temperature limit. GHG emissions decrease by 30% in 2050 and needs almost zero-emissions after 2100. Temperature rises to just over 2 degree in 2100 and then declines to 2 degree.

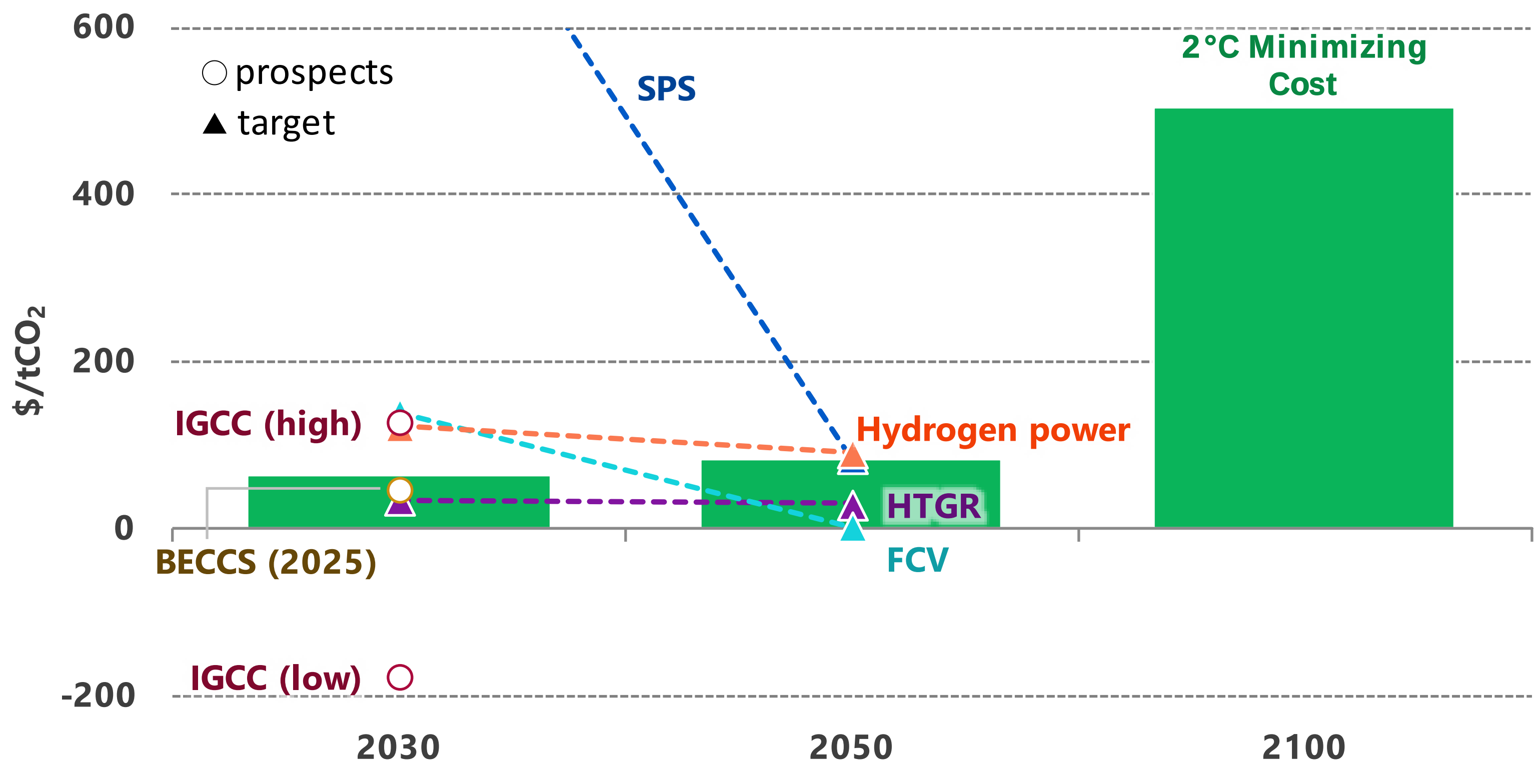
*Emissions path reflected "RCP 2.6" in the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC).

