Long Term Outlook For Global Energy Market and the Role of Renewable Energy

Putrajaya, Malaysia, July 2019

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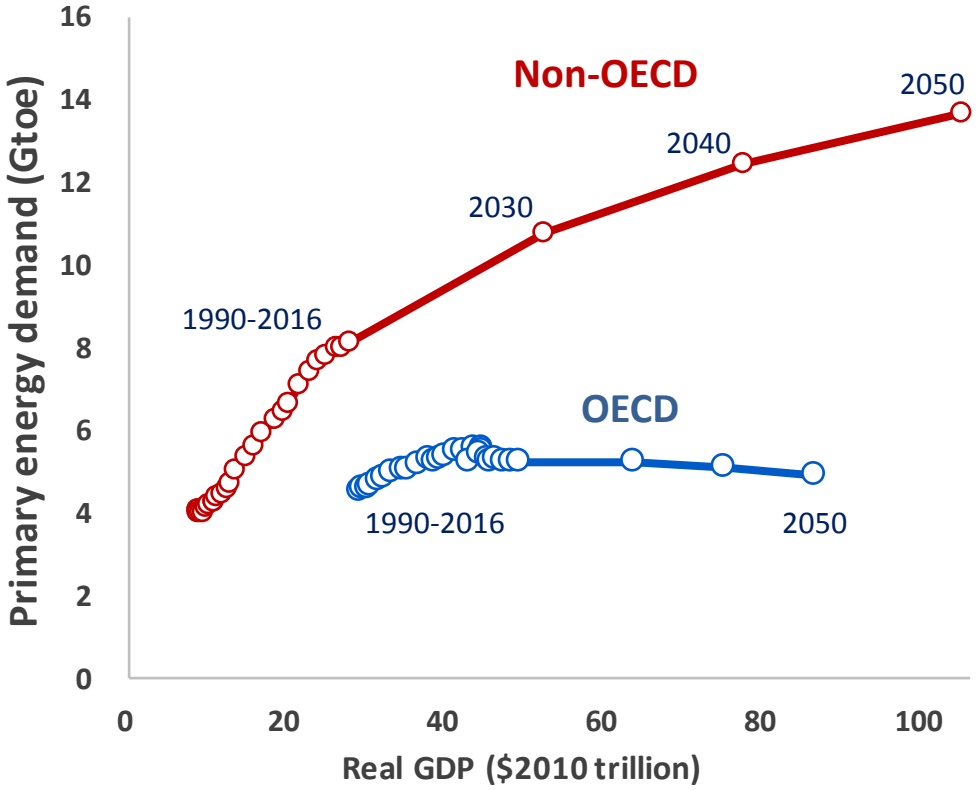
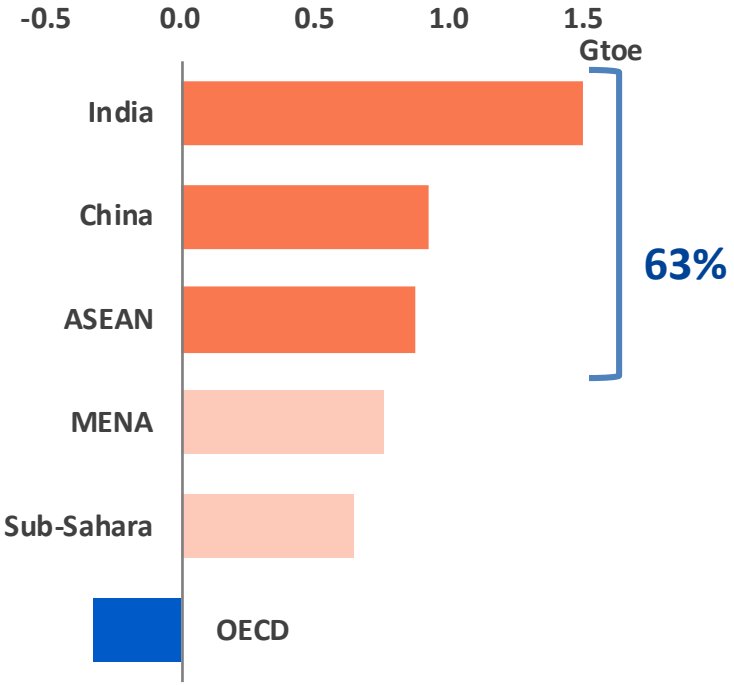
Dramatic growth of energy demand in Asia

❖ Primary energy demand vs. real GDP



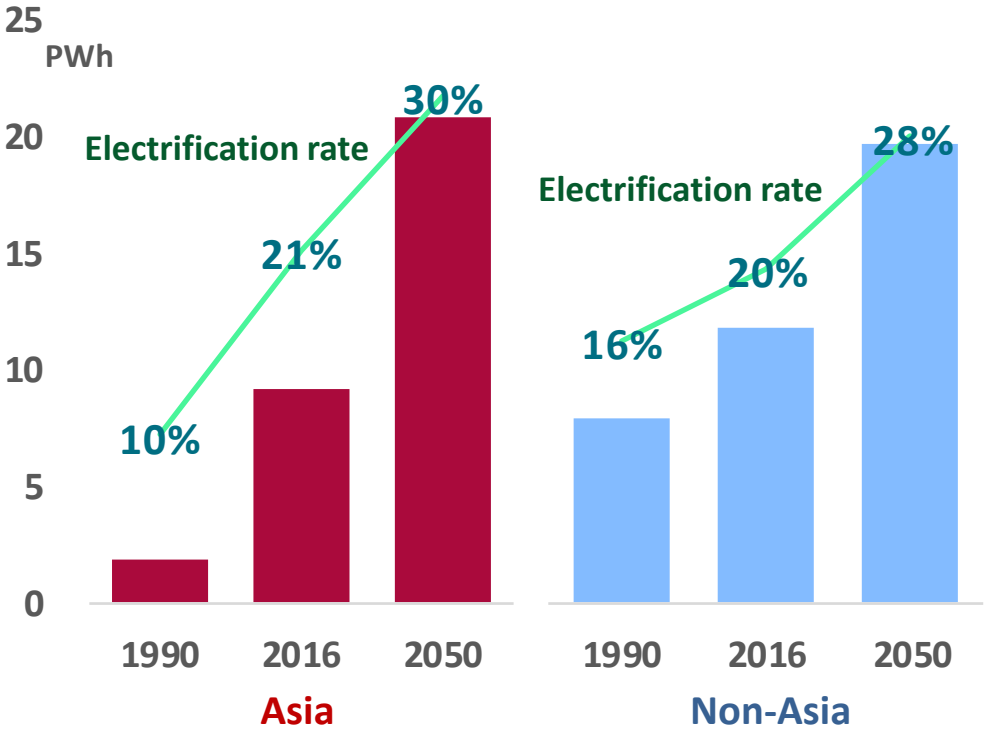
❖ Change in energy demand (2016-2050)



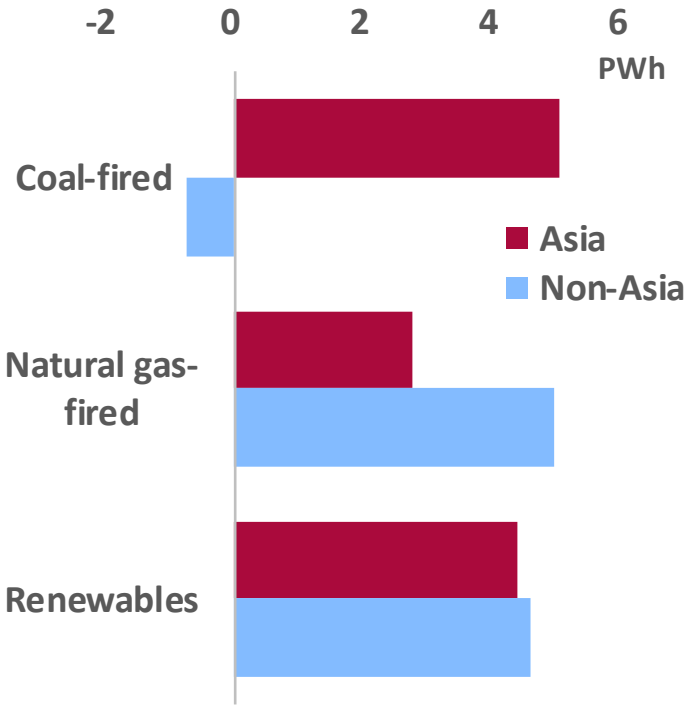
* MENA: The Middle East and North Africa

Growth of dependence to electricity

❖ Electricity demand and electrification rate



❖ Change in electricity generation (2016-2050)

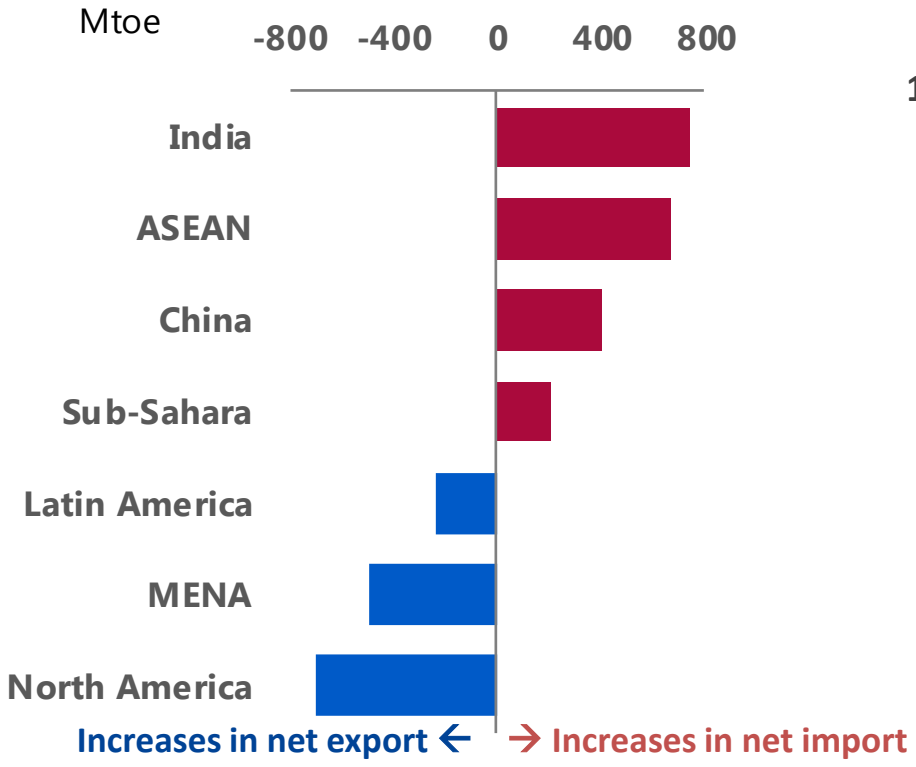


* Electrification rate: Share of electricity in the final energy consumption

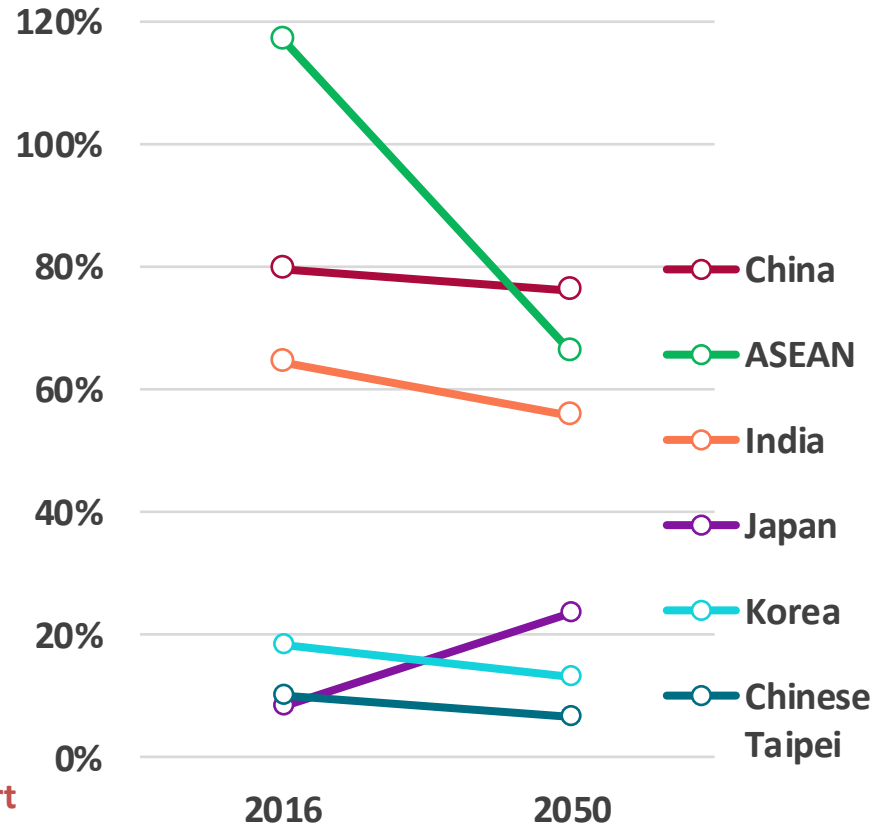
- 60% of the increment in the primary energy demand will be consumed for power generation.
- The global electricity demand will double in 2050, and 60% of the increment will occur in Asia.
- In Asia, electrification rate will increase to 30% in 2050, and 40% of electricity demand will be covered by coal, which can be obtained plentifully and inexpensively.
- Except for Asia, natural gas-fired power generation will be applied more than the coal-fired.

