## 424th Forum on Research Works

# Asia/World Energy Outlook 2016

*– Consideration of 3E's+S under new energy circumstances in the world –*

21 October 2016

Shigeru SUEHIRO, Tomoko MURAKAMI and YANAGISAWA Akira
The Institute of Energy Economics, Japan

# Today's Topics

## Overlooking the global energy market

✓How is the future energy structure projected?

✓Is ASEAN, which started the economic community, a promising market?

## Addressing energy security and climate change issues

✓How is the risk for supply disruption assessed?

✓How should we deal with the climate issue in the super long-term?

✓What impacts on the issues by hydrogen and CCS technology?

## Understanding the meaning of nuclear energy

✓How is the "3Es+S" of nuclear energy evaluated?

# Overlooking the global energy market

## Signs of change in the global energy trend

✓China's re-balancing economic structure and strengthening environment policy, resulting in drops in coal demand for 2 years in a row.

✓Ending the 18-months reducing trend of oil prices and re-balancing supply-demand. Decreasing investment in upstream for 2 years in a row.

✓Weakening links between energy demand and economic growth and growing low-carbon energy rapidly. Paris Agreement effecting in November and shifting toward more eco-friendly energy system.

## ASEAN marks 50th anniversary in 2017

✓As a hub of Asia, becoming new ASEAN with remarkable economic growth and establishment of economic community (AEC) in 2015. Collaboration in energy sector contributing to "3Es".

✓Diversity among countries for political system, economic size, living standard, religion and structure of energy supply and demand.

✓Low energy-living standard, which is a half of global average, with no access to electricity for 20% of inhabitants and modern cooking system for half.

# Scenario Setting

## Reference Scenario

This scenario reflects past trends as well as energy and environment policies that have been introduced so far. This scenario does not reflect any aggressive policies for energy conservation or low-carbon measures.

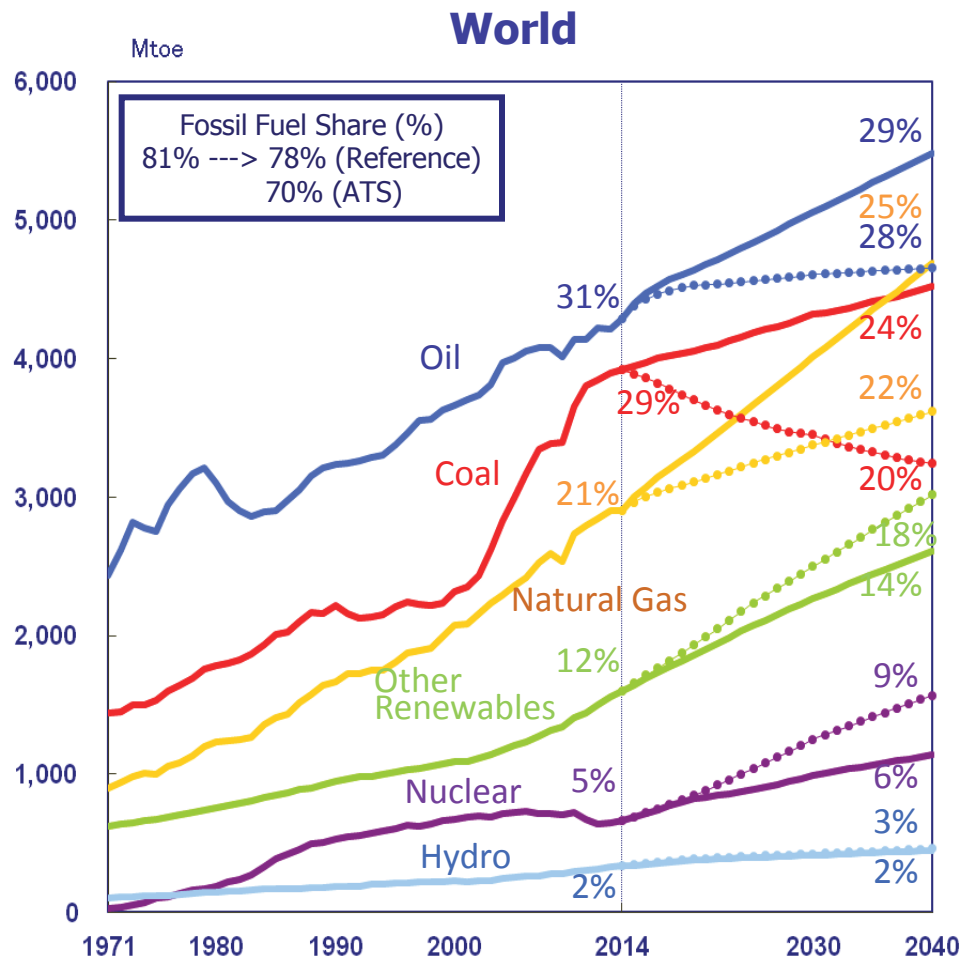
## Advanced Technologies Scenario (ATS)

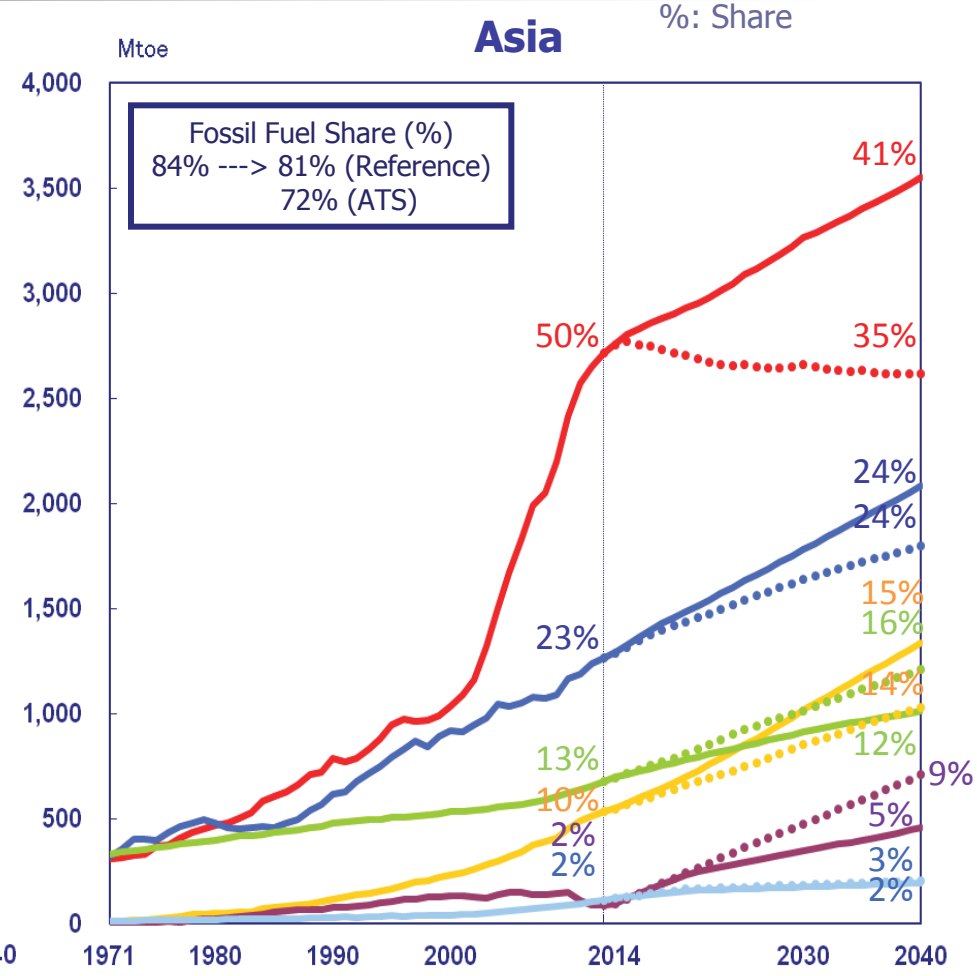
In this scenario, energy conservation and low-carbon technologies are promoted for maximum impacts, as each country is assumed to implement powerful policies to enhance energy security and address climate change issues.

# Primary Energy (by energy)

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

%: Share

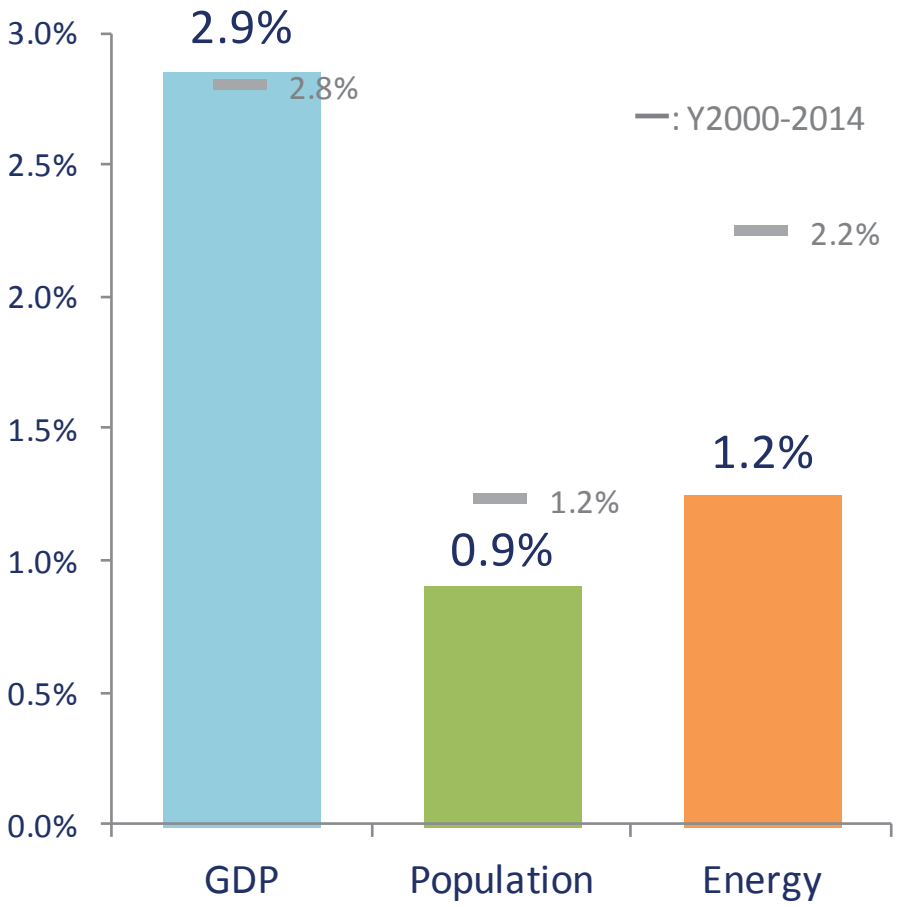


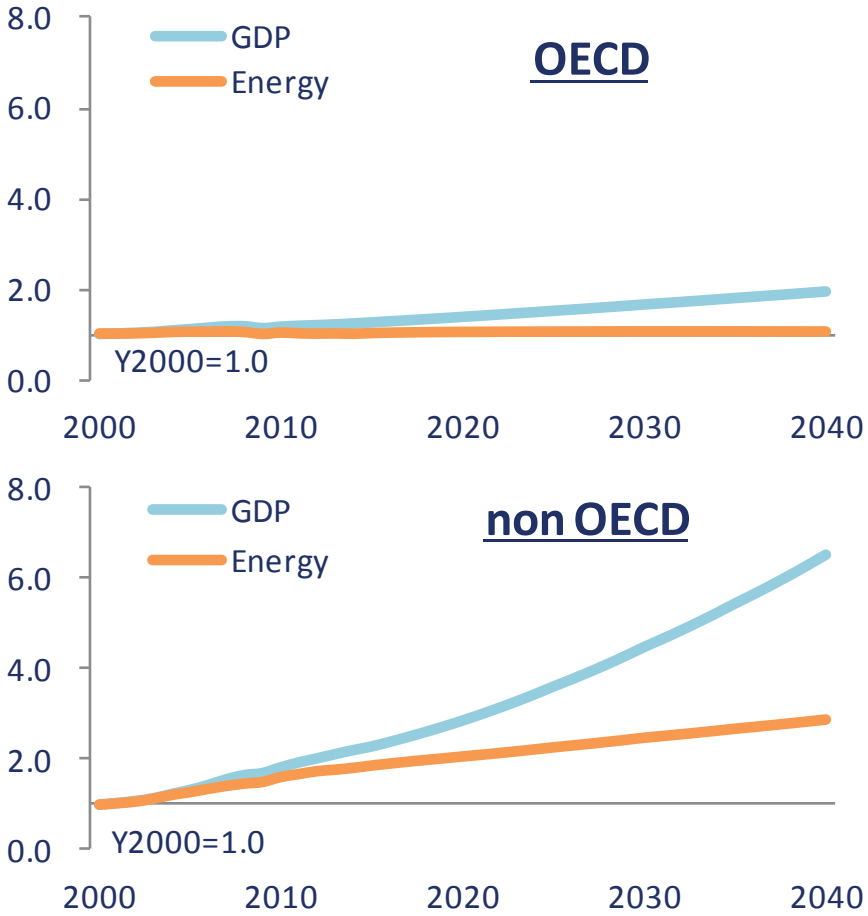

- ✓ Oil remains the most important fuel in the global energy mix for both Reference and ATS, even though the demand levels off in 2030's in the latter scenario.
- ✓ In Asia, coal demand keeps the largest among primary fuels, even though declining largely in ATS.
- ✓ Fossil-fuel dominates the both global and Asian energy mix, with 70% share even in ATS, although reducing from today's level.

# Huge Improvement in Economic Efficiency

## Annual Growth Rate (World：2014-2040)



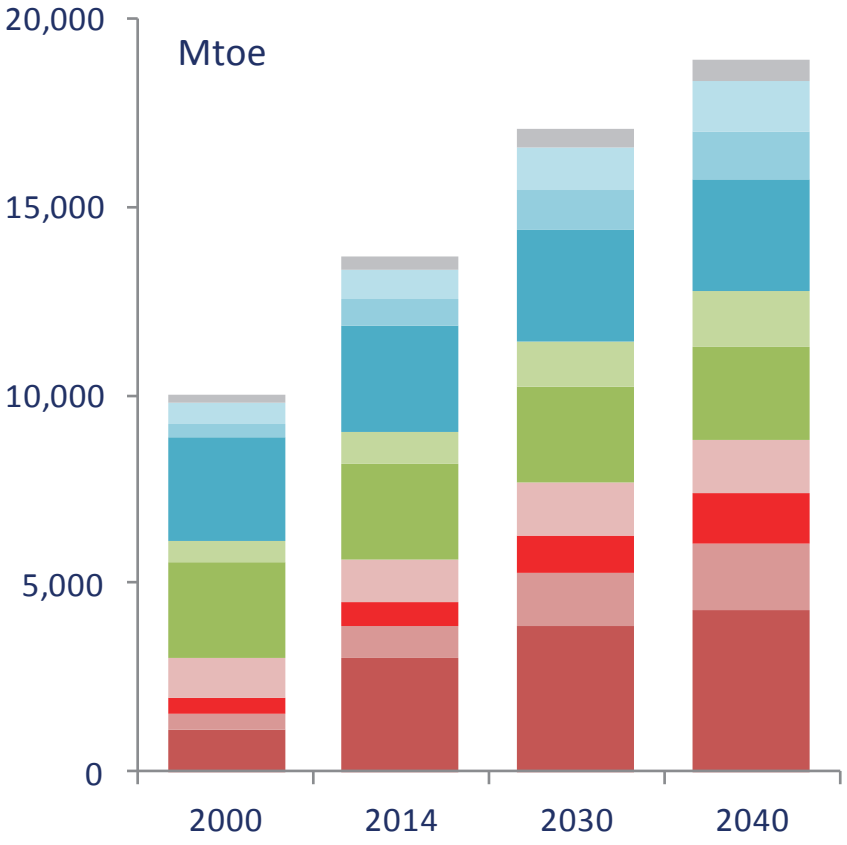

## GDP and Primary Energy Demand



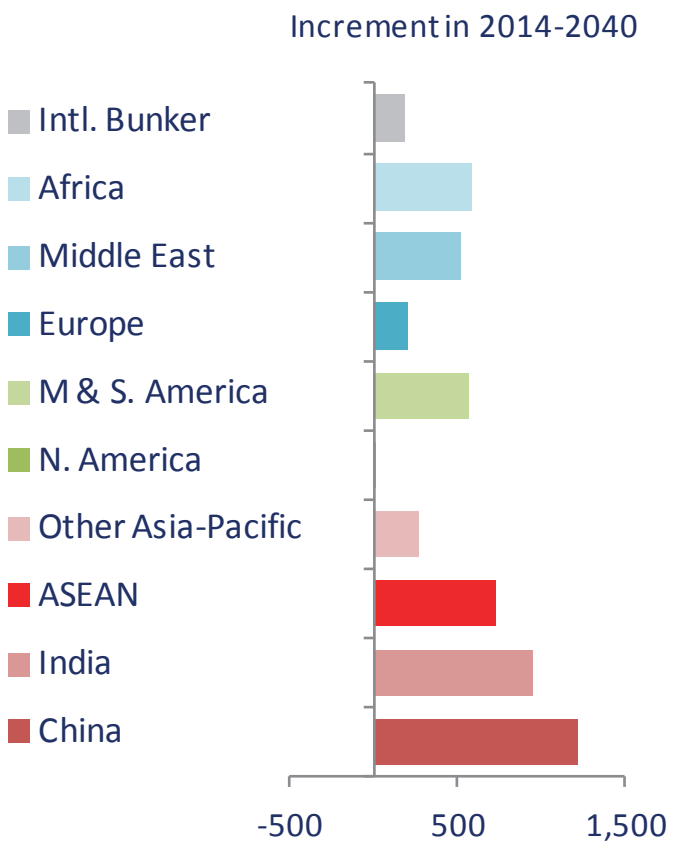

- ✓ Energy demand, which peaks at around 2030, decouples from economic growth in developed countries.
- ✓ Developing countries continue to increase energy demand although energy efficiency improving.

# Energy Market Shifts towards Asia

## World's Primary Energy Demand



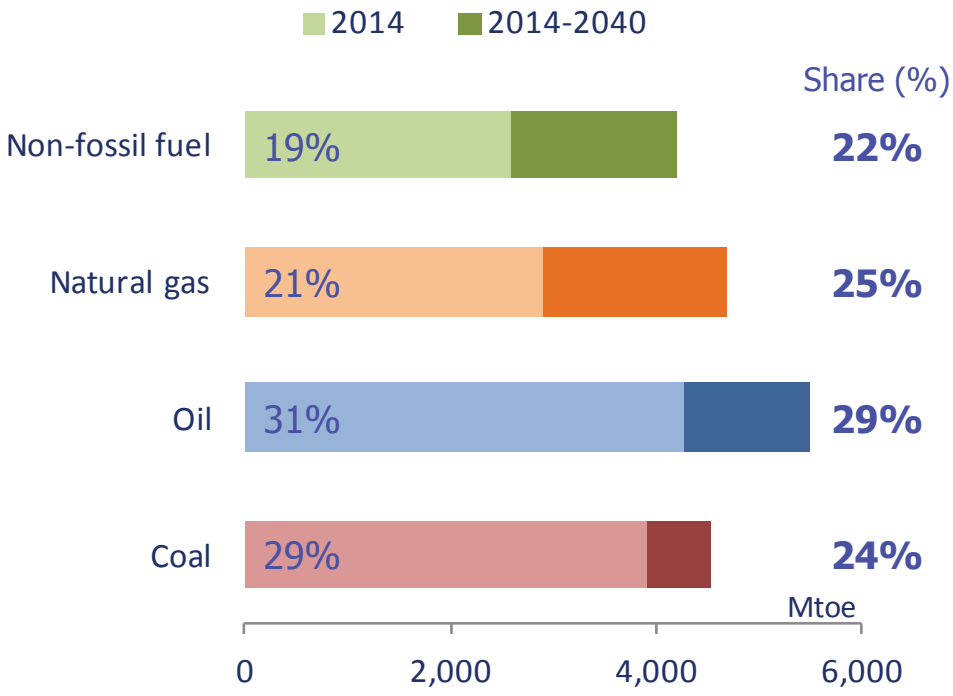

## Increase of Primary Energy Demand



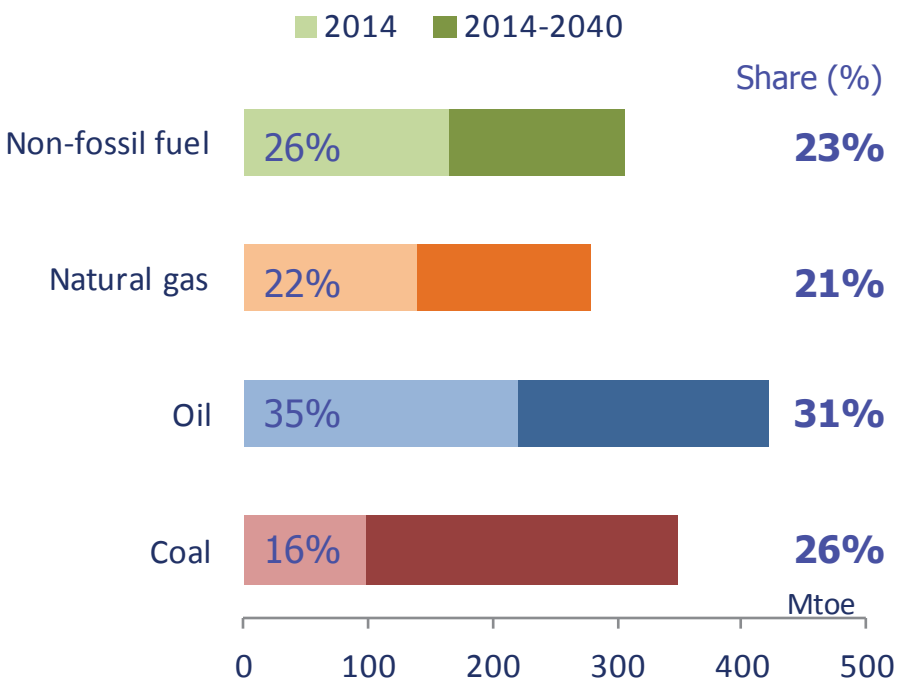

- ✓ Global energy demand increases by 1.4 times and 60% of the growth comes from Asia. Asia is the final destination for around three quarters of oil, gas and coal traded inter-regionally.
- ✓ ASEAN has the third largest demand growth, after China and India.

# Higher Dependency in Coal in ASEAN for Power Generation

## World's Primary Energy Demand



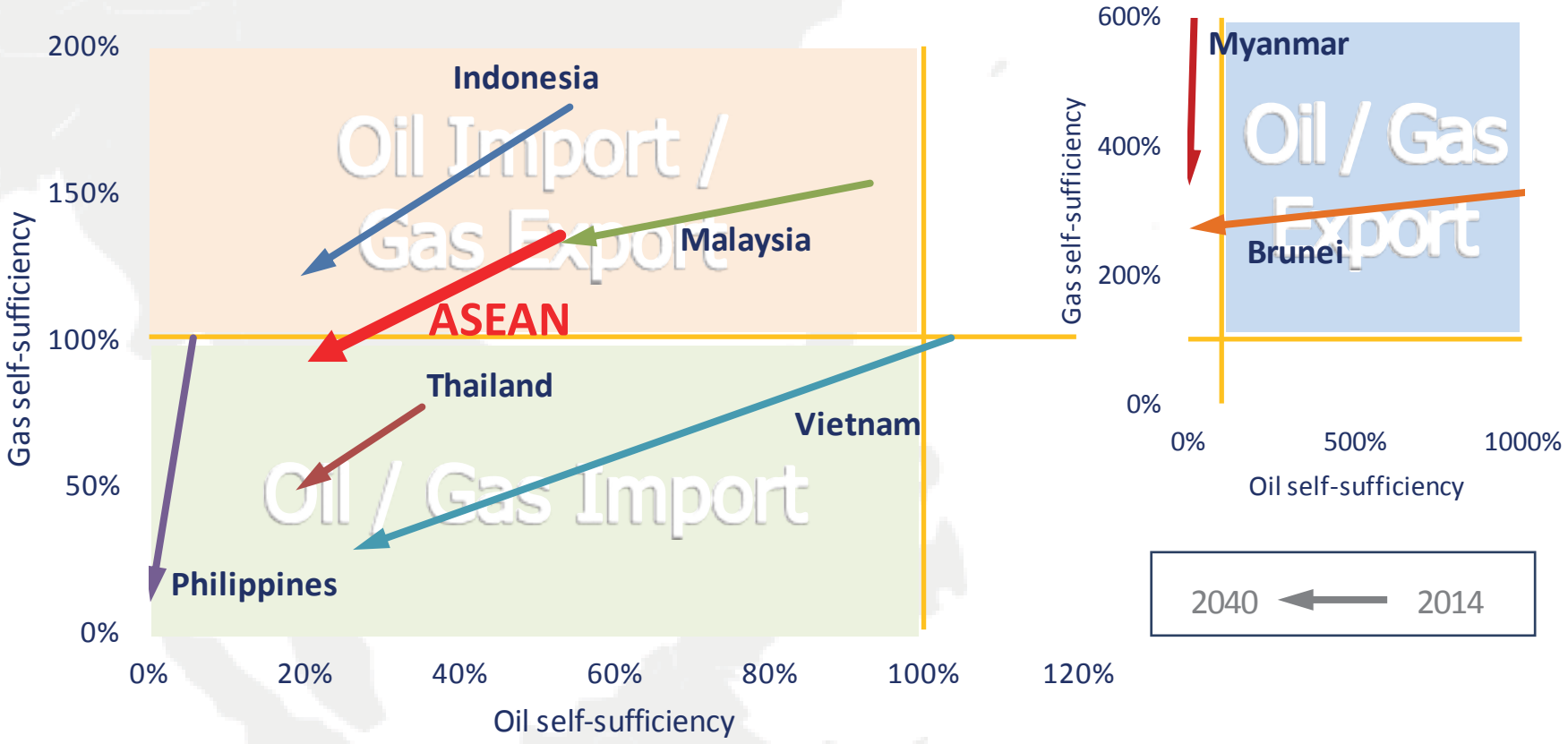

## Primary Energy Demand in ASEAN




- ✓ 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.

# ASEAN Becomes Gas Importer

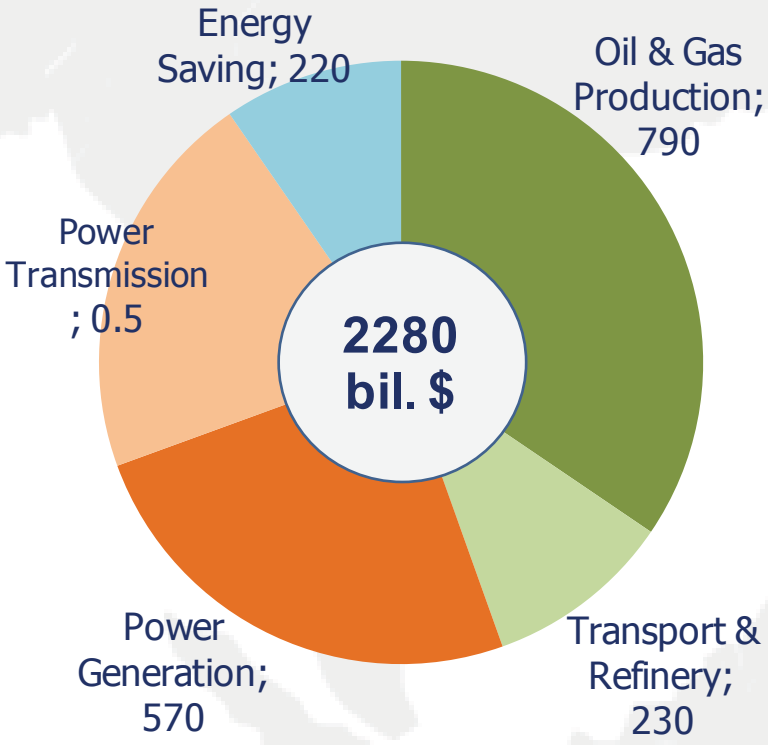
## Outlook of Self Sufficiency Ratio for ASEAN



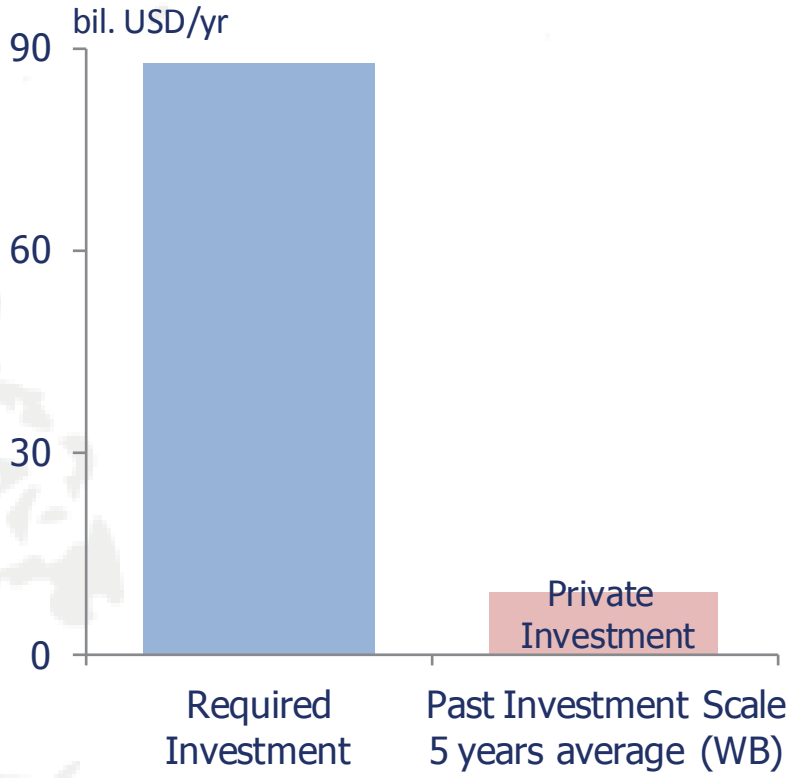

- ✓ Energy imports increase because domestic production expansion fail to compensate demand growth. Oil self-sufficiency ratio decreases to 20% from 53% and gas becomes net import fuel by 2030.
- ✓ Fuel net-import bills amount to $300 billion in 2040, comparing with $10 billion today.

# Needs for Finance to Induce Energy Investment

## Required Energy Investment Value for ASEAN (cumulative up to 2040)



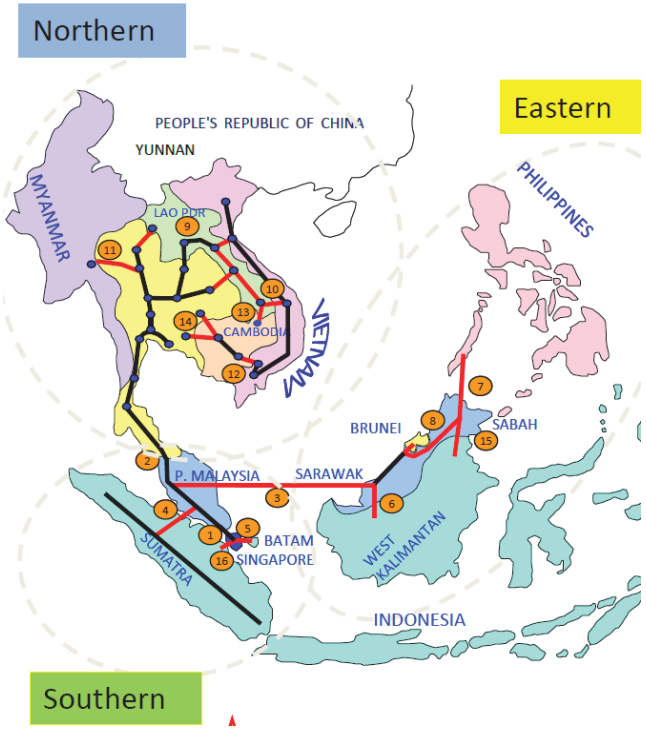

## Average Annual Investment Value




- ✓ Cumulative energy-related investments amount to $2.3 trillion by 2040. Most of them are for energy supply — fuel and electricity divided almost equally.
- ✓ A big challenge is how to finance $90 billion needed annually.

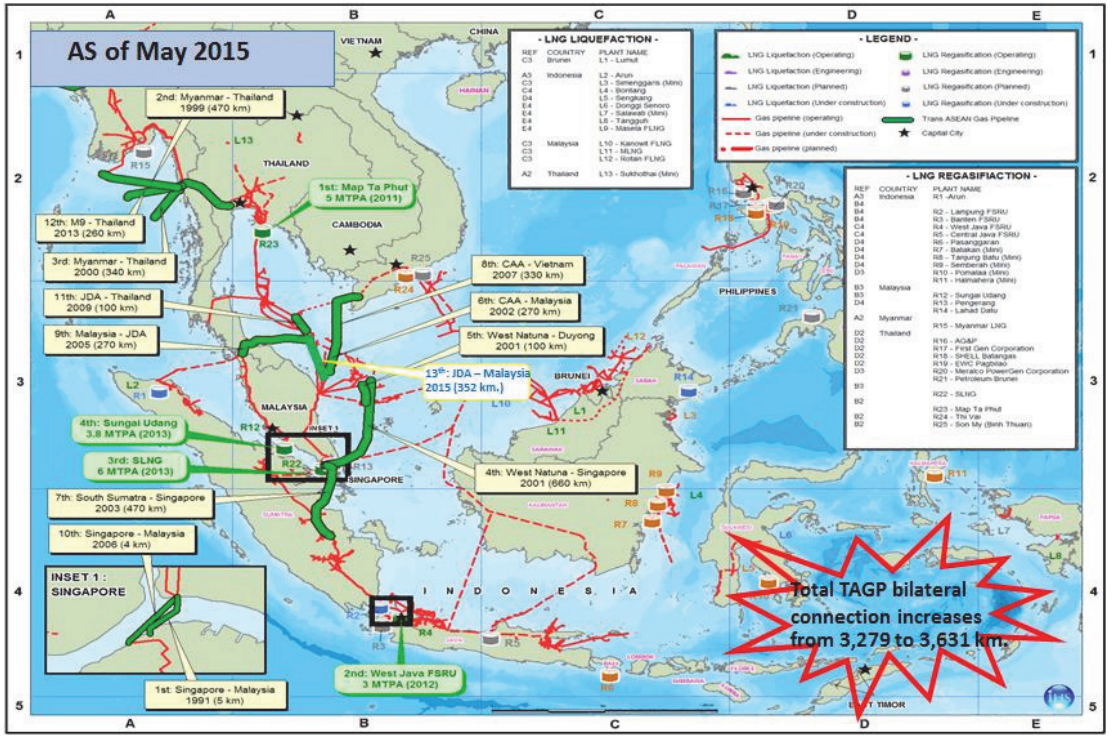
# Energy Market Integration Plan is Slower than Expected

## ASEAN Power Grid




source: HAPUA

## Trans ASEAN Gas Pipeline

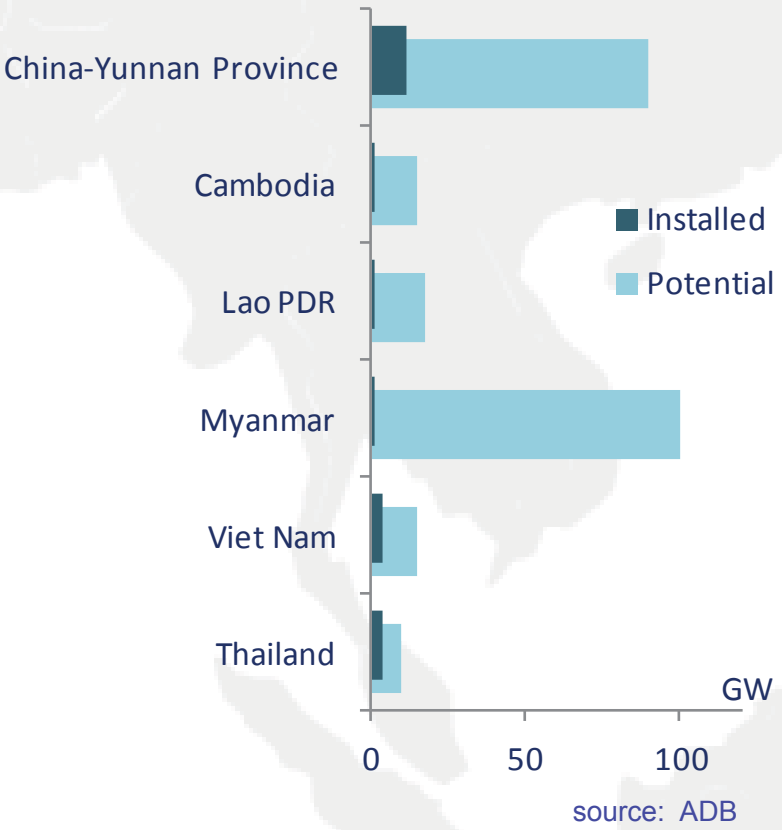



source: ASCOPE HP

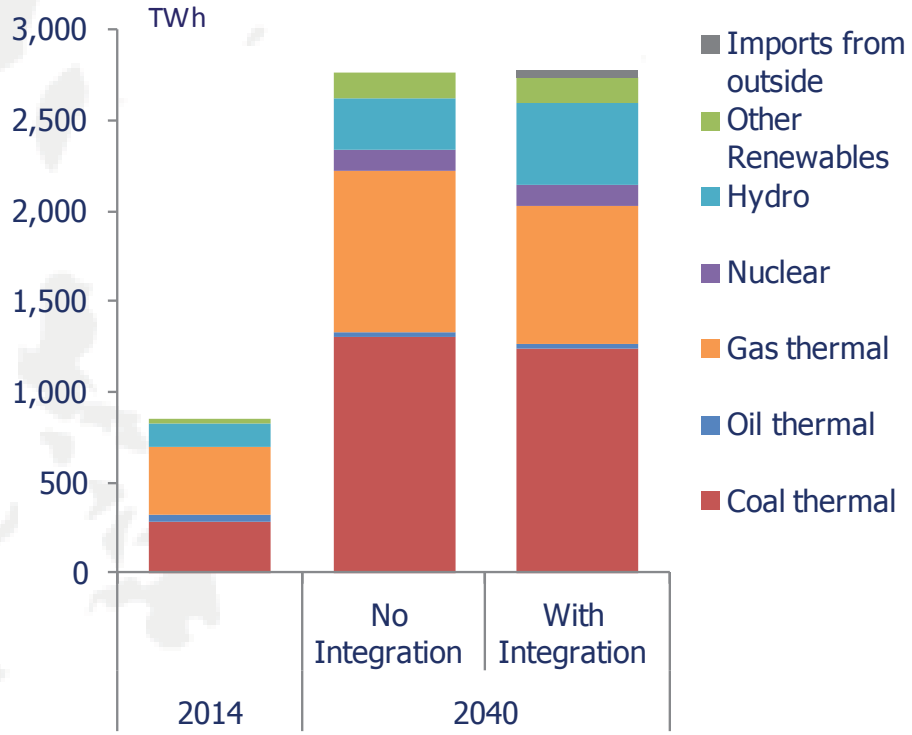
- ✓ Energy market integration is proposed in 1997 as parts of "ASEAN Vision 2020," which aims further economic development by regional cooperation. Contributing to effective utilization of regional resources, further economic collaboration and energy security.
- ✓ ASEAN Power Grid (APG): 5.2GW in operation, 3.3GW under construction and over 20GW under planning. Many challenges such as short of finance and technical experts, and development of legal systems.
- ✓ Trans ASEAN Gas Pipeline (TAGP): 13 international pipelines in operation. The plan for covering the region is behind schedule due to the lowering export capacity in producing countries.

# Utilizing Hydro Potential of the Mekong Area

## Hydro Potential in Mekong Area



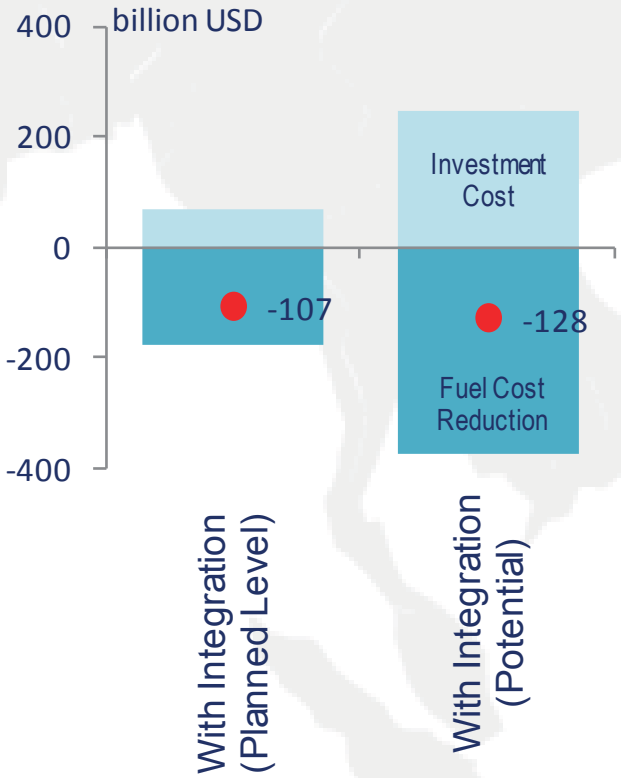

## Power Generation Mix in ASEAN



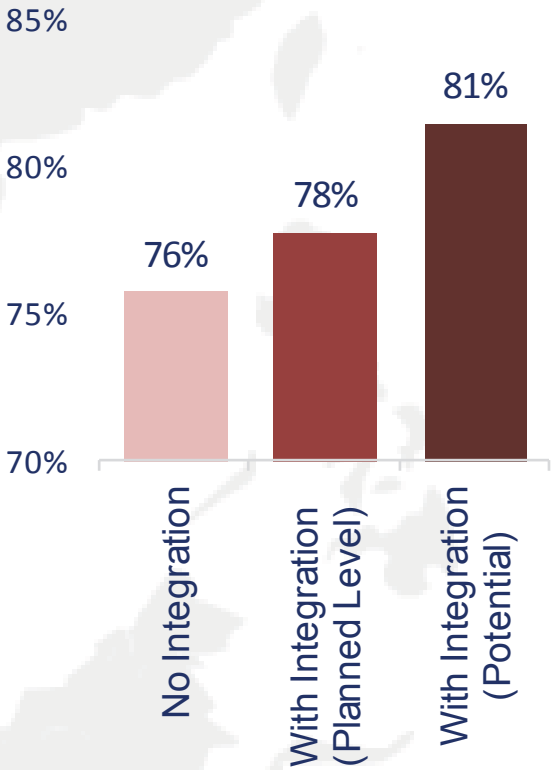

- ✓ Mekong and Borneo have huge untapped hydro potential.
- ✓ Fossil-fuel thermal generation can be reduced, with connecting electricity demand area to supply area and utilizing hydro potential.

# Effective Utilization of Regional Resources Improves 3Es

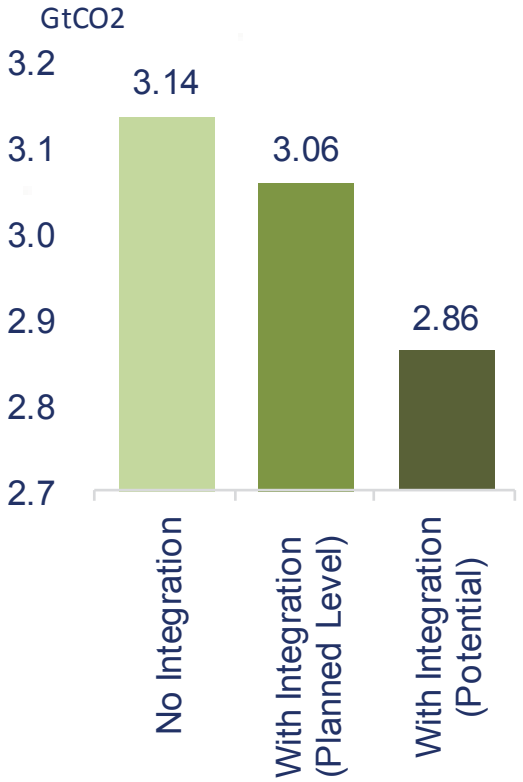
## Economic Effect of Power Integration（up to 2040）




## Energy Sufficiency of ASEAN（2040）




## ASEAN $CO_2$ Emissions (2040)




- ✓ APG has an economic benefit with $100 billion by reducing fuel bills despite of huge initial investment.
- ✓ Self-sufficiency ratio increases by utilizing domestic hydro resources, instead of importing fossil-fuels.
- ✓ Reducing fossil-fuel combustion contributes to domestic and global environment issues.

# Conclusion: How to Assess ASEAN Market

- ✓ ASEAN has a large potential for economic and energy market. Energy demand rapidly increases with progressing industrialization and improving living standard and energy access.
- ✓ ASEAN sees higher dependence on cheap coal, which is different from the global trend. Oil and gas self-sufficiency is decreasing rapidly.

  ---> Urgency to address Energy Security and Climate Change
- ✓ ASEAN needs huge investment in energy-supply infrastructure in order to meet growing energy demand. Finance is a big challenge for ASEAN but a big chance for foreign companies.

  ---> Needs for De-regulation, Policy Transparency and Stability to attract Private Investment into the region
- ✓ Energy market integration improves 3Es (energy security, economic efficiency and environment).

  ---> High expectation towards Japan with the challenge of finance and technologies needs

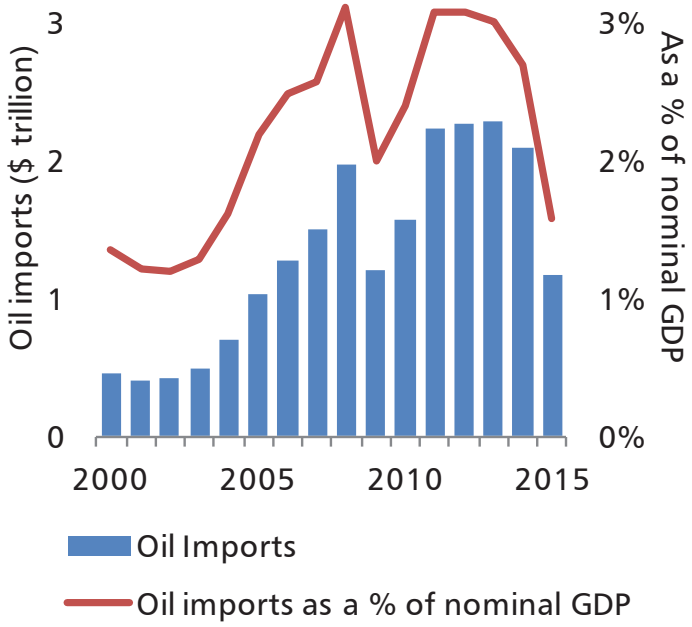
# Supply disruption of oil and natural gas

# In prosperity prepare for adversity

**Energy Security | The uninterrupted availability of energy sources at an affordable price** — IEA

## Economic issue » Relaxed by lower oil price

### ❖ World oil import value



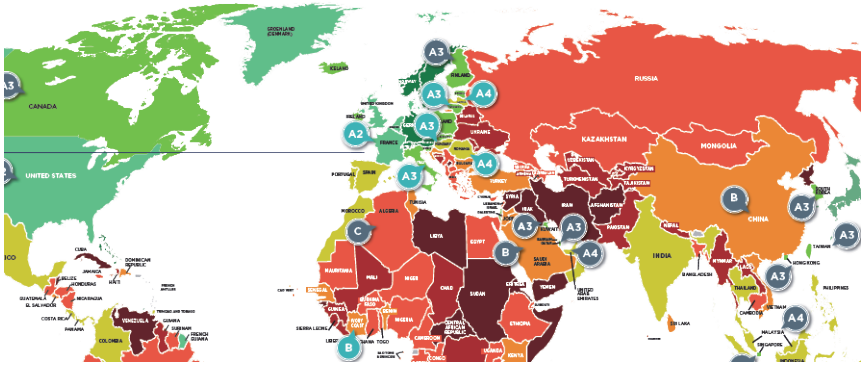

Source: estimated from BP, IMF

Note that there are some Mid-term concern:

- Investment shortage from price volatility and lower energy price,
- Investment shortage with concerns for turning into "stranded" assets, …

## Physical supply disruption » Risk will remain

### ❖ Country risks




Source: Coface "Country Risk Assessment Map" 2Q2016

Despite the current over-supply, geopolitical risk factors have not been resolved. While there are few issues such as Iranian nuclear issue, there are others which became more complex and aggravated.

- Saudi Arabia – Iran Relationships,
- ISIS issues, Syrian situation,
- Ukrainian issues, Western Countries – Russia relationships,
- Domestic situations of MENA countries, …

# Analytical flow of economic impact analysis of physical supply disruption

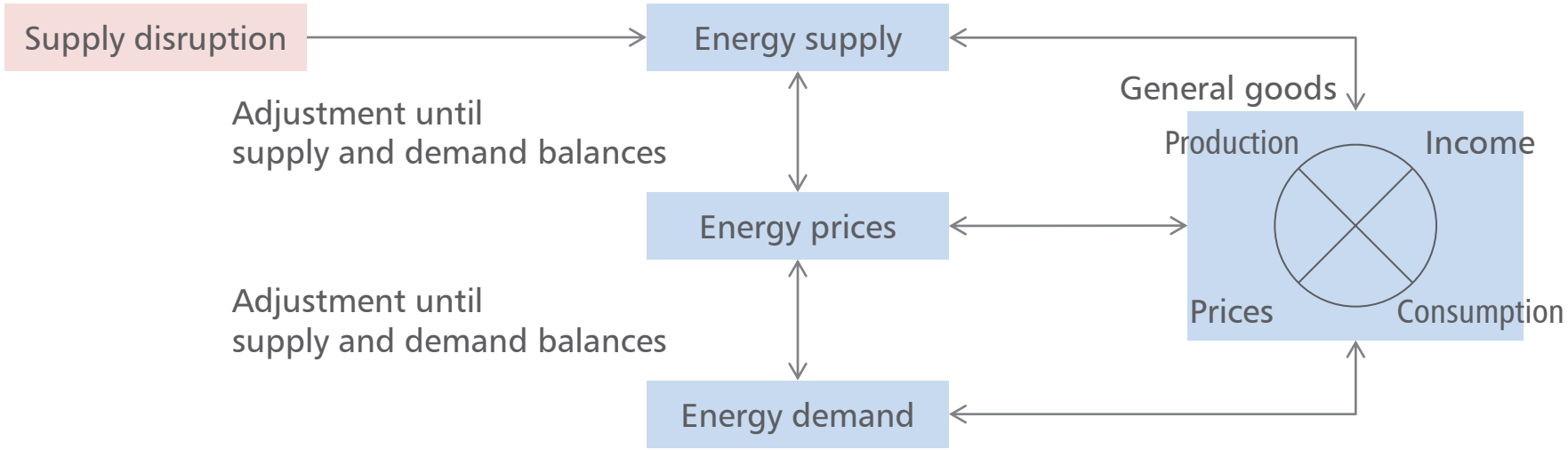
## Hypothetical case setting utilising computable general equilibrium model

### Description of the assumptions and situation

Immediate panic after the supply disruption has subsided while effects are yet to be seen from supply increase from other countries/regions or from energy saving.

This is a comparative statics analysis with no assumption on concrete number for the duration of supply disruption. It is not expected to last for only a few days nor for as long as several decades.
Price volatility caused by speculative factors are not included.
Effects of stock pile release is omitted for simplification.

