IEE JAPAN

## The 427th Forum on Research Work

# IEEJ Outlook 2018

## – Prospects and challenges until 2050 –

Energy, Environment and Economy

Tokyo, 12 October 2017

The Institute of Energy Economics, Japan

# Overview of the current global energy market

- Although the trend of Asia as leading the global energy market remains unchanged, developments in the US and China, which accounts for 40% of the energy market, must be carefully monitored.
- World coal demand dropped for two years in a row (US and China largely) while oil and gas grew. China's coal consumption declined for the third consecutive year (2016, BP).
- Discussions on Peak Oil (supply) of the 2000s are now changing to Peak Demand. Note the recent movements that aim to ban the sale of internal combustion engine vehicles.
- $CO_2$ emissions dropped in 2015 but increased again in 2016. India and ASEAN showed big increases despite the declined observed in the US and China.
- Paris Agreement calls for "Long-term low greenhouse gas emission development strategies" by 2020. This Outlook expands its estimation period to 2050.

# Scenarios in this Outlook

## <Energy Model Analysis>

### #Reference Scenario

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

### #Advanced Technologies Scenario

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

### #Oil Demand Peak Case

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

## ❖Examples for Technology

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

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

## <Climate Model Analysis>

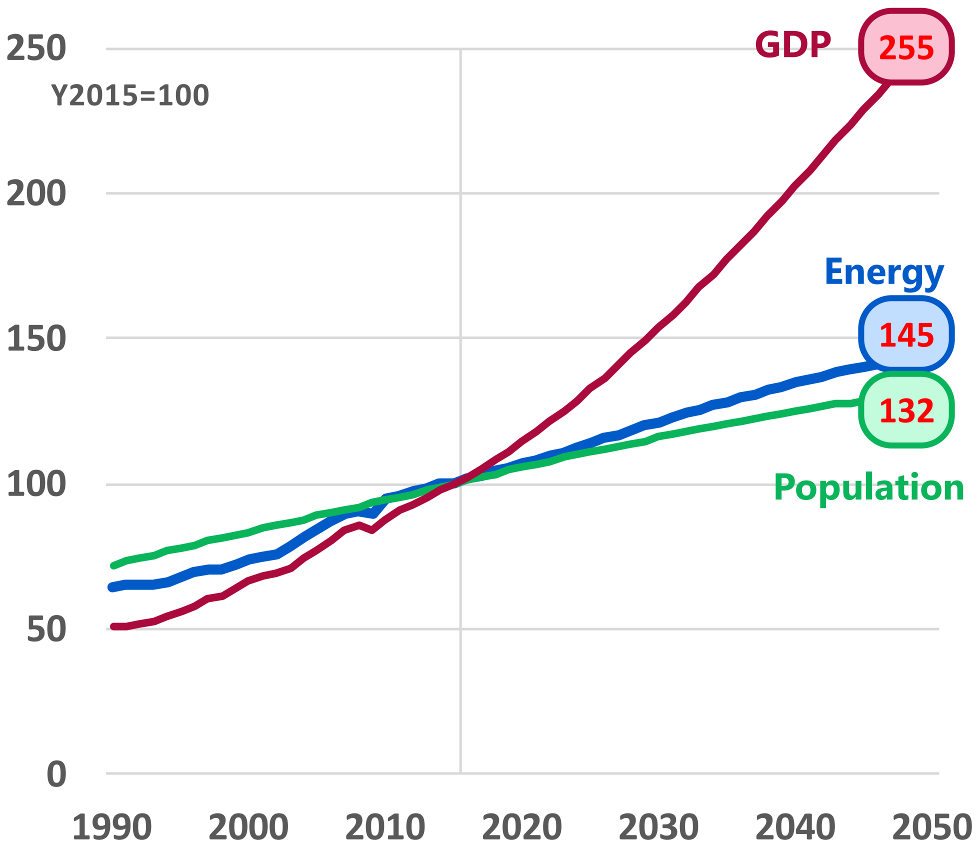
#Reference: Emissions path with continuing past trends
#Minimizing Cost: Emissions path with minimizing total cost
#Halving Emissions by 2050: Emissions path reflected RCP2.6 in AR5 by IPCC

# Energy Outlook up to 2050

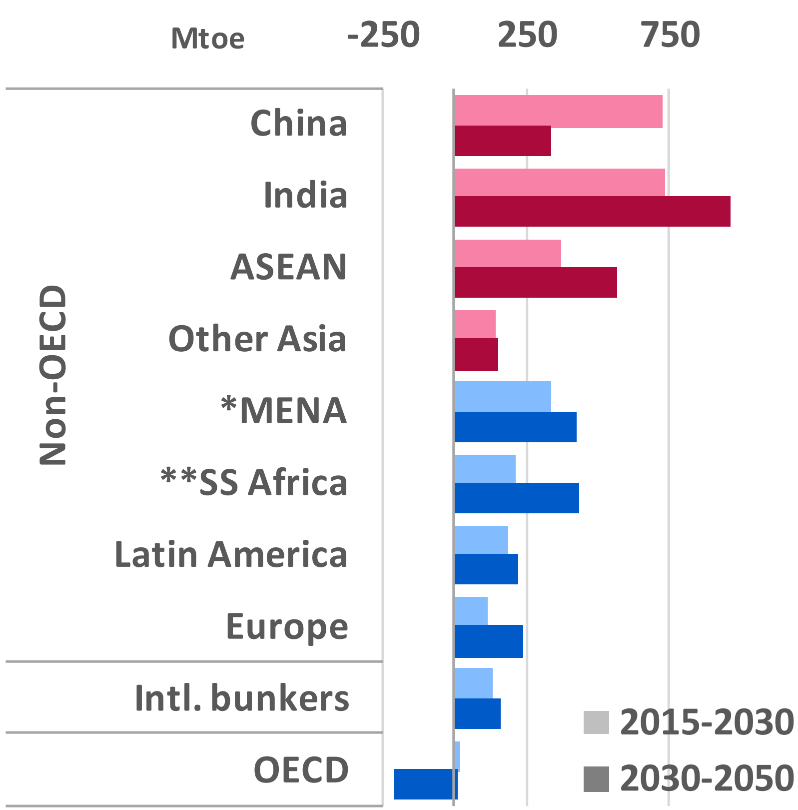
<Reference>

# Energy market shifting to southern Asia

## ❖ Global Population, GDP and Energy




## ❖ Growth in Primary Energy

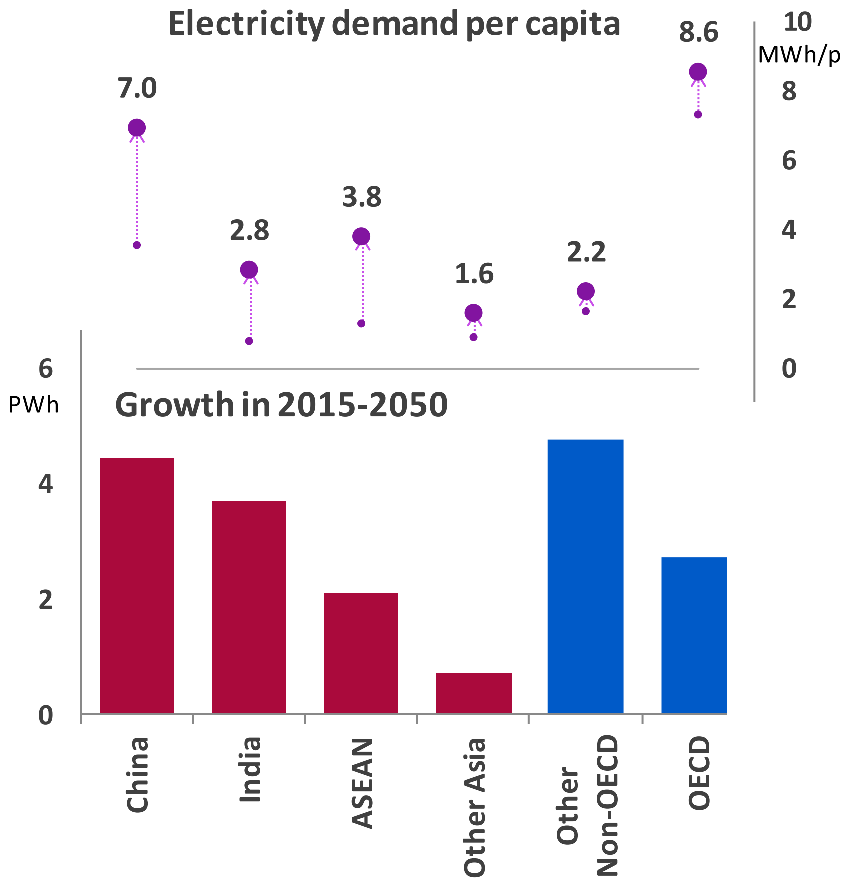



* Middle East and North Africa, **Sub-Saharan Africa

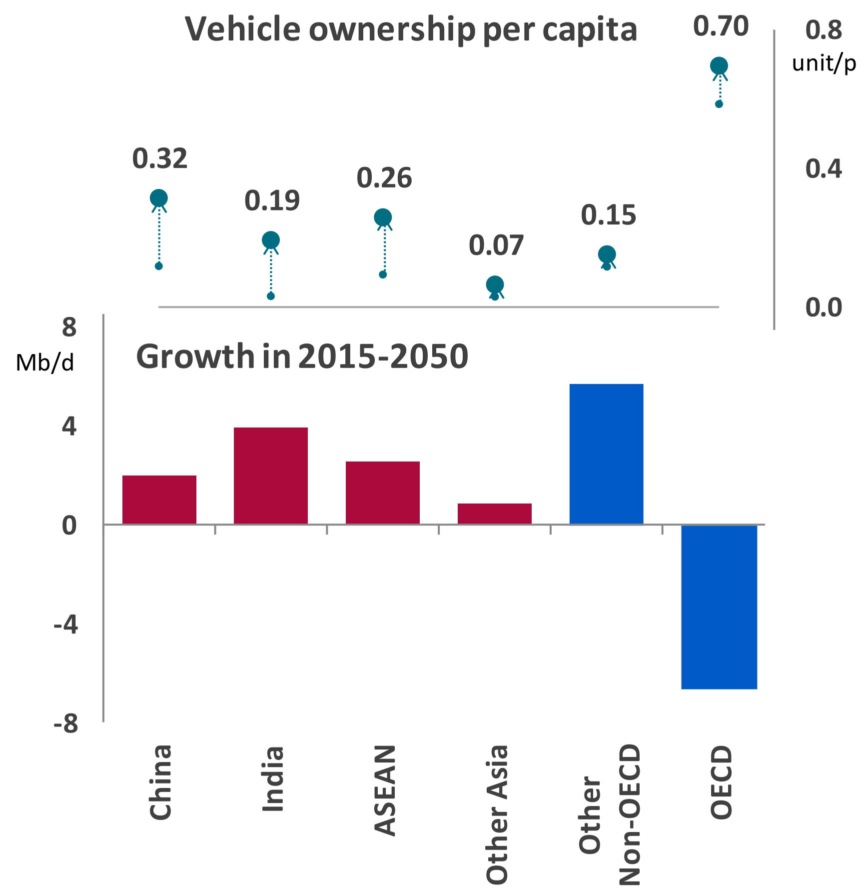
Despite large improvements in energy efficiency/intensity, global energy demand continues to increase. Two thirds of the energy growth comes from non-OECD Asia. As China peaks during the 2040s, the center of gravity of the market shifts within Asia towards the south.

# Demand led by fuels for Generation & Transport

## Electricity




## Oil fuels for vehicles

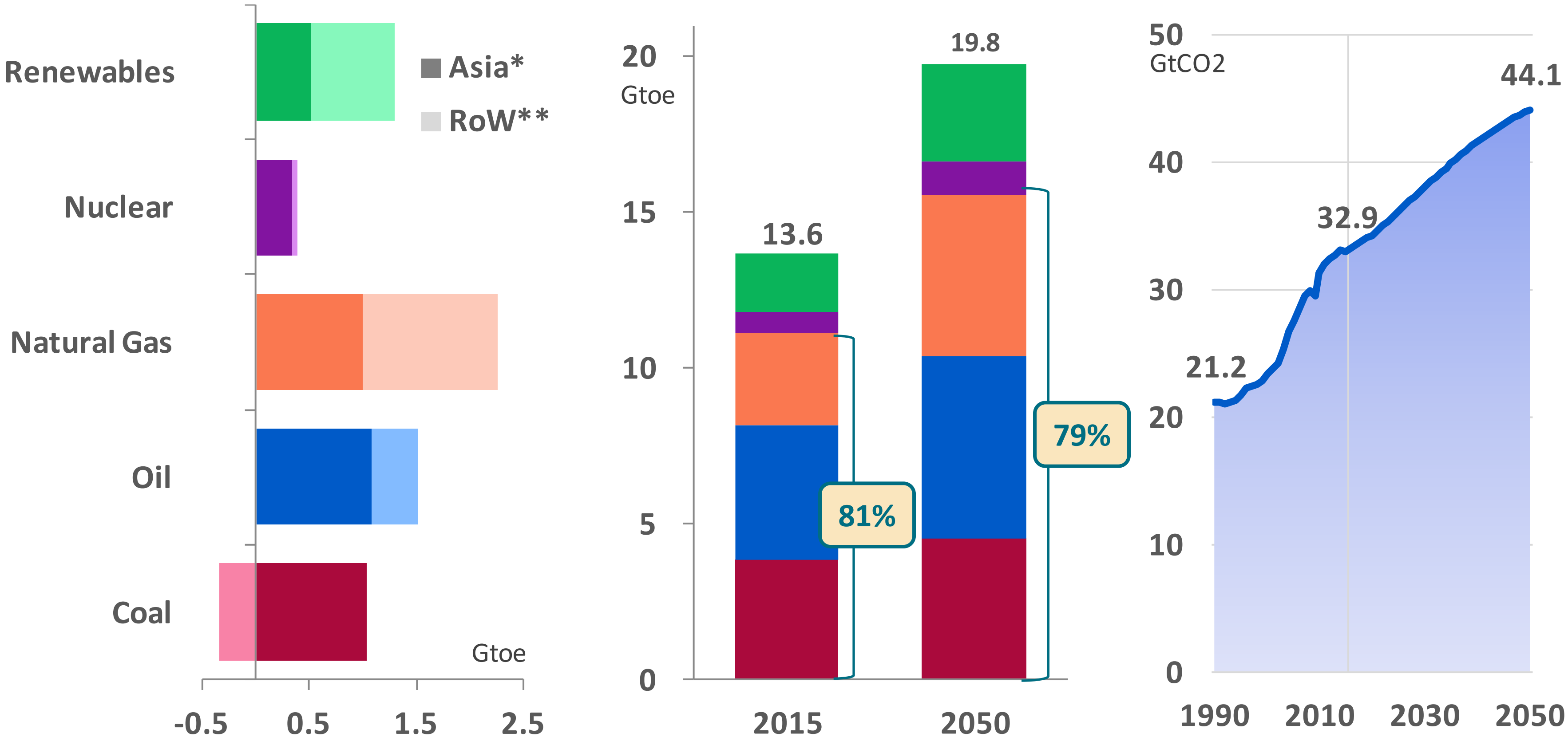



Three quarters of the growth until 2050 are for fuels for power generation and transportation. The economic development and improvements in living standards of the relatively poor and populous areas – non-OECD Asia – contribute to the global energy expansion.

<Reference>

# High dependence on fossil fuels continues

❖ Growth in Primary Energy ❖ Energy Mix ❖ Energy-related $CO_2$

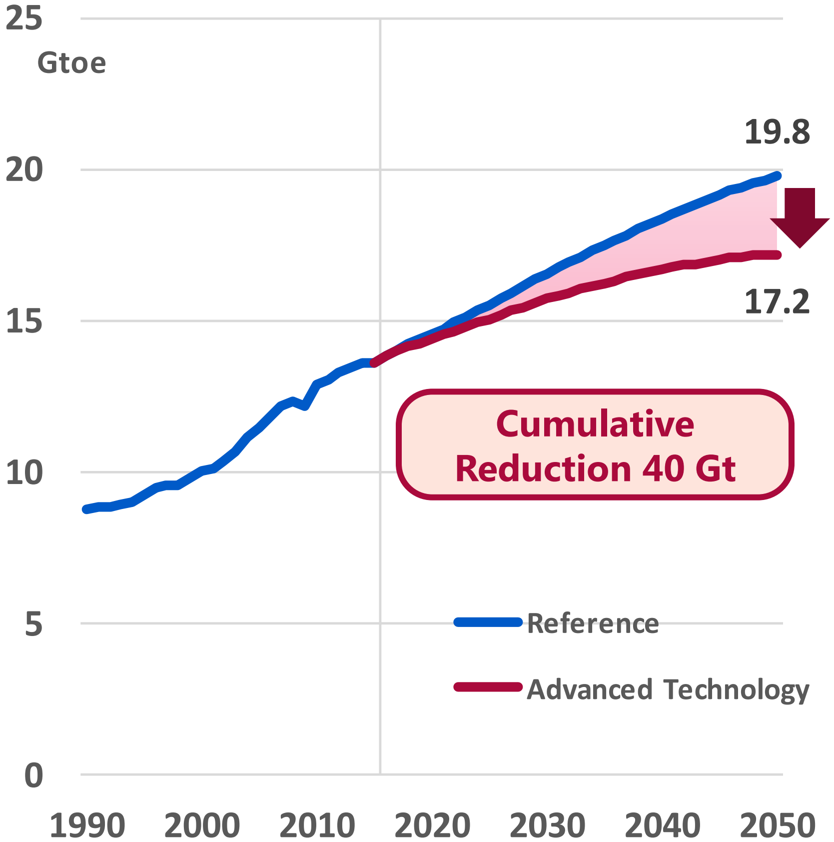



* Non-OECD Asia, **Rest of the world

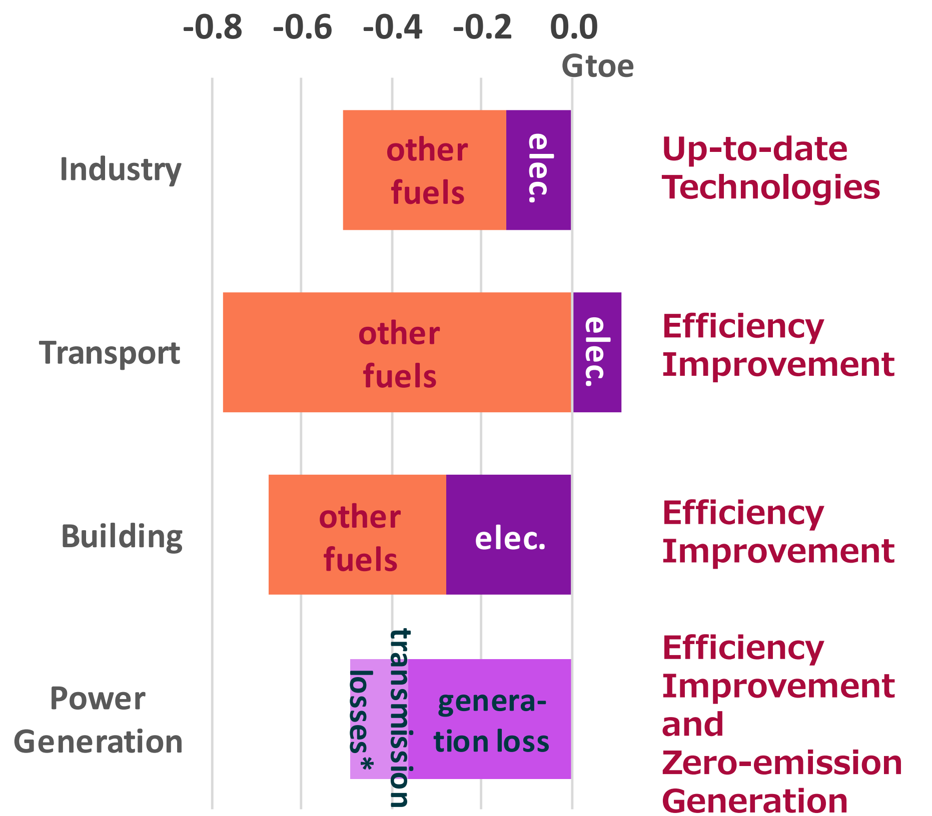
Sixty percent of the growth in electricity demand will be met by thermal power generation, especially natural gas. Asia leads the large global increase in fossil fuels required for power generation as well as for transportation. The high dependence on fossil fuels remains unchanged and energy related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

# Drawing another path – Advanced Technologies Scenario

## Global Primary Energy




## Reduction Effects by ATS in 2050

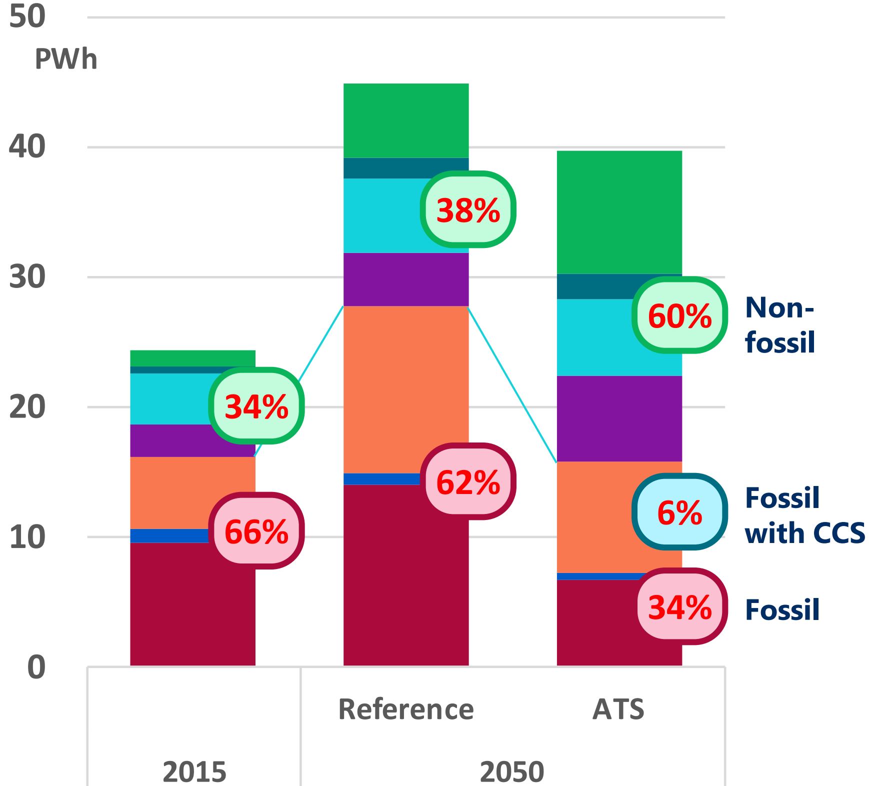



* Including station service power

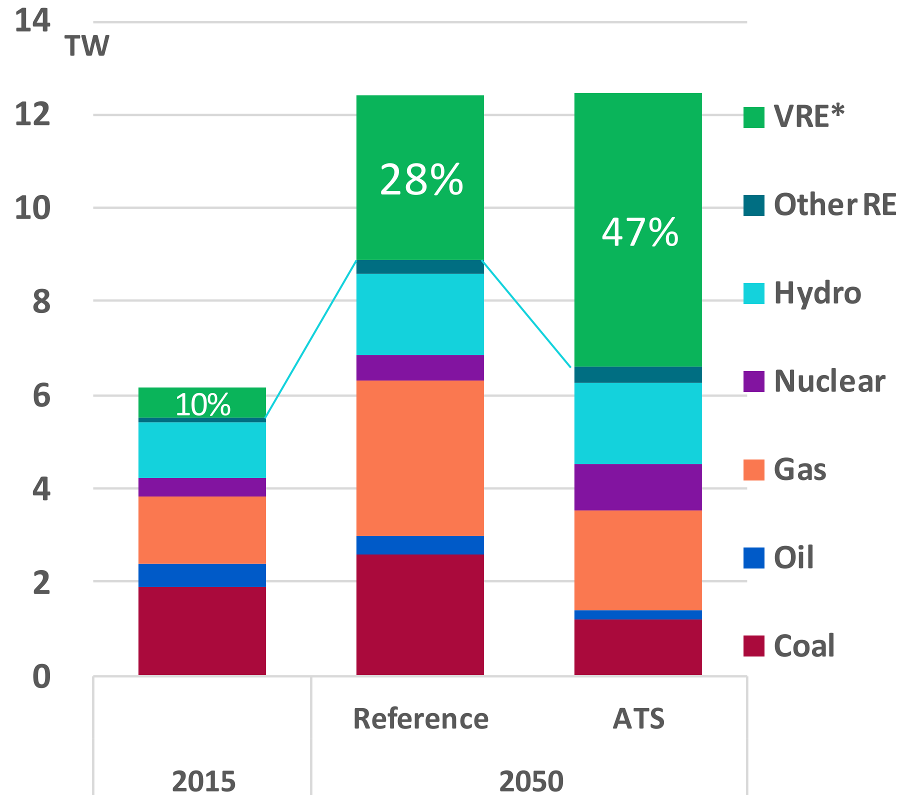
With the maximum installation of low-carbon technologies, the Advanced Technologies Scenario can reduce energy consumption by 13% in 2050. Energy efficiency in power supply/demand technologies would account for 30% of the total reduction. The energy conservation in the transport sector is quite large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

# Zero-emission Generation occupies two thirds

## Global Power Generation




## Global Power Capacity

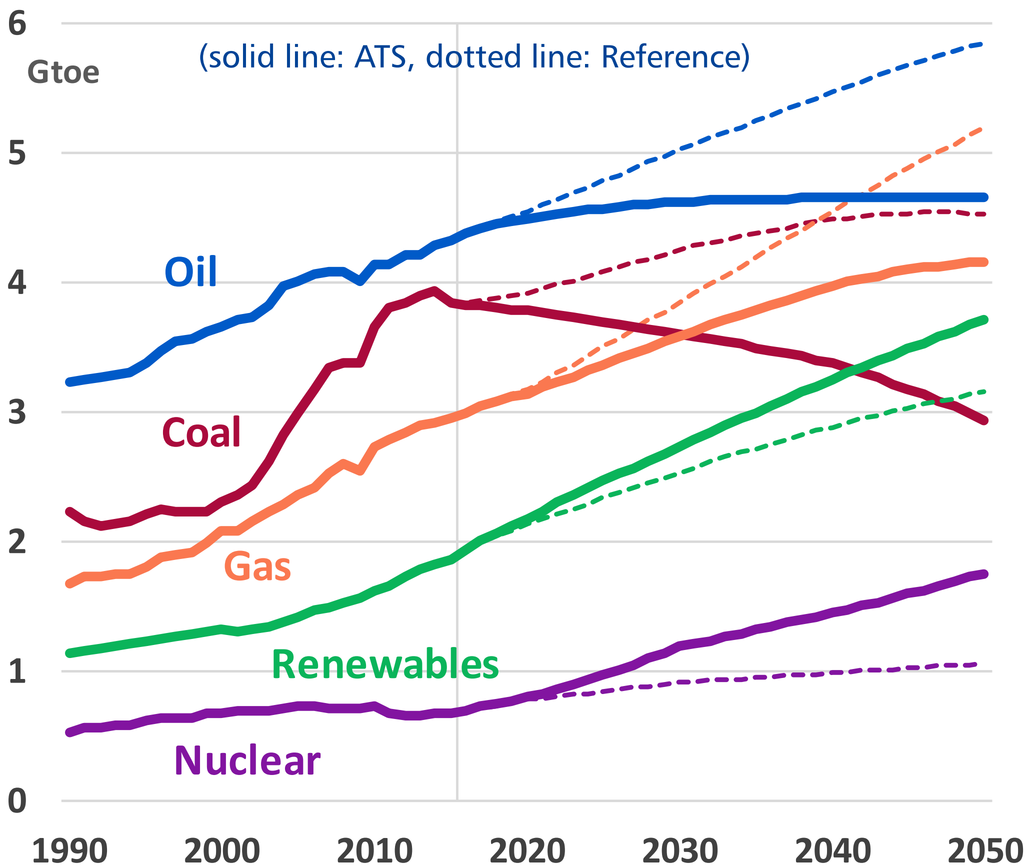



* Variable Renewable Energy includes solar PV, CSP, wind and marine.

