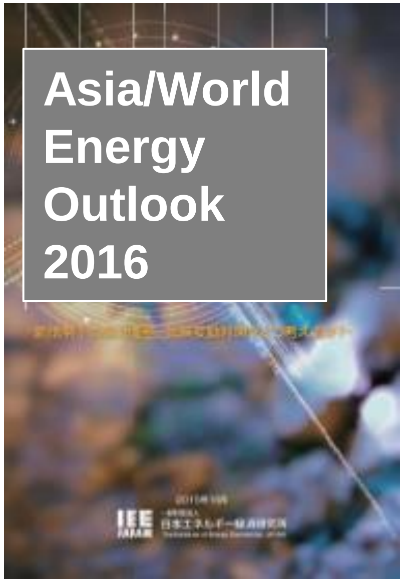
Uncertainties: Entering Uncharted Waters
- IEEJ's Energy Outlook-



16 May 2017

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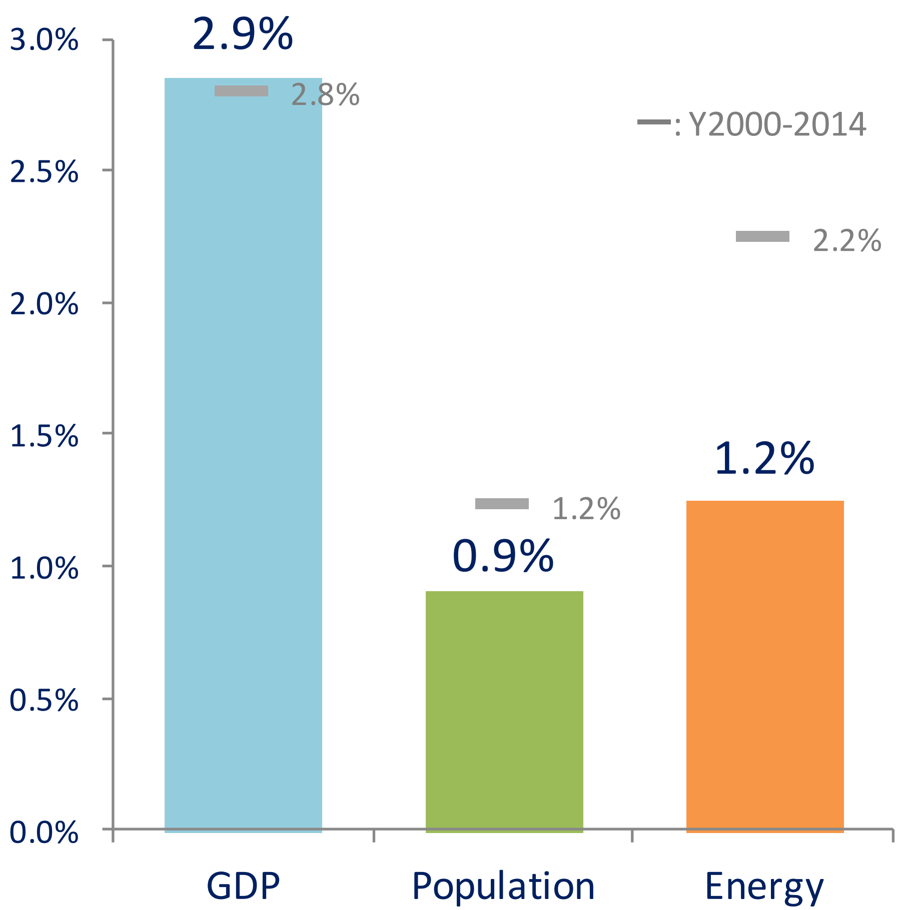
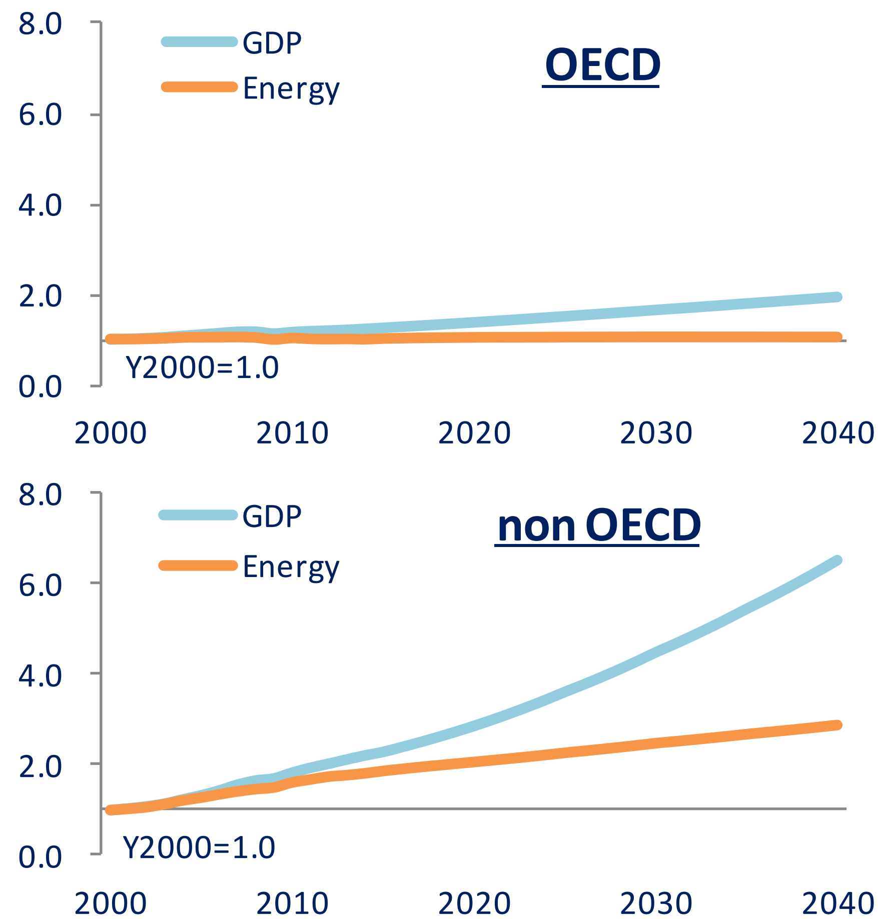
Huge Improvement in Economic Efficiency

Annual Growth Rate (World：2014-2040)