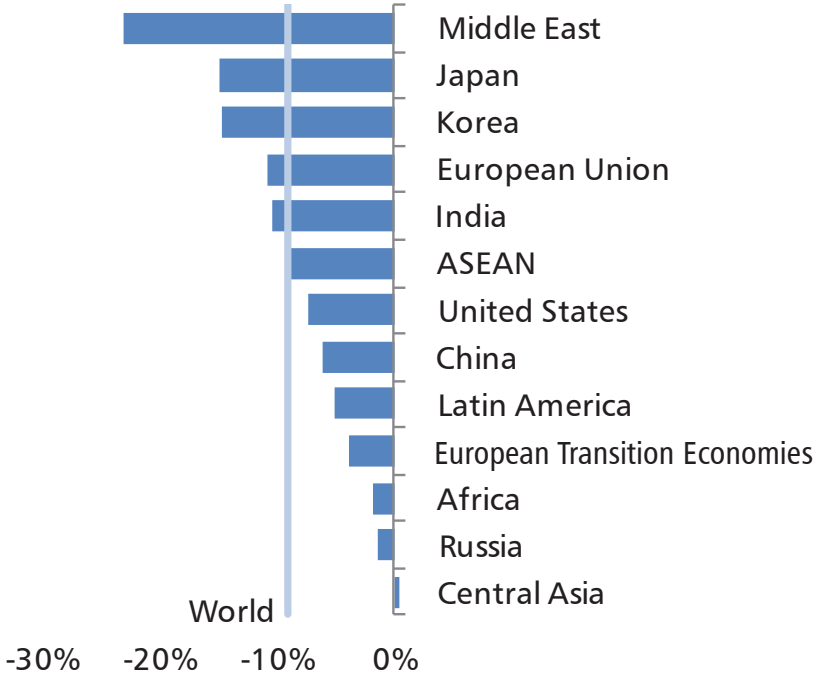
### ❖ Model flow



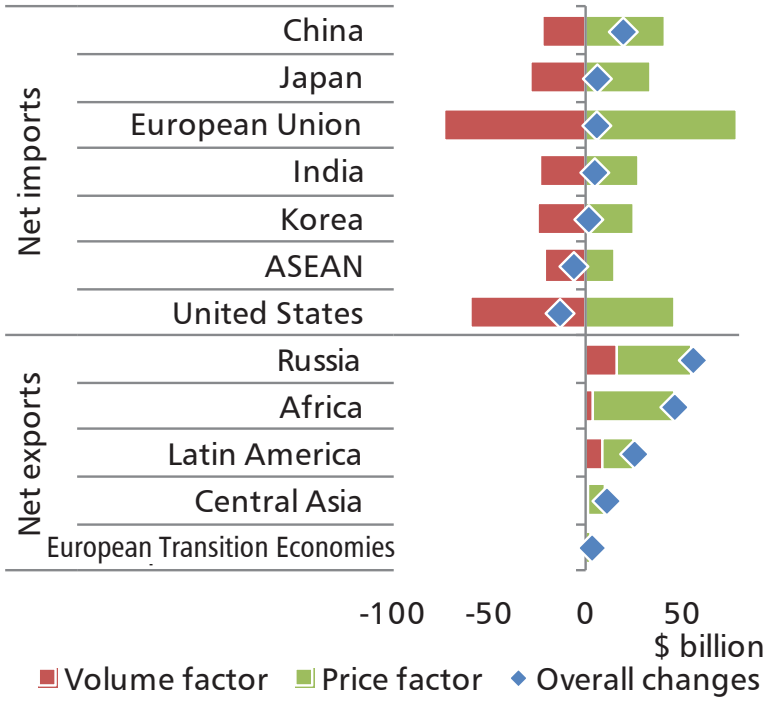

This is the IEEJ's first attempt to analyze the effect of supply disruption on economy. Such analysis is relatively rare in comparison to those of the effect of change in energy prices.

# Supply disruption of 10 Mb/d incurs serious damage to the world economy

## Real GDP




## Crude oil net export value




Note: Crude oil exports from the Middle East diminishes by $139 billion.

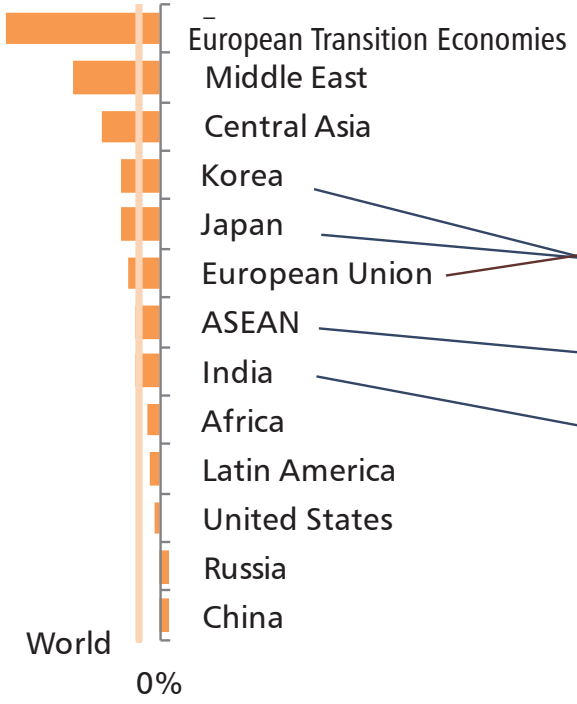
In the situation where crude oil production in the Middle East drops unexpectedly and by large amount while other countries/regions are unable to increase the production to replace the lost volume, the world economy will shrink by 9%. It hits countries such as Japan and Korea which are dependent on imported oil the most.

Despite the increase in export value, the economy of the non-Middle East exporting regions will not manage to avoid being hit by the depression pressure.

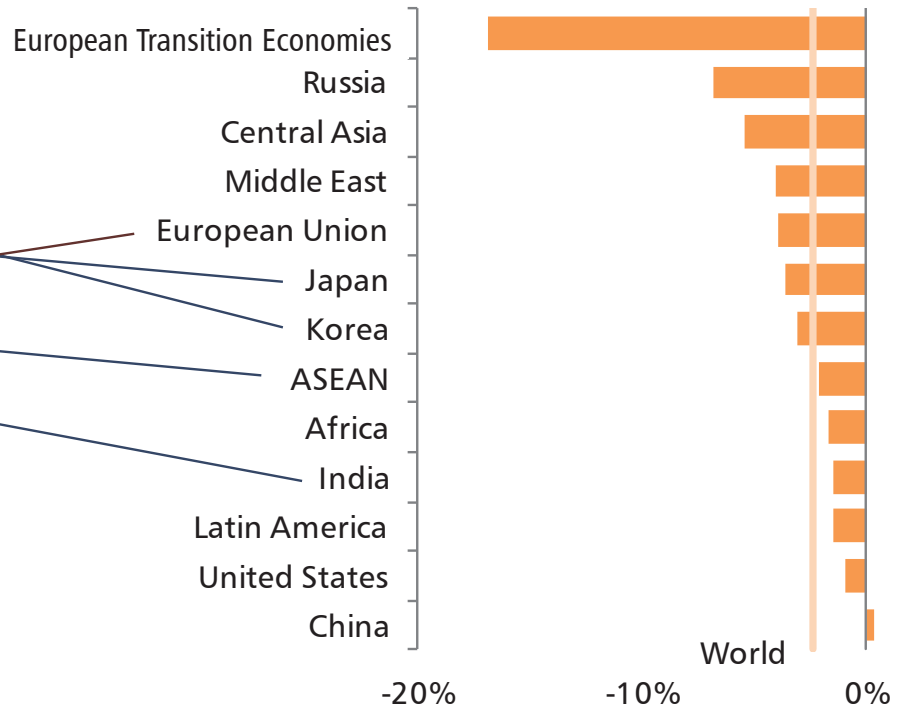
# Natural gas supply disruption hits Europe

## ❖ Changes in real GDP

### Reduced exports from ME by 110 Bcm




### Reduced exports from Russia by 110 Bcm




Notes: 110 Bcm of natural gas ≈ 80 Mt of LNG

With gas supply disruption, the European transition economies will be hardest hit because of the lower energy efficiency and higher dependence on natural gas. In case of Russian gas supply disruption, EU will also be hit hard. Japan and Korea suffer from the gas supply shortage as in the case of oil supply disruption.

Natural gas supply disruption causes smaller effect than crude oil disruption because of the smaller energy value (i.e. 110 Bcm/year natural gas is only 1/5 of 10 Mb/d crude oil).

# Climate change measures |

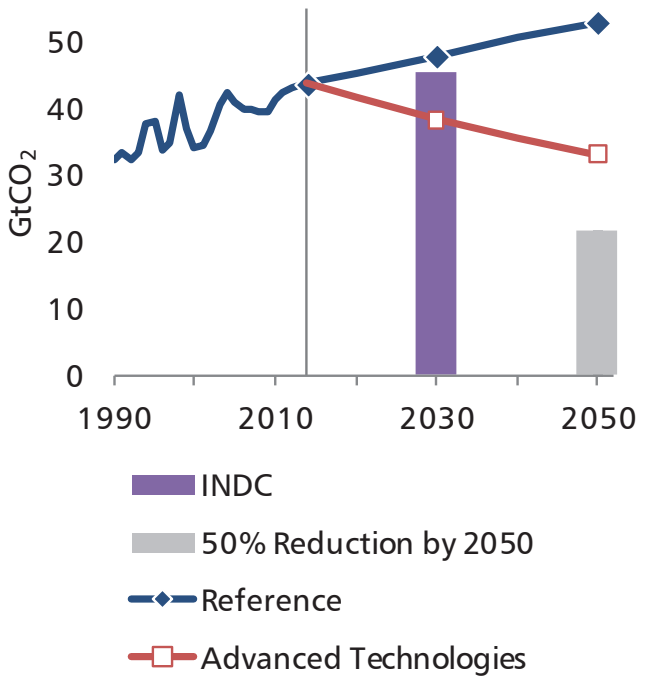
## Paris Agreement, Advanced Technologies Scenario, Ultra long-term path, and CCS/Hydrogen Scenarios

# Paris Agreement | A step towards global action

## ❖ Evaluation of Paris Agreement

| | |
|---|---|
| **Good!!** ☺☺☺ | Over 180 countries, including emerging countries such as China and India, agreed to take actions to reduce emissions.<br>Using bottom-up approach to add individually set reduction targets rather than a top-down approach used by Kyoto agreement where the reduction targets were set first and then allocated to the countries.<br>Method is to evaluate the total target numbers every five years and decide any additional efforts if necessary. |
| **Challenges** ☹☹☹ | Global GHG emissions will increase from the current level. |

## ❖ GHGs emissions

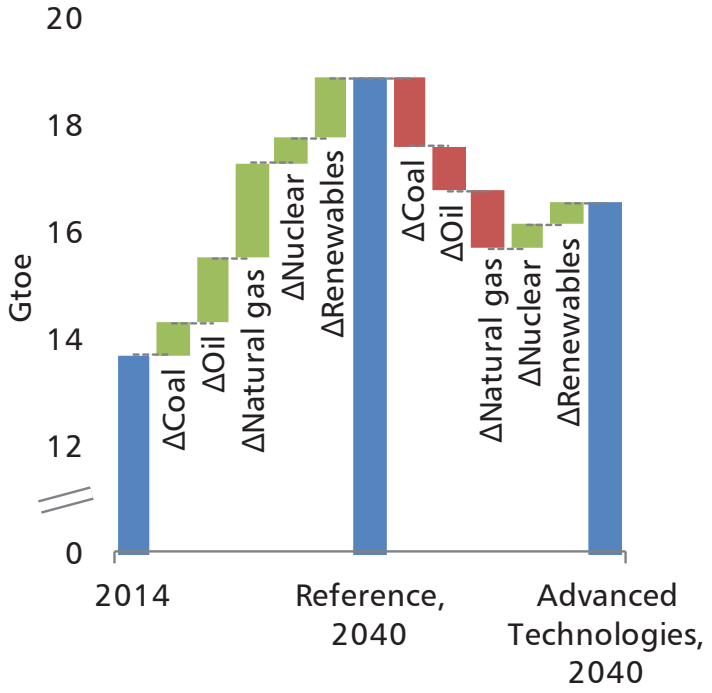



GHG emissions in 2030 under submitted INDC which are set voluntarily by each country are expected to increase from the current level of emissions. Trend will be subdued but 50% reduction by 2050 cannot be achieved.

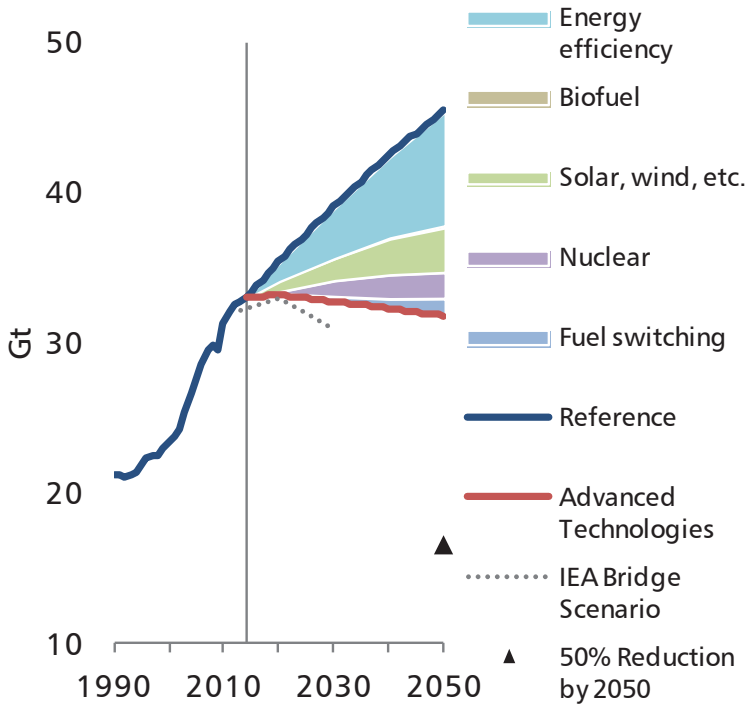
It is necessary to achieve the target agreed under the Paris Agreement and further reduce emissions. It is essential to promote reduction worldwide via technology transfer as well as technology innovation.

# Global actions will reduce $CO_2$ by 3.8%

## ❖ Changes in primary energy consumption




## ❖ $CO_2$ emissions and reduction




In the Advanced Technologies Case where the maximum possible $CO_2$ reduction measures (assuming social acceptance) are introduced, energy consumption in 2040 is smaller than the Reference Case by 2,343 Mtoe or 12%.

$CO_2$ emissions in the Advanced Technologies Case will peak at around 2020 and will start to decline after. By 2050, emissions will be reduced by 3.8% from 2014 level and by 13.7 Gt from the Reference Case level which is equivalent to 42% of the global emissions.

Note: See p.24- for scenarios reducing further $CO_2$ emissions from the Advanced Technologies Case by CCS/hydrogen.

# 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.

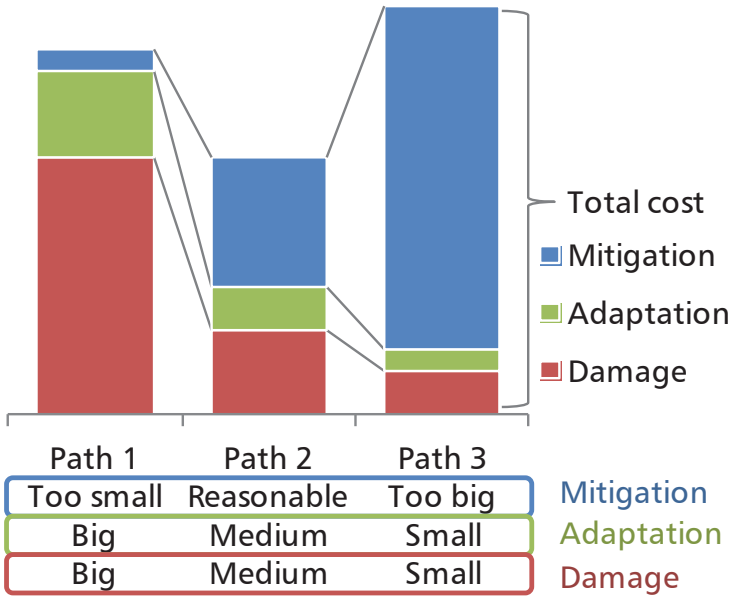
**Adaptation**

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.

## ❖ Image of total cost for each path

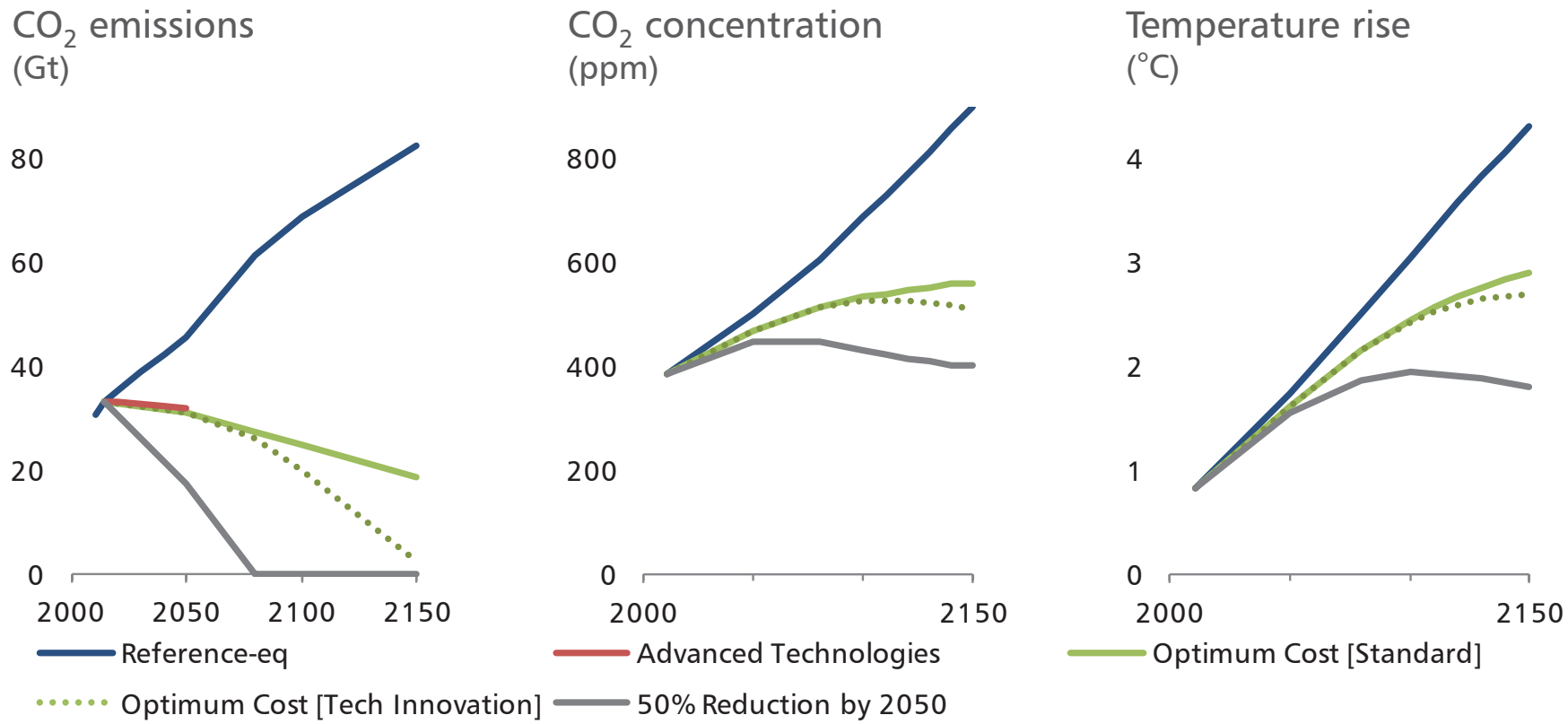



Without any measure against climate change, no mitigation cost incurs. On the other hand, adaptation costs and damage will become massive. Tough mitigation measures will reduce adaptation costs and damage but mitigation costs will be notably big.

Climate change issue is a long-term challenge which influences vast areas for many generations. From the sustainability point of view, combination of different measures which reduces the total cost of mitigation, adaptation and damage is important.

# Beyond “Simply mitigation”

## ❖ In the ultra long-term paths




$CO_2$ emissions of the Optimum Cost Path will be much lower than the Reference Case equivalent emissions but not as low as the 50% Reduction by 2050 Case emissions. Emissions in 2150 will be 50% lower than the current level and temperature will rise by about 3°C.

If technology innovations reduce mitigation, temperature rise reaches the peak of 2.7°C around 2150 and will start to go down. Total cost will be around $100 billion which is much lower than both Reference Case equivalent and 50% Reduction by 2050 Case.

Note: Estimated with climate sensitivity set as 3°C. If CS is 2.5°C, then temperature will rise by 3.7°C, 2.5°C and 1.4°C, respectively for the three cases, namely Reference Case equivalent, Optimum Cost with innovation and 50% Reduction by 2050 Cases, by 2150.

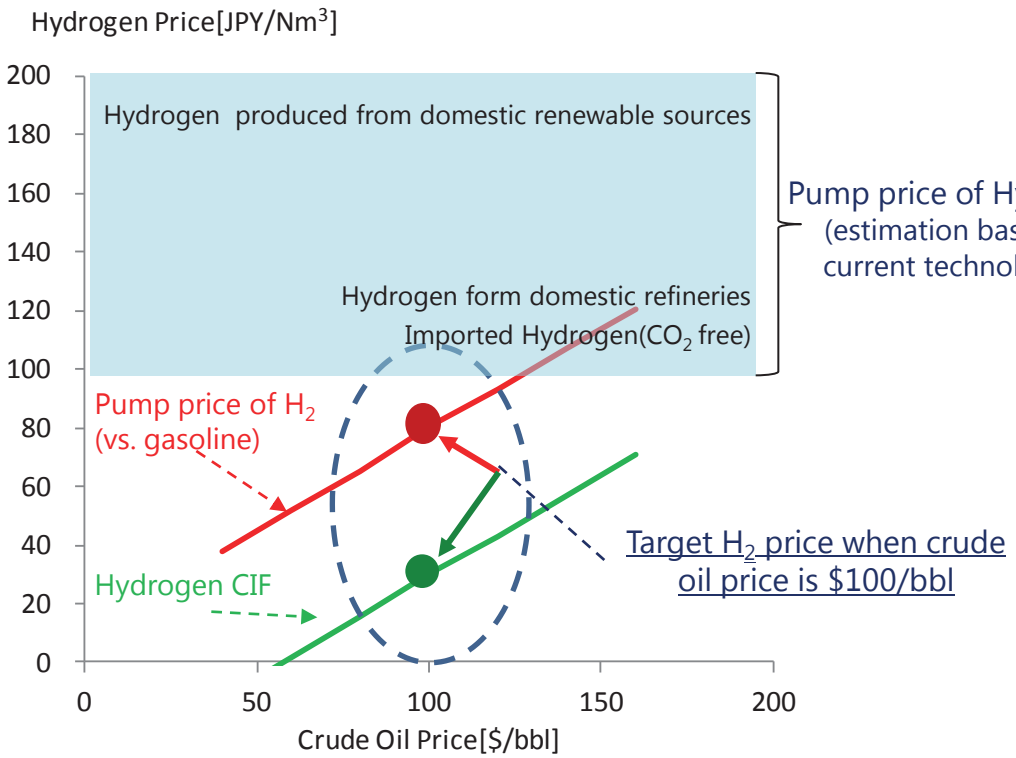
# Examples: Technology development for ultra long term

| Technologies | | Description | Challenges |
|---|---|---|---|
| Technologies to reduce $CO_2$ emissions | Next Generation Nuclear Reactors | Fourth-generation nuclear reactors such as ultra-high-temperature nuclear reactors 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 | 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 (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. |
| | $CO_2$ sequestration 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.<br>$CO_2$ can be removed from the atmosphere. | Dramatically improvement in quantity and efficiency, etc. |

# An example of hydrogen competitiveness analysis

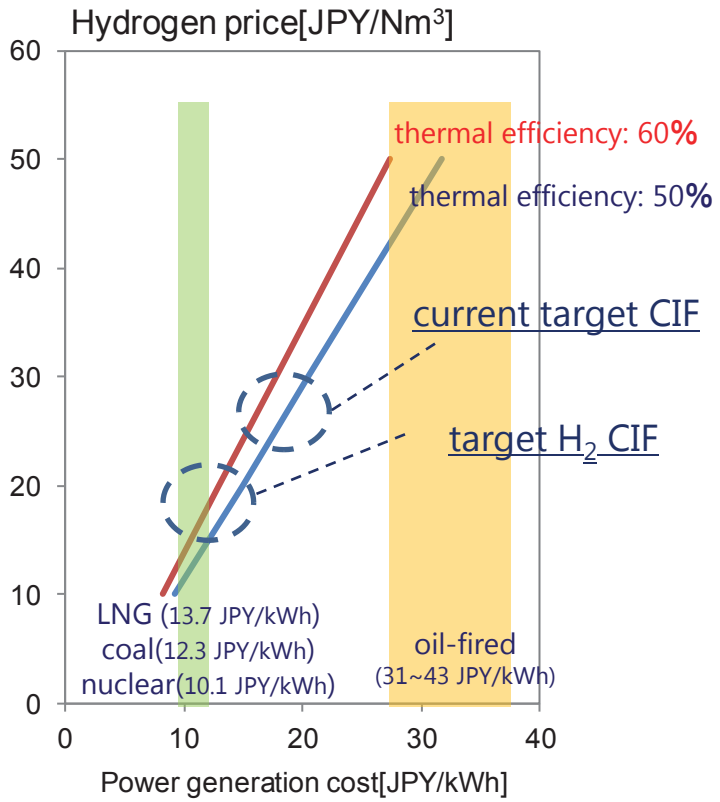


[ $H_2$ price in FCV(comparison with gasoline) ]




note：comparison limited to fuel cost (FCV vs. ICE).FCV is assumed to have 2.5 times better fuel economy.

[ cost of hydrogen-thermal power]
(imported hydrogen based analysis)

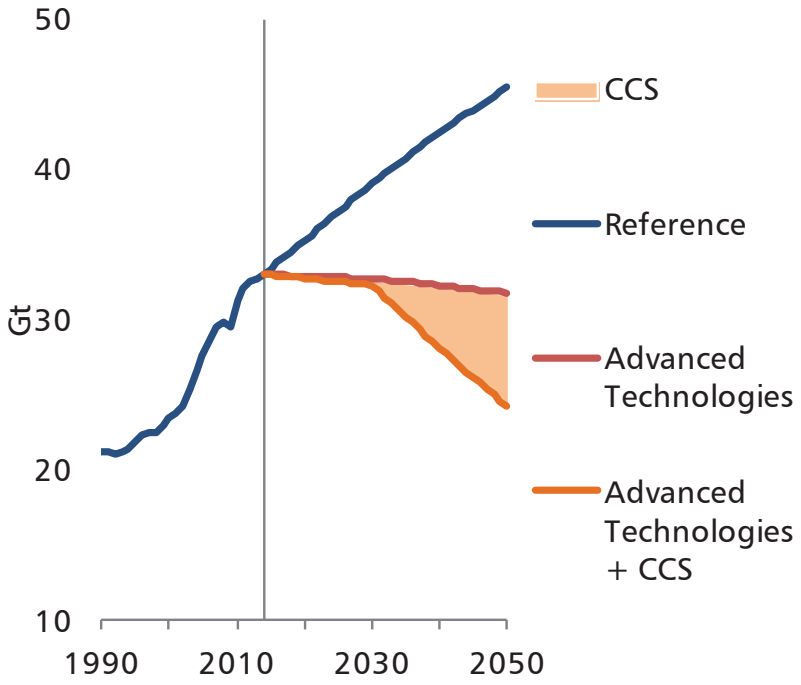


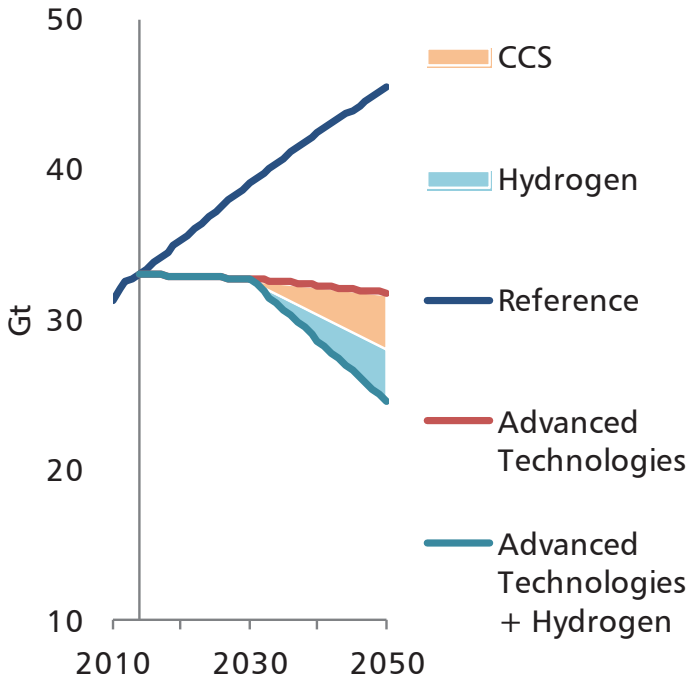

note：capacity factor: 50%; CAPEX: 120 mil. JPY/MW

- In the current status, hydrogen price for FCV less cost-effective. However hydrogen would be cost –effective through crude oil price rise and cost reduction of hydrogen supply chain.

# There is no royal road, but there is a road

## ❖ $CO_2$ emissions and reduction



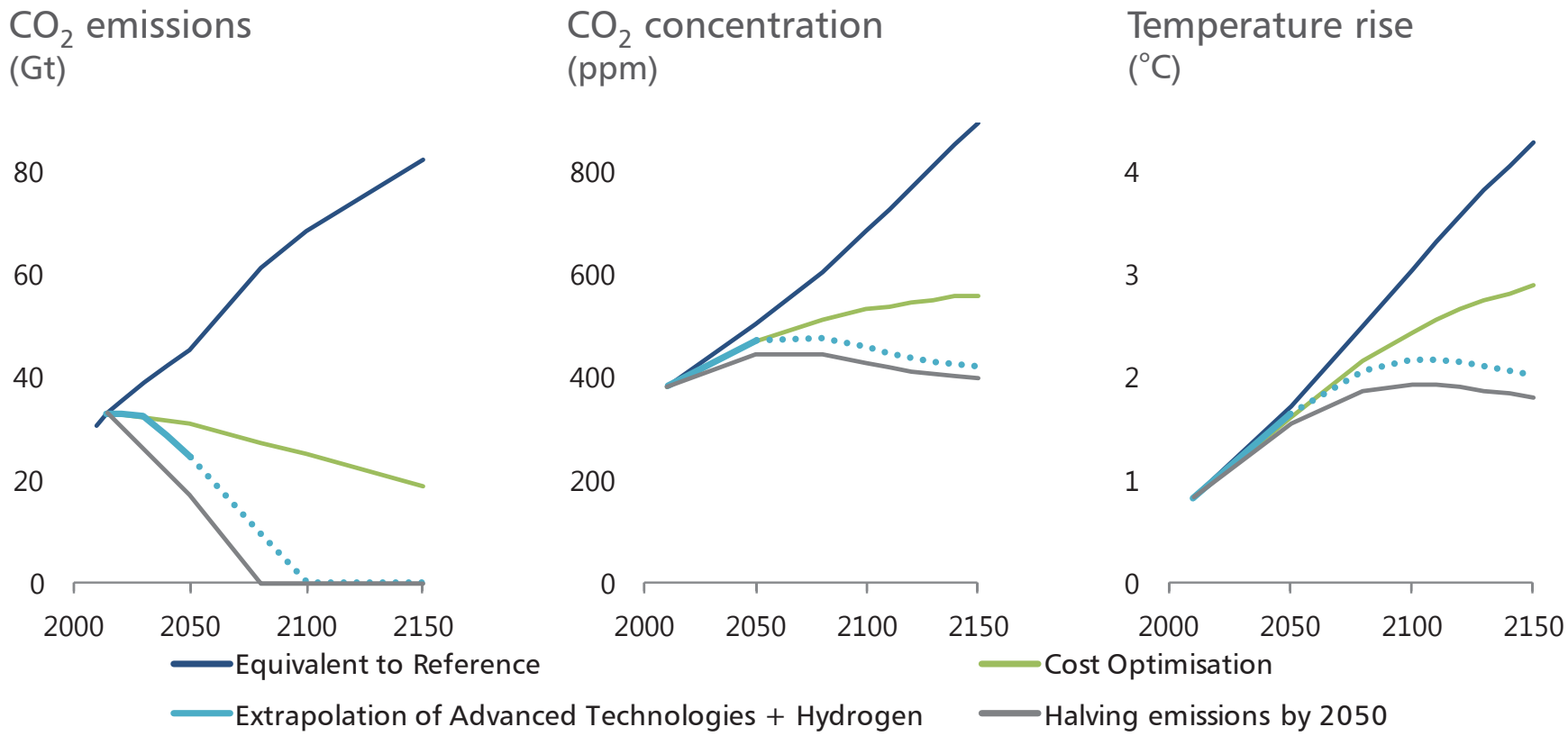




Although there are not small numbers of technical and economical hurdles to be overcome both for CCS and for hydrogen, about 7 Gt of $CO_2$ can be reduced by 2050.

CCS, however, does not contribute to secure directly energy supply. Hydrogen requires more exhaustible resources such as coal and natural gas for its production. There is no perfect technologies/energy source to solve all of the problems.

# Hydrogen may be one option of measures if its cost is reduced

## ❖ In the ultra long-term paths

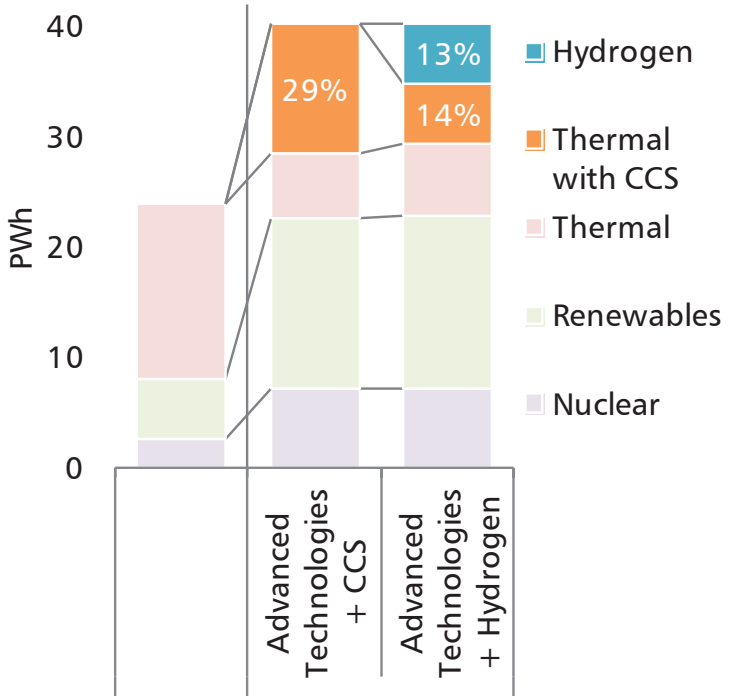



CCS and hydrogen may contribute to reduce $CO_2$ emissions by 7 Gt in 2050 combined though not few problems to be solved exist for both of them including technology and economics.

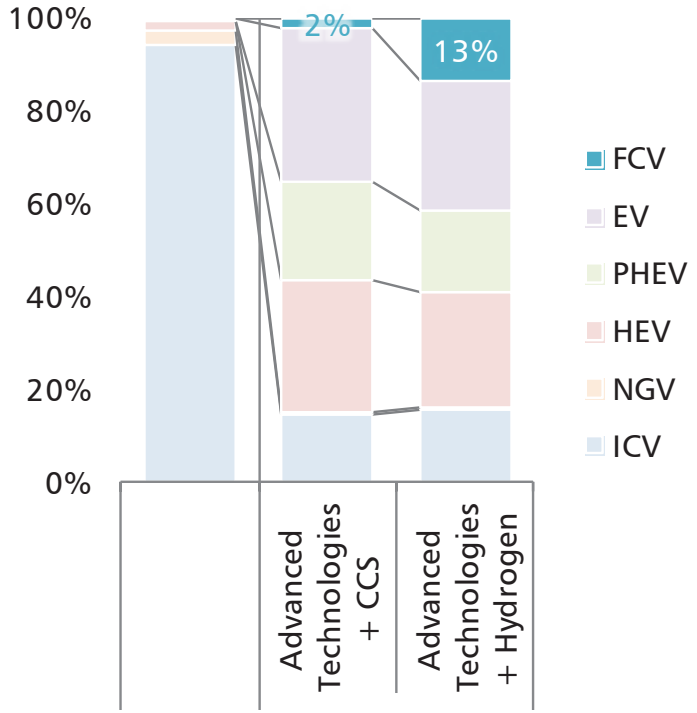
If technology innovations result in keeping the $CO_2$ emission reduction trend, temperature rise will peak at about 2.2℃ around 2100 and turn to decline. Temperature rise fall back to about 2.0℃ in 2150.

# Main use of hydrogen: power generation and automobile

## Power generation mix




## New passenger car sales

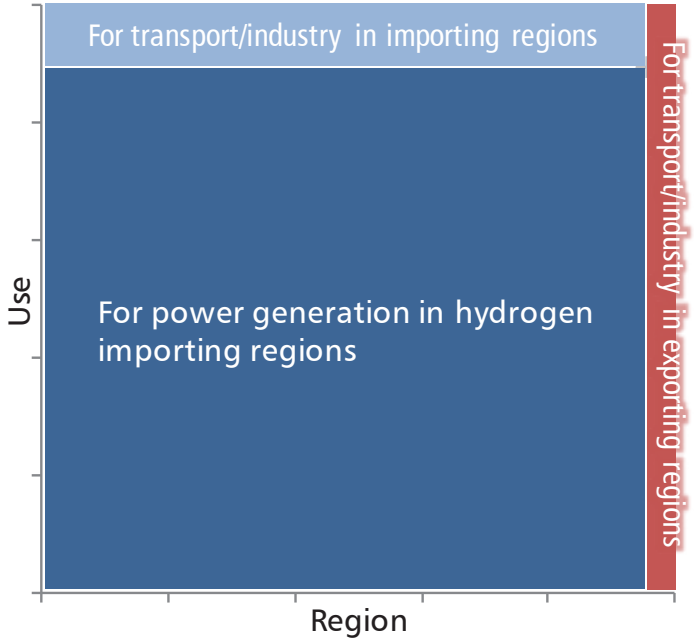



CCS and hydrogen are complementary in reducing $CO_2$. In terms of the location where CCS will be done, there are two possibilities: 1/ at energy consuming countries, 2/ at countries where hydrogen will be produced from fossil fuels. These are substitutional.

Beyond 2030 under the Advanced Technologies Case + Hydrogen, all the coal- and natural gas-fired power stations are assumed to be replaced by hydrogen-fired power stations in the regions where CCS is not feasible. Fuel cell vehicles dissemination is assumed also to accelerate.

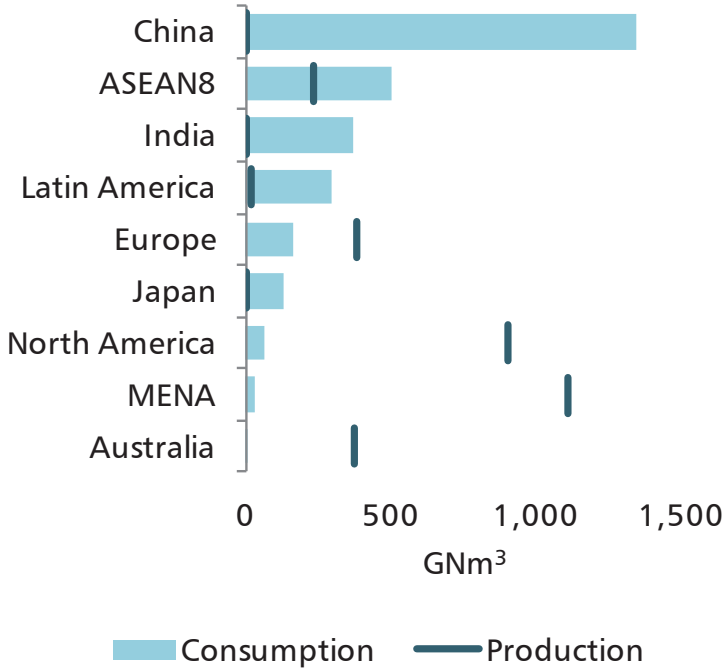
# Hydrogen: An option for countries without CCS potential

## ❖ Hydrogen consumption [Advanced Technologies + Hydrogen, 2050]




Total consumption: 3,240 GNm³

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




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

Under the Advanced Technologies Case + Hydrogen, over 3.2 TNm³ hydrogen will be produced and consumed. Of which, 90% will be used for power generation in the hydrogen importing countries where CCS is not feasible.

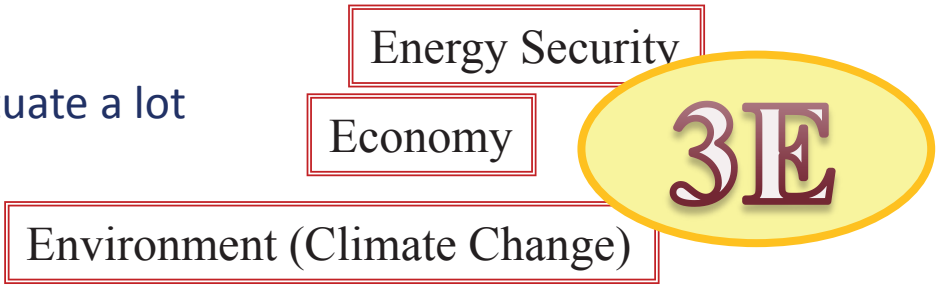
Major producers and exporters of hydrogen are MENA, North America, Australia and Europe, especially Russia. Conventional oil and natural gas exporting countries have potential to become key suppliers of hydrogen.

# Putting the Role of Nuclear into Perspective

—from Asia/World Nuclear Scenario 2016—

# 0. Nuclear in Japan's "Basic Energy Strategy"

- "Basic Energy Strategy" (11 April 2014, Cabinet Decision)
  - Energy output v.s. fuel input by far huge
  - Quasi domestic energy which can generate for several years utilizing stored fuel
  - Stable supply capability and efficiency
  - Low operation cost which does not fluctuate a lot
  - No GHGs emissions during operation




⇒"Important Base Load Power" assuming the secured "Safety"

- Big uncertainty about nuclear capacity prospects

⇒ Imperative to show "benefits" and "challenges" via multiple scenarios

# 1. Assumptions for Scenario Analysis

- Following analysis will show Nuclear Prospects up to 2040 under the assumptions shown below:

1. Reference
2. Advanced Technologies Scenario (currently foreseeable max capacity)
3. The world without dependence on Nuclear (Low Nuclear)
4. Nuclear to be widely used as base load power source (High Nuclear)

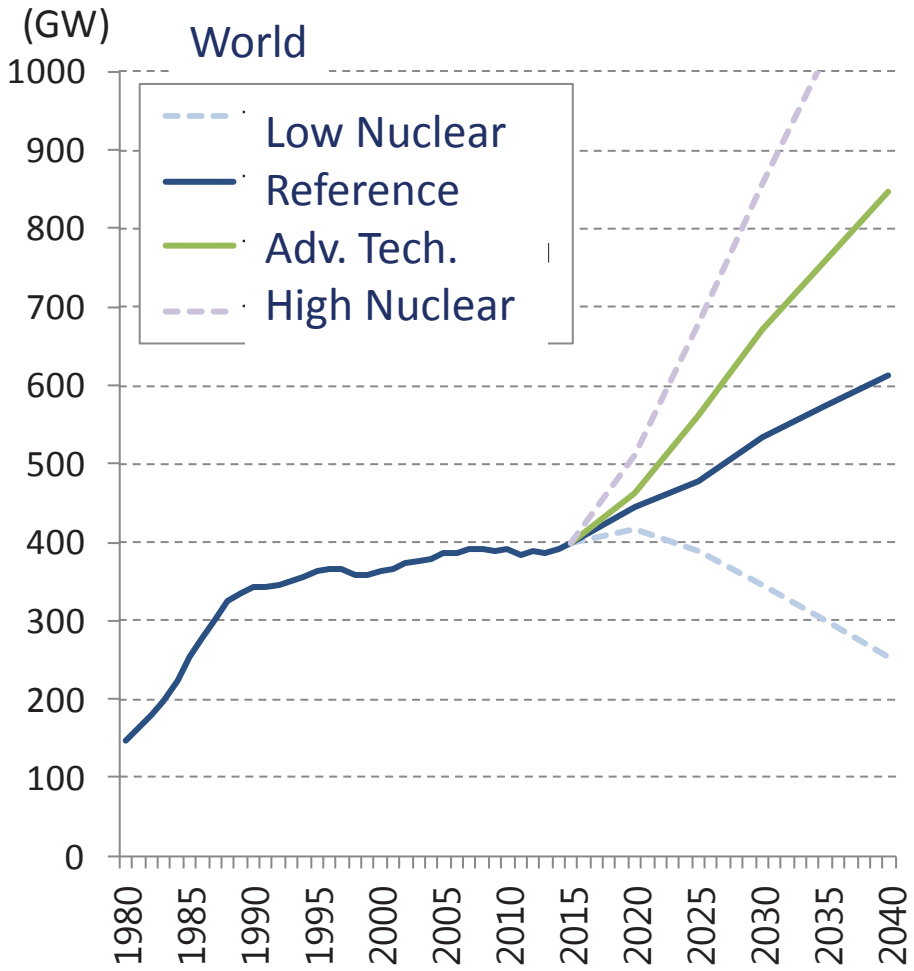
## Nuclear Capacity Assumptions

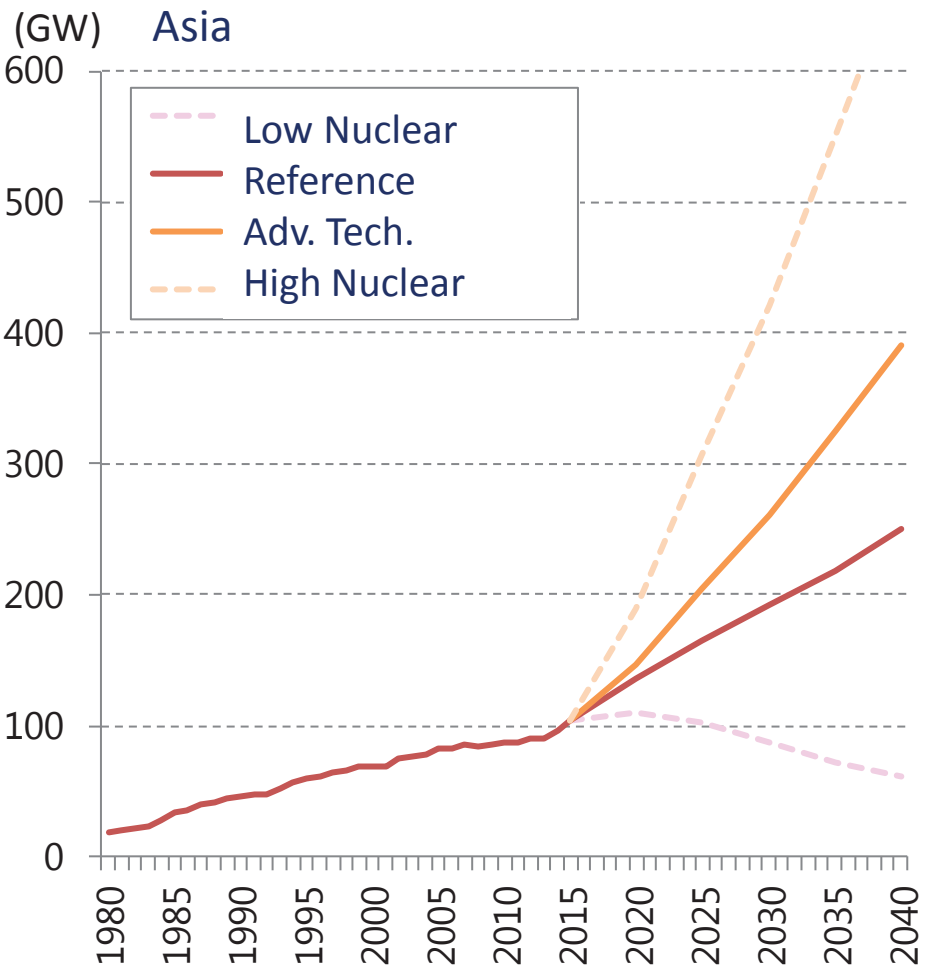
◎Reference and Advanced Technologies Scenarios: Same as in Outlook 2016 main scenarios.
◎Low Nuclear: Those reactors under planning on 1 January 2016 will not be constructed. Those which are under construction with starting date will start operation that year. Those under construction without starting date will not operate.
◎Low Nuclear Scenario: Nuclear reactors will operate for 60 years in North America and OECD Europe, 40 years in Latin America, Asia, Middle East and Africa. For Germany, Switzerland (50 years), Belgium (40 years with Tihange-1 to operate until 2025) and UK, with reference to the individual reactors' closure schedule.
◎ High Nuclear Scenario: capacity of nuclear for Middle East, Asia (except Japan and Chinese Taipei), and Africa will be doubled from the Adv. Tech. level beyond 2020 .

Based on the above assumptions, trends of capacities, CO2 emissions, self-sufficiency rates and generation costs will be shown.