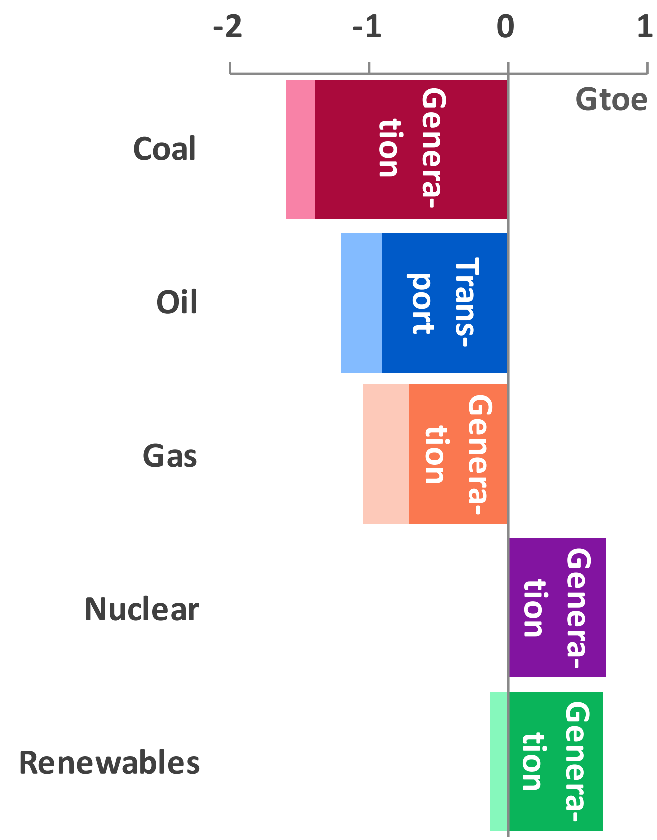
ATS slows the growth in electricity demand from 1.8 times in the reference, down to 1.6 times. In ATS, non-fossil power generation accounts for 60% and zero-emission generation, including thermal generation with CCS represents two thirds (that's half today's $CO_2$ emissions per unit of generation).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

# Coal falls significantly and below renewables

## ❖ Primary Energy




## ❖ Effects by ATS in 2050



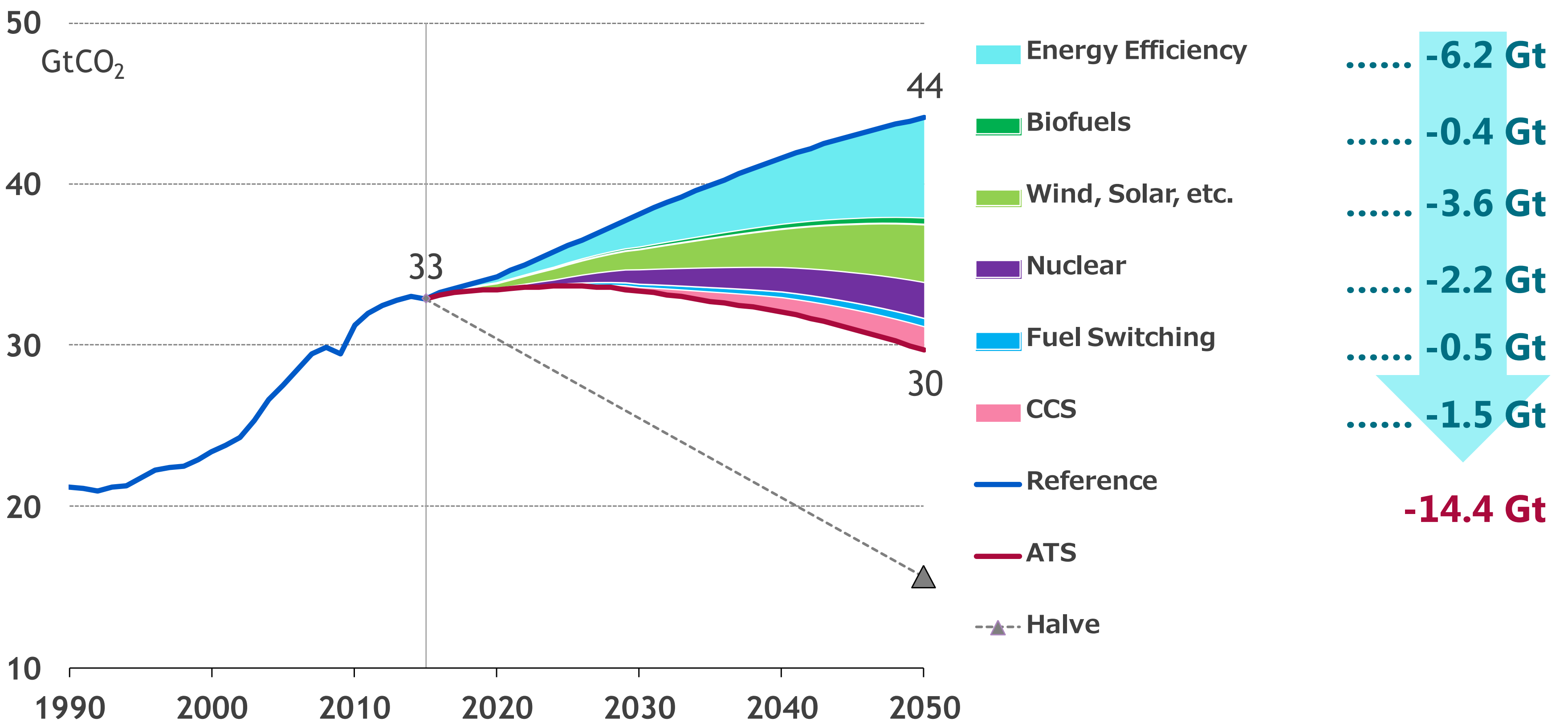

In ATS, coal starts to decline from now and is surpassed by renewables around 2040, due mainly to energy efficiency and the elimination of emissions in the power supply/demand sectors. Despite large decline in transportation fuels, oil does not reach a peak. Fossil fuels share of the total in 2050 is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

<Advanced Technologies>

# $CO_2$ emissions peak in the middle of 2020s

❖ Energy-related $CO_2$ Emissions

❖ Reductions by technology




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

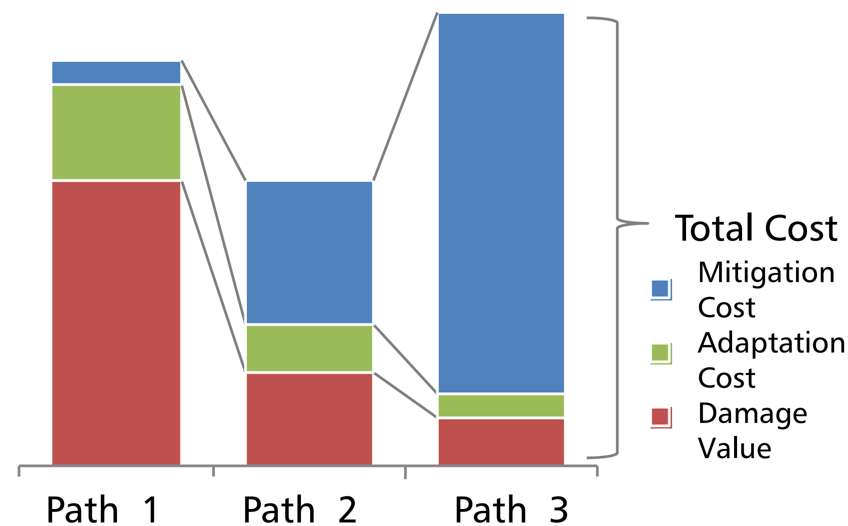
# Ultra-long-term Climate Analysis

# Rule for ultra long-term: Reduce the total cost

## ❖ Mitigation+Adaptation+Damage=Total Cost

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

## ❖ Illustration of Total Cost for Each Path



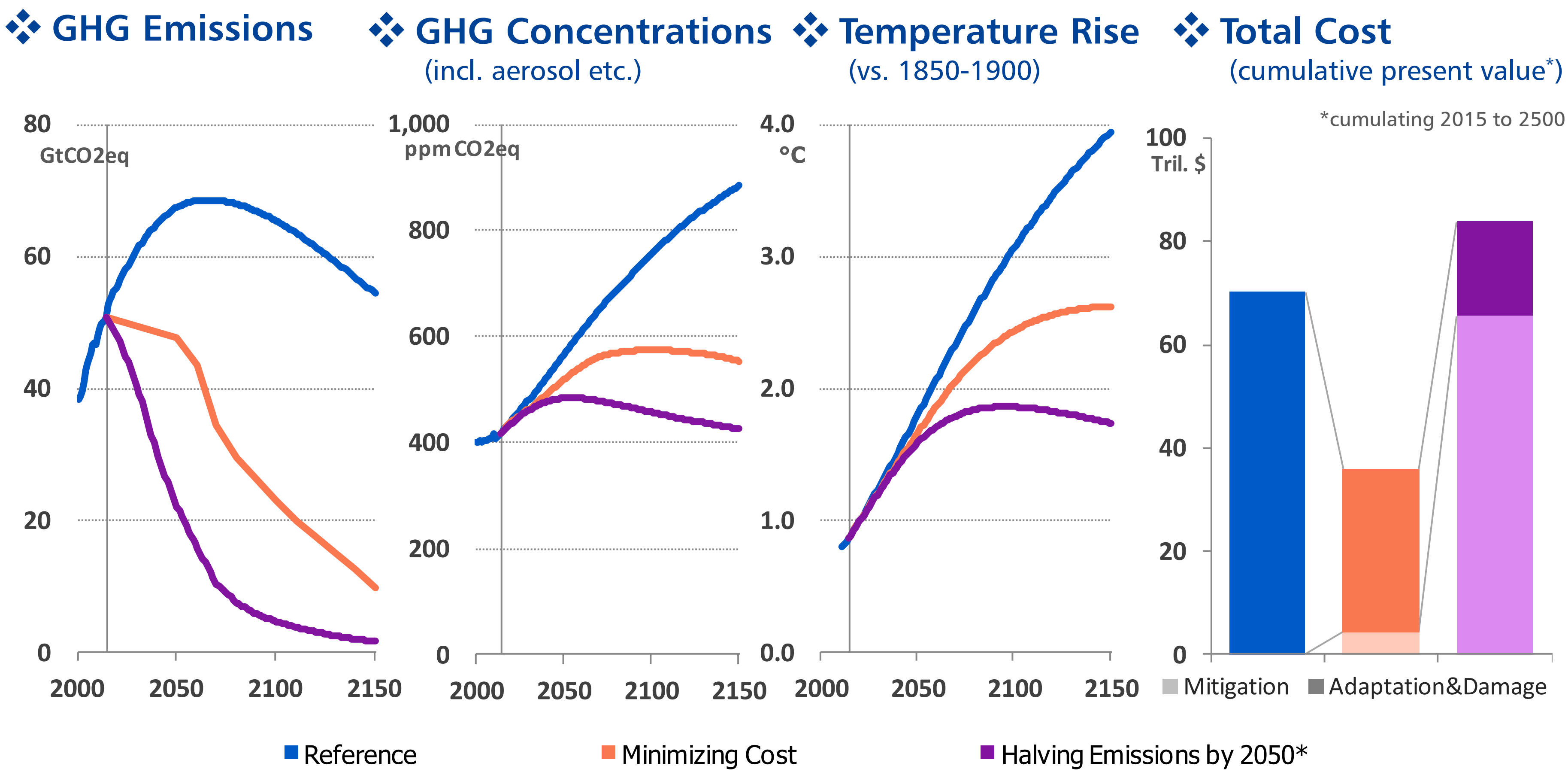

| | Path 1 | Path 2 | Path 3 |
|---|---|---|---|
| Mitigation | Too Small | Reasonable | Too Big |
| Adaptation | Big | Medium | Small |
| Damage | Big | Medium | Small |

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

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

# Minimizing Total Cost in IAM*

*Integrated Assessment Model

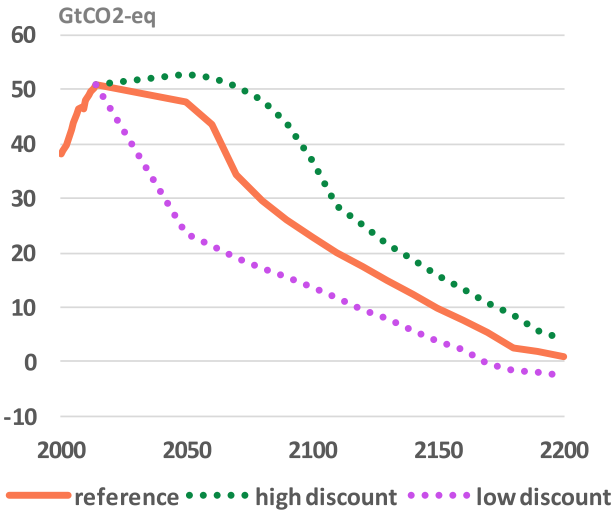


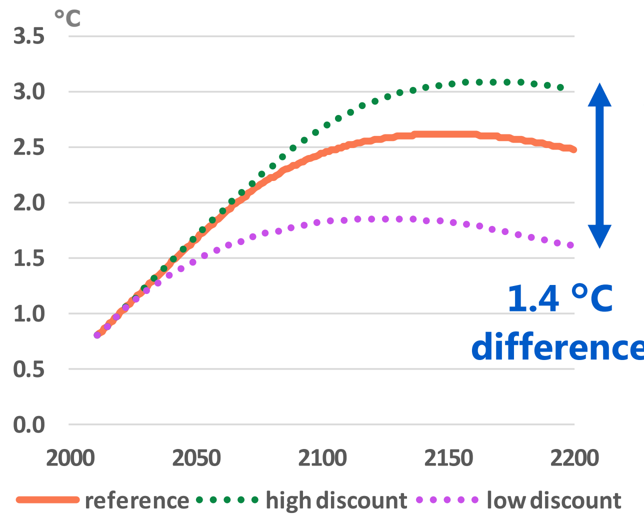

Total cost of "Minimizing Cost" is half of the reference. In 2150, GHG emissions decrease by 80% from now and temperature rises by 2.6 °centigrade from the late 19th century. In "Halving Emissions by 2050", temperature peaks at 2100, resulting in 1.7℃ in 2150. However, total cost is 20% higher than the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

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

# Still large uncertainties in the climate analysis

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



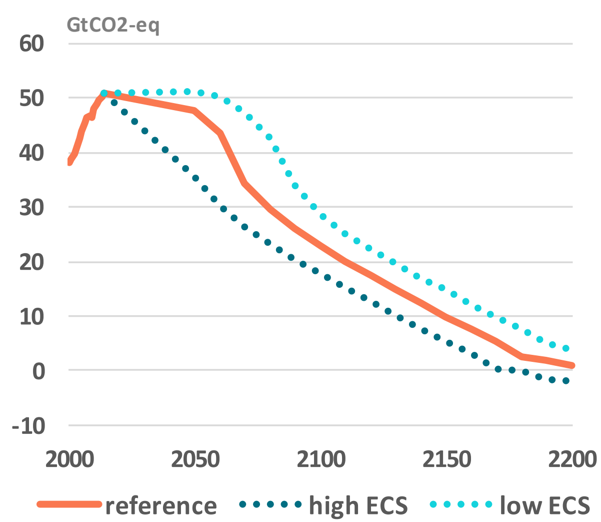

**Discount rate**
This model uses 2.5%. There are a range of 1.1 to 4.1% summarized by AR5.

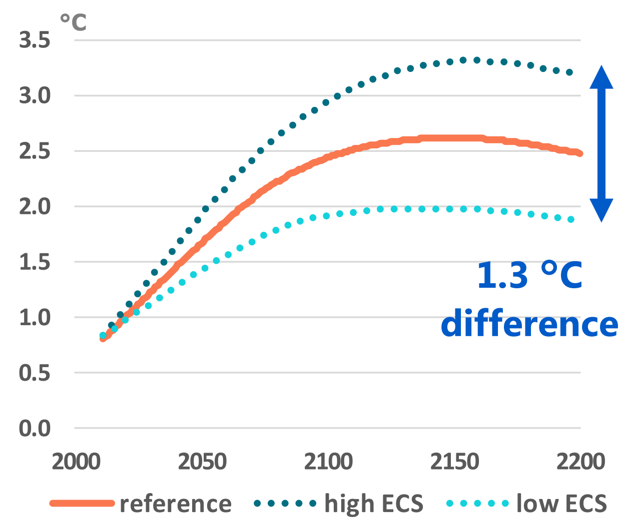
Note: The value used when converting future value (income and expenditure) into current value. The lower discount rate tends to raise emphasis of adaptation and damage, and strengthen the latest GHG reduction. The higher discount rate raises emphasis of mitigation costs and delays GHG reduction efforts.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

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

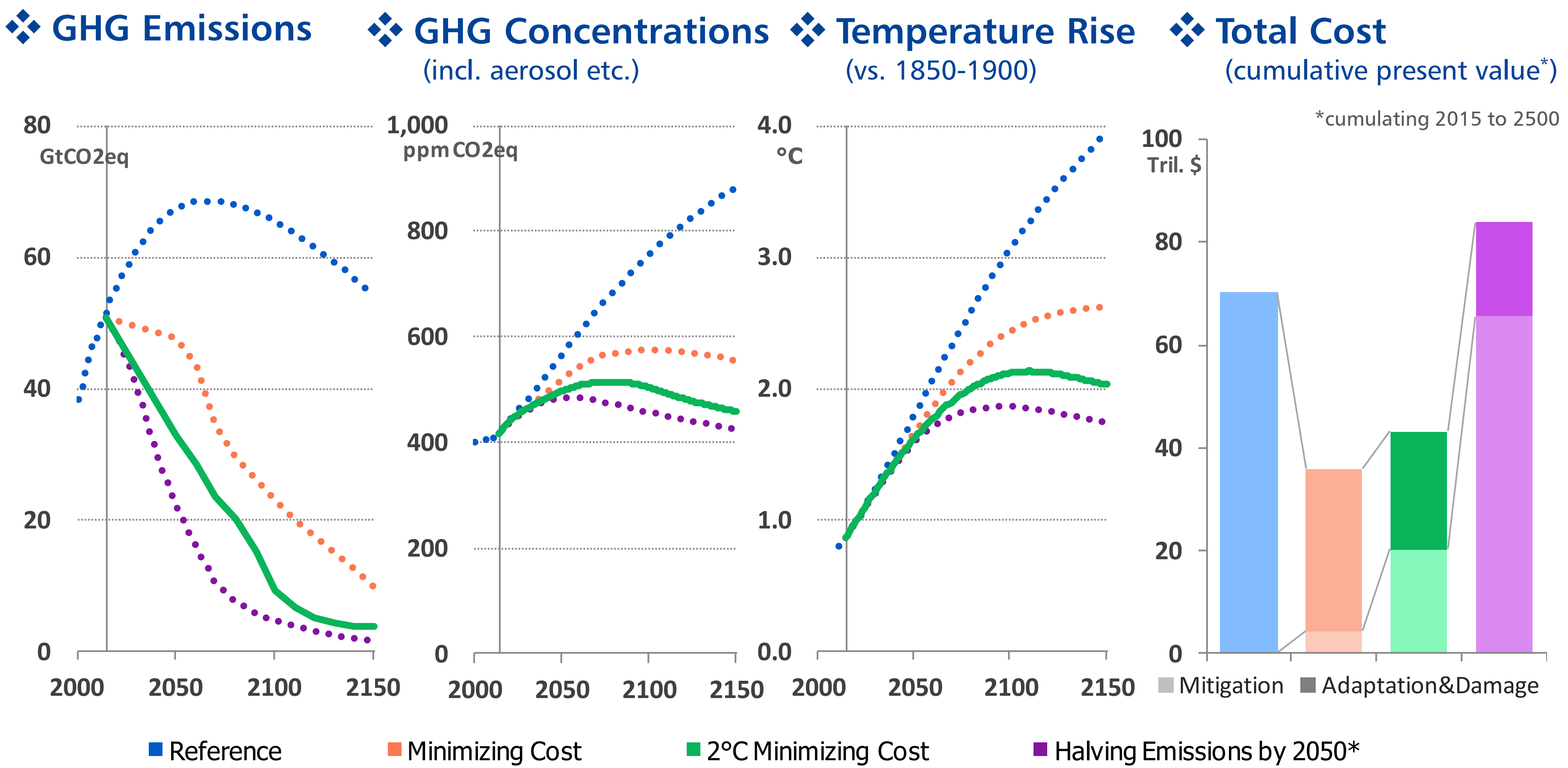
**Equilibrium Climate Sensitivity (ECS)**
This model uses 3 degree.
According to AR5, high possibility that ECS is between 1.9 and 4.5 degree.

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



# Another path to “2°C target”




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

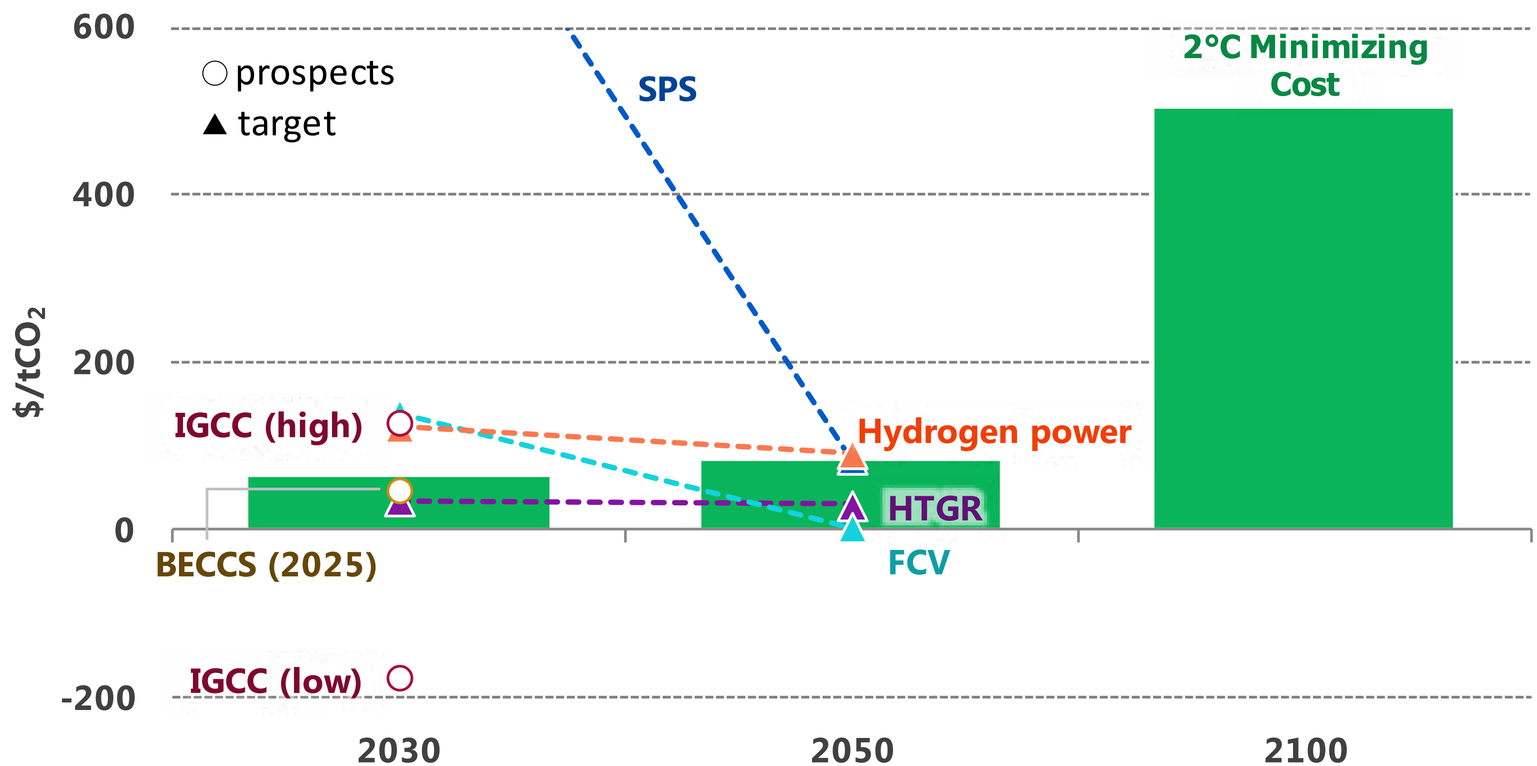
*Emissions path reflected “RCP 2.6” in the 5th Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC).

# Technology development for ultra long-term

| Technologies | | Description | Challenges |
|---|---|---|---|
| Technologies to reduce $CO_2$ emissions | Next Generation Nuclear Reactors | Fourth-generation nuclear reactors such as ultra-high-temperature gas-cooled reactors(HTGR) and fast reactors, and small- and medium-sized reactors are now being developed internationally. | Expansion of R&D support for next generation reactors |
| | Nuclear fusion reactor | Technology to extract energy just like the sun by nuclear fusion of small mass number such as hydrogen. Deuterium as fuel exists abundantly and universally. Spent nuclear fuel as high-level radioactive waste is not produced. | Technologies for continuously nuclear fusion and confining them in a certain space, energy balance, cost reduction, financing for large-scale development and establishment of international cooperation system, etc. |
| | Space Photovoltaic Satellite (SPS) | Technologies for solar PV power generation in space where sunlight rings abundantly above than on the ground and transmitting generated electricity to the earth wirelessly via microwave, etc. | Establishment of wireless energy transfer technology, reduction of cost of carrying construction materials to space, etc. |
| Technologies to sequestrate $CO_2$ or to remove $CO_2$ from the atmosphere | Hydrogen production and usage | Production of carbon-free hydrogen by steam reforming of fossil fuels and by CCS implementation of $CO_2$ generated. | Cost reduction of hydrogen production, efficiency improvement, infrastructure development, etc. |
| | CO2 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. $CO_2$ can be removed from the atmosphere. | Dramatic improvement in quantity and efficiency, etc. |
| | Bio-energy with carbon capture and storage (BECCS) | Absorption of carbon from the atmosphere by photosynthesis with biological process and CCS. | It requires large-scale land and may affect land area available for the production of food etc. |

# Lower cost is key for innovative technologies

## ❖ $CO_2$ Reduction Cost by Innovative Technology

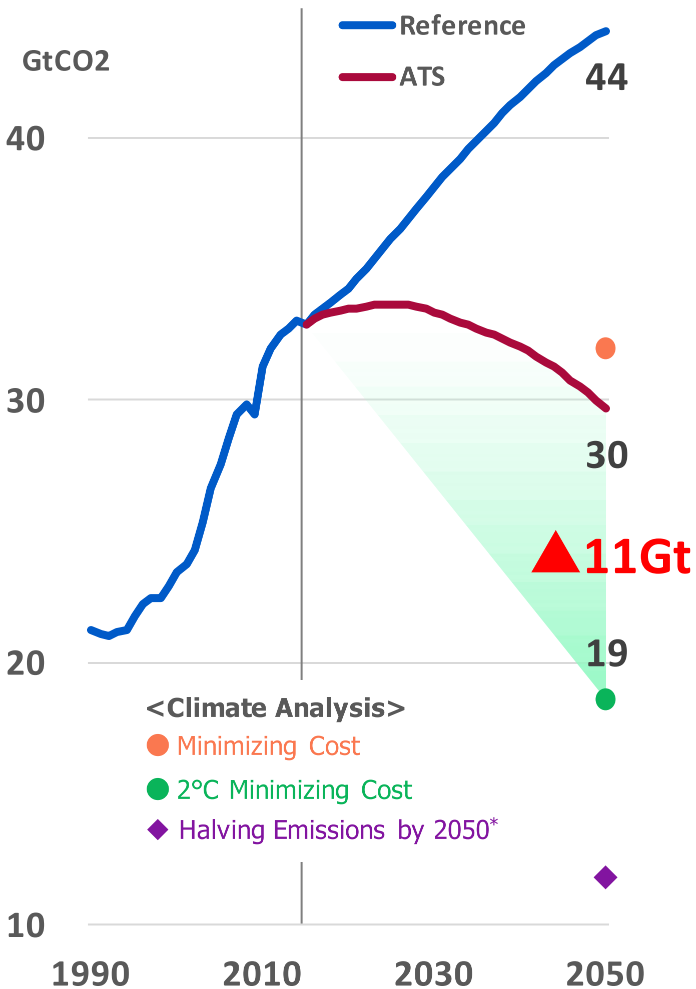



Note: Cost (=carbon price) for "2 °C Minimizing Cost" is the highest cost of the technology adopted at each year. Refer to the main report for detail.