Technology development for ultra long-term

Technologies		Description	Challenges
Technologies to reduce CO_2 emissions	Next Generation Nuclear Reactors	Fourth-generation nuclear reactors such as ultra-high-temperature gas-cooled reactors(HTGR) and fast reactors, and small- and medium-sized reactors are now being developed internationally.	Expansion of R&D support for next generation reactors
	Nuclear fusion reactor	Technology to extract energy just like the sun by nuclear fusion of small mass number such as hydrogen. Deuterium as fuel exists abundantly and universally. Spent nuclear fuel as high-level radioactive waste is not produced.	Technologies for continuously nuclear fusion and confining them in a certain space, energy balance, cost reduction, financing for large-scale development and establishment of international cooperation system, etc.
	Space Photovoltaic Satellite (SPS)	Technologies for solar PV power generation in space where sunlight rings abundantly above than on the ground and transmitting generated electricity to the earth wirelessly via microwave, etc.	Establishment of wireless energy transfer technology, reduction of cost of carrying construction materials to space, etc.
Technologies to sequestrate CO_2 or to remove CO_2 from the atmosphere	Hydrogen production and usage	Production of carbon-free hydrogen by steam reforming of fossil fuels and by CCS implementation of CO_2 generated.	Cost reduction of hydrogen production, efficiency improvement, infrastructure development, etc.
	CO2sequestration and usage (CCU)	Produce carbon compounds to be chemical raw materials, etc. using CO_2 as feedstocks by electrochemical method, photochemical method, biochemical method, or thermochemical method. CO_2 can be removed from the atmosphere.	Dramatic improvement in quantity and efficiency, etc.
	Bio-energy with carbon capture and storage (BECCS)	Absorption of carbon from the atmosphere by photosynthesis with biological process and CCS.	It requires large-scale land and may affect land area available for the production of food etc.

Lower cost is key for innovative technologies

❖ CO_2 Reduction Cost by Innovative Technology

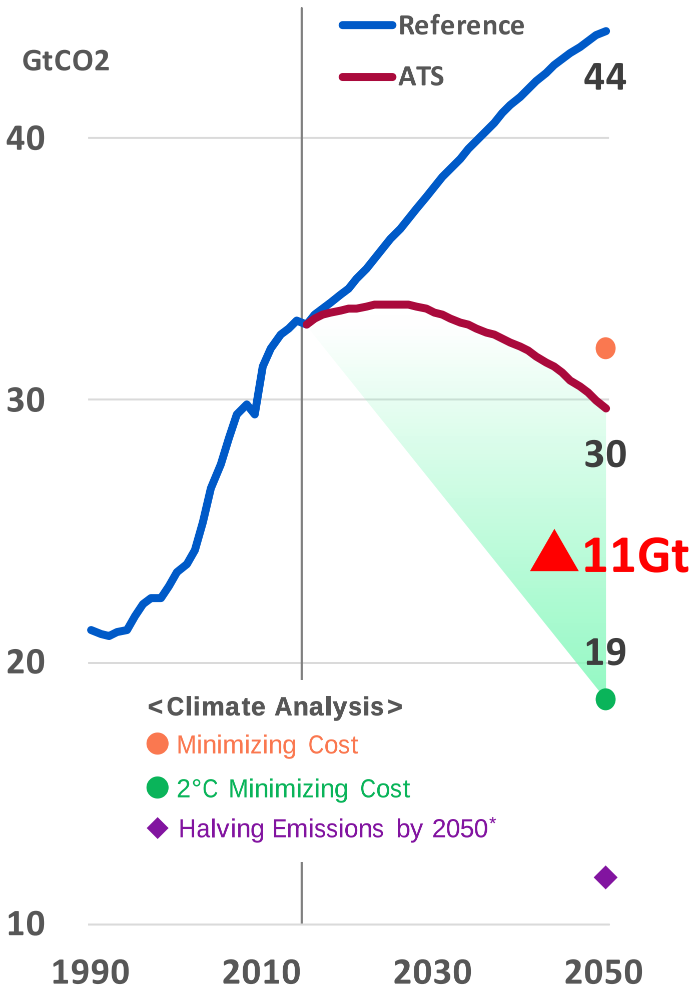


Note: Cost (= carbon price) for “2 ℃ Minimizing Cost " is the highest cost of the technology adopted at each year. Refer to the main report for detail.

Implicit carbon price for “2 ℃ Minimizing Cost" is \$85/tCO_2 in 2050. The target costs for innovative technologies, such as BECCS, hydrogen power, FCV, HTGR, SPS, are within the range of the carbon price. The 2 degree target can be reached with using these technologies. It is important to enhance R&D from the long term view and international collaboration is dispensable.