# 2. Result (1) Trend of Capacities

- High Case Nuclear capacity will increase by 2040: World : tripled, Asia: septupled
- Low Case: Nuclear capacity will diminish by 50% both in the World and in Asia

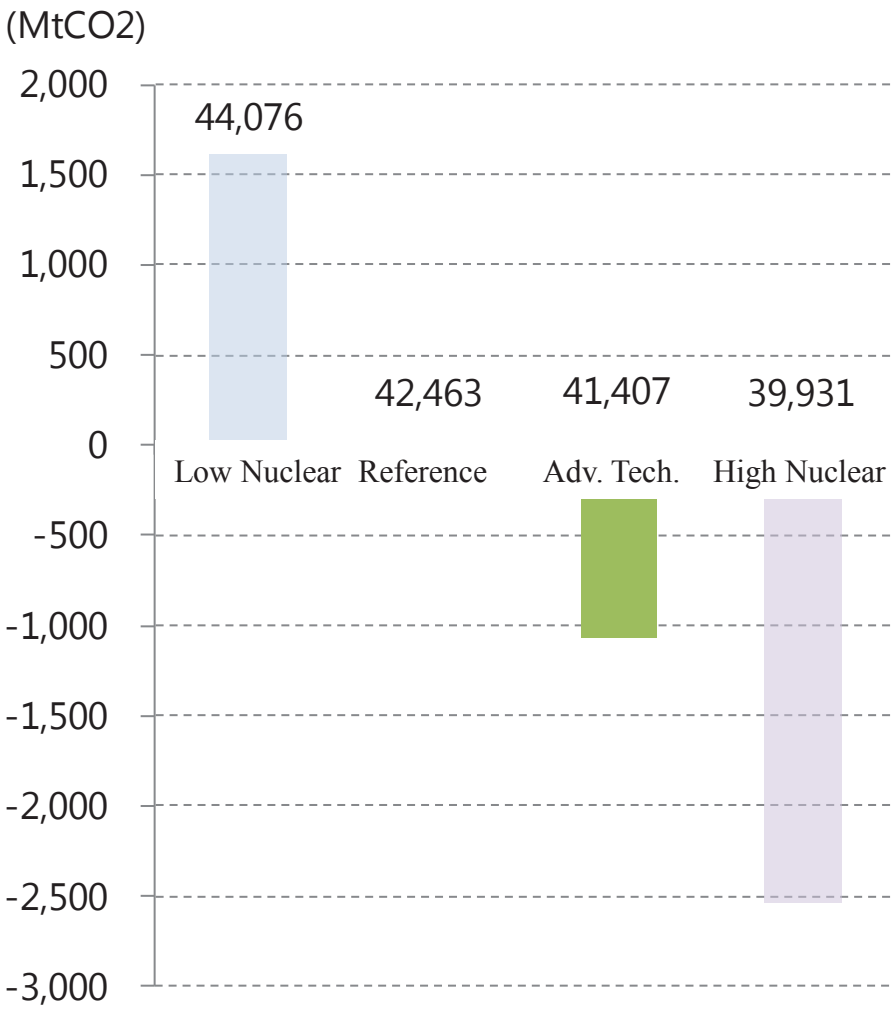


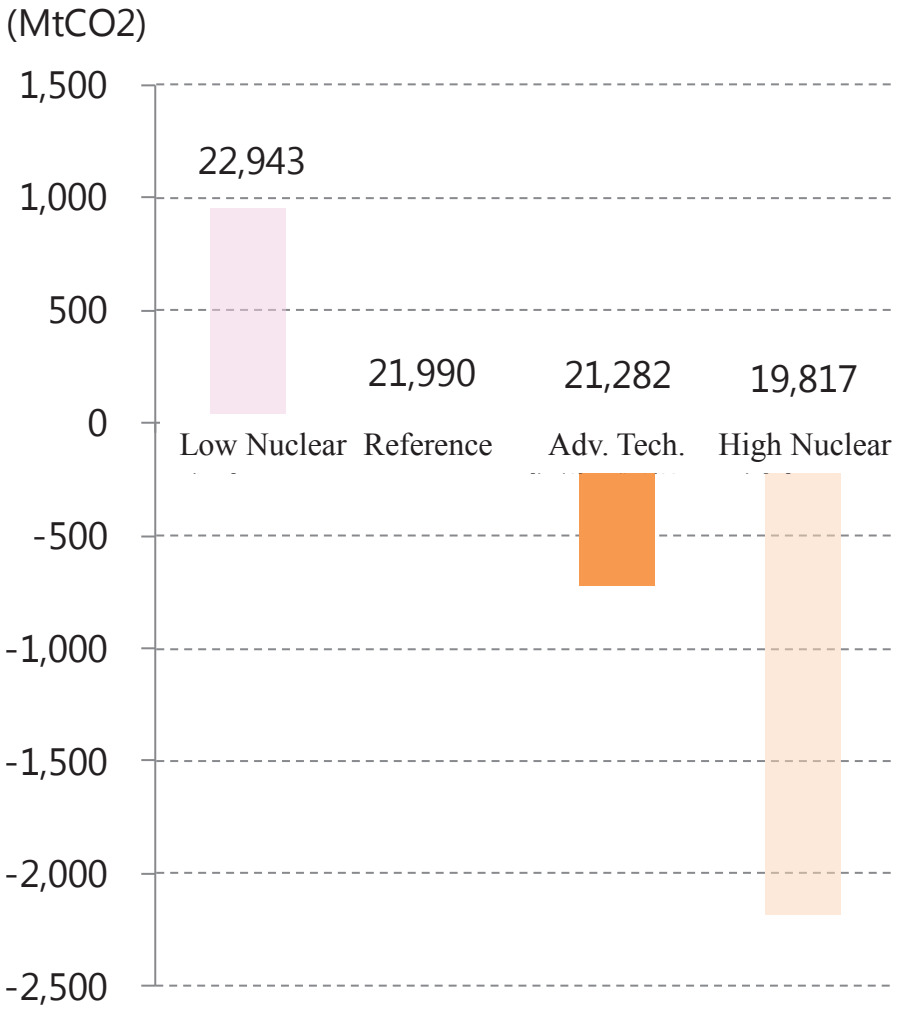




Source: IEEJ, Asia/ World Energy Outlook 2016

# 2. Result (2) Trends of $CO_2$ Emissions

- High Case:
  Asian $CO_2$ emissions deminishe by 10% (2 billion t-$CO_2$) compared to Reference Case



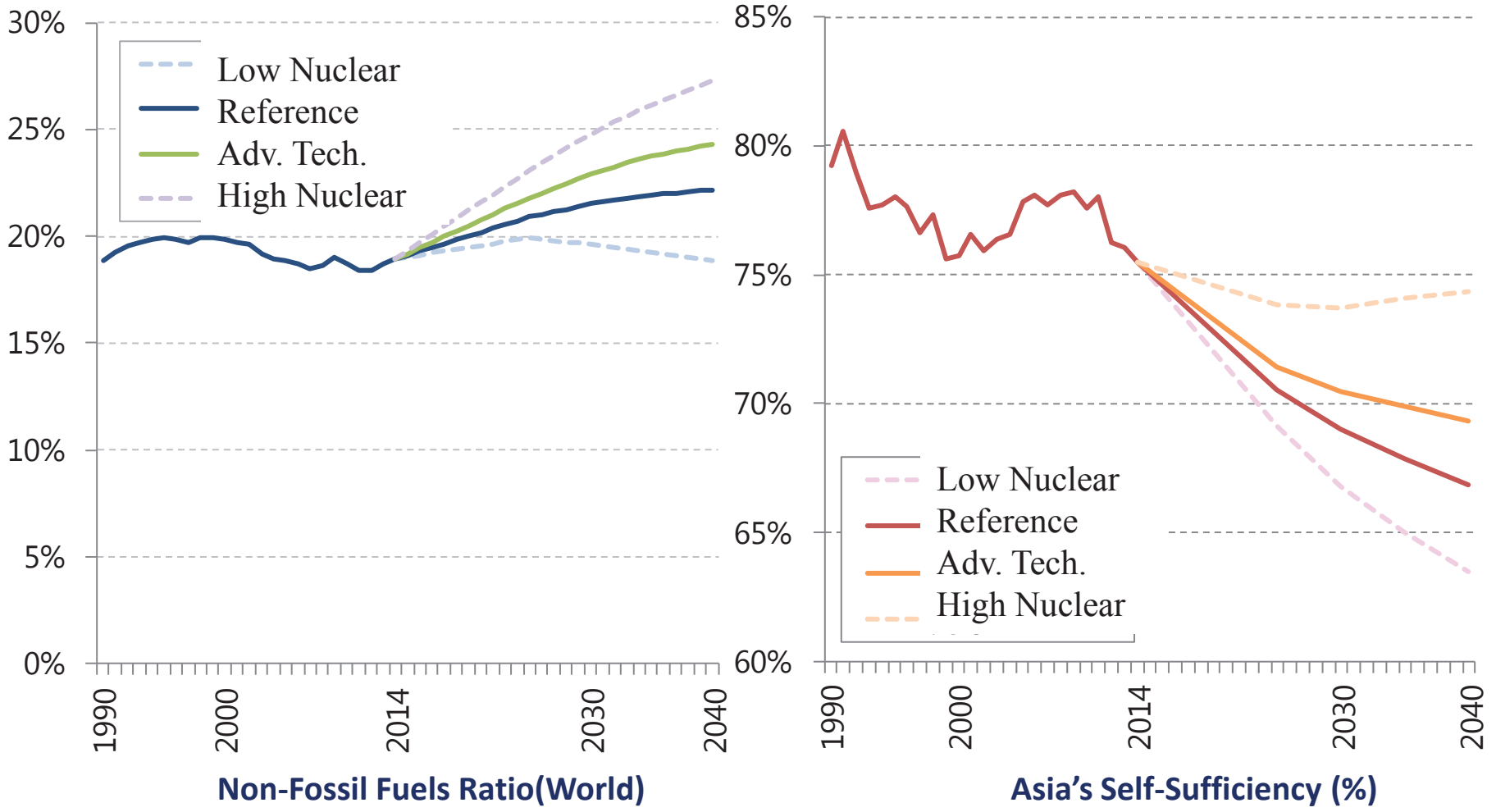




Source: IEEJ, Asia/ World Energy Outlook 2016

# 2.Result (3) Non-Fossil Fuels Share (World) and Asia's Self-Sufficiency (%)

- High Case: Non-fossil fuel ratio is significantly higher
- Low Case: Self-sufficiency in Asia goes down to 60%

## Contribution to Energy Security

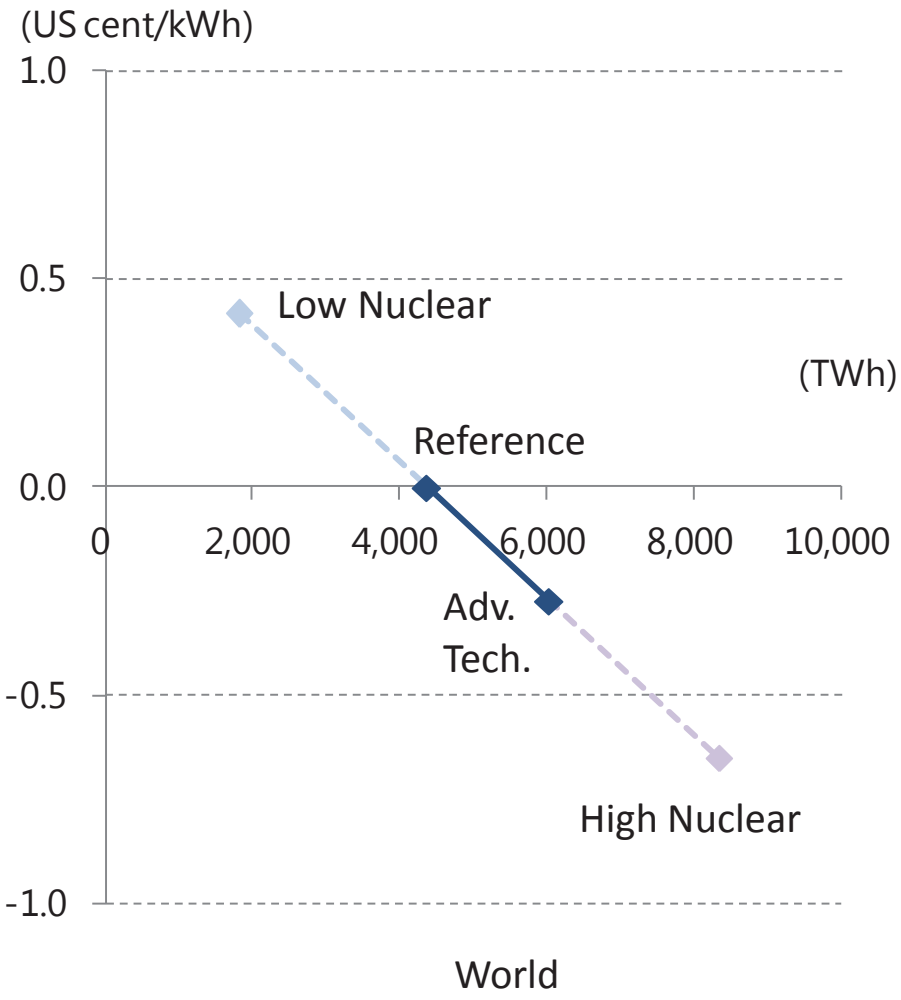


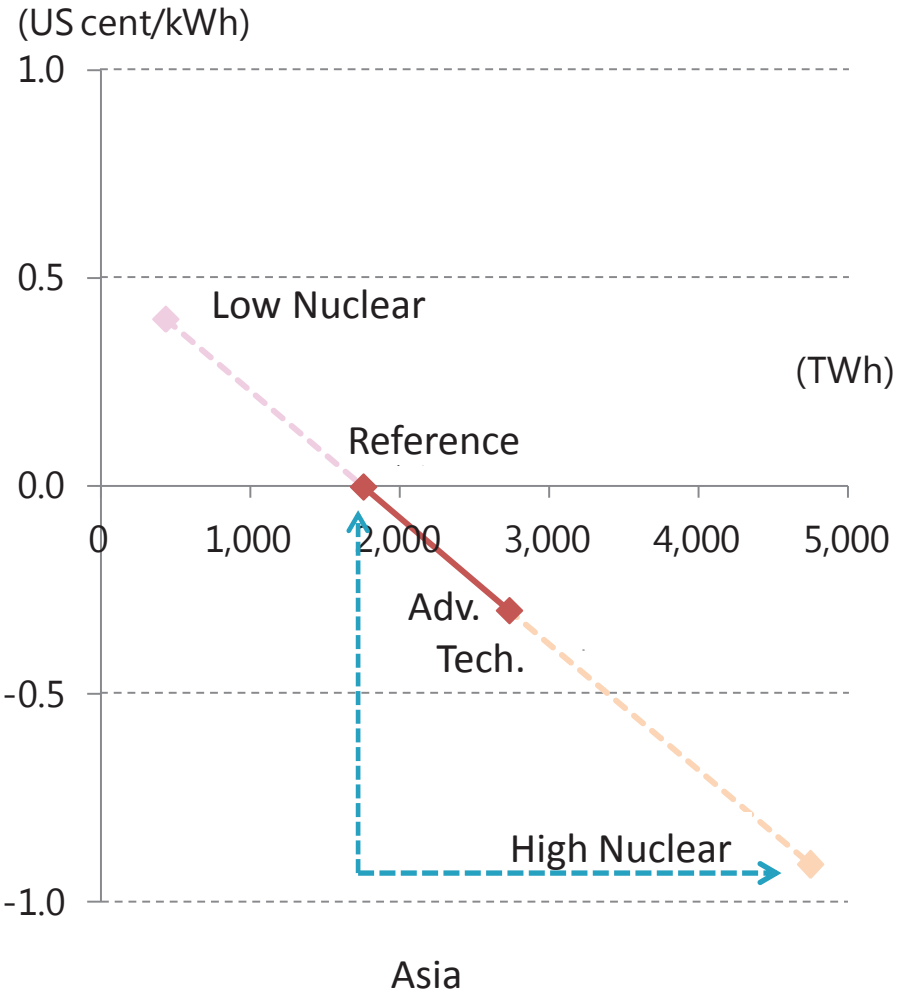

Source: IEEJ, Asia/ World Energy Outlook 2016

# 2. Result (4) Generation Cost

- High Case: Generation cost is lower than Reference Case by 0.9 ¢/kWh

**Nuclear largely contributes to reduction of power costs**




Source: IEEJ, Asia/ World Energy Outlook 2016

# 3. Implications from the Scenario Analysis

- There are challenges if each scenario happens under certain conditions

| | Necessary Conditions | Challenges |
|---|---|---|
| Adv. Tech. | For both liberalized and regulated market:<br>•Cost competitiveness of nuclear<br>•Confidence and development & dissemination support for low-carbon technologies<br>•Effective framework to prevent global warming | •Discrepancy in Safety Standards（Best practices v.s. minimum）<br>•Earlier handling of nuclear waste treatment issues<br>•Fuel supply disruption risks<br>•Nuclear proliferation, security threats |
| High | In addition to the above:<br>•Social infrastructures (power grid, etc.)<br>•Stable fuel supply network<br>•Nuclear and infrastructure technology transfer to emerging economies | In addition to the above:<br>•Voluntary safety improvement efforts to overwhelm Regulatory Authority's requirements by setting Best Practice as industry's standard. |
| Low | For both liberalized and regulated market:<br>•Weaker cost competitiveness of nuclear<br>•Less confidence in nuclear and no support for development and deployment<br>•No inclusion of nuclear into global warming countermeasures | With diminishing basis for nuclear industries, followings will face bigger challenges:<br>•Smooth reactor decommissioning procedures and nuclear waste treatment<br>•Adequate safety for nuclear facilities<br>•International cooperation in emergency |

**Safety is indispensable for nuclear energy use**

Source: IEEJ, Asia/ World Energy Outlook 2016

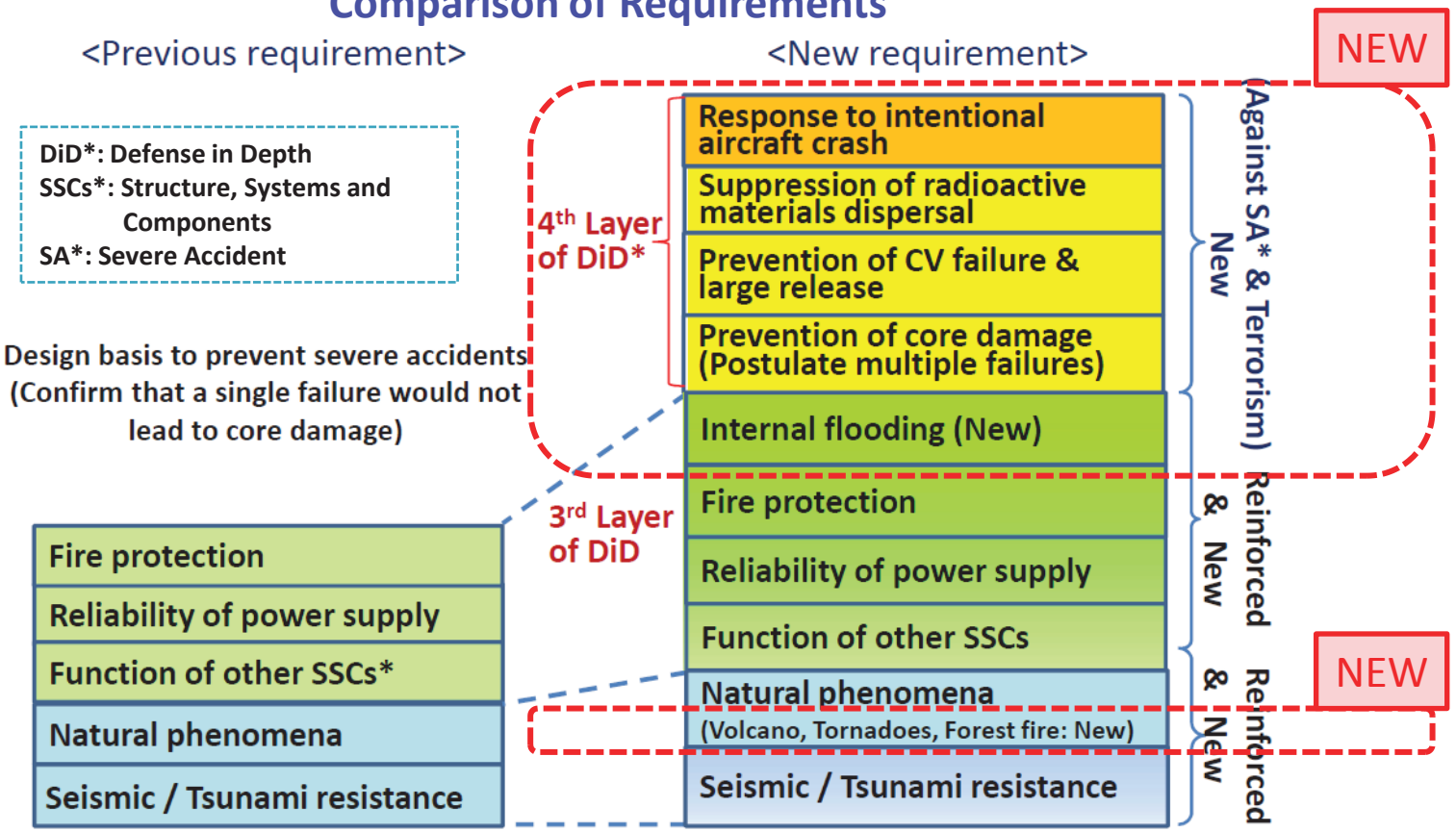
# 4. Nuclear Safety Measures

## (1) Japan's New Safety Standard: Strengthened Defense in Depth

- Strengthened requirements for measures to prevent core damage and CV failure, as well as to suppress radioactive materials dispersal.
  → Robustness and mitigation measures have been improved in comparison to pre-2011.
- Inclusion of measures to address the radioactive materials dispersal into the requirement despite new and strengthened requirements.

**No Need for Counter Measures with no chance for core damage (Safety myth) : NOT acceptable ANY MORE**

### Comparison of Requirements




Source：
NRA, Japan HP

# 4. Nuclear Safety Measures

## (2) US , etc: Voluntary Measures to Improve Safety and Implications

- Since 1980s, US, Switzerland, etc. started voluntary safety improvement efforts for the industries' own sake. The efforts are continuing to date.

1. Establish common understanding among related parties on the importance of nuclear
2. Understand the "risk" itself
3. Mutual trust and confidence among the parties
4. Good performance of power stations were required for the utilities which faced severe competition under the liberalized electricity markets.
5. To support understand the merit of regulatory authorities' reasonable regulations (merits > costs ) and their transparency, to strengthen monitoring function and to foster an environment where regulatory authorities can have sound dialogue with industries.

Implications for Japan and Asia

**• It is necessary to develop common understanding among parties on importance of nuclear energy through discussion on attitude towards risk.**
**• Industry to establish standardization of "Best Practice" and encourage discussion with regulatory authority based on mutual respect.**
**• Required conditions are independence of regulatory authority and transparency and reasonability of regulations.**

# 4. Nuclear Safety Measures

## (3) Regulatory Authority : Independence and Transparency

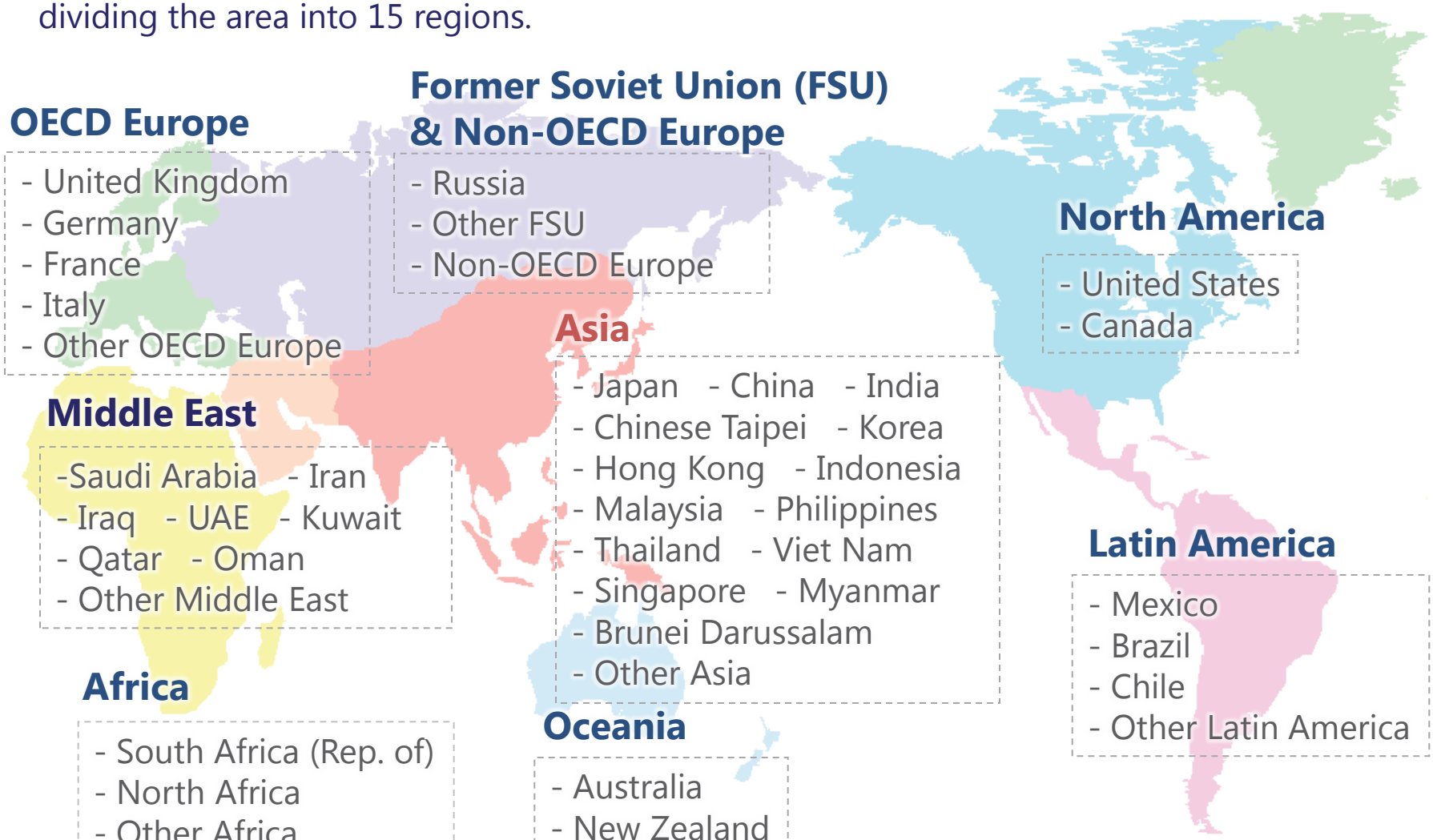
| Europe, US | Asia |
|---|---|
| • Major regulatory authorities in Europe and US have been maintained high independency and comfortable level of human resource even prior to 2011.<br><br>• Continuous improvement of organizations and regulatory activities based on the IAEA's Integrated Regulatory Review Service (IRRS) results, contributes to securing safety. | • Japan and Korea revisited regulation system post-2011 and secured legal independence of regulatory authorities.<br><br>• China, India, etc. have received IRRS recommendation to ensure regulatory authority independence.<br><br>• Continuous improvement of independence and transparency required. |


IRRS Mission Report (2011, Korea), IAEA

# Reference materials

# Geological coverage

- The world is geographically divided into 42 regions.
- Especially the Asian energy supply/demand structure is considered in detail, dividing the area into 15 regions.



## OECD Europe
- United Kingdom
- Germany
- France
- Italy
- Other OECD Europe

## Former Soviet Union (FSU) & Non-OECD Europe
- Russia
- Other FSU
- Non-OECD Europe

## North America
- United States
- Canada

## Asia
- Japan - China - India
- Chinese Taipei - Korea
- Hong Kong - Indonesia
- Malaysia - Philippines
- Thailand - Viet Nam
- Singapore - Myanmar
- Brunei Darussalam
- Other Asia

## Middle East
- Saudi Arabia - Iran
- Iraq - UAE - Kuwait
- Qatar - Oman
- Other Middle East

## Latin America
- Mexico
- Brazil
- Chile
- Other Latin America

## Africa
- South Africa (Rep. of)
- North Africa
- Other Africa

## Oceania
- Australia
- New Zealand

# Modeling framework

## Major assumptions

GDP, population, energy prices, exchange rates, international trade, etc.

## Macroeconomic model

Calculate GDP-related indices, price indices, activity indices including material production, etc. consistently.

## Technology assessment model

Use a bottom-up approach to calculate future efficiencies of appliances, vehicles, etc.

## Optimal power generation planning model

Calculate the cost-optimal power generation mix to meet the projected future electricity demand.

## Energy supply-demand model

Econometric model to forecast future energy supply and demand by regression analysis of historical trends based on the energy balance tables data of the International Energy Agency (IEA).
This model calculates energy demand, supply and transformation as well as related indices including $CO_2$ emissions, $CO_2$ intensities and energy self sufficiency ratios.

Experts' opinions

## World trade model

Use the linear programming (LP) method to calculate the future international trade flows of crude oil, petroleum products, etc.

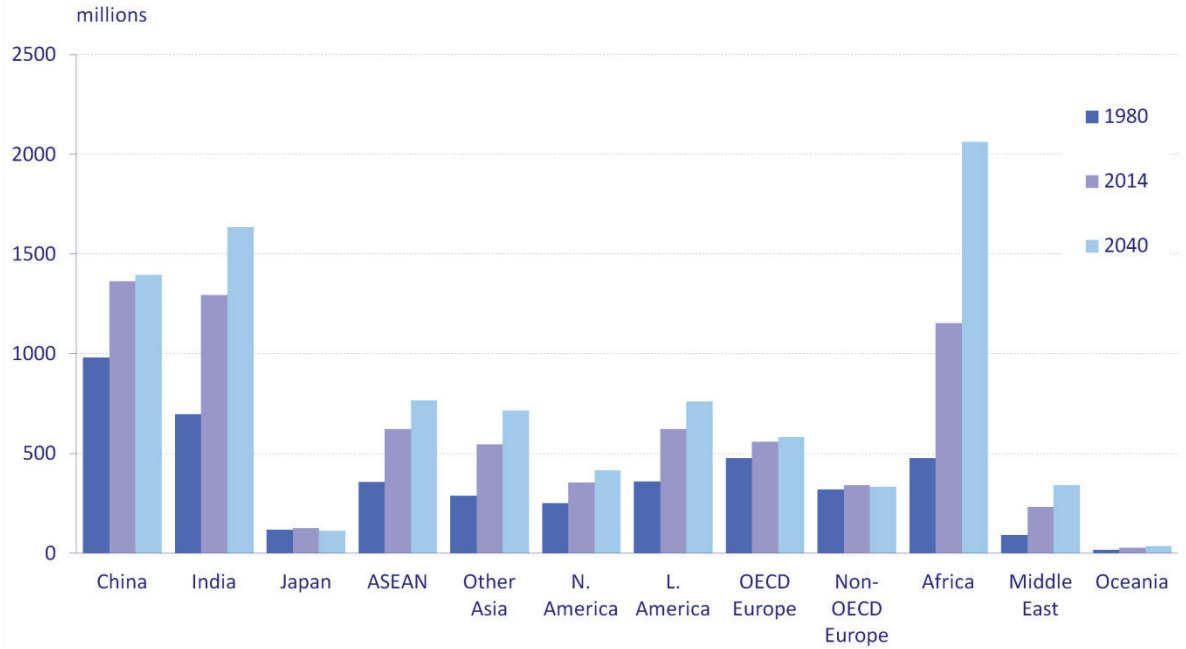
## Computable general equilibrium model

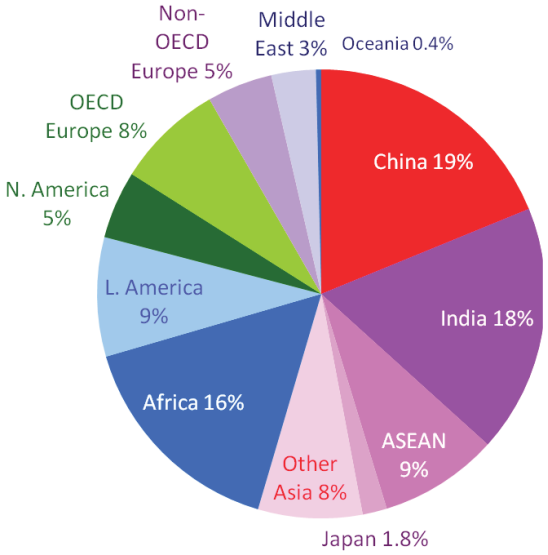
Estimate the economic impacts induced by the changes in energy supply and demand, based on input-output data.

## Climate change model

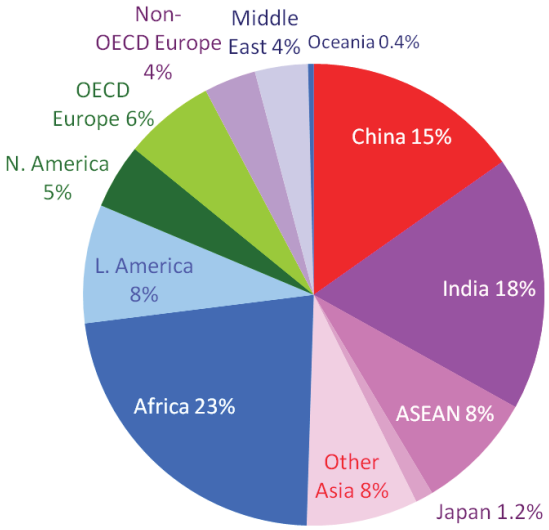
Calculate future GHG concentration in the atmosphere, temperature rise, damage caused by climate change, etc.

# Major assumptions: Population



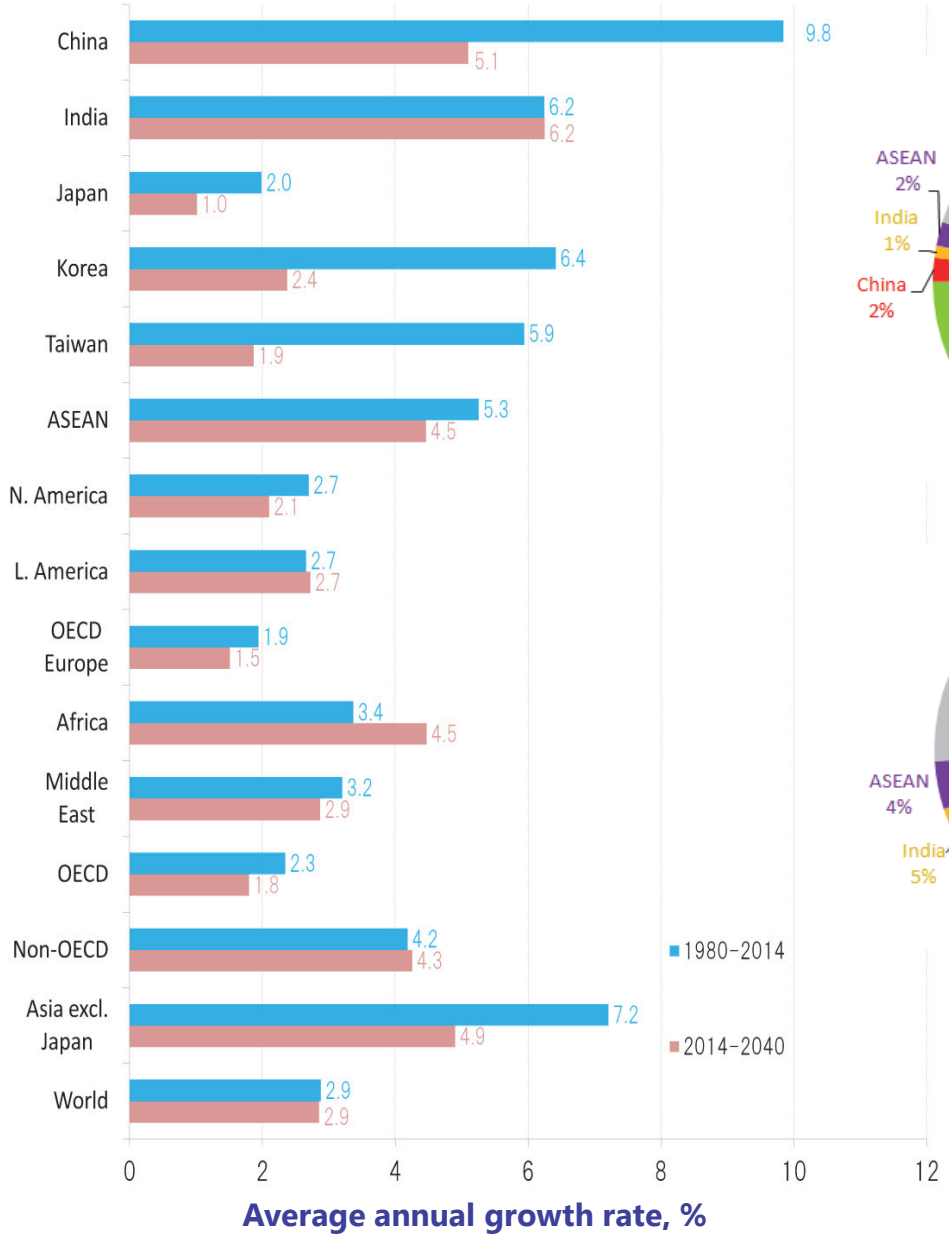

**2014: 7.2 billion**



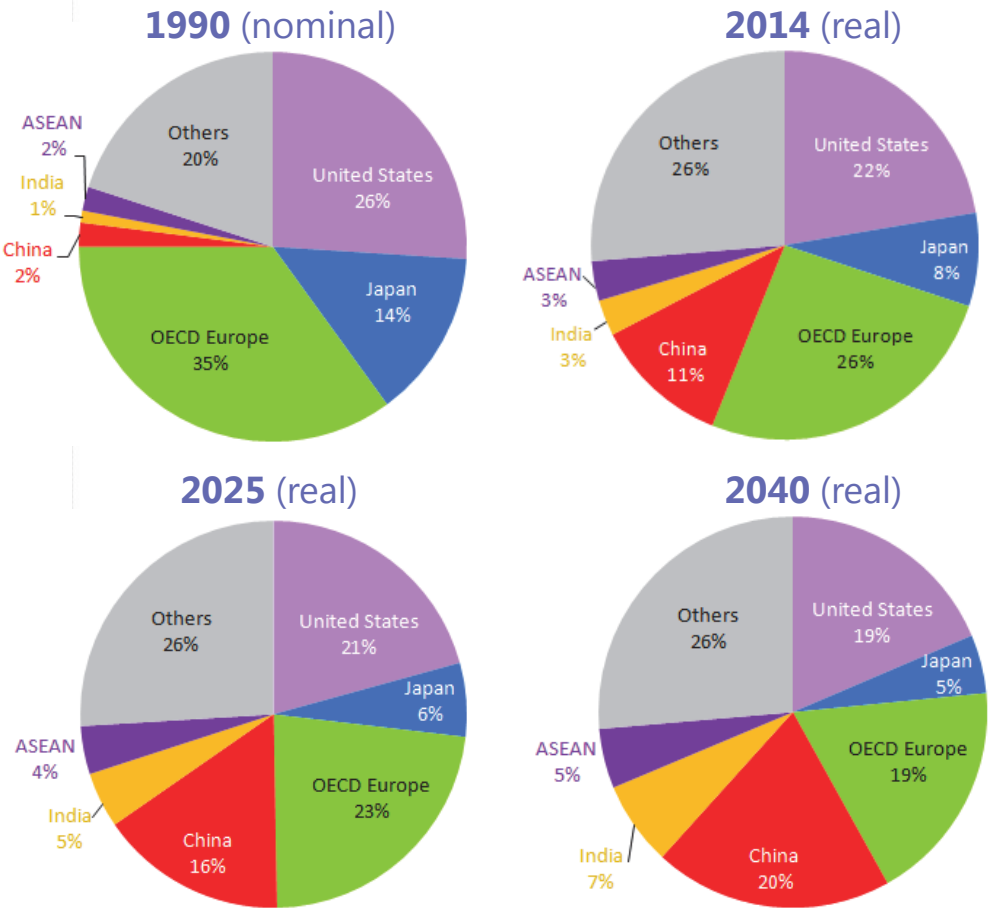

**2040: 9.2 billion**

- Population is expected to increase mainly in developing (non-OECD) countries.
- China's population gradually ages and peaks out around 2030. Meanwhile, population rapidly increases in India and Africa, thanks to medical technology and food nutrition improvement.
- India replaces China as the most populated country in Asia (and the world) around 2025; population should reach 1.6 billion in 2040.

# Major assumptions: Economic growth




Note: Real values are in $2010




- While the world economy is facing a variety of challenges, it is assumed to achieve strong growth over the medium to long term.
- In the Reference Scenario, China's real GDP in 2040 is ahead of the United States and is 4.1 times that of Japan. India also overtakes Japan in the late 2030s; it is 1.4 times that of Japan in 2040.

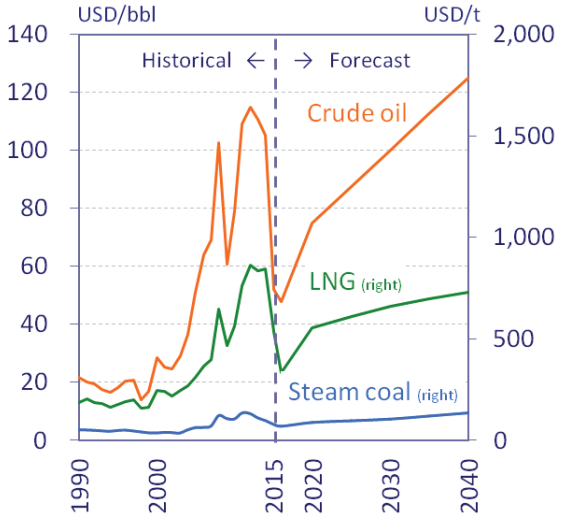
# Major assumptions: Primary energy prices

| | | | 2015 | 2020 | 2030 | 2040 |
|---|---|---|---|---|---|---|
| Crude oil | USD/bbl | Real | 52 | 75 | 100 | 125 |
| | | Nominal | 52 | 83 | 135 | 205 |
| Natural gas | Japan | Real | 536 | 554 | 663 | 730 |
| | USD/t | Nominal | 536 | 611 | 892 | 1,197 |
| | Japan | Real | 10.4 | 10.7 | 12.8 | 14.1 |
| | USD/MBtu | Nominal | 10.4 | 11.8 | 17.2 | 23.1 |
| | Europe | Real | 6.5 | 8.5 | 9.8 | 11.7 |
| | USD/MBtu | Nominal | 6.5 | 9.4 | 13.2 | 19.2 |
| | USA | Real | 2.6 | 4.5 | 5.6 | 6.3 |
| | USD/MBtu | Nominal | 2.6 | 5.0 | 7.5 | 10.3 |
| Steam coal | USD/t | Real | 80 | 89 | 106 | 132 |
| | | Nominal | 80 | 98 | 142 | 217 |

- Prices are for calendar years. Real prices are in $2015.
- Japan's energy prices are on a CIF import basis.

- In the Reference Scenario, crude oil prices rise gradually again to $100/bbl by 2030 due to robust demand growth in non-OECD countries, emerging geopolitical risks and financial factors, oil supply constraints reflecting rising depletion rates for oil fields, etc. LNG prices will rise accordingly, with the existing price disparity shrinking due to expanding interregional trades.

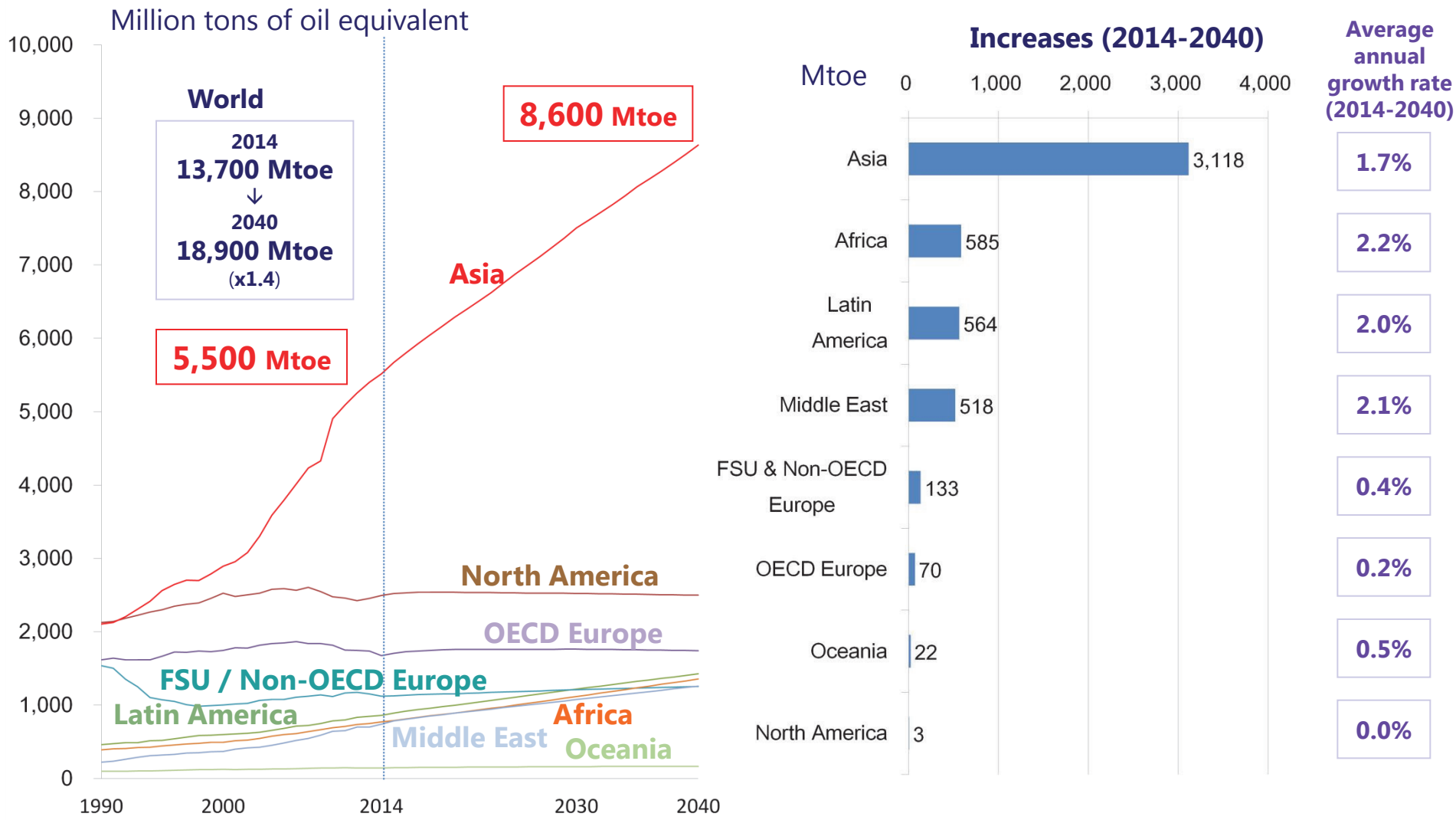
**CIF import prices for Japan**



# Energy outlook in Asia and the world 2014-2040

# Primary energy consumption by region

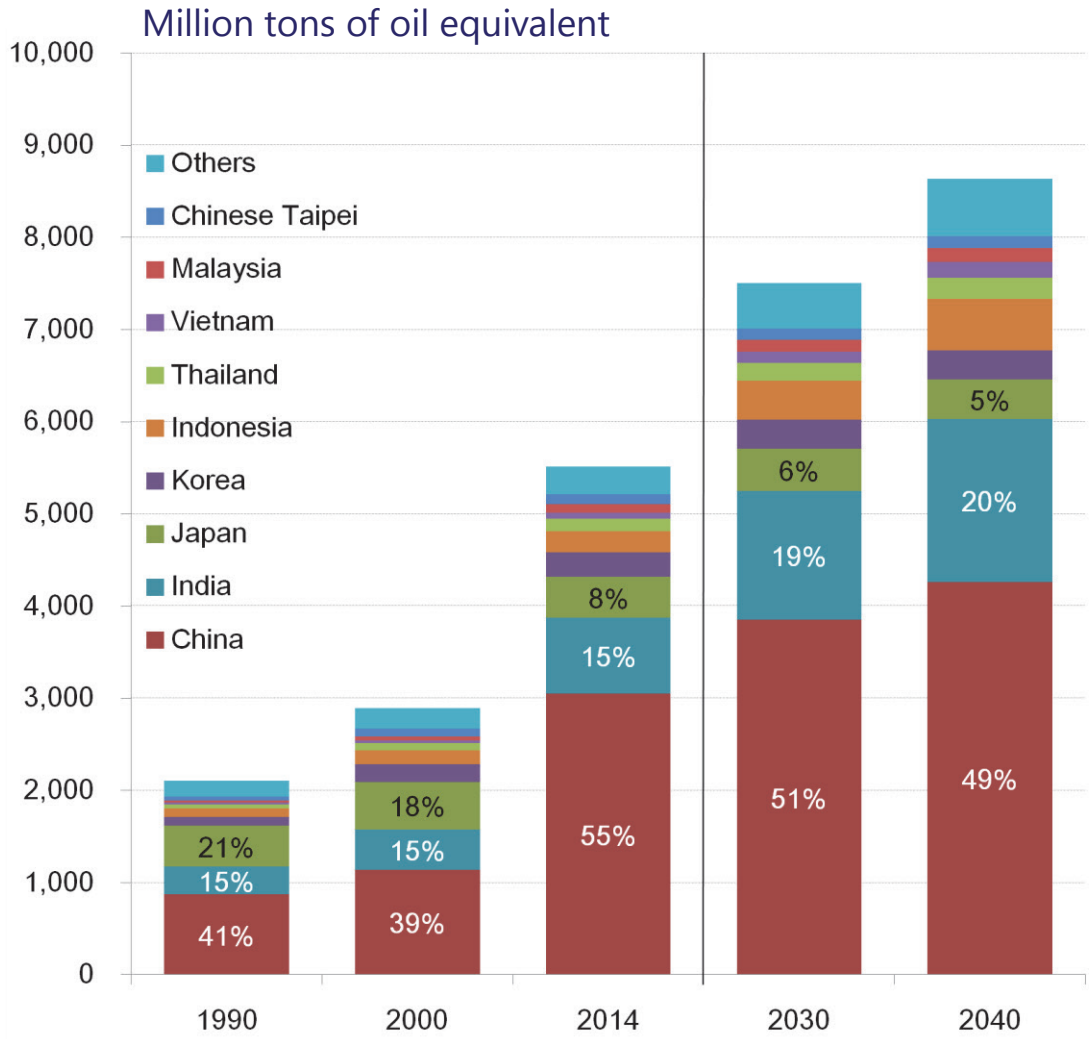
Reference Scenario




- Under the steady economic growth assumption, Asian energy consumption in 2040 increases 1.4-fold from the present level (from 5.5 Gtoe in 2014 to 8.6 Gtoe in 2040).
- Non-OECD countries account for about 90% of global energy consumption increase between 2014 and 2040.

# Primary energy consumption (Asia)

Reference Scenario




**Asia**

**2014**
**5,500 Mtoe**
↓
**2040**
**8,600 Mtoe**
**(x1.6)**

**China** **India**

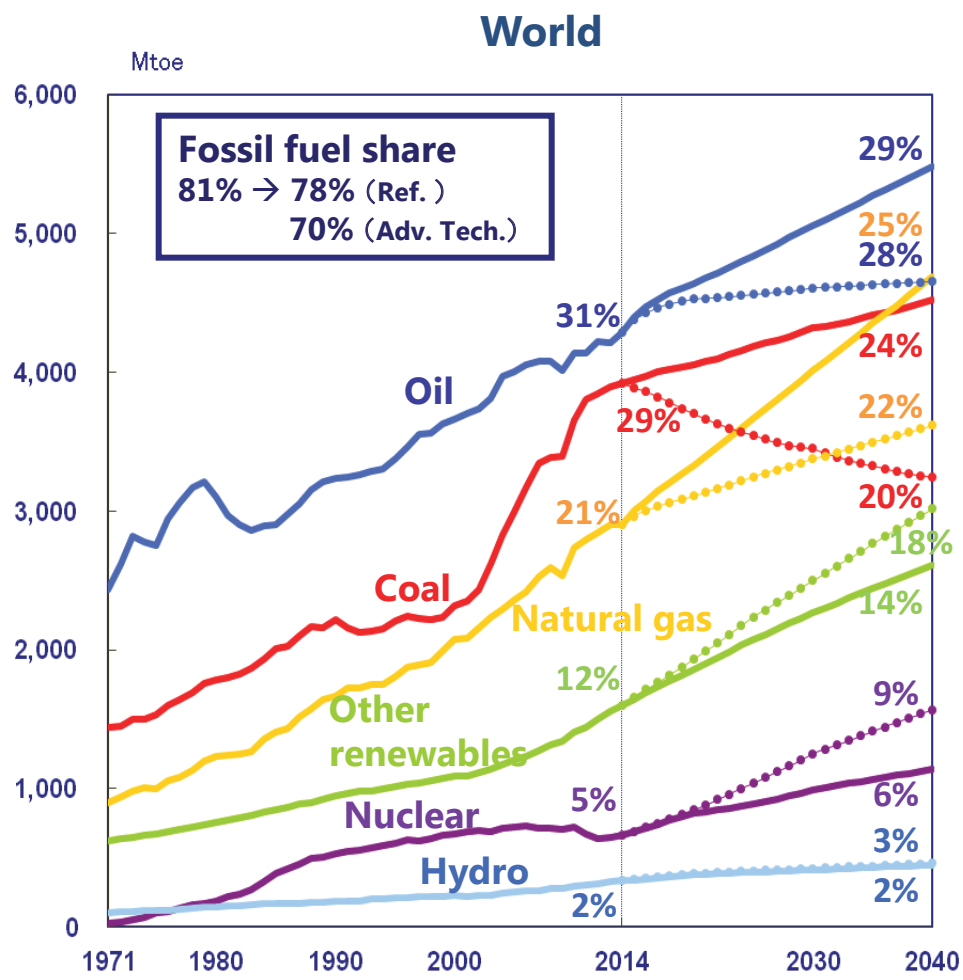
**2014**
**3,100 Mtoe** **820 Mtoe**
↓
**2040**
**4,300 Mtoe** **1,800 Mtoe**
**(x1.4)** **(x2.1)**

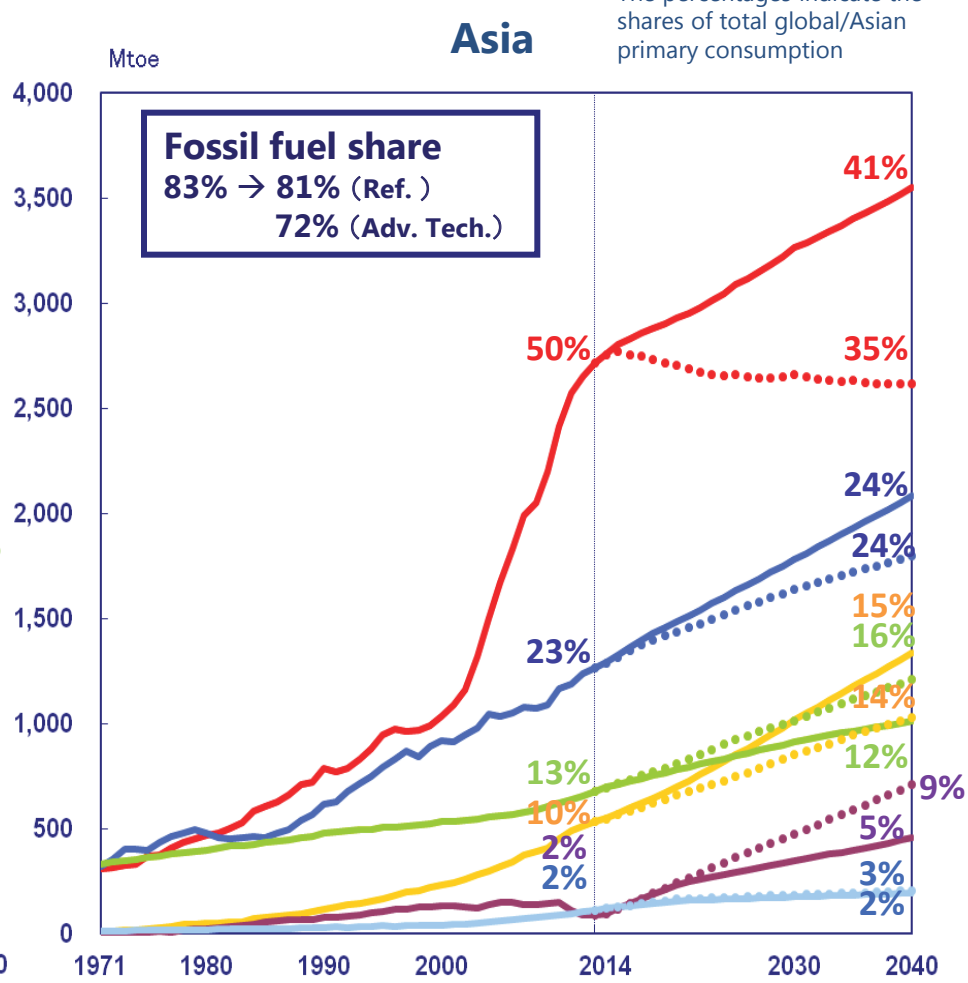
- Energy demand in China and India increase rapidly in line with economic growth. Their share of Asian energy demand will expand to 70% in 2040.
- Japan's energy consumption declines as a result of progress in energy efficiency combined with maturity of its economy and decrease of its population. Its share of Asian energy consumption will shrink from 8% to 5%.