Implicit carbon price for "2°C Minimizing Cost" is \$85/t$CO_2$ in 2050. The target costs for innovative technologies, such as BECCS, hydrogen power, FCV, HTGR, SPS, are within the range of the carbon price. The 2°C target can be reached with using these technologies. It is important to enhance R&D from the long term view and international collaboration is dispensable.

# Further $CO_2$ reductions from ATS

## ❖ Energy-related $CO_2$ Emissions




## ❖ Examples of technologies needing further reductions

### 1) $CO_2$ Free Hydrogen (refer to previous Outlook)

- **Hydrogen power 1 GW x 3000 units**
- **Fuel cell vehicles 1 billion units**

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

### 2) Negative-emission Technology

- **BECCS: Biomass power 0.5 GW x 2800 units**

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

### 3) Zero-emission Power and Factories with CCS

**-10 $GtCO_2$** (Maximum reduction volume by substituting thermal power generation without CCS)

- **SPS: 1.3 GW x 2300 units**

or • **HTGR: 0.275 GW x 8700 units**

or • **Fusion reactor: 0.5 GW x 4500 units**

or • **Thermal power with CCS: 2800 GW**

(Estimated $CO_2$ storage potential is over 7000Gt)

+

**-1 $GtCO_2$**

- **CCS: Installed in 20% of factories and plants**

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

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

# Peak Oil "Demand" Case

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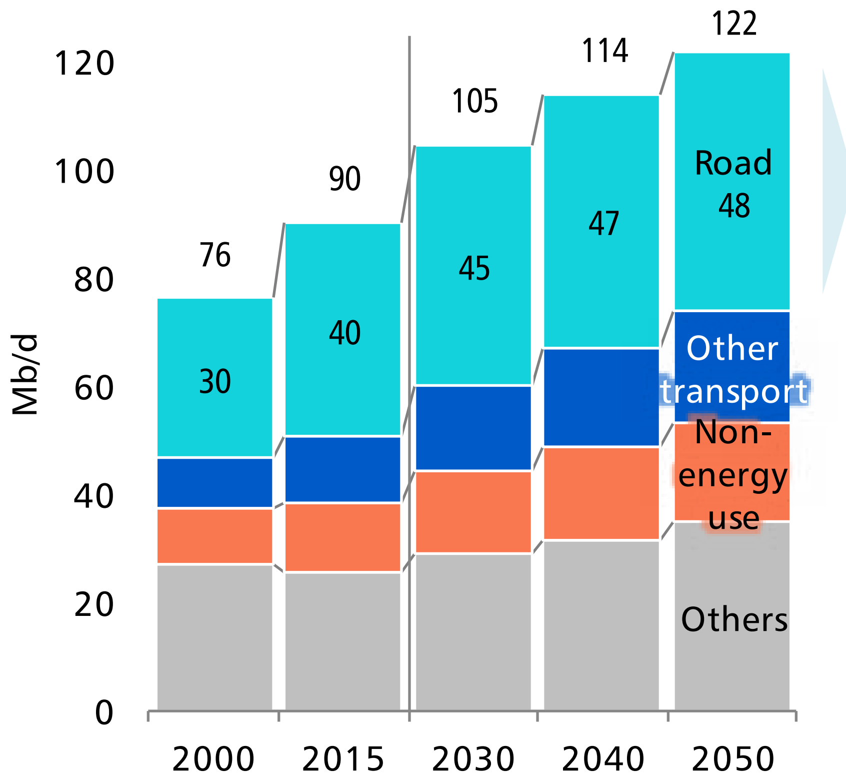
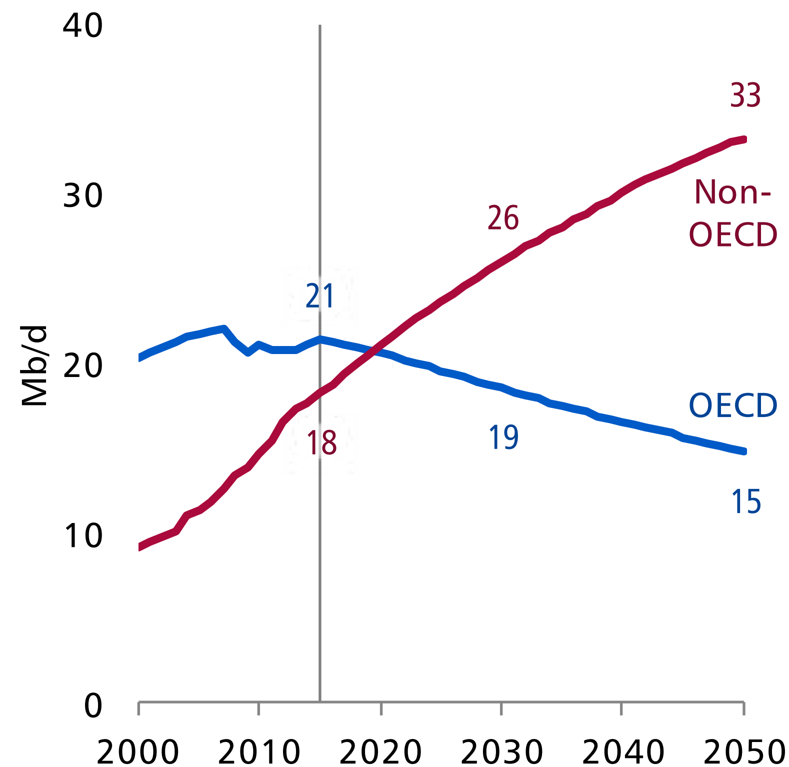
# Transport, especially cars, drives oil demand

## Oil consumption [Reference Scenario]




## Oil for Road [Reference Scenario]




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

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

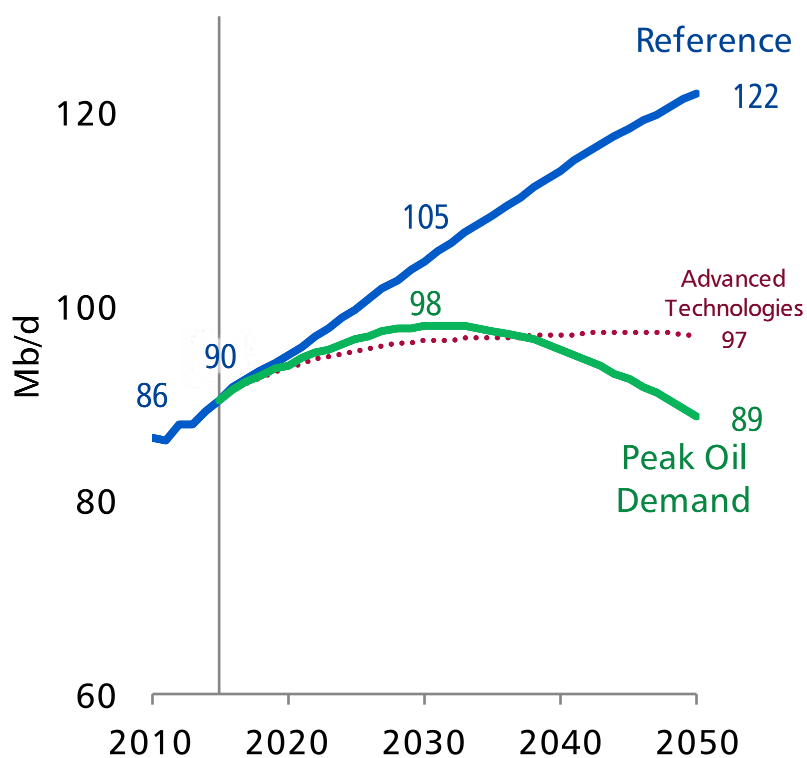
# The time for car electrification has come?

## Selected recent movements by governments/assemblies and car makers

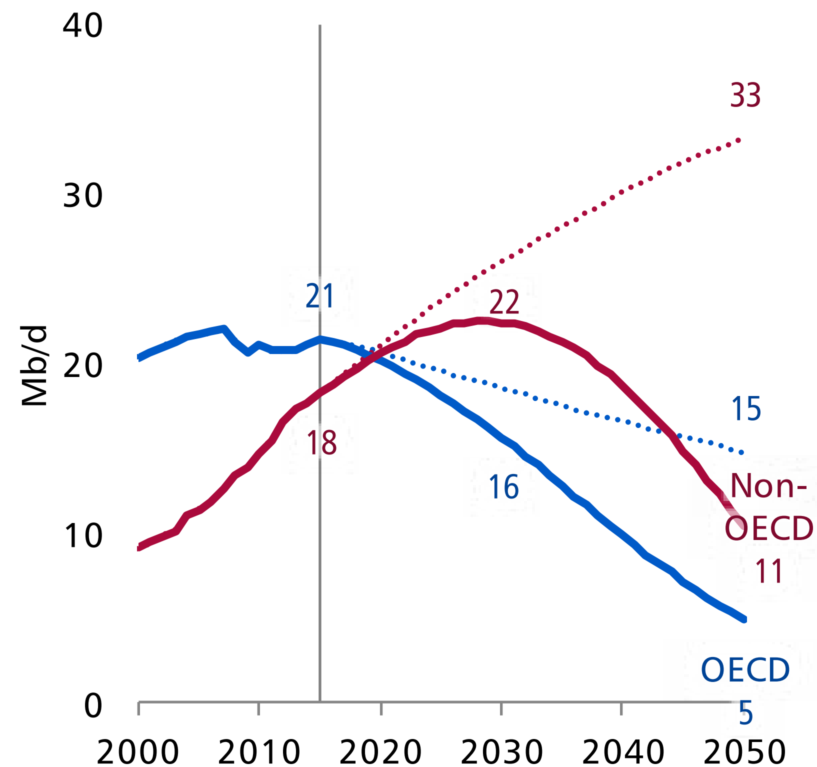
| | | | |
|---|---|---|---|
| Germany | A resolution to ban conventional car sales in the European Union by 2030 was passed by the Bundesrat of Germany (2016) | Toyota | The target for FCV sales is more than 30,000/year in 2020 (2015). Reported of full-scale entry into EVs in 2020 (2016) |
| Norway | The ruling and opposition parties proposed the abolition of conventional vehicles by 2025 (2016) | Volkswagen | Announced the strategy to increase EV share in its total sales to 25% with more than 30 models of EVs by 2025 (2017) |
| France | The Government announced that it would ban conventional car sales by 2040 (2017) | Renault-Nissan | Introducing 12 models of EVs by 2022. The target of 30% of its total sales as EVs (2017) |
| United Kingdom | The Government announced that it would ban conventional car sales by 2040 (2017) | Hyundai | The plan to prepare EVs at all line up by 2020 (2015) |
| India | Minister said that all new car sales after 2030 would be electric vehicles (2017) | Ford | Announced that eco-cars combined with EVs and HEVs will be raised to 70% by 2025 (2017). |
| China | Deputy Minister mentioned that the ban on the sale of conventional vehicles was under investigation (2017) | Honda | In 2030, two-thirds of automobile sales will be electrified. EVs will be released in China in 2018 (2017). |

# Oil peaks around 2030 with a rapid penetration of ZEVs

## Oil consumption




## Oil for Road [Peak Oil Demand Case]



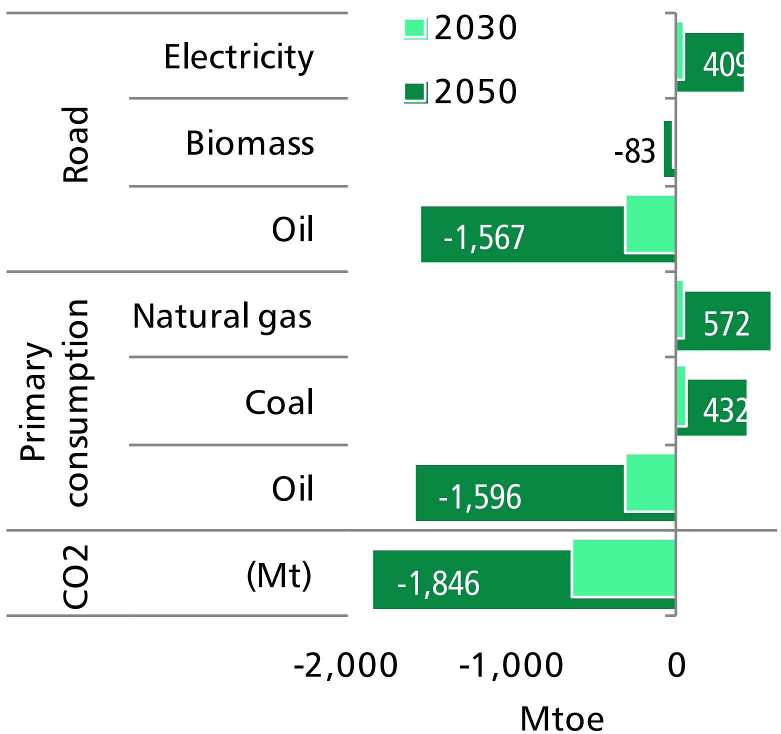

Note: Dotted lines are the Reference Scenario

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

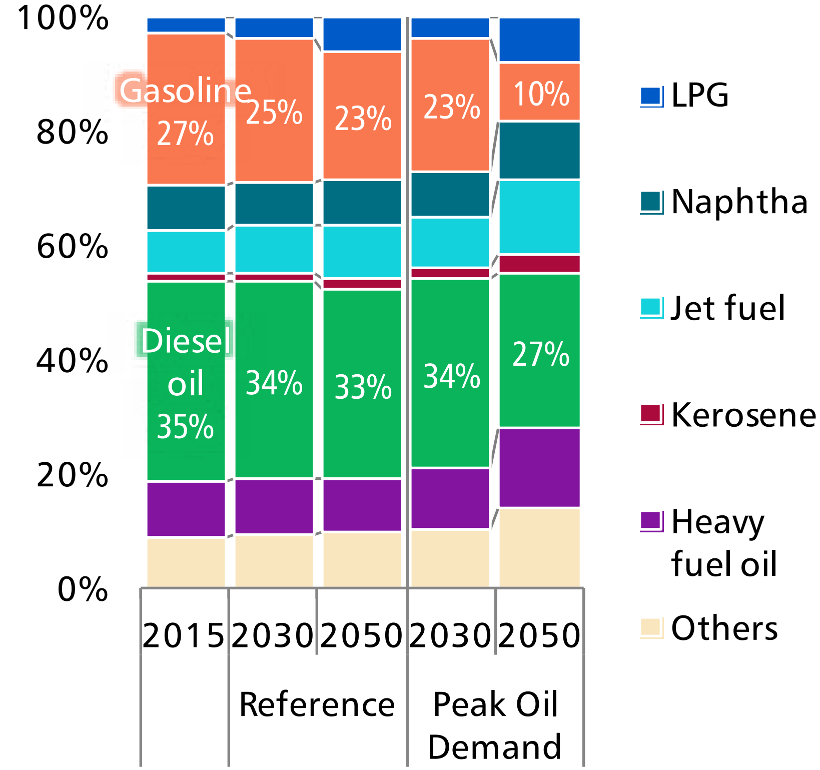
Oil consumption by cars in Non-OECD, which continues to increase rapidly in the Reference Scenario, also declines from around 2030. It is as much as one third of the Reference Scenario in 2050.

# While natural gas and coal increase, the petroleum product composition changes

## Changes in consumption (from the Reference Scenario)




## Composition of petroleum products consumption



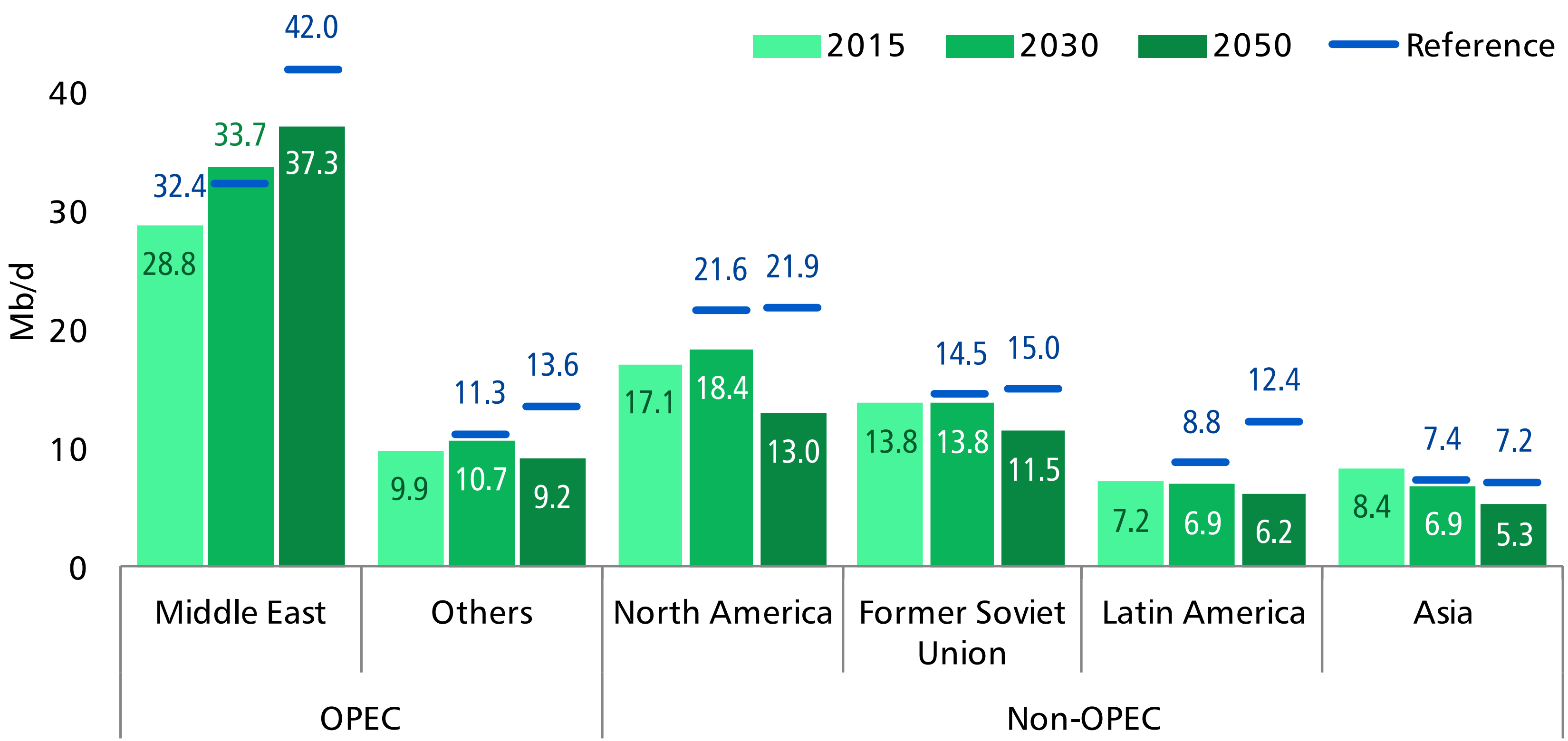

Note: Excluding own use

As ZEVs demand for oil declines and electricity increases, the fuel required for power generation also increases. Both natural gas and coal exceeds oil by the late 2030s. Natural gas becomes the largest energy source thereafter.

Gasoline reduces its share from 27% to 10% in 2050. The share of diesel oil is not reduced as much because diesel oil has other uses. Diesel share in 2050 is 8 points lower than today.

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

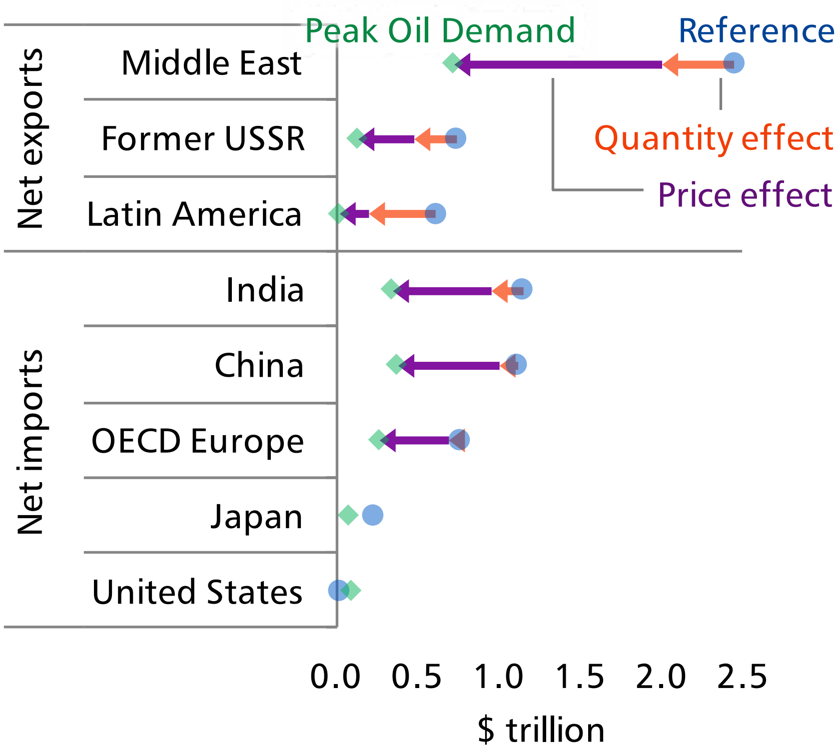
## Crude oil production [Peak Oil Demand Case]

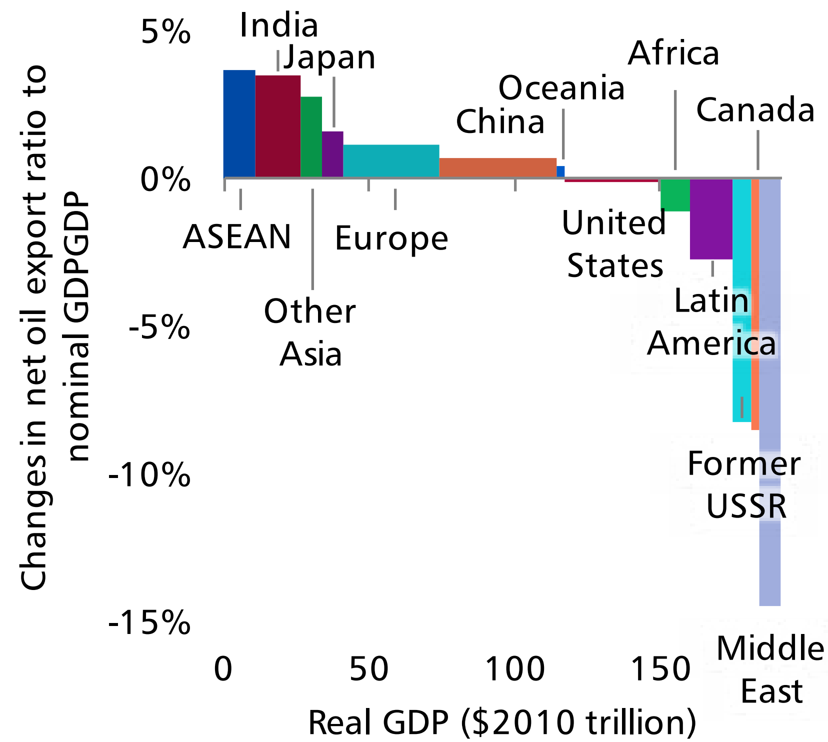



Oil price falls due to the change in supply and demand pressure and market perception. Relative to the Reference Scenario (in $2016), prices drop from $95/bbl to $65/bbl in 2030 and from $125/bbl to $50/bbl in 2050. Given such drastic price decreases, regions with low production costs would be the only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

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

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



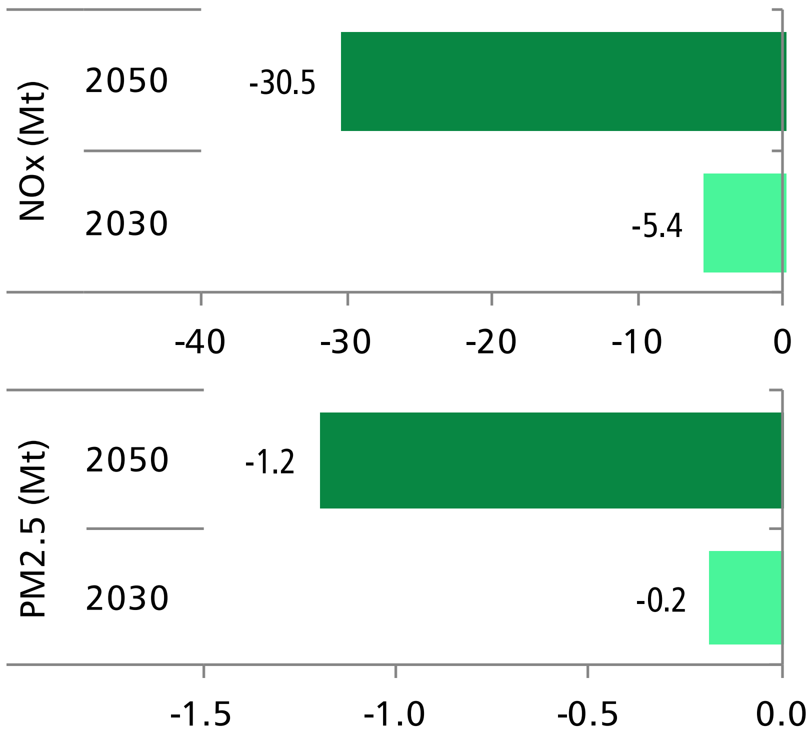




Note: Europe excludes the former Soviet Union

Although the Middle East achieves a relative gain, the decrease in net oil export revenues is $1.6 trillion; a significant drop of 13% of nominal GDP. At the other end of the spectrum, India which is the second largest oil consumer, benefits the most with a decrease in net oil import costs. It is followed by China, in which more cars are on road than in any other countries. Despite its consumption scale, the United States faces little impact since it is almost oil self-sufficient.