Further CO_2 reductions from ATS

❖ Energy-related CO_2 Emissions



❖ Examples of technologies needing further reductions

1) CO_2 Free Hydrogen (refer to previous Outlook)

・ Hydrogen power 1GW x 3000 units

□ Fuel cell vehicles 1 billion units

(H_2 demand of 800Mt/yr corresponds 3 times of today's LNG)

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2) Negative-emission Technology

□ BECCS: Biomass power 0.5GW x 2800 units

(Fuel supply of 2000Mtoe/yr needs land of 2.85 million km^2)

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3) Zero-emission Power and Factories with CCS

▲10GtCO_2 (Maximum reduction volume by substituting thermal power generation without CCS)

□ SPS: 1.3GW x 2300 units

or □ HTGR: 0.275GW x 8700 units

or □ Fusion reactor: 0.5GW x 4500 units

or □ Thermal power with CCS: 2800GW

(Estimated CO_2 storage potential is over 7000Gt□

+

▲1 GtCO_2

□ CCS: Installed in 20% of factories and plants

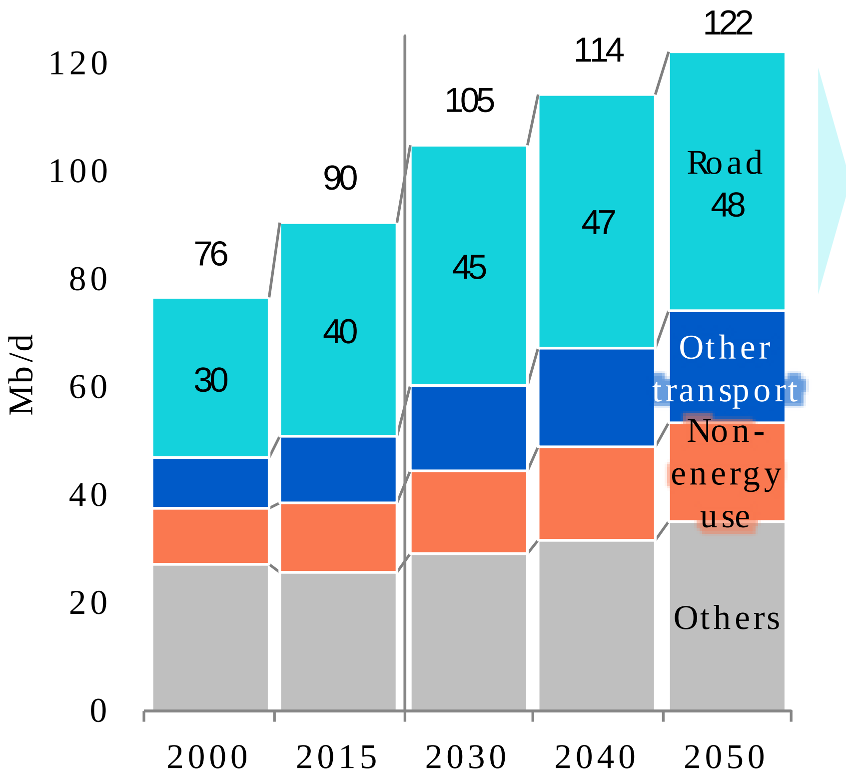
(iron & steel, cement, chemicals, pulp & paper, refinery and GTL/CTL)

*Emissions path reflected "RCP 2.6" in the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC).

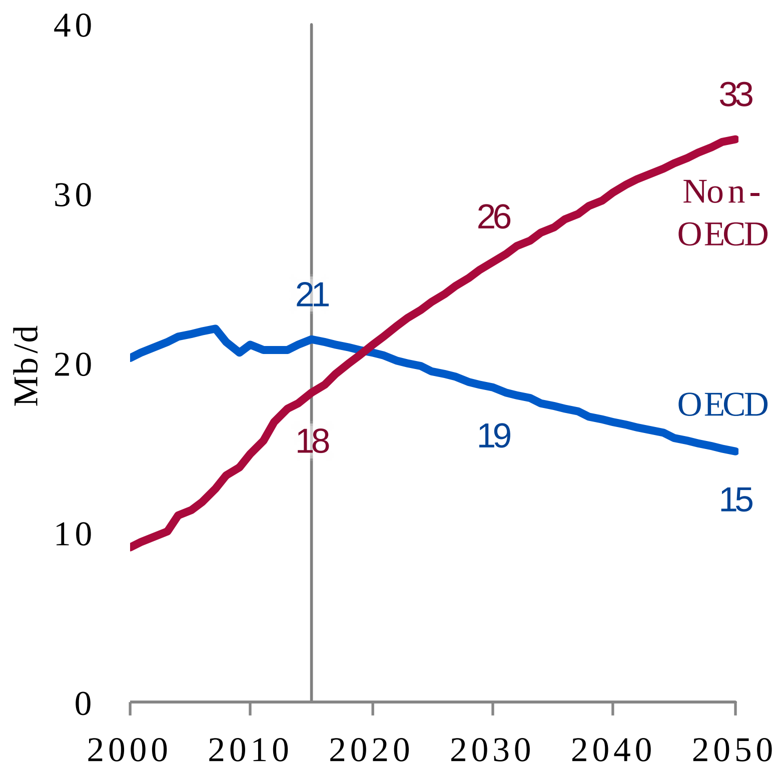
Peak Oil “Demand” Case

Transportation, especially cars drive oil demand

Oil consumption [Reference Scenario]



Oil for Road [Reference Scenario]



About 70% of the increases in oil consumption until 2050 is by transportation and petrochemical feedstocks. In particular, road transport may decide where to go.