Increase of energy imports in Asia

Increase of net import energy (2016-2050)



Self-sufficiency rate

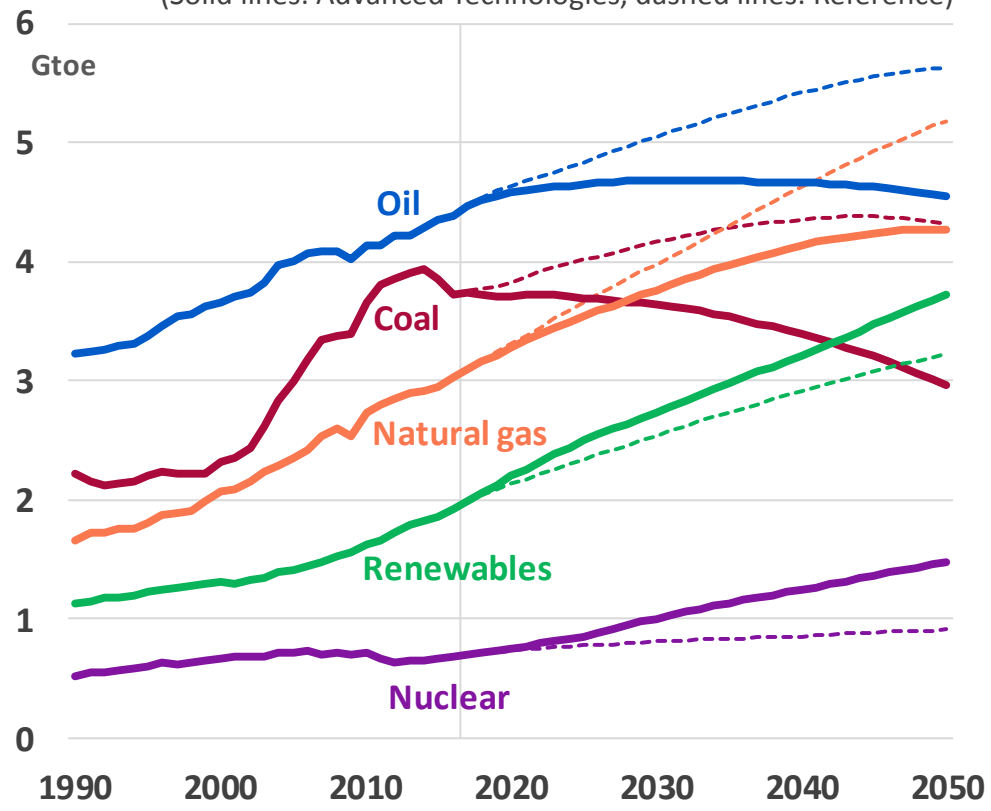


- Energy imports of Asia will increase dramatically.
- 80% of energy traded globally will be consumed in Asia.
- United States will be a net exporter in the middle of the 2020s.
- Self-sufficiency rate in Asia will decrease from 72% to 63%. This tendency is remarkable for ASEAN, which will be a net importer in the first half of the 2020s.

Coal declines while oil hits peak in 2030

Primary energy demand

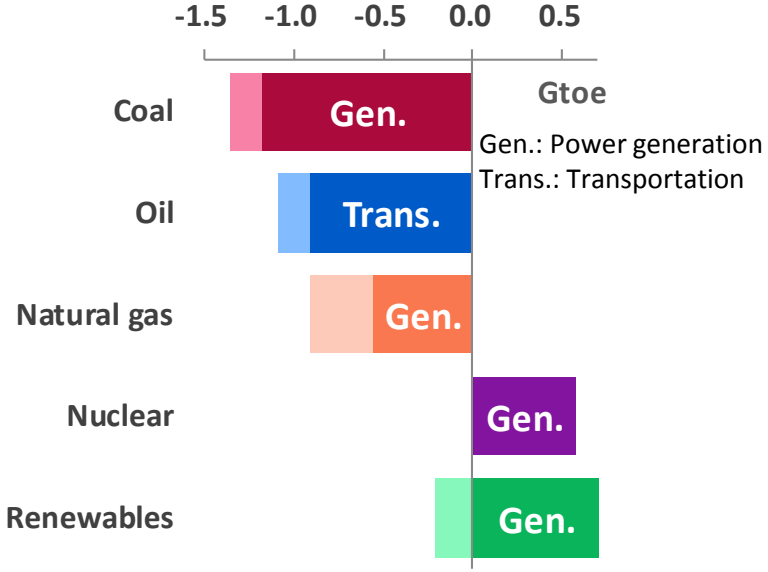
(Solid lines: Advanced Technologies, dashed lines: Reference)



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

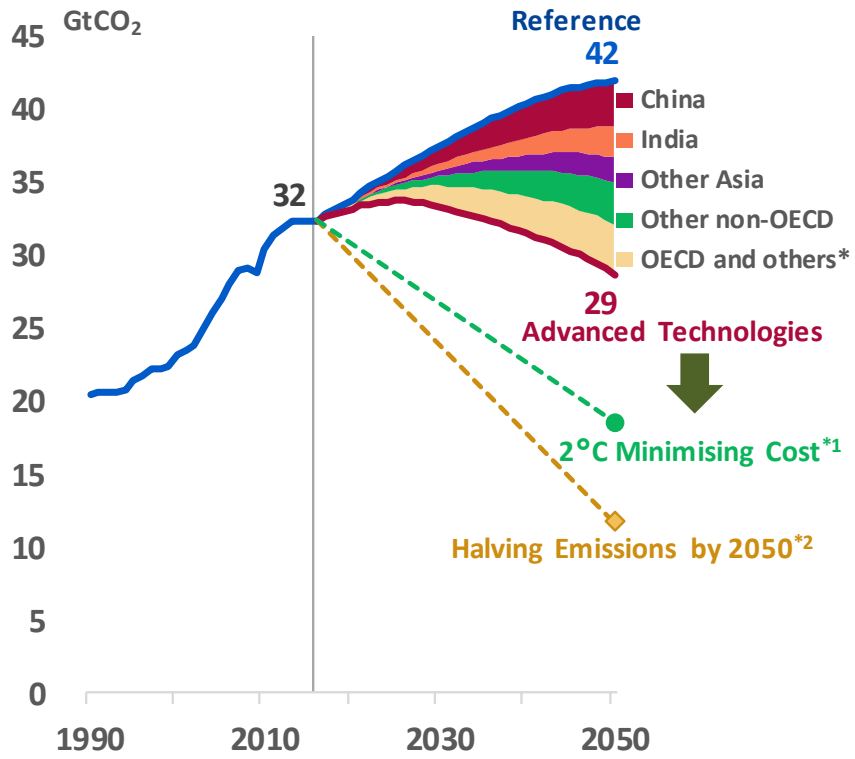


In the Advanced Technologies Scenario…

- 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.

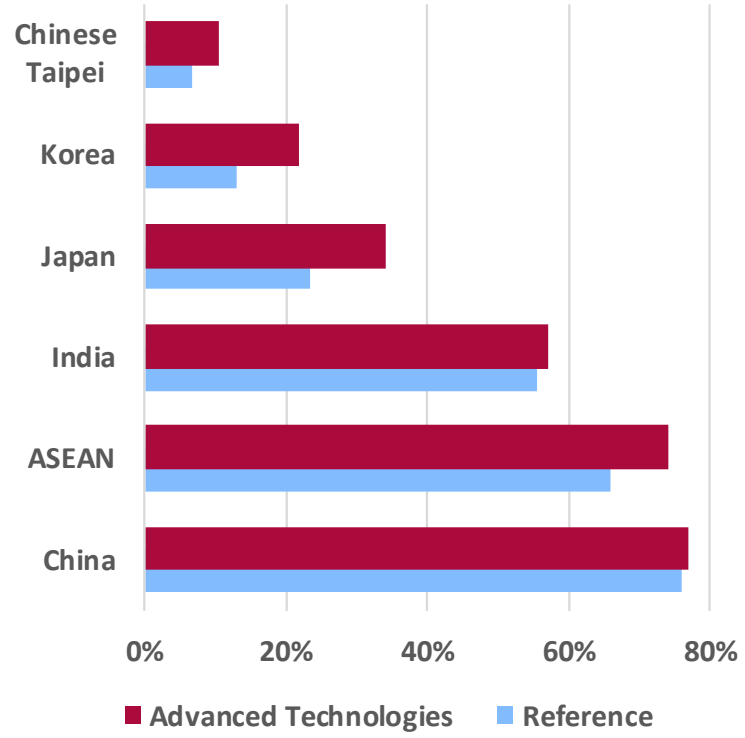
Improve environmental and security issues

❖ Energy-related CO_2 emissions



* Includes international bunkers.
*1 Refer "IEEJ Outlook 2018". *2 This path represents an emission path in the RCP2.6 scenario summarised in the fifth Assessment Report by IPCC.

❖ Self-sufficiency rate in Asia (2050)



In the Advanced Technologies Scenario…

◆ CO_2 emissions will peak in the mid-2020s and will decrease by 11% in 2050 from 2016. However, to maintain temperature rise caused by the climate change within 2 degree Celsius, additional programs and innovative technologies are required.

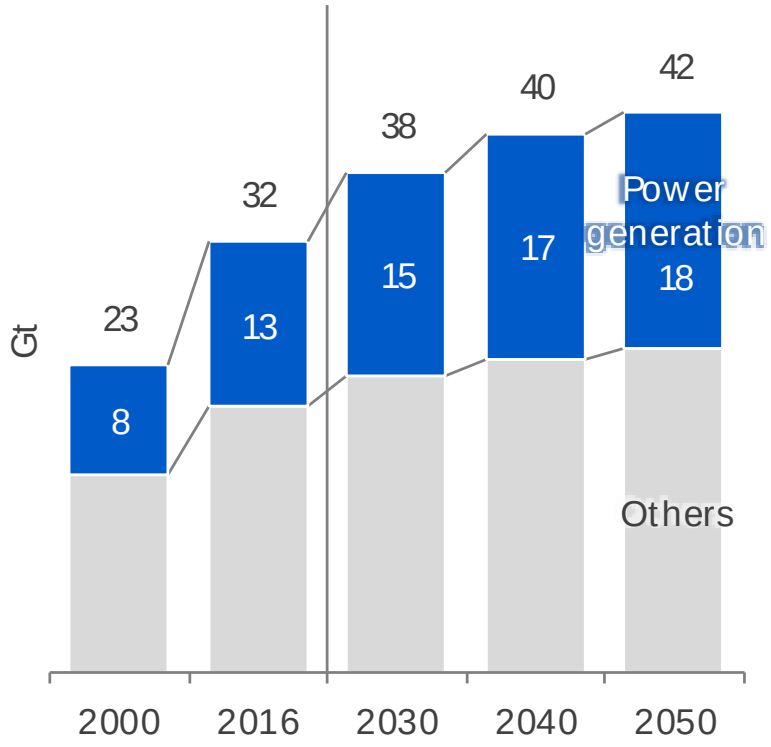
◆ Compared with the Reference Scenario, self-sufficiency rate in Asia will improve by 3%p in 2050.

Impact of banning construction of new coal-fired power plants

from IEEJ's Outlook 2019

Decarbonisation in power sector is required

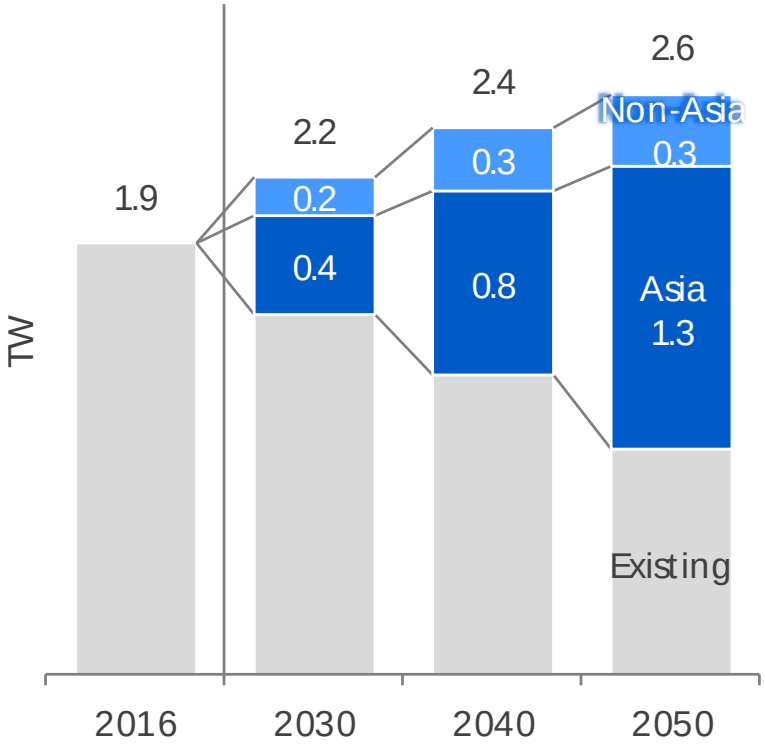
❖ **CO_2 direct emissions** [Reference Scenario]



Of additional emissions in 2050 (9.6 Gt), more than half (5.2 Gt) comes from power sector.

ESGs and divestment movements discourage investment for coal-fired power plant.

❖ **New coal-fired power plant capacity** [Reference Scenario]



In the Reference Scenario, coal keeps the largest share in power generation mix.

In 2050, 1.6 TW of new coal-fired power plants were built after 2020 exist. → Without them?