# Impact of less oil consumption diverges

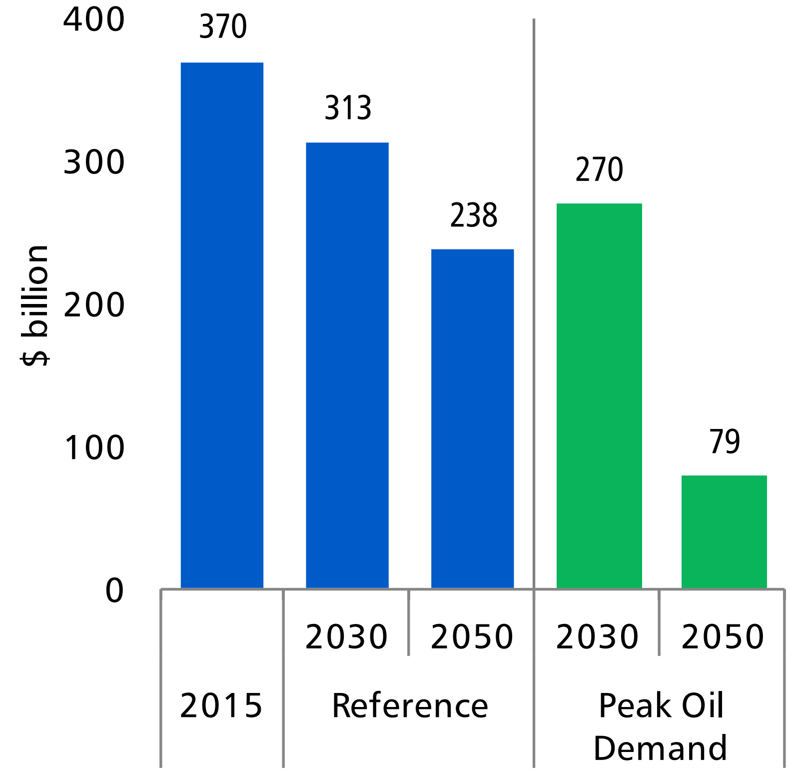
## Changes in emissions (from the Reference Scenario)




Note: Automobile origin. Does not include effect on improvement of conventional automobile emission control performance

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

## Excise taxes on gasoline and diesel oil for automobiles in OECD




Revenues from excise taxes on automotive gasoline and diesel oil will be reduced significantly, unless tax regime changes. They may become financial issues similar to the subsidies for ZEVs at their promotion stage.

# How do we recognise the rapid de-oiling?

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

...and then

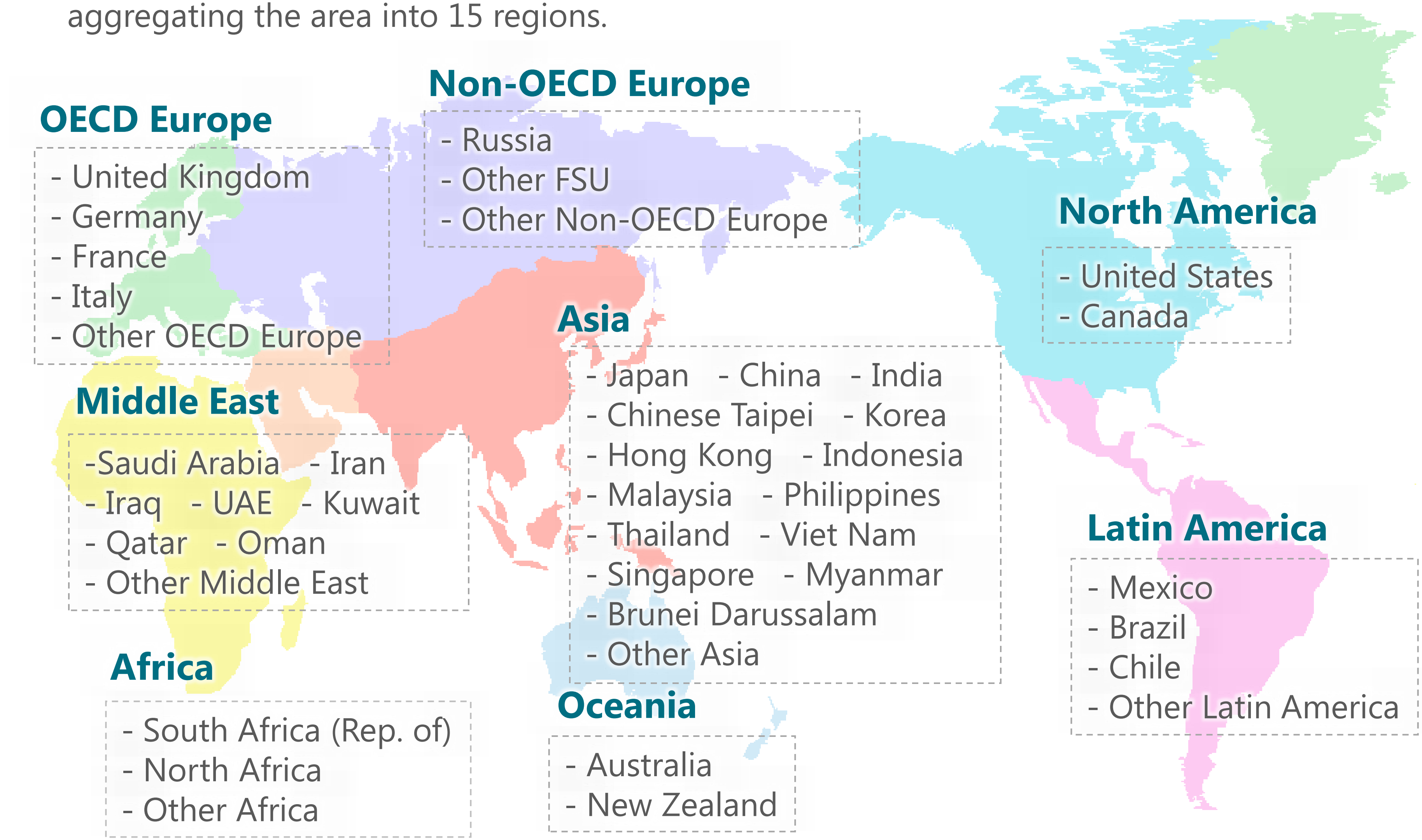
- It should not be overlooked that in the Peak Oil Demand Case, oil remains required in 2050 on a scale that does not differ from today.
- If the supply investment becomes insufficient due to excessive pessimism in the future , it can trigger the switching from oil to other energies threatening energy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

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

# Reference materials

# Geographical coverage

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



# Modelling 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 project 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.

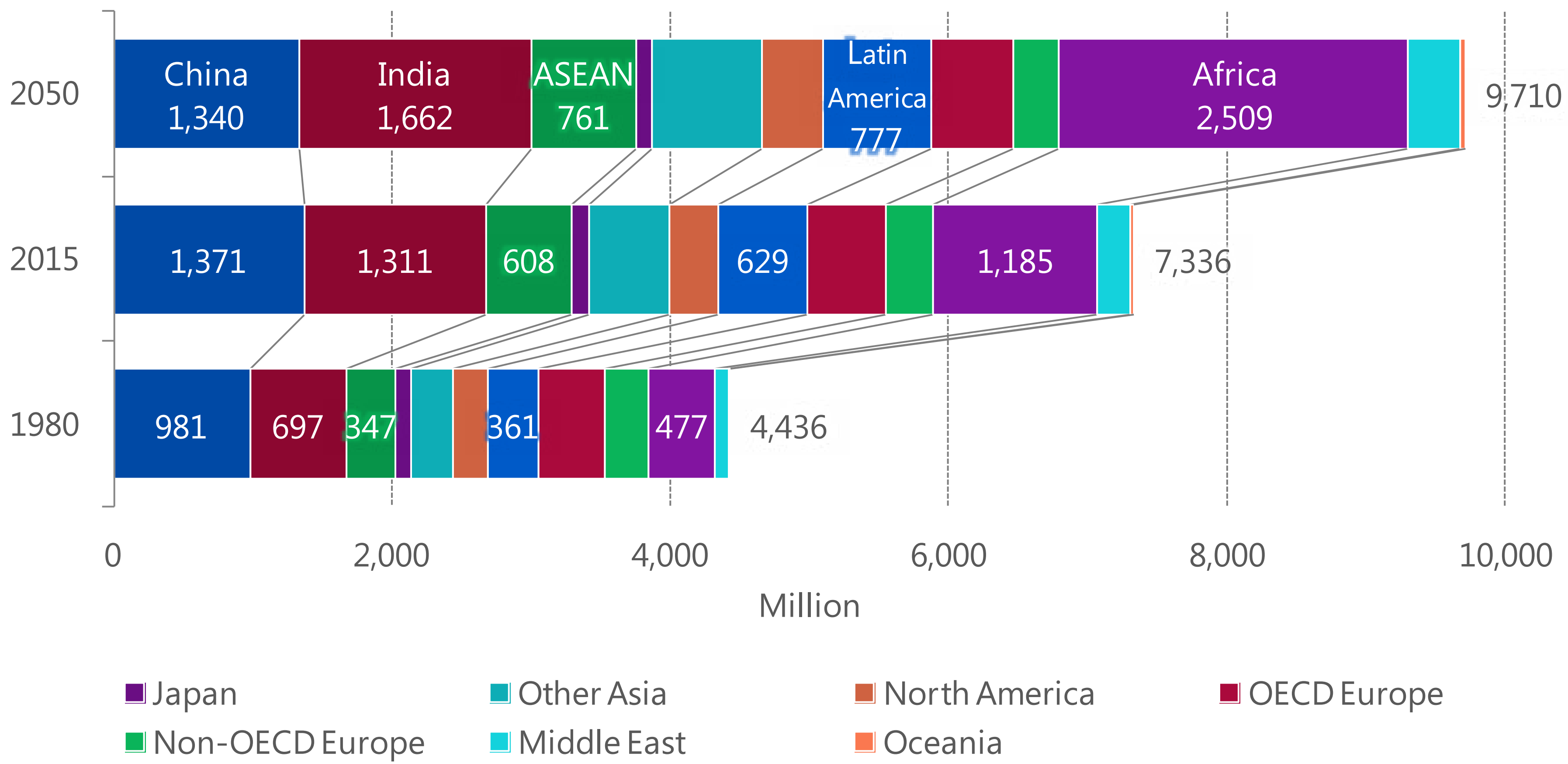
## Computable general equilibrium model

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

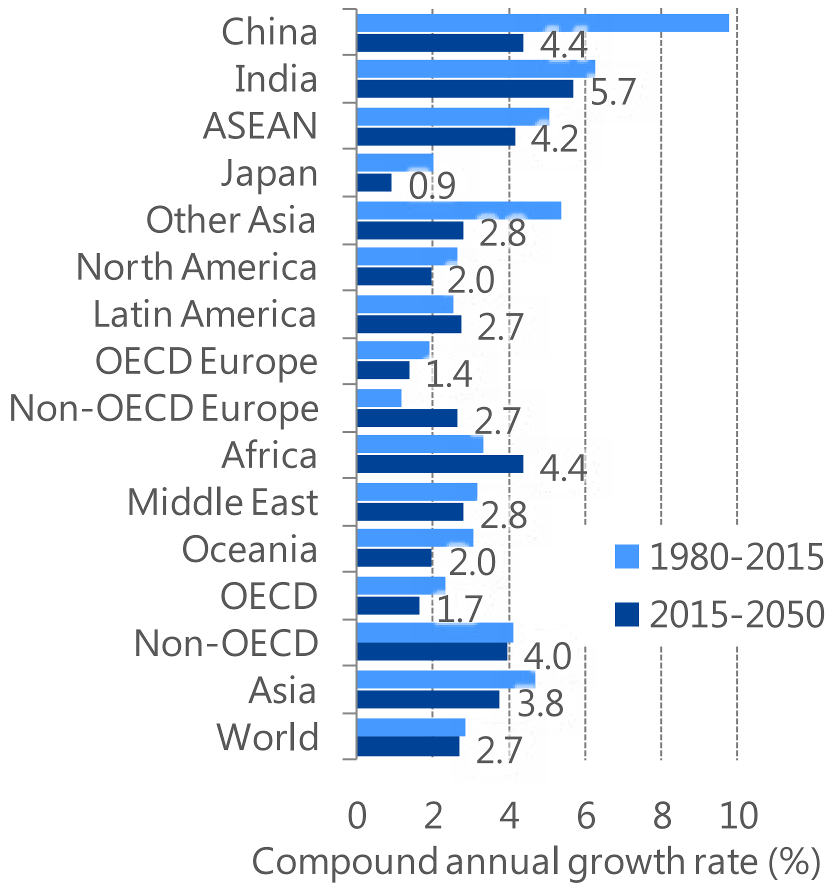
## Climate change model

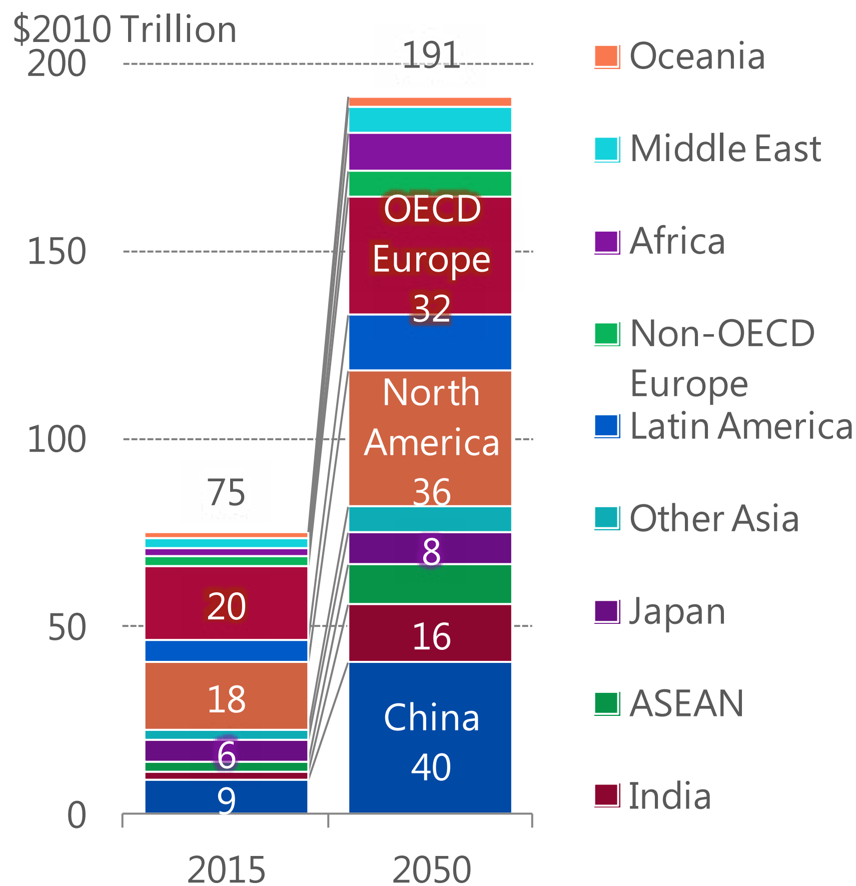
Calculate future GHG concentration in the atmosphere, temperature rise, damage caused by climate change, etc.

# Major assumption: Population

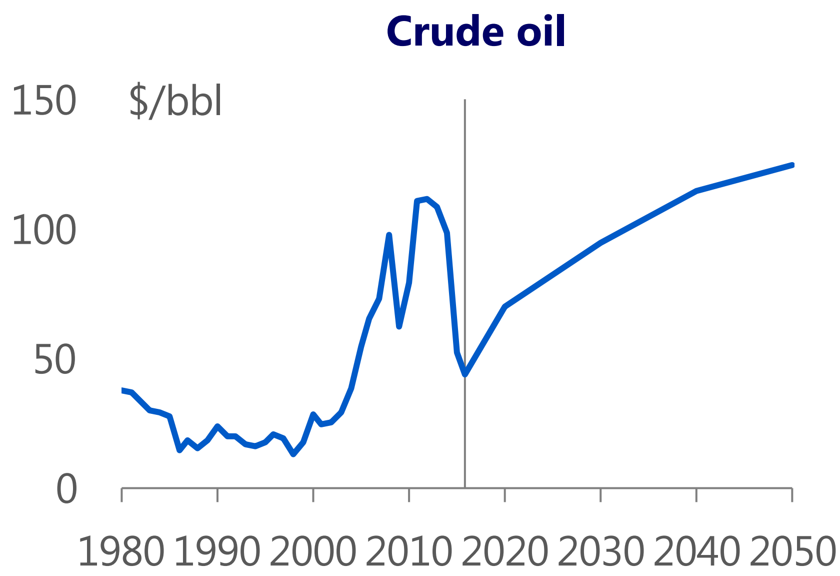


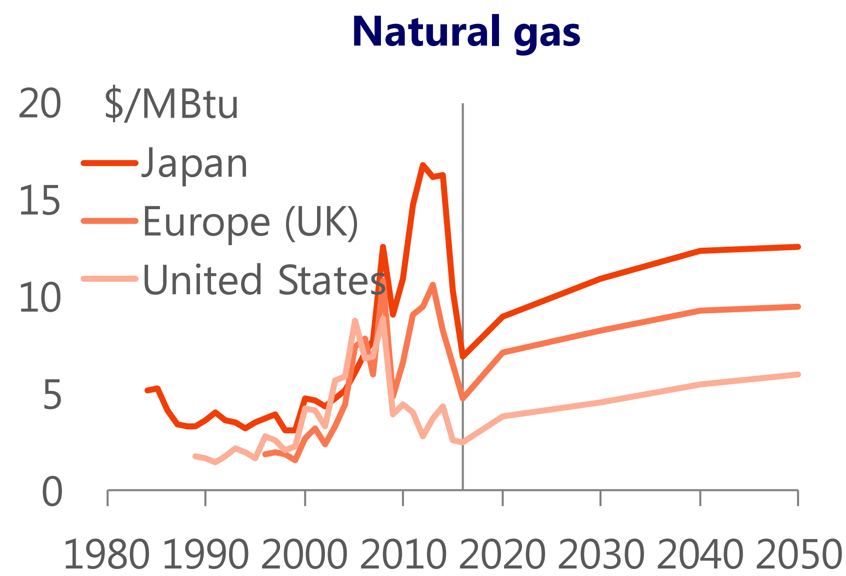
# Major assumption: Real GDP

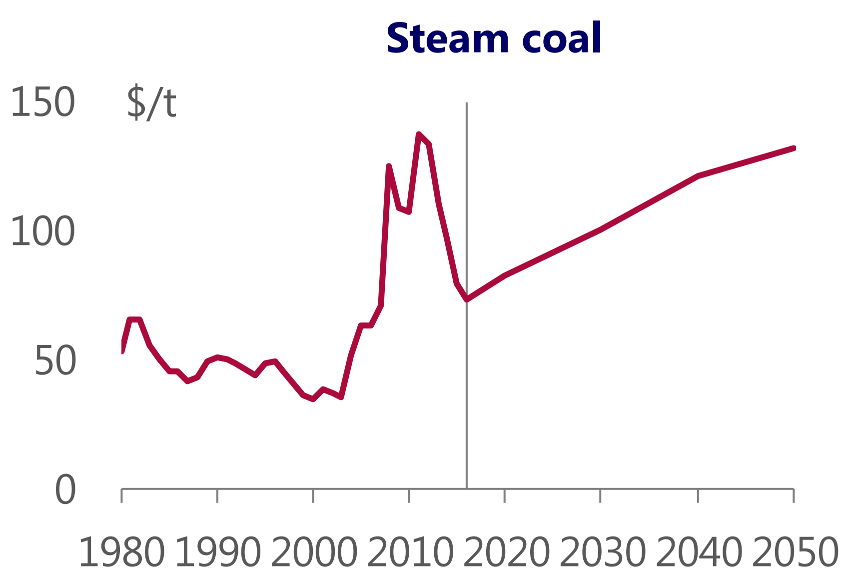


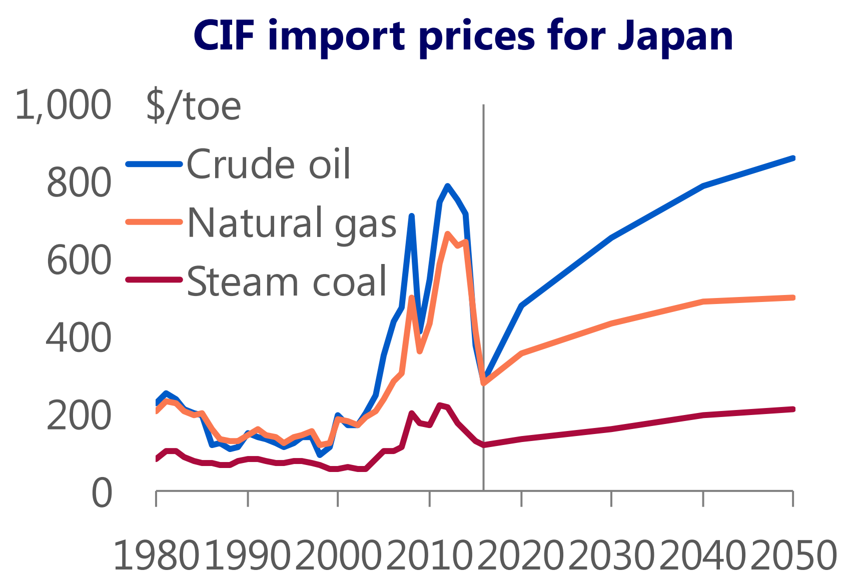



# Major assumption: International energy prices



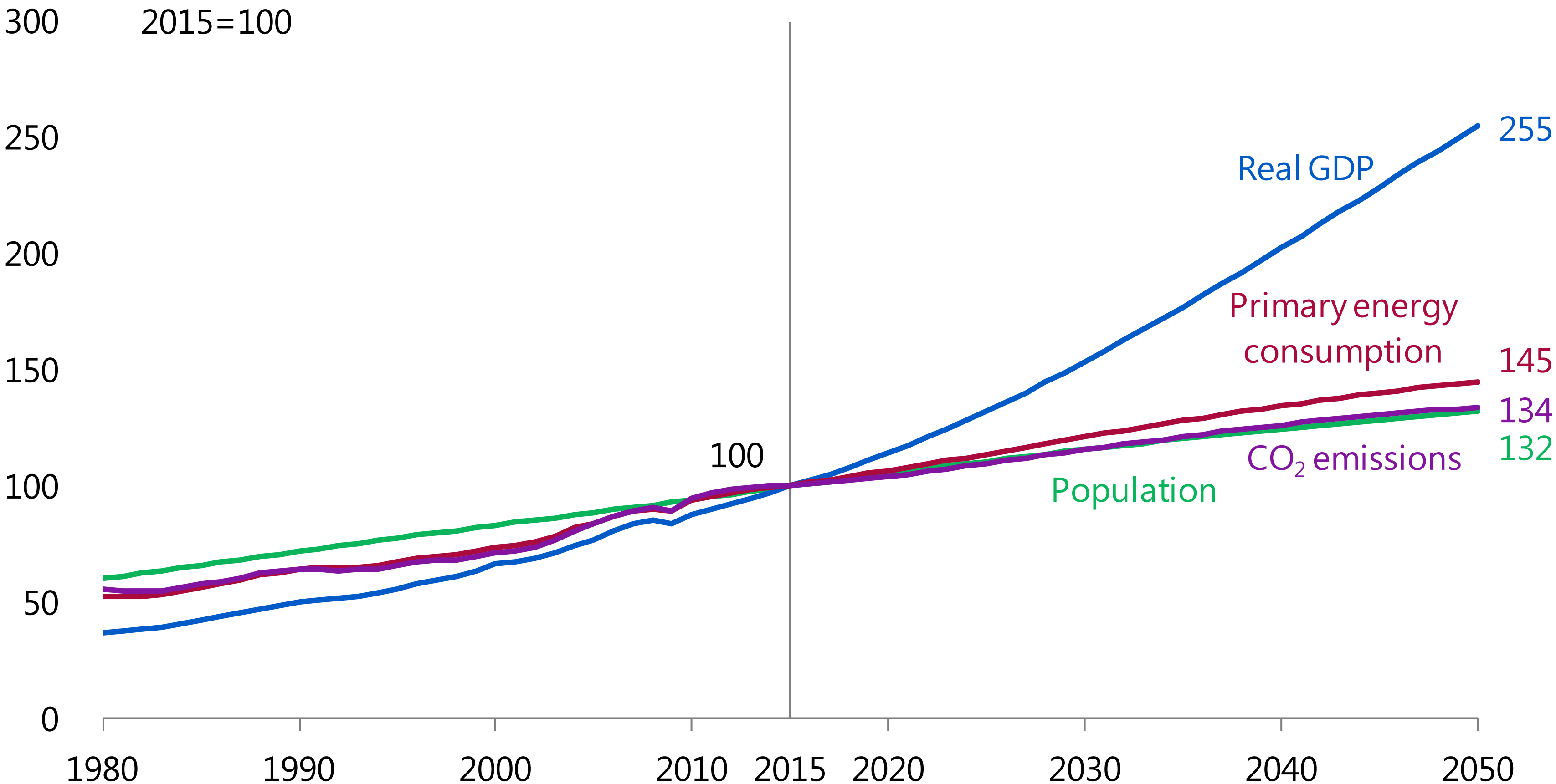

* Historical prices are nominal price. Assumed future prices are real price in $2016.