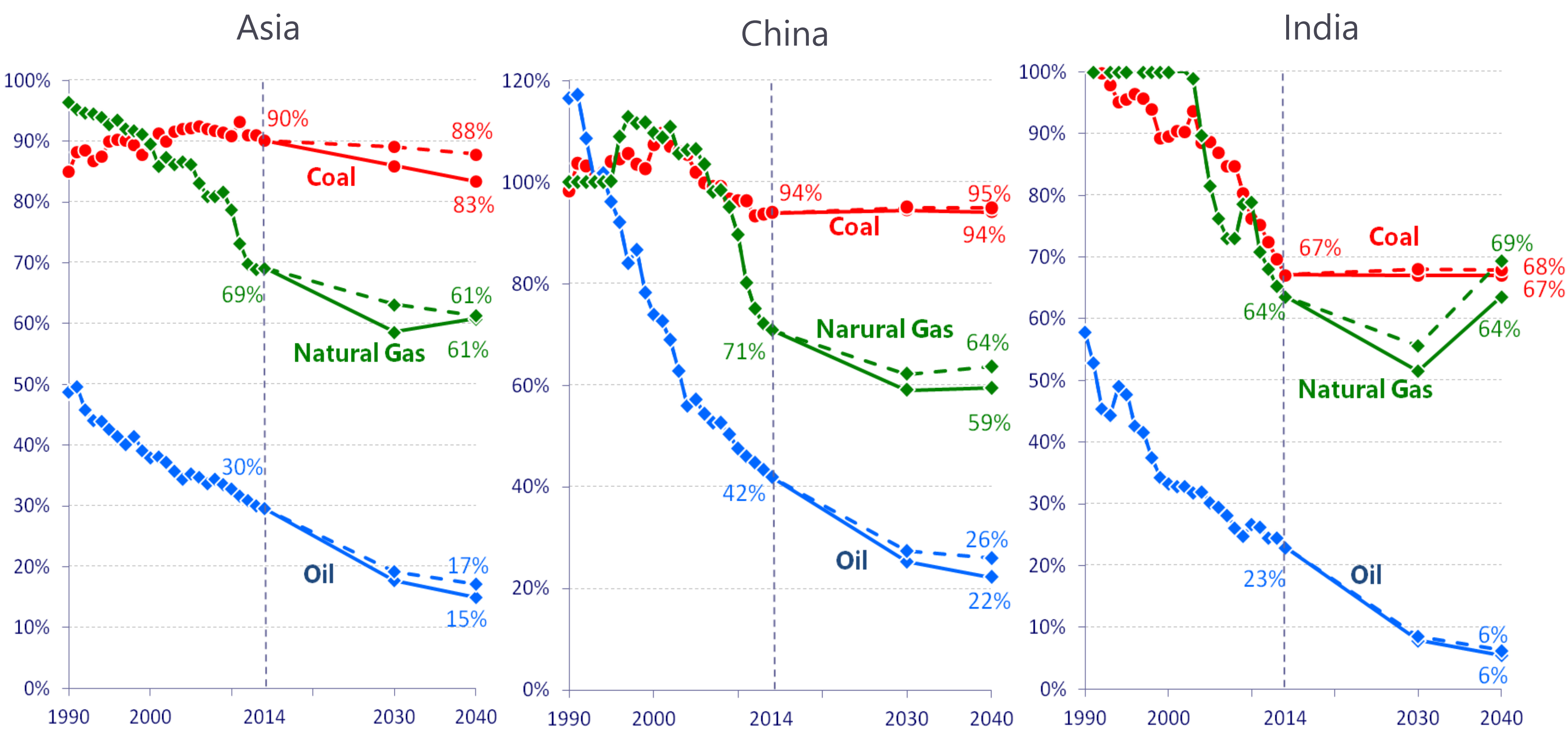
GDP and Primary Energy Demand



- ✓ Energy demand, which peaks at around 2030, decouples from economic growth in developed countries.
- ✓ Developing countries continue to increase energy demand although energy efficiency improving.

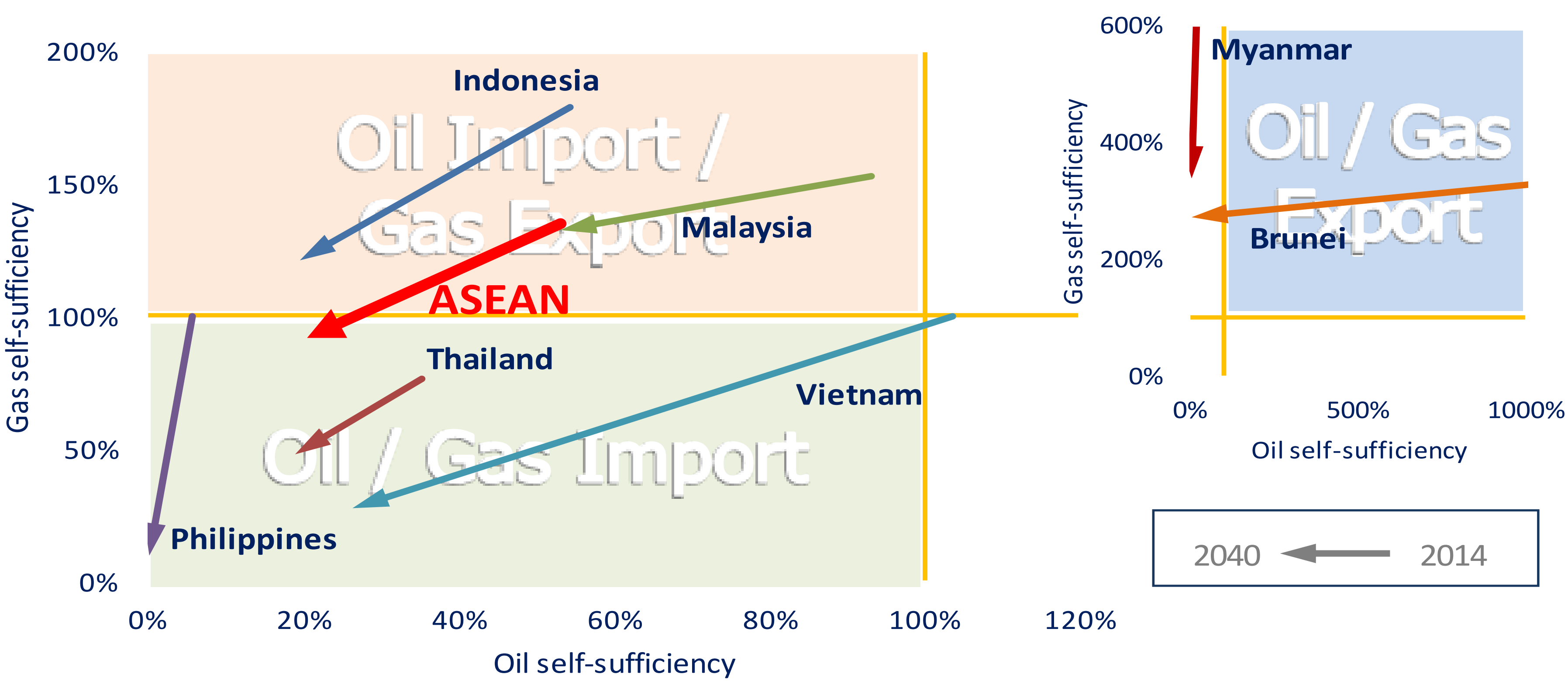
Energy self-sufficiency in Asia

Reference Scenario (solid)
Advanced Technologies Scenario (dotted)