# Primary energy consumption by source

Reference Scenario (solid)
Advanced Technologies Scenario (dotted)

The percentages indicate the shares of total global/Asian primary consumption




- In both the Reference and Advanced Technologies Scenarios, oil continues to be the largest share of primary energy consumption and remains a major energy source up to 2040.
- In Asia, coal remains the largest share among energy sources. In the Advanced Technologies Scenario, coal consumption declines substantially while retaining the largest share among energy sources.
- The share of fossil fuel in Asia will decline until 2040 while maintaining 70% of its share in the Advanced Technologies Scenario.

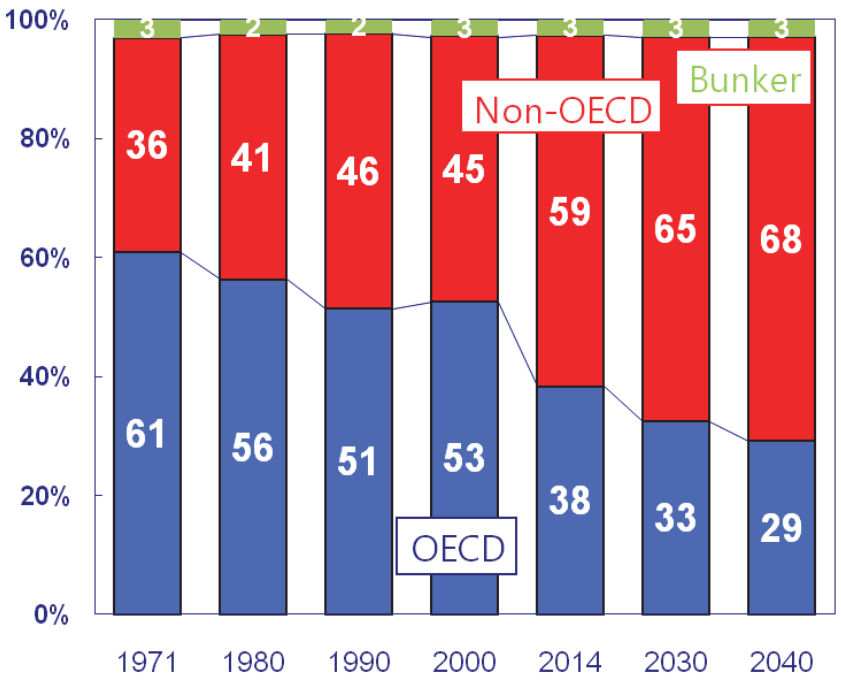
# Primary energy consumption (regional share)

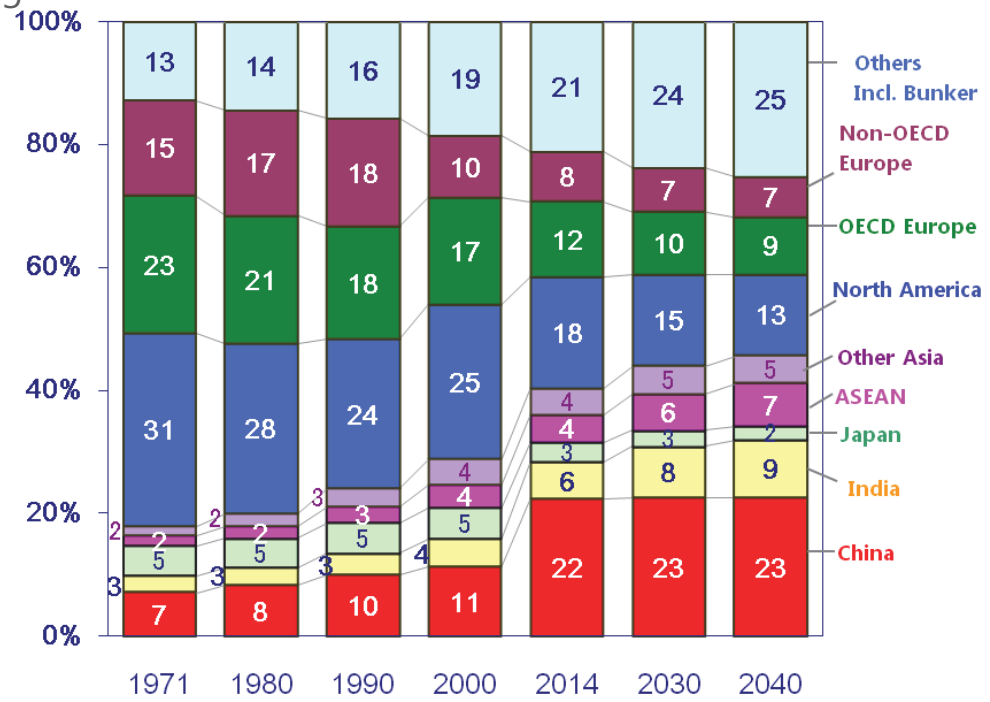
Reference Scenario

## Shares in increases (2014-2040)

| China | India | Japan | ASEAN | Other Asia | North America | OECD Europe |
|---|---|---|---|---|---|---|
| 24% | 19% | 0% | 14% | 5% | 0% | 1% |

Asia accounts for more than 60% of total growth.

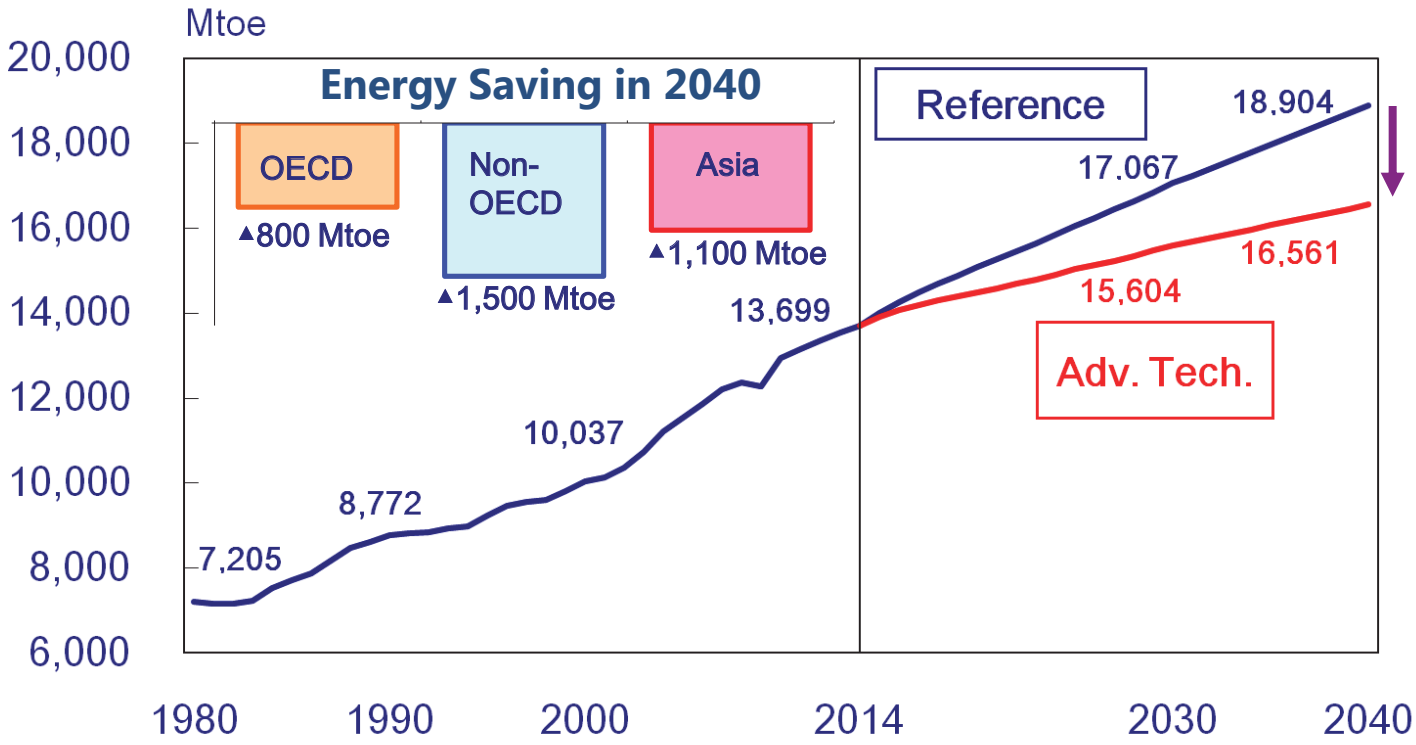



- Reflecting a steady economic growth, energy consumption in Non-OECD exceeds that of OECD.
- Energy consumption in Asia exhibits a rapid growth, with the share of Asia in the world energy consumption expanding from 40% in 2014 to 46% by 2040.
- By 2040, the share of China in the world energy consumption will increase to 23%, and India to 9% (for a total of 33%). The share of Japan will decline from 3% in 2014 to 2% of the world energy consumption in 2040.

# Primary energy consumption (world)

Reference Scenario
Advanced Technologies Scenario




**-2,300** Mtoe
(-**12**%)

**OECD**
**-800** Mtoe
(**35**% of total saving)

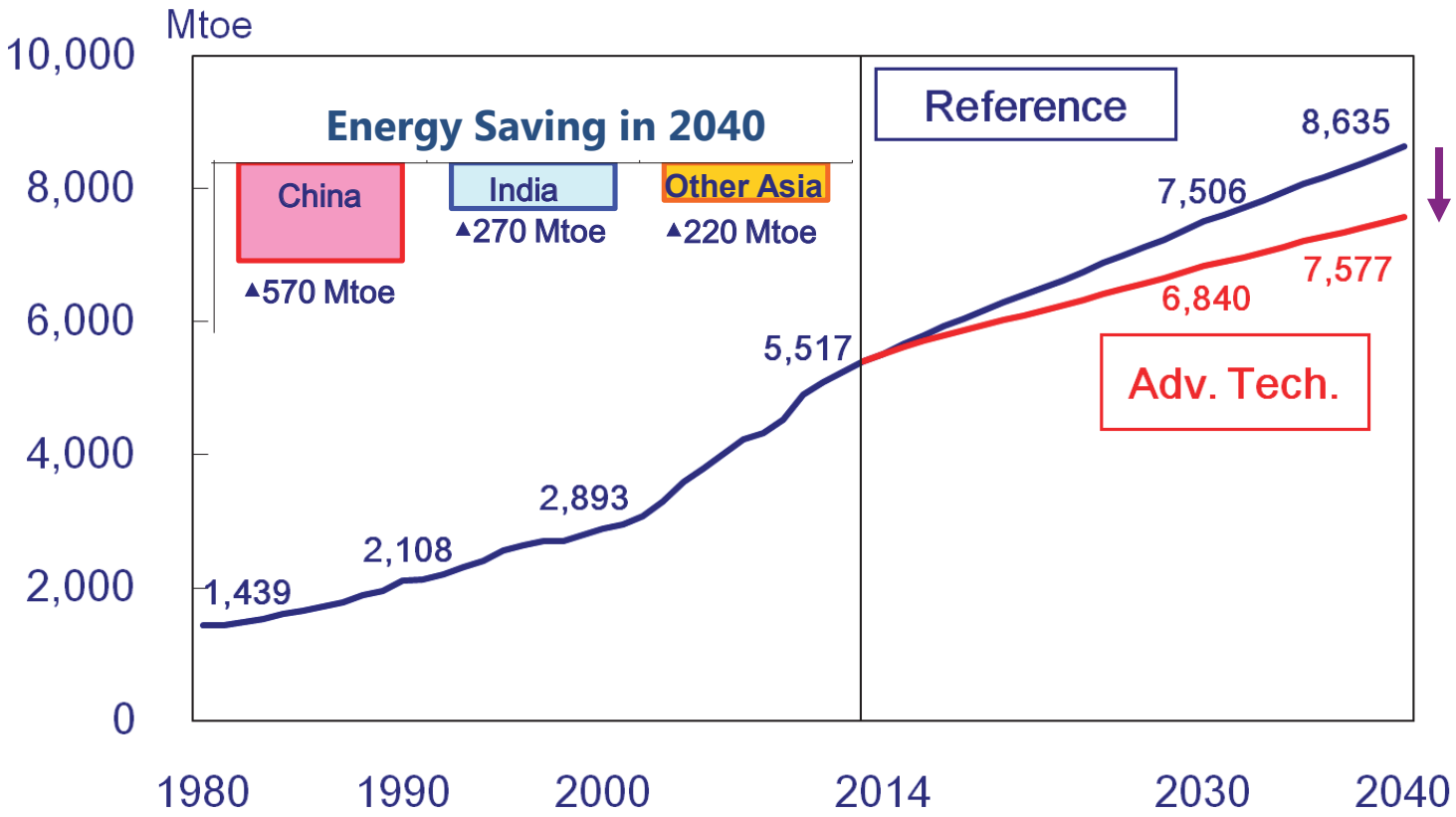
**Non-OECD**
**-1,500** Mtoe
(**65**% of total saving)

**Asia**
**-1,100** Mtoe
(**45**% of total saving)

- In 2040, total primary energy consumption in the Advanced Technologies Scenario will be 2,300 Mtoe (about 12%) lower than the case of the Reference Scenario. The energy saving is more than 5.3 times total consumption of Japan in 2014.
- In the Advanced Technologies Scenario, Non-OECD contributes to about 65% of the potential savings. In particular, Asia accounts for 45% of the saving.

# Primary energy consumption (Asia)

Reference Scenario
Advanced Technologies Scenario




**-1,060** Mtoe
(**-12**%)

**China**
**-570** Mtoe
(**54**% of saving in Asia)

**India**
**-270** Mtoe
(**25**% of saving in Asia)

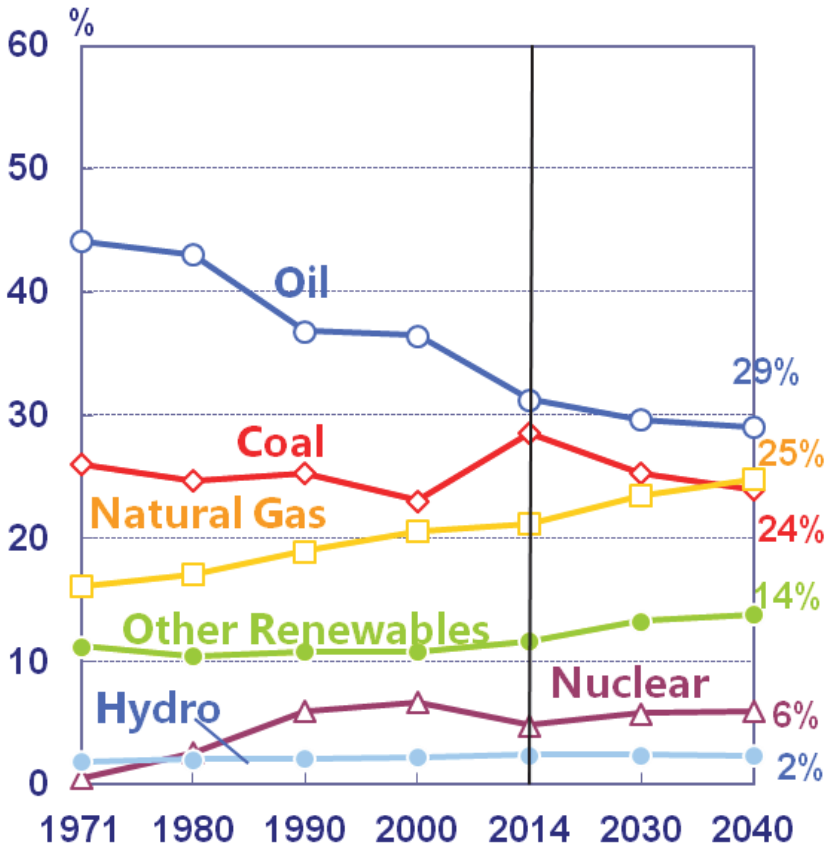
**Other Asia**
**-220** Mtoe
(**21**% of saving in Asia)

- The potential savings in Asia under the Advanced Technologies Scenario is 1,060 Mtoe (equivalent to about 2.4 times Japan's current consumption).
- The total saving of China and India accounts for around 80% of that in Asia.

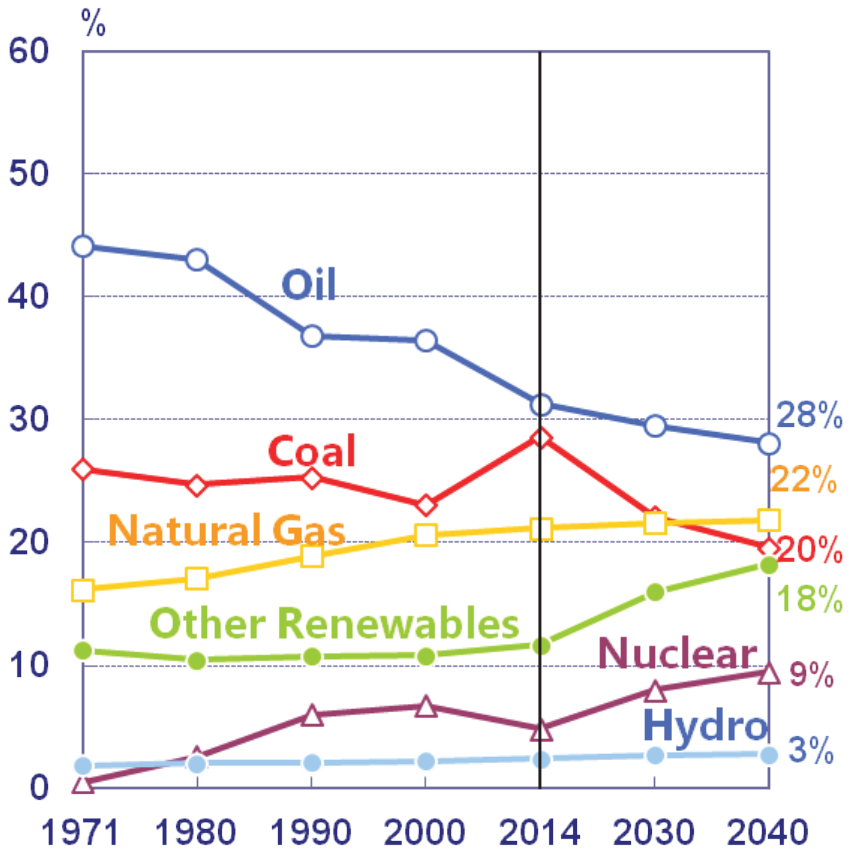
# Primary energy mix (world)



## Reference Scenario




## Advanced Technologies Scenario

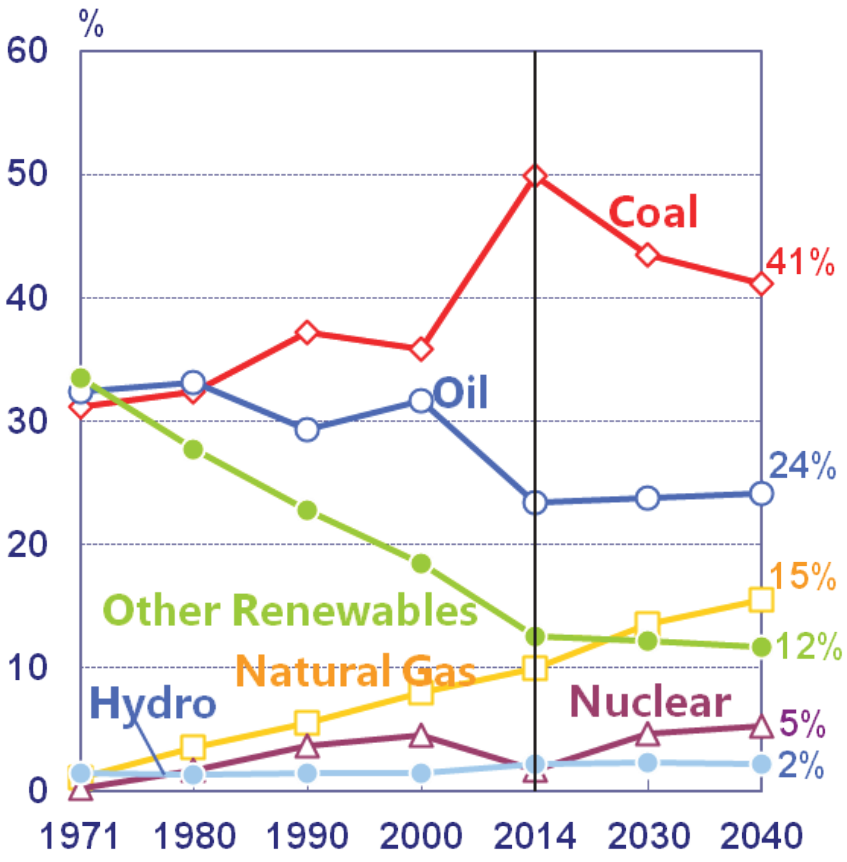



- In the Reference Scenario, the oil's share decreases substantially to 29%, while the shares for natural gas and renewables expand substantially.
- In the Advanced Technologies Scenario, coal significantly decreases mainly in Non-OECD while the shares for nuclear and renewables gradually expand. Fossil fuels, nonetheless, remain the most important source for energy in the primary energy mix in 2040, maintaining about 70% share.

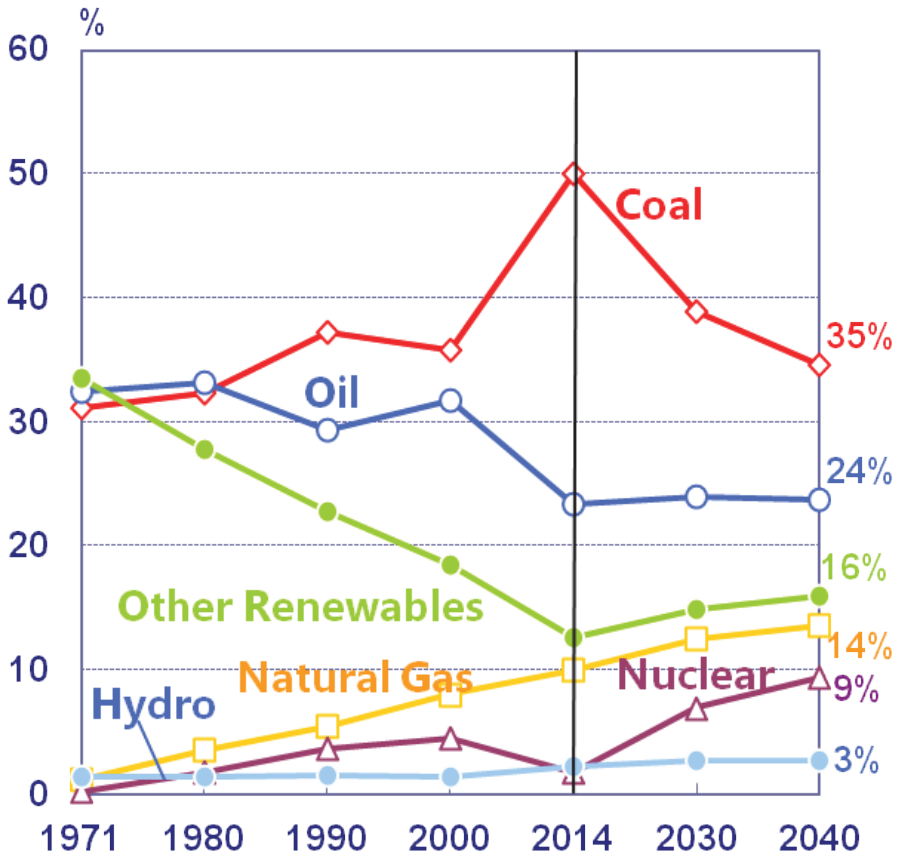
# Primary energy mix (Asia)

Reference Scenario
Advanced Technologies Scenario

## Reference Scenario



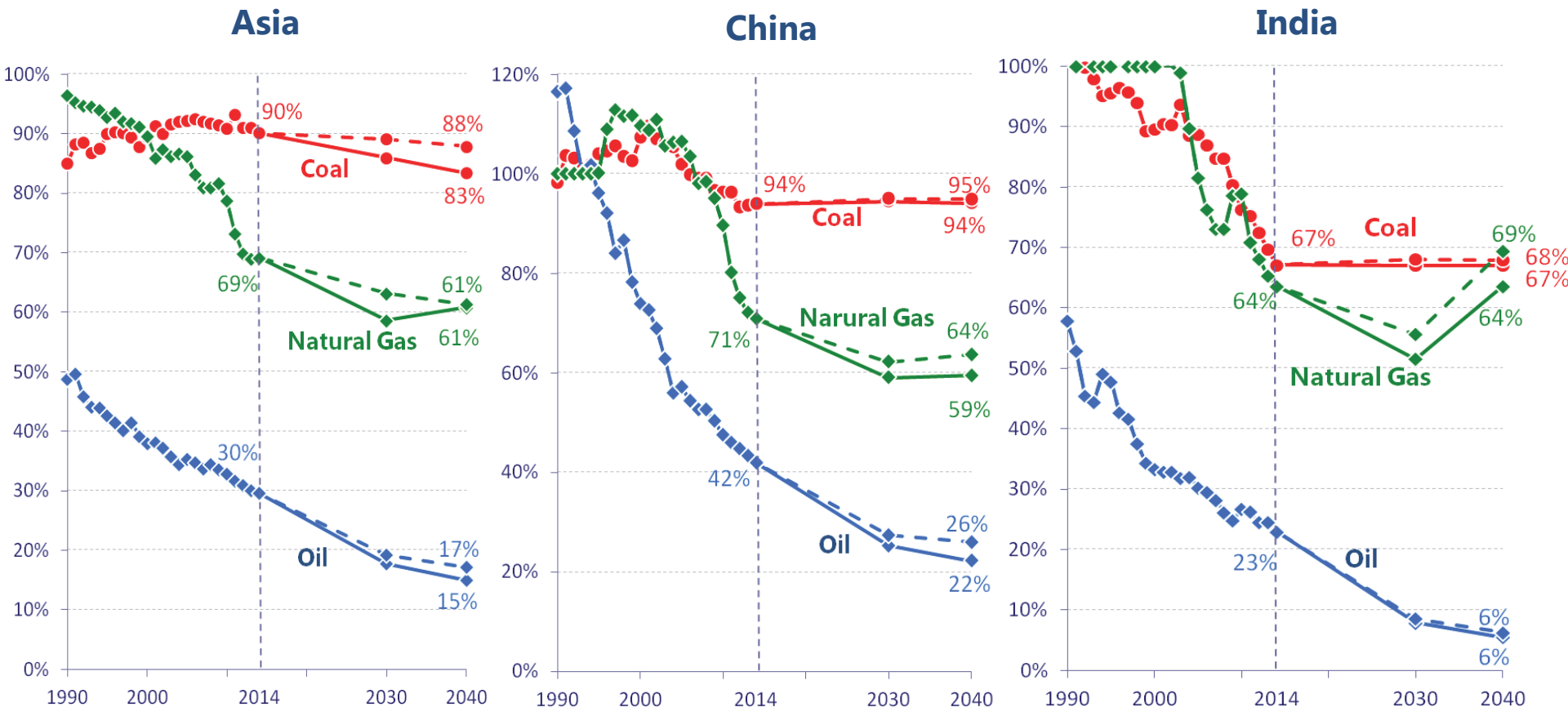

## Advanced Technologies Scenario




- Coal keeps the biggest share of primary energy consumption driven by the power generation demand through 2040. The share drops from 50% in 2014 to 41% in 2040 in the Reference Scenario and to 35% in the Advanced Technologies Scenario.
- Natural gas continues to grow in both scenarios. In the Advanced Technologies Scenario, the share of nuclear gradually increases with additional nuclear power plants in China, India, Korea, and so forth.

# Energy self-sufficiency in Asia

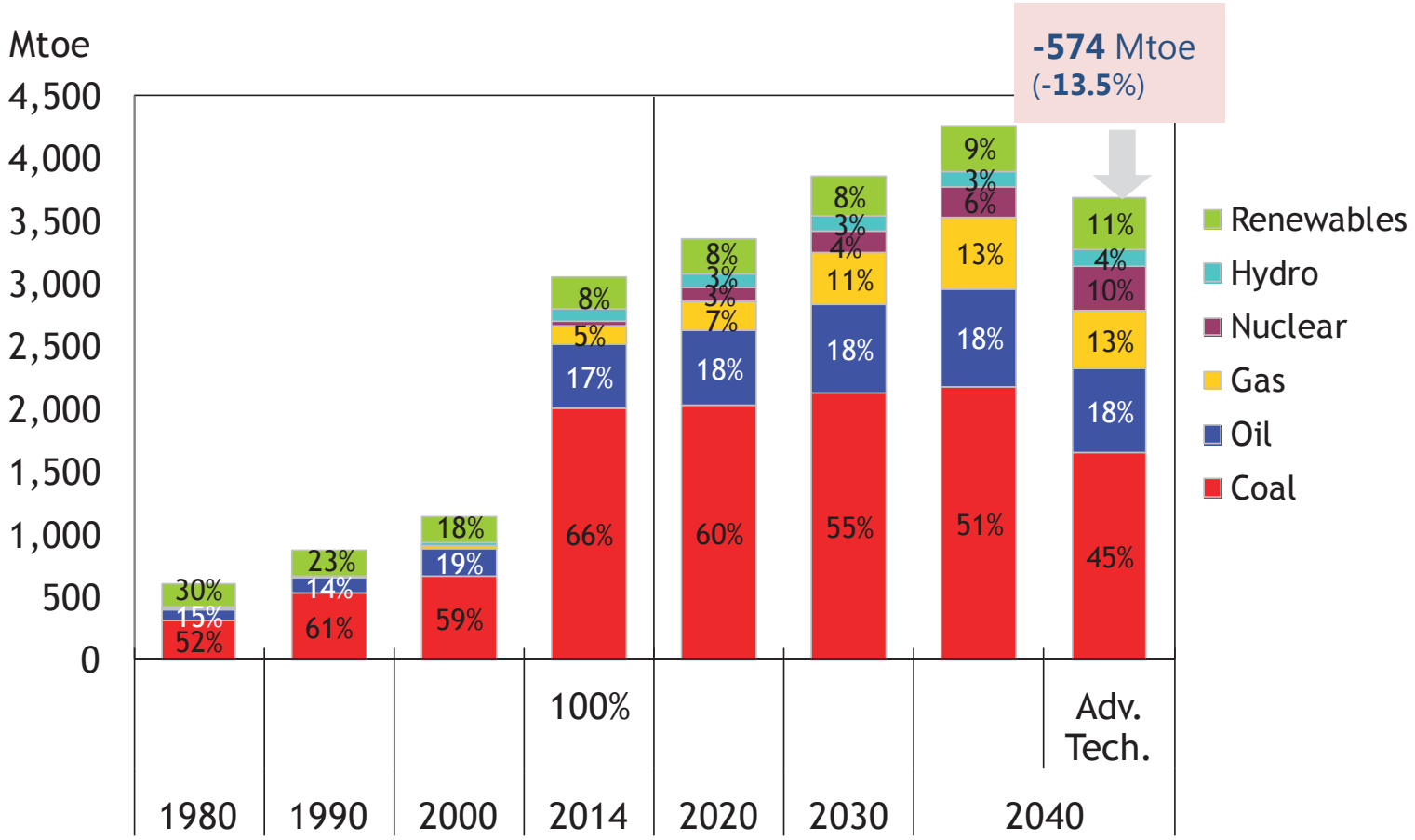
Reference Scenario (solid)
Advanced Technologies Scenario (dotted)




- While Asia including China and India is poor in oil and natural gas resources, coal resources are abundant. so coal contributes to stabilize energy self-sufficiency in Asia.
- Asian fossil fuel self-sufficiency rate has been decreasing and it keeps decreasing not only in the Reference Scenario where demand rapidly increases, but also in the Advanced Technologies Scenario where energy saving technologies are heavily implemented.

# Primary energy consumption in China

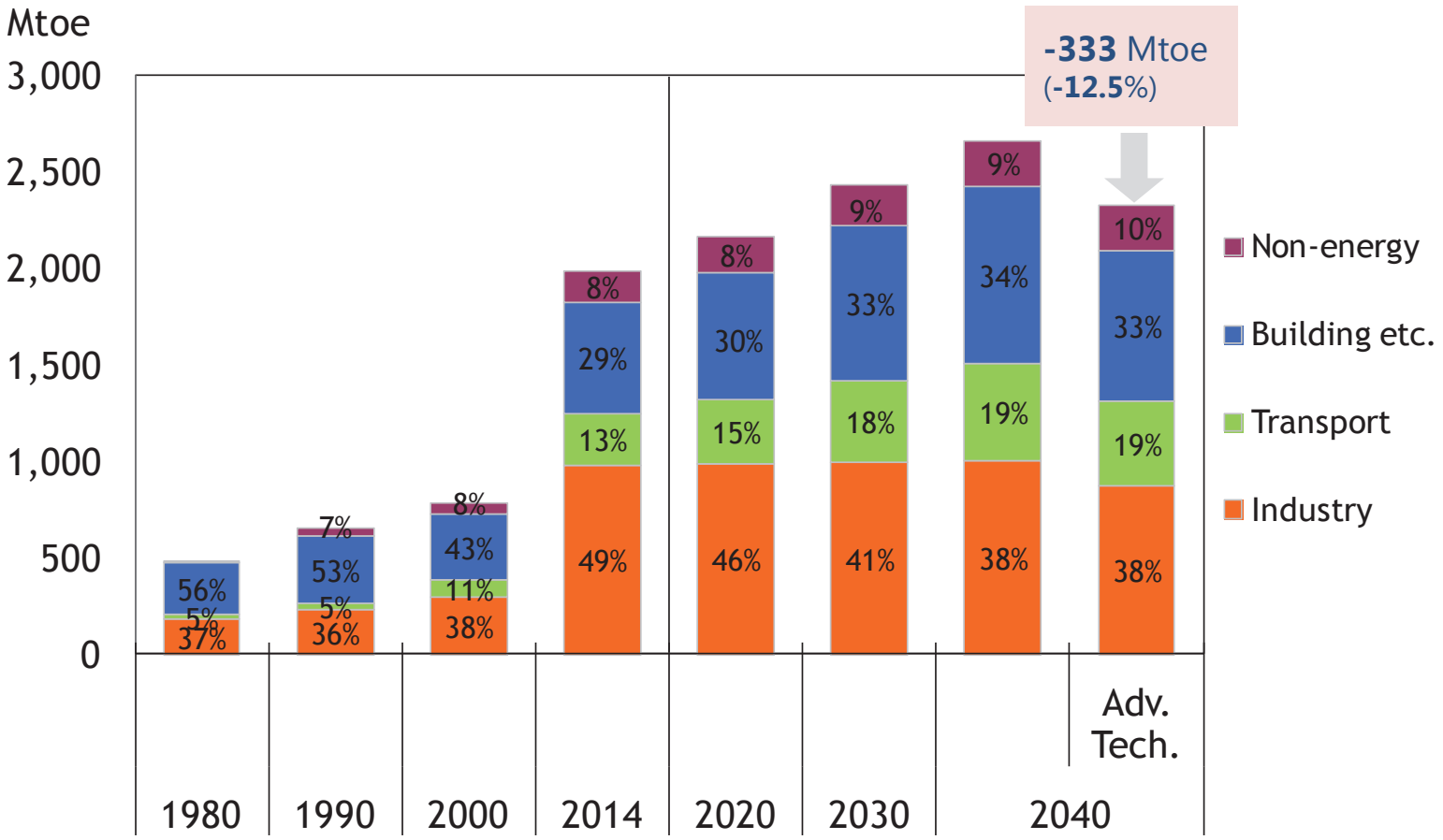
Reference Scenario
Advanced Technologies Scenario




- TPED increases at an annual rate of 1.3% in the Reference Scenario at the back of economic growth. Oil expands reflecting rapid motorization.
- Natural gas increases sharply for residential and commercial use, especially in urban areas.
- In the Advanced Technologies Scenario, coal consumption decreases, especially in power generation, TPED is 574 Mtoe, or 13.5% lower than that in the Reference Scenario in 2040.

# Final energy consumption in China

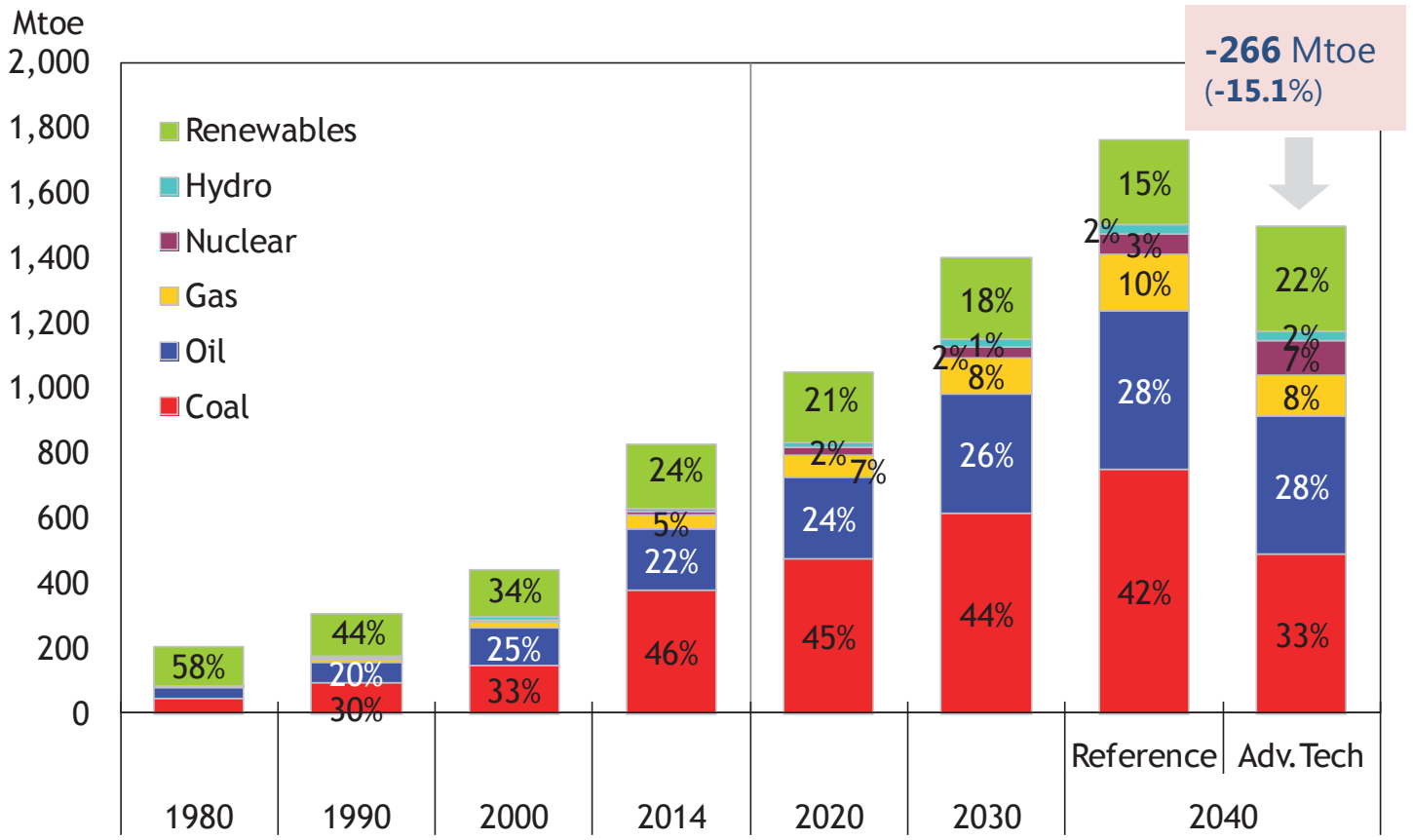
Reference Scenario
Advanced Technologies Scenario




- Final energy consumption increases strongly, reaching 2,667 Mtoe in 2040, from 1,988 Mtoe in 2014.
- Energy consumption of heavy industries which has been strong up until now grows relatively slowly in the future.
- By contrast, energy consumption of the buildings and transport sectors increase substantially. The share of the buildings sector reaches 34% in 2040 from 29% in 2014.
- In the Advanced Technologies Scenario, energy consumption of the buildings and industry sectors is expected to have large potential for reduction, final energy consumption is 333 Mtoe, or 12.5% lower than the Reference Scenario.

# Primary energy consumption in India

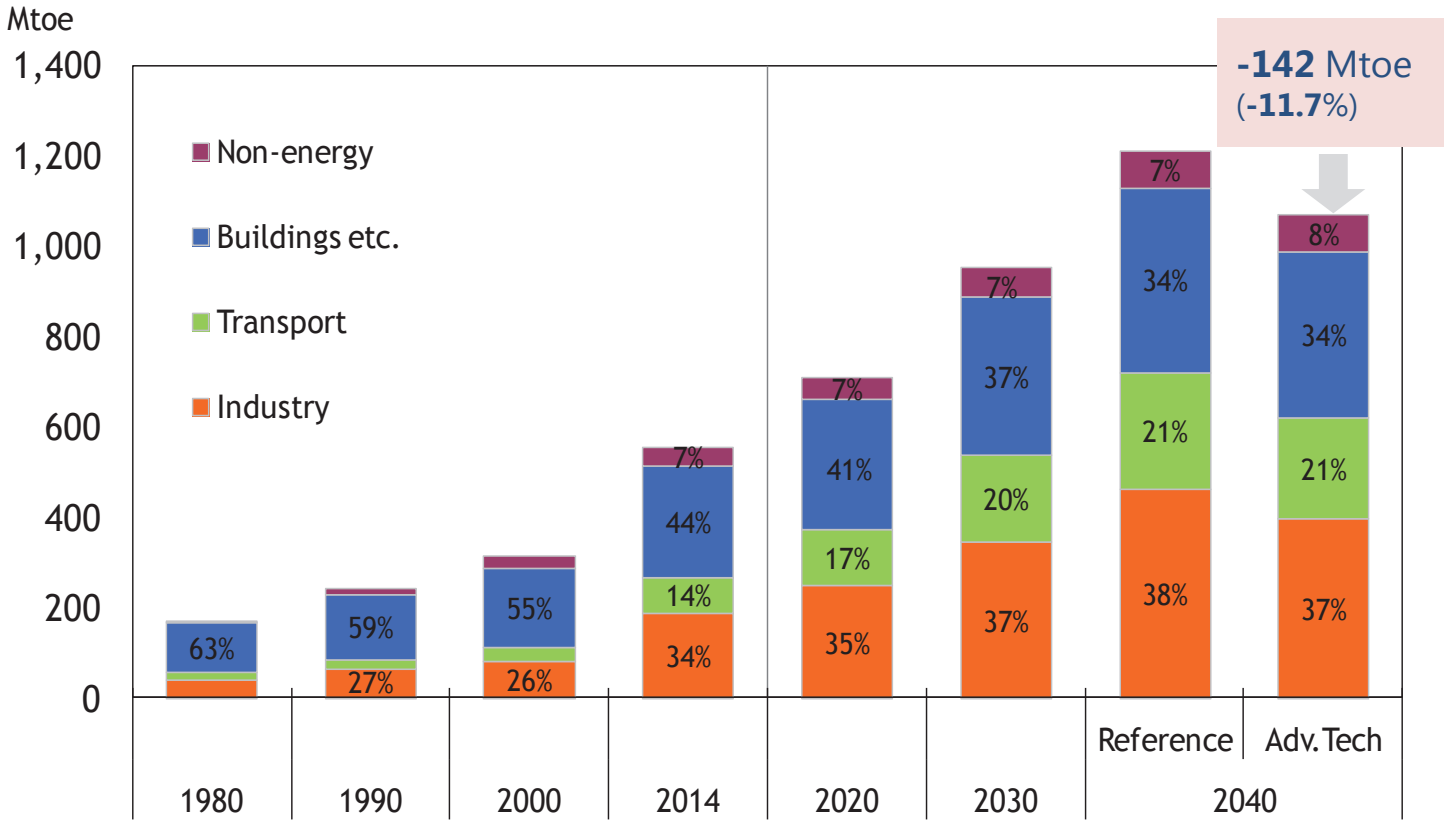
Reference Scenario
Advanced Technologies Scenario




- In the Reference Scenario, TPED increases at an annual rate of 3.0%. Fossil fuels account for 80% of the increases by 2040.
- Driven by the power generation and industry sectors, coal maintains the largest share at about 44% throughout the projection period.
- The power and industry sectors also lead natural gas consumption growth. Although development of domestic resources is expected, much of the natural gas consumption should be met by imports.
- TPED in 2040 in the Advanced Technologies Scenario is 266 Mtoe, or 15.1% lower compared with the Reference Scenario.

# Final energy consumption in India

Reference Scenario
Advanced Technologies Scenario

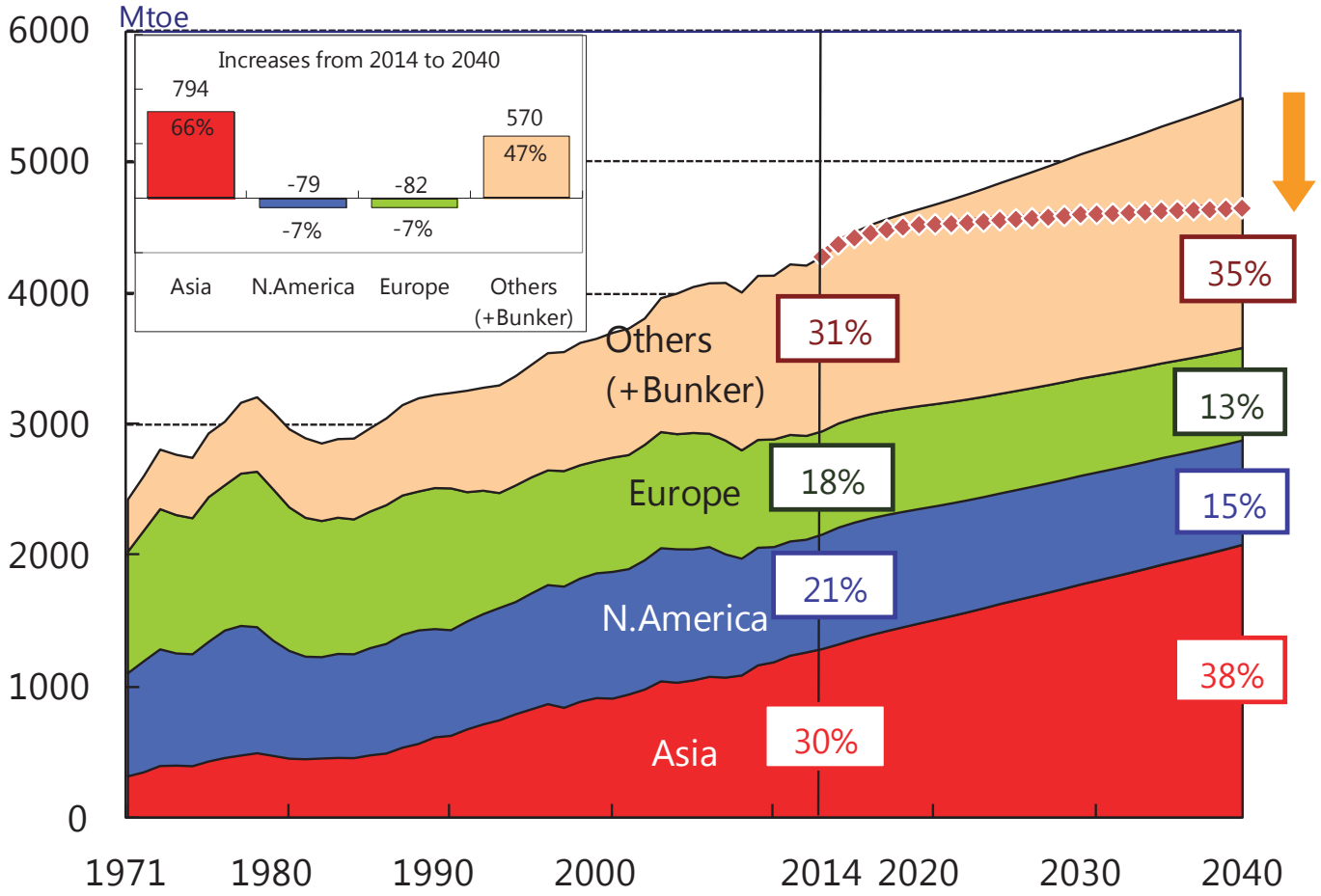



Note: The industry sector includes non-energy use.

- Industry increases rapidly due to industrialization and production increases from the heavy industry. Energy consumption for industry and transport sectors are 2.4 times and 3.3 times of current energy consumption, respectively.
- Electricity consumption grows at an annual rate of 4.4%.
- In the Advanced Technologies Scenario, energy consumption is 142 Mtoe, or 11.7% lower in 2040 compared to the Reference Scenario. Renovation with the India's developed ICT and industrialization will promote energy efficiency.

# Oil consumption by region (world)

Reference Scenario (solid)
Advanced Technologies Scenario (dotted)




Saving:
**832** Mtoe
(**15**%)

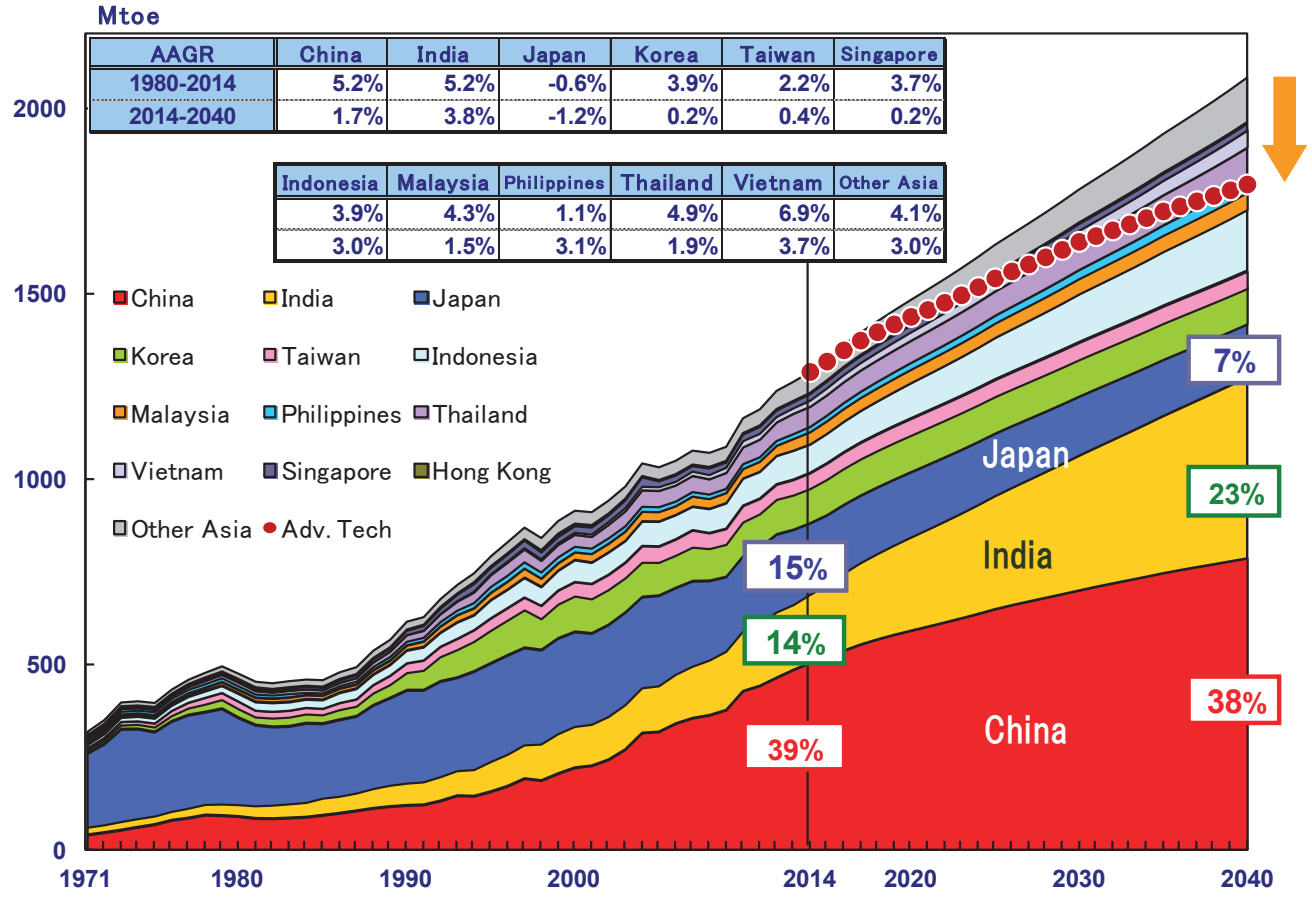
2014
**4,285** Mtoe
(**89** Mb/d)
↓
2040
**Reference Scenario**
**5,488** Mtoe
(**114** Mb/d)

**Advanced Technologies Scenario**
**4,656** Mtoe
(**96** Mb/d)

- The share of Asia in the world oil consumption increases from 30% in 2014 to 38% in 2040. About 66% of the global oil growth takes place in Asia.
- In the Advanced Technologies Scenario, the world oil consumption is 832 Mtoe (15%) lower in 2040 compared to the Reference Scenario.