# Energy outlook in the world and Asia 2015-2050

# Reference Scenario

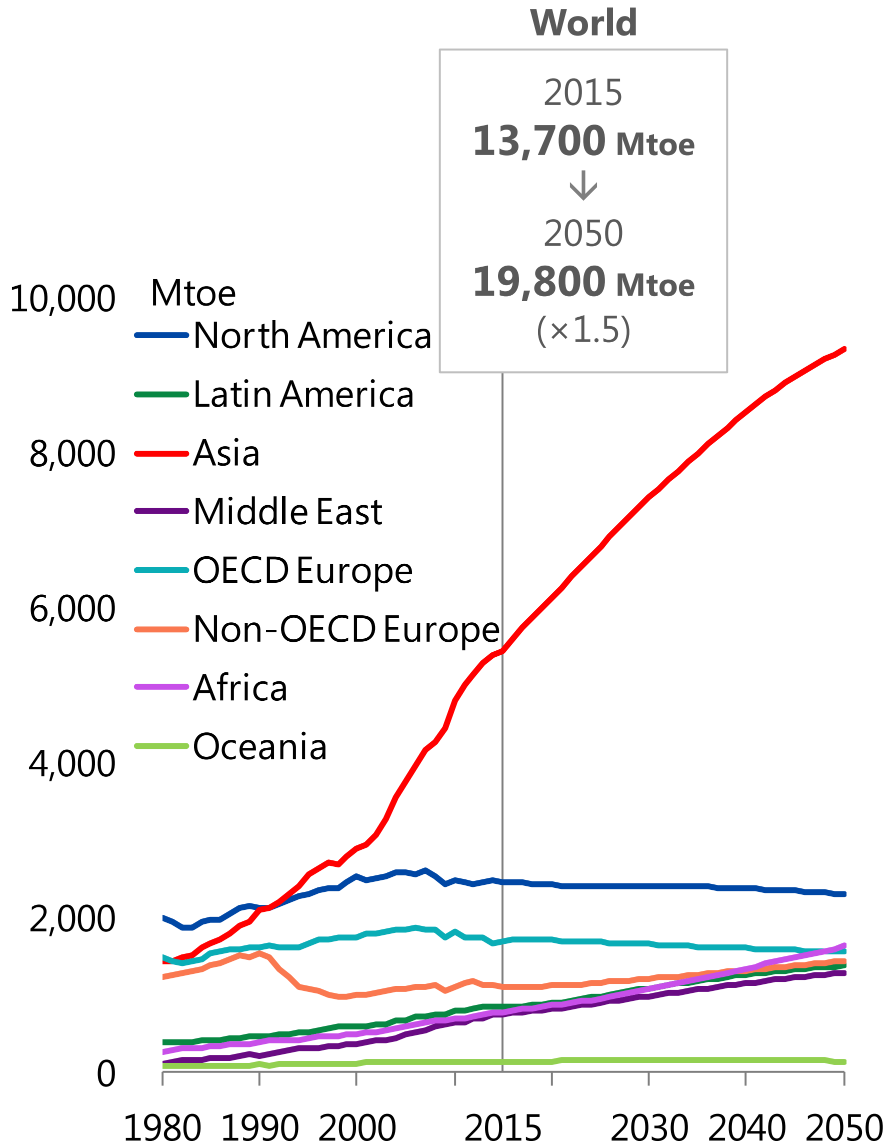
# World population, GDP, primary energy consumption and $CO_2$ emissions