No New Coal-fired Power Plant Case
—— a hypothetical option in the future

There are a lot of problems to be worked on to accomplish the shift from coal.
However, such problems in the real world are set aside in this case study.

No New Coal-fired Power Plant Case

A hypothetical case in which all new coal-fired power plant construction would be banned after 2020.

Two patterns with different substitution options (natural gas; solar PV / wind) for coal-fired power generation are prepared:

No New Coal-fired Power Plant (Natural Gas Substitution) Case

No New Coal-fired Power Plant (Renewables Substitution) Case

Judging from base-load function of coal-fired power generation, nuclear can be supposed as one of the substitution options. However, world-wide nuclear penetration requires challenges on technology transfer, matured regulation, and non-proliferation, which are difficult to overcome in short period. In addition, today's coal phase-out opinions rarely suppose the substitution of nuclear. Therefore, just two patterns (natural gas and renewables) are prepared in this case study.

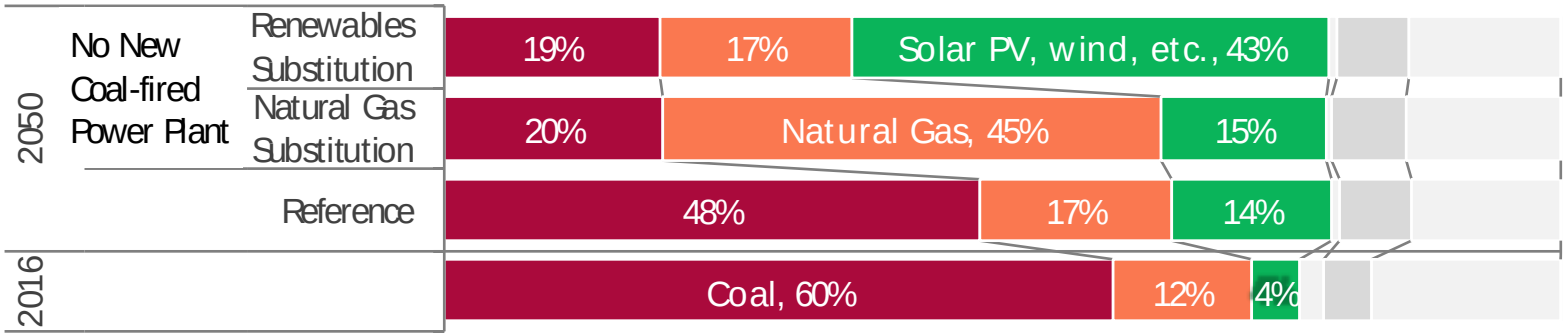
Discuss effects of banning the construction of new coal-fired power plants, in terms of energy supply-demand balances and economics.

No New Coal-fired Power Plant Case does not indicate prospect or feasibility of the coal-fired power plant ban.

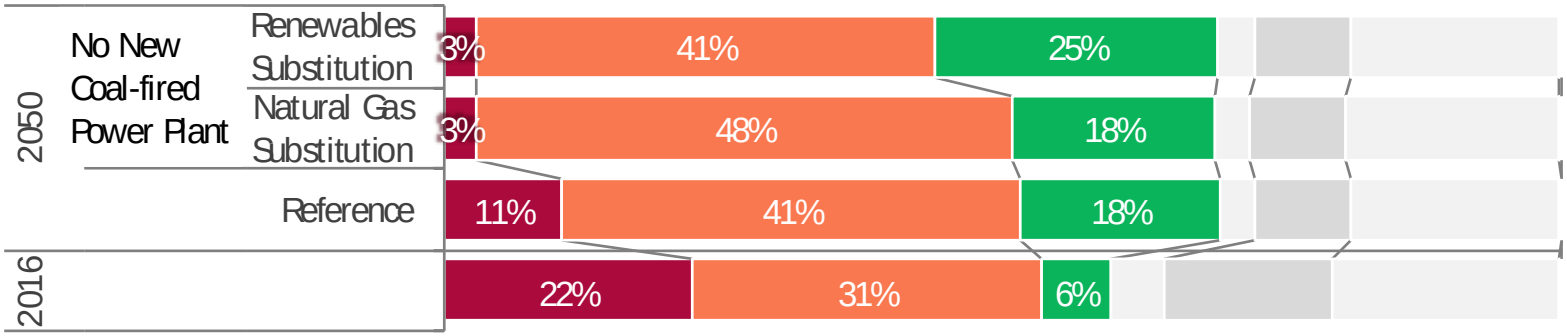
Drastic transition of power generation mix! Especially in Asia!!

❖ Power generation mix

Asia



Non-Asia

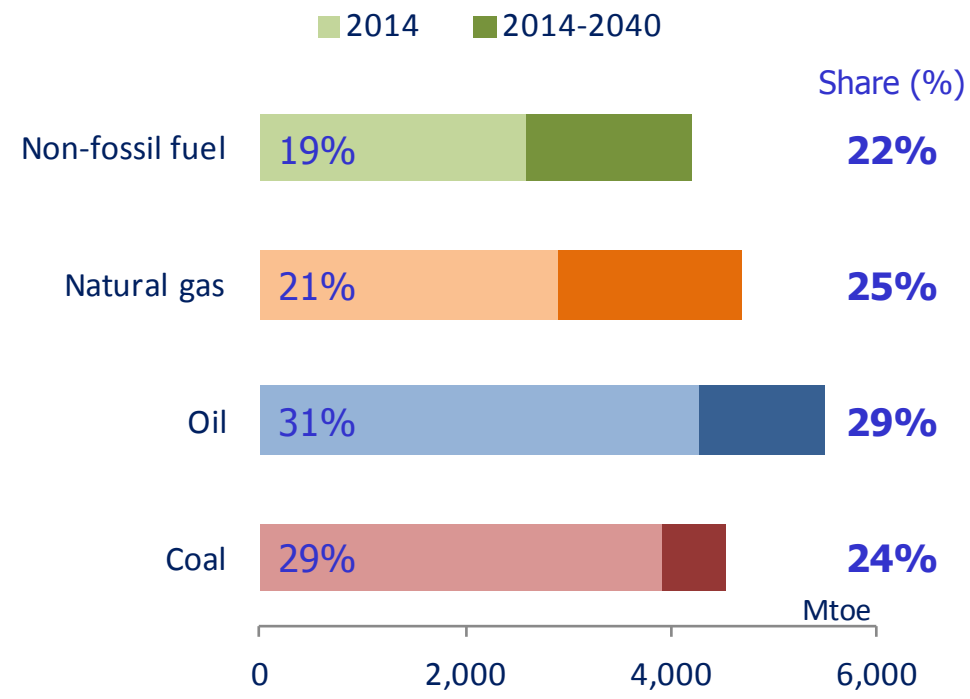


Since Asia largely depends on coal-fired power generation, abolishment of coal-fired power plant construction means drastic transition of power generation mix.

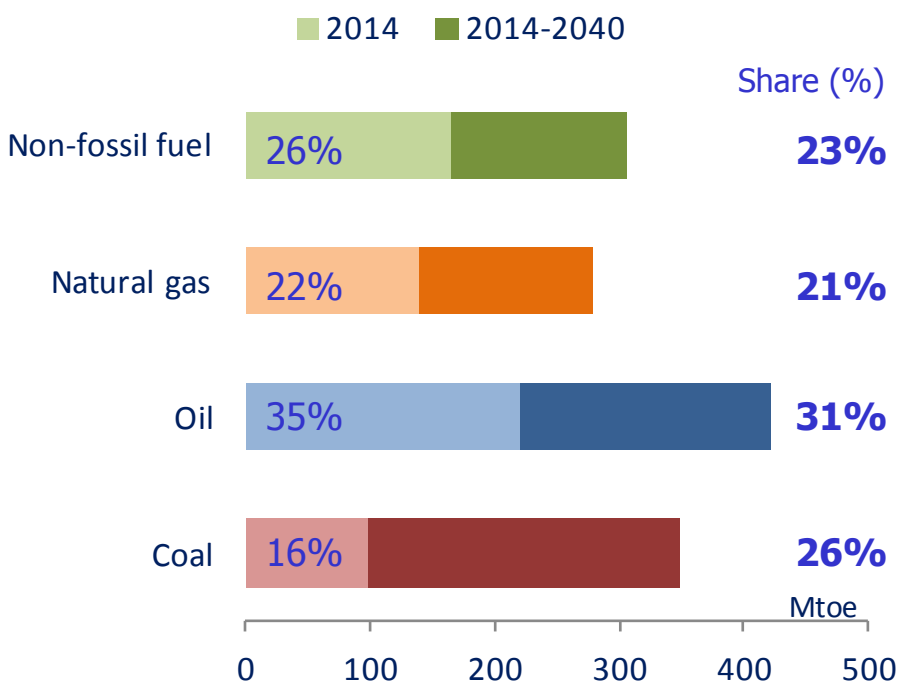
On the other hand, transition is relatively limited in non-Asia. Even if solar PV and wind substitute for coal-fired power generation, natural gas remains the largest share.

Higher Dependency in Coal in ASEAN for Power Generation

World's Primary Energy Demand



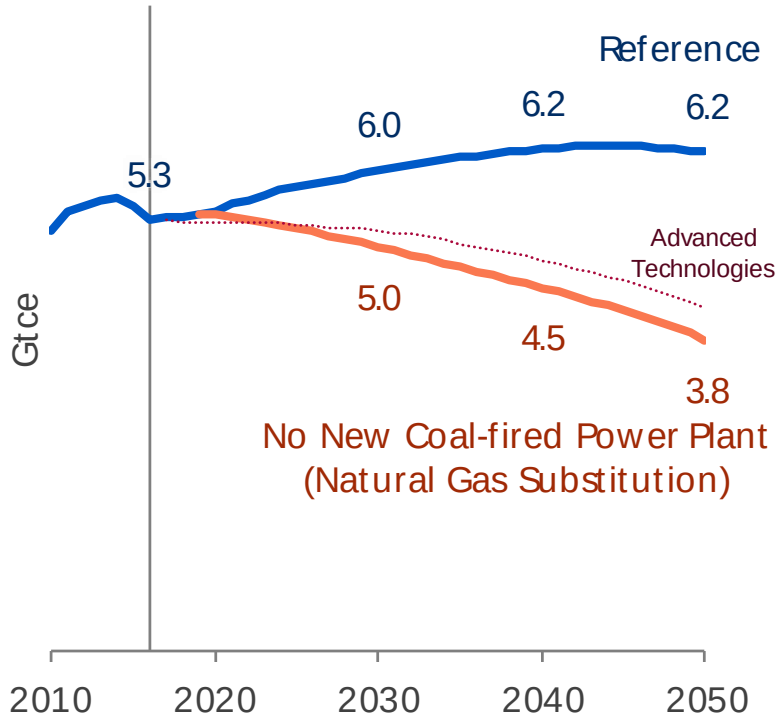
Primary Energy Demand in ASEAN



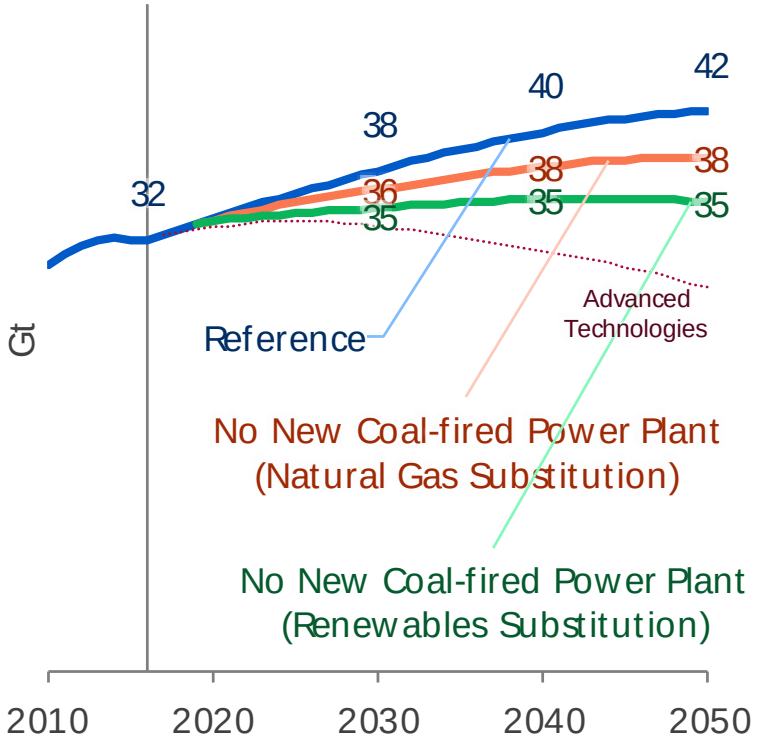
- ✓ Global energy mix shifts towards gas, which becomes the second important fuel with surpassing coal. Renewables and nuclear also increase rapidly. As a result, the energy mix splits more or less equally among coal, oil, gas and non-fossil fuels.
- ✓ In ASEAN, on the other hand, coal grows rapidly (accounts for 40% of the global increment) and becomes the second largest fuel.

Pros of ban on new coal-fired power plant construction

❖ Primary consumption of coal



❖ CO_2 emissions



The reduction of 2.3 Gtce in 2050 is comparable to the current production of China.

It leads to reduction of local pollutants.