# Oil consumption by region (Asia)

Reference Scenario (solid)
Advanced Technologies Scenario (dotted)




| AAGR | China | India | Japan | Korea | Taiwan | Singapore |
|---|---|---|---|---|---|---|
| 1980-2014 | 5.2% | 5.2% | -0.6% | 3.9% | 2.2% | 3.7% |
| 2014-2040 | 1.7% | 3.8% | -1.2% | 0.2% | 0.4% | 0.2% |

| Indonesia | Malaysia | Philippines | Thailand | Vietnam | Other Asia |
|---|---|---|---|---|---|
| 3.9% | 4.3% | 1.1% | 4.9% | 6.9% | 4.1% |
| 3.0% | 1.5% | 3.1% | 1.9% | 3.7% | 3.0% |

Saving:
**287** Mtoe
(**14**%)

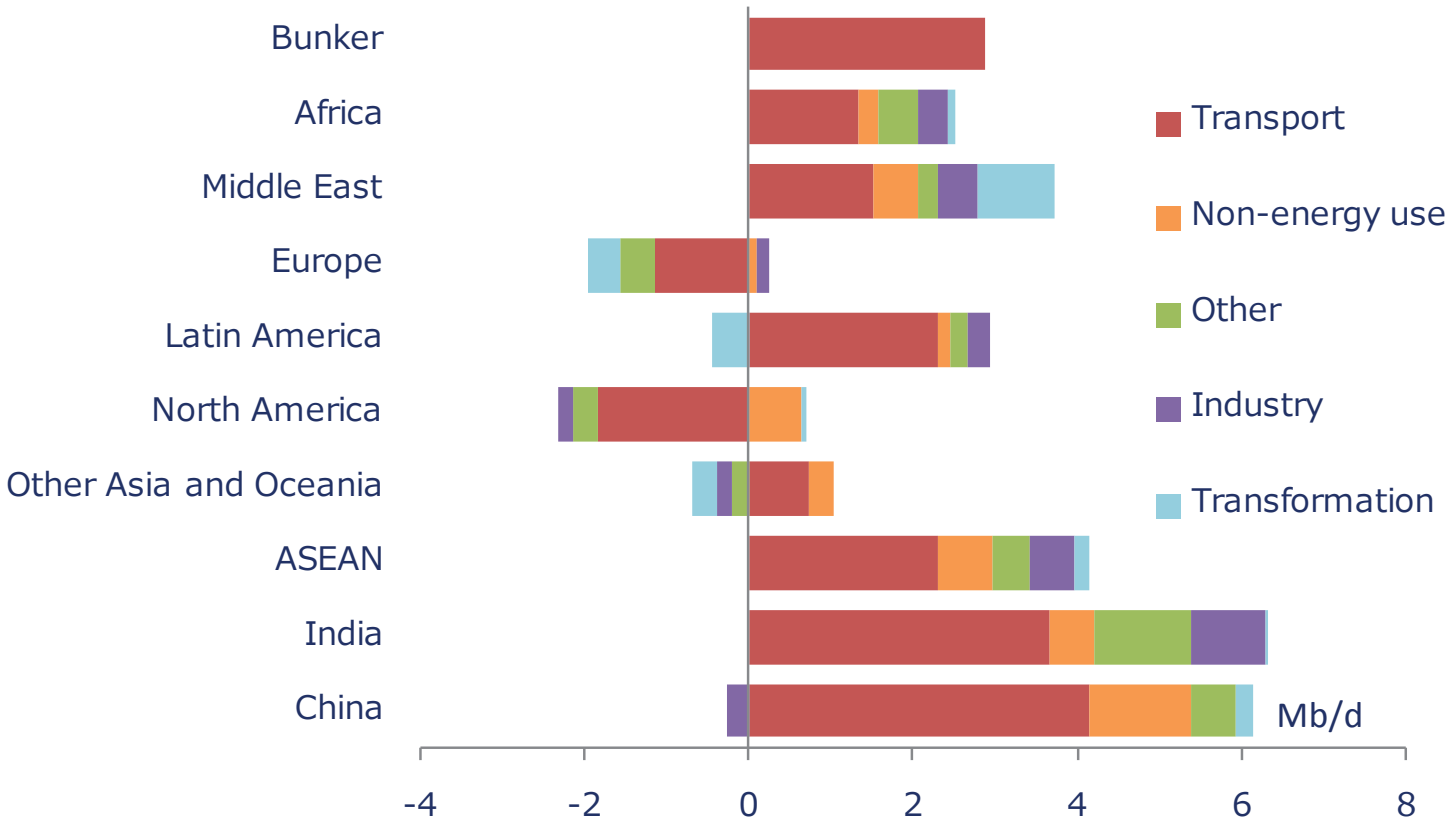
2014
**1,291** Mtoe
(**26.7** Mb/d)
↓
2040
**Reference Scenario**
**2,085** Mtoe
(**43.1** Mb/d)

**Advanced Technologies Scenario**
**1,798** Mtoe
(**37.2** Mb/d)

- Though the vehicles' fuel efficiency improves and clean energy vehicles expand, oil consumption in Asia expands from 26.7 million b/d in 2014 to 43.1 Mb/d in 2040, due mainly to its escalating vehicle ownership. The share of China and India combined in Asian oil consumption grows from 53% in 2014 to 61% in 2040.
- Oil savings in the Advanced Technologies Scenario are equivalent to 14% of the Reference Scenario in 2040.

# Changes of world oil consumption (2014-2040)

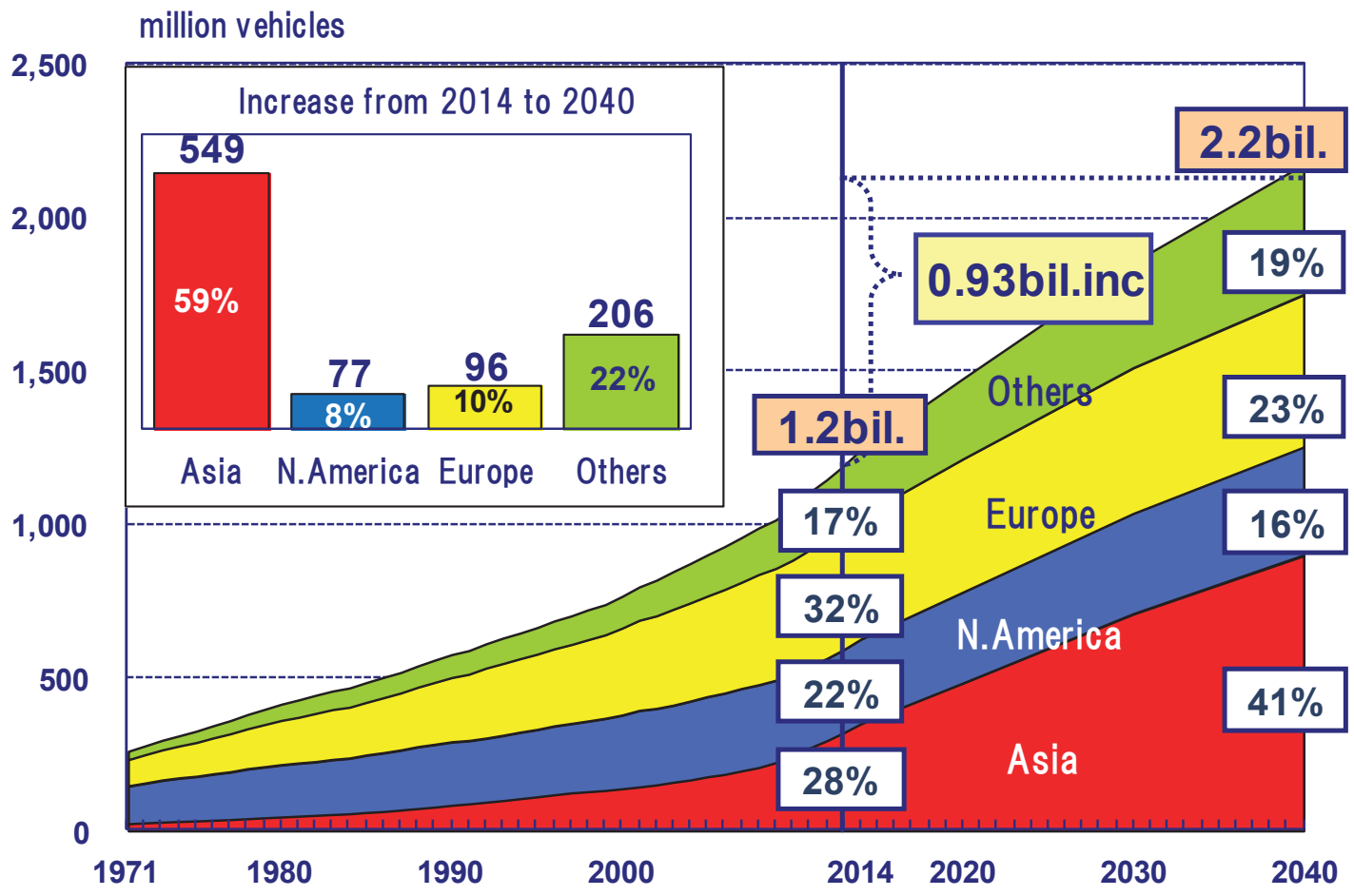
Reference Scenario




- ✓Oil demand increases to 25Mb/d and more than 60 percent of the increase is attributed to Transport, more than 10 percent to Bunker, and nearly 20 percent to Non-energy use.
- ✓India accounts for a quarter; Asia and Oceania for two thirds of the world oil demand increase.
- ✓On the other hand, oil demand decrease in North America, Europe, and Japan.

# The number of vehicles (world)

Reference Scenario
Advanced Technologies Scenario




**World**

2014
**1.2** billion
↓
2040
**2.2** billion
**(x1.7)**

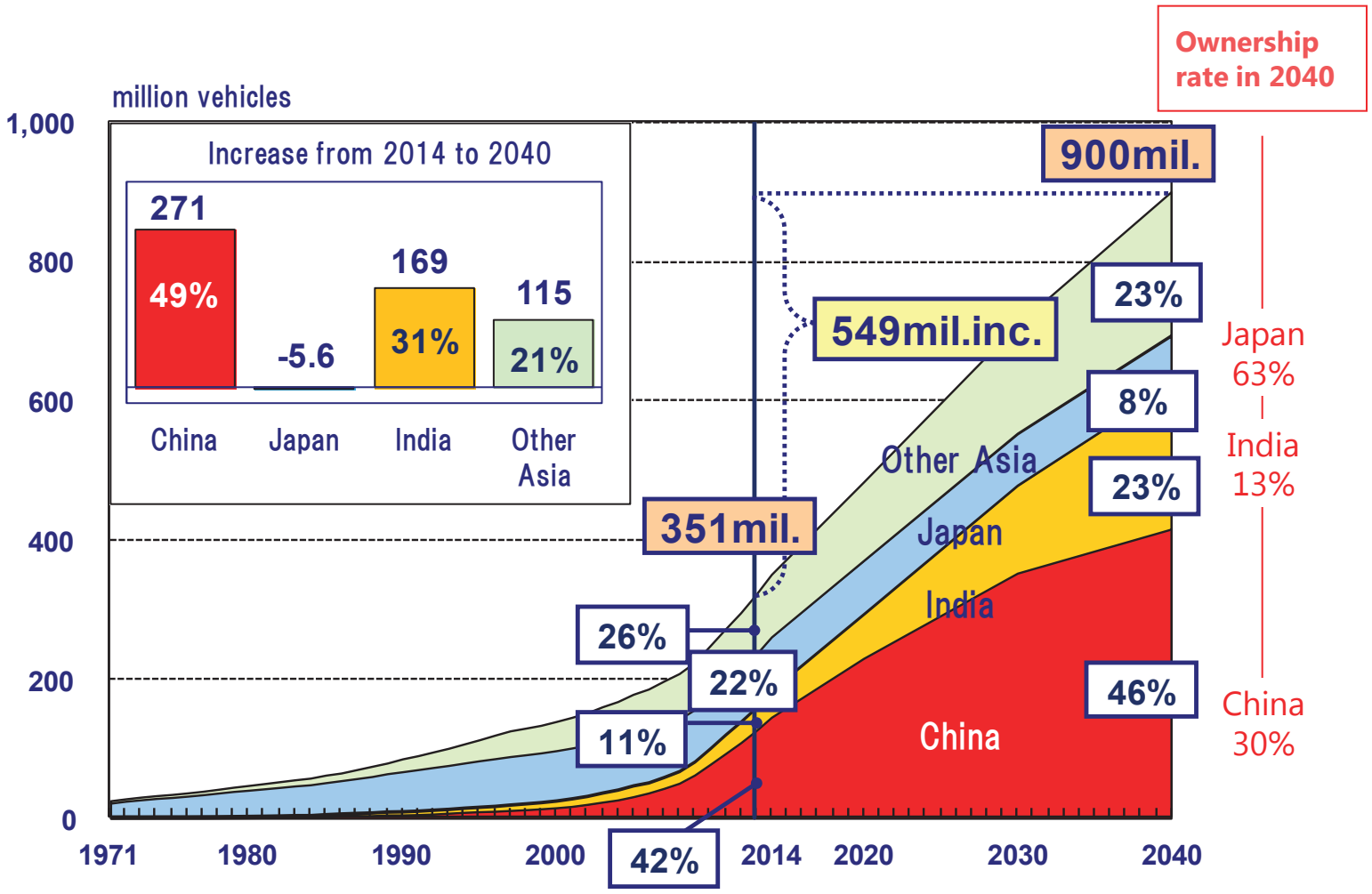
**Asia**

2014
**0.35** billion
↓
2040
**0.90** billion
**(x2.6)**

- 41% of the world vehicle stocks is concentrated in Asia in 2040.
- The share of vehicle stocks in OECD countries declines from 59% in 2014 to 43% in 2040. The stock in Non-OECD countries surpasses that of OECD by 2040.

# The number of vehicles (Asia)

Reference Scenario
Advanced Technologies Scenario




**China**

2014
146 million
↓
2040
417 million
(x2.9)

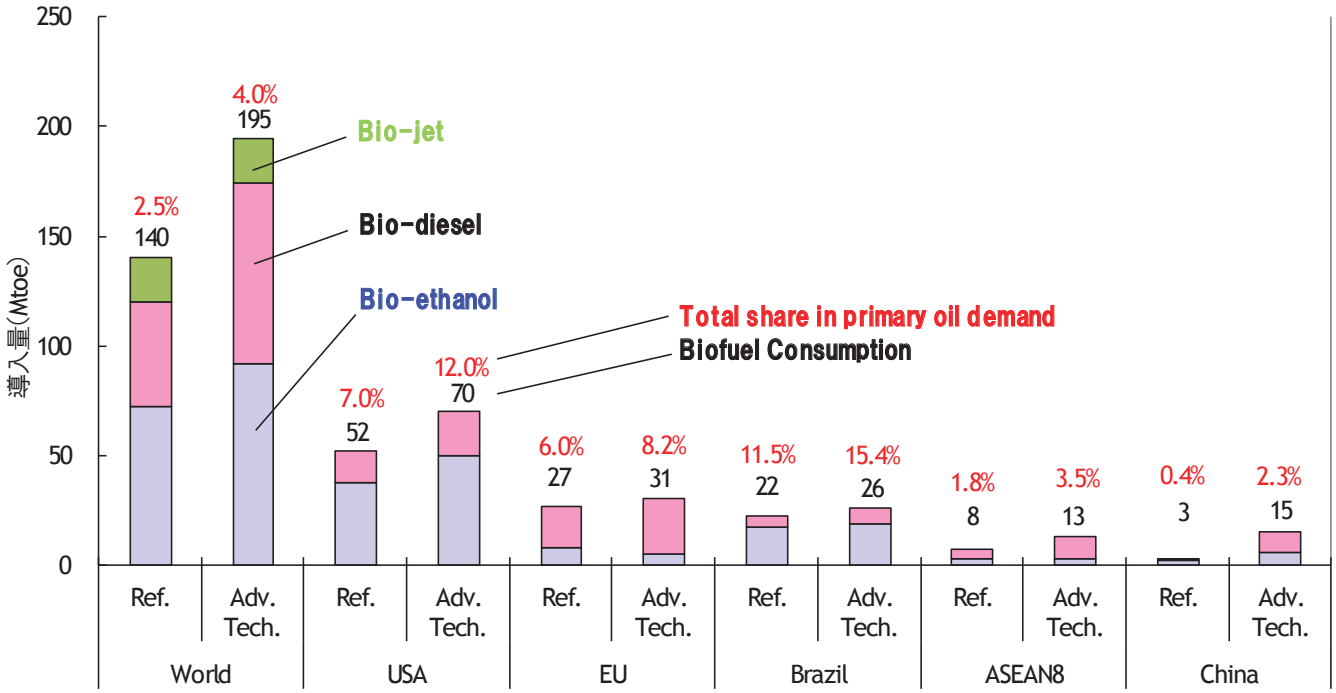
**India**

2014
38 million
↓
2040
207 million
(x5.4)

■ China vehicle stock expands substantially due to an increase in the income level. The stock of vehicle in China increases from 146 million units in 2014 to 417 million units in 2040. India's vehicle stock surpasses that of Japan around 2022, increasing from 38 million units in 2014 to 207 million units in 2040.

# Biofuel consumption in the world (2040)

Reference Scenario
Advanced Technologies Scenario




## World

**2014**
**77** Mtoe
↓
**2040**

| Ref. | Adv. Tech. |
|---|---|
| **140** Mtoe | **195** Mtoe |
| (**x1.8**) | (**x2.5**) |

## Asia

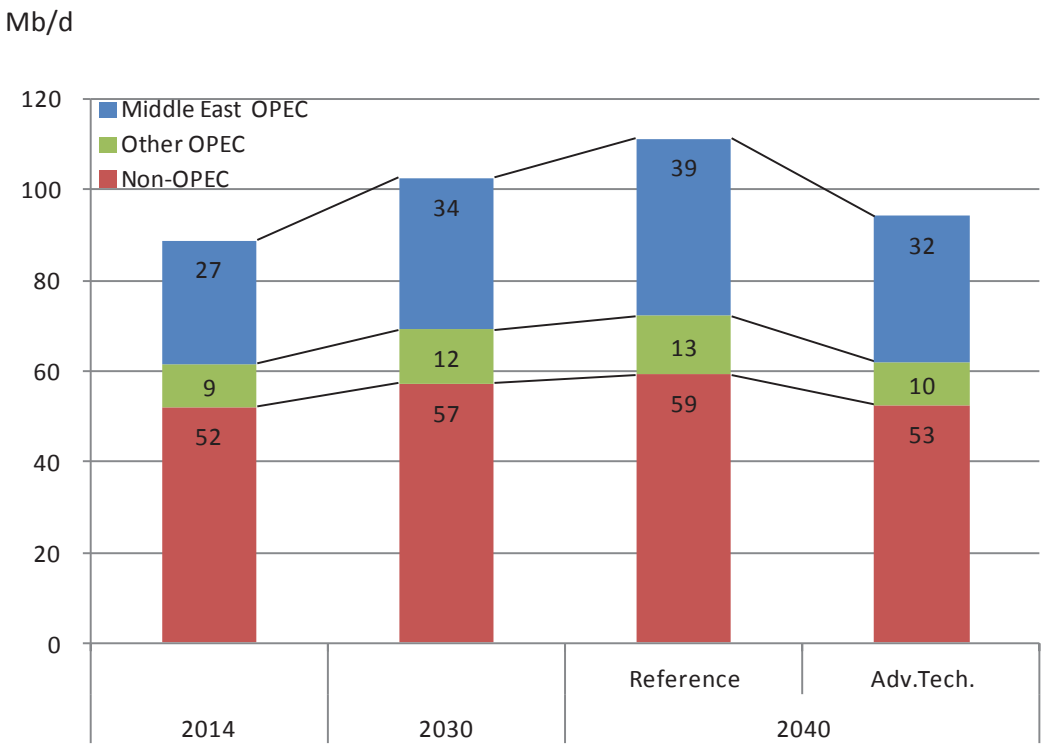
**2014**
**6.1** Mtoe
↓
**2040**

| Ref. | Adv. Tech. |
|---|---|
| **13** Mtoe | **36** Mtoe |
| (**x2.1**) | (**x5.9**) |

- In the Reference Scenario, the world biofuel consumption is expected to reach 140 Mtoe by 2040, mainly driven by the growth in North America, Europe and Latin America. Asia reaches 13 Mtoe of biofuel by 2040. The share of biofuel in global liquid fuel amounts to 2.5% in 2040.
- In the Advanced Technologies Scenario, the world biofuel consumption reaches 195 Mtoe by 2040, and that of Asia reaches 36 Mtoe.

# Oil production

Reference Scenario
Advanced Technologies Scenario




## OPEC

**2014**
**37** Mb/d
↓
**2040**

| **Reference** | **Adv. Tech.** |
|---|---|
| **52** Mb/d (**+15** Mb/d) | **42** Mb/d (**+5** Mb/d) |

## Non-OPEC

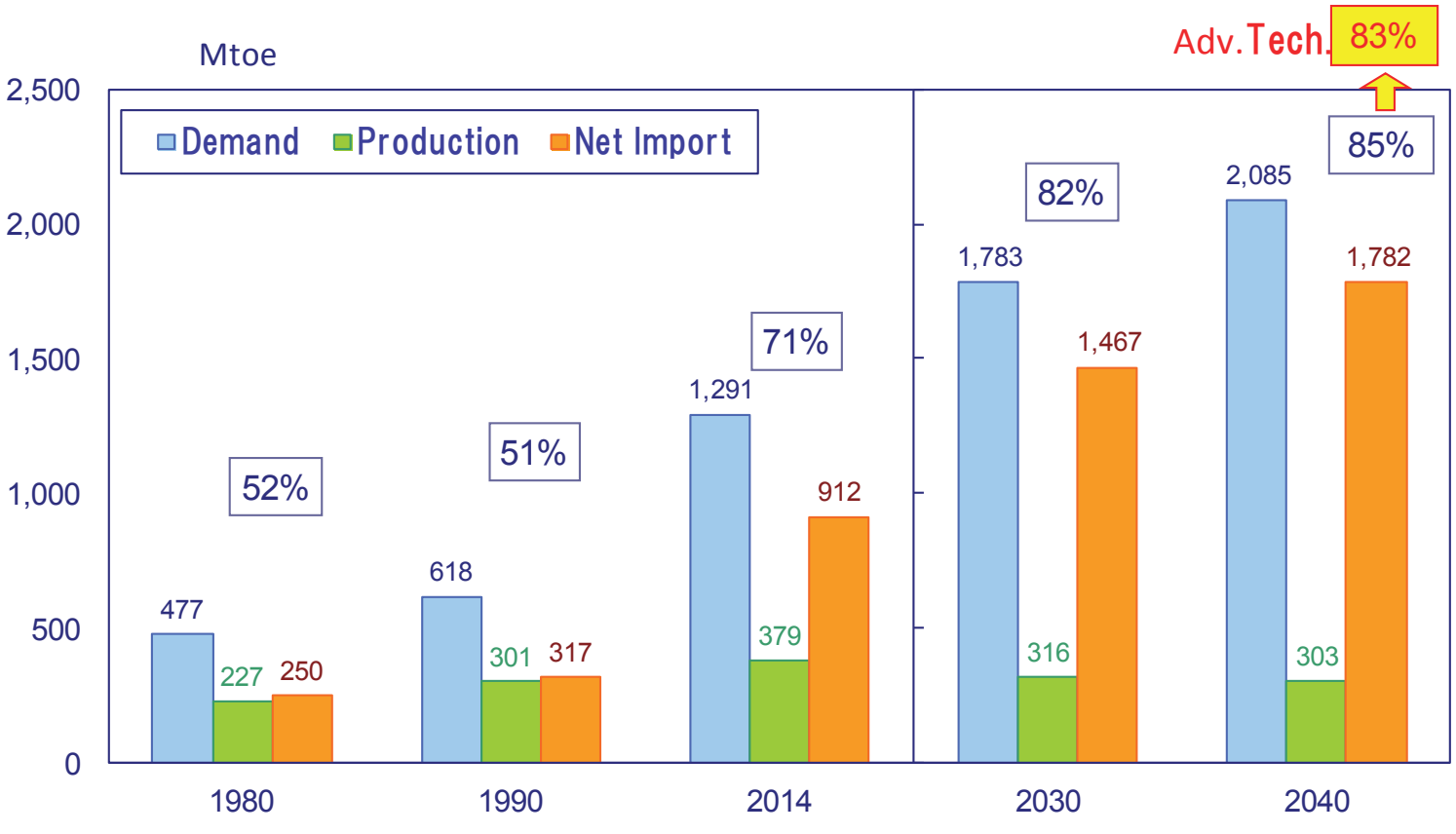
**2014**
**52** Mb/d
↓
**2040**

| **Reference** | **Adv. Tech.** |
|---|---|
| **59** Mb/d (**+7** Mb/d) | **53** Mb/d (**+0.4** Mb/d) |

- 67% of the increases in world oil consumption is met by OPEC. OPEC's share of world oil production in 2040 increases to 46%.
- However, the domestic oil consumption in the Middle East OPEC is also projected to increase significantly. Enhancement of production capacity and improvement of energy efficiency in the Middle East OPEC is necessary to ensure availability of oil supply to the world market.

# Oil supply and demand in Asia

Reference Scenario
Advanced Technologies Scenario




**Net oil imports**

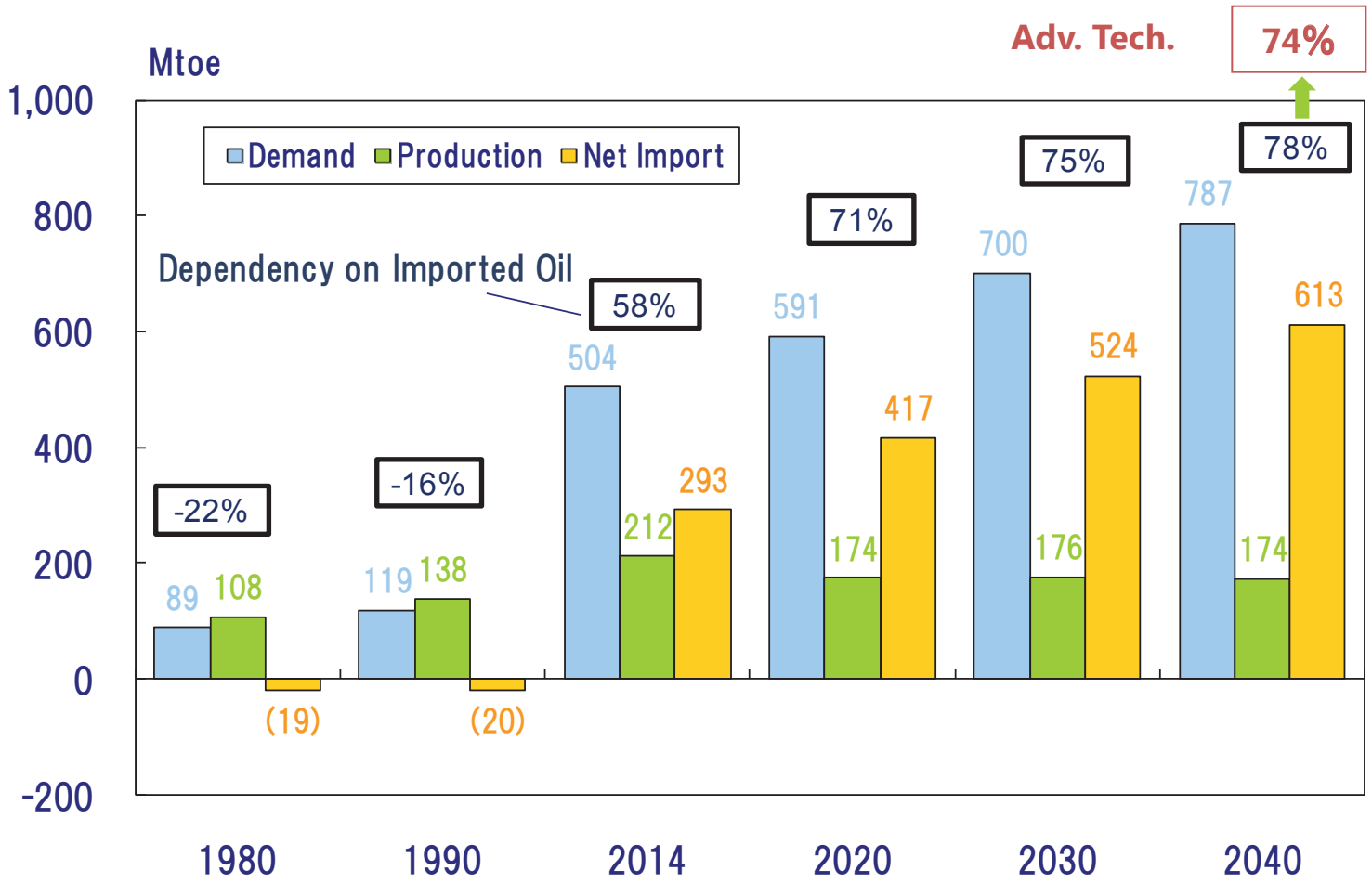
**2014**
**18.92** Mb/d
↓
**2040**
**Reference**
**36.98** Mb/d
**(x2.0)**

**Adv. Tech.**
**31.10** Mb/d
**(x1.6)**

- In the Reference Scenario, net oil imports are projected to expand to 1,782 million ton (36.98 Mb/d) in 2040 from 912 million ton (18.92 Mb/d) in 2014. With the sluggish oil production of in Asia (China, India, Indonesia), net oil import ratio reaches 85% in 2040.
- In the Advanced Technologies Scenario, oil demand grows at a relatively slow rate, but net oil import ratio still increases to 83% in 2040.

# Oil supply and demand in China

Reference Scenario
Advanced Technologies Scenario




**Net oil imports**

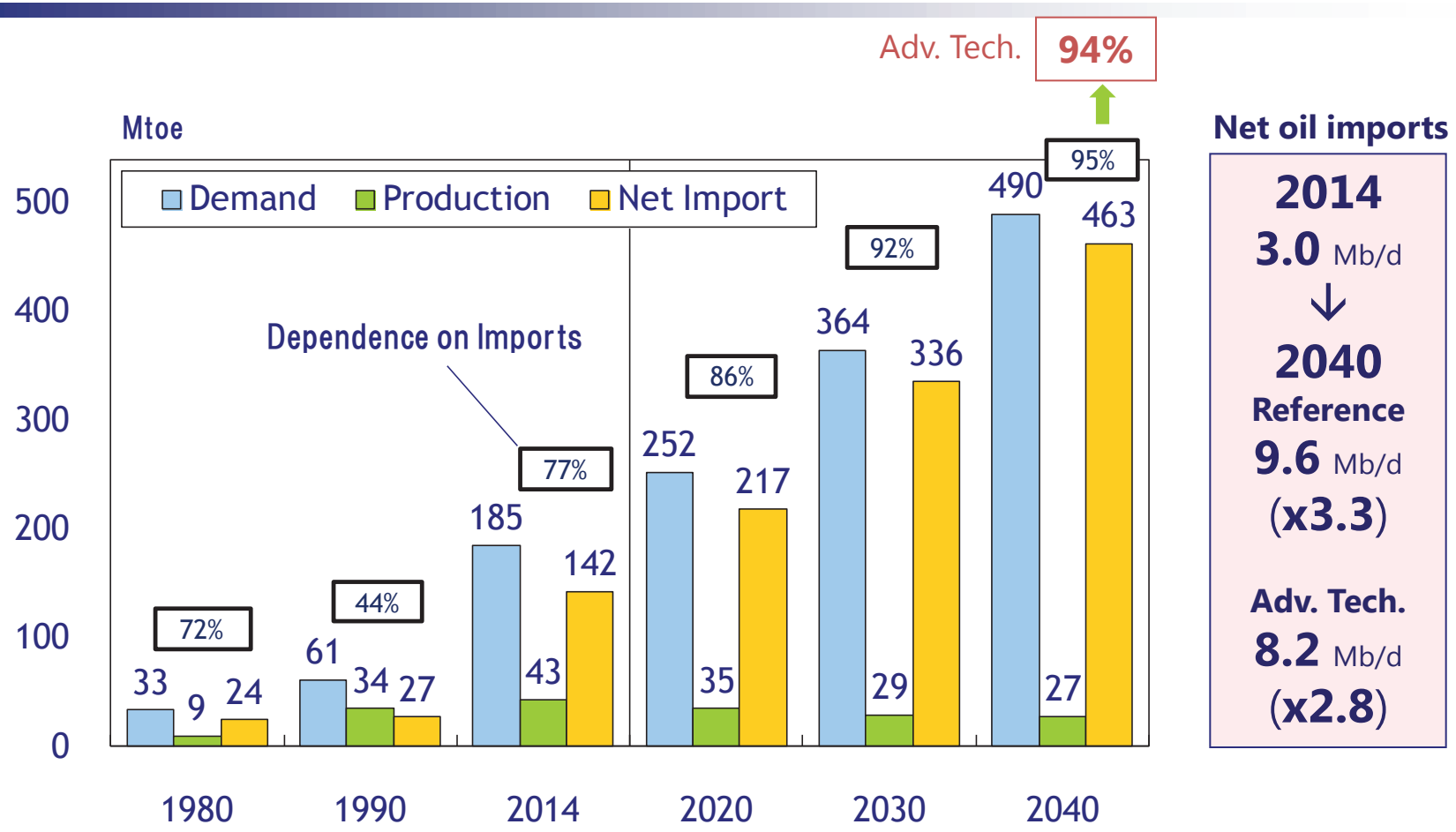
**2014**
**6.06** Mb/d
↓
**2040**
**Reference**
**12.68** Mb/d
**(x2.1)**

**Adv. Tech.**
**10.10** Mb/d
**(x1.7)**

- Net oil imports are projected to expand to 613 million ton (12.68 Mb/d) in 2040. As a result, net oil import ratio reaches 78% in 2040.
- In the Advanced Technologies Scenario, oil demand grows at a relatively slow rate, but net oil import ratio still increases to 74% in 2040.
- In order to sustain domestic oil production, continued investments are required to explore and develop oil fields in the western part of China and offshore.

# Oil supply and demand in India

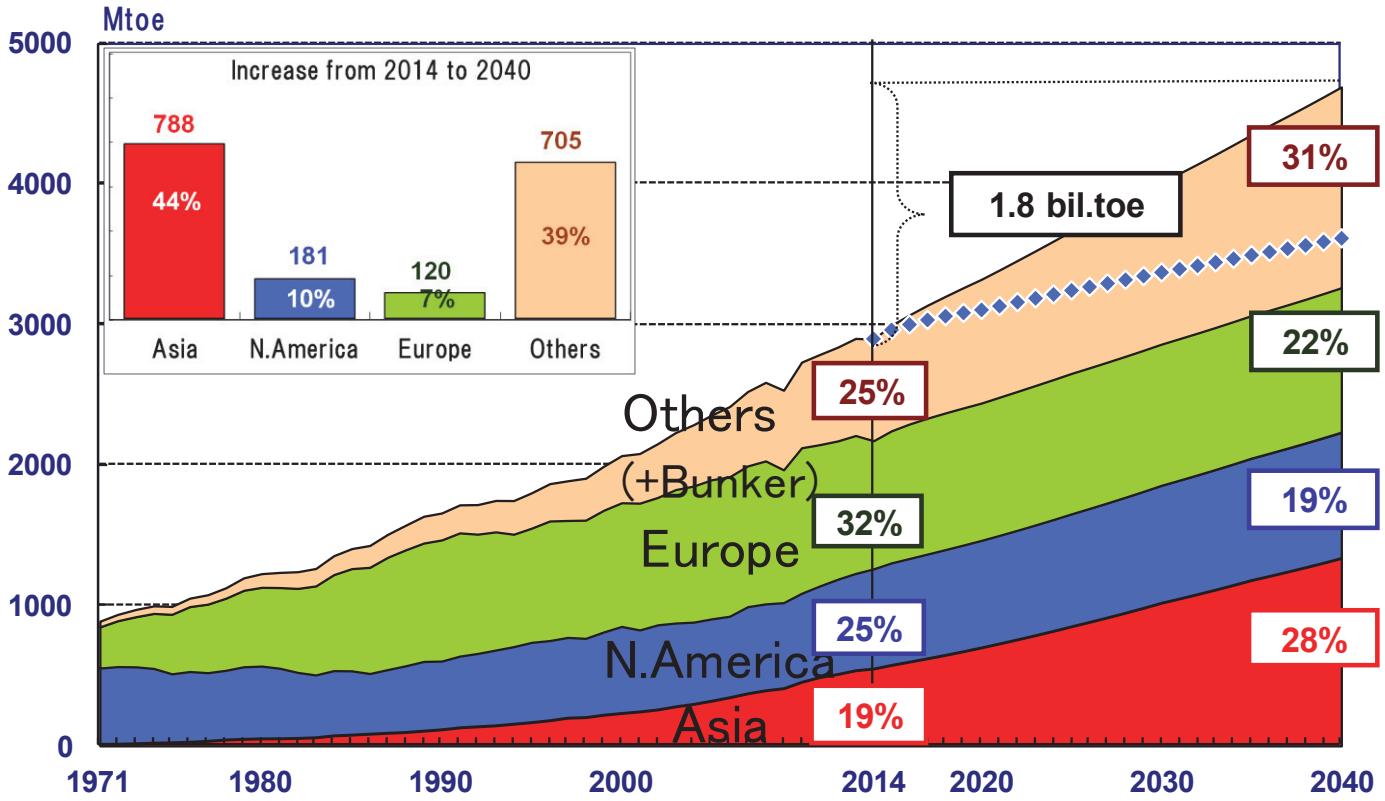
Reference Scenario
Advanced Technologies Scenario




- Net oil imports are projected to expand from 142 million ton (3.0 Mb/d) in 2014 to 463 million ton (9.6 Mb/d) in 2040. Net oil import ratio reaches 95% in 2040.

# Natural gas consumption by region (world)

Reference Scenario
Advanced Technologies Scenario



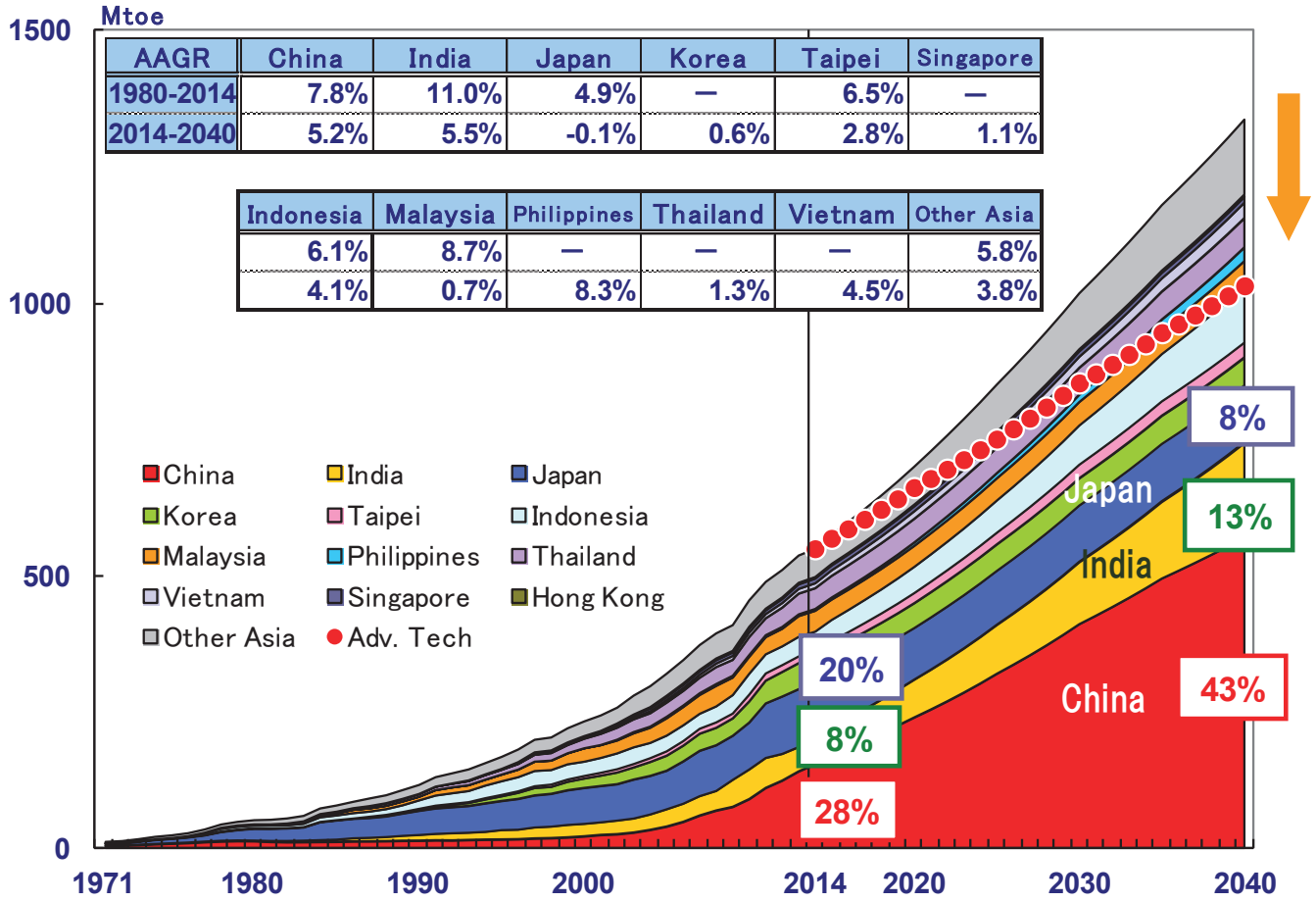

**1.08** Gtoe
**(23%)**
reduction

**2014**
**2.9** Gtoe
(**3.5** Tcm)
(**2.4** Gt of LNG-eq)
↓
**2040**
Reference
**4.7** Gtoe
(**5.7** Tcm)
(**3.8** Gt of LNG-eq)
**Adv. Tech.**
**3.6** Gtoe
(**4.4** Tcm)
(**3.6** Gt of LNG-eq)

- The world natural gas consumption is expected to increase from 3.5 trillion cubic meters (Tcm) in 2014 to 5.7 Tcm in 2040, a 1.6-fold increase.
- In the Advanced Technologies Scenario, natural gas consumption is 1.3 Tcm lower than the Reference Scenario. Despite projected savings, natural gas consumption continues to grow in the Advanced Technologies Scenario suggesting further needs of energy resources development.

# Natural gas consumption by country (Asia)

Reference Scenario
Advanced Technologies Scenario




| AAGR | China | India | Japan | Korea | Taipei | Singapore |
|---|---|---|---|---|---|---|
| 1980-2014 | 7.8% | 11.0% | 4.9% | — | 6.5% | — |
| 2014-2040 | 5.2% | 5.5% | -0.1% | 0.6% | 2.8% | 1.1% |

| Indonesia | Malaysia | Philippines | Thailand | Vietnam | Other Asia |
|---|---|---|---|---|---|
| 6.1% | 8.7% | — | — | — | 5.8% |
| 4.1% | 0.7% | 8.3% | 1.3% | 4.5% | 3.8% |

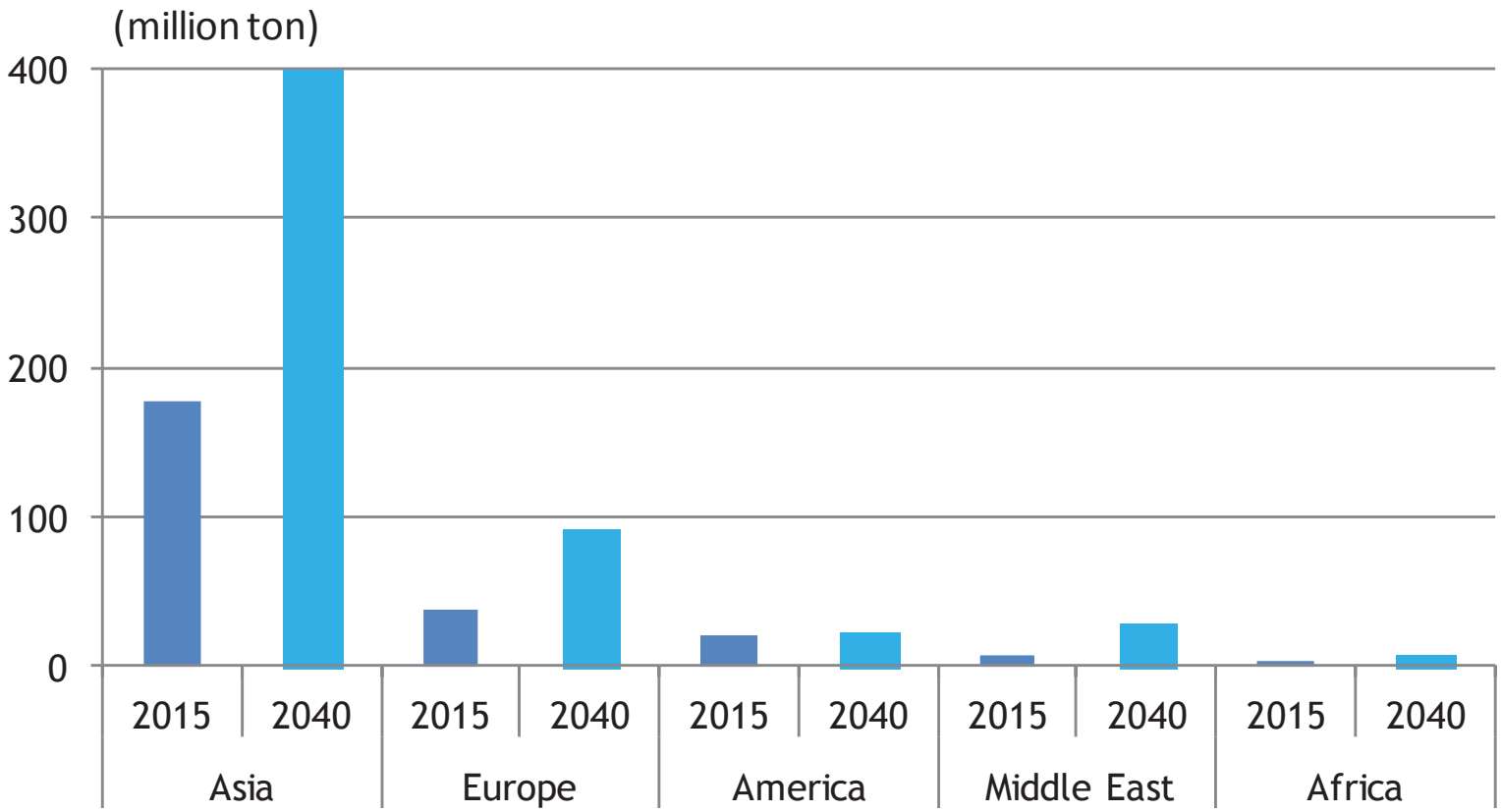
**0.3** Gtoe
**(23%)**
reduction

**2014**
**0.55** Gtoe
(**666** Bcm)
(**0.45** Gt of LNG-eq)
↓
**2040**
Reference
**1.34** Gtoe
(**1.62** Tcm)
(**1.09** Gt of LNG-eq)
**Adv. Tech.**
**1.03** Gtoe
(**1.25** Tcm)
(**0.84** Gt of LNG-eq)

- Natural gas consumption in China considerably increases (5.2%/y) due mainly to the increasing consumption for power generation and use in urban areas. India's natural gas consumption also expands but at a similar pace (5.5%/y), representing more than a four-fold increase from 2014 to 2040.
- In the Advanced Technologies Scenario, the Asia natural gas consumption is 325 Bcm (or 19%) lower than the Reference Scenario by 2040. Even in this scenario, natural gas consumption increases at a relatively fast pace of 3.7% per year through 2040.

# LNG imports (world)

Reference Scenario



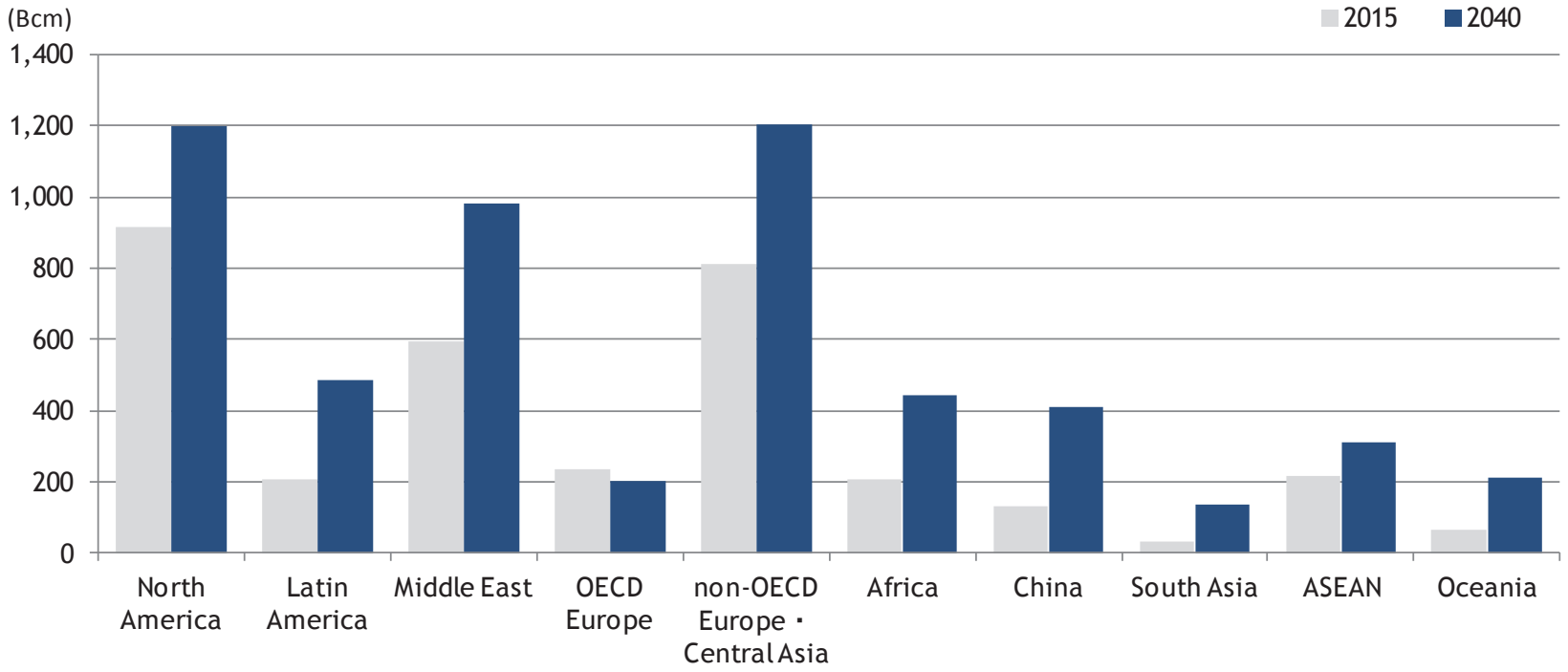

- World LNG demand expands from 245 million tons in 2015 to 547 Mt in 2040 (2.2 times).
- Asia's LNG demand increases by 222 Mt, accounting for about 70% of the world's LNG demand growth, whereas the growth in Europe (53 Mt) accounts for around 20%. LNG import from North America to Latin America increases by 3 Mt.
- LNG supply capacity is sufficient to meet demand if new LNG projects starts on schedule in the future.