Reference Scenario

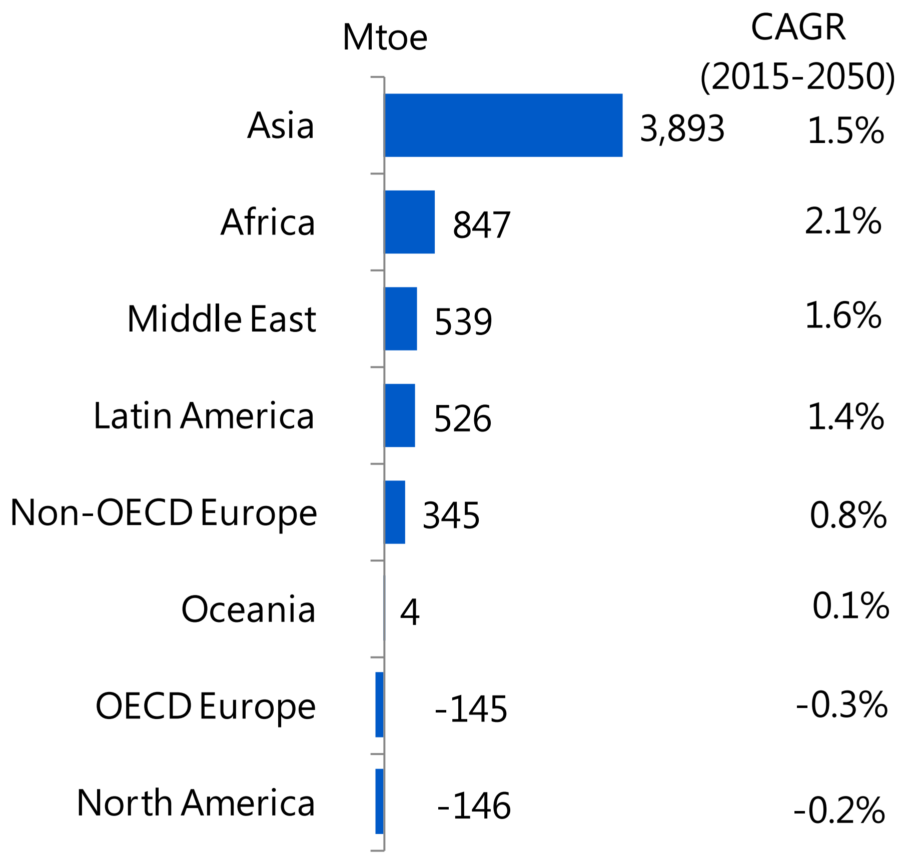


# Primary energy consumption by region

Reference Scenario

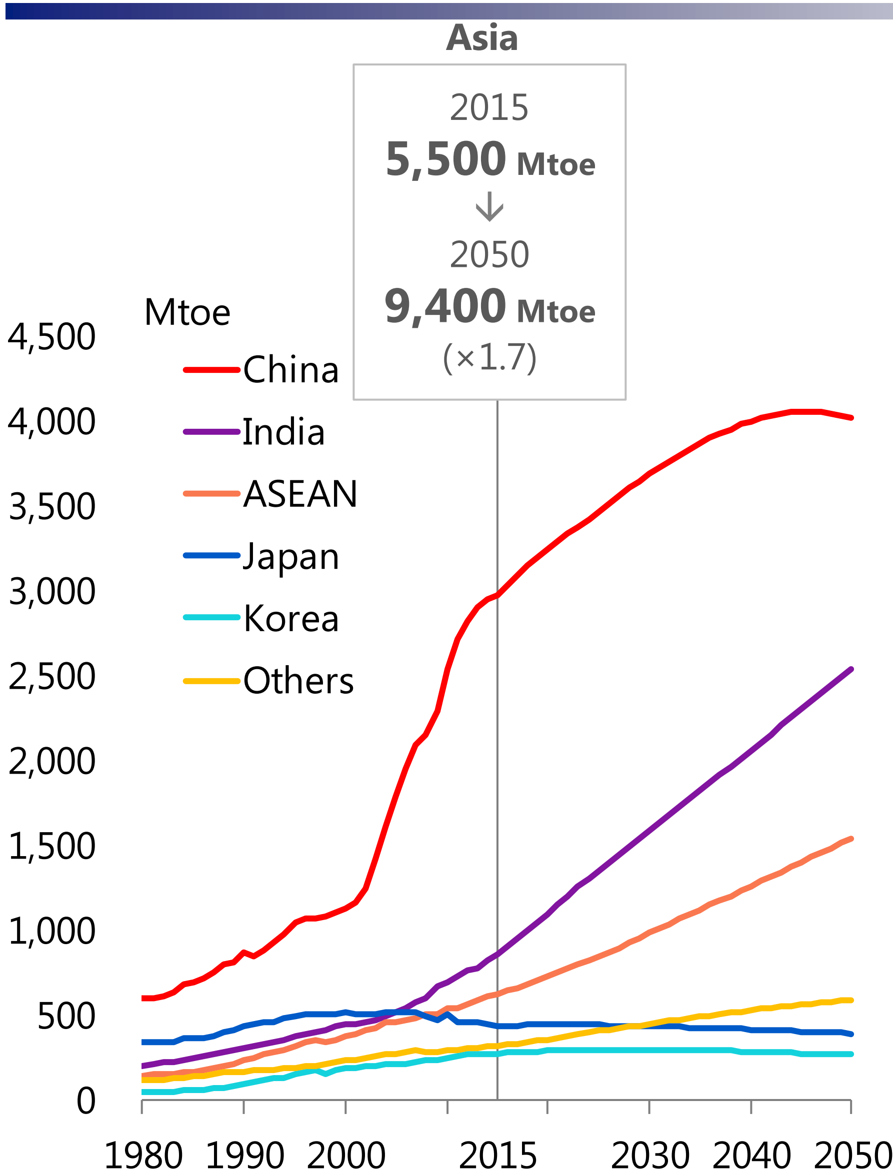


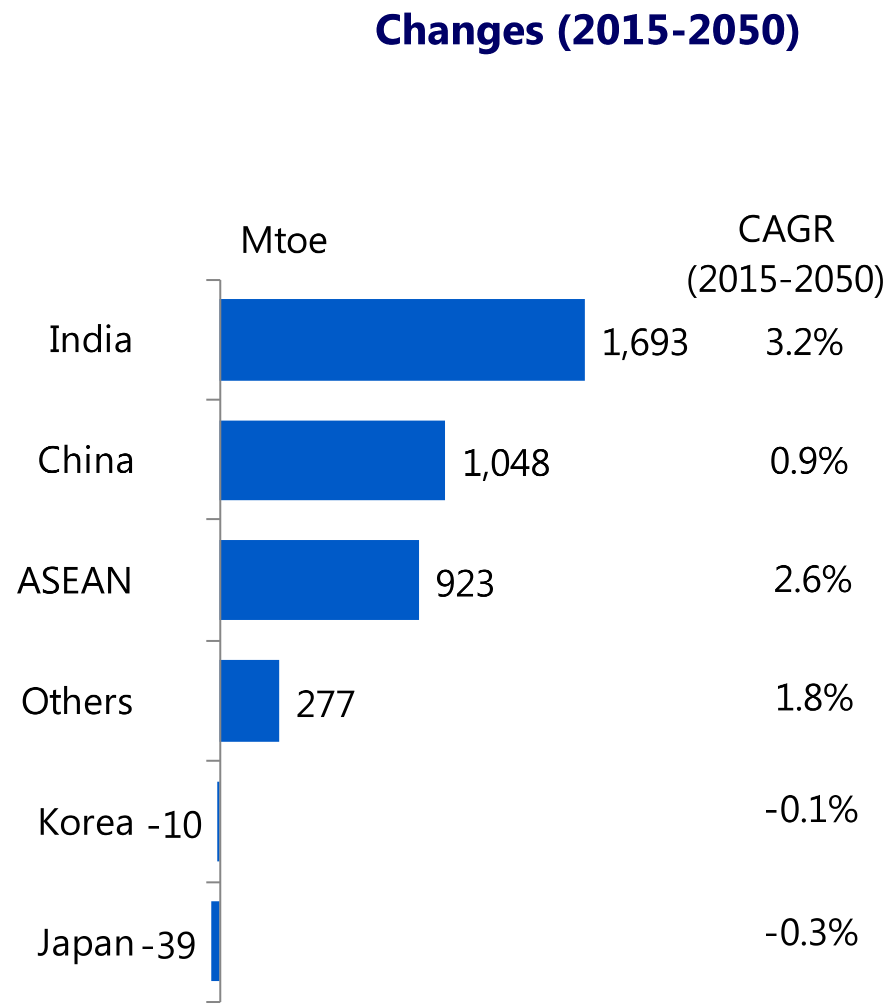

## Changes (2015-2050)



# Primary energy consumption by region (Asia)

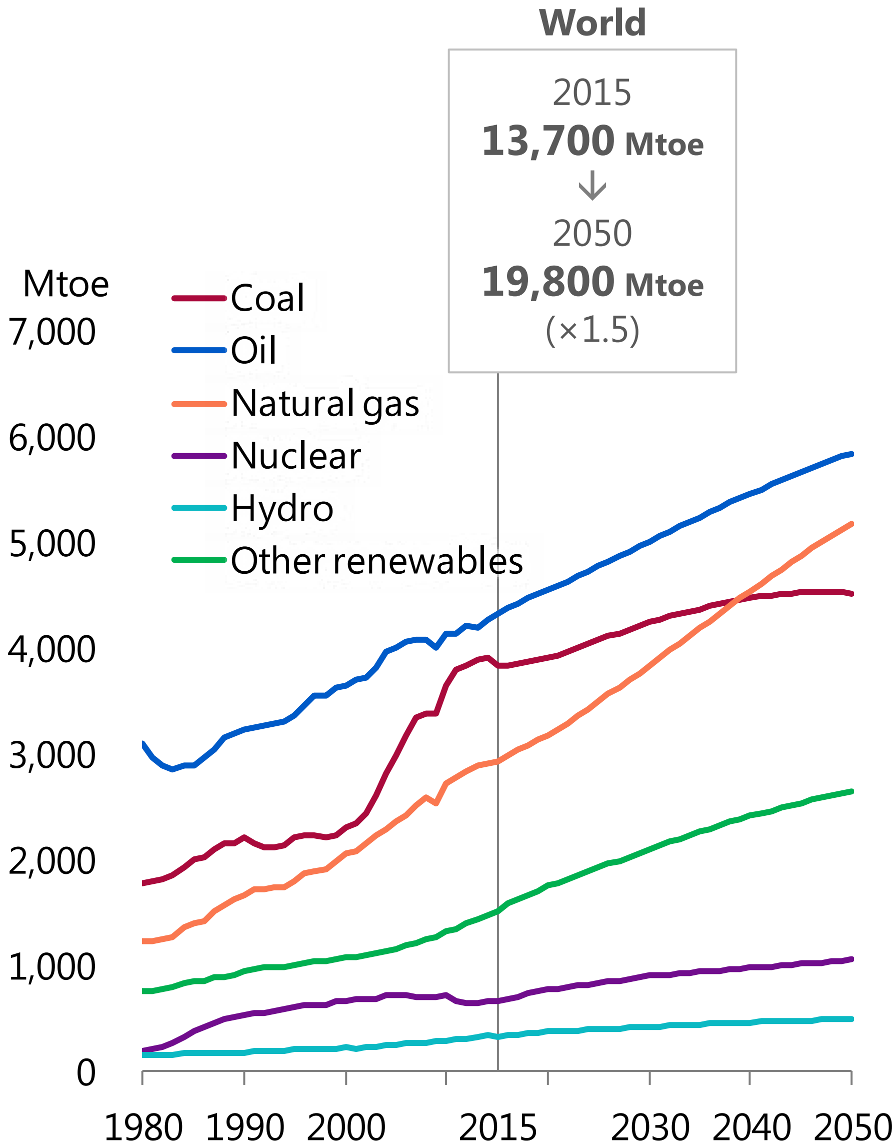
Reference Scenario



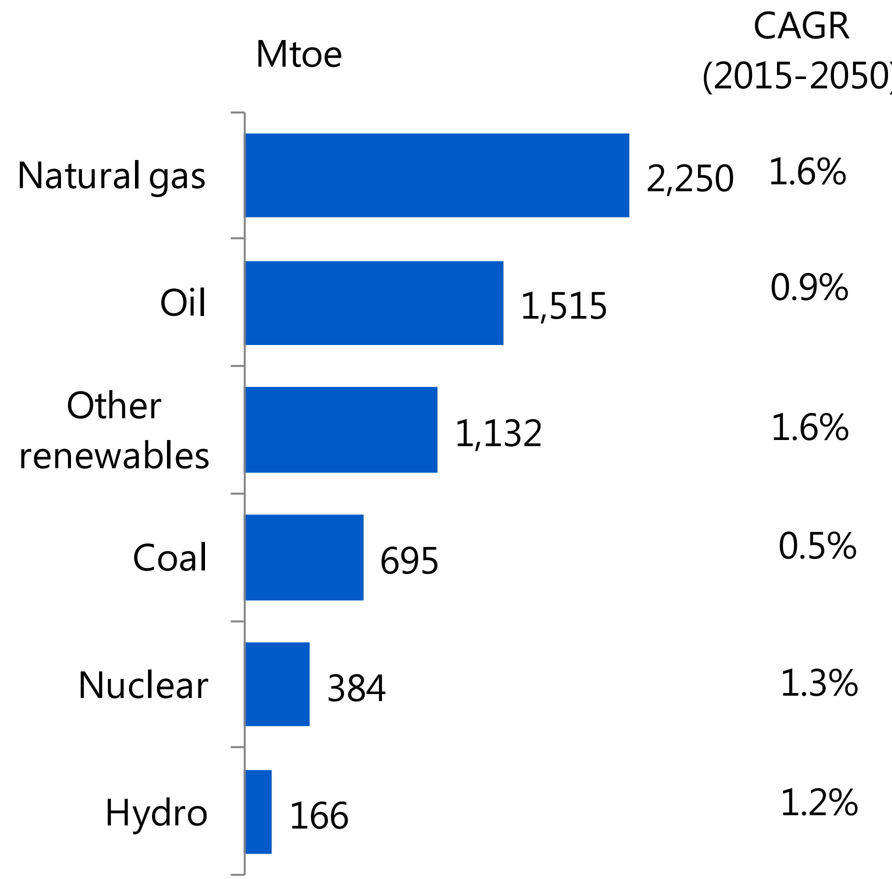



# Primary energy consumption by source

Reference Scenario



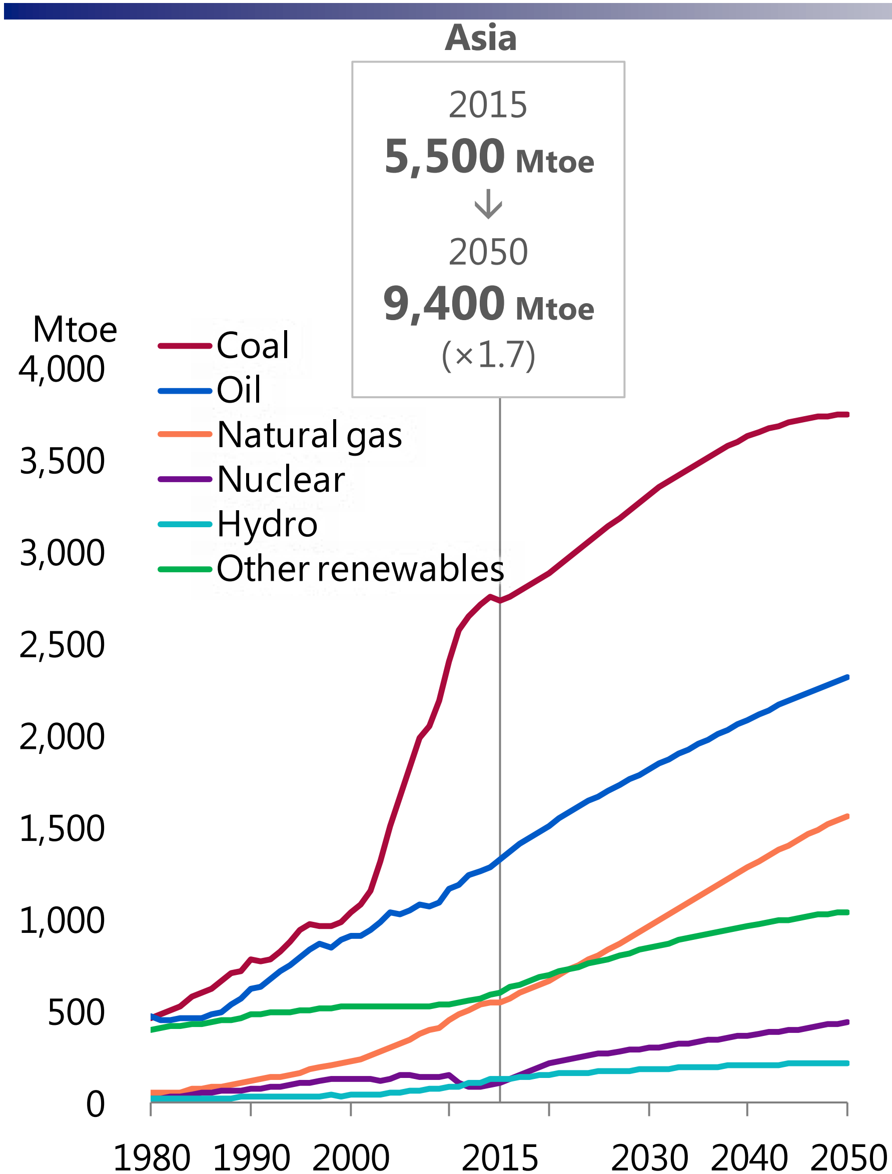

## Changes (2015-2050)

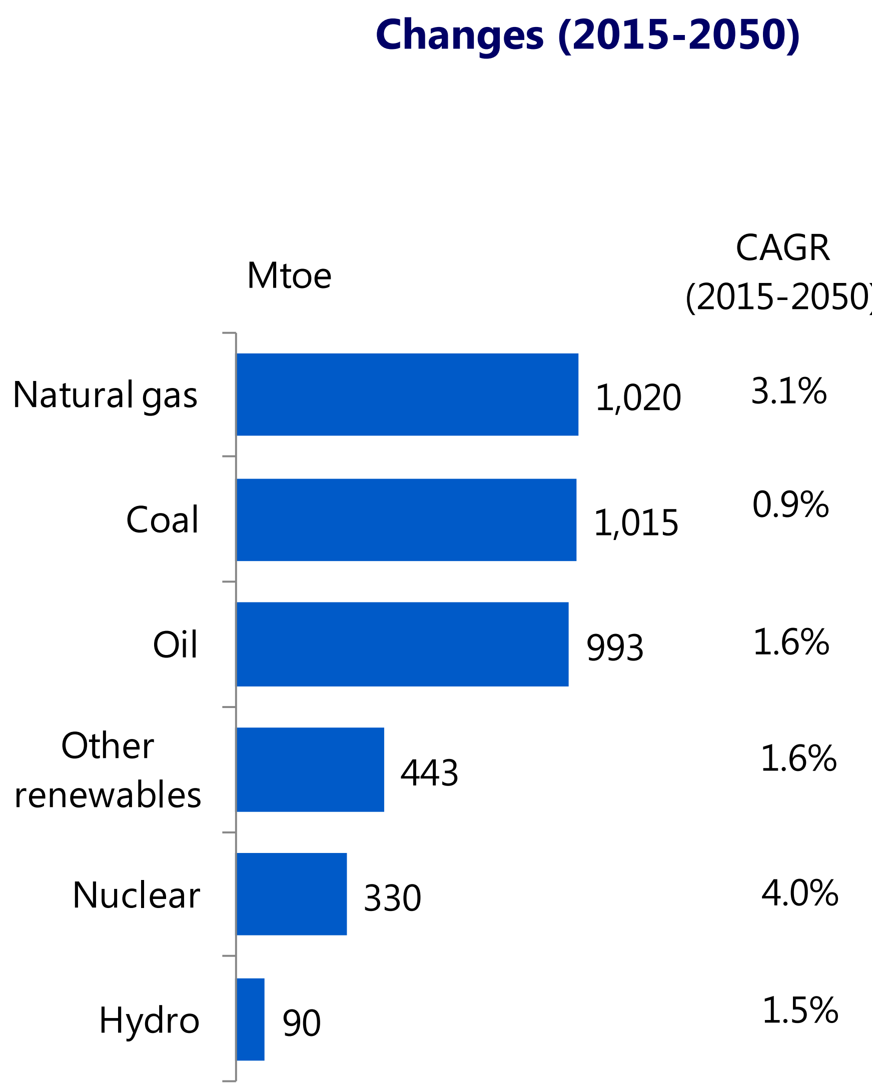


# Primary energy consumption by source (Asia)

IEE JAPAN

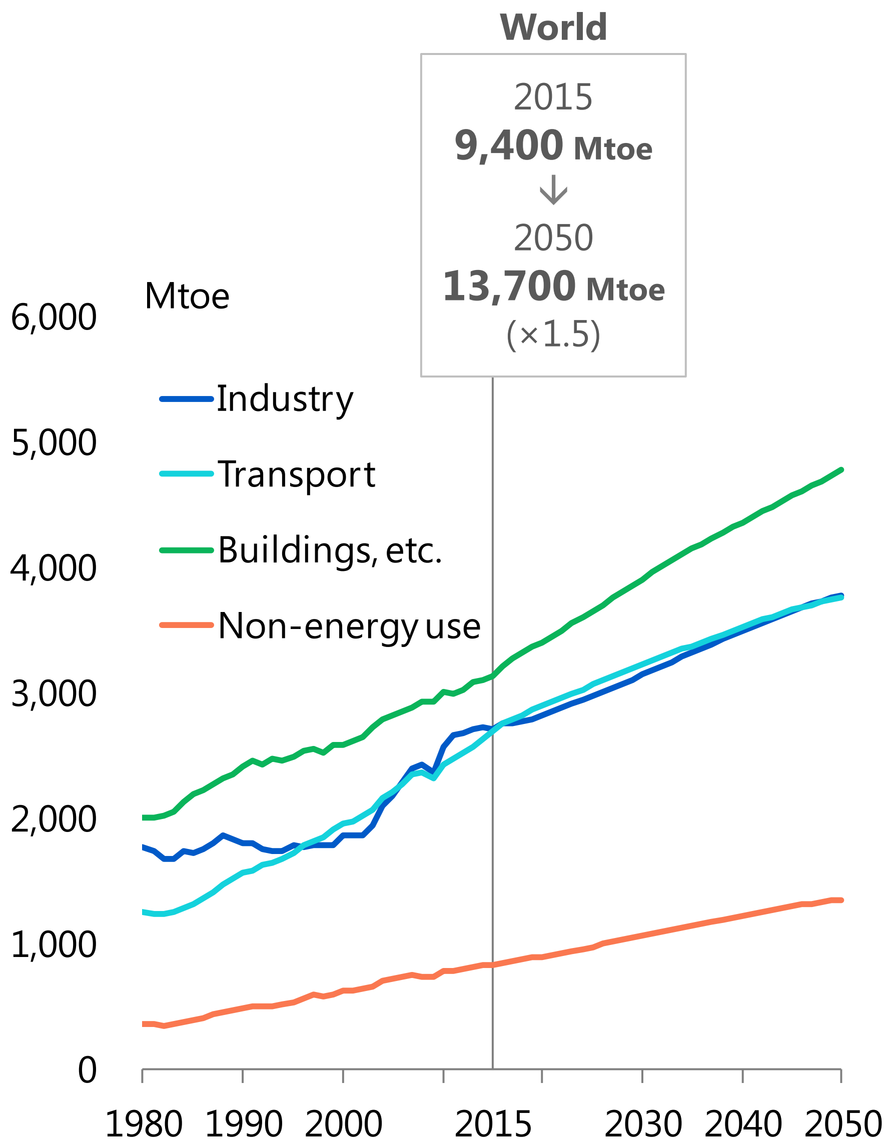
Reference Scenario

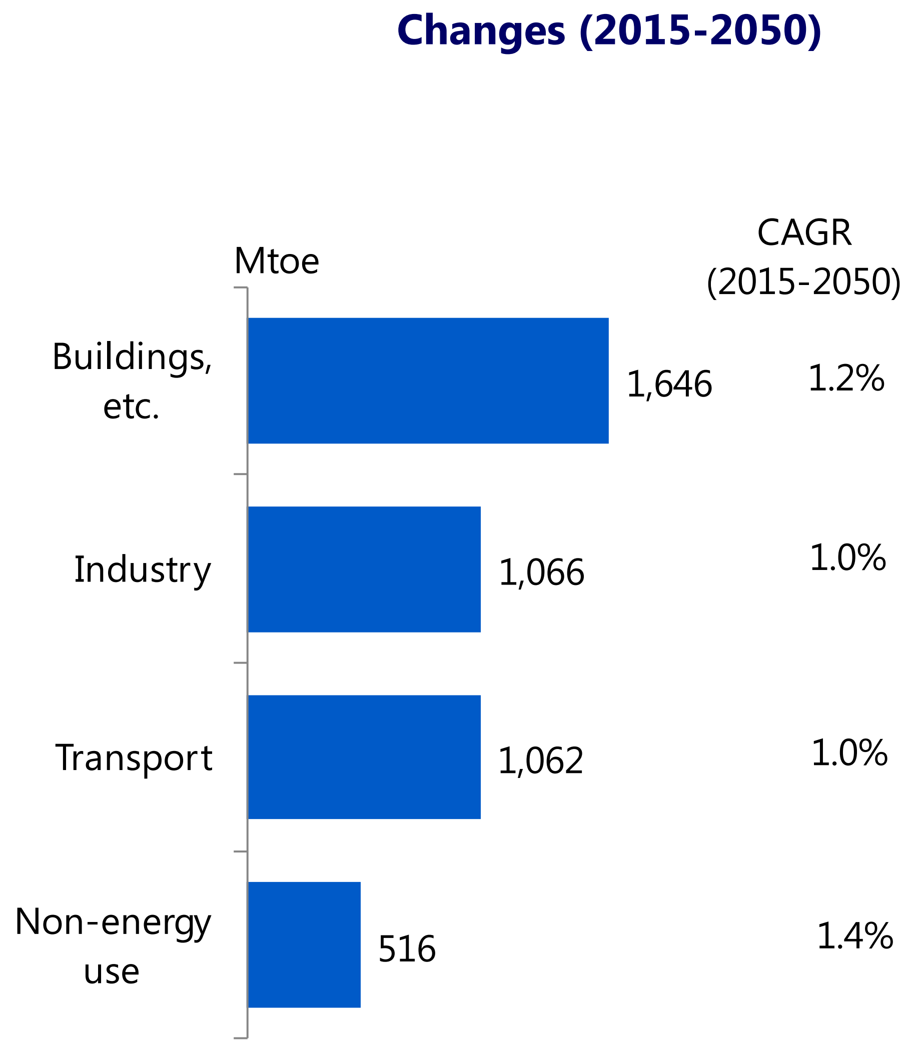


# Final energy consumption by sector

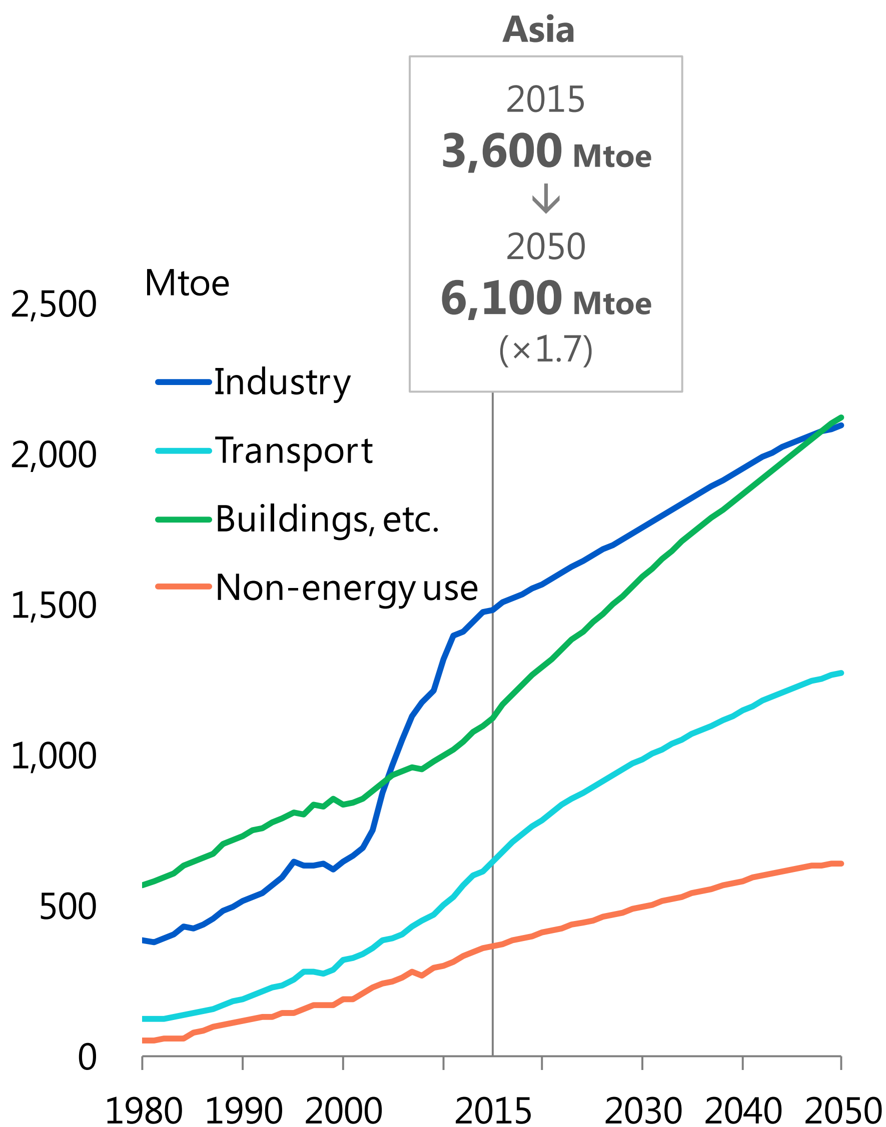
Reference Scenario



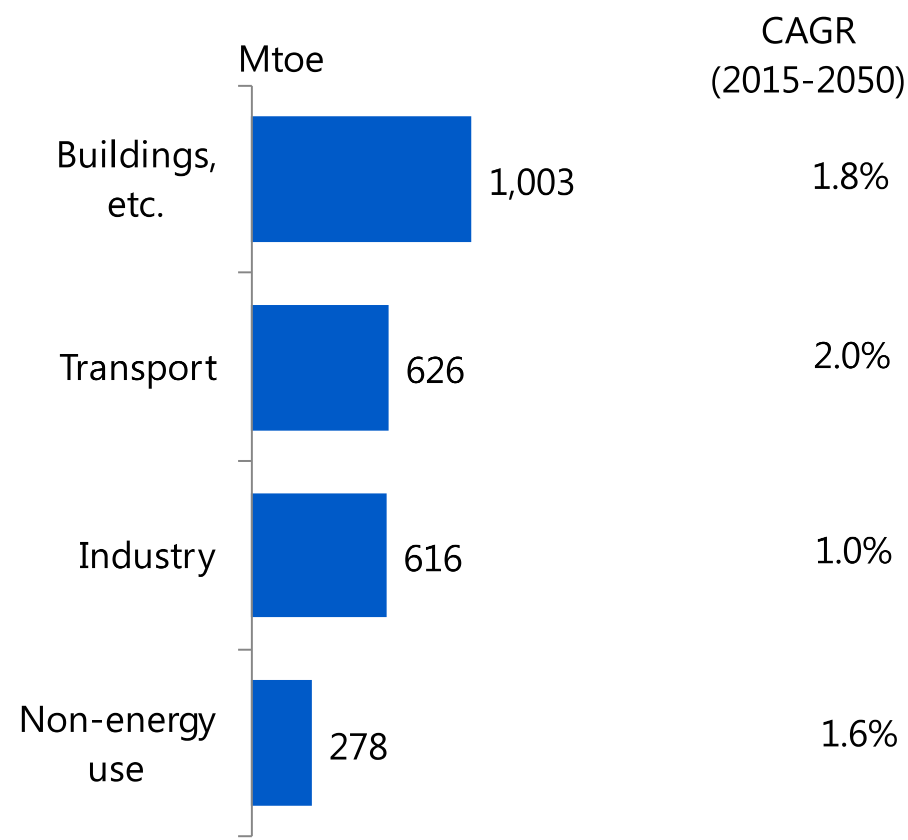



# Final energy consumption by sector (Asia)

Reference Scenario

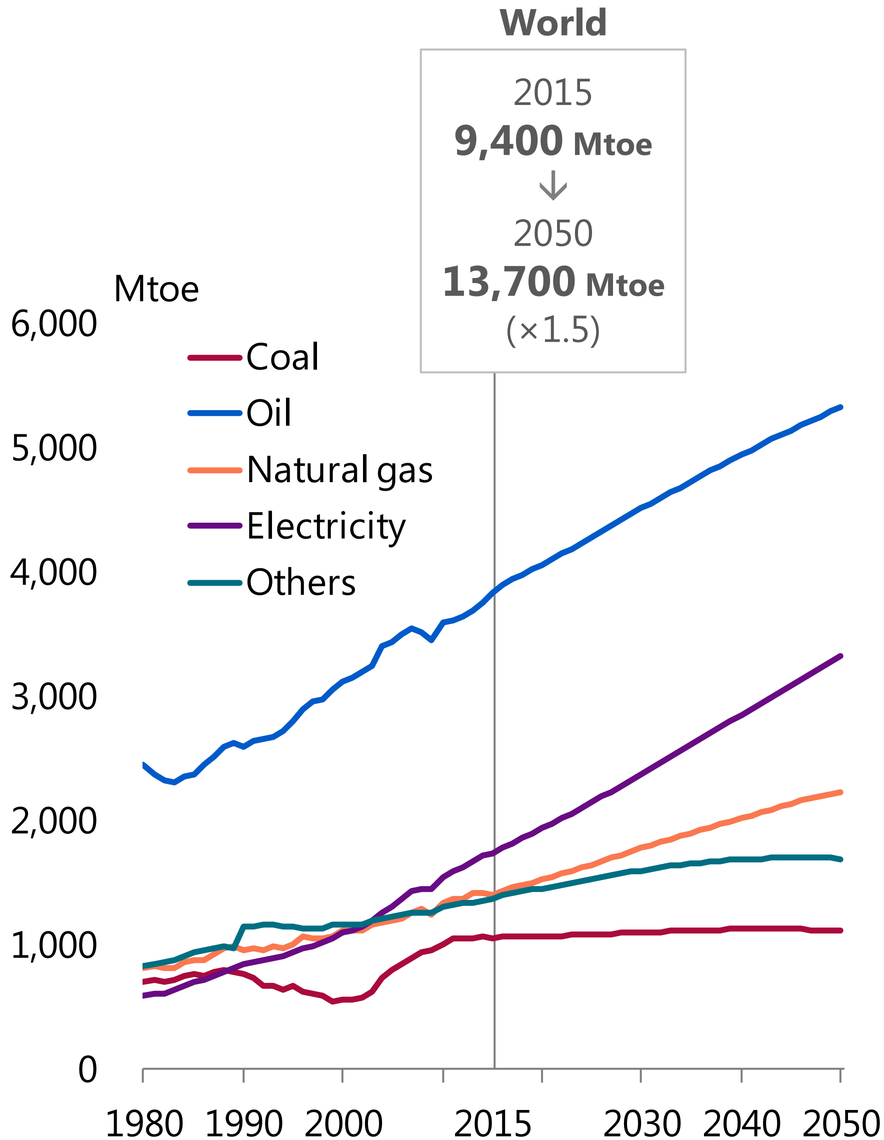



## Changes (2015-2050)

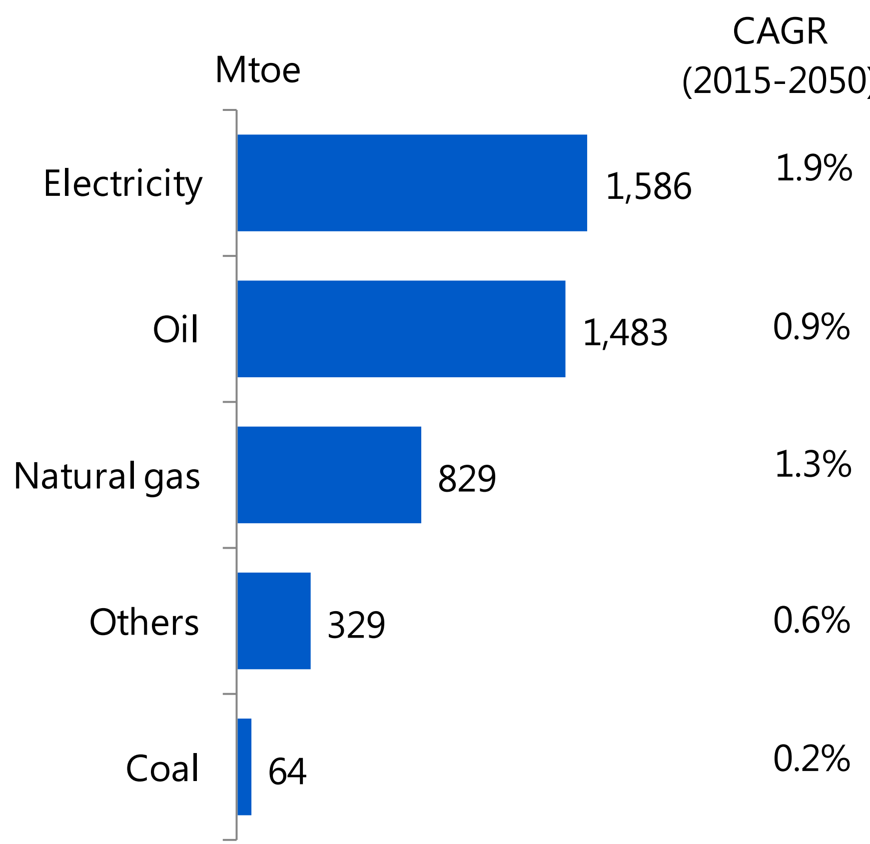


# Final energy consumption by source

Reference Scenario

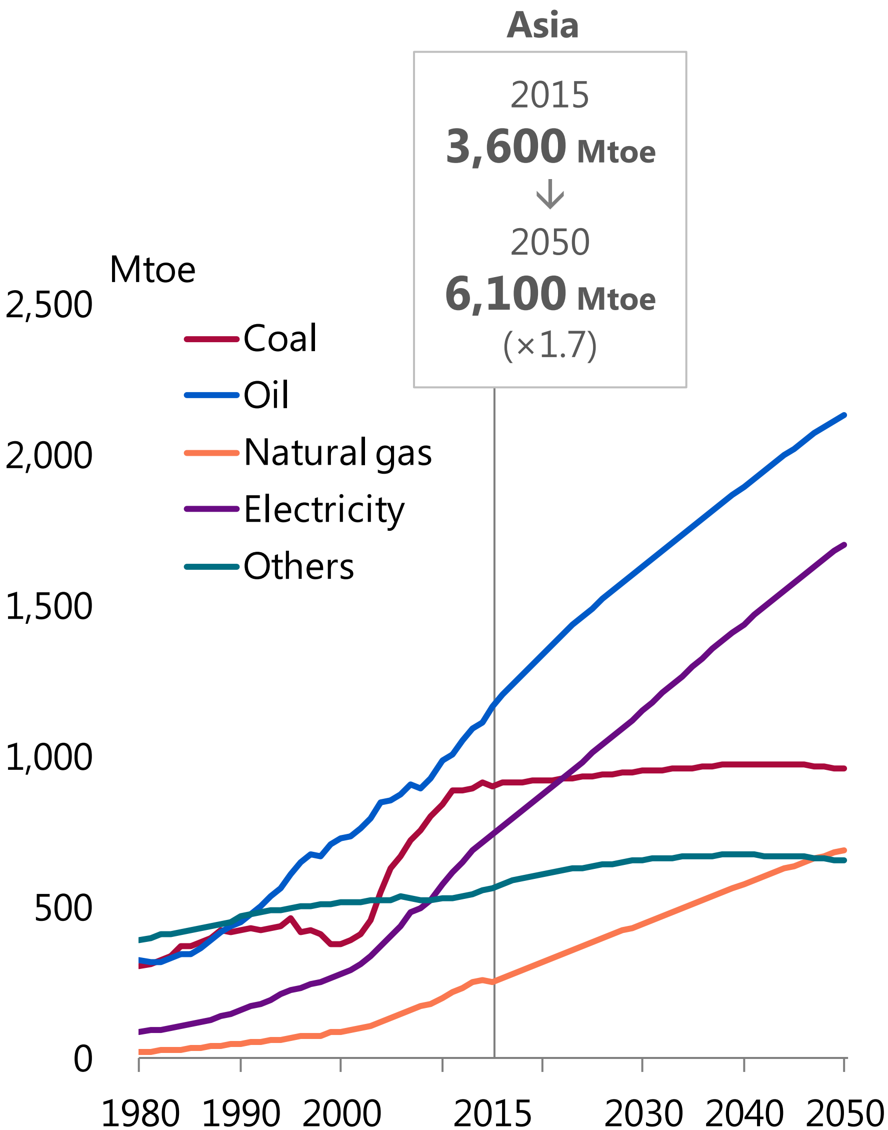



## Changes (2015-2050)



# Final energy consumption by source (Asia)

Reference Scenario

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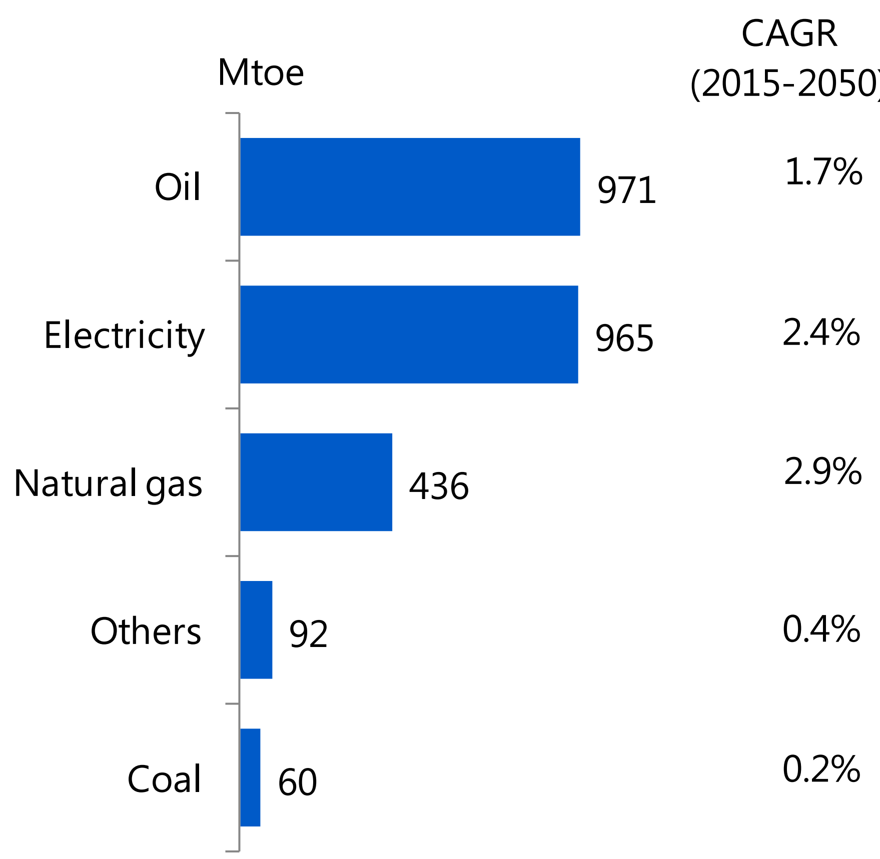
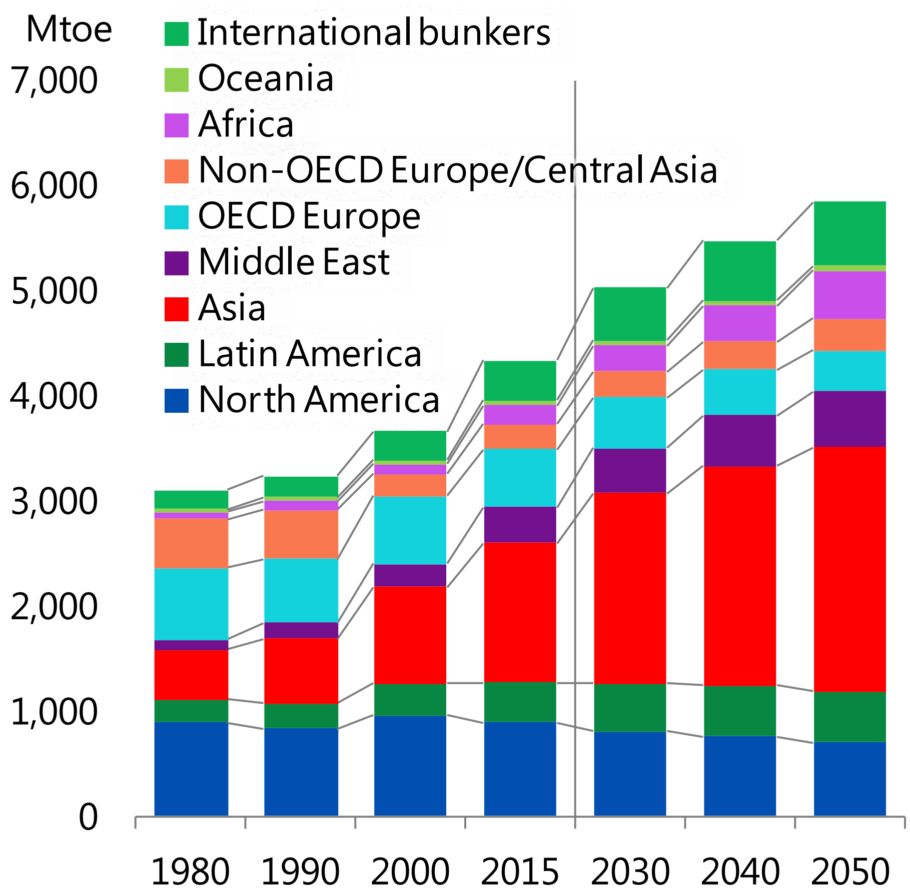


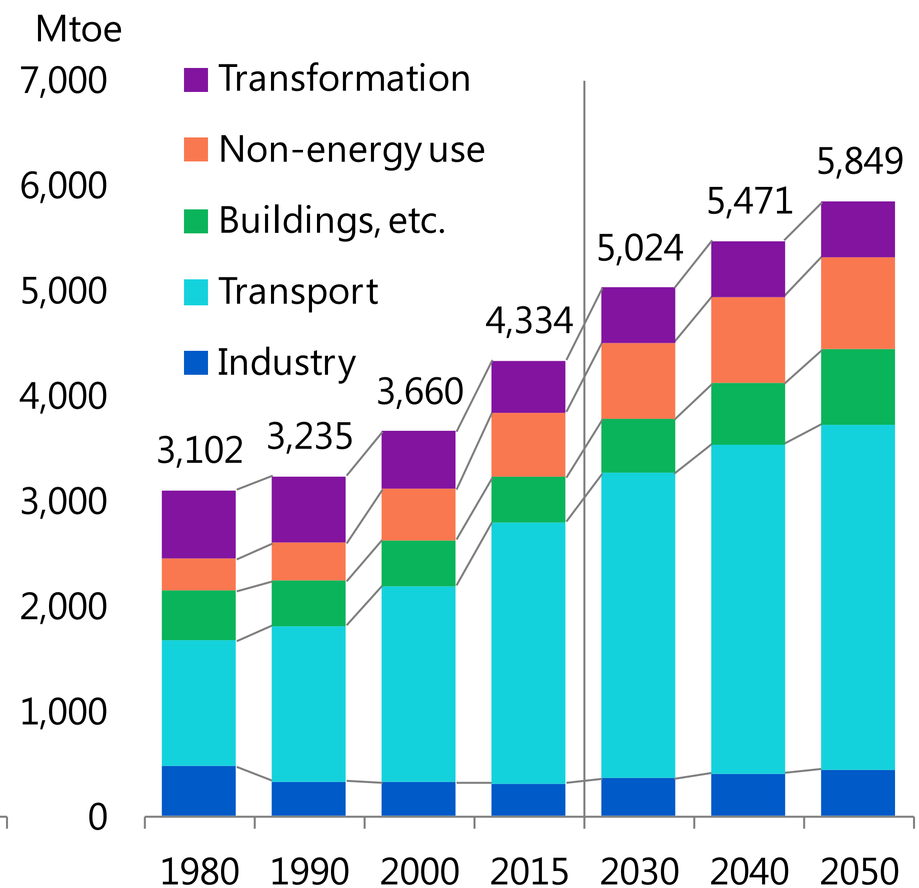
# Oil consumption

Reference Scenario

## By region



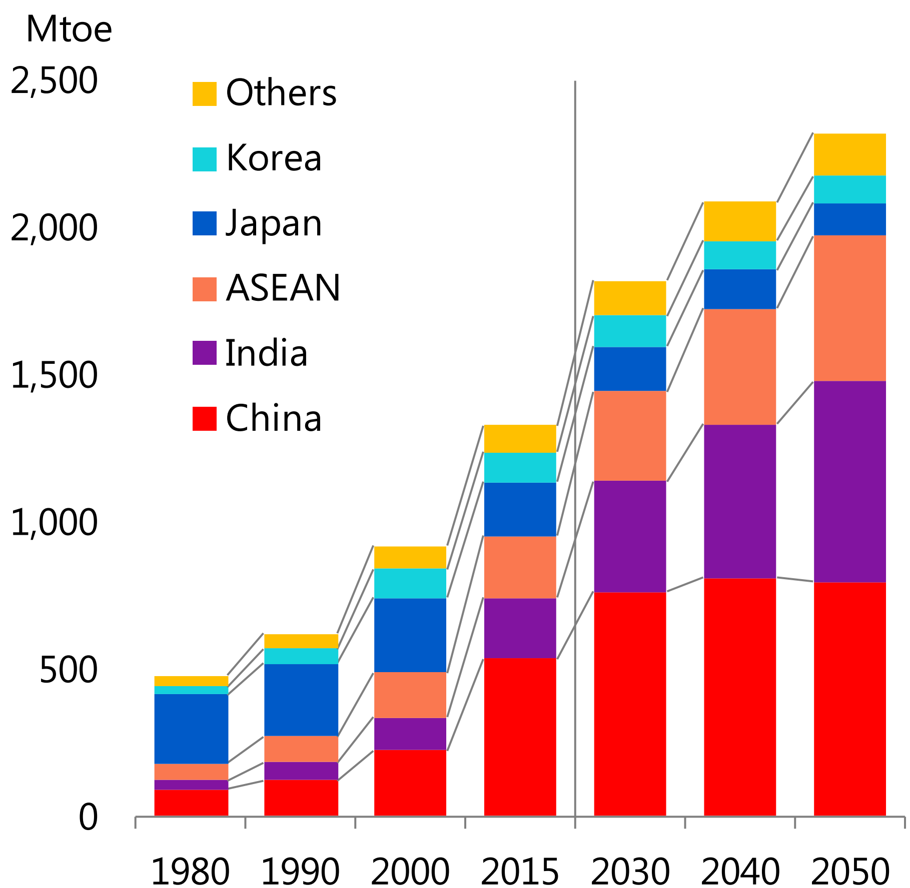

## By sector



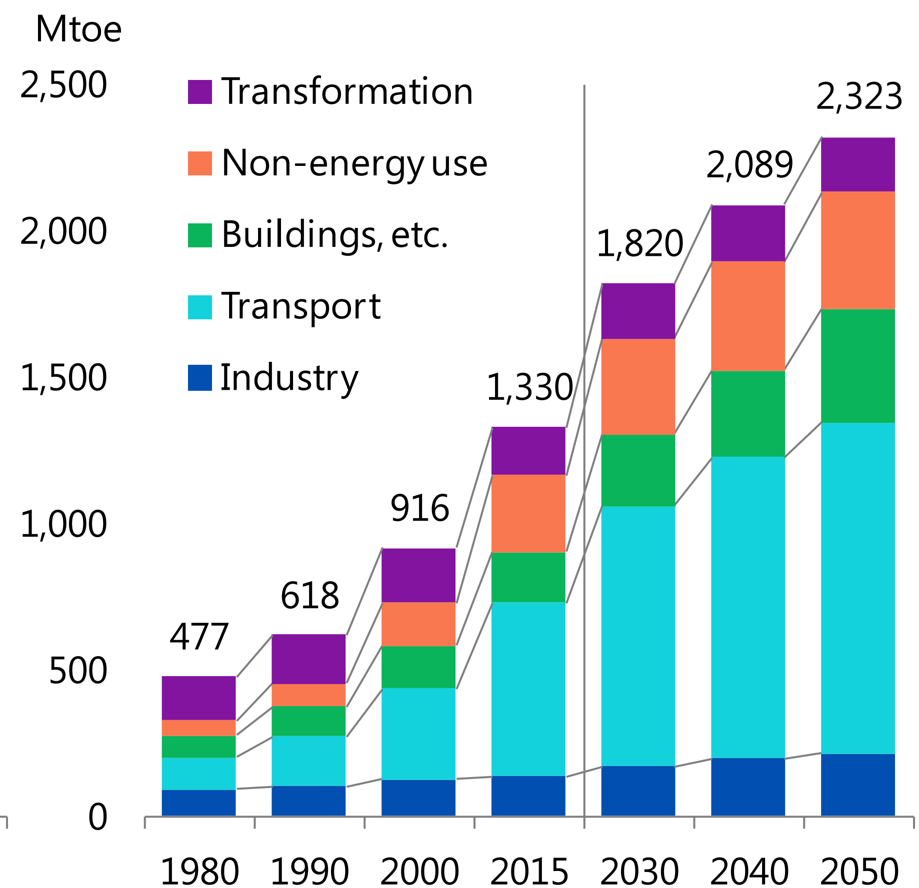
# Oil consumption (Asia)