ASEAN Becomes Gas Importer

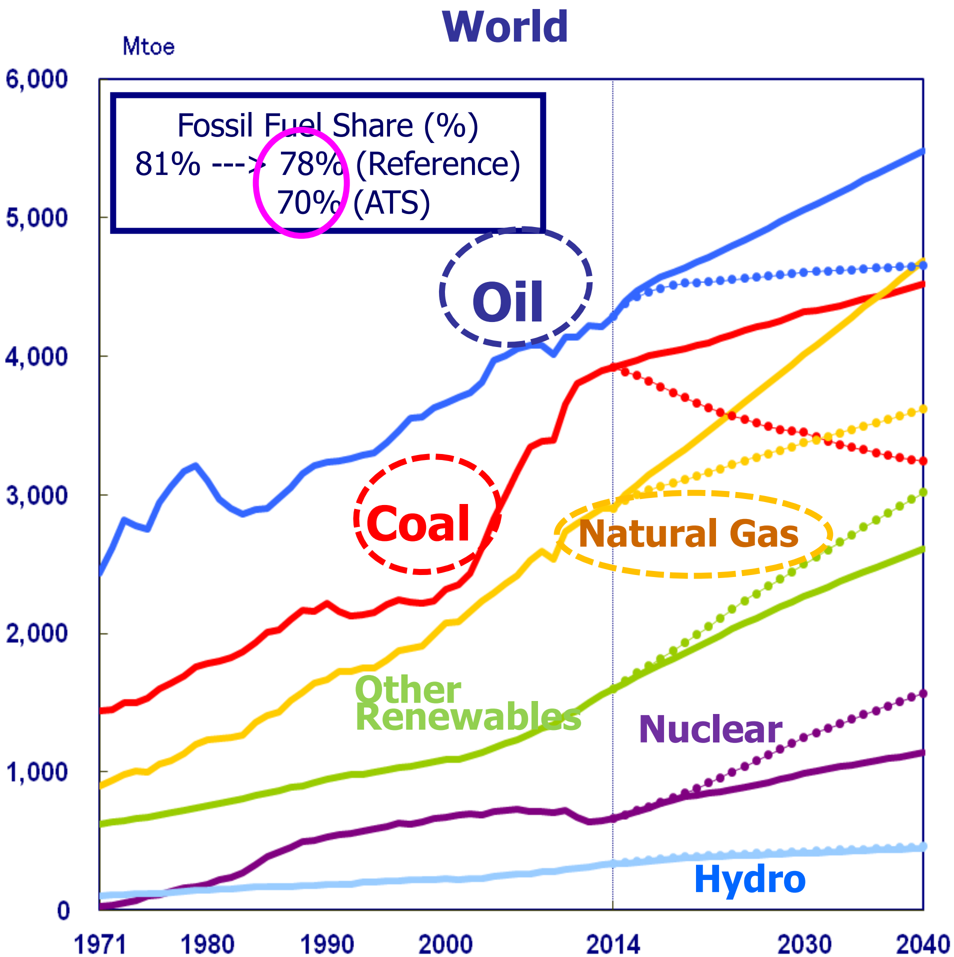
Outlook of Self Sufficiency Ratio for ASEAN

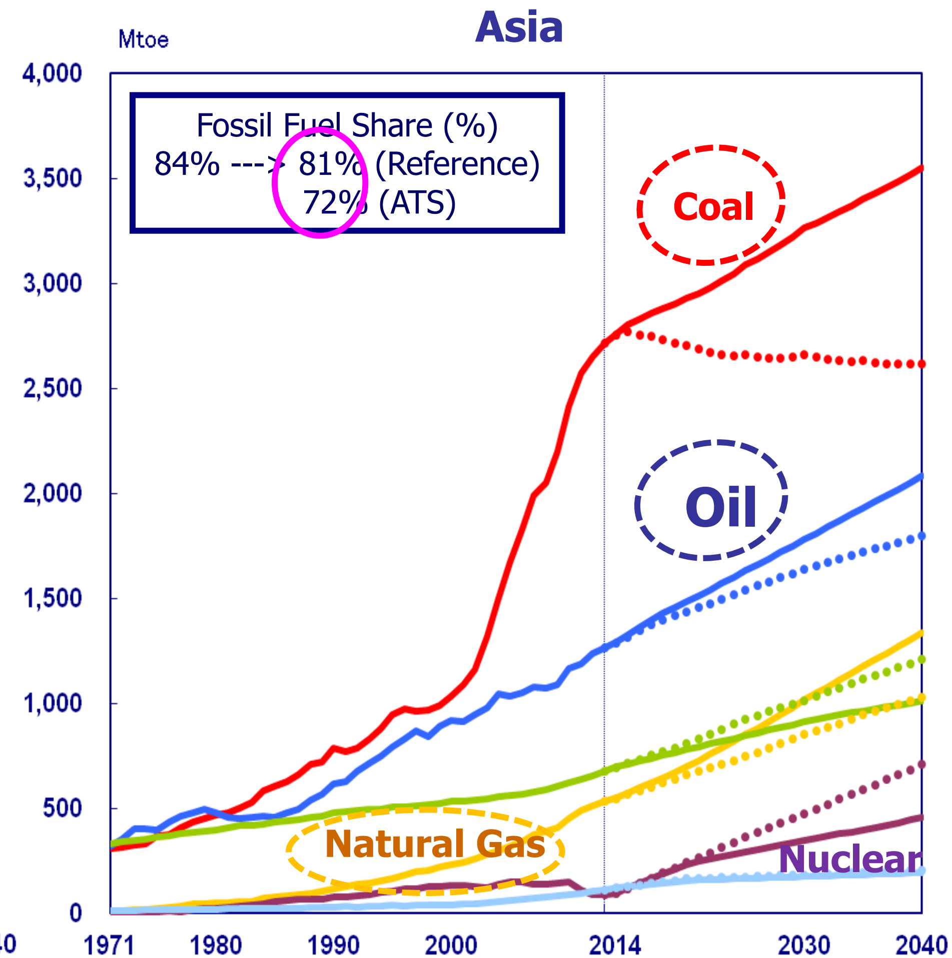


Fossil Fuels Will Remain Important

Line ...... Reference
Dotted line ...... ATS

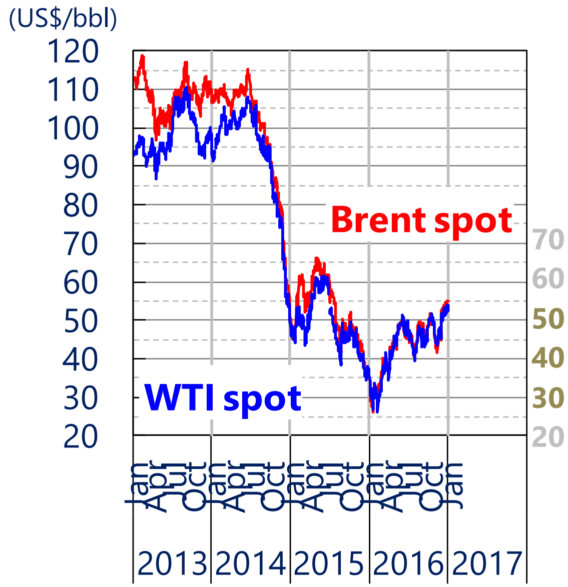
Primary Energy (by energy)