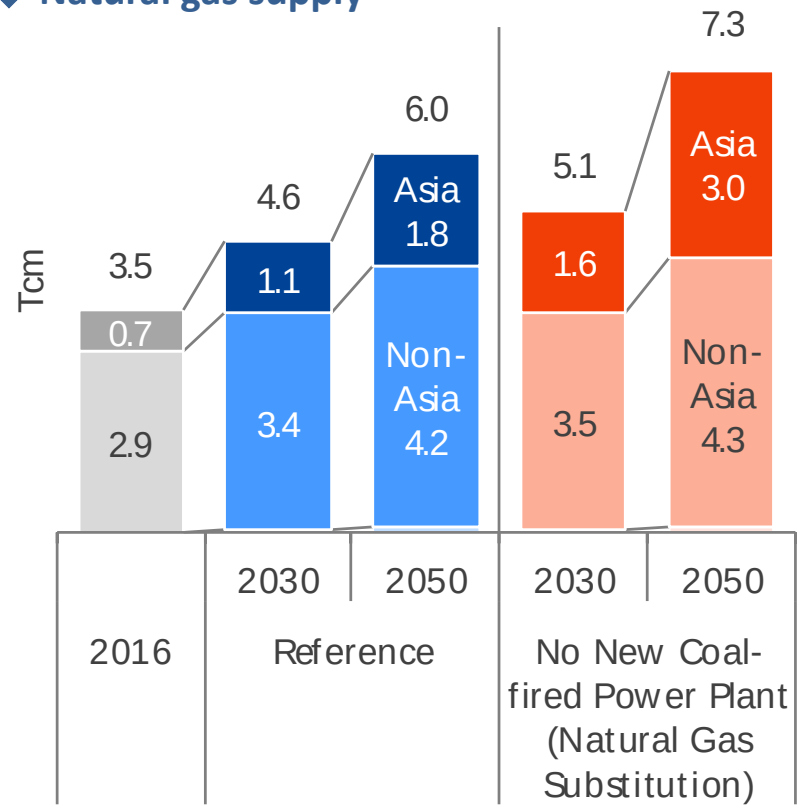
CO_2 reduction in 2050 is 3 Gt (Natural Gas Substitution), or 7 Gt (Renewables Substitution).

However, even in the latter case, CO_2 emissions are not less than the current level.

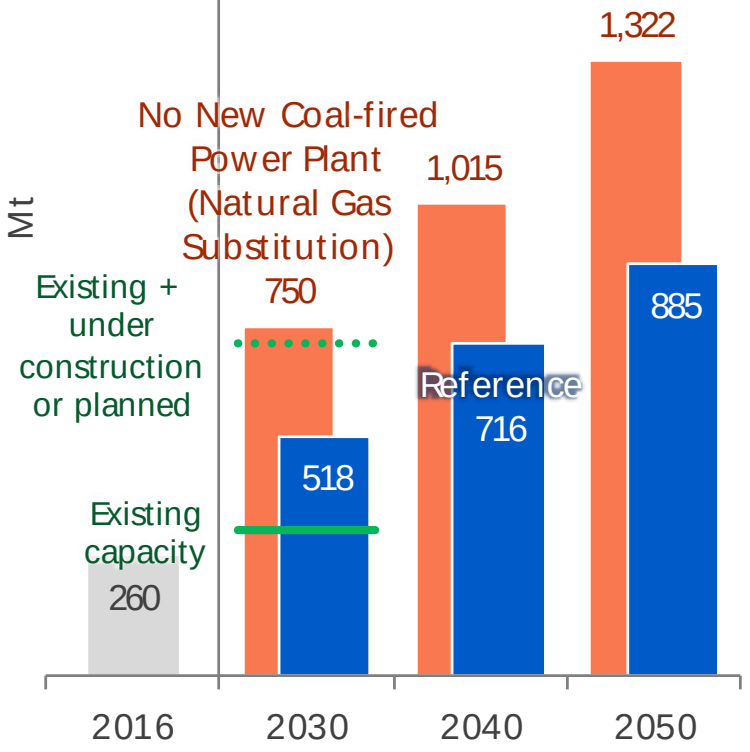
Note: Consumption of coal in the Renewables Substitution is almost same as that of the Natural Gas Substitution.

Substitution of natural gas requires dramatic expansion of supply

Natural gas supply



LNG demand



Natural gas consumption in 2050 reaches twice the current level. Cumulative consumption until 2050 may exceed the proven reserves.

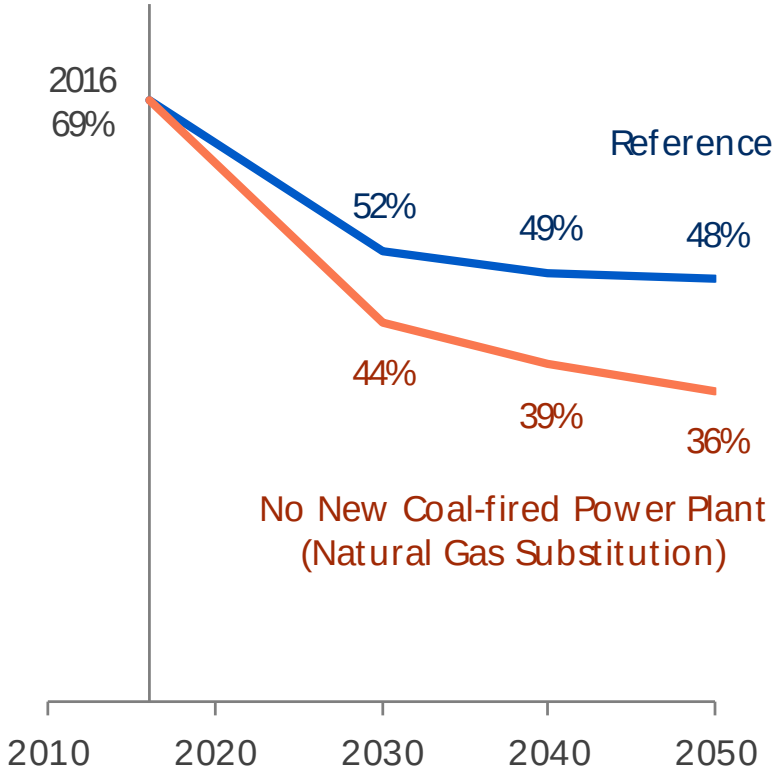
All possible resources need to be developed no matter how difficult.

LNG demand in 2030 is 3 times the current level.

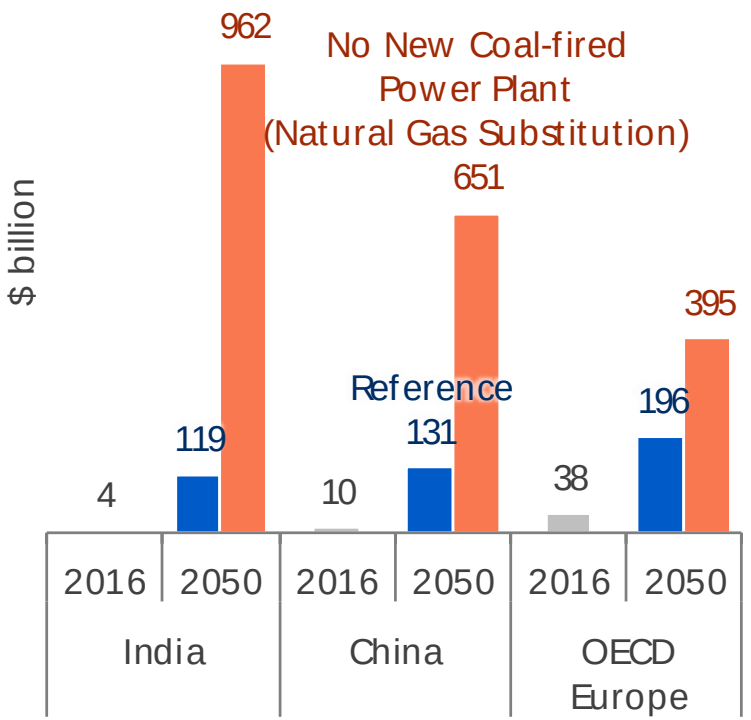
To meet enormous demand, even LNG projects without definite developed plan need to come into operation.

Challenges are not only the supply chains…

❖ Natural gas self-sufficiency rate (Asia)



❖ Net import spending of natural gas



Even if these rapid increases in production and trade can be realized, Asia will face energy security problems.

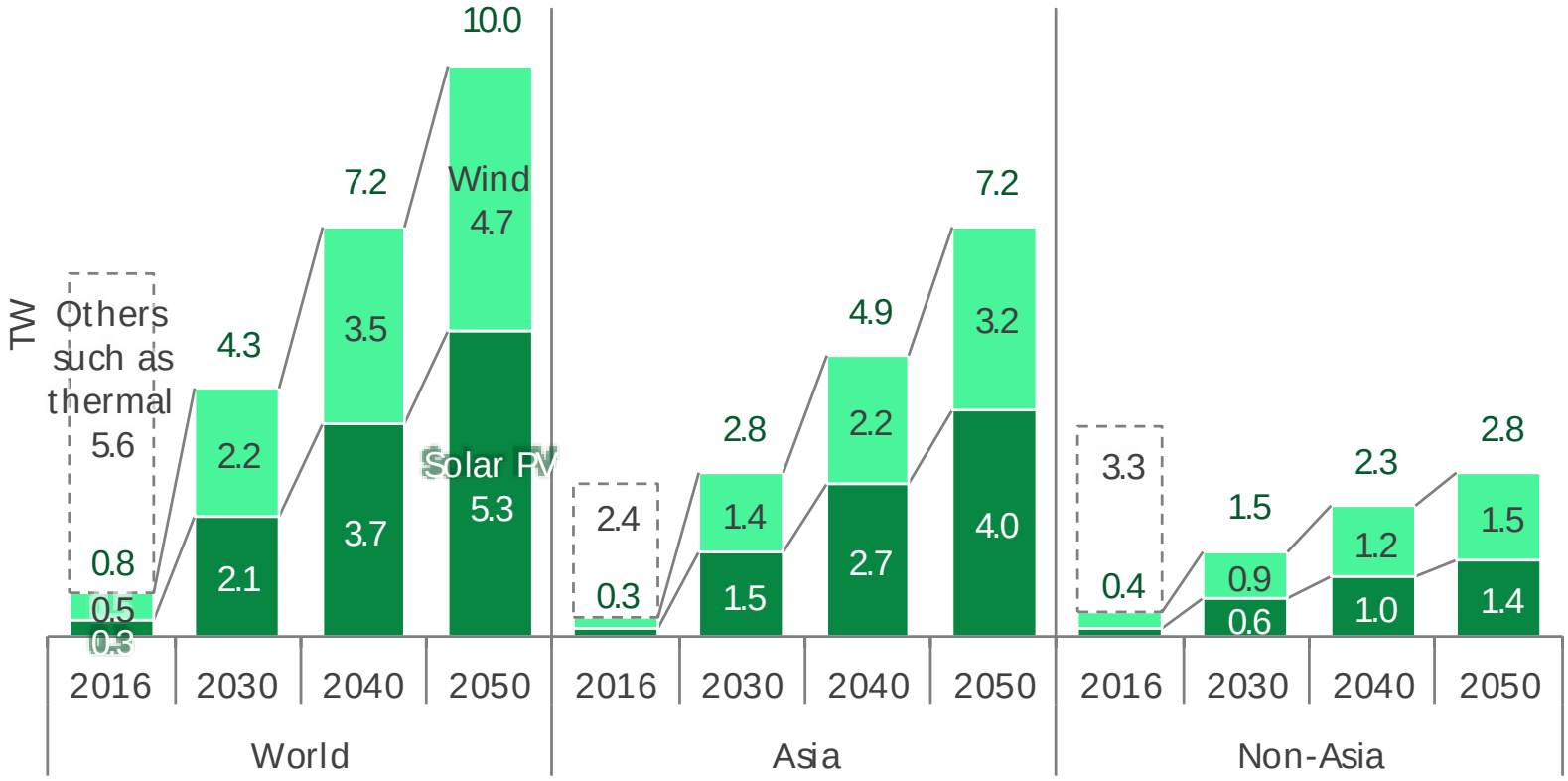
Self-sufficiency rates of natural gas fall to half of the current level.

If natural gas prices rise due to drastic increase of demand, undesired effects reach non-Asia such as OECD Europe, in which natural gas demand slightly increases.

Substitution of solar PV / wind requires unprecedented capacity expansion

❖ **Solar PV and wind power generation capacity**

[No New Coal-fired Power Plant (Renewables Substitution) Case]

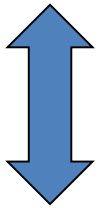


Even if efficient storage and transmission technologies without any loss become available worldwide, 10 TW of solar PV and wind power generation capacity combined is required in 2050.

In Asia, solar PV and wind power generation capacity combined reaches 7.2 TW, 2.7 times the current total generation capacity. Sustainable measures to promote mass adoption are essential.