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.

The time for car electrification has come?

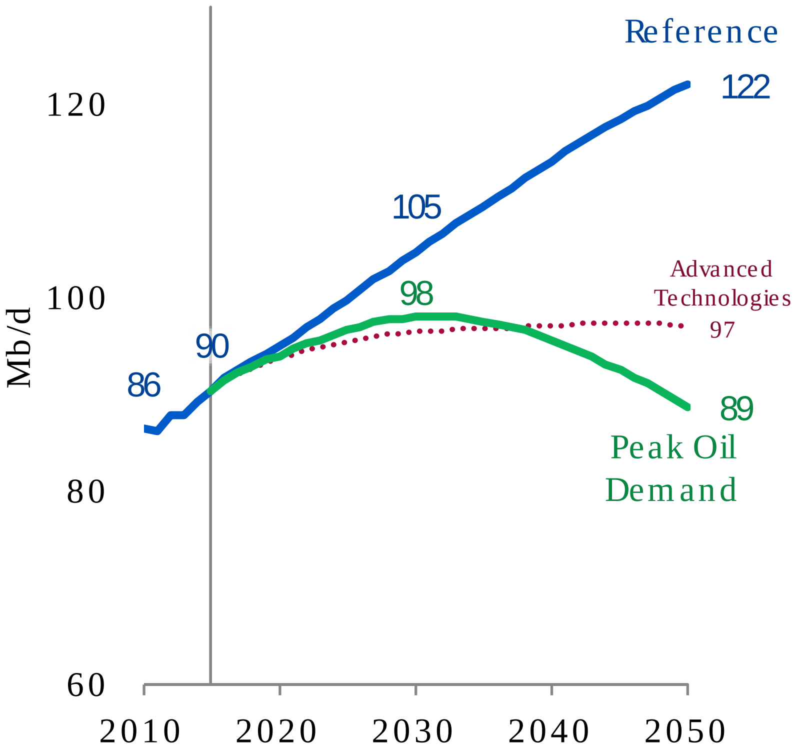
Selected recent movements by governments/assemblies and car makers

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

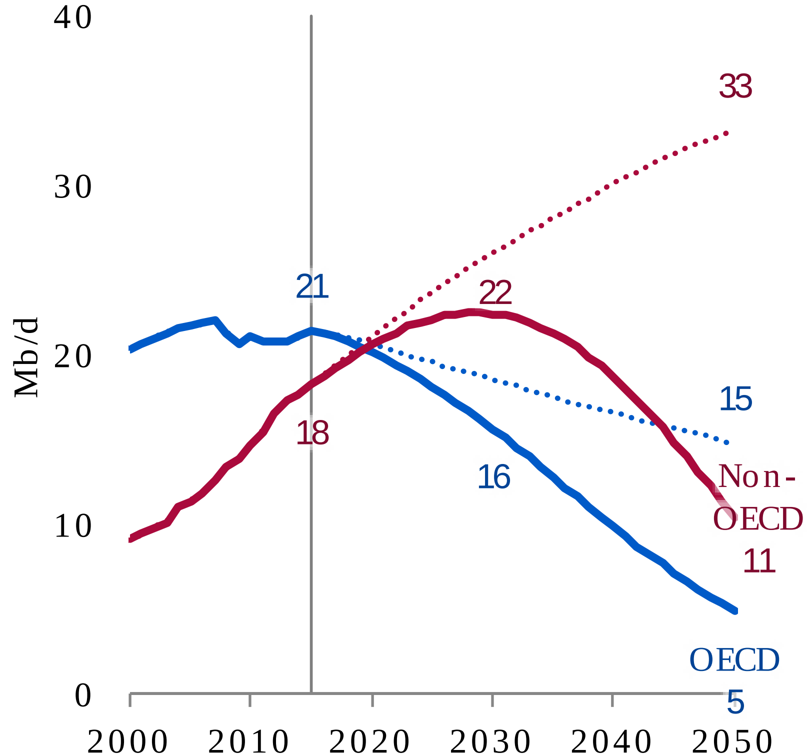
Toyota	The target for FCV sales is more than 30,000/year in 2020 (2015). Reported of full-scale entry into EVs in 2020 (2016)
Volkswagen	Announced the strategy to increase EV share in its total sales to 25% with more than 30 models of EVs by 2025 (2017)
Renault-Nissan	Introducing 12 models of EVs by 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)
Ford	Announced that eco-cars combined with EVs and HEVs will be raised to 70% by 2025 (2017).
Honda	In 2030, two-thirds of automobile sales will be electrified. EVs will be released in China in 2018 (2017).