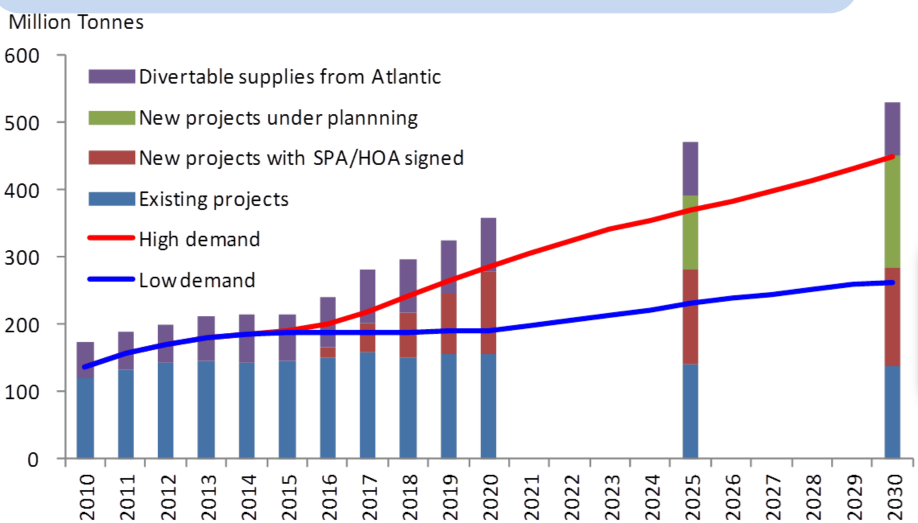
Source: IEEJ, Asia/ World Energy Outlook 2016

Oil Price Fluctuations and Growing Geopolitical Instability



(Source) US/EIA "Spot Prices for Crude Oil and Petroleum Products"

LT LNG Supply-Demand Outlook for Asia



Destabilization of the Middle East

Uncertainty over Middle East Peace issues

Iraqi situation after the war

Tensions over nuclear deal with Iran

Shale Revolution and its impact on Middle East economies

Growing anti-US sentiment in Arabic and Islamic societies

Uncertainties over the current regimes in the Middle East due to "Arab Spring"

Terrorism, threats to energy production and exports

(Source) Prepared by IEEJ

Paris Agreement : A step towards global action

❖ Evaluation of Paris Agreement

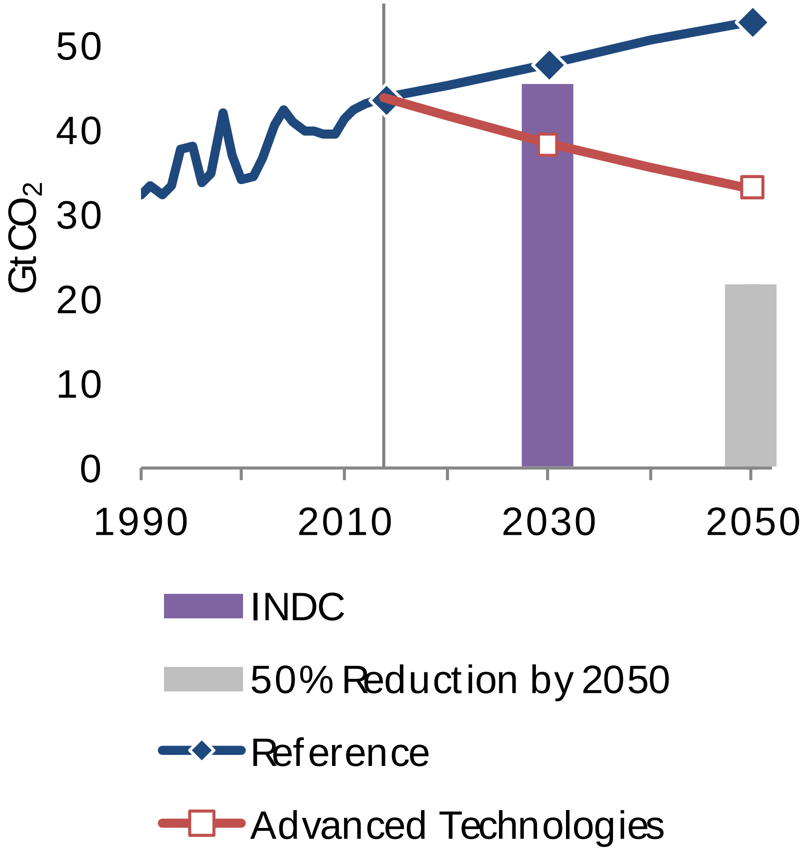
Good!! ☺☺☺

Over 180 countries, including China and India, agreed to take actions using bottom-up approach.

Challenges ☹☹☹

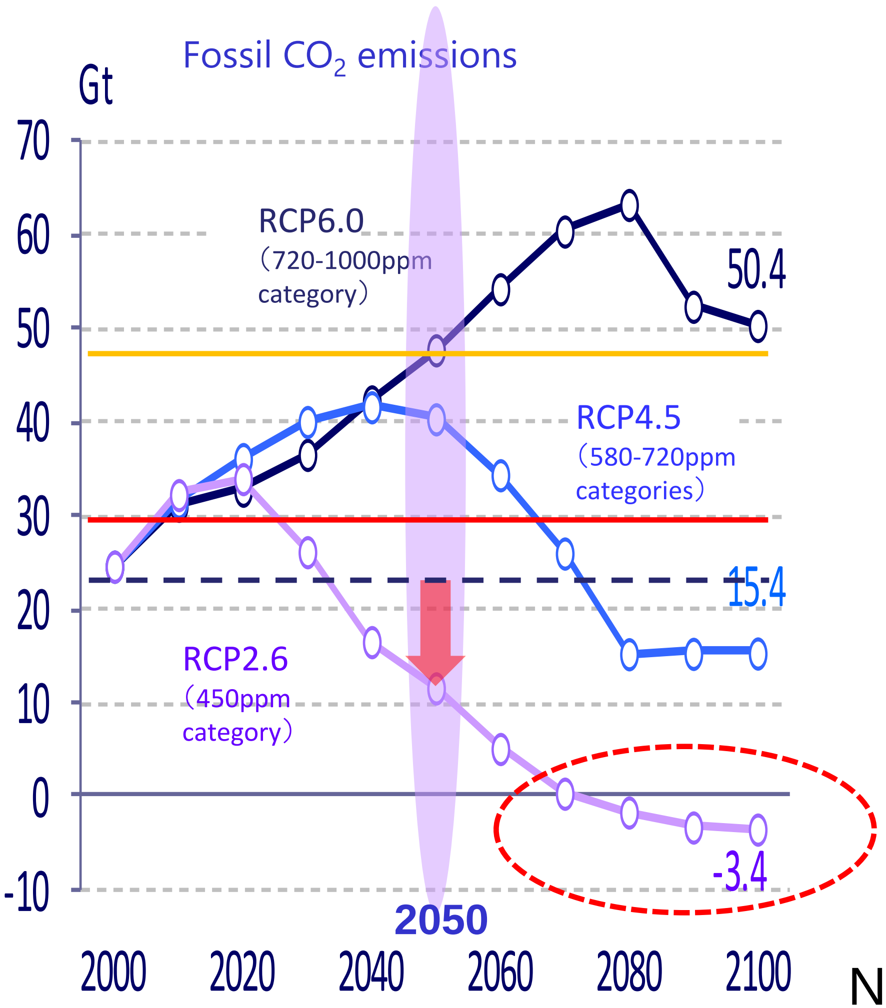
Global GHG emissions will increase from the current level.