Pros and Cons of Renewable

- No carbon emission for generation
- Natural and domestic resource
- No running cost
- Even household can own capacity
- Emergency preparedness for district (distributed power)
- Batteries and PV panels are becoming more efficient and cheaper

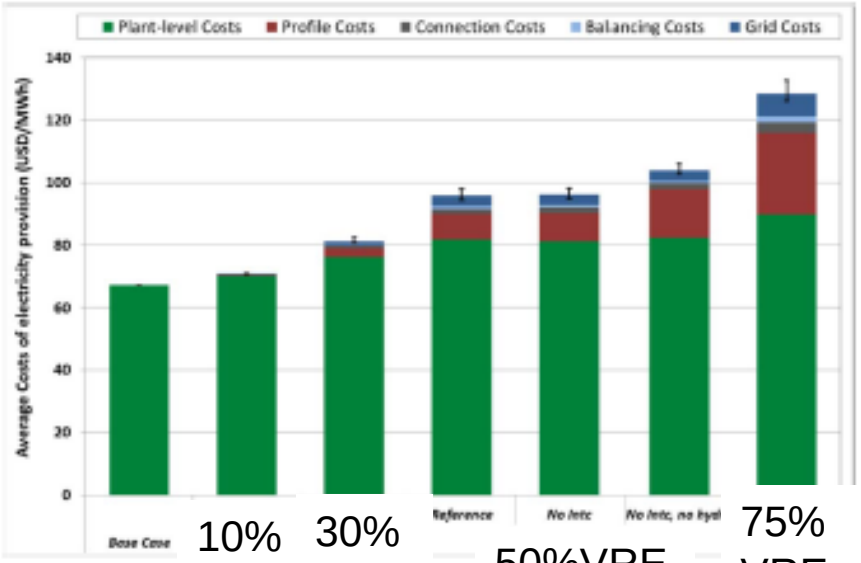


- Uncertainty and Intermittency (backup capacity (typically thermal) is required)
- Utilization ratio is low (PV:13%, Onshore Wind:20%, Offshore Wind:30%)
  - ➔ More capacity (and space!) is required to replace thermal plants
- Central grid may not be available in peak generation hour (output suppression)
  - ➔ Flexibility is required in demand-supply balancing

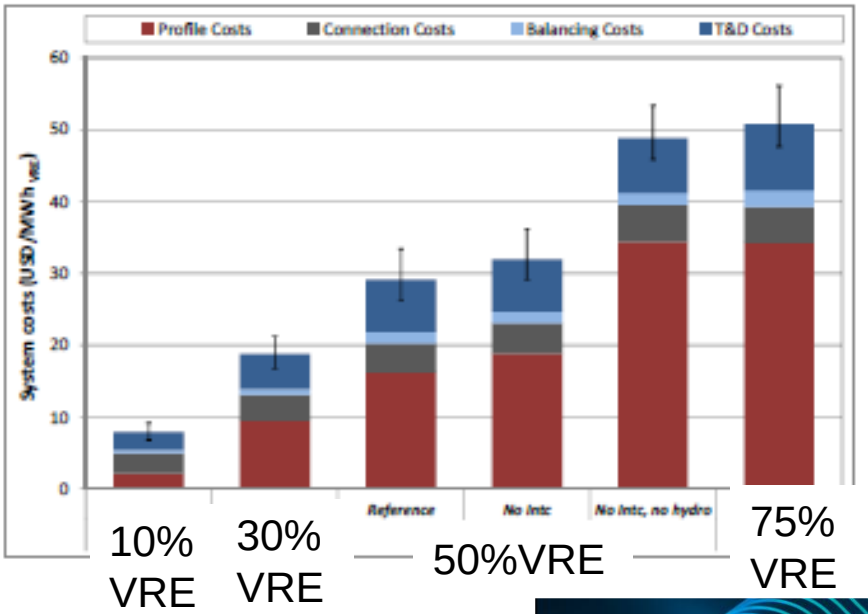
☐ All “cons” above mean additional “costs”

As VRE Share Increases, System Costs Increase

Total Costs



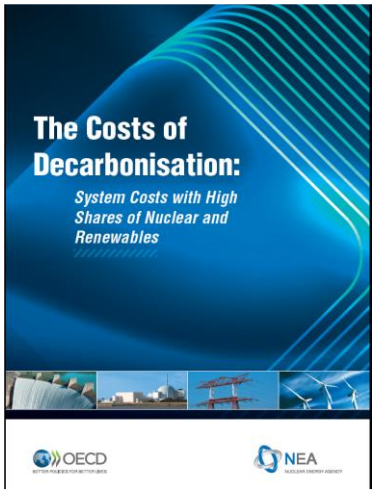
Breakdown of System Costs



Characteristics of Wind & PV

- Variable
- Uncertain
- Location-constrained
- Non-synchronous
- Modular
- With low variable costs

- ☐ Profile Costs
- ☐ Balancing Costs
- ☐ Grid Costs
- ☐ Connection Costs



Victoria concordia crescit

(Victory comes from harmony)

An entire ban on construction of coal-fired power plants

☺

3 Gt～7 Gt of CO_2 reduction

☹

Drastic increase of alternative energy demand

Energy security challenges such as natural gas / electricity stable supply, economics, etc.

!

The country should promote to abolish coal-fired power generation that can do so.

If difficult, or with better CO_2 reduction measures, they should assess their priorities, making effort quickly to replace low-efficiency coal-fired power plants with high-efficiency ones and reduce dependency on coal-fired power generation.

Always keep in mind……

Are you prepared to support for the drastic energy transition in developing Asia?

Think it over.

Shift from coal-fired power generation is only one means, and that the end is to address climate change.

On a larger scale,

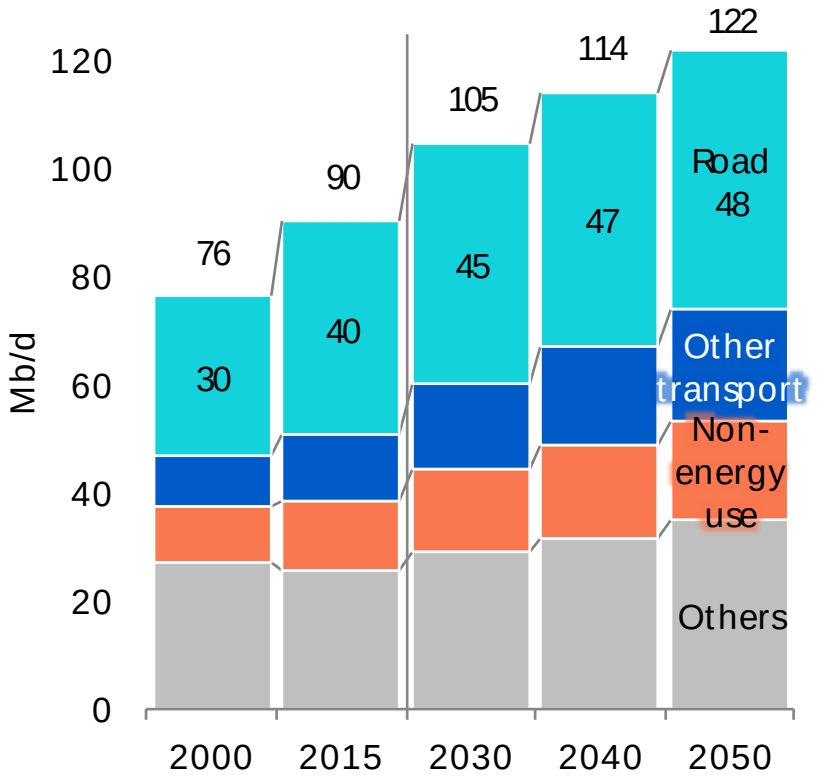
Climate change is one of humanity's great challenges, but not the only one.

Peak Oil “Demand” Case

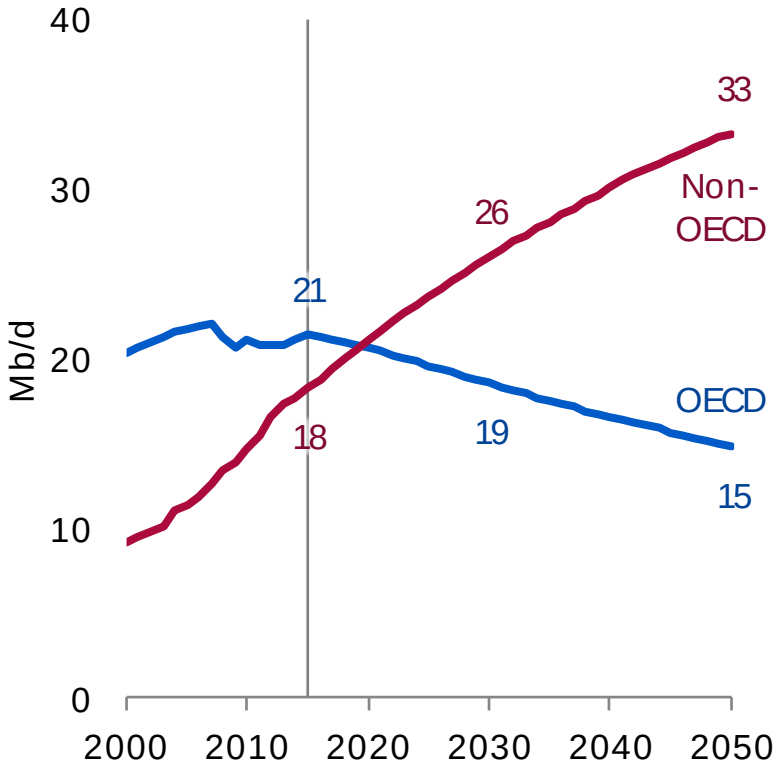
from IEEJ’s Outlook 2018

Transport, especially cars, drives oil demand

Oil consumption [Reference Scenario]



Oil for Road [Reference Scenario]



About 70% of the increases in oil consumption until 2050 is for transport or petrochemical feedstocks. Road transport, in particular, may decide where the consumption will go.

Oil consumption by cars in OECD countries is decreasing and will be surpassed by non-OECD around 2020. Non-OECD accounts for all future consumption 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)

➔ Withdrawn later

China

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

Toyota

The target for 2030: EV&FCV sales is more than one million. Sales of all motor driven vehicles is 5.5 million. (2017)

Volkswagen

Increase EV share in its total sales to 25% with more than 80 models of ZEVs (20 EV models) by 2025 (2017)

Renault-Nissan

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

Hyundai

Plan to prepare EV models for all line up by 2020 (2015) Introduce 14 models of EVs by 2025 (2017)

Ford

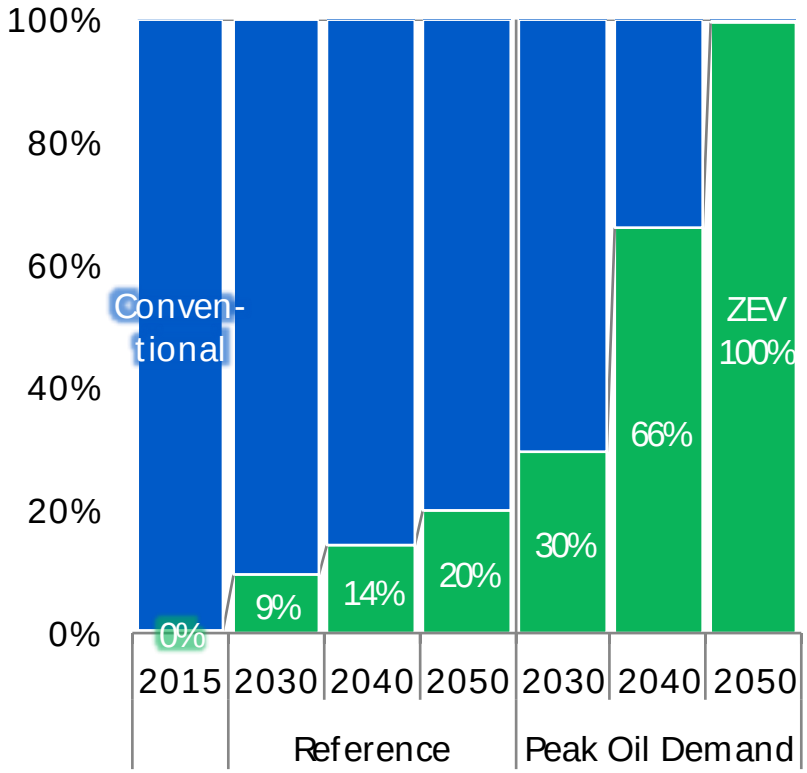
Introduce 13 new EV models by 2022 while doubling the investment to 11 billion US$ (2017).

Honda

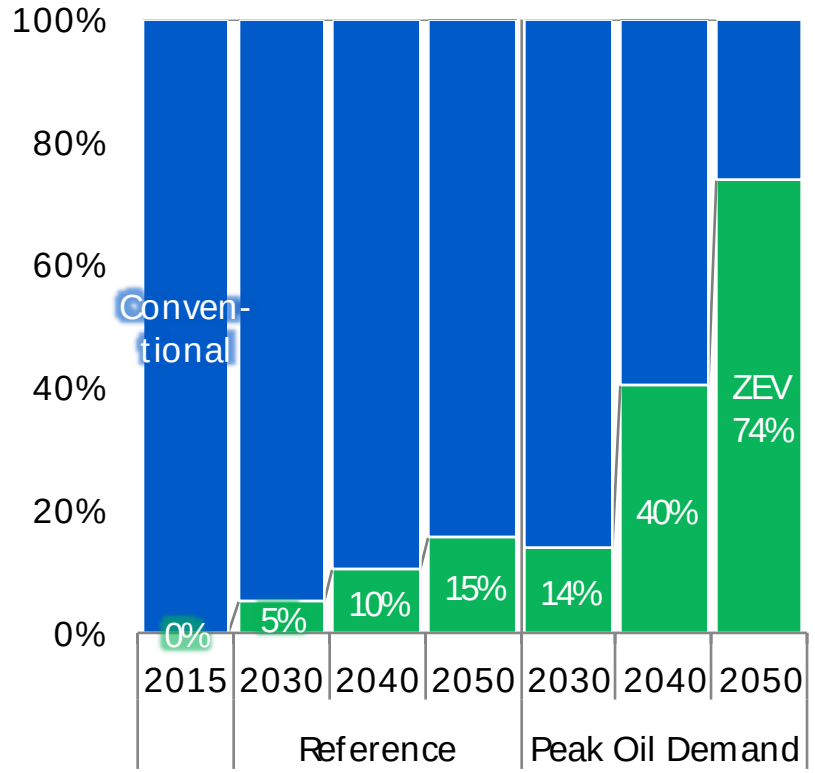
In 2030, two-thirds of automobile sales will be electrified. EVs will be released in China in 2018 (2017).