Oil peaks around 2030 by rapid penetration of ZEVs

Oil consumption



Oil for Road [Peak Oil Demand Case]



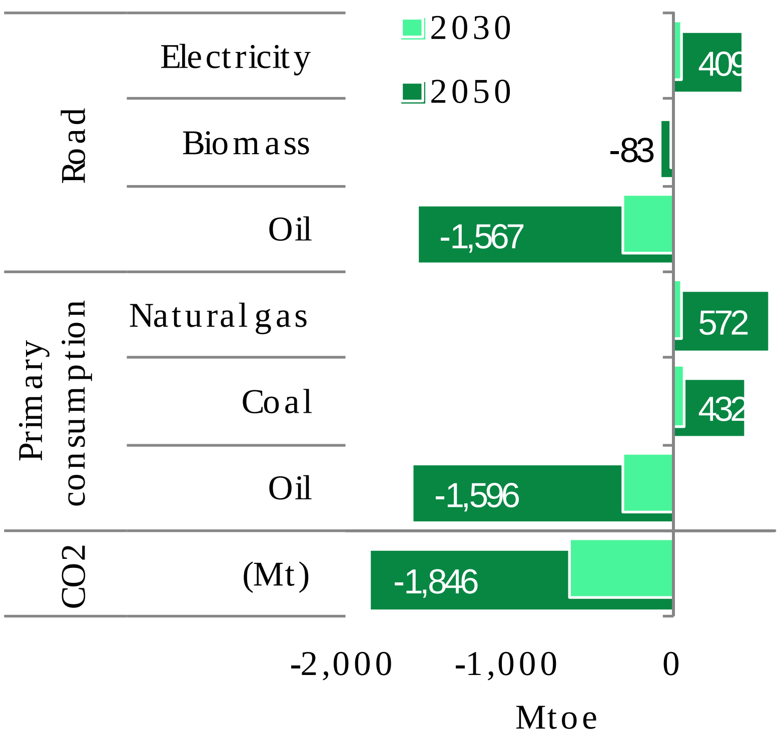
Note: Dotted lines are the Reference Scenario

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.

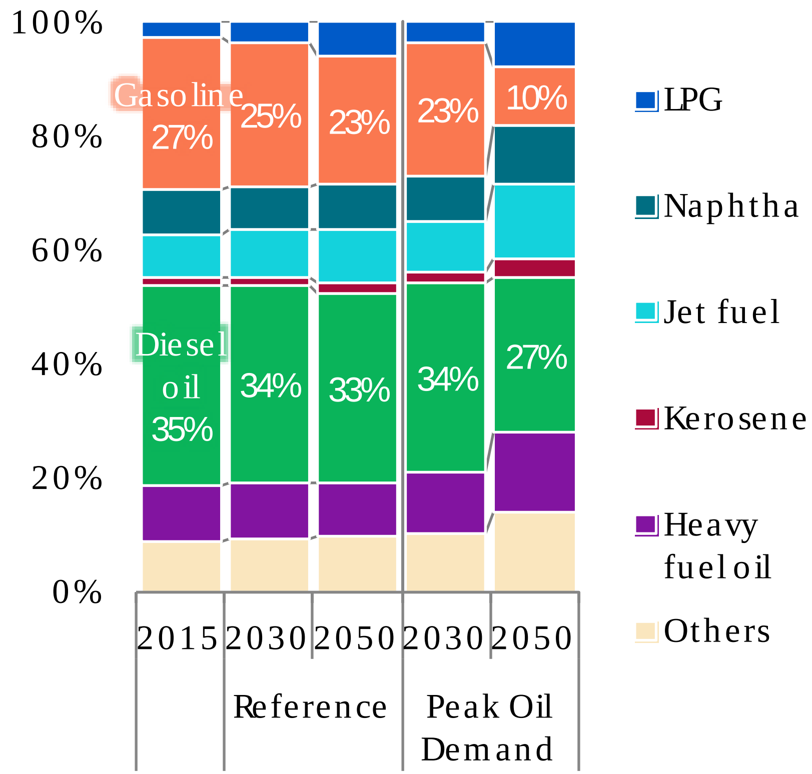
Oil consumption by cars in Non-OECD, which continues to increase rapidly in the Reference Scenario, also declines from around 2030. It is as much as one third of the Reference Scenario in 2050.