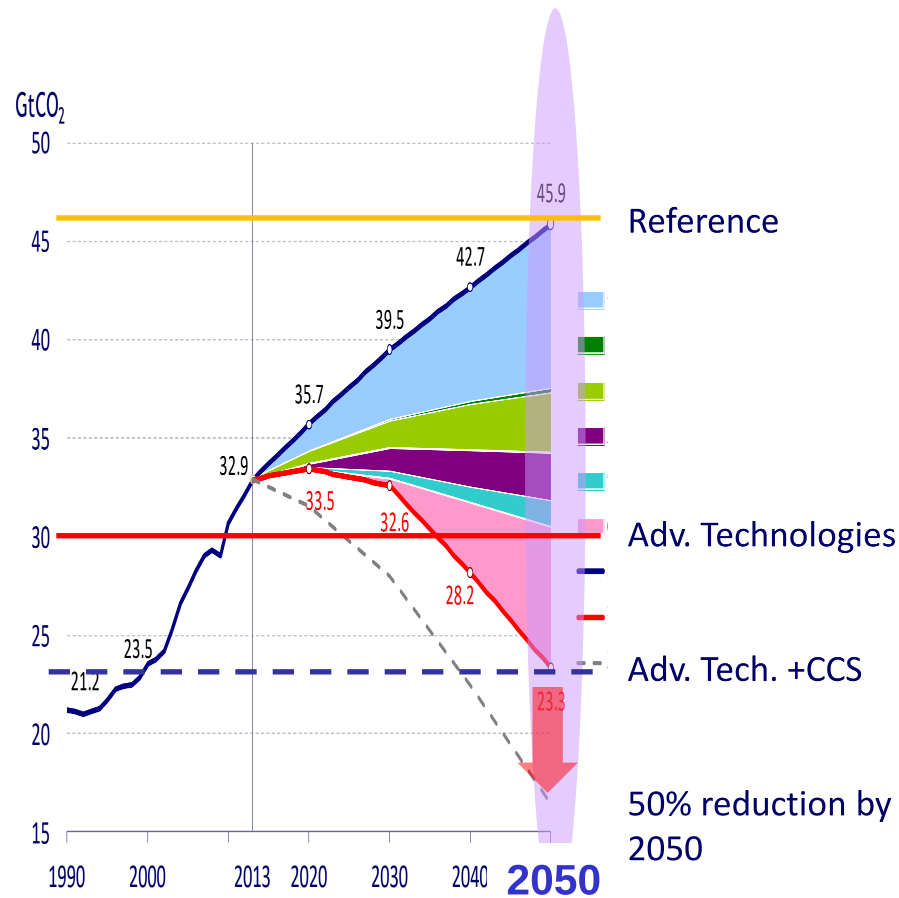
❖ GHGs emissions



Source: IEEJ, Asia/ World Energy Outlook 2016

IPCC 5th Assessment Report v.s. IEEJ Outlook





Negative emission

※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.

Pragmatic/Practical Approach to address Climate Change

IEEJ’s understanding is as follows;

1) **Economic growth** and **measures to cope with Climate Change** need to be compatible with each other
   <note> IPCC 4th Assessment Report (AR4, WGⅢ, Ch.1)
   Balancing between “not enough measures” (and resulting damage including food security and ecosystems) and “too much measures” (that may threaten sustainable development).

2) Uncertainty around **Climate Science** need to be fully considered

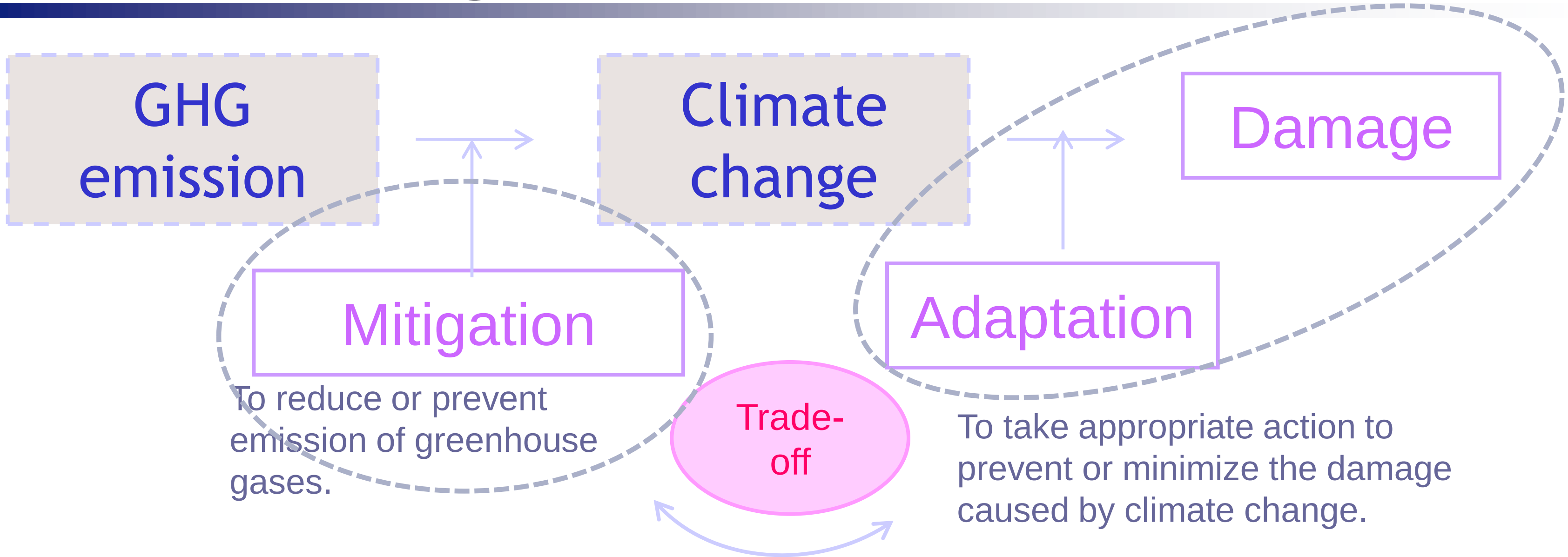
3) One way to look is to minimize the total cost (**Mitigation** + **Adaptation** + **Damage**) rather than uniquely reducing the damage through mitigation.