# Natural gas production (world)

Reference

**Production in 2040**
**5,700** Bcm
**+2,202** Bcm from 2015

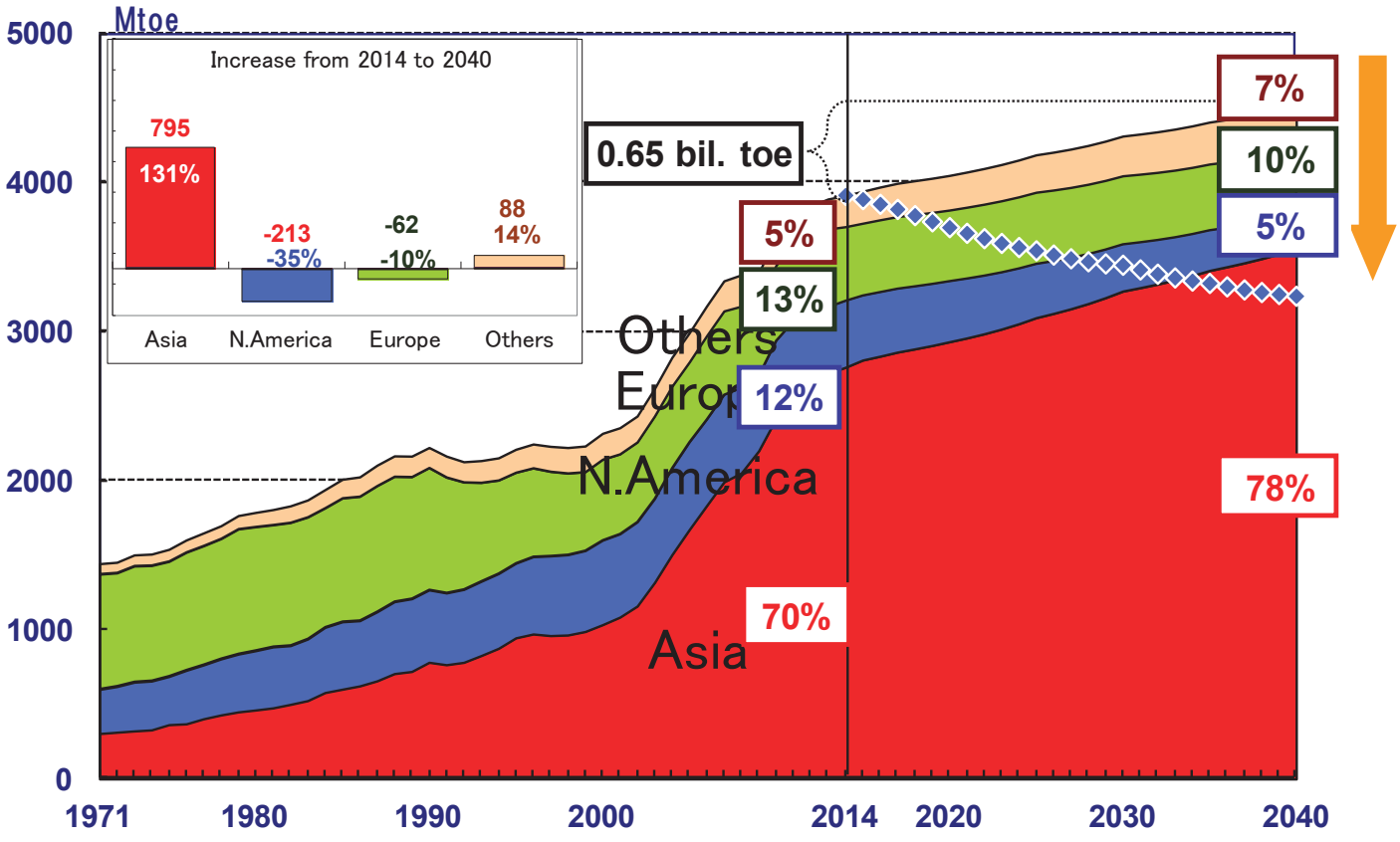
**Shares of the increase**
**North & Latin Americas 26%**
**Middle East 18%**
**Africa 11%**




- Natural gas production expands to meet the increasing demand around the world especially in North America, the Middle East, Russia, Africa, China, India and Australia.
- Unconventional gas is to be commercialized gradually in Latin America, the Middle East, non-OECD Europe/Central Asia, and OECD Europe in addition to North America and China.

# Coal consumption by region (world)

Reference Scenario
Advanced Technologies Scenario




**1.5** Gtoe
**(28%)**
reduction

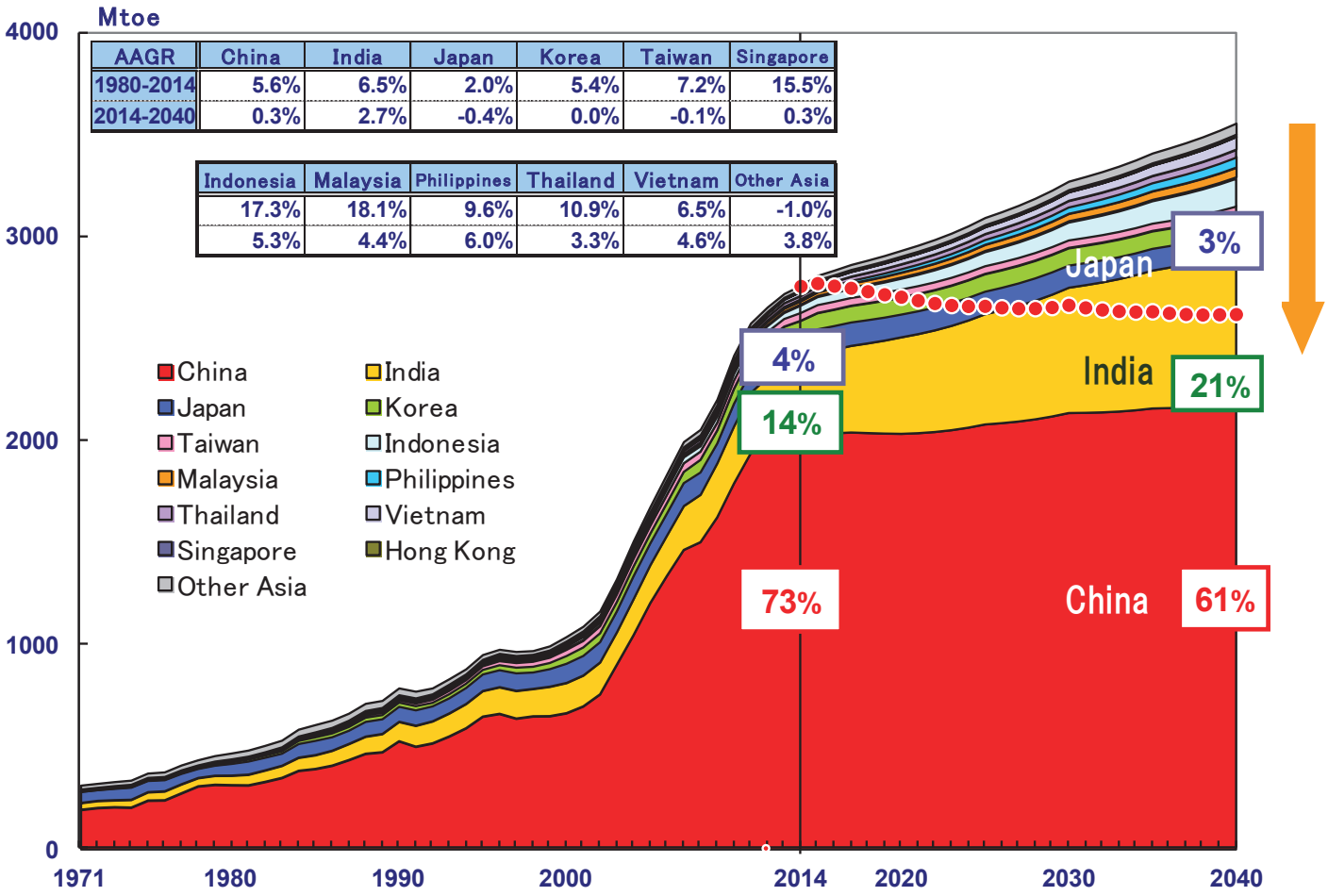
**2014**
**3.9** Gtoe
(**5.6** Gtce*)
↓
**2040**
**Reference**
**4.5** Gtoe
(**6.5** Gtce*)
**Adv. Tech.**
**3.2** Gtoe
(**4.6** Gtce*)

*Tons of coal equivalent

- Asia accounts for about 80% of the world coal consumption growth through 2040. The share of Asia in total coal consumption expands to 78% in 2040 from 70% in 2013.
- In the Advanced Technologies Scenario, the world coal consumption in 2040 is 1.2 billion toe (or **28**%) lower compared with the Reference Scenario.

# Coal consumption by country (Asia)

Reference Scenario
Advanced Technologies Scenario




| AAGR | China | India | Japan | Korea | Taiwan | Singapore |
|---|---|---|---|---|---|---|
| 1980-2014 | 5.6% | 6.5% | 2.0% | 5.4% | 7.2% | 15.5% |
| 2014-2040 | 0.3% | 2.7% | -0.4% | 0.0% | -0.1% | 0.3% |

| Indonesia | Malaysia | Philippines | Thailand | Vietnam | Other Asia |
|---|---|---|---|---|---|
| 17.3% | 18.1% | 9.6% | 10.9% | 6.5% | -1.0% |
| 5.3% | 4.4% | 6.0% | 3.3% | 4.6% | 3.8% |

**1.1** Gtoe
**(31%)**
reduction

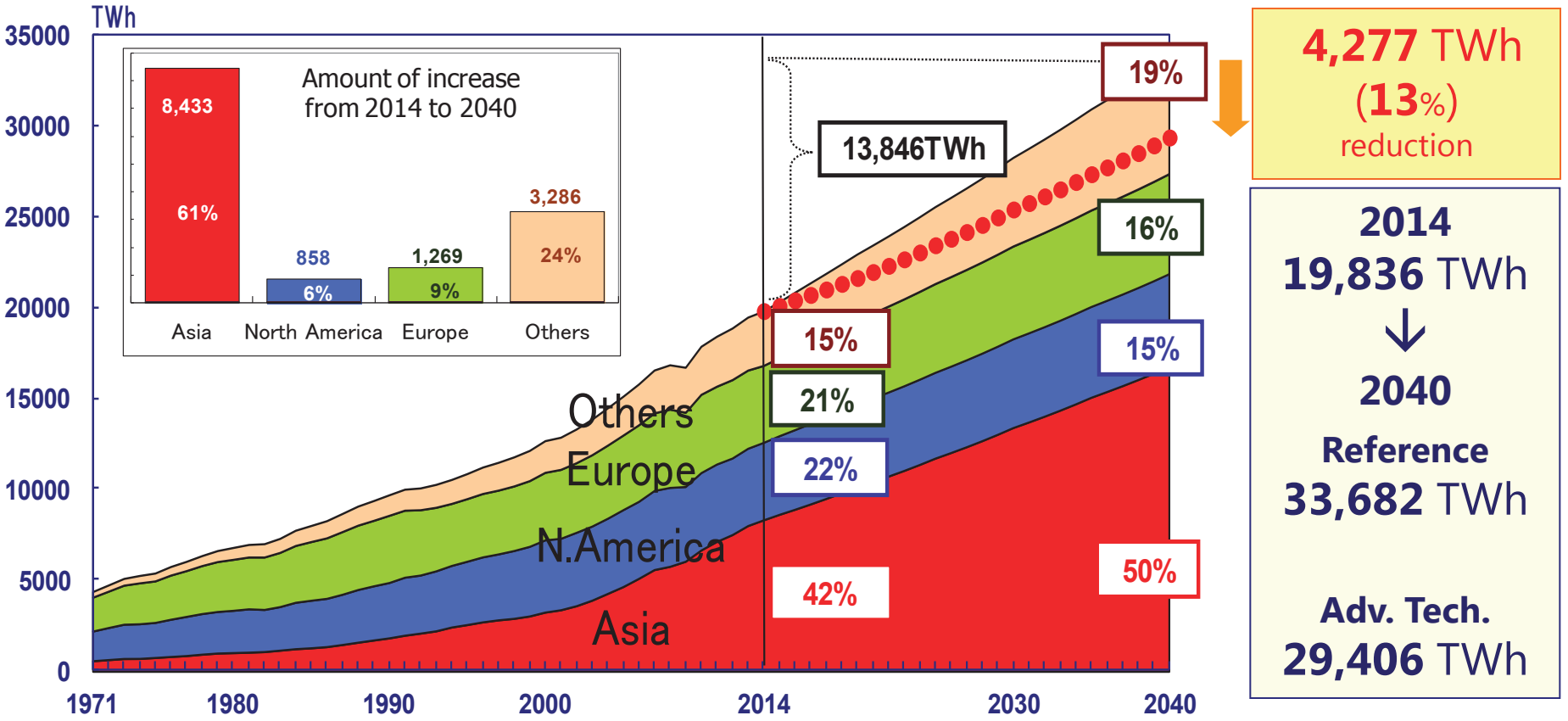
**2014**
**2.8** Gtoe
(**3.9** Gtce*)
↓
**2040**
**Reference**
**3.6** Gtoe
(**5.1** Gtce*)
**Adv. Tech.**
**2.5** Gtoe
(**3.5** Gtce*)

*Tons of coal equivalent

- The power sector, mainly in China and India, drives coal consumption. Both those countries have abundant domestic coal reserves.
- In the Advanced Technologies Scenario, coal consumption in Asia by 2040 is 1.1 billion toe (or 31%) lower due to a shift to natural gas and the enhancement of power generation efficiency compared to the Reference Scenario.

# Electricity consumption by region (world)

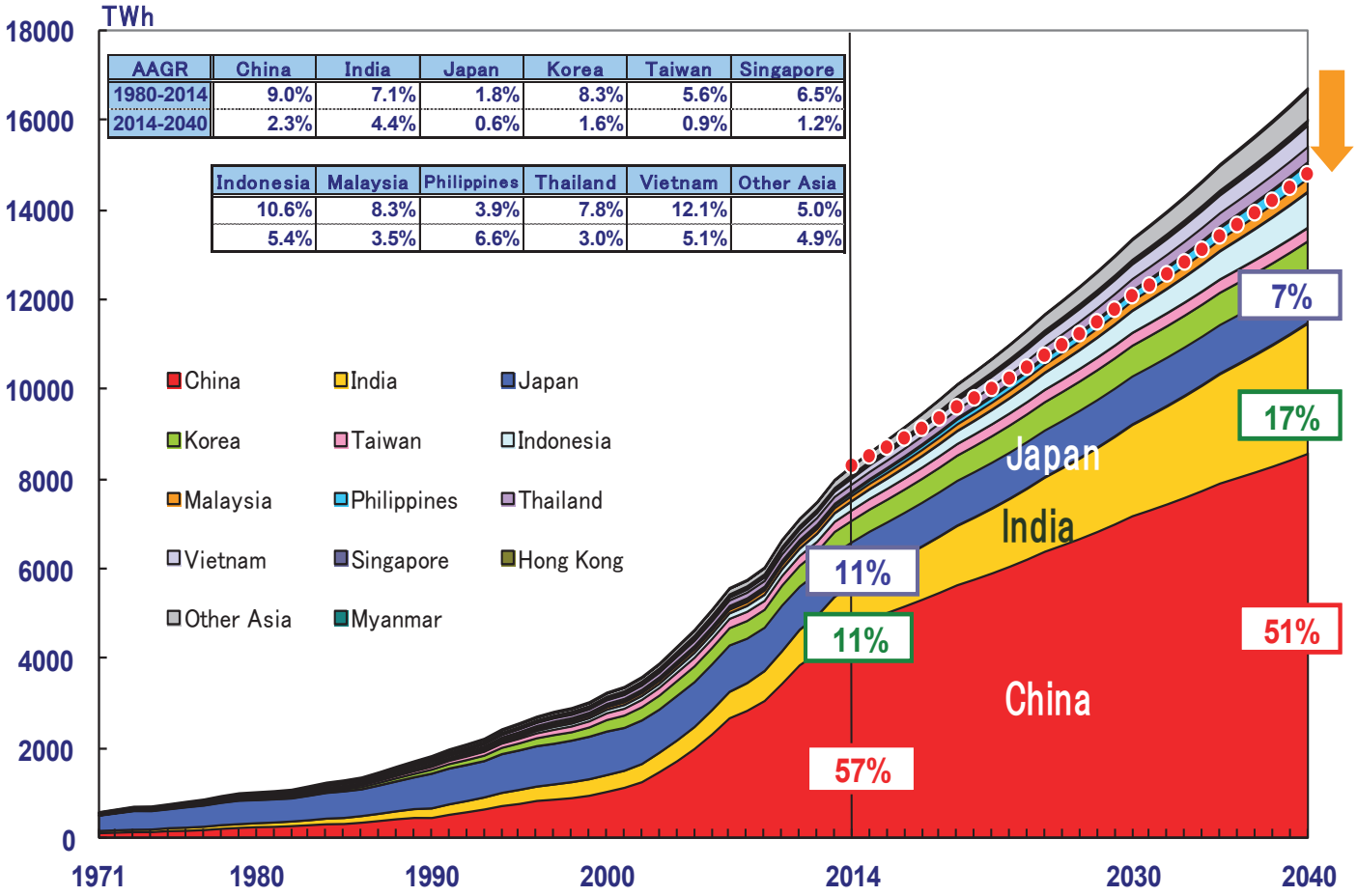
Reference Scenario
Advanced Technologies Scenario




- Asia accounts for 60% of the world electricity consumption growth through 2040, and the share of Asia in total electricity consumption expands to almost 50%.
- In the Advanced Technologies Scenario, the world electricity consumption in 2040 is 4,277 TWh (or 13%) lower compared to the Reference Scenario.

# Electricity consumption by country (Asia)

Reference Scenario
Advanced Technologies Scenario




| AAGR | China | India | Japan | Korea | Taiwan | Singapore |
|---|---|---|---|---|---|---|
| 1980-2014 | 9.0% | 7.1% | 1.8% | 8.3% | 5.6% | 6.5% |
| 2014-2040 | 2.3% | 4.4% | 0.6% | 1.6% | 0.9% | 1.2% |

| Indonesia | Malaysia | Philippines | Thailand | Vietnam | Other Asia |
|---|---|---|---|---|---|
| 10.6% | 8.3% | 3.9% | 7.8% | 12.1% | 5.0% |
| 5.4% | 3.5% | 6.6% | 3.0% | 5.1% | 4.9% |

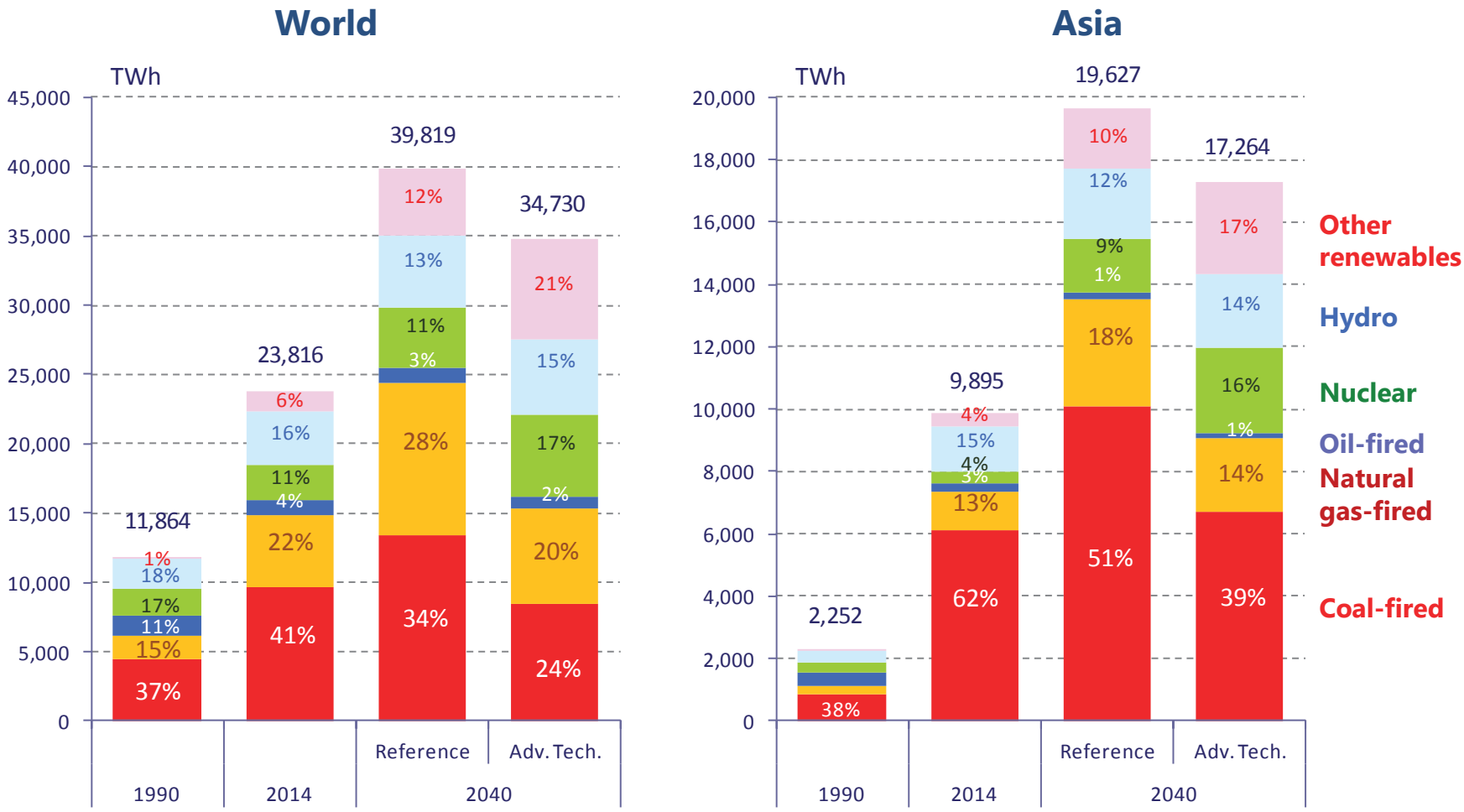
**1,929 TWh (12%) reduction**

**2014**
**8,329 TWh**
↓
**2040**
**Reference**
**16,764 TWh**

**Adv. Tech.**
**14,835 TWh**

- Electricity consumption in Asia increases rapidly driven by the improvement of living standards. Electricity consumption in China expands 182% by 2040, and India expands 307% during the same period.
- Through 2040, electricity consumption increases at a faster rate than final energy consumption (Reference Scenario at 2.7%, and Advanced Technologies Scenario at 2.2% per year).

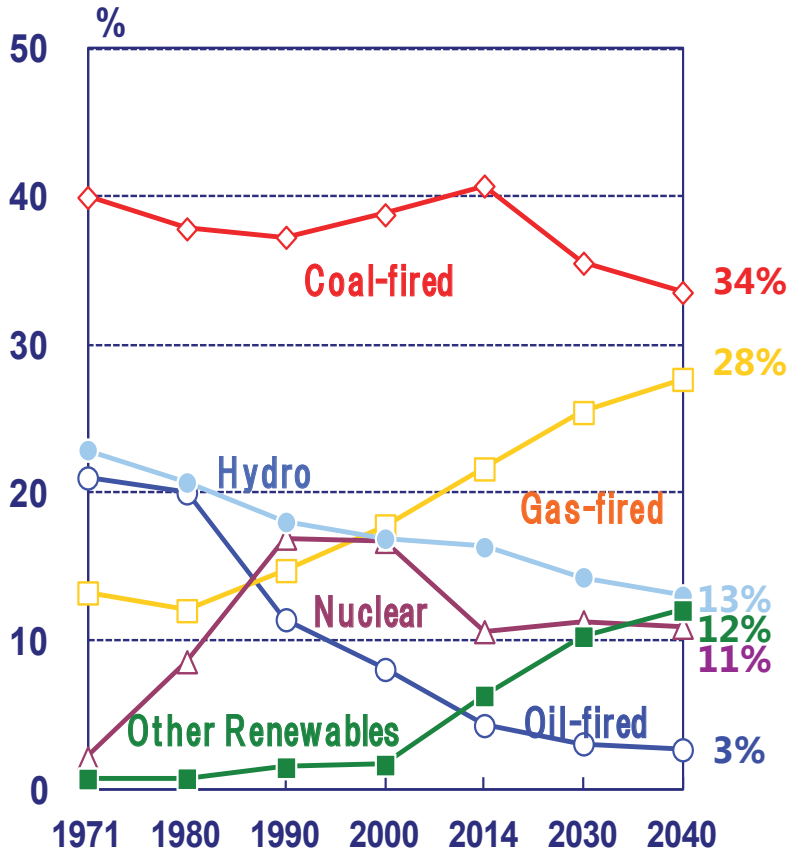
# Power generation mix in 2040



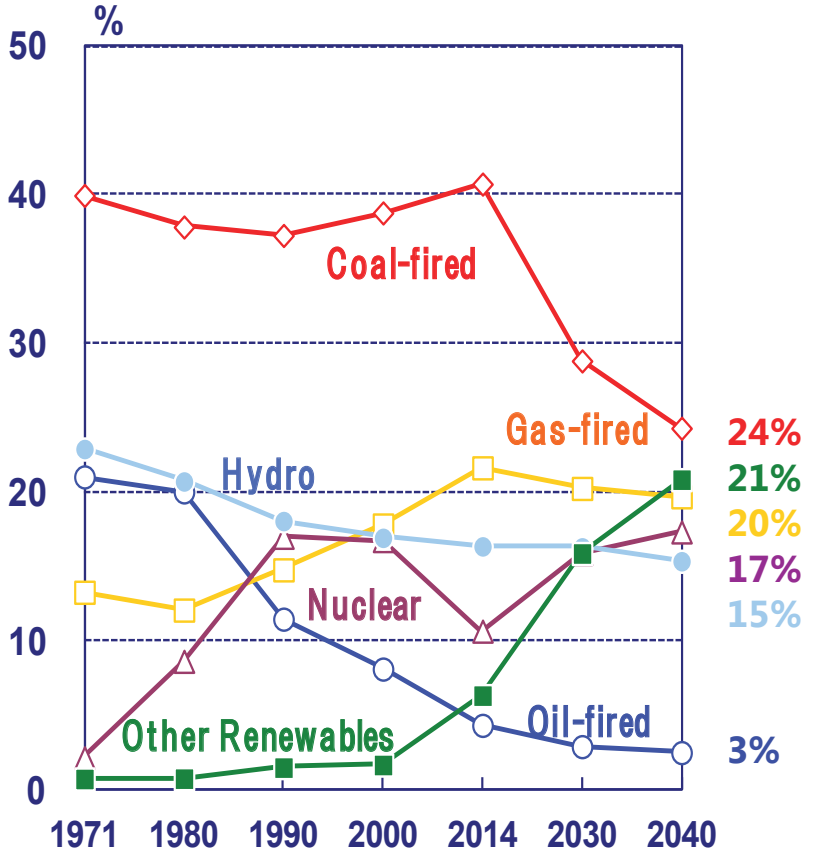

- In 2040, coal still accounts for the largest share of power generation. Natural gas-fired power plants globally increase on the introduction of natural gas combined cycle plants. Renewable energy sources including wind and solar energy also expand their share of power generation.
- In the Advanced Technologies Scenario, coal's share of power generation declines to 24%, while nuclear, hydro and other renewables expand their respective shares.

# Power generation mix (world)

## Reference Scenario



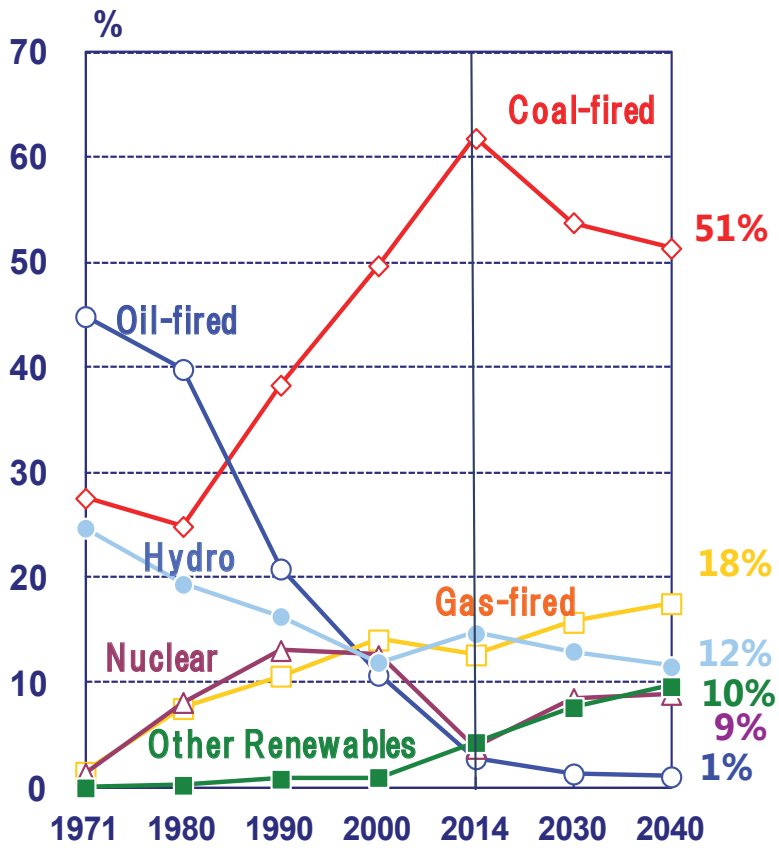

## Advanced Technologies Scenario



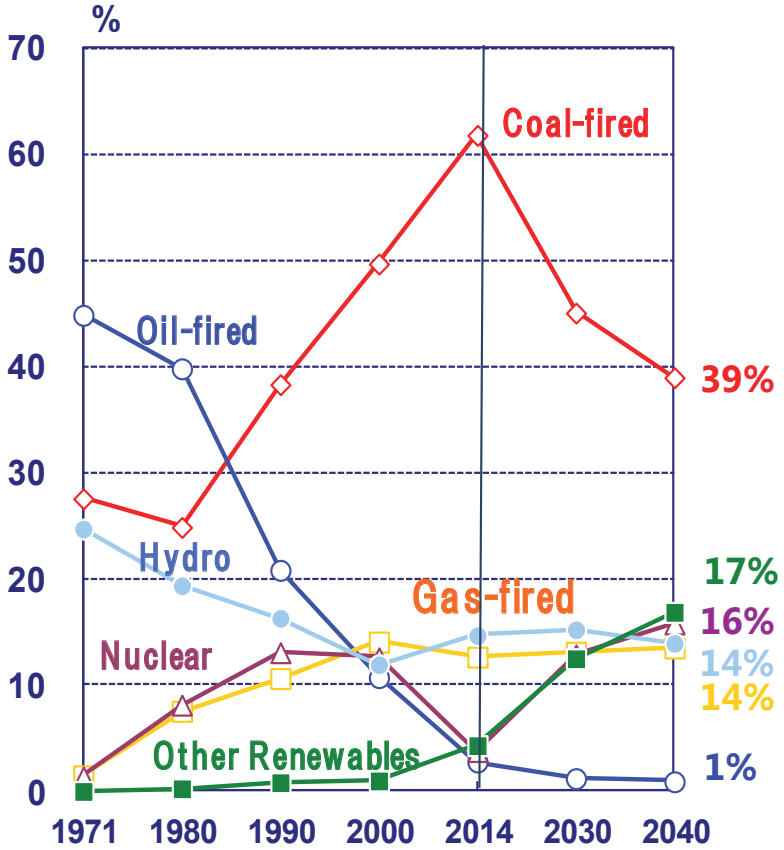

- In the Reference Scenario, coal maintains the biggest share in the power generation mix by 2040.
- In the Advanced Technologies Scenario, the share of coal-fired power generation decreases substantially, while that of renewable energy increases. Renewable energy will be the second highest share next to coal-fired.

# Power generation mix (Asia)

## Reference Scenario



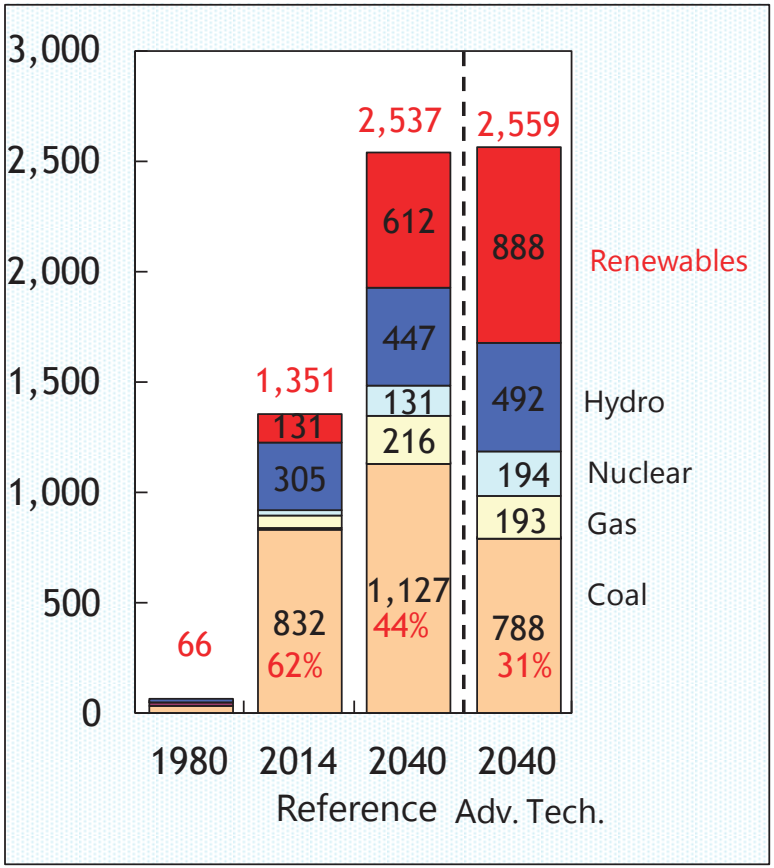

## Advanced Technologies Scenario



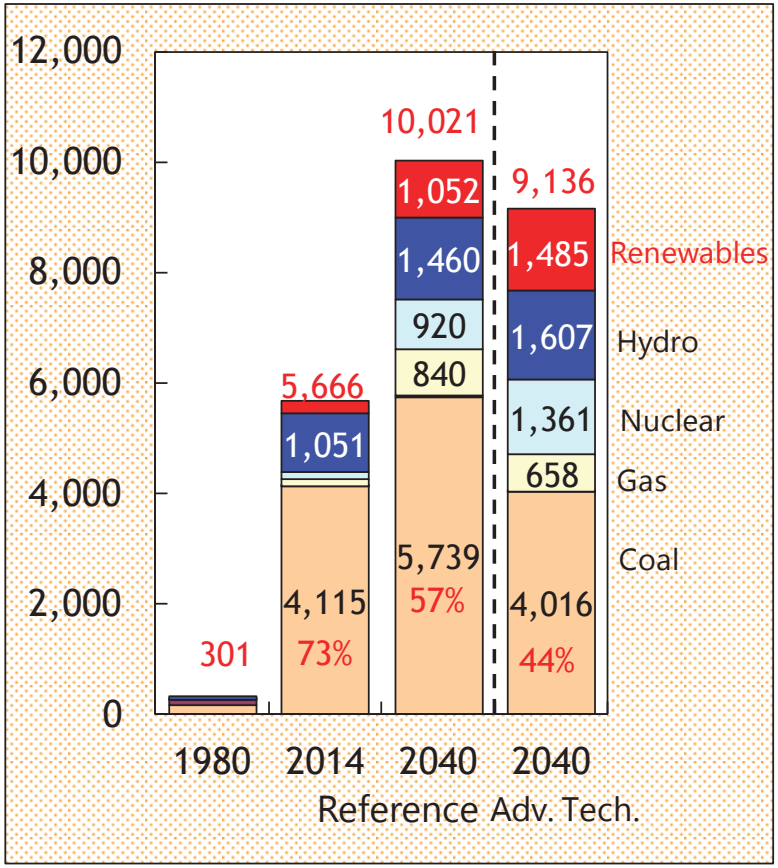

- In Asia, the share of coal-fired power generation remains the highest in order to meet a growing electricity consumption.
- In the Advanced Technologies Scenario, the share of coal-fired power generation decreases substantially, substituted by increases in renewable energy, hydro and nuclear shares.

# Power generation mix in China

## Capacity (GW)



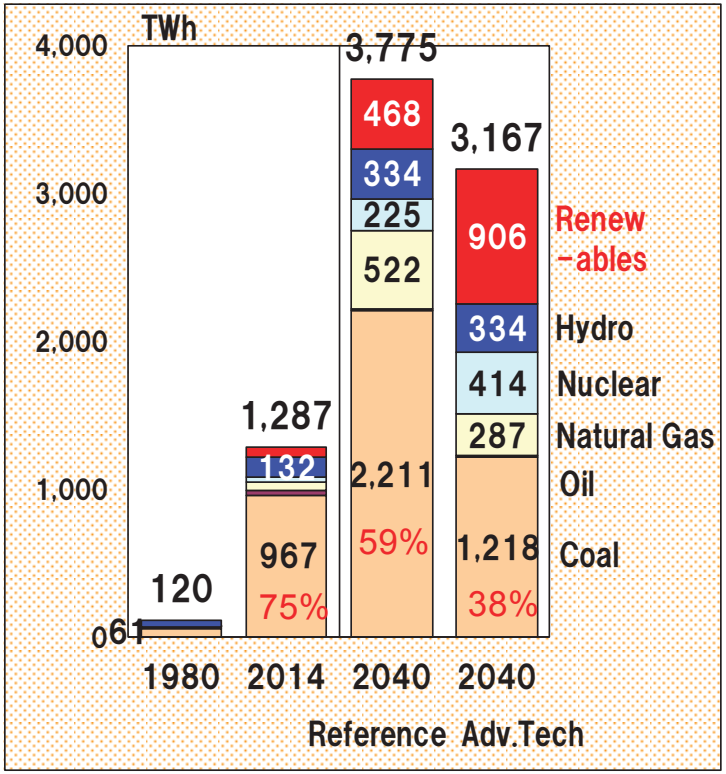

## Power generation (TWh)



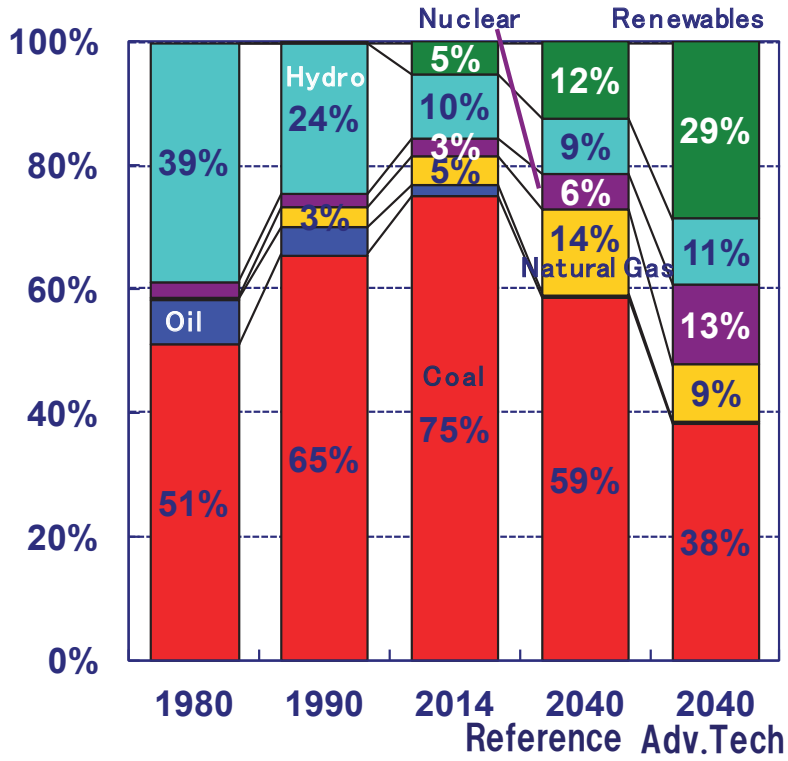

- Total power generation capacity increases on average by 46 GW per year, from 1,351 GW in 2014 to 2,537 GW in 2040. The share of coal-fired power plant gradually declines to 44% in 2040.
- Total power generation increases 77%, from 5,666 TWh in 2014 to 10,021 TWh in 2040. The share of coal-fired power generation declines from 73% in 2014 to 57% in 2040.
- Power generation from gas-fired, nuclear and renewables substantially increase.
- In the Advanced Technologies Scenario, generation from nuclear, hydro and renewable energy sharply expand to substitute a further decline in coal-fired power generation.

# Power generation mix in India

## Power generation

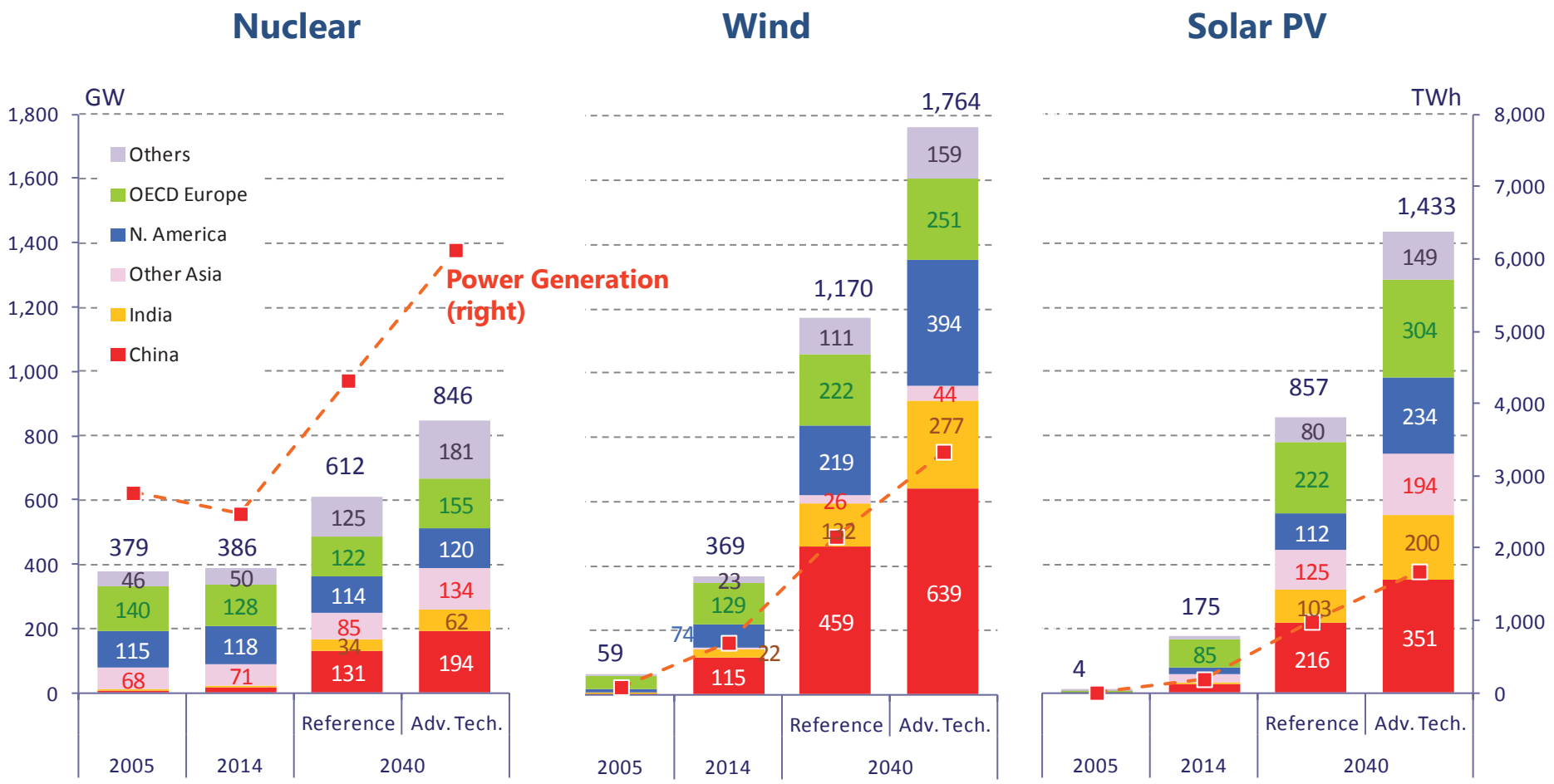



## Power generation mix




- On the other hand, the share of natural gas and nuclear gradually expands and power generation mix becomes more diversified.
- Nuclear capacity increases from 5.8 GW in 2015 to 34 GW in 2040 (x5.9) in reference scenario, 62 GW in 2040 (x10.8) in Advanced Technologies Scenario.

# Nuclear and renewable power generation capacities

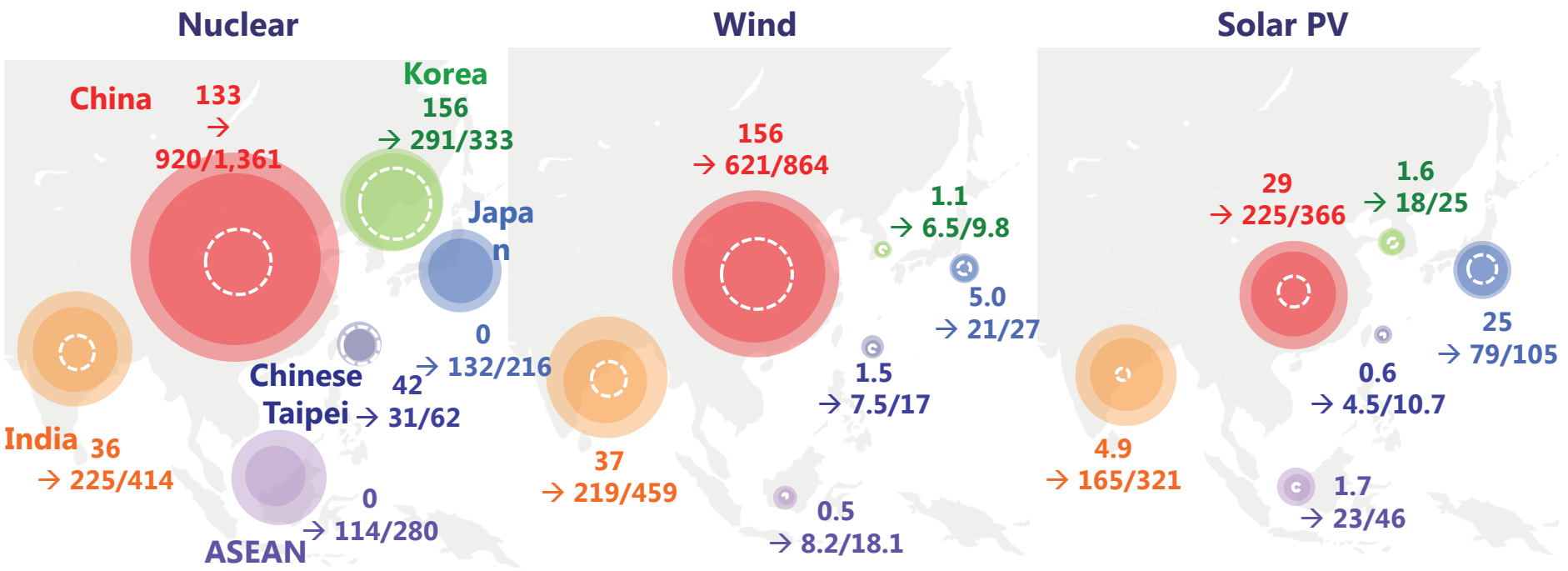



- In the Reference Scenario, global nuclear, photovoltaic generation capacity, and wind power expand x1.6, x3.2, and x4.9, respectively, from 2014 to 2040. In the Advanced Technologies Scenario they are x2.2, x4.8, and x8.2, respectively.
- In particular, expansions in Asia are significant and China and India account for nearly half in all technologies in the Advanced Technologies Scenario.

# Nuclear and renewables power generation expansion in Asia

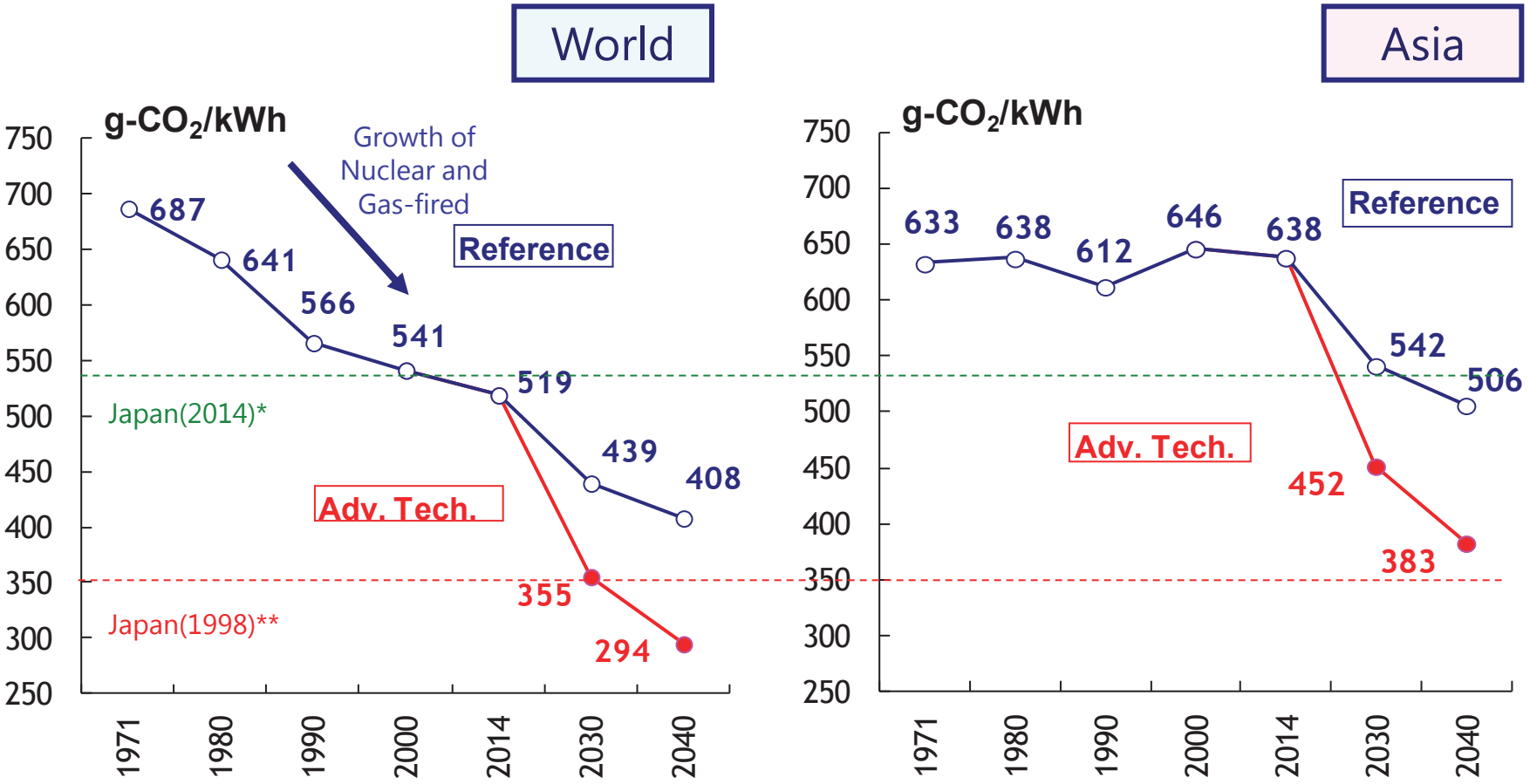
Unit: TWh

2014 (dashed line)
→2040 Reference (inner circle)
/ 2040 Adv. Tech. (outer circle)




・Nuclear power generation will continue to increase in China, India and Korea. Viet Nam becomes the first country to operate a nuclear power plant in Southeast Asia, followed by other ASEAN countries.
・Wind power expands in China and India. Its diffusion in ASEAN will be limited because of the complex topography.
・Solar power grows at the highest rate. Due to the low capacity factors, however, it falls behind wind power in terms of electricity generated.