While natural gas and coal increase, petroleum product composition changes

Changes in consumption (from the Reference Scenario)



Composition of petroleum products consumption



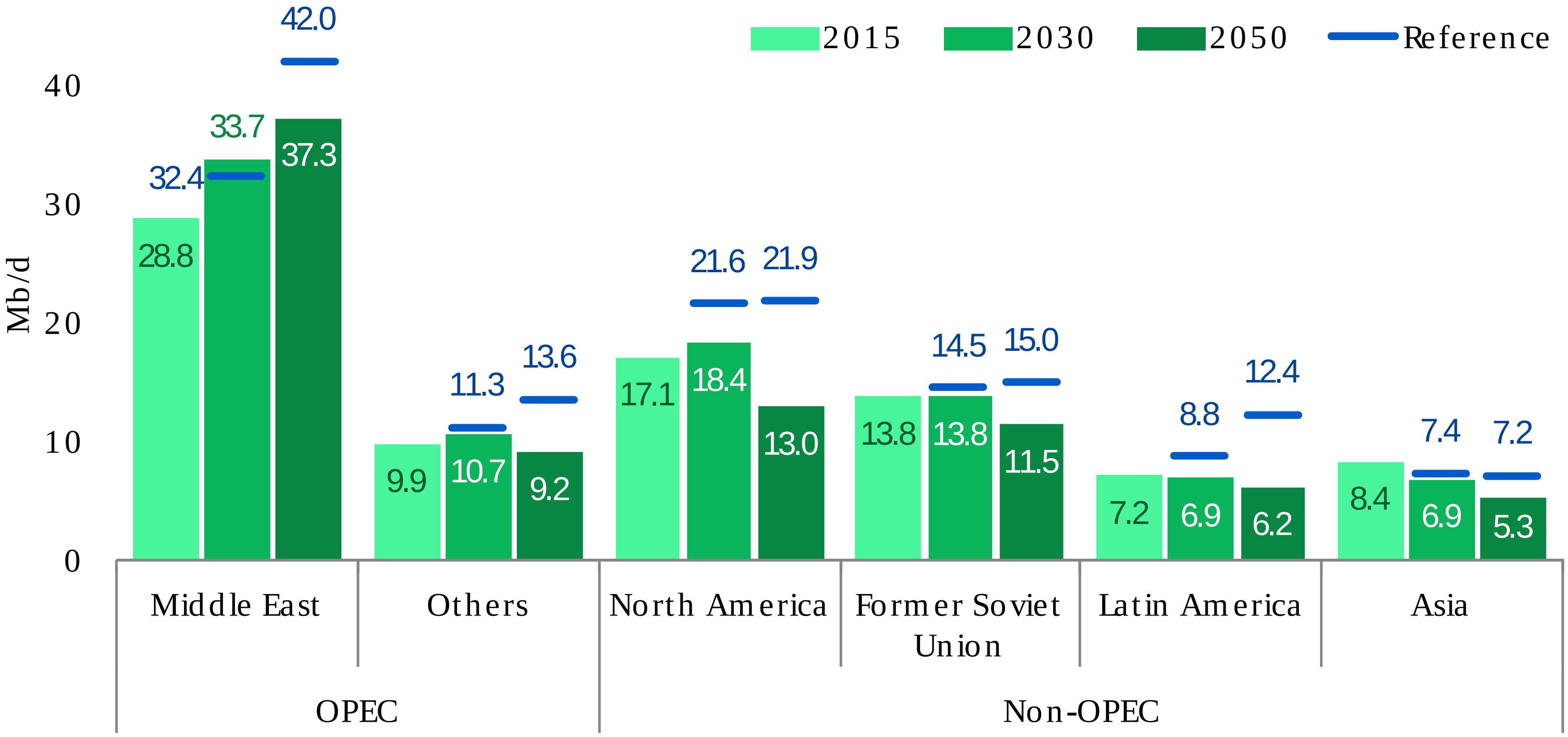
Note: Excluding own use

Whilst oil consumption declines, electricity demand by ZEVs increases fuel consumption for power generation. Both natural gas and coal exceed oil in the late 2030s. Since then, natural gas is the largest energy source.

Gasoline reduces its share to 10% in 2050. Share of diesel oil is not smaller than gasoline because diesel oil has other uses, but it is 8 points lower than today.

Crude oil production shifts more to low-cost regions...