4) The **transfer of** state of the art **technologies** to developing countries is important. It, of course, would require appropriate **financial schemes**.

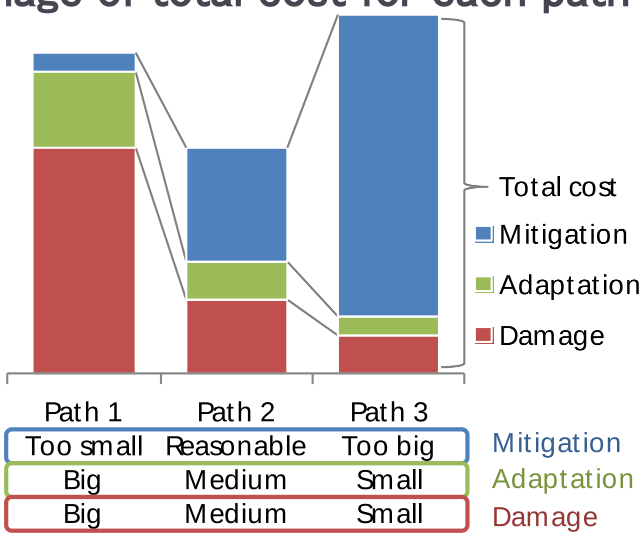
5) **New technologies** are essential **to further reduce** GHG emissions at affordable cost .

6) **Innovation** can be achieved through **international collaboration.**

Rule for ultra long-term: Reduce the total cost



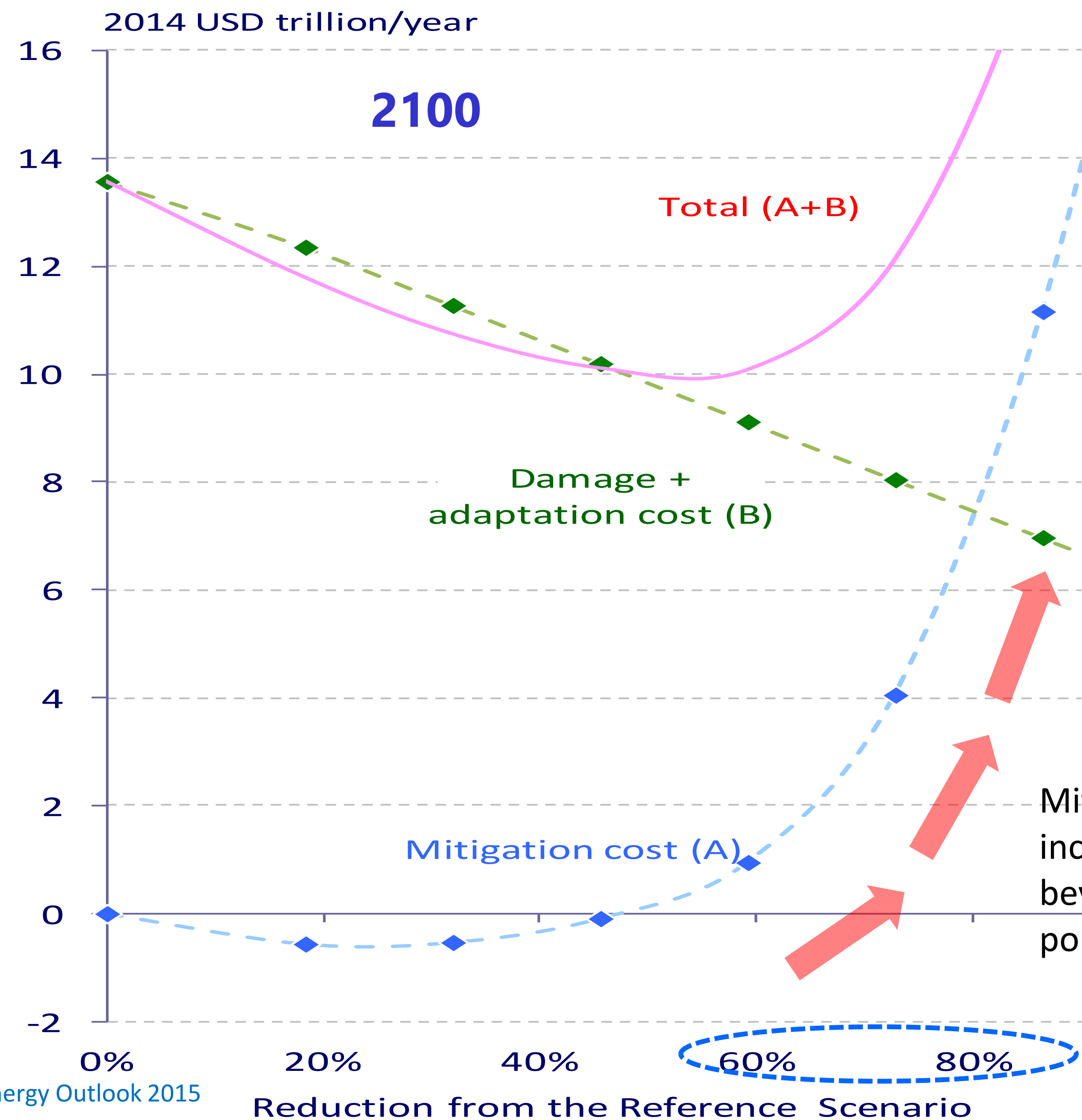
❖ **Image of total cost for each path**



-There is a trade-off relationship among the mitigation, damage costs, adaptation. It is impossible to reduce all three costs at the same time.
- It would be realistic to expect a balance among the three, while minimizing the total cost.

Source: IEEJ, Asia/ World Energy Outlook 2016

Mitigation vs. Adaptation Costs in 2100



Mitigation cost increases rapidly beyond certain point

Source: IEEJ, Asia/ World Energy Outlook 2015

Uncertainty in estimating the long-term optimal path

Mitigation, adaptation and damage costs

- The **uncertainty** is **extremely large.**
- **Future R&D** should aim to **reduce cost hike.**

Climate sensitivity

- According to IPCC, some recent studies **suggest** that the "**climate sensitivity**" may be **lower** than previous studies (no more agreement on a best estimate of 3 'C).

- **With lower climate sensitivity**, damage caused by climate change becomes smaller, resulting in **a less ambitious mitigation path being optimal**.

Discount rate (social discount rate)

- With higher discount rates, future climate costs are valued less, resulting in smaller mitigation being optimal.