New car sales and car ownership

❖ Assumption of new car sales



❖ Car ownership



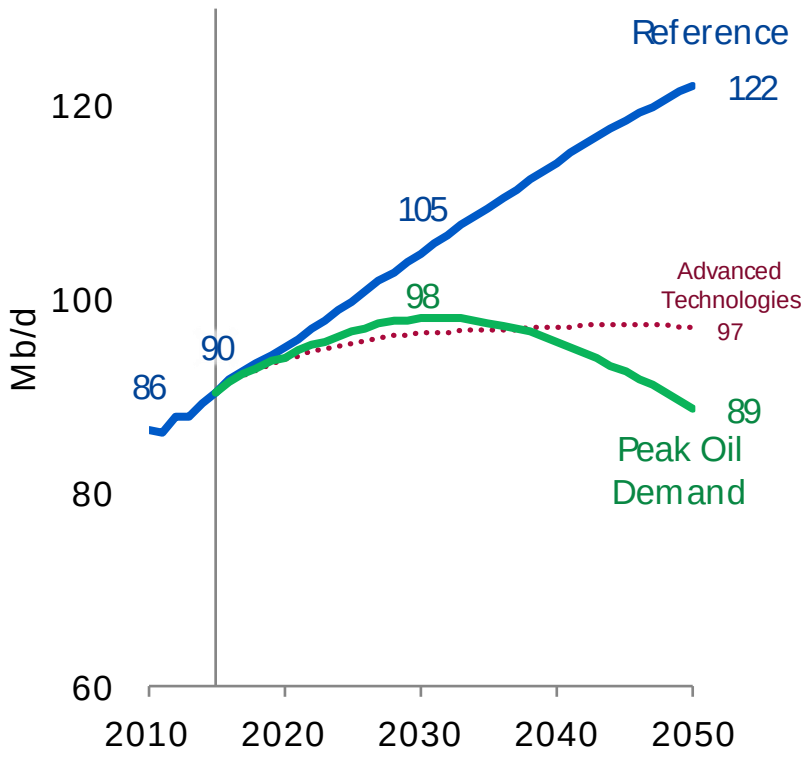
Note: ZEV consists of plug-in hybrid vehicles, electric vehicles and fuel cell vehicles

Expectation on penetration speed of ZEVs varies a lot. In the Peak Oil Demand Case, 30% and 100% of global new car (passenger and freight) sales are assumed to be ZEVs in 2030 and in 2050, respectively.

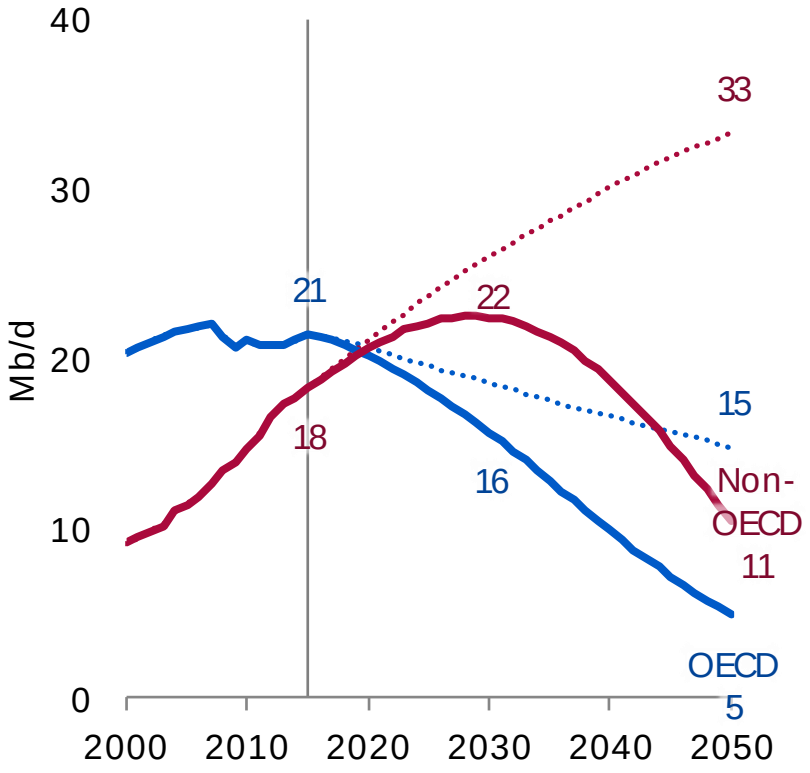
Sensitivity analysis of energy supply and demand was conducted assuming that the electricity demand increased by the ZEVs will be met by thermal power generation.

Oil peaks around 2030 with a rapid penetration of ZEVs

Oil consumption



Oil for Road [Peak Oil Demand Case]



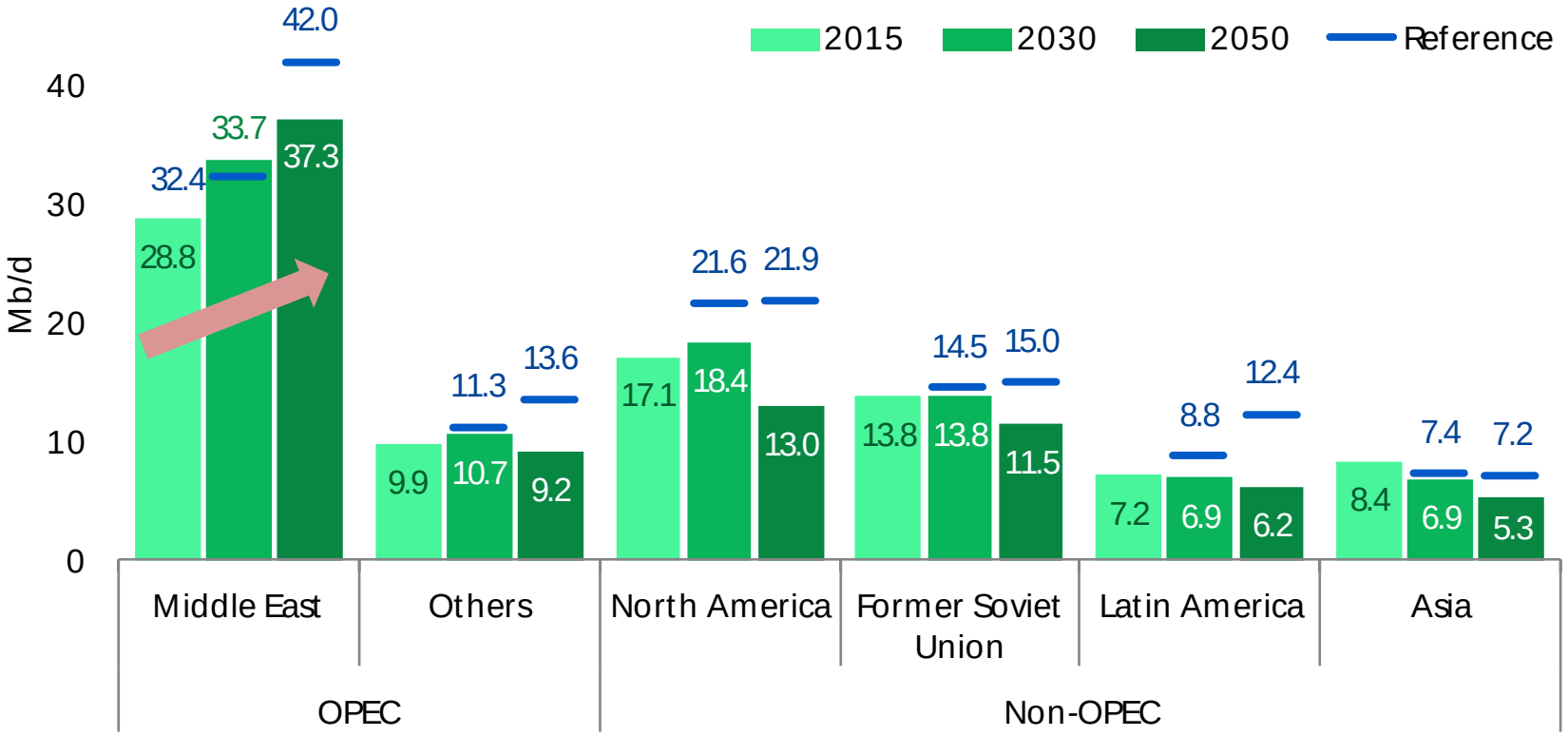
Note: Dotted lines are the Reference Scenario

In the Peak Oil Demand Case, oil consumption hits a peak of 98 Mb/d around 2030 before declining. 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.

Crude oil production shifts towards low-cost regions...

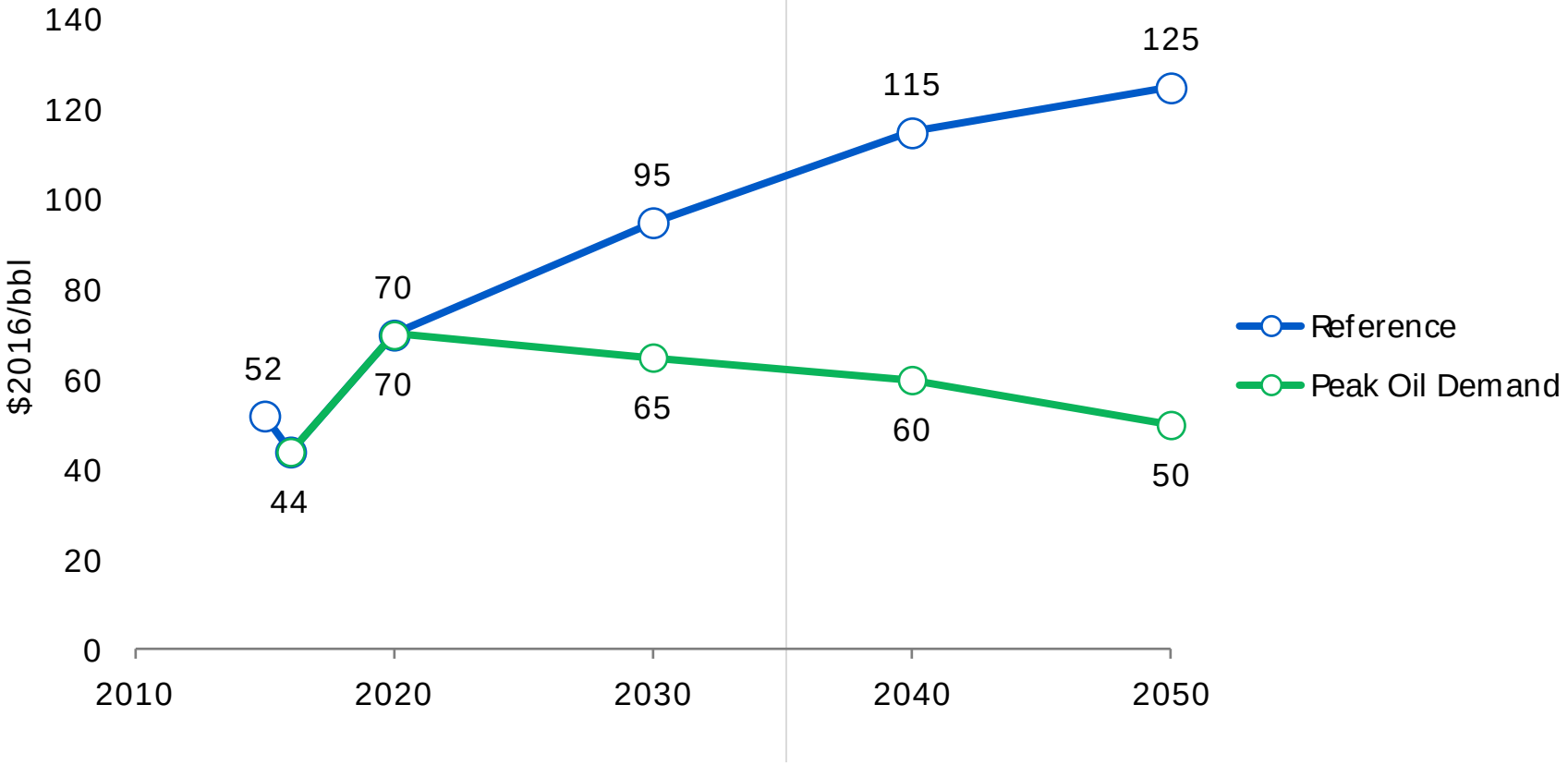
Crude oil production [Peak Oil Demand Case]



Oil price falls due to the change in supply and demand pressure and market perception. Relative to the Reference Scenario (in $2016), prices drop from $95/bbl to $65/bbl in 2030 and from $125/bbl to $50/bbl in 2050. Given such drastic price decreases, regions with low production costs would be the only ones with potential for increases. Only the Middle East is expected to produce more in 2050 than today. North America production decreases by 40% from the Reference Scenario to 13 Mb/d.