# Carbon intensity of electricity ($CO_2$ emissions per kWh)



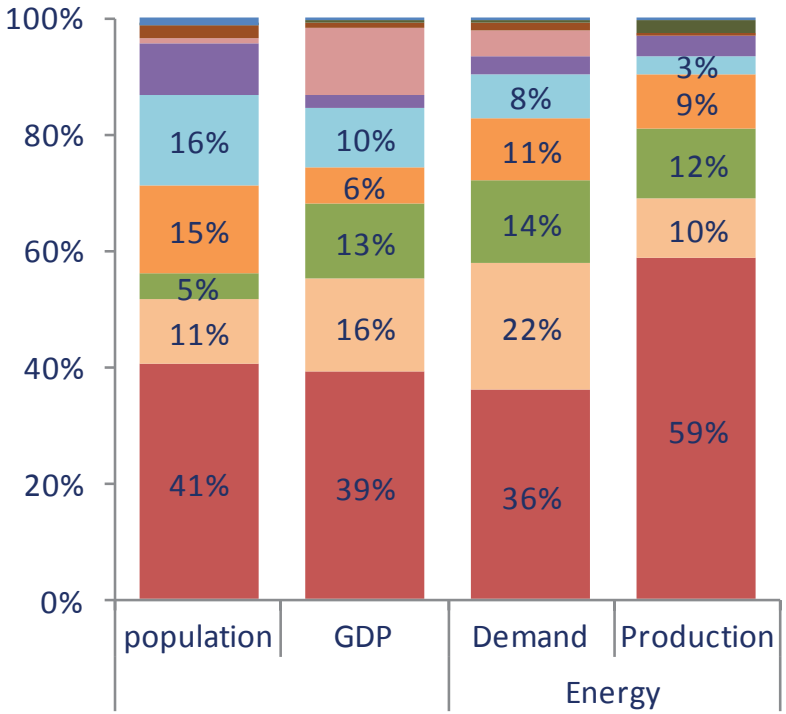

*540 g-$CO_2$/kWh **350 g-$CO_2$/kWh

- The average $CO_2$ emissions per kWh is reduced substantially reflecting the expansion in nuclear and renewable energy as well as efficiency improvements in fossil-fired power generation.
- In the Advanced Technologies Scenario, the average $CO_2$ emissions per kWh in the world in 2040 are 43% less than the 2014 level. In Asia, the reduction reaches 40%.

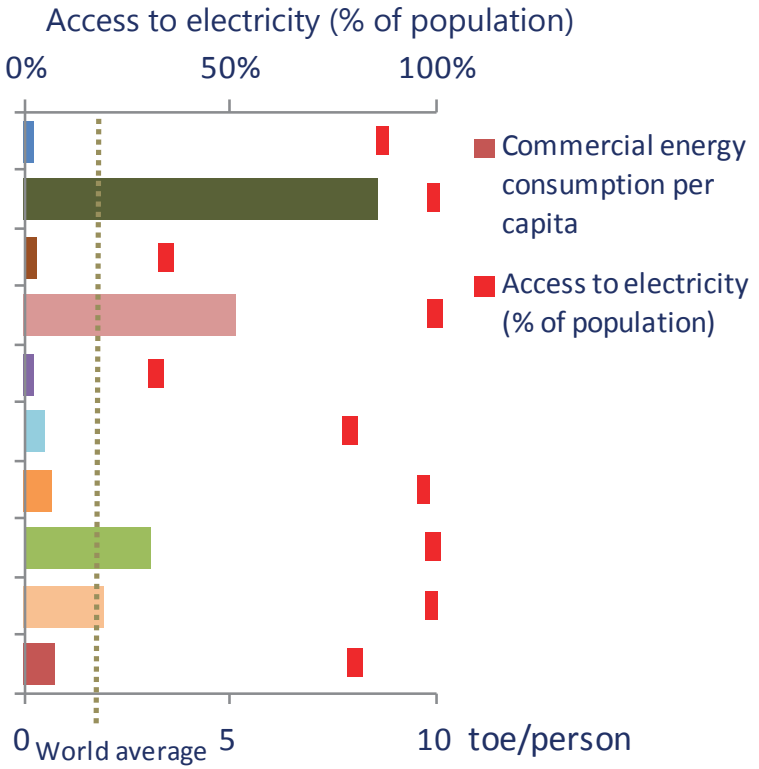
# ASEAN energy outlook

# ASEAN: Huge market, varying economy and society

## Shares of ASEAN members



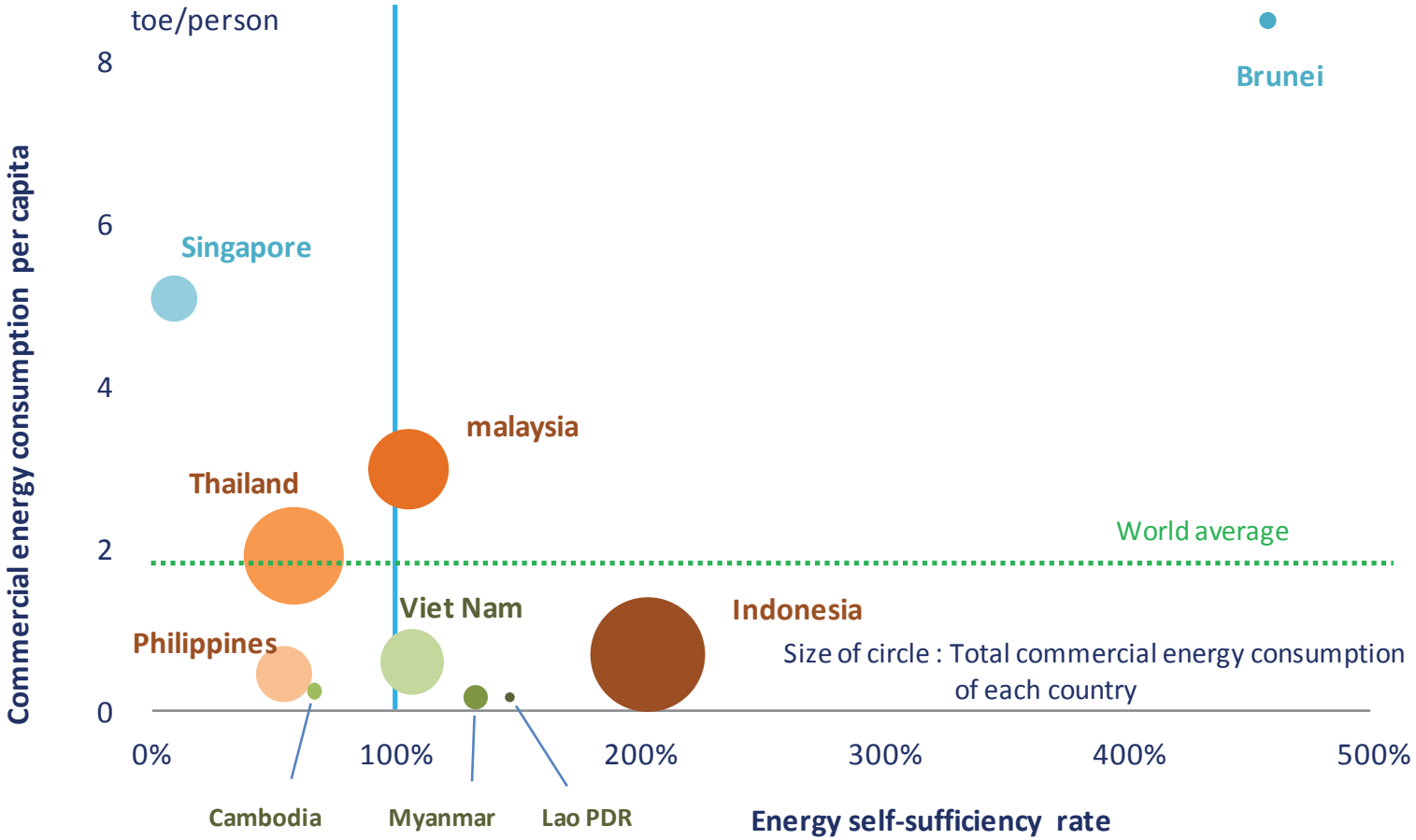

## Commercial energy consumption per capita and access to electricity




- ✓ ASEAN, with 600 million population, closes to the huge markets of China and India, has large economic growth potential.
- ✓ The 10 members highly diverse in economic scale, living level, and energy supply and demand structure.

# ASEAN: Huge market, varying economy and society

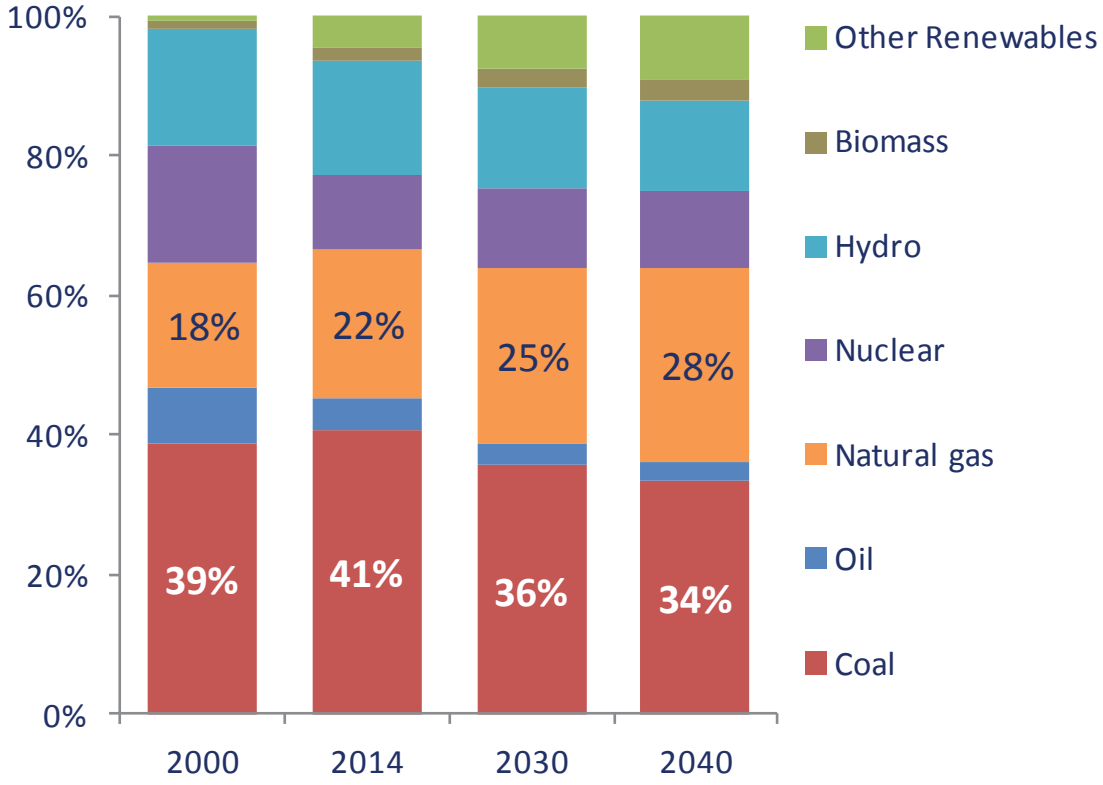
## Energy self-sufficiency rate and energy consumption per capita in 2014



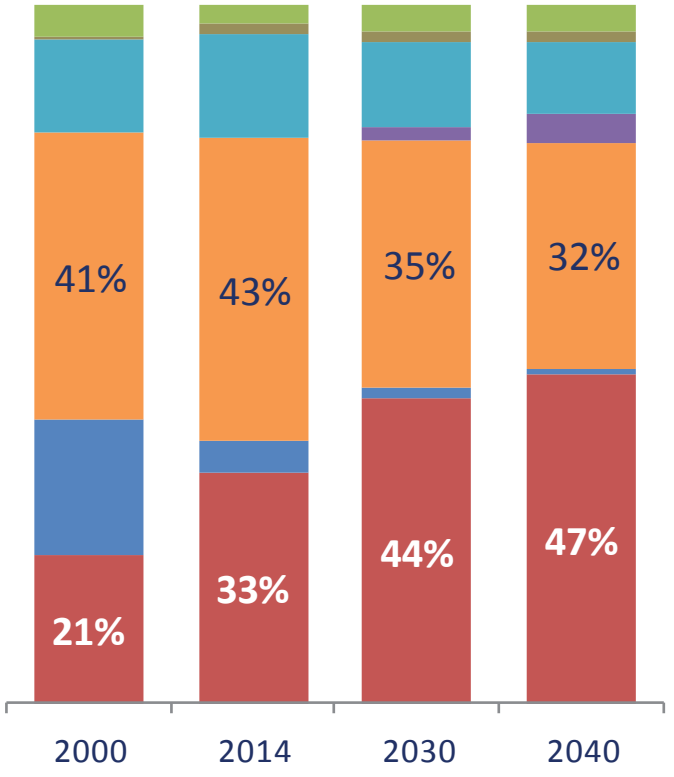

- ✓ ASEAN, with 600 million population, closes to the huge markets of China and India, has large economic growth potential.
- ✓ The 10 members highly diverse in economic scale, living level, and energy supply and demand structure.

# AESAN differs from the world trend in power generation mix

## Power generation mix of world




## Power generation mix of ASEAN



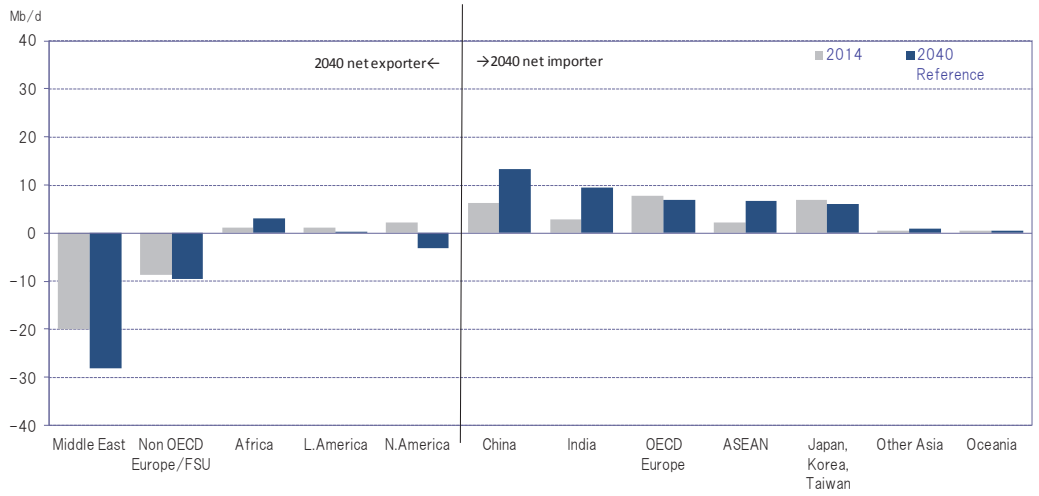

- ✓ To meet the tripled electricity demand, ASEAN will utilize the cheap and abundant resource of coal.
- ✓ While the world trend is to increase the share of natural gas in power generation, ASEAN is going to raise its dependency on coal.

# Fossil fuel international trade

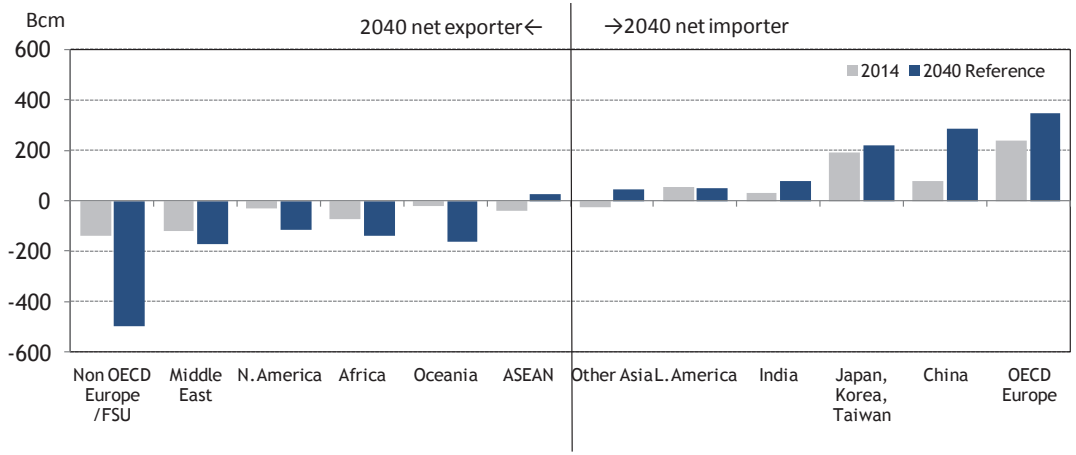
# Oil and natural gas net imports

Reference Scenario

## Oil

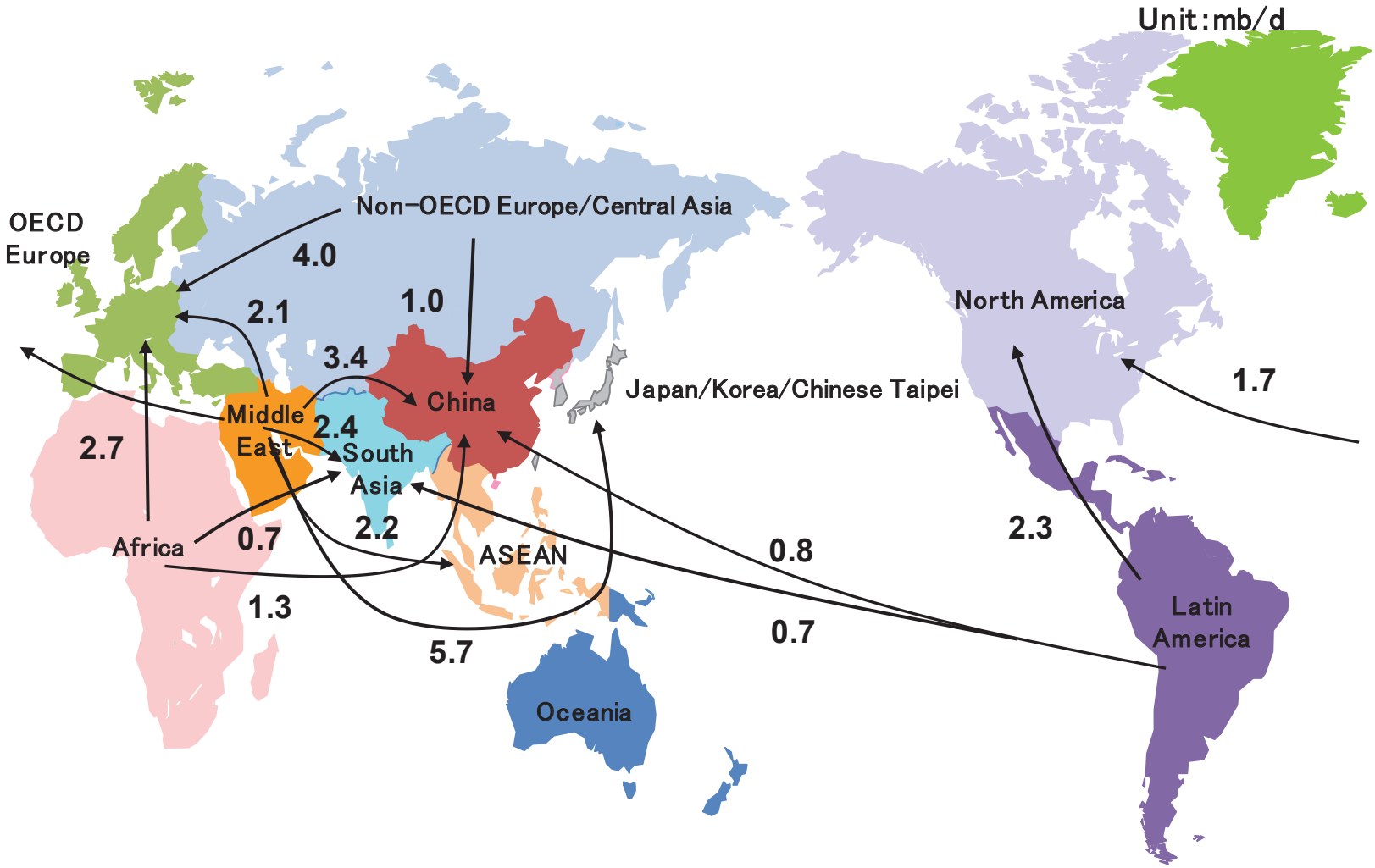



## Natural gas



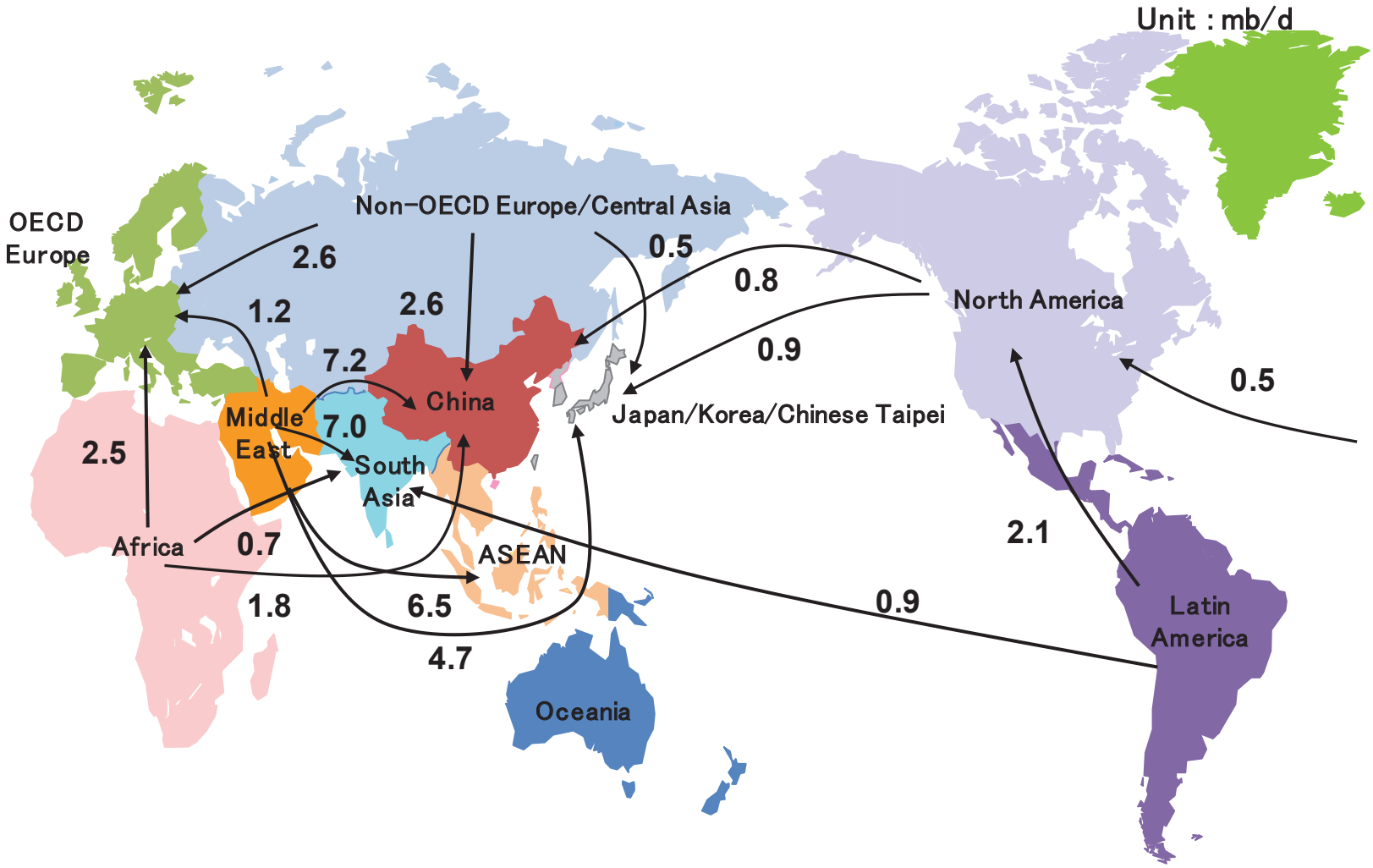

- While oil consumption expands in Asia up to 2040, North America turns into an exporting region.
- Oil production increase in the Middle East is imperative in correspondence with Asian consumption increase.
- Asia also increases natural gas imports. Exports from North America increase largely.

# Major crude oil trade flows (2015)



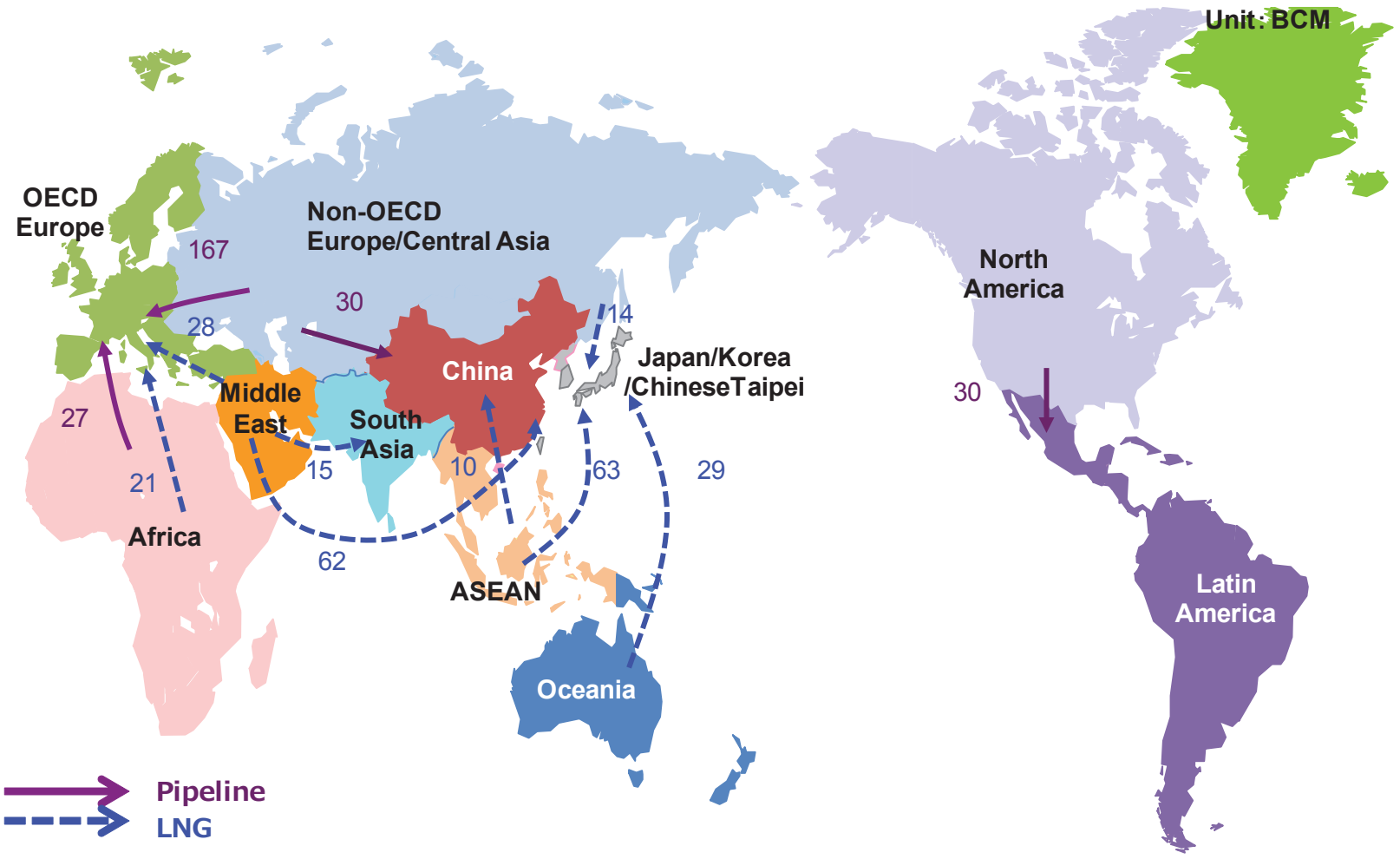

- This chart shows the crude oil flows for 2015, from production region such as the Middle East, Africa, Non-OECD/Central Asia, and Latin America, to consumption region such as North America, Asia, and Europe in the world.

# Major crude oil trade flows (Reference Scenario, 2040)



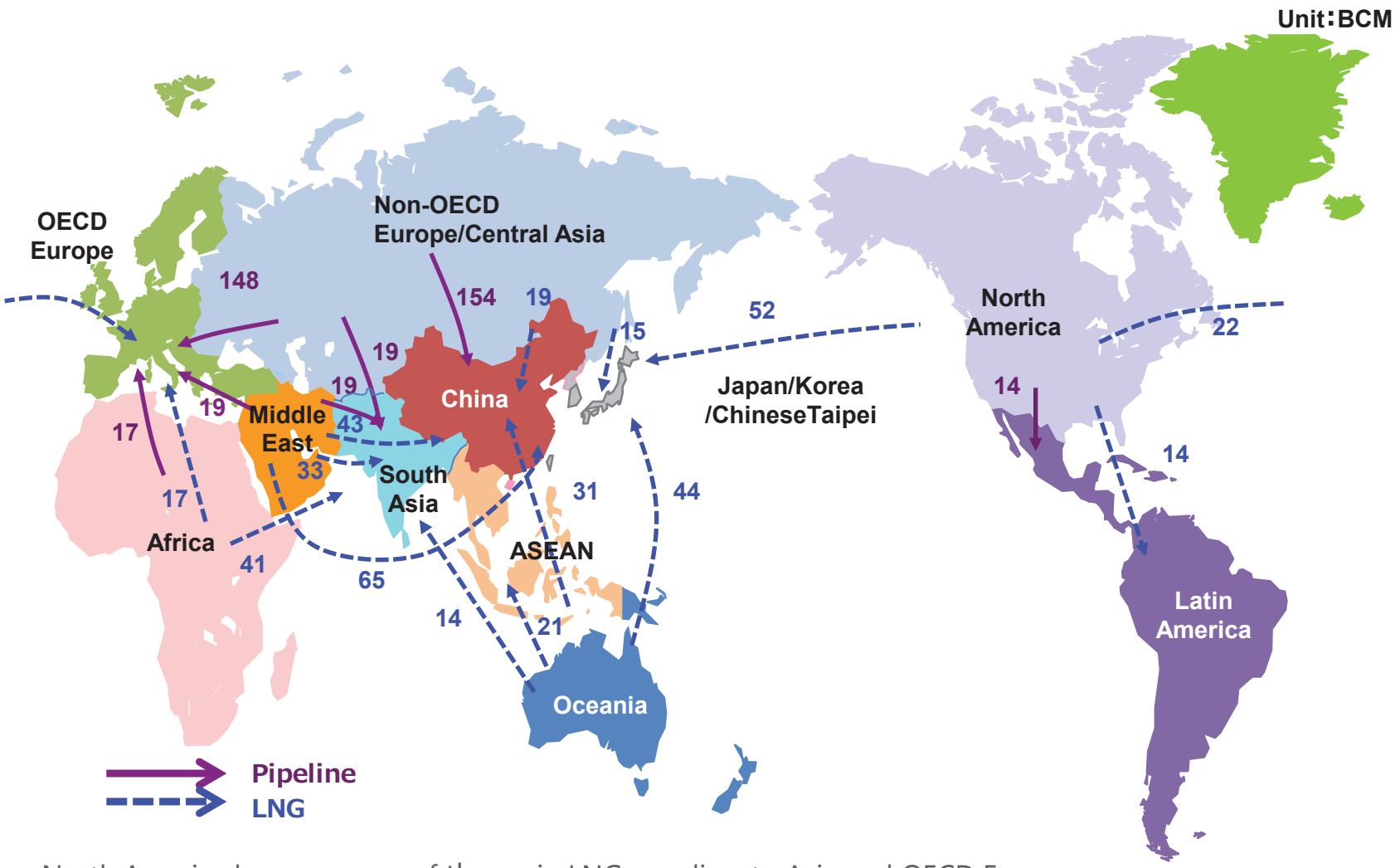

- China's crude oil imports reach 12 Mb/d and increase imports from multiple regions such as the Middle East, Africa, Non-OECD Europe/Central Asia.
- Crude oil exports from the Middle East to North America become zero.

# Major natural gas trade flows (2015)




- In 2015, pipelines are used mainly to transport natural gas from Non-OECD Europe/Central Asia to OECD Europe while LNG is transported from ASEAN, Oceania, the Middle East to Japan/Korea/Chinese Taipei.

# Major natural gas trade flows (Reference Scenario, 2040)



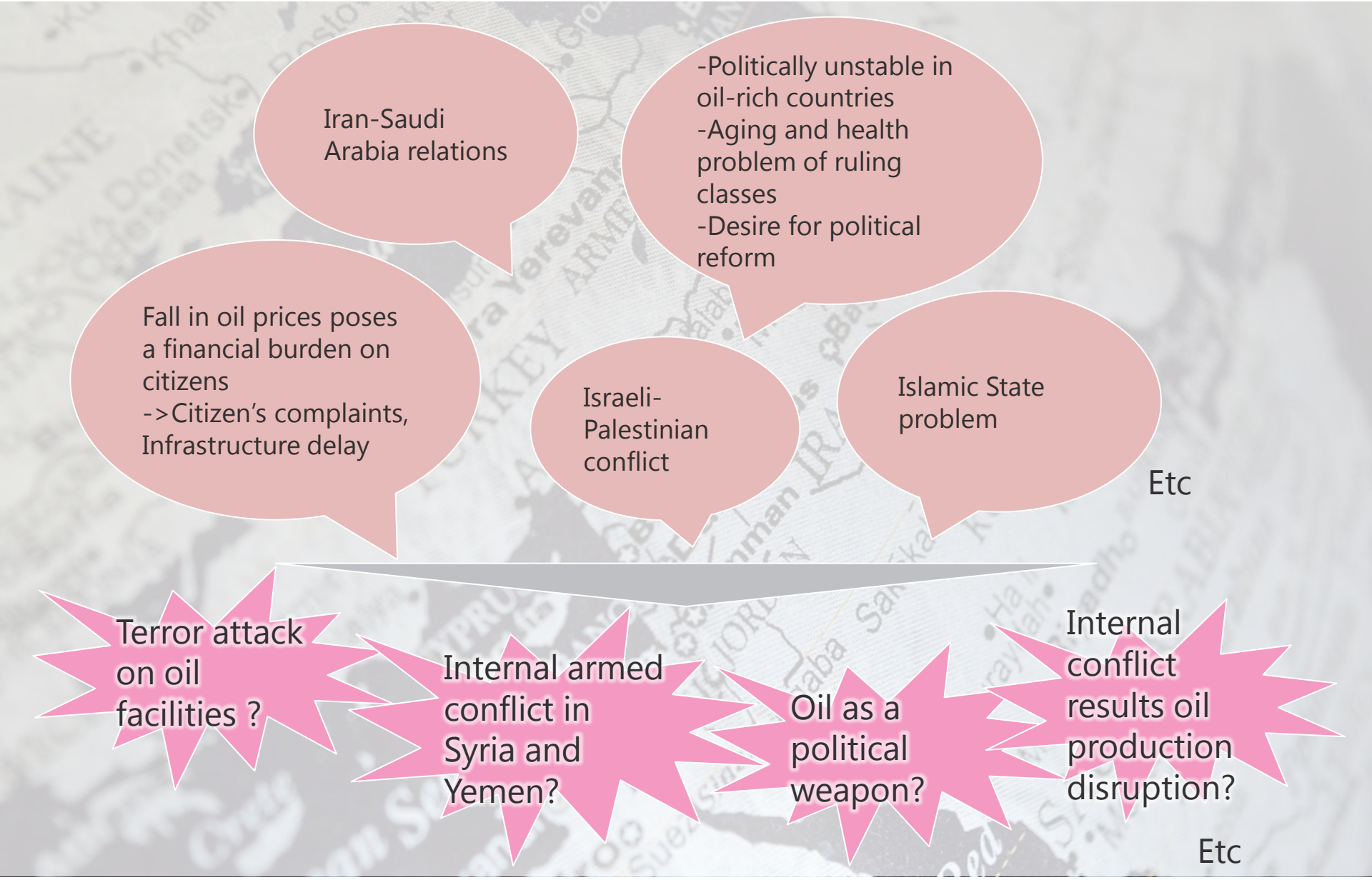

- North America becomes one of the main LNG suppliers to Asia and OECD Europe.
- China and South Asia moreover increase imports from traditional producers such as Non-OECD Europe/Central Asia and the Middle East.

# Energy Security

# Energy Crises

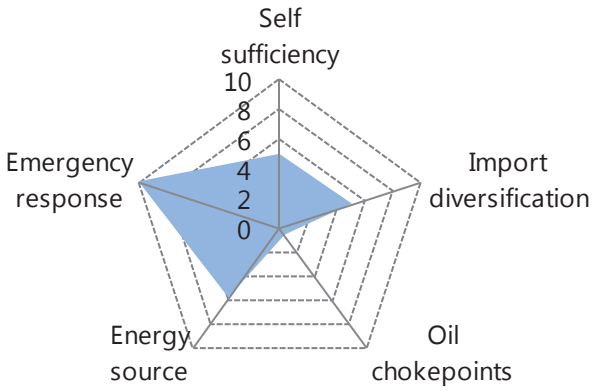
| The 1st oil crisis | The 2nd oil crisis | The Ukraine crisis |
|---|---|---|
| 1973-1974 | 1978-1982 | 2006～ |
| The fourth Arab-Islaeli war results OPEC Gulf states raised oil price.<br>Arab OPEC members extended the embargo to countries that supported Israel including the Netherlands and US. | -Iran's crude oil export stopped in the awake of the Iranian Revolution.<br>-OPEC stated raise oil price.<br>-The situation of quantitatively shortage of crude oil as in the first oil crisis was avoided. | [2006] Russia cut off 30% of natural gas deliveries to Ukraine.<br>Ukraine caused a drop in pressure throughout EU's integrated natural gas pipeline system.<br>[2009]Russia cut off gas deliveries to Ukraine and EU. |
| Arabian light oil<br>1973: $2.83/bbl<br>1974: $10.41/bbl | Arabian light oil<br>1978: $13.03/bbl<br>1980: $35.69/bbl | No significant rise in natural gas prices in the EU |
| World oil share<br>1973: 46% | World oil share<br>1979: 44% | EU natural gas share<br>2006: 24%<br>2009: 25% |

# Middle East Concern

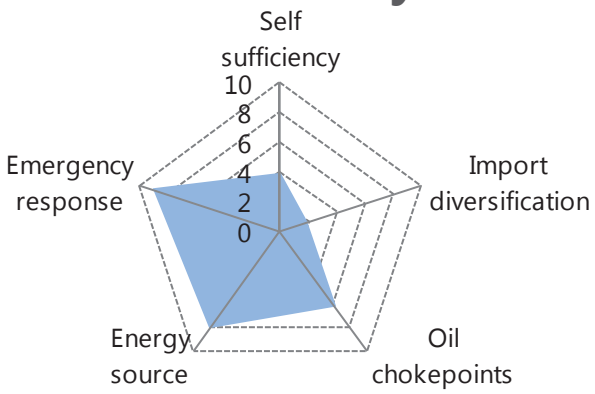


# Energy security index

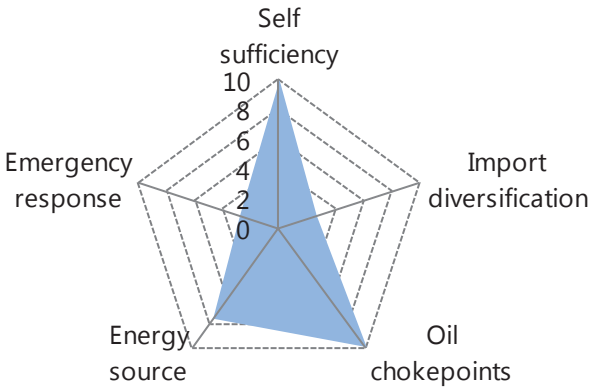
## France



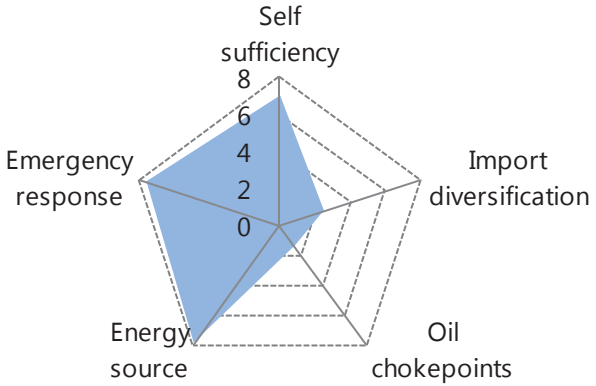

## Germany



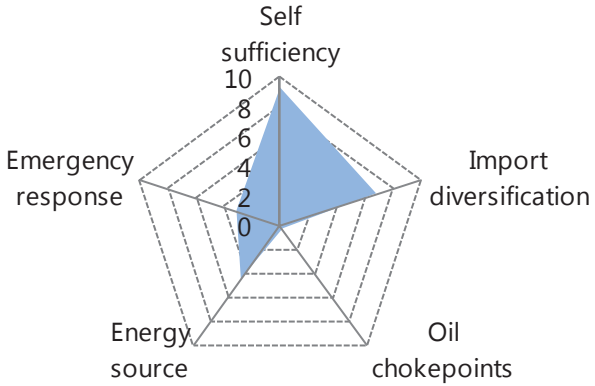

## UK



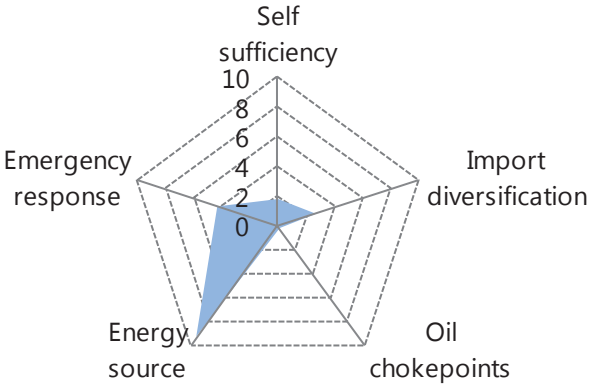

## US




## China




## Japan




(1)Development and utilization of domestic energy resources
…Self sufficiency ratio (including nuclear)
(2)Diversification of import sources
… Oligopoly of import resource

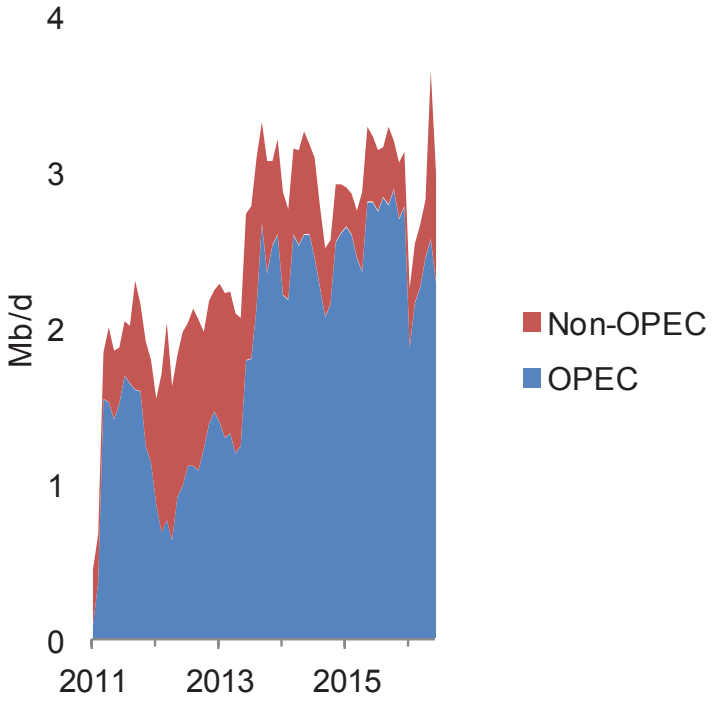
(3)Energy transportation risk management
…Depend on chokepoints
(4)Diversification of energy sources
…Primary energy source
…Electricity generation structure

(5)Responding to oil disruption
… Oil stock level in days

Source: 2010 Energy white paper

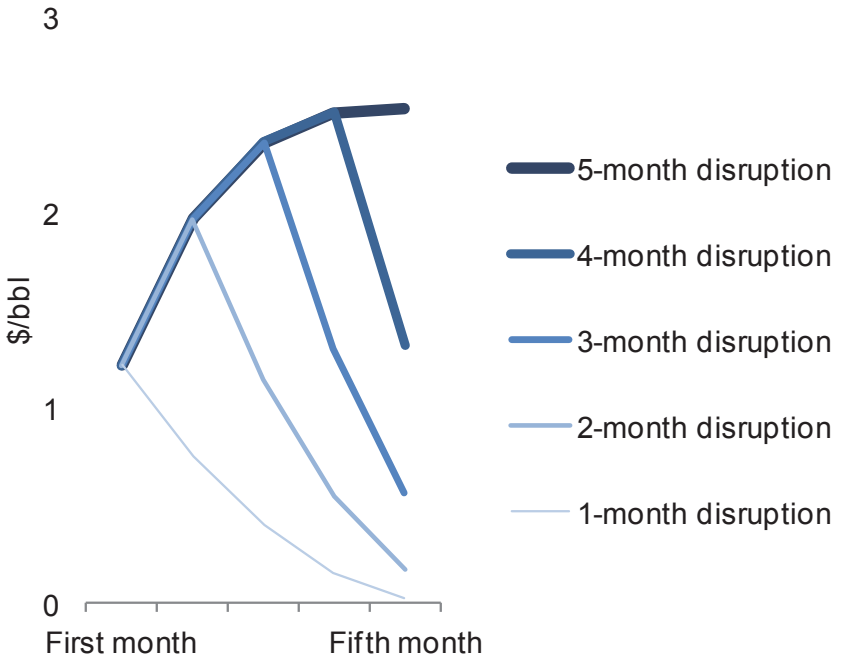
# Is energy security sustainable?

## 【Unplanned oil production disruption】




Source: US DOE/EIA

## 【Oil price impact of 100kb/d unplanned production disruption】




Note: The scenario assumes that oil production stops at Non-OPEC.
Oil price is an average of first half from 2011 to 2016.

- Fossil fuel sources have made up at over 80% of world energy consumption. Large scale oil production disruption have not occurred in recent years, but unplanned production stops are always occurring somewhere.
- If unplanned production disruption of 100kb/d occurred in non-OPEC which tends to lead to reduced production actually, it had the effect of boosting the crude oil price of the month by $1.2/bbl. If the outage continues for 5 months, the increase is expanded to $2.5 /bbl.

# Advanced Technologies Scenario assumptions

# Advanced Technologies Scenario assumptions

In this scenario, each country further enhances policies on energy security and address climate change. Technology developments and international technology transfers are promoted to further expand the penetration of innovative technologies.

### Introducing and enhancing environmental regulations and national targets

Environment tax, emissions trading, RPS, subsidy, FIT, efficiency standards, automobile fuel efficiency standard, low carbon fuel standard, energy efficiency labeling, national targets, etc.

### Promoting technology development and international technology cooperation

R&D investment expansion, international cooperation on energy efficient technology (steelmaking, cement and other areas), support for establishing energy efficiency standards, etc.

## Demand side technology

### Industry

Under sectoral and other approaches, best available technologies on industrial processes (for steelmaking, cement, paper-pulp and oil refining) will be deployed globally

### Transport

Clean energy vehicles (highly fuel efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles) will diffuse further.

### Buildings

Efficient electric appliances (refrigerators, TVs, etc.), highly efficient water-heating systems (heat pumps, etc.), efficient air conditioning systems and efficient lighting will diffuse further, with heat insulation enhanced.

## Supply side technology

### Renewable energy

Wind power generation, photovoltaic power generation, CSP (concentrated solar power) generation, biomass-fired power generation and biofuel will penetrate further.

### Nuclear

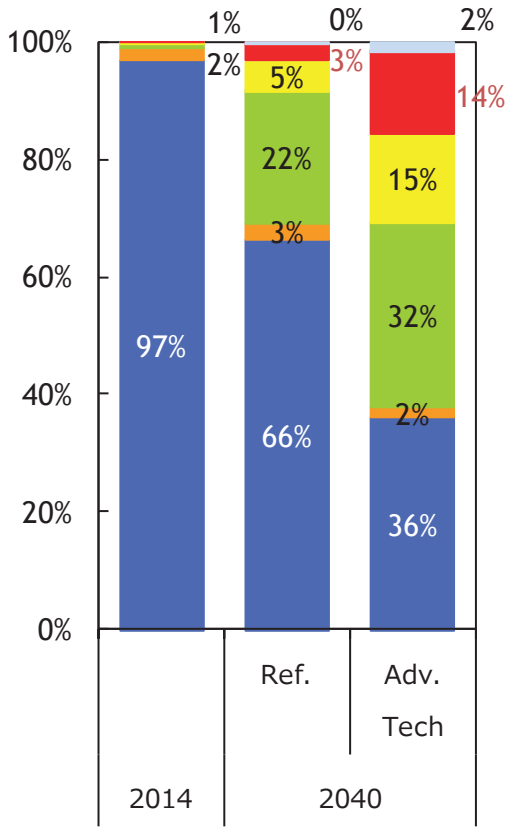
Nuclear power plant construction will be accelerated with operating rates improved.

### Highly efficient fossil fuel-fired power generation technology

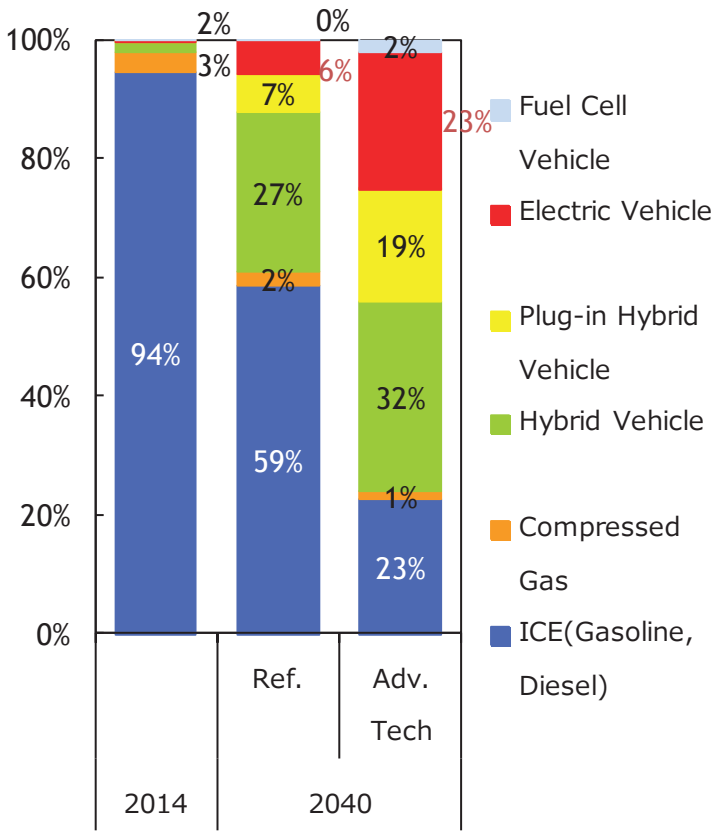
Coal-fired power plants (USC, IGCC, IGFC) and natural gas –fired more advanced combined cycle (MACC) plants will penetrate further.