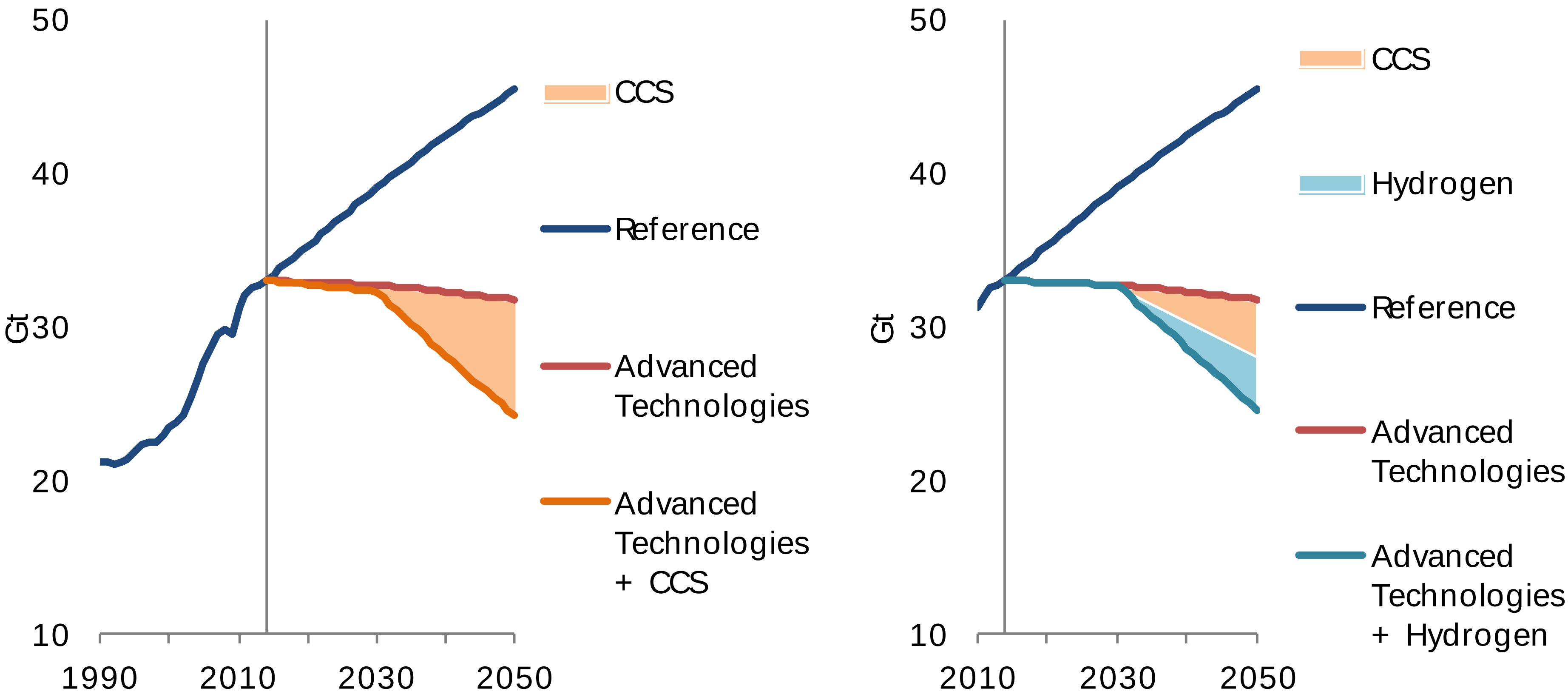
Importance of Technology Development for Ultra Long Term

Technologies		Description	Challenges
Technologies to reduce CO_2 emissions	Next Generation Nuclear Reactors	Fourth-generation nuclear reactors including very high temperature and fast reactors are being developed internationally.	Expanding support for research and development of next-generation nuclear reactors, etc.
	Nuclear Fusion	Technology for fusing hydrogen and other elements with small atomic numbers to create energy as the sun does. Deuterium as nuclear fusion fuel exists abundantly and universally. Nuclear fusion does not emit spent fuel as high-level radioactive waste.	Technology for continuous nuclear fusion and containing it a fixed space, reduction of the energy balance and costs, building fundraising and international cooperation systems for large-scale technology development, etc.
	Space Photovoltaic (SPS)	Technology for implementing solar photovoltaic electricity generation in outer space with more abundant sunlight than on earth and for transmitting generated electricity through microwaves wirelessly to earth for use on ground	Developing wireless energy transmission technology, reducing costs for transporting construction materials to outer space, etc.
Technologies to sequestrate CO_2 or to remove CO_2 from the atmosphere	Hydrogen Production & Usage	Producing hydrogen by converting fossil fuel through steam reforming. CO_2 emissions are subjected to CCS (carbon capture and storage) technology to make hydrogen production free from carbon.	Cutting hydrogen production costs, improving hydrogen production efficiency, developing necessary infrastructure, etc.
	CO2 Sequestration & Usage (CCU)	Producing carbon compounds as chemical materials from CO_2 with electrochemical, photochemical, biochemical and thermochemical methods to eliminate CO_2 from the atmosphere	Improving CO_2 volume for capture and effective use and efficiency dramatically, etc.