Oil prices

❖ Assumption of real crude oil prices

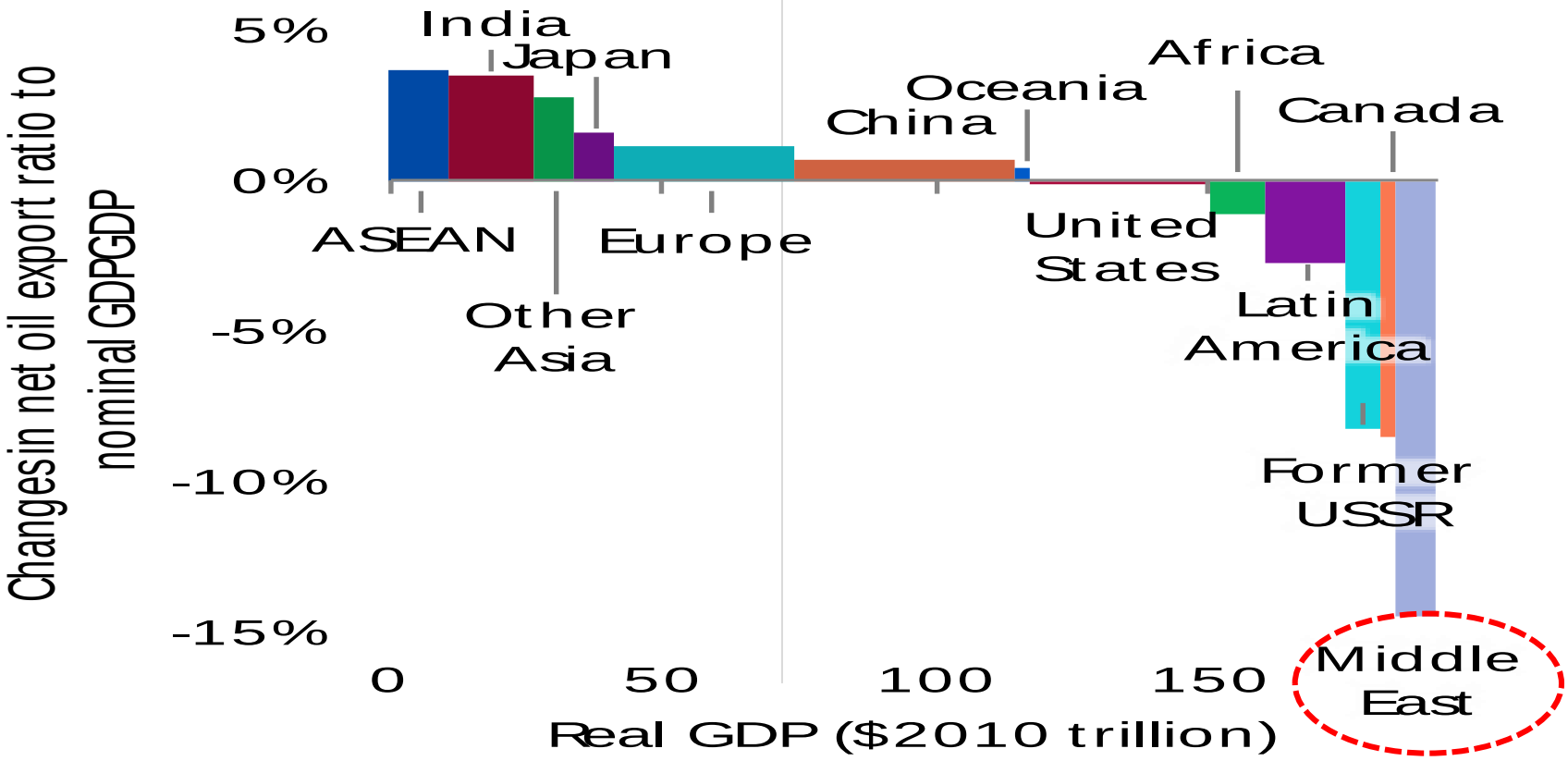


Assuming that the supply and demand relaxation will result in a decline in international oil prices.

In the Peak Oil Demand Case, the prices begin to decline after the 2020s and fall to $50/bbl in 2050.

...but the economic downturn will affect the Middle East

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



Note: Europe excludes the former Soviet Union

How do we recognise the rapid de-oiling?

- The Peak Oil Demand Case shows that, under some circumstances, oil consumption can turn into a decline in the not too distant future,.
- 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. It can be said that oil consumption may not be so easily reduced, so quickly.

...and then

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

- The rising dependence on the Middle East crude oil will increase geopolitical risk for stable supply.
- Although it is reasonable to expect that Governments in the Middle East would cut public investment and subsidies to reduce budget deficits while coping with low oil prices, it is difficult to deny the possibility of increasing social anxiety and of a worsening situation in the region.
- The role of consuming countries as well as producing countries' own efforts continue to be important. Support to the efforts represented by Saudi Arabia "Saudi Vision 2030" is needed.

Uncertainty and Instability Continue in MENA

Terrorist attacks in Paris & Belgium…

US recognition of Jerusalem as a capital.

Situation in/out of Iraq after the war

Iran's Nuclear Development

Lift of economic sanction and Iran's return to market⇒US withdrawal

Opacity of Peace in the Middle East

Refugee issue in Europe

Gaza Conflict

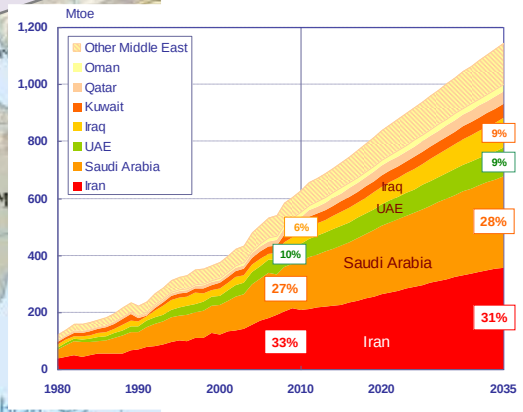
Armed conflicts over IS

Air raid by Russia

Russian air force downed by Turkey

Increasing domestic energy demand and its repercussions

Wide spread Arab Spring movements



Tension between Saudi Arabia and Iran

Issues in Syria, Yemen and Egypt

Spread of protests and/or discontent among Arab citizens against US

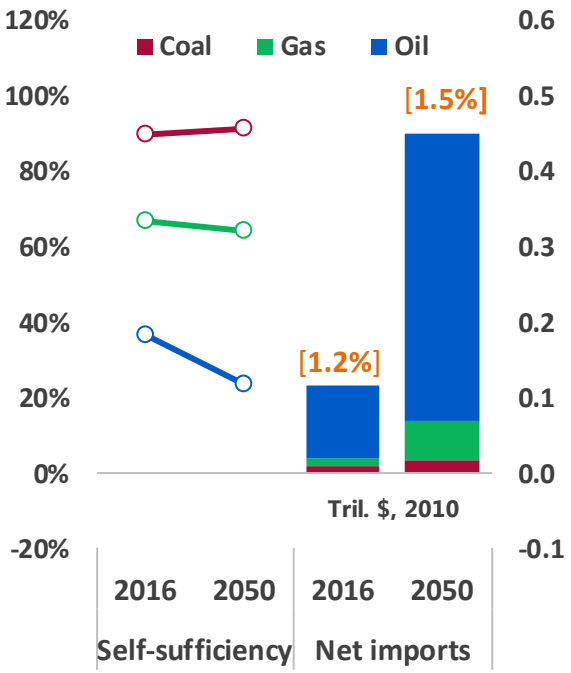
Insecurity factors surrounding current ME Governments /systems.

Arrest and imprisonment of Royal Families and Cabinet Ministers by KSA Anti Corruption Committee (Nov. 2017)

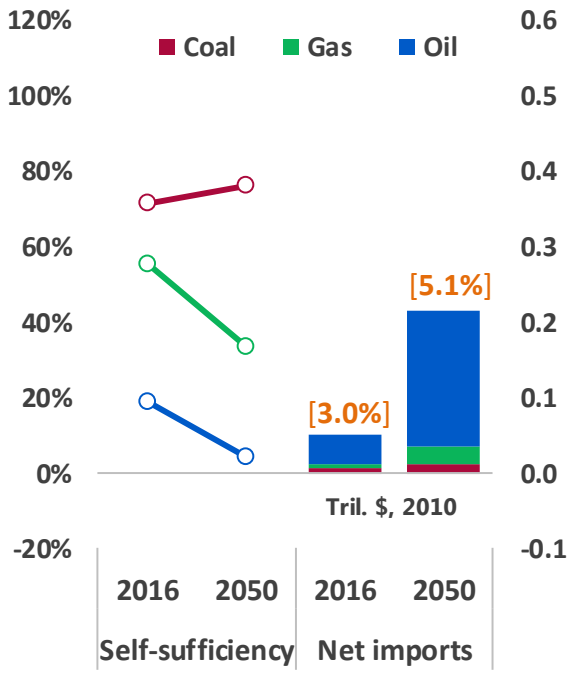
Potential threats of terrorists' attack on oil facilities

Increase of oil import spending in Asia

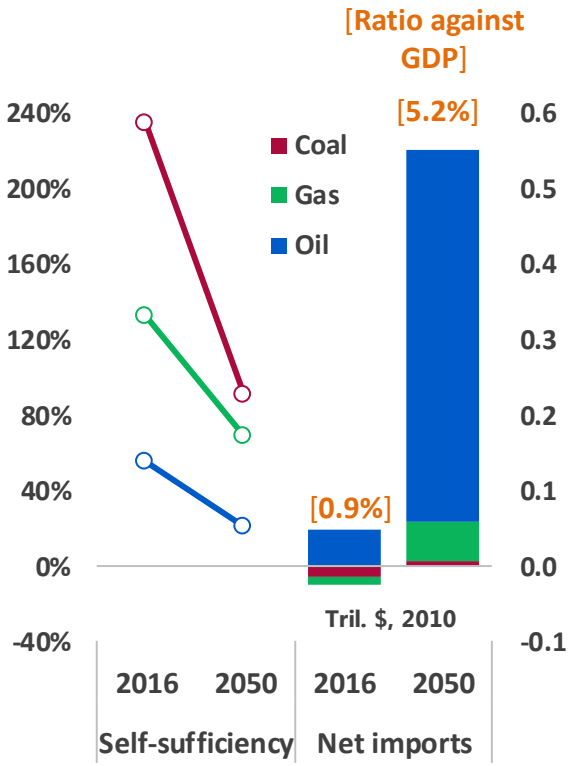
China



India



ASEAN

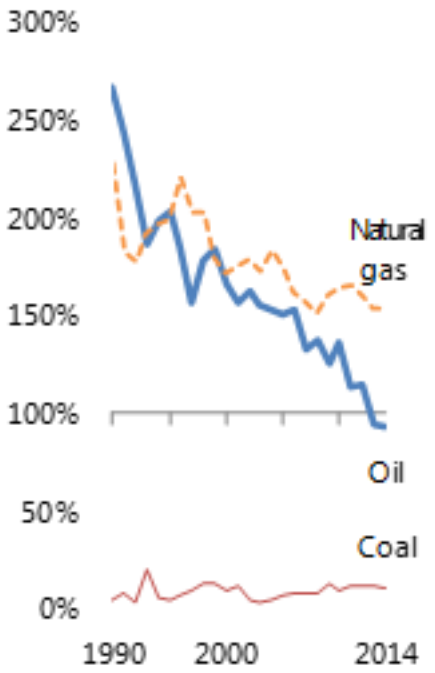


In Asia…

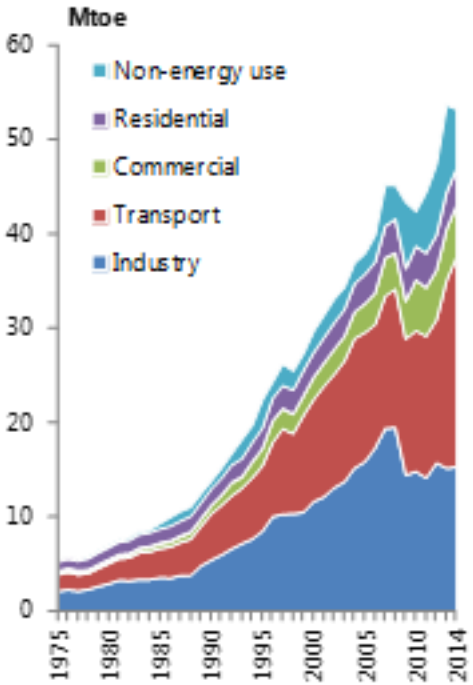
- Self-sufficiency rate of oil will decrease from 28% to 14%, due to increase of consumption for transportation. Self-sufficiency rate of natural gas will also decrease remarkably.
- Self-sufficiency rate of coal will be maintained at a level of 80%.
- The amount of oil import will increase remarkably, and the total amount of energy import will grow from 1.6% to 3.0% against the GDP (from 0.9% to 5.2% in the ASEAN).