# Vehicle stock and sales by type (world)

### The share of vehicle stocks




### The share of new vehicles sales




### Share of clean energy vehicles in total stocks (2040)

Reference **34%**
Adv. Tech. **64%**

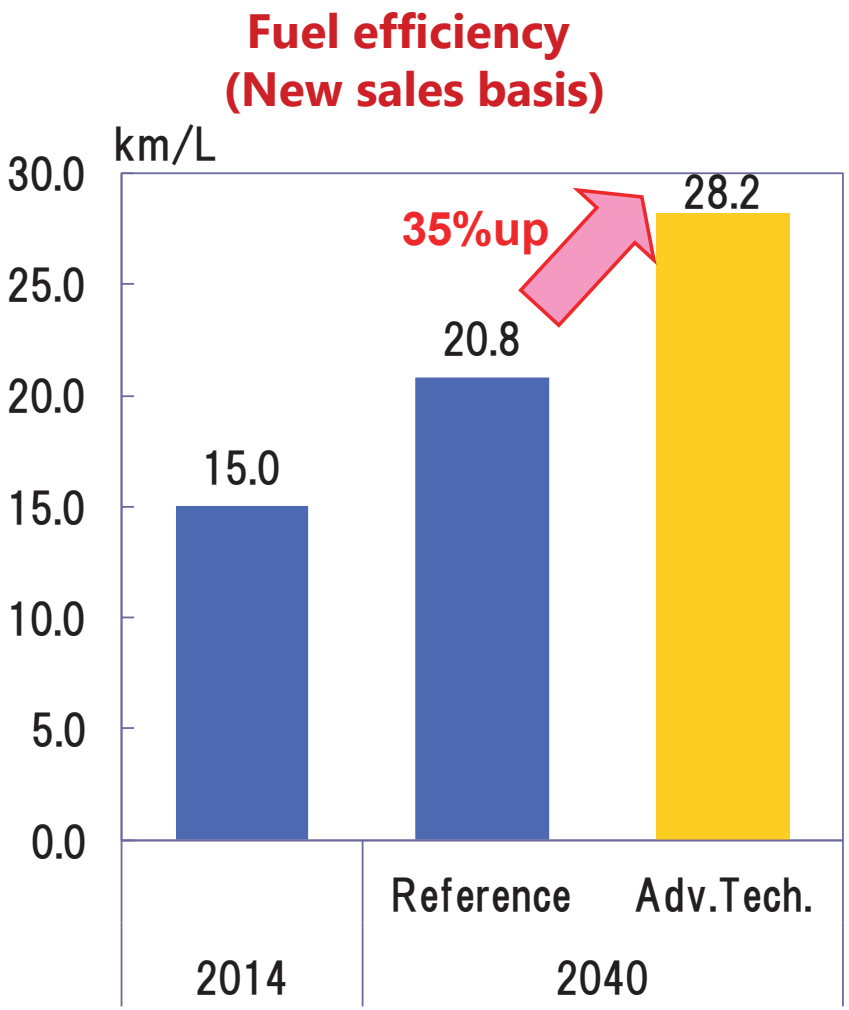
### Share of clean energy vehicles in annual sales (2040)

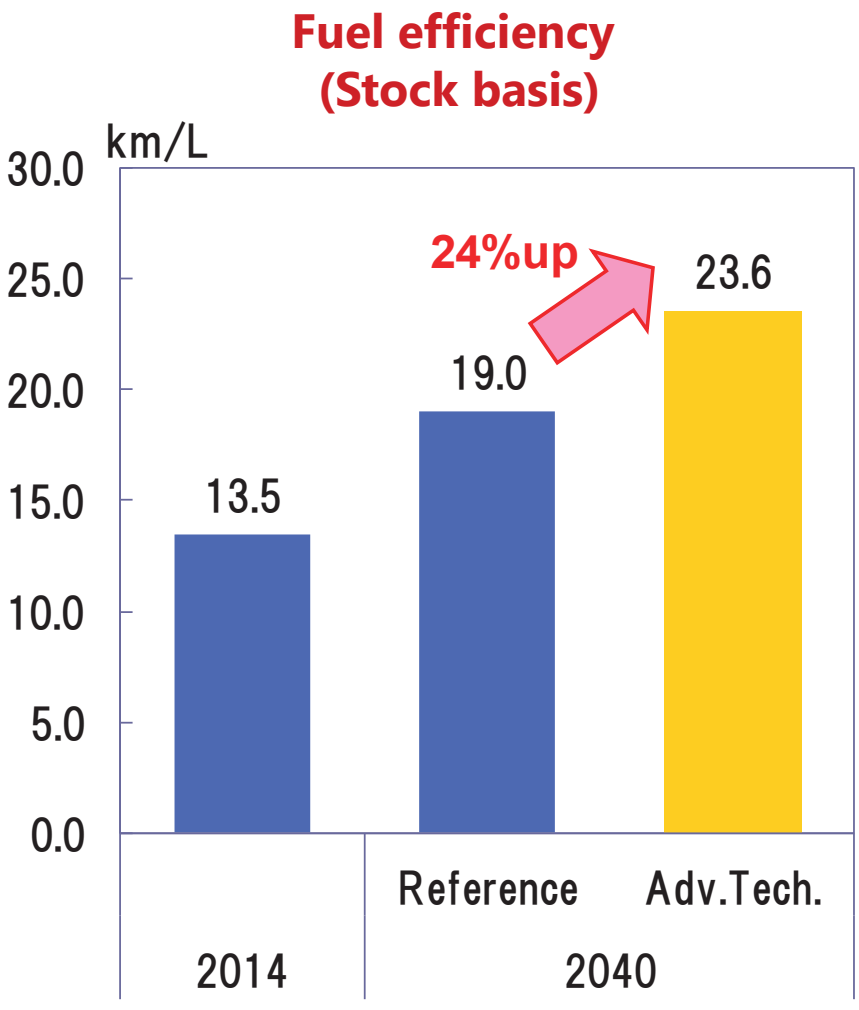
Reference **41%**
Adv. Tech. **77%**

■ In the Reference Scenario, in 2040, ICE accounts for 66% of the total stocks and 59% of the annual sales. Clean energy vehicles increase mainly by hybrid vehicles.

■ In the Advanced Technologies Scenario, ICE drops to 36% of the total stocks and 23% of the annual sales. Within clean energy vehicles, in 2040, hybrid (32%), plug-in hybrid (15%), and electric vehicles (14%) are the main stream of the total stocks. Similarly, hybrid (32%), plug-in hybrid (19%), and electric vehicles (23%) are the main stream of the total sales, and fuel cell vehicles are also introduced (2%).

# Fuel efficiency of passenger cars (world)

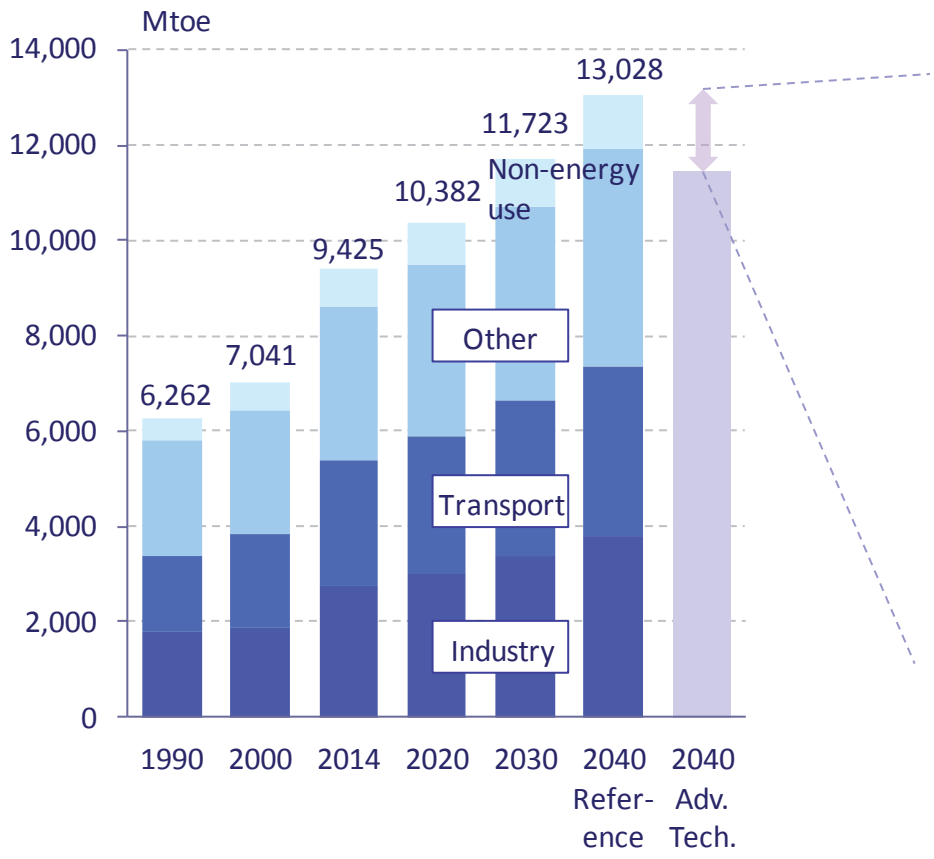


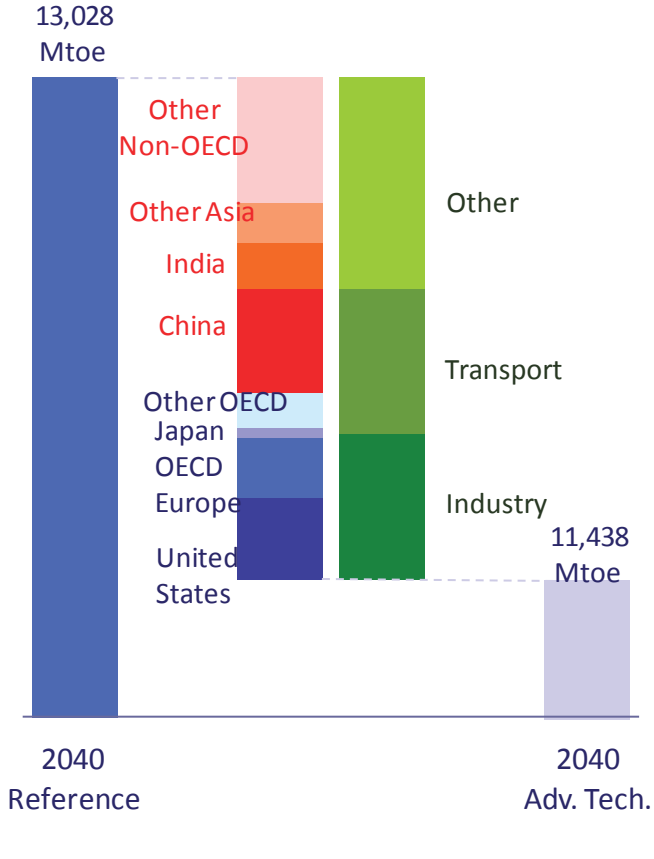

In 2040, stock-based fuel efficiency of passenger vehicles in the Advanced Technologies Scenario achieves a 35% improvement in comparison with the Reference Scenario due to an increase of next generation vehicles such as plug-in hybrid and electric vehicles.

# Energy saving in 2040 by region and by sector

## Global final energy demand




## Energy saving by region and by sector




- Global final energy demand expands 1.4-fold from 9,425 Mtoe in 2014 to 13,028 Mtoe in 2040 in the Reference Scenario.
- In the Advanced Technologies Scenario, final energy demand in 2040 is reduced by 12% to 11,438 Mtoe. 60% of the energy saving is attributable to non-OECD countries. By sector, “other” sector including residential and commercial sectors accounts for 42% of total energy saving.

# Energy outlook in Asia and the world through 2050 and actions against climate change

# GDP, population and energy prices

| | 2014 | 2040 | 2050 |
|---|---|---|---|
| GDP ($2010 trillion) | 73 (AAGR in 1990-2014: 2.8%) | 152 (AAGR in 2014-2040: 2.9%) | 192 (AAGR in 2040-2050: 2.4%) (AAGR in 2014-2050: 2.7%) |
| Population (billion) | 7.2 | 9.2 (+2.0 from 2014) | 9.7 (+2.5 from 2014) |
| GDP per capita ($2010 thousand) | 10 | 17 | 20 |
| Real oil price ($2015/bbl) | 52 (2015) | 125 | 130 |
| Nominal oil price ($/bbl) | 52 (2015) | 205 | 260 |

- Global GDP grows annually at 2.7% from 2014 to 2050.
- World total population expands from 7.2 billions in 2014 to 9.7 billions in 2050.
- Crude oil price ($2015 real price) is assumed to increase from $52/bbl in 2014 to $130/bbl in 2050.

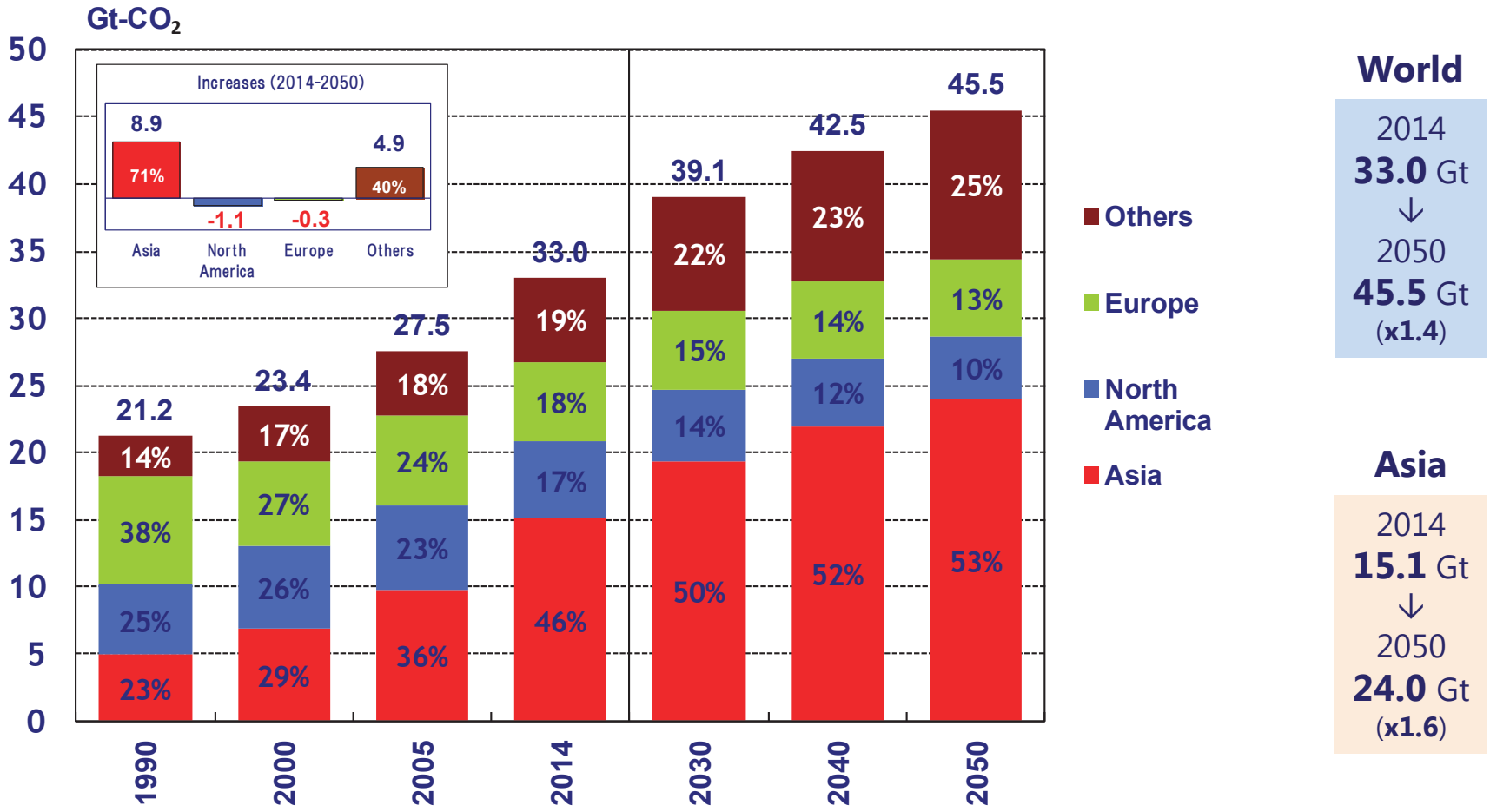
# Energy and environmental technologies

| | 2014 | 2040 | | 2050 | |
|---|---|---|---|---|---|
| | Historical | Reference | Advanced Technologies | Reference | Advanced Technologies |
| Nuclear (GW) | 399 (2015) | 612 | 846 | 694 | 992 |
| Thermal efficiency | | | | | |
| Coal-fired | 37% | 41% | 41% | 42% | 45% |
| Natural gas-fired | 41% | 52% | 53% | 54% | 57% |
| Solar photovoltaic (GW) | 175 | 857 | 1,433 | 1,216 | 2,080 |
| CSP (GW) | 4 | 84 | 220 | 153 | 407 |
| Wind (GW) | 366 | 1,170 | 1,764 | 1,572 | 2,417 |
| Biomass power generation (GW) | 76 | 201 | 226 | 244 | 268 |
| Biofuel (Mtoe) | 73 | 120 | 174 | 122 | 203 |
| Share in annual vehicle sales | | | | | |
| PHEV | 0% | 7% | 19% | 8% | 21% |
| EV/FCV | 3% | 8% | 26% | 10% | 36% |
| Average fuel efficiency of new vehicle sales (km/L) | 15 | 21 | 28 | 23 | 33 |

CSP: Concentrated solar power, PHEV: Plug-in hybrid electric vehicle, EV: Electric vehicle, and FCV: Fuel cell vehicle

# $CO_2$ emissions by region (world)

Reference Scenario




**World**

2014
**33.0** Gt
↓
2050
**45.5** Gt
(**x1.4**)

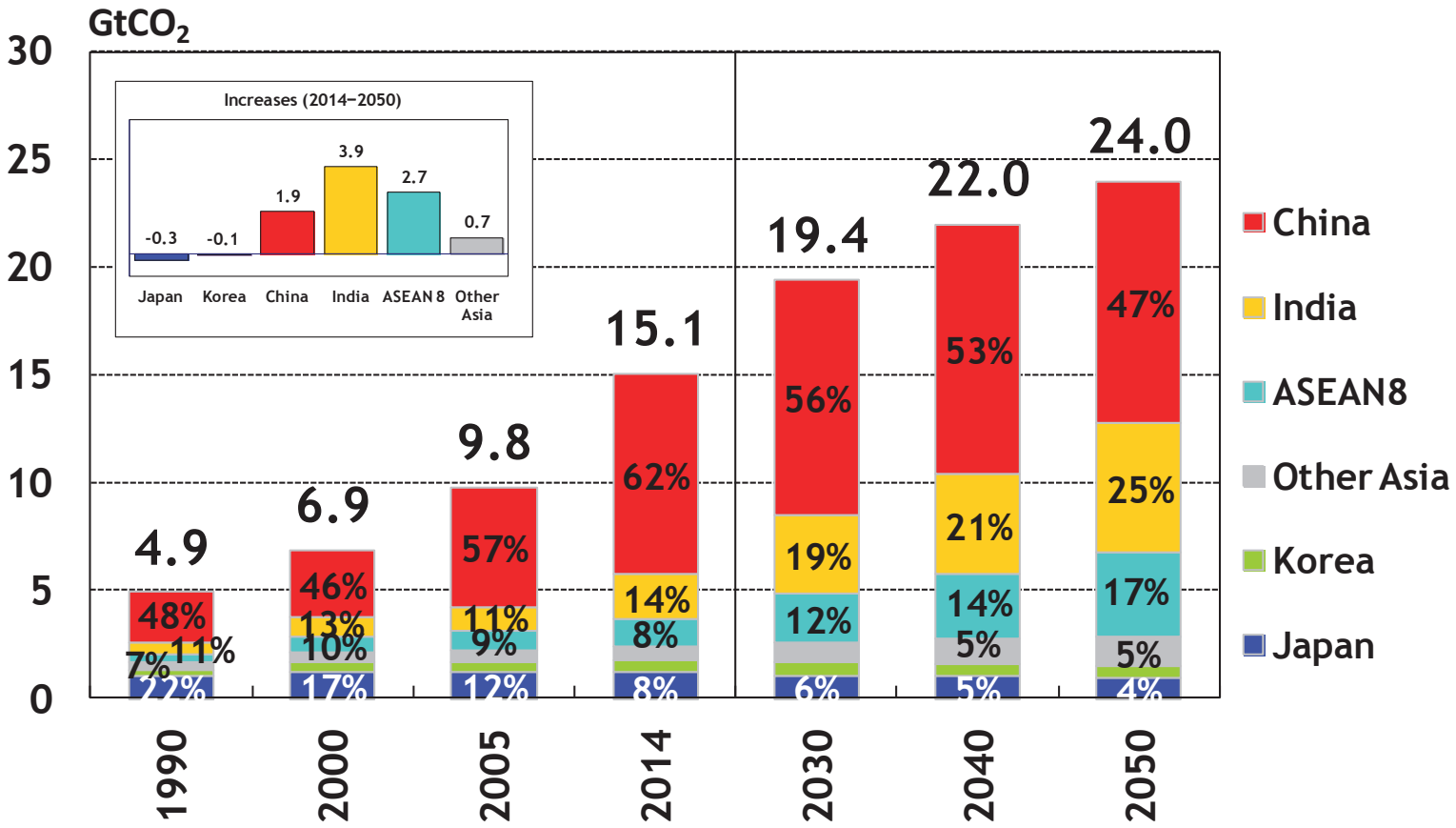
**Asia**

2014
**15.1** Gt
↓
2050
**24.0** Gt
(**x1.6**)

- $CO_2$ emissions in the world reach 45.5 Gt in 2050 from 33.0 Gt in 2014.
- Asia alone accounts for about 71% of the increase in global $CO_2$ emissions through 2050. The total share of North America and Europe decreases from 36% in 2014 to 23% in 2050.

# $CO_2$ emissions by region (Asia)

Reference Scenario




**China**

2014
**9.3** Gt
↓
2050
**11.2** Gt
(**x1.2**)

**India**

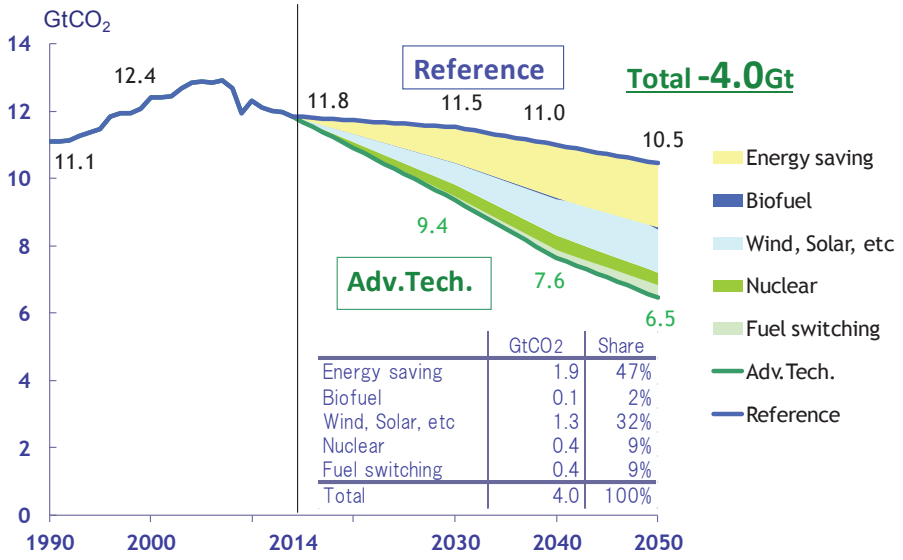
2014
**2.1** Gt
↓
2050
**5.9** Gt
(**x2.9**)

- $CO_2$ emissions in Asia steadily increase driven by coal consumption. The combined share of China and India in the Asian region remains constant throughout the projection period at almost 75%.
- The increases in Asia account for about 71% of the world $CO_2$ emission growth through 2050. The development of clean coal technology plays an important role to reduce $CO_2$ emissions in Asia.

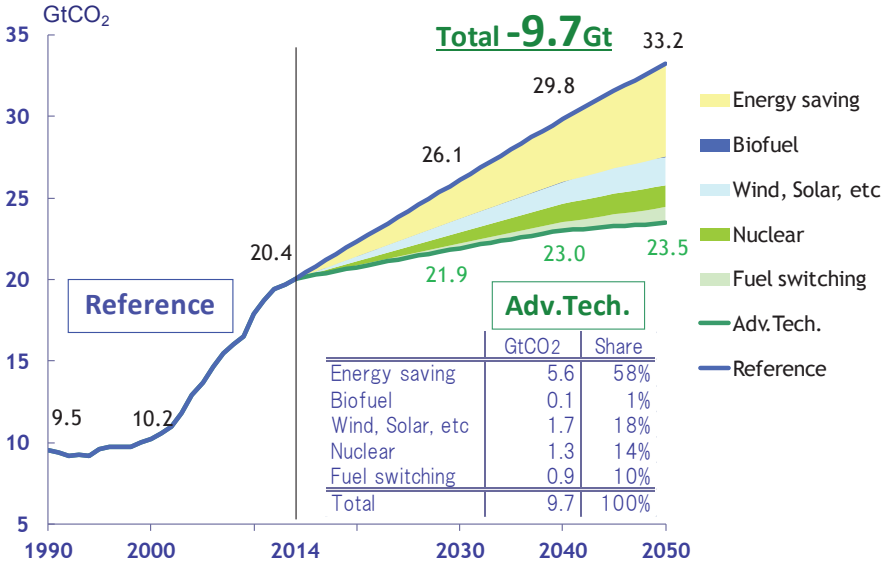
# $CO_2$ emission reduction by technology (OECD and non-OECD)

Reference Scenario
Advanced Technologies Scenario

## OECD




## Non-OECD

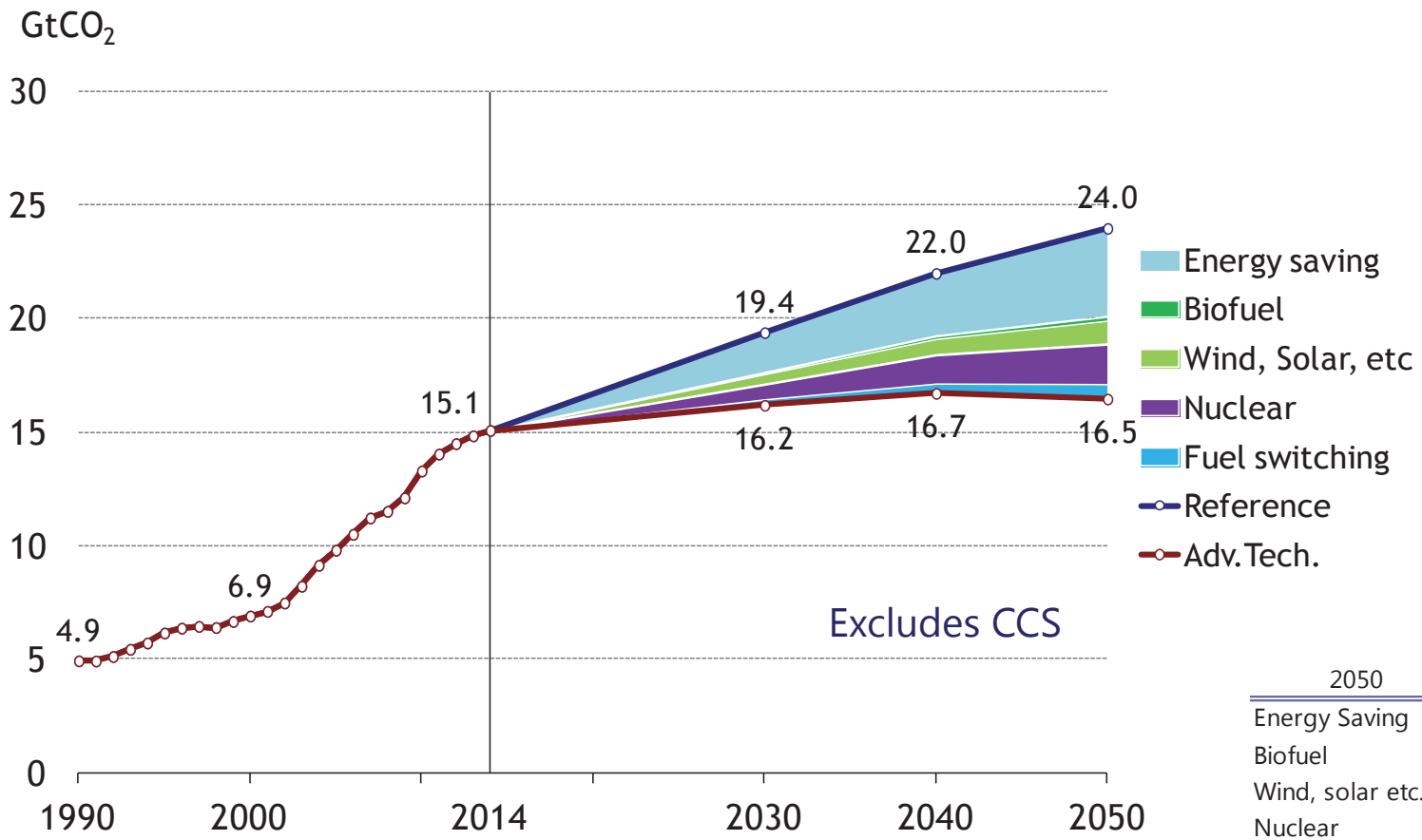



Excludes CCS

- Various technologies are required to reduce $CO_2$ emissions. In OECD, energy saving is responsible for the largest share at 47% (or 1.9 Gt). It is followed by renewable energy at 32% (or 1.3 Gt), nuclear at 9% (or 0.4 Gt), and fuel switching at 9% (or 0.4 Gt).
- In Non-OECD countries, energy saving is responsible for more than half of the 9.7 Gt reduction. Supportive measures concerning technology transfer and the establishment of efficiency standards are important to realize those $CO_2$ emission reduction while further enhancing energy security.

# $CO_2$ emission reduction by technology (Asia)

Reference Scenario
Advanced Technologies Scenario




**Total 7.5 Gt**
**31% reduction**

Energy saving **51%**

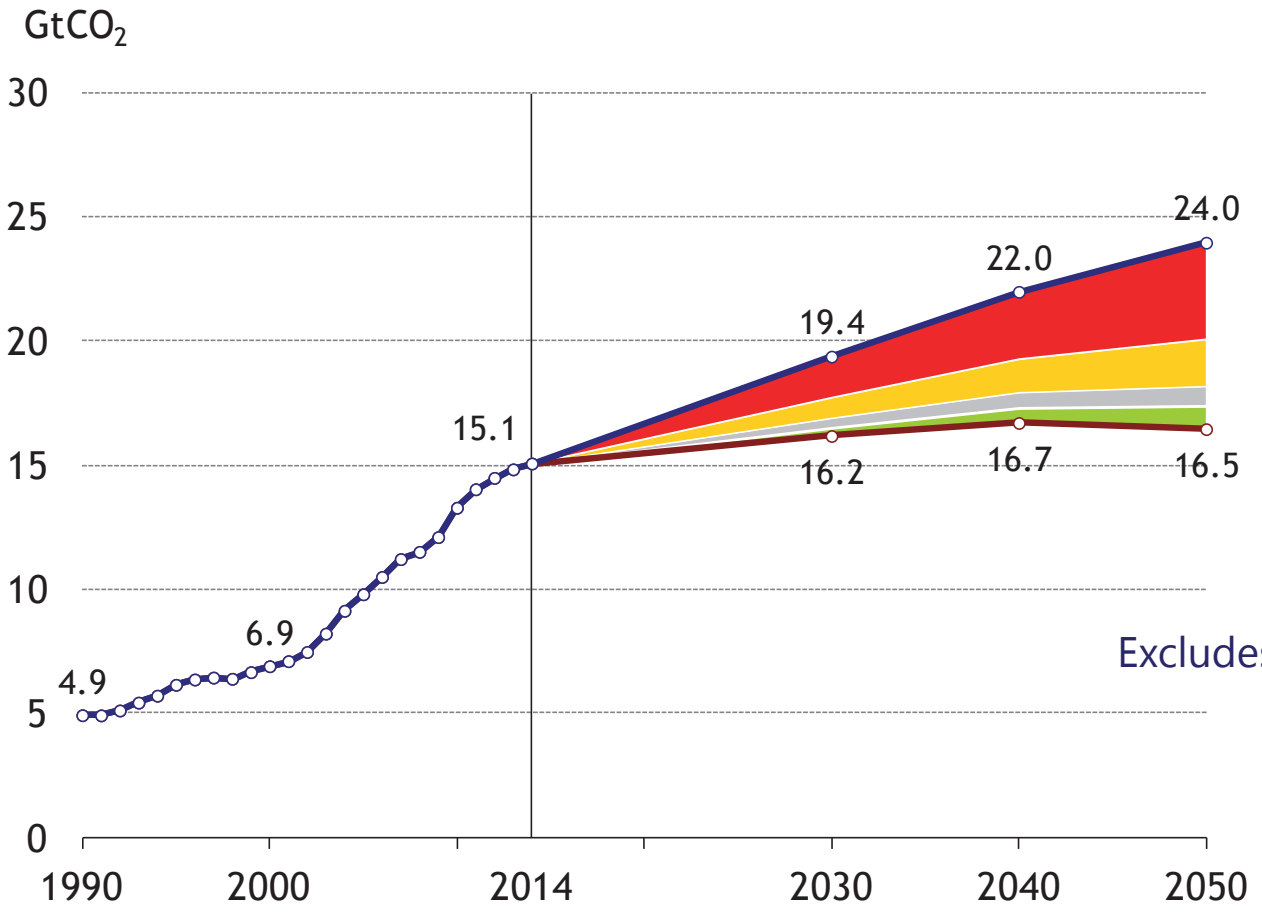
Energy substitution **49%**

| 2050 | $GtCO_2$ | Share |
|---|---|---|
| Energy Saving | 3.9 | 51% |
| Biofuel | 0.2 | 2% |
| Wind, solar etc. | 1.1 | 14% |
| Nuclear | 1.7 | 23% |
| Fuel Switching | 0.7 | 9% |
| Total | 7.5 | 100% |

- Aggressive development and deployment of advanced technologies in Asia considerably reduce $CO_2$ emissions. Energy saving accounts for 51% of Asia's $CO_2$ reduction in 2050.

# $CO_2$ emission reduction by region (Asia)

Reference Scenario
Advanced Technologies Scenario




Total **7.5** Gt
(31% reduction)

**China**
**3.9** Gt
(**52%** of total)

**India**
**1.9** Gt
(**25%** of total)

**ASEAN8**
**0.8** Gt
(**11%** of total)

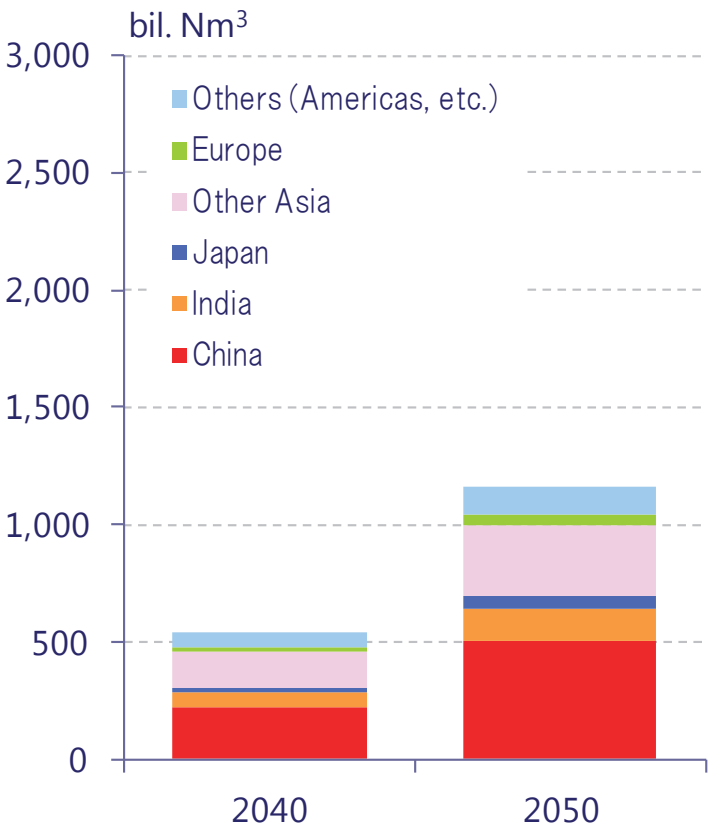
- In the Advanced Technologies Scenario, $CO_2$ emissions in Asia is reduced by 7.5 Gt in 2050.
- China and India have great potential to reduce $CO_2$ emissions. China's $CO_2$ emission reduction accounts for 52% of Asia's reduction in 2050. The reduction of India and ASEAN8 accounts for 36% of Asia's reduction in 2050.

# Hydrogen scenario

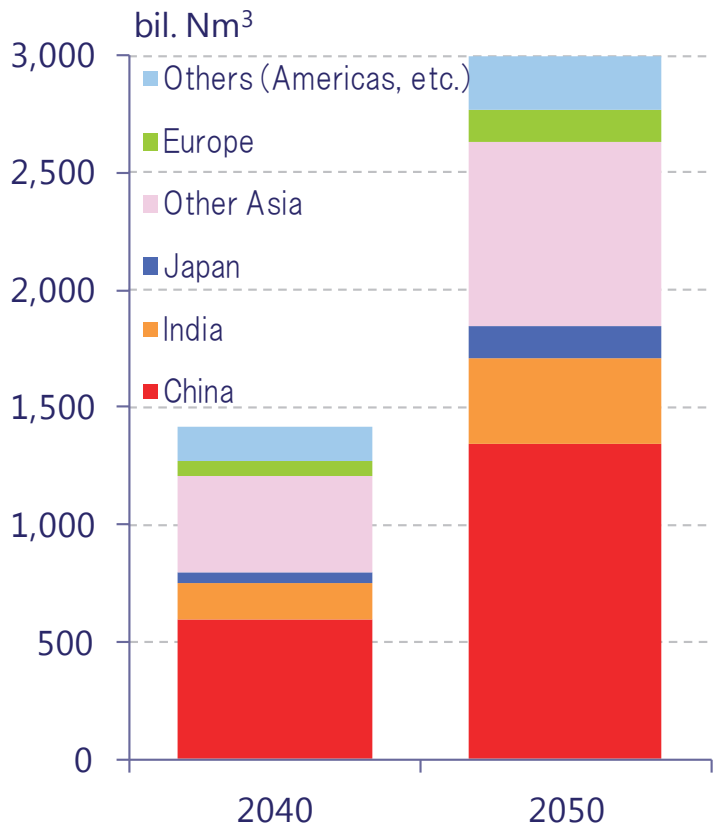
# Hydrogen demand in power generation sector

Lower Hydrogen Scenario

## [Lower hydrogen case]



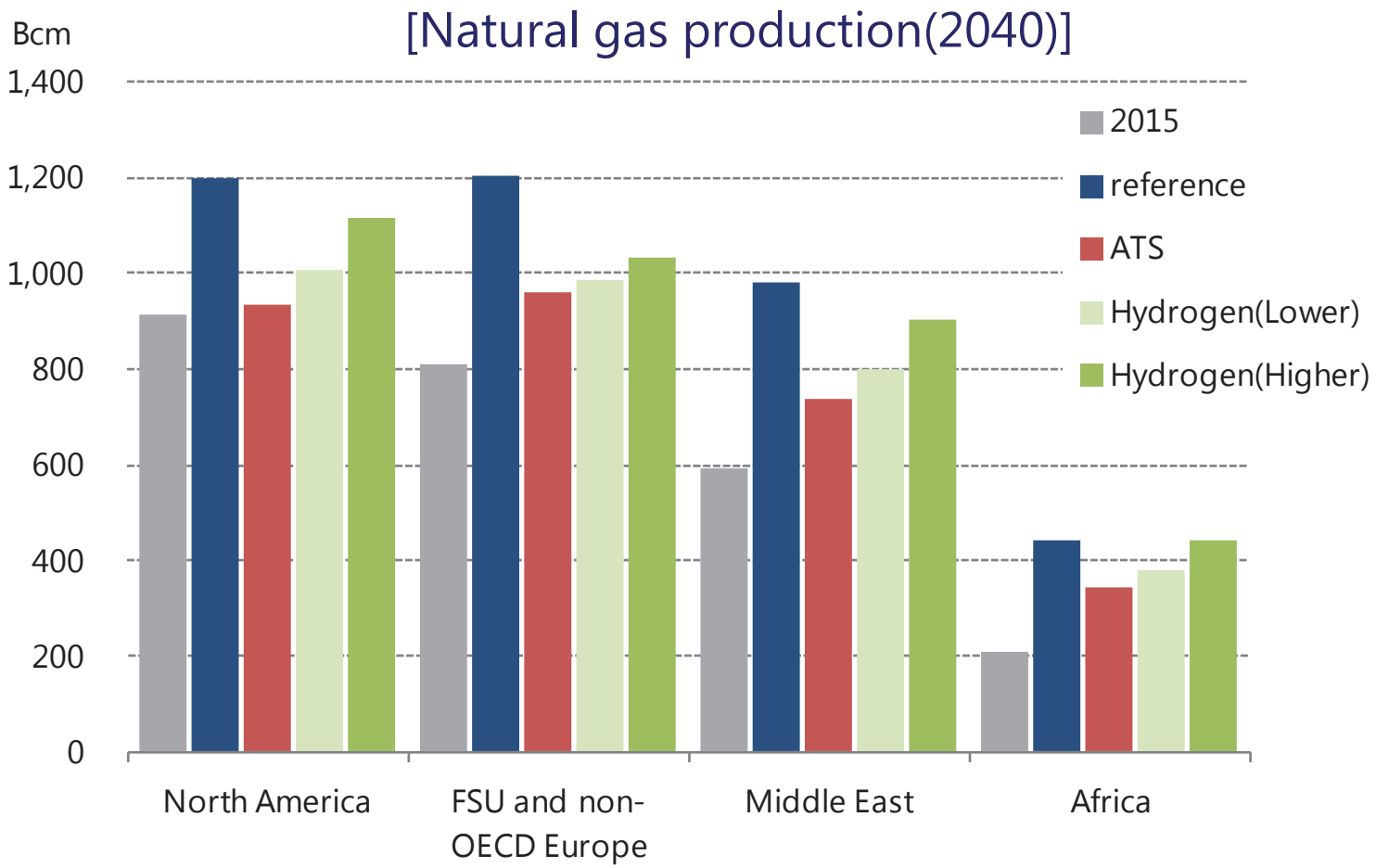

## [Higher hydrogen case]




- In the Hydrogen Scenario, demand of hydrogen in power generation sector in 2050 reaches 1.15 tril. normal cubic meter (ncm) in the lower case and 3 tril. ncm in the higher case.
- The demand in the power generation sector accounts for over 90% of total hydrogen demand in both case and the share of hydrogen-thermal generation accounts for 5% in the lower case and 13% in the higher case in 2050.

# Increase of natural gas production

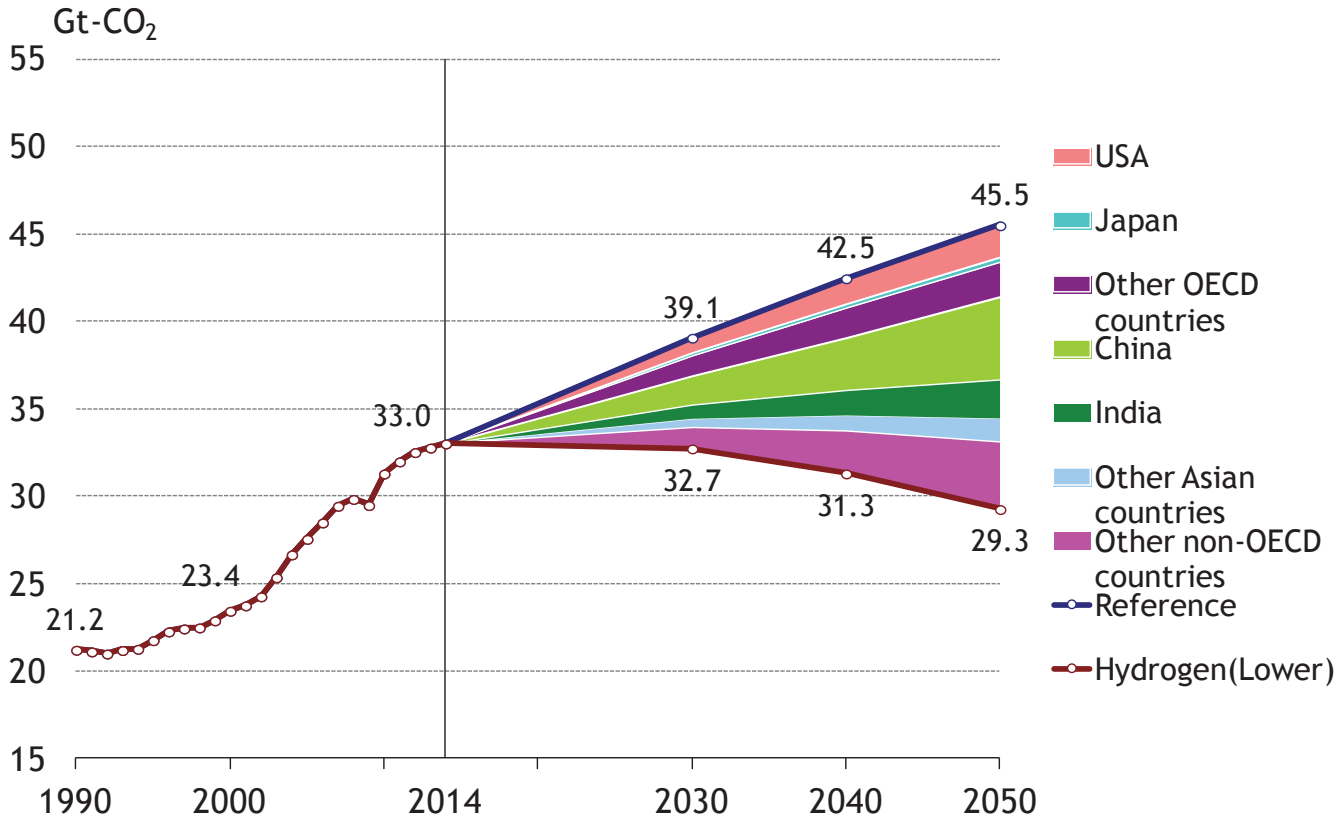
Lower Hydrogen Scenario




- Hydrogen is made from natural gas in most regions although made from coal in Australia. Therefore natural gas production increases in the Hydrogen Scenario.
- The production amount in North America in 2040 reaches 1,006 bcm in the lower case and 1,115 bcm in the higher case compared with 935 bcm in the ATS.

# $CO_2$ emissions in the world(by region)

Reference Scenario
Lower Hydrogen Scenario




## Reduction in 2050 (Regional Breakdown)

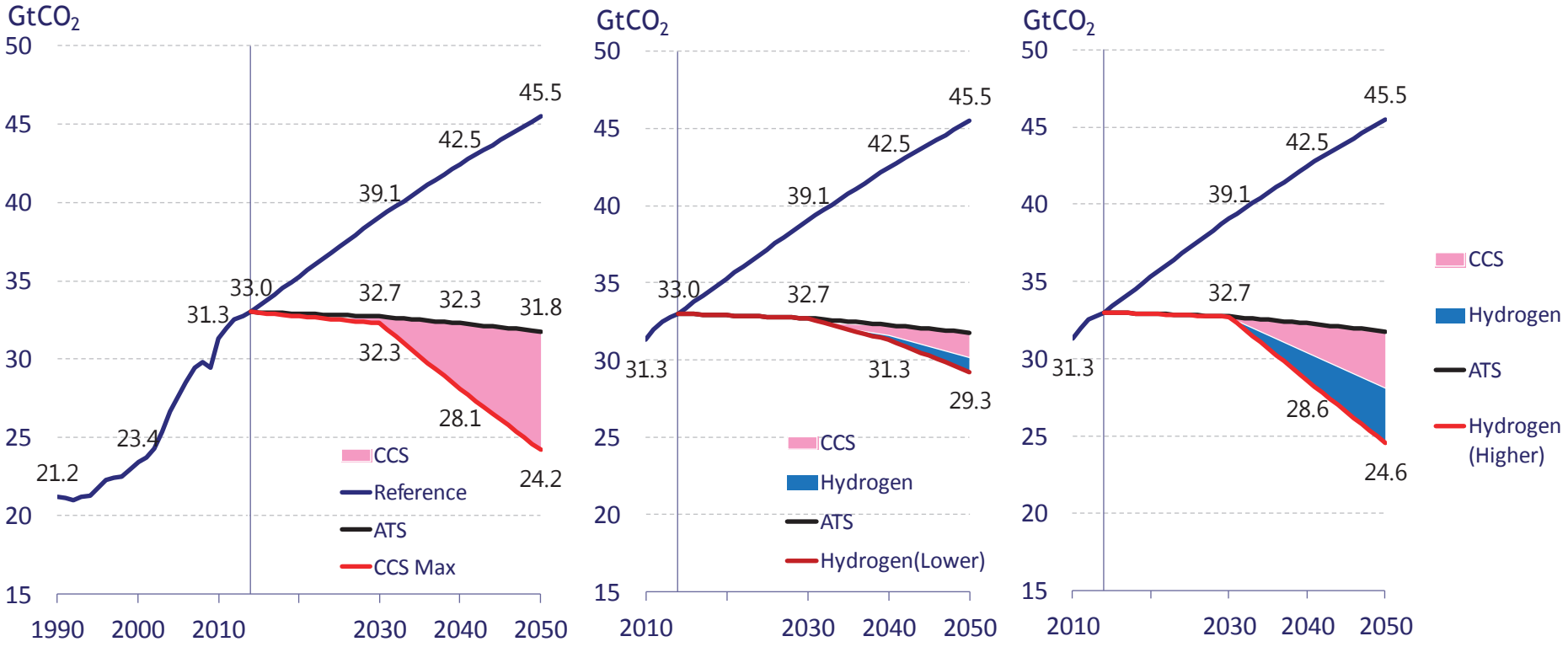
| | Gt-$CO_2$ | Share |
|---|---|---|
| USA | 1.8 | 11% |
| Japan | 0.3 | 2% |
| Other OECD | 2.0 | 12% |
| China | 4.7 | 29% |
| India | 2.3 | 14% |
| Other Asian countries | 1.3 | 8% |
| Other non-OECD | 3.8 | 24% |
| OECD | 4.1 | 25% |
| Non-OECD | 12.2 | 75% |
| Non-OECD Asia | 8.3 | 51% |
| World total | 16.2 | 100% |

- Asia has quite a big potential of $CO_2$ reduction: Non-OECD Asia of 8.3 bil. ton and China of 4.7 bil. ton.

# $CO_2$ emissions in the world(by scenario)

Advanced Technologies Scenario
Hydrogen Scenario

## [$CO_2$ emissions in the world]
## left: CCS max., middle: Hydrogen(lower), right: Hydrogen(higher)




- In the CCS maximum case, $CO_2$ emissions decrease by 7.6 Gt through CCS to 24.2 Gt. In the Hydrogen Scenario, on the other hand, CCS cannot be deployed in all regions and the reduction with CCS is relatively small.
- CO2 emissions in 2050 are 29.3 Gt in the lower hydrogen case and 24.6 Gt in the higher case.

# Nuclear

# Comparison of nuclear regulatory bodies in major countries (1) U.S.A and Europe

| | U.S.A | France | U.K | Sweden | Finland |
|---|---|---|---|---|---|
| Regulatory body | NRC (Nuclear Regulatory Commission) | ASN (Autorité de sûreté nucléaire) | ONR (The Office for Nuclear Regulation) | SSM (Strålsäkerhets-myndigheten) | STUK (Säteilyturvakeskus) |
| Position | Independent agency of the federal government | Independent authority | Statutory public corporation | Independent authority under the Ministry of the Environment and Energy | Independent authority under the Ministry of Social Affairs and Health |
| Legal basis | Energy Reorganization Act,1974 | Act on Transparency and Security in the Nuclear Field, 2006 | Energy Act, 2013※1 | Act on Nuclear Activities, 2008 | Nuclear Energy Act, 2015※2 |
| Decision-maker | Commission (Votes of five commissioners) | Commission (Agreements of five commissioners) | Board※3 | Several departments such as the department of nuclear power plant safety, etc. under the head | Several departments such as the department of nuclear reactor regulation, etc. under the director general |
| (Ref.) Number of staff | About 4,000 | About 470 | About 500 | About 300 | About 320 |

※1 After self-reorganization of regulatory bodies since 2008, ONR was established in 2014 based on the Energy Act, 2013.

※2 Although STUK had worked as an independent authority before 2015, legal basis of its independence was clarified in 2015 based on the recommendations by IRRS in 2012.

※3 Regulatory decisions are delegated to suitably qualified and experienced staff via a formal delegation to the Chief Nuclear Inspector and the ONR Board itself is not responsible for regulatory decisions.

# Comparison of nuclear regulatory bodies in major countries (2) Asia

| | Japan | South Korea | China | India | Viet Nam |
|---|---|---|---|---|---|
| Regulatory body | NRA (Nuclear Regulation Authority) | NSSC (Nuclear Safety & Security Commission) | NNSA (National Nuclear Safety Administration) | AERB (Atomic Energy Regulatory Board) | VARANS (Vietnam Agency for Radiation and Nuclear Safety) |
| Position | Independent authority under the Ministry of the Environment | Independent authority directly under Prime Minister | Authority under the Ministry of Environmental Protection | Independent authority | Authority under the Ministry of Science and Technology |
| Legal basis | Act for Establishment of the Nuclear Regulation Authority, 2012 | Act on the Establishment and Management of Nuclear Safety and Security Commission, 2013 | Nuclear Safety Act (in preparation) | Atomic Energy Act, 1983 | Law on Atomic Energy, 2008 |
| Decision-maker | Commission (Agreements of five commissioners) | Commission (Agreements of five commissioners) | Several departments such as the nuclear safety supervision department, etc. under the director | Board (Agreements of the chairman and five commissioners) | Several departments such as the inspectorate department, etc under the director general |
| Recommen-dations by the recent IRRS regarding independence | - | - | Independence of NNSA should be ensured by the Nuclear Safety Act (2016) | Independence of AERB should be embedded in law (2015) | Independence of VARANS from MOST, MOIT and MONRE should be ensured by the Law on Atomic Energy (2014) |