Reference Scenario

## By region

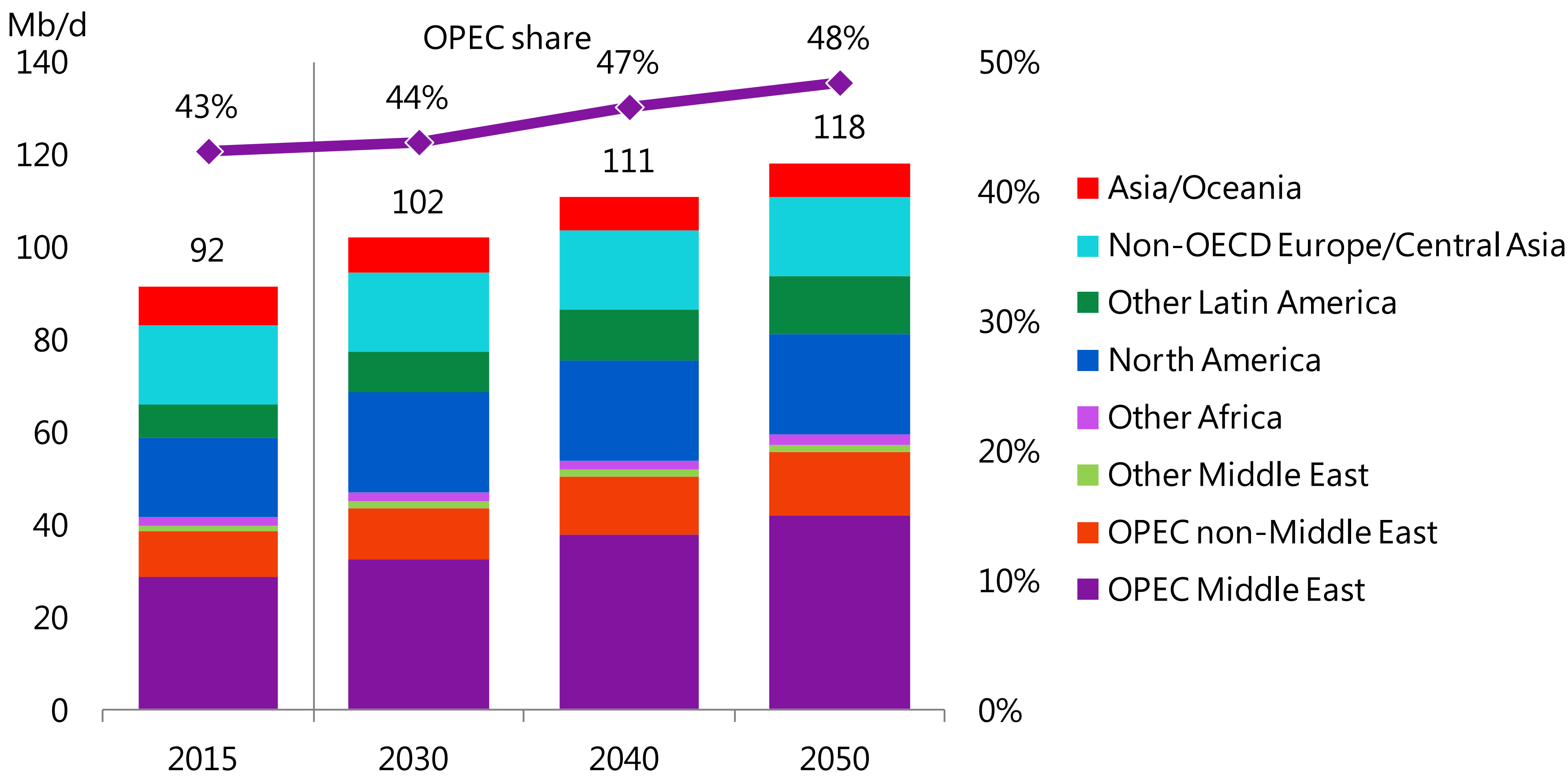



## By sector



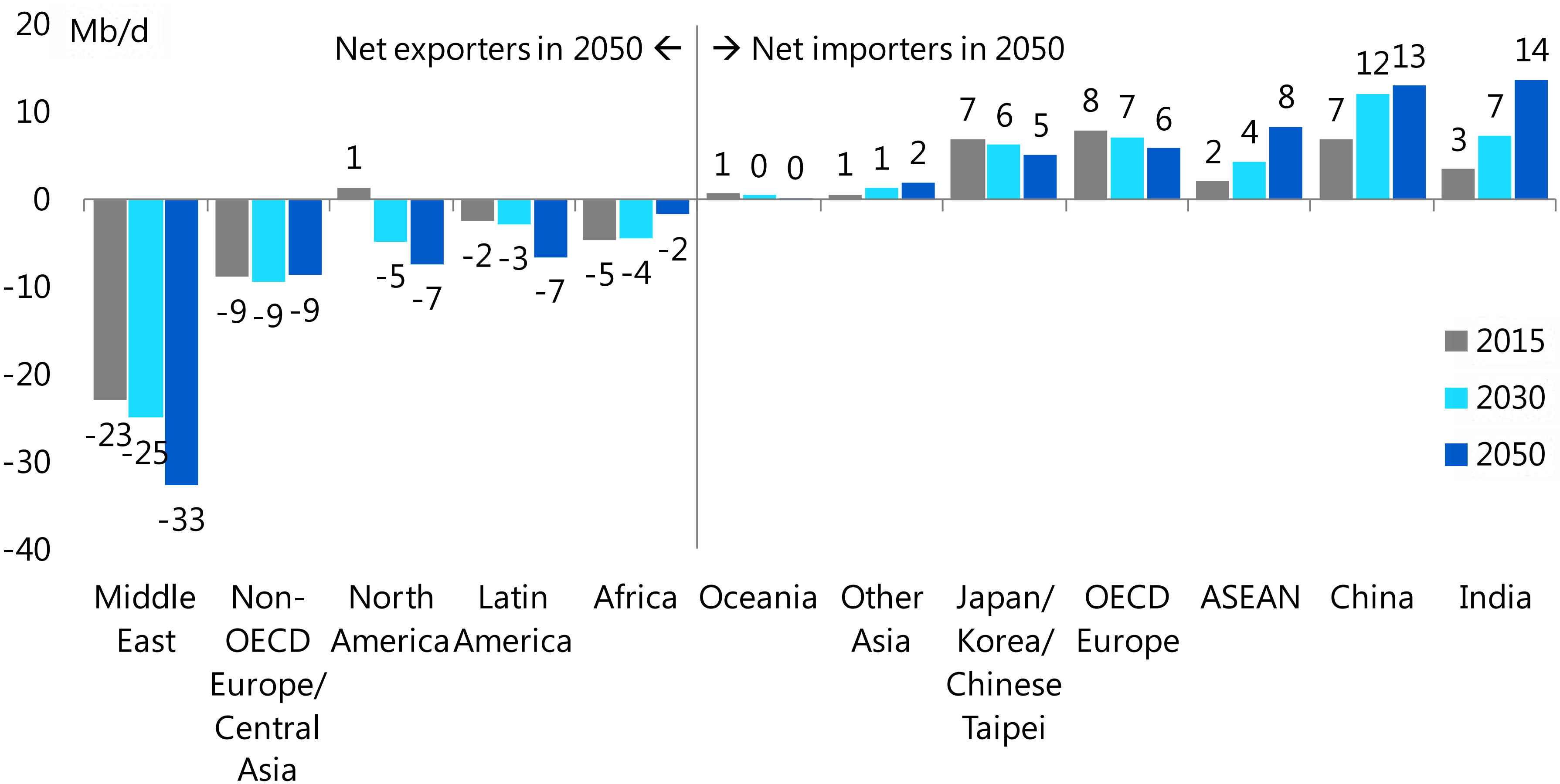
# Oil production

Reference Scenario

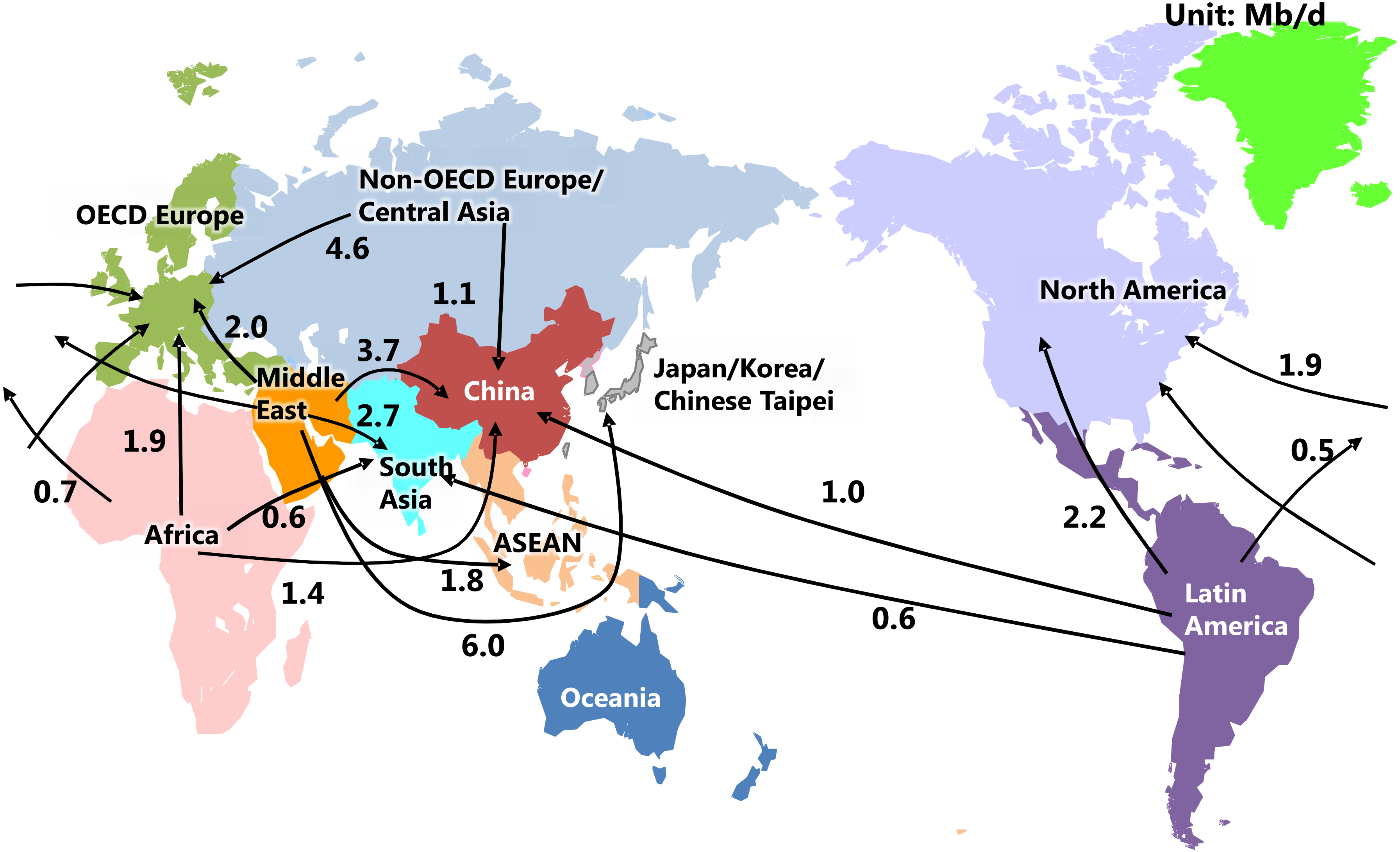


# Oil net imports

Reference Scenario

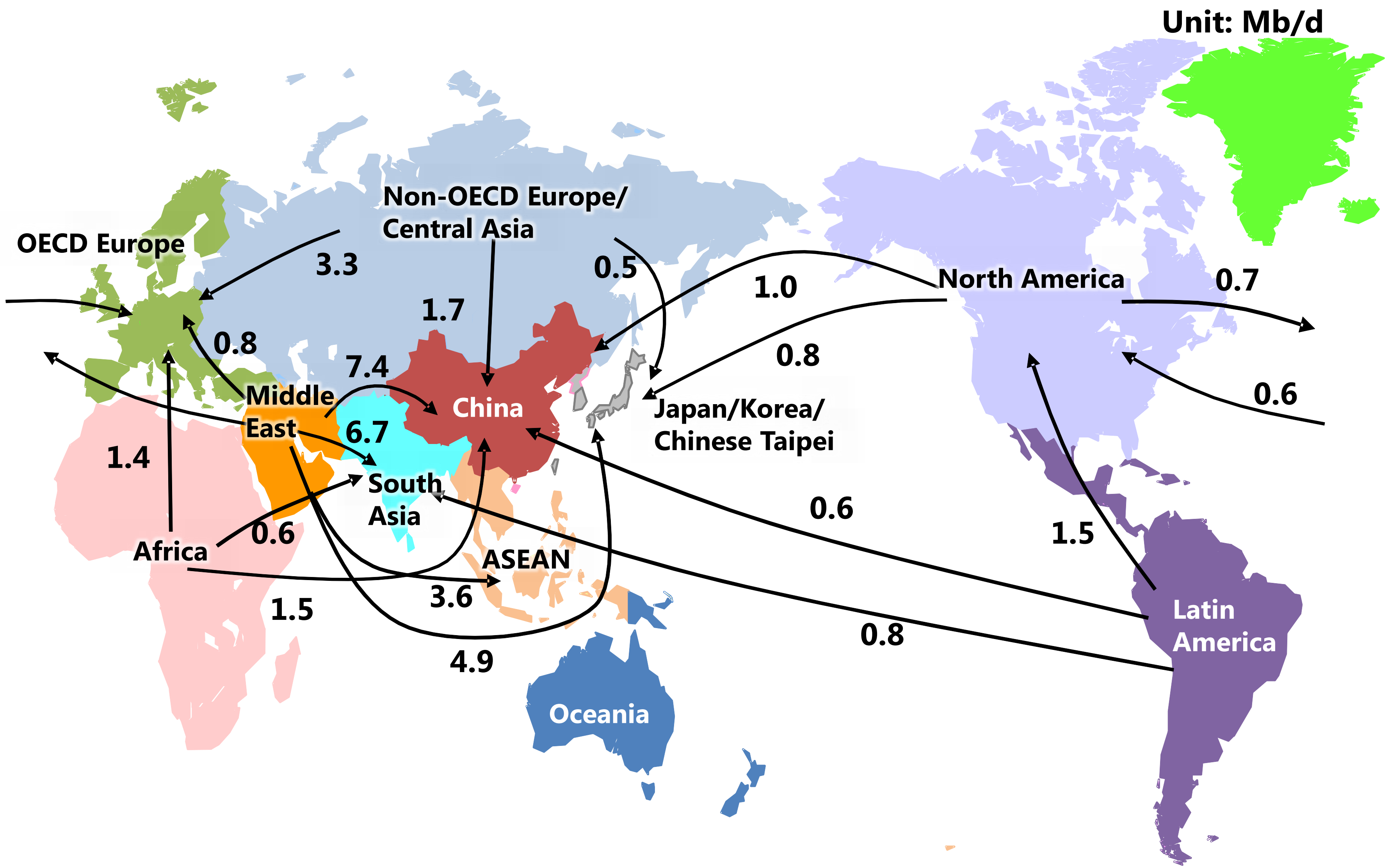


# Major crude oil trade flows (2016)



# Major crude oil trade flows (2030)

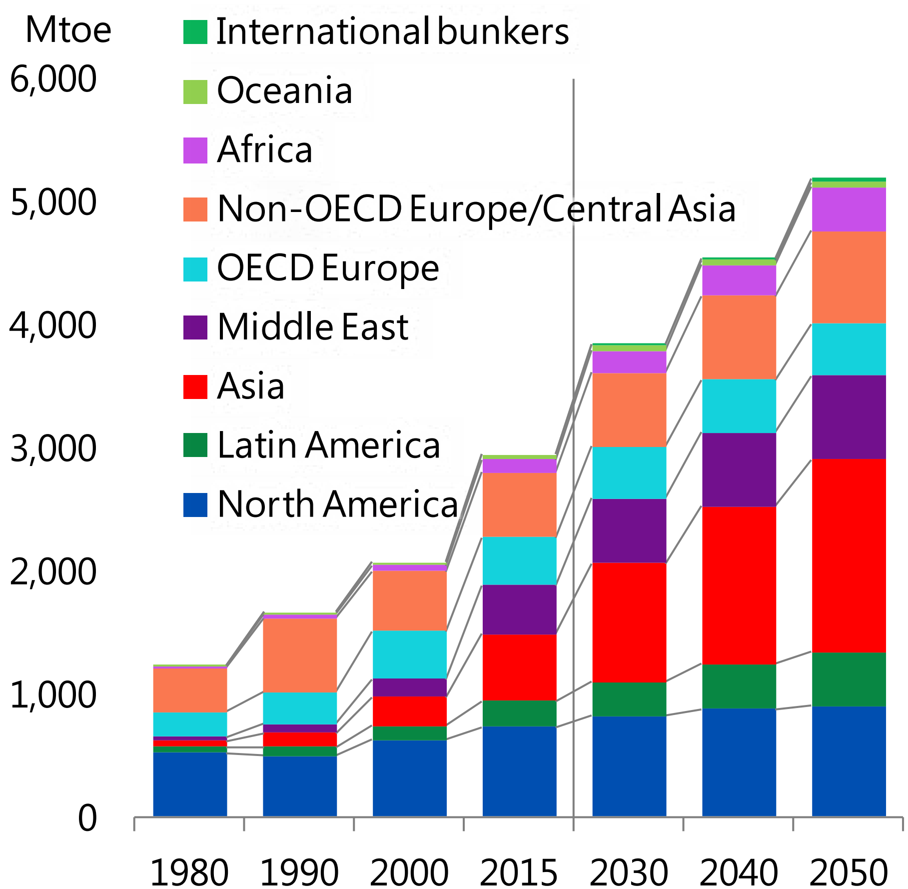
Reference Scenario



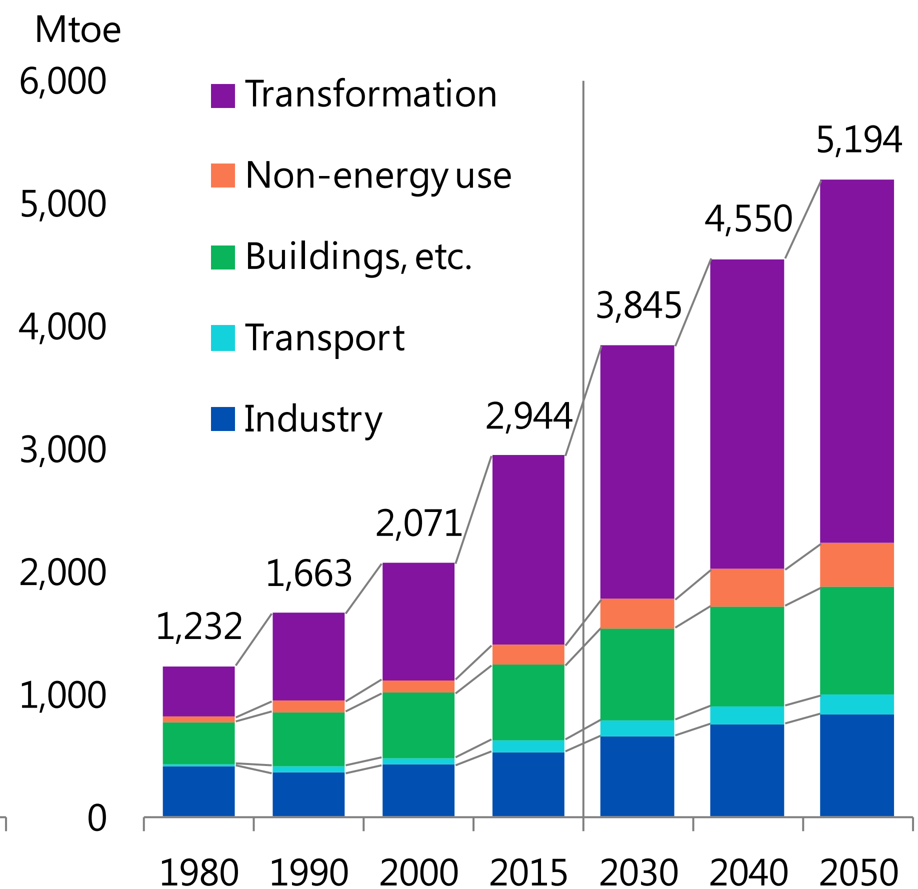
# Natural gas consumption

Reference Scenario

## By region



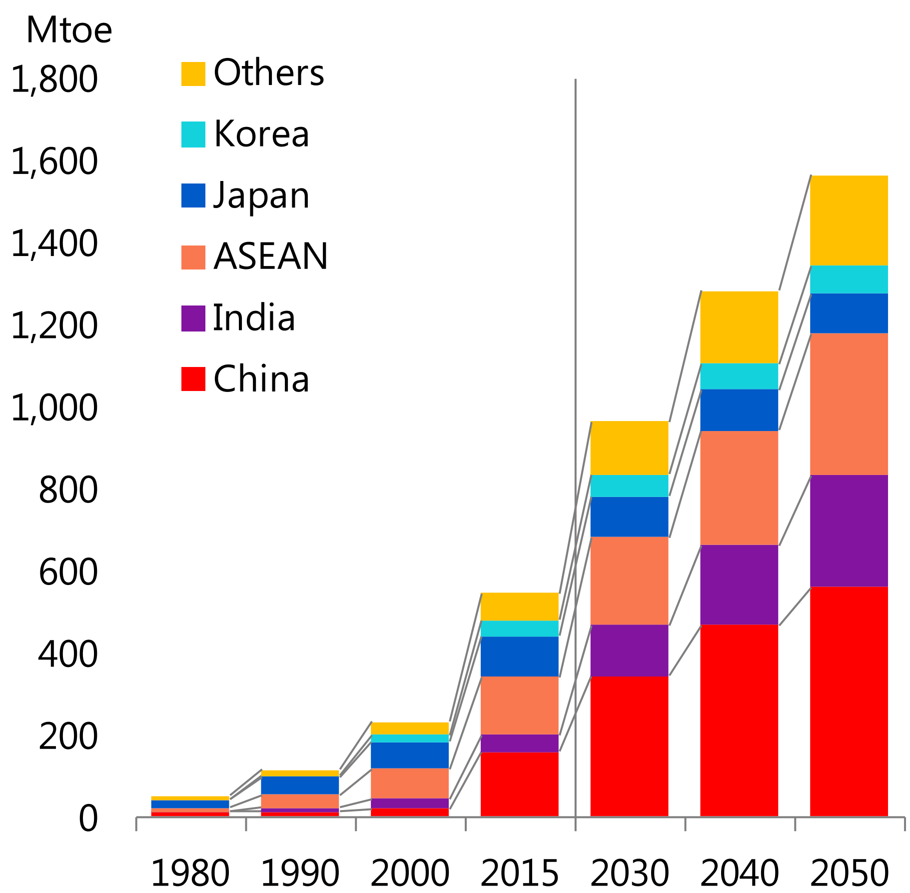

## By sector



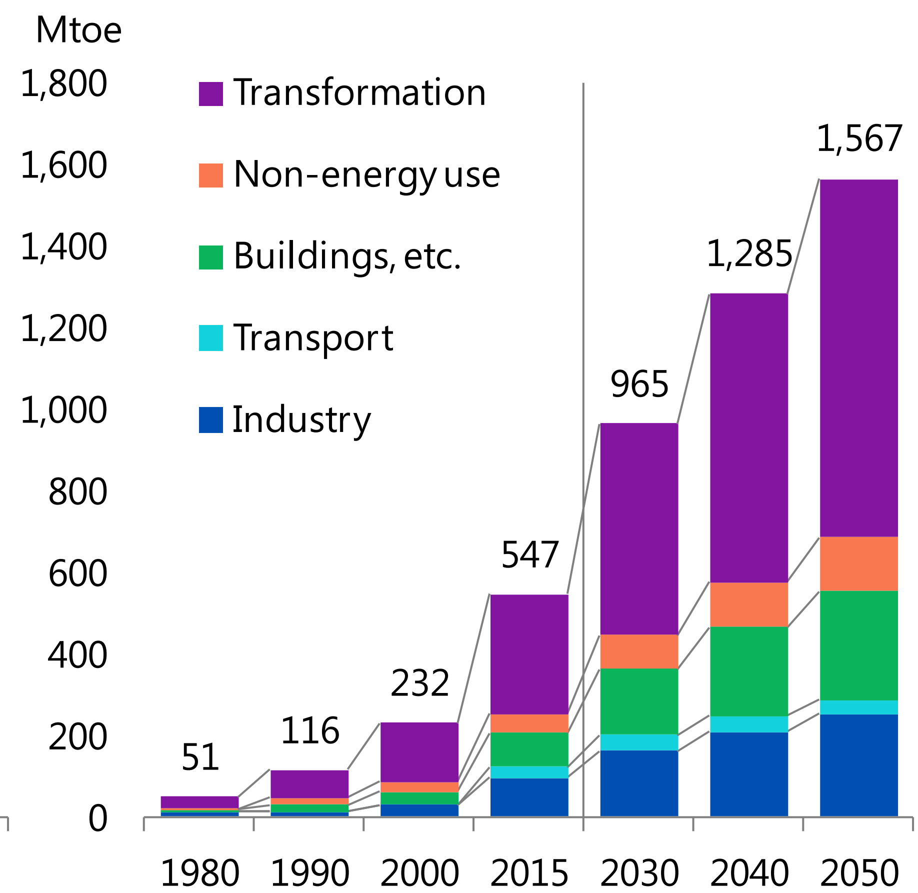
# Natural gas consumption (Asia)