Source: IEEJ, Asia/ World Energy Outlook 2016

Hydrogen : There is No Royal Road, but There is A Road

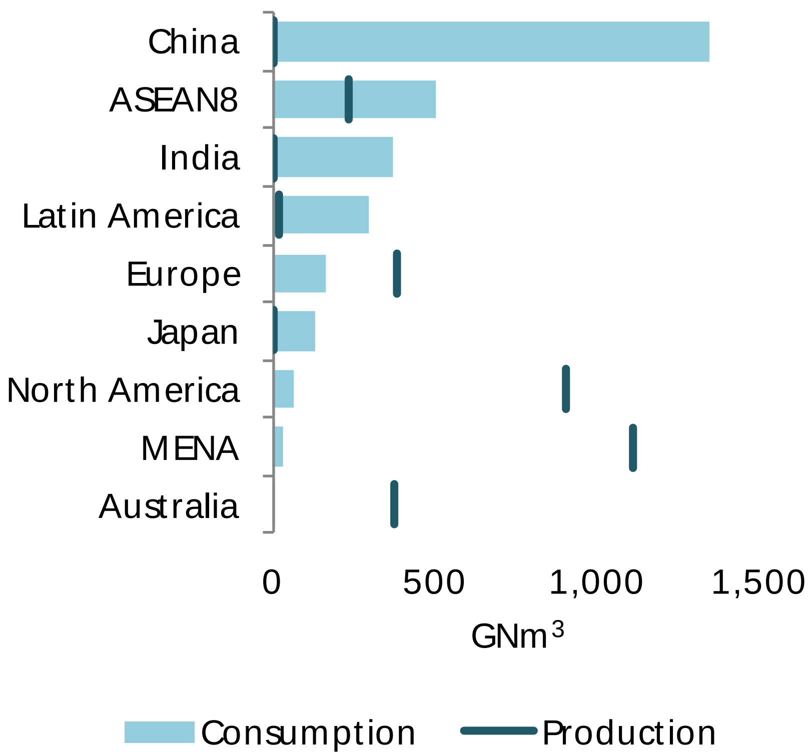
❖ CO_2 emissions and reduction



Source: IEEJ, Asia/ World Energy Outlook 2016

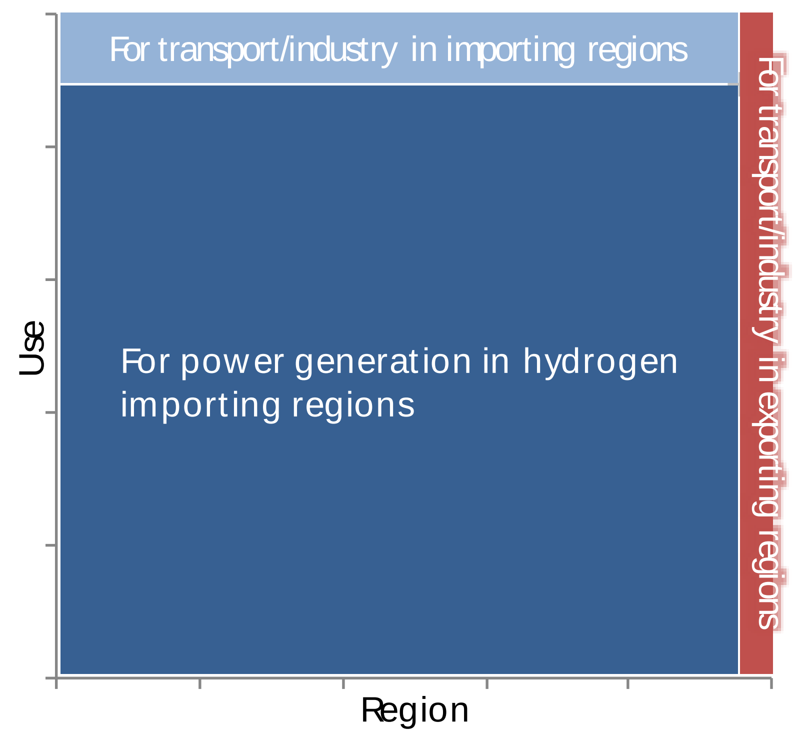
Hydrogen: An option for countries without CCS potential

❖ Supply and demand of hydrogen
[Advanced Technologies + Hydrogen, 2050]



Note: Net export/import is defined as the difference in consumption and production

❖ Hydrogen consumption
[Advanced Technologies + Hydrogen, 2050]

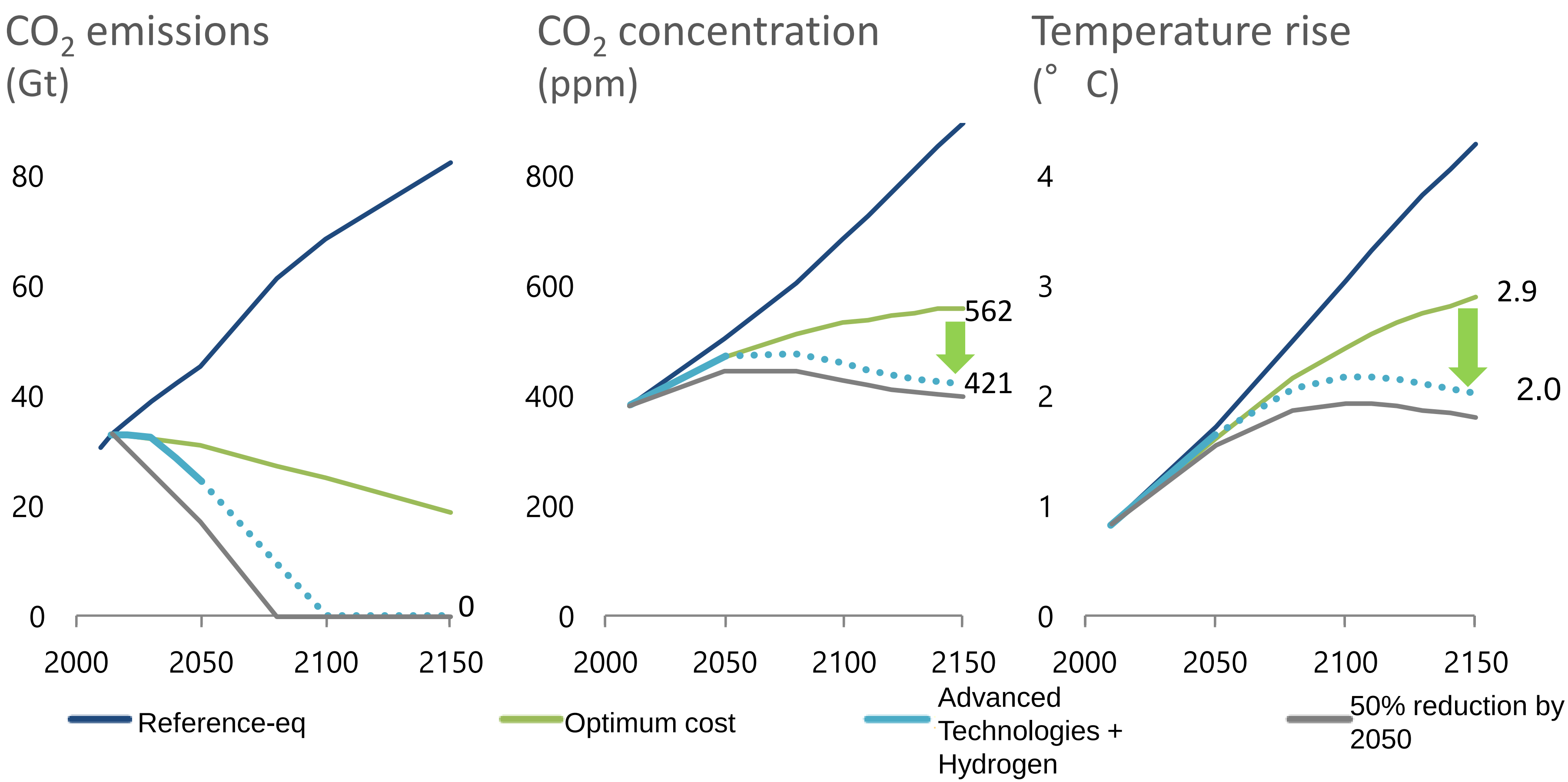


Total consumption: 3,240 GNm3

Source: IEEJ, Asia/ World Energy Outlook 2016

Hydrogen Will Become an Option Depending on Cost Cut

❖ In the ultra long-term paths



Source: IEEJ, Asia/ World Energy Outlook 2016

Note: "Advanced Technologies + Hydrogen" means the "Higher Hydrogen Scenario" in the body.

Conclusion

1. Asia will be the center for energy demand growth and fossil fuels will remain key energy used globally. USA will enjoy energy independence while conventional energy suppliers may need to adjust to the new reality.

2. Gas supply may remain sufficient until past 2020. The current low oil price slows down upstream investment and may cause future supply issue. Ongoing unstable geopolitical situation adds uncertainties for the future energy balance.

3. Paris agreement is a success. But only a success towards a greater success. We need to make further efforts to reduce GHG emissions.

3. Pragmatic approach is to start by minimizing the total cost of damage, mitigation and adaptation while achieving the sustainable growth of the economy, and not only through mitigation with huge economic costs.

5. Further cost reduction and more innovation is required as the next step.

6. Production of carbon free hydrogen from fossil fuels can be one option as a start.

Thank you for your attention!