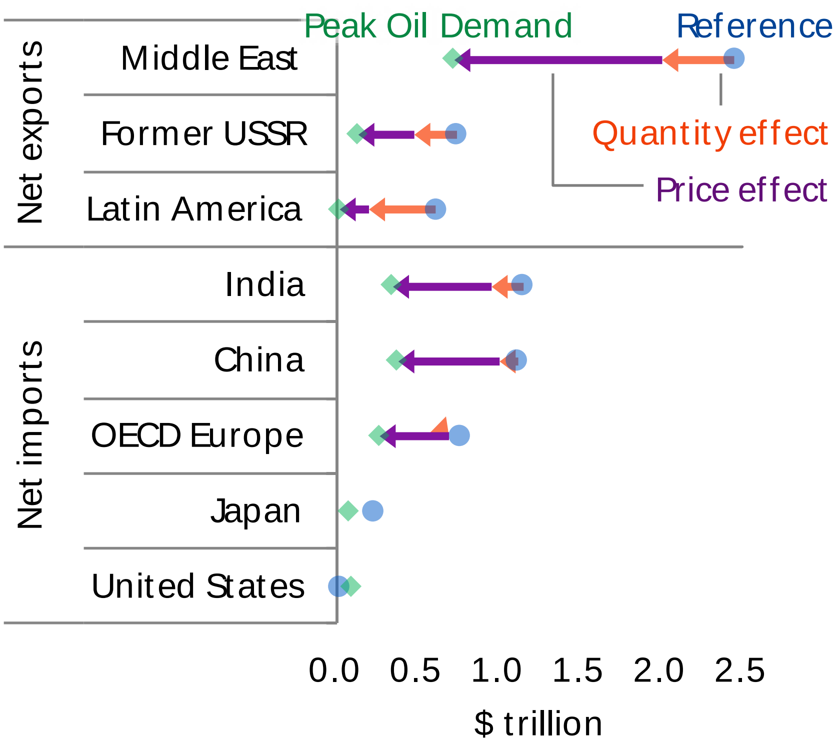
Crude oil production [Peak Oil Demand Case]

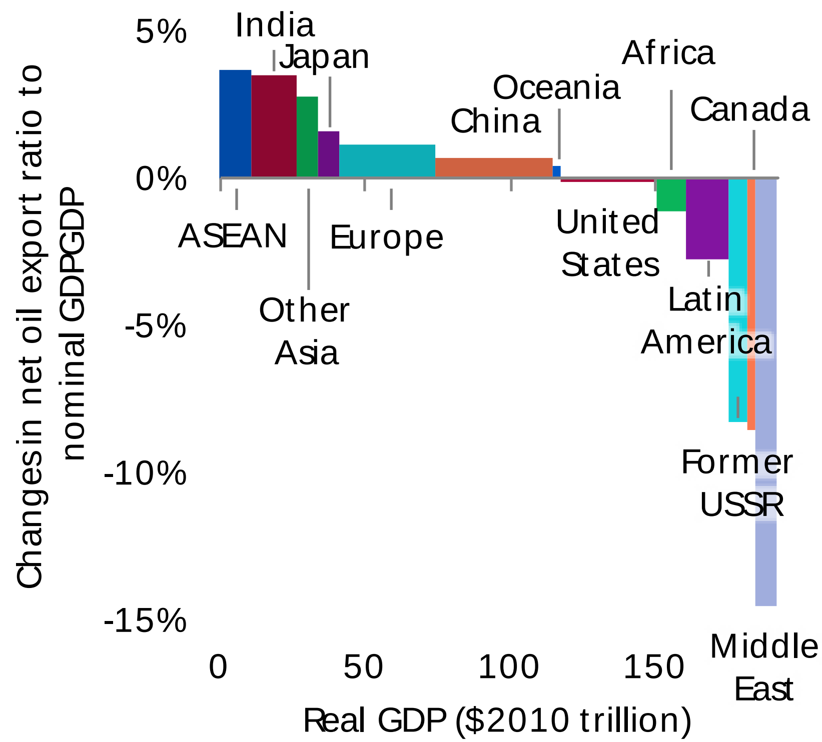


Oil price falls due to the change in supply and demand pressure and market sentiment – $65/bbl and $50/bbl in 2030 and in 2050, respectively, compared to $95/bbl and $125/bbl in 2030 and in 2050, respectively, in the Reference Scenario (in $2016). Given this drastic price decrease, superiority of lower 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.