Malaysia Energy Overview

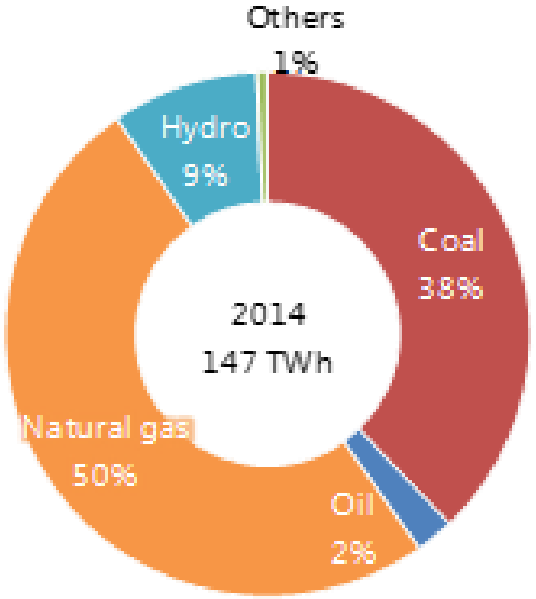
Self Sufficiency (%)



Final Energy Demand

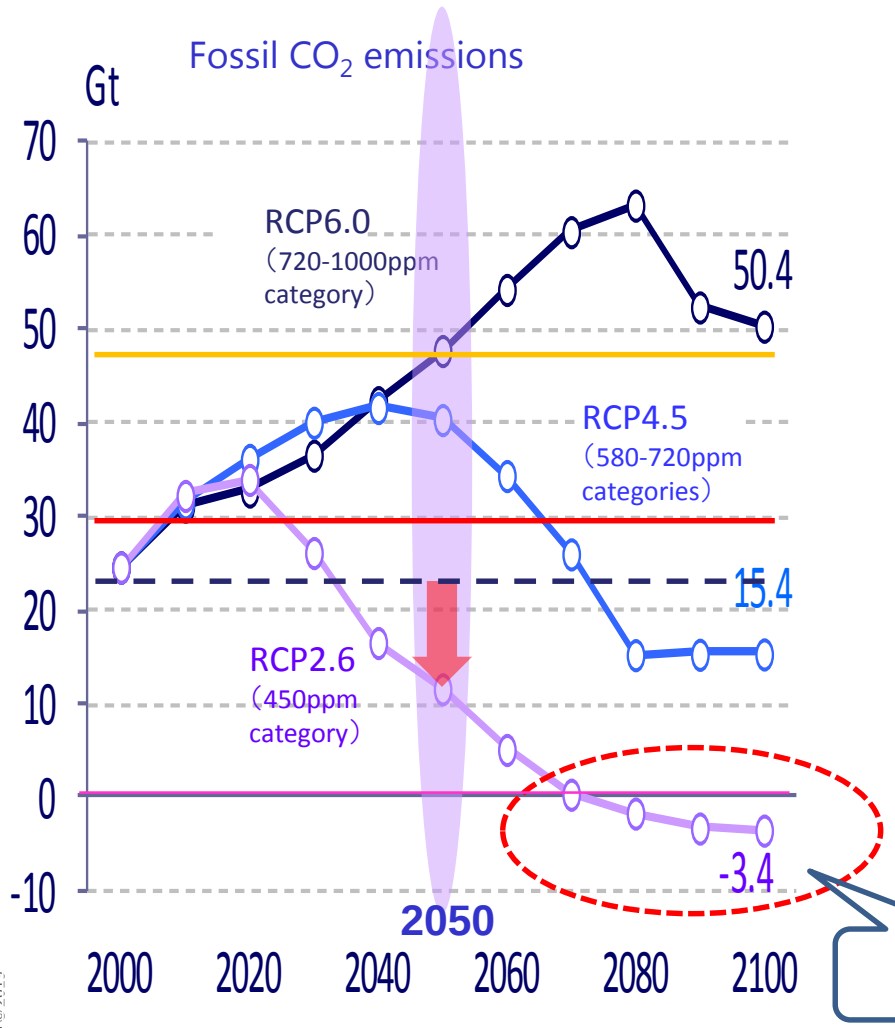


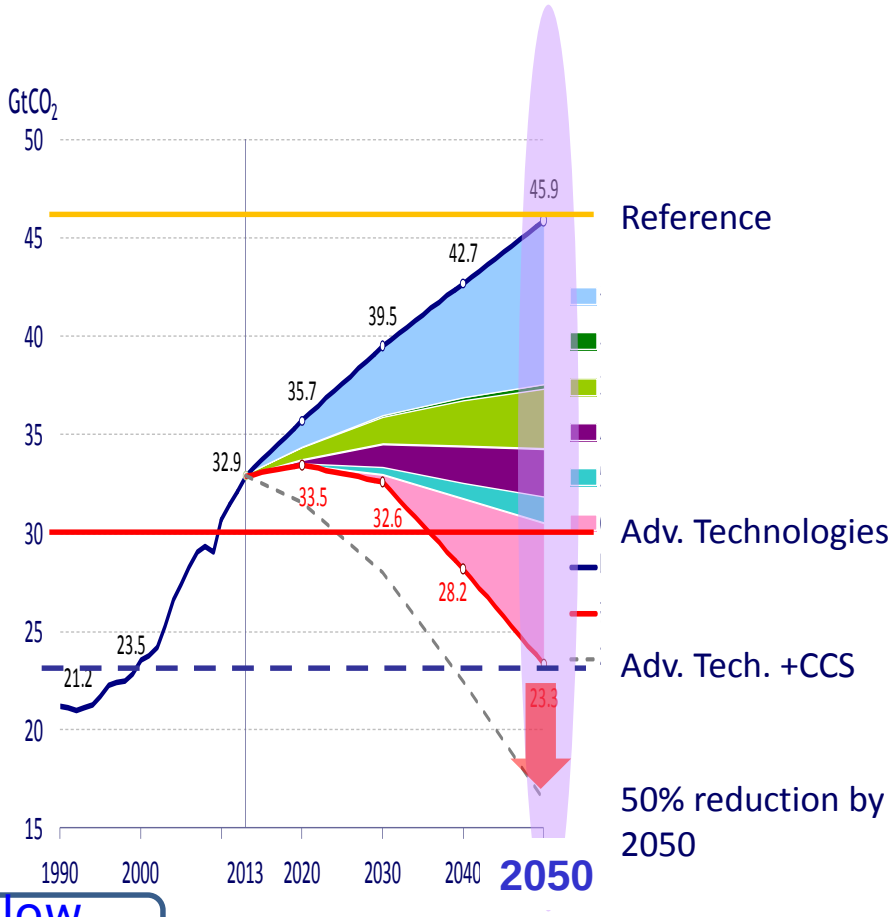
Electricity Supply



Source: IEEJ, Asia/World Energy Outlook 2016

IPCC 5th Assessment Report v.s. IEEJ Outlook





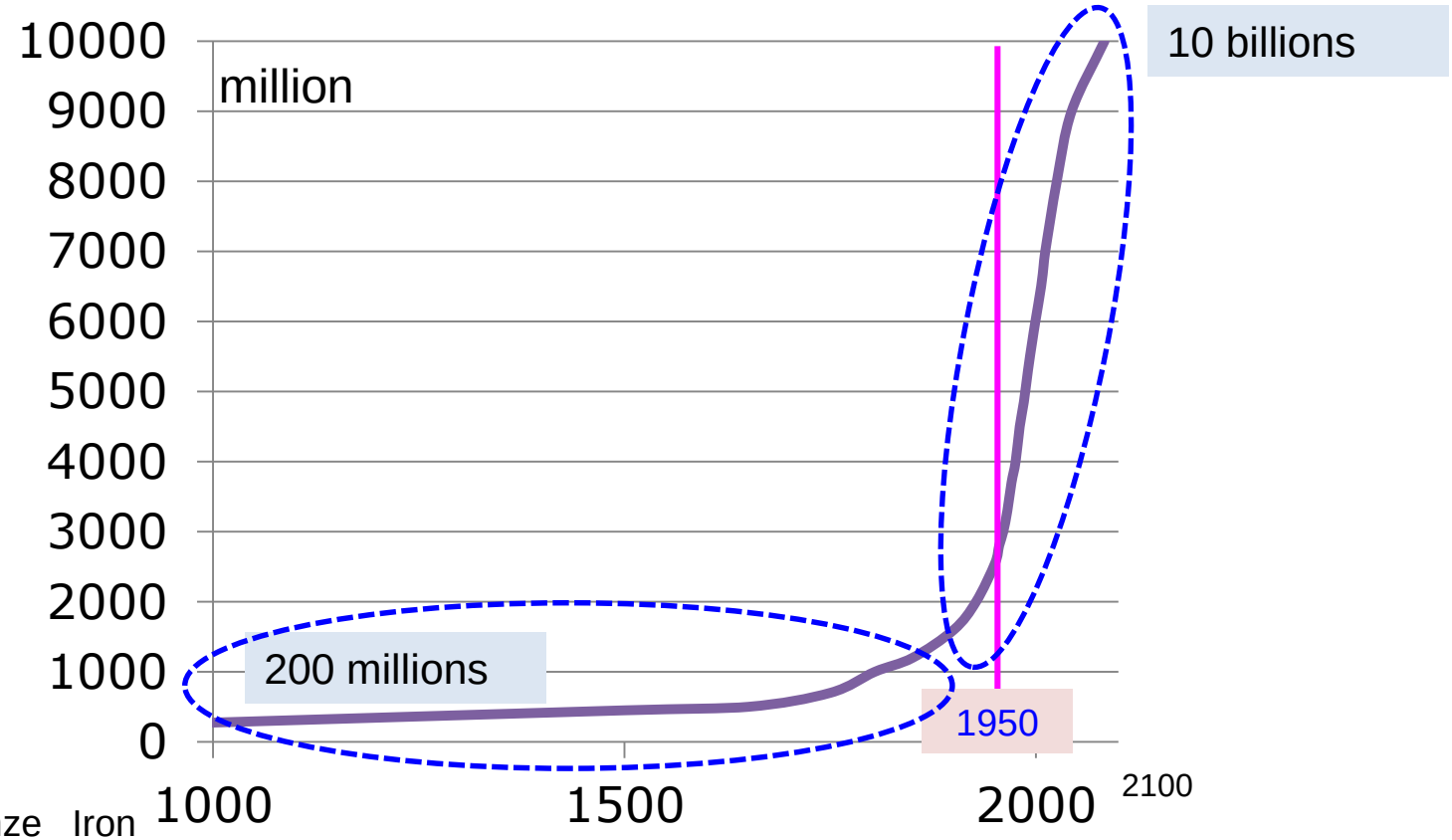
※Calculated using MAGICC 6.0
Meinshausen, M., S. C. B. Raper and T. M. L. Wigley (2011). "Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6: Part I – Model Description and Calibration." Atmospheric Chemistry and Physics 11: 1417-1456.

IEEJ: **Asia/World Energy Outlook 2015**

Population Explosion since the 20th Century

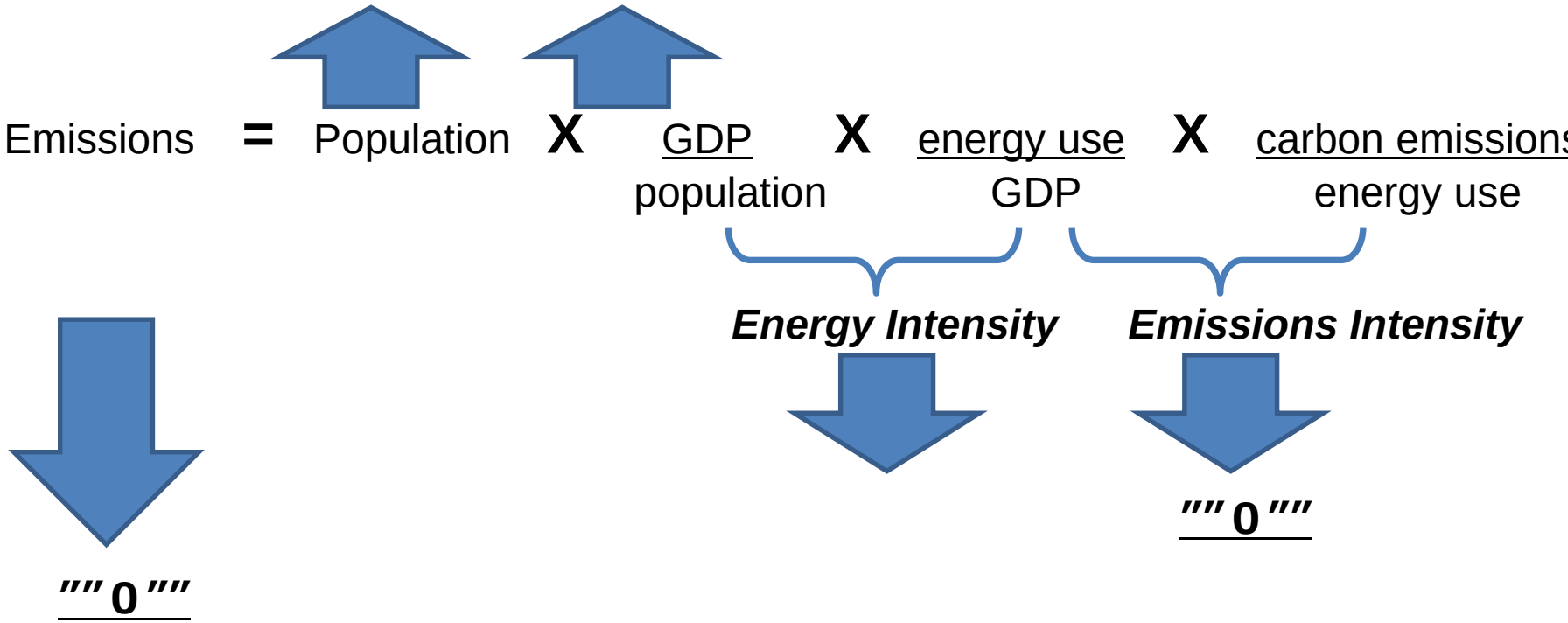
- Population: 200 millions (year 1000), some say that **wars, low life expectancies and diseases** were keeping the count under control.

The average life expectancy : 40 (1950) ➔ 60 (or even 70) (2013)
People 65 and older : 10-15% (2010, world) ➔ 20-30% by 2050.



A world in transition with lower carbon emissions

the Kaya **identity**



Energy Security is IMPORTANT

Thank you for your attention!