...but the economic downturn also works in the Middle East

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





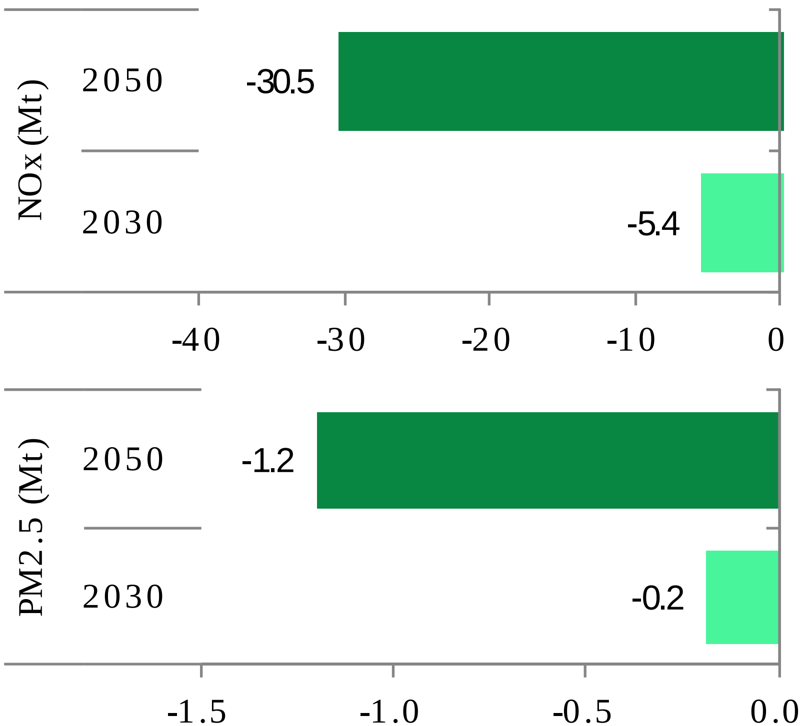
Note: Europe excludes the former Soviet Union

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.

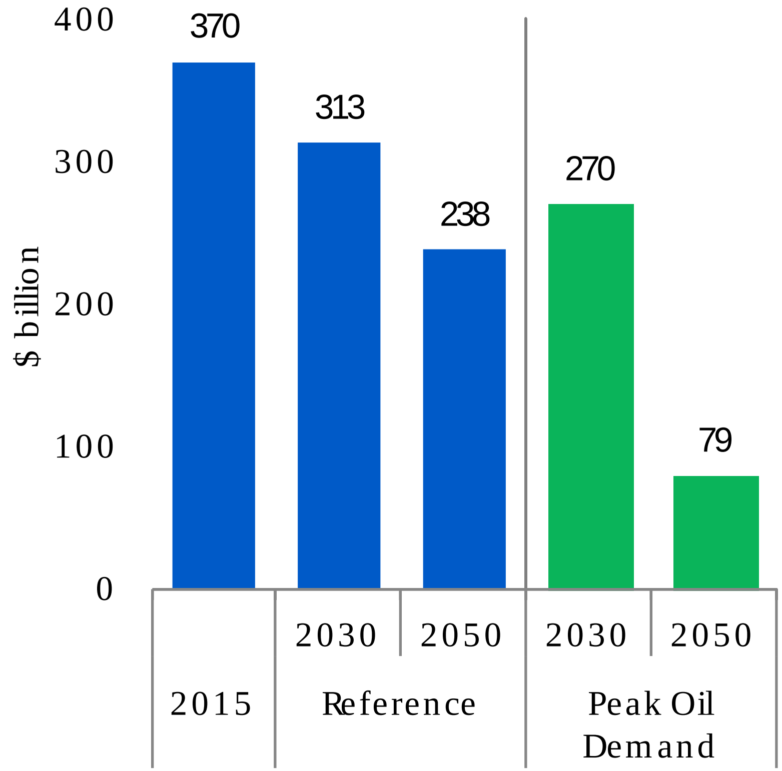
Impact of less oil consumption diverges

Changes in emissions (from the Reference Scenario)



Note: Automobile origin. Excluding effect on improvement of conventional automobile emission control performance

Excise taxes on gasoline and diesel oil for automobiles in OECD



Emission reductions in NO_x and $PM_{2.5}$, major drivers of the car electrification, are 27% and 3%, respectively, compared to total emissions in 2010. Some contributions are expected to improve air quality in urban areas.

Excise taxes on automotive gasoline and diesel oil decline significantly unless tax regime changes. They may cause financial problems along with the subsidies for ZEVs at their promotion period.

How do we recognise the rapid de-oiling?

- The Peak Oil Demand Case shows that oil consumption can turn into a decline in the not too distant future under some circumstances.
- However, the feasibility of this Case can be said to be extremely challenging because the penetration of ZEVs is far greater than that in the "Advanced Technologies Scenario," in which a bottom-up approach to the maximum implementation of advanced technologies is adopted. Rather, it can be interpreted that oil consumption may not be easily peaked out.

...and then

- It should not be overlooked that oil is required even in 2050 in the Peak Oil Demand Case on a scale that does not differ from today.
- If the supply investment becomes insufficient due to excessive pessimism in the future, it could threaten energy security and trigger the switching from oil to other energies.

- The rising dependence on the Middle East crude oil will increase geopolitical risk for stable supply.
- Although it is reasonable the Governments in the Middle East cut public investment and subsidies to reduce the budget deficit coping with low oil price, it is difficult to deny the possibility of increasing social anxiety and worsening situation in the region.
- The role of consuming countries continues to be important as well as producing countries' own efforts. Supporting such efforts as Saudi Arabia "Saudi Vision 2030" is needed.

Thank you for your attention.

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