Reference Scenario

## By region

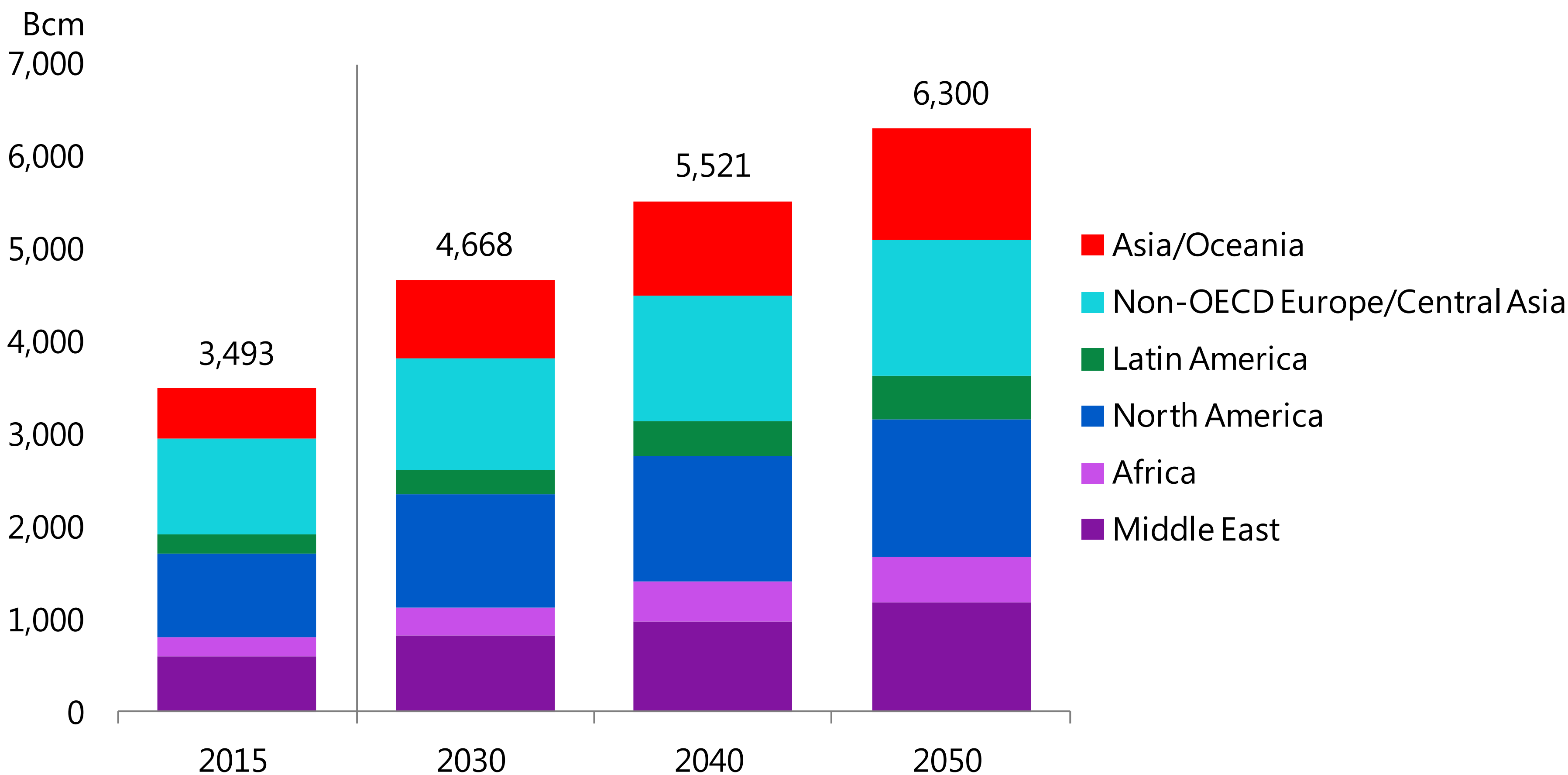



## By sector



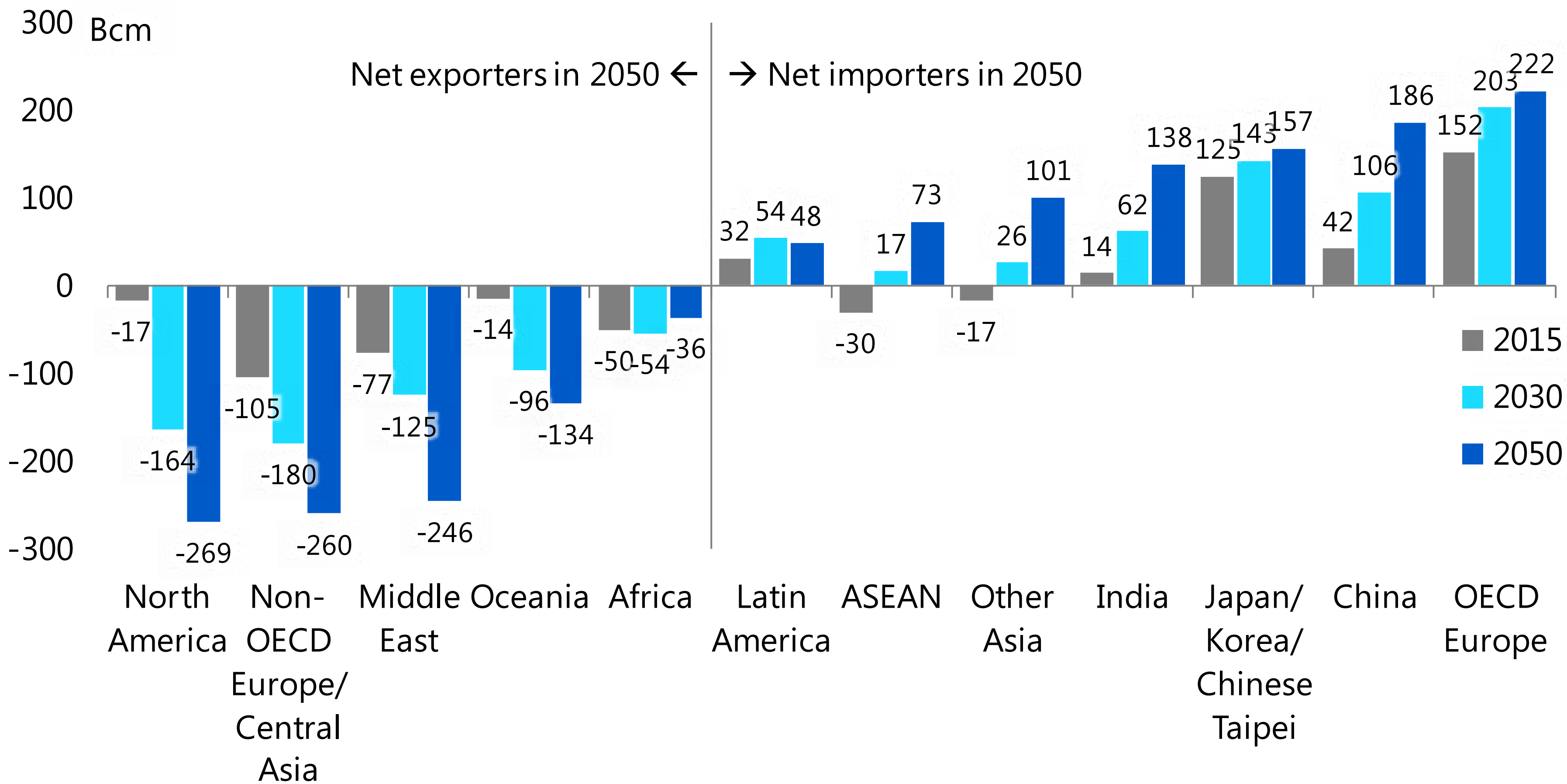
# Natural gas production

Reference Scenario



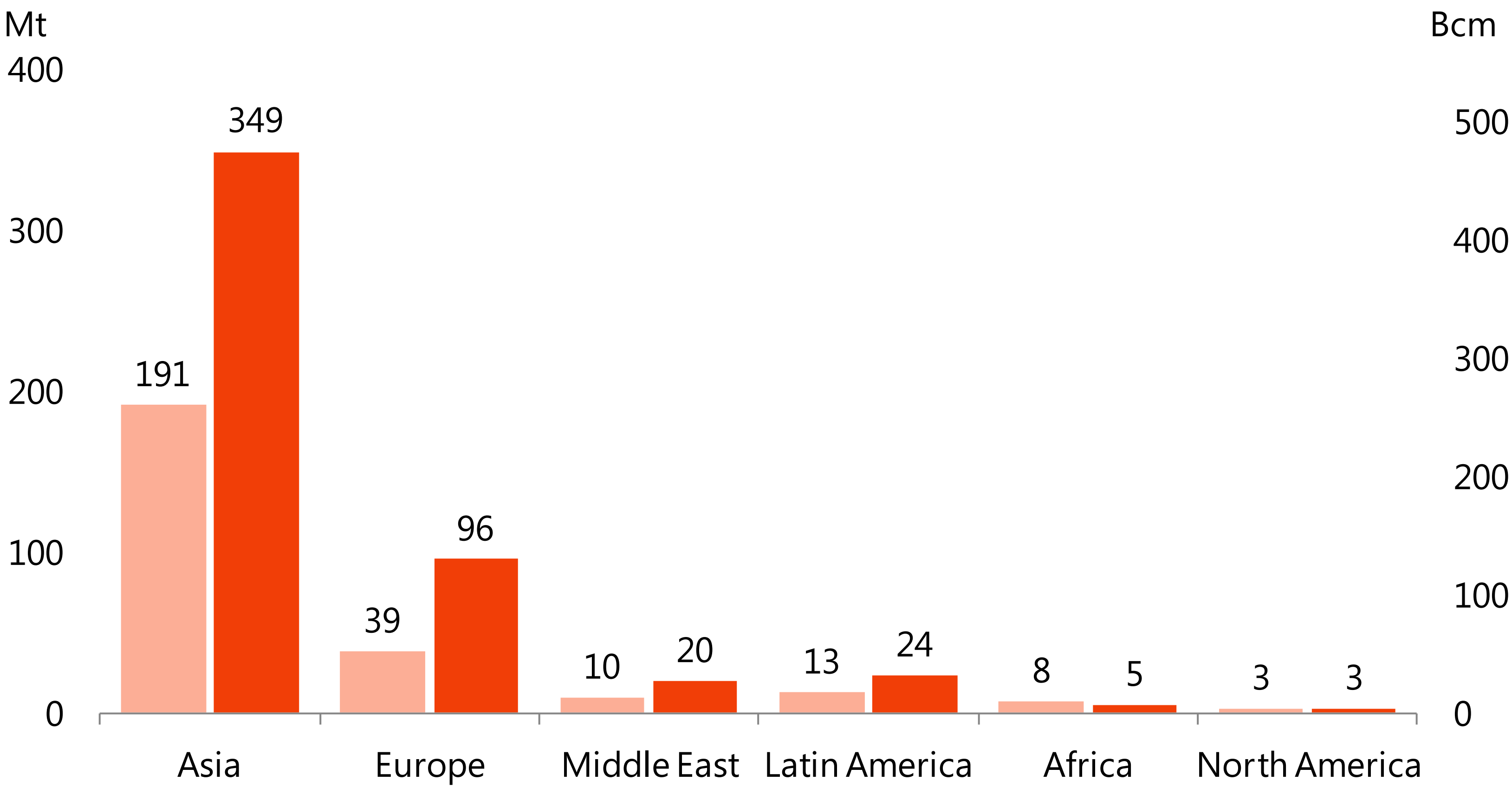
# Natural gas net imports

Reference Scenario

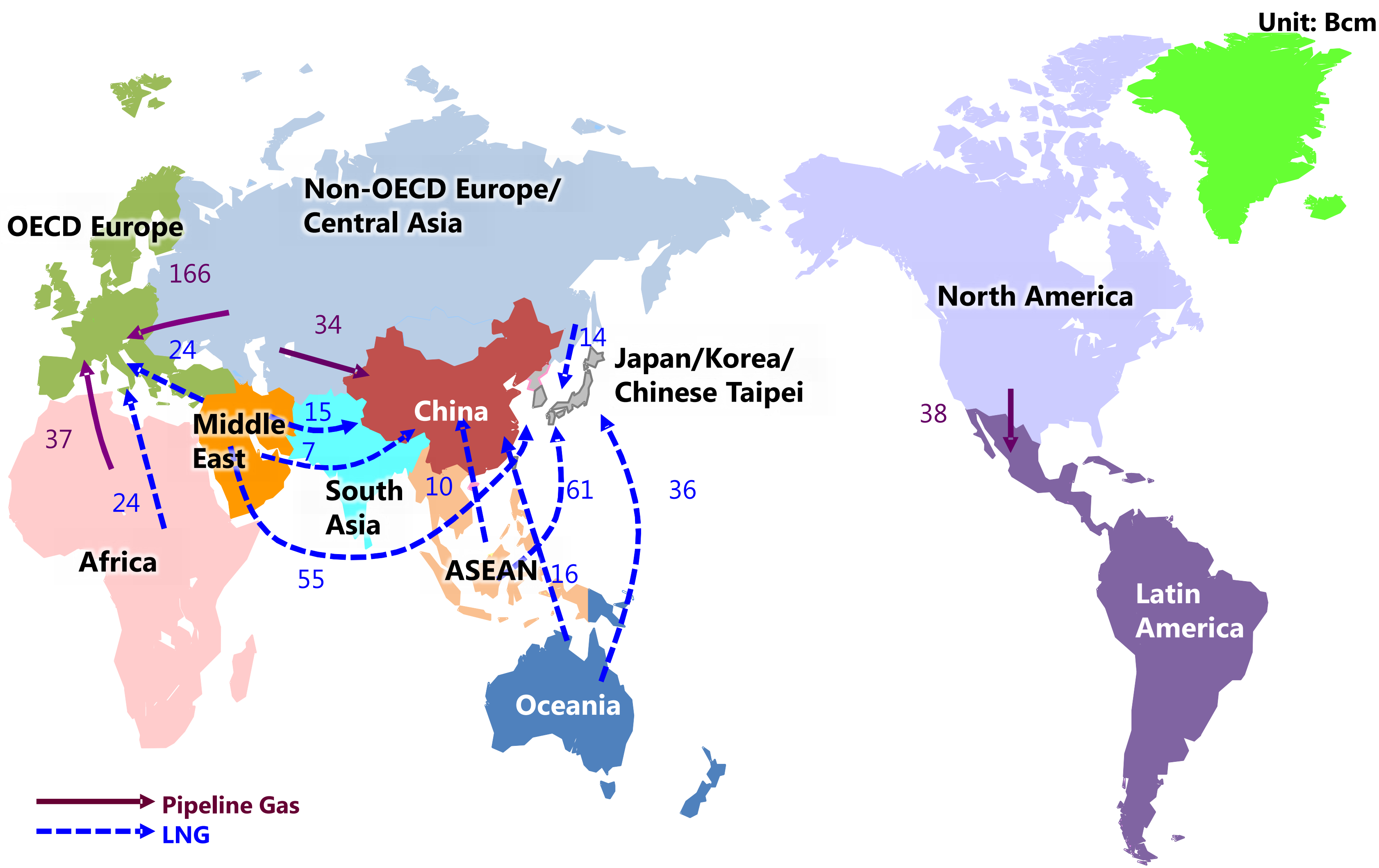


# LNG imports

Reference Scenario

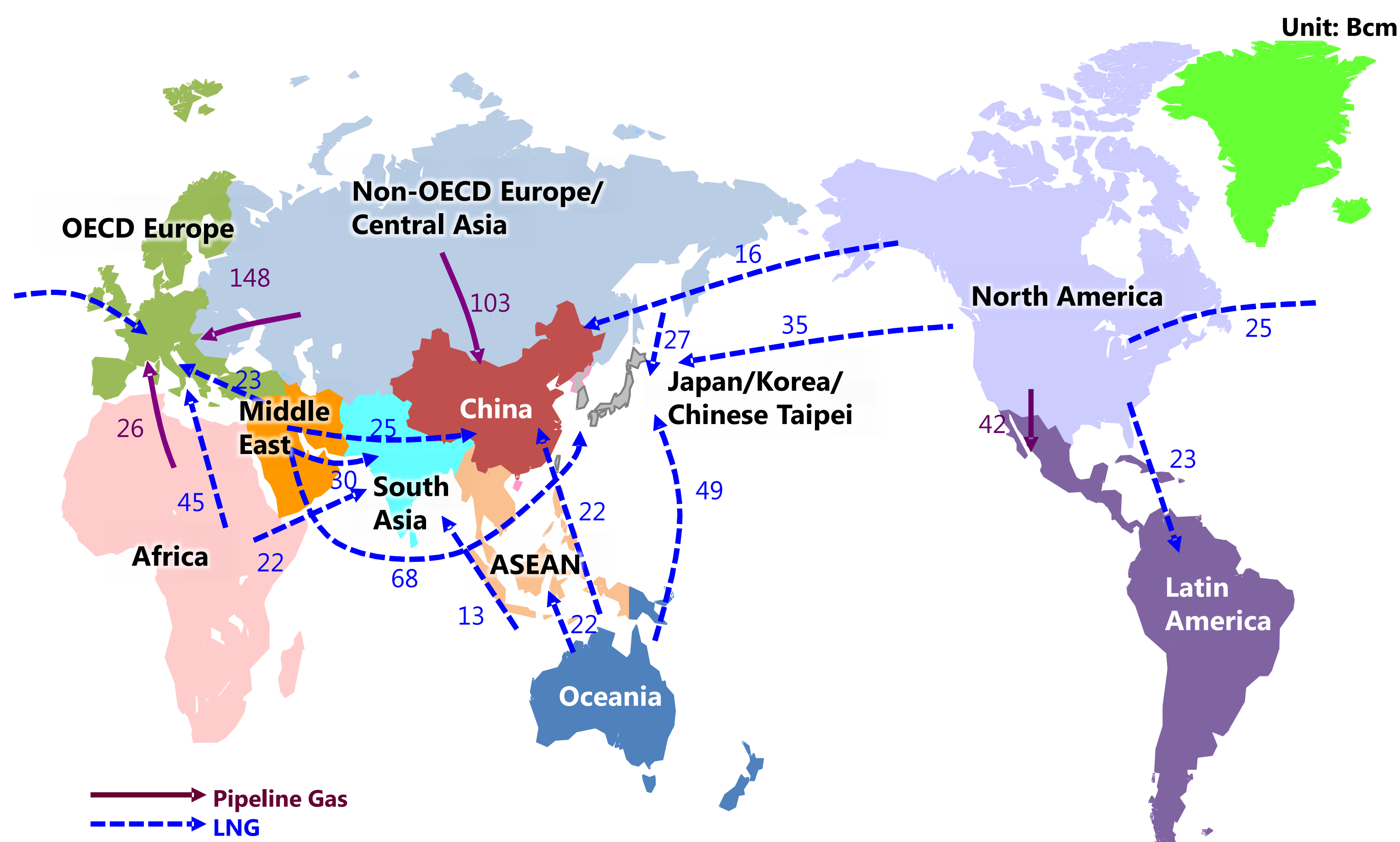


# Major natural gas trade flows (2016)



# Major natural gas trade flows (2030)

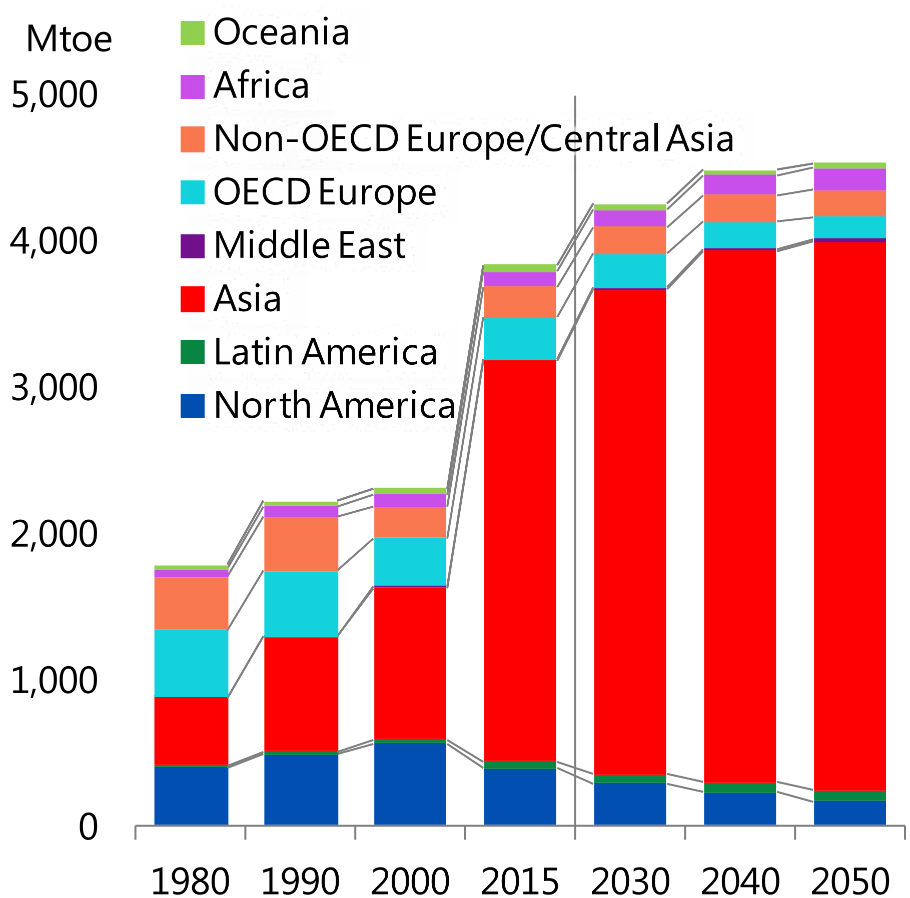
Reference Scenario



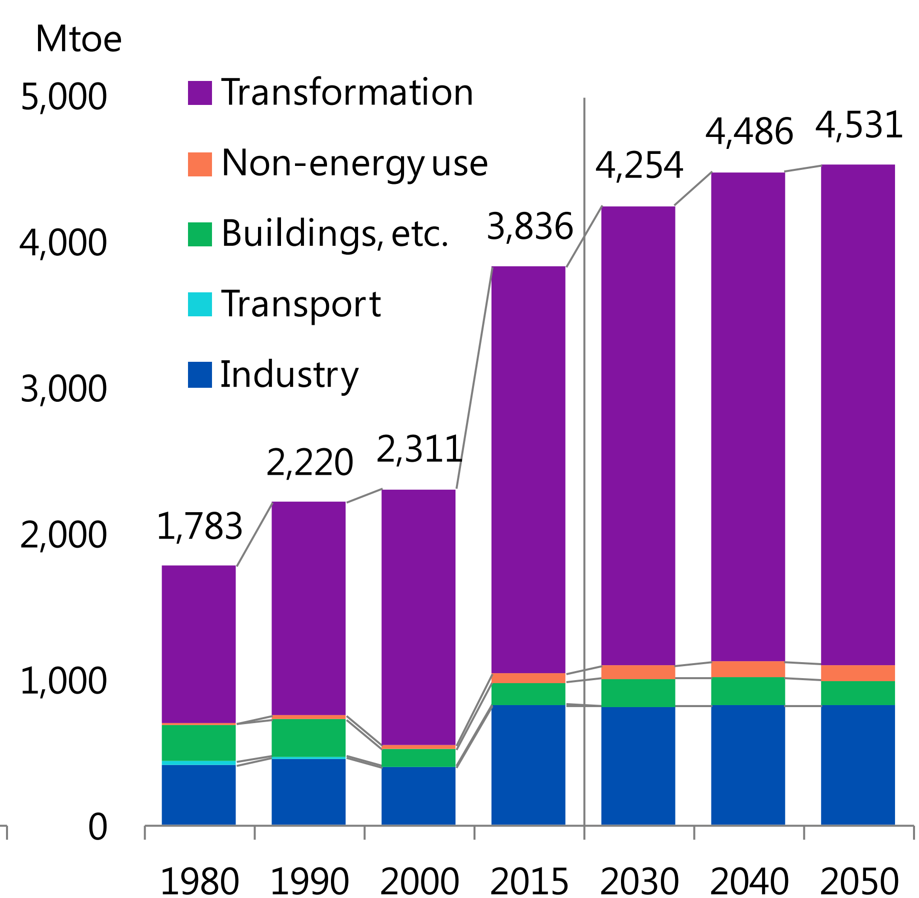
# Coal consumption

Reference Scenario

## By region



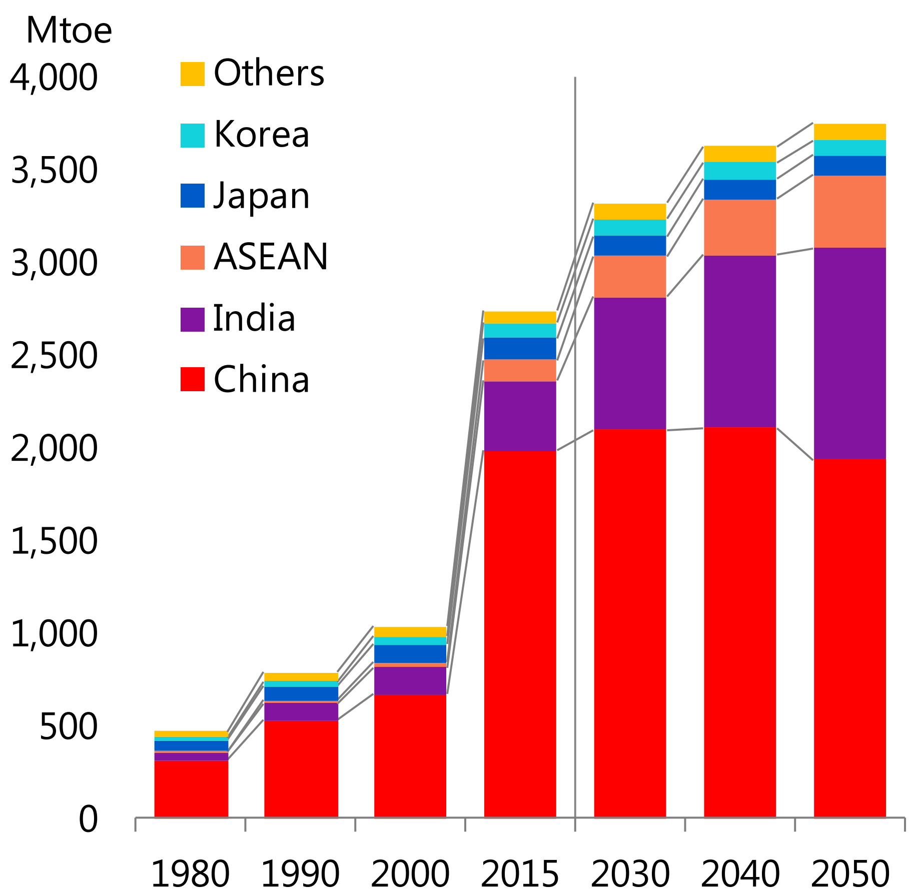

## By sector



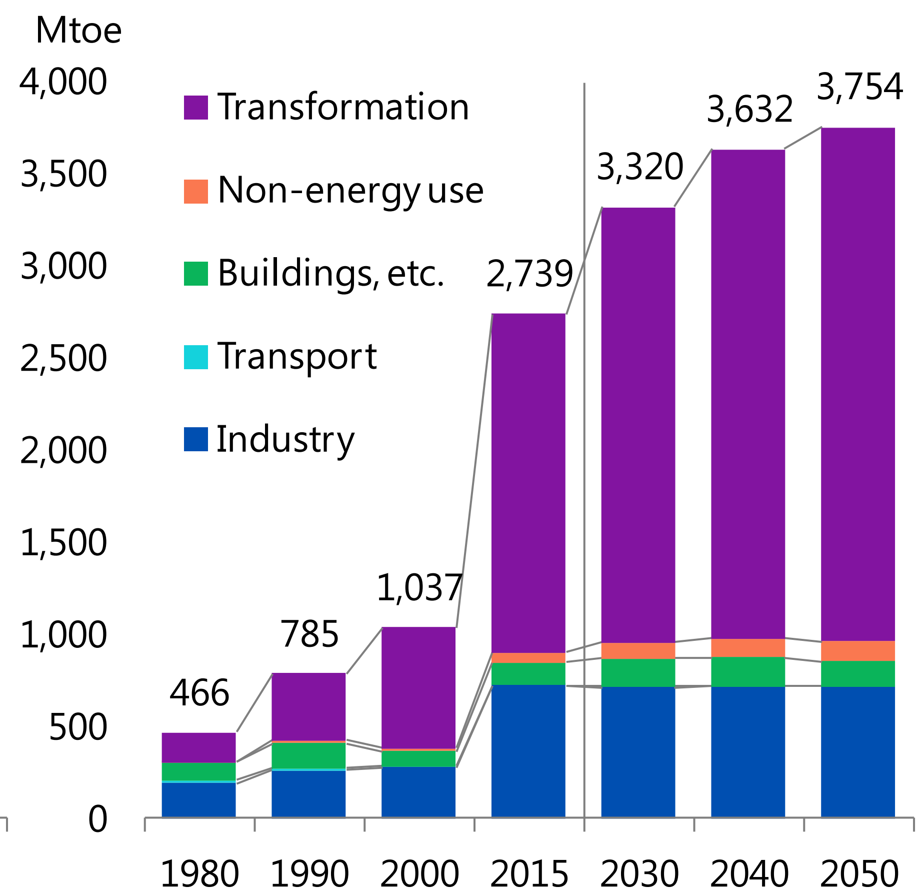
# Coal consumption (Asia)

Reference Scenario

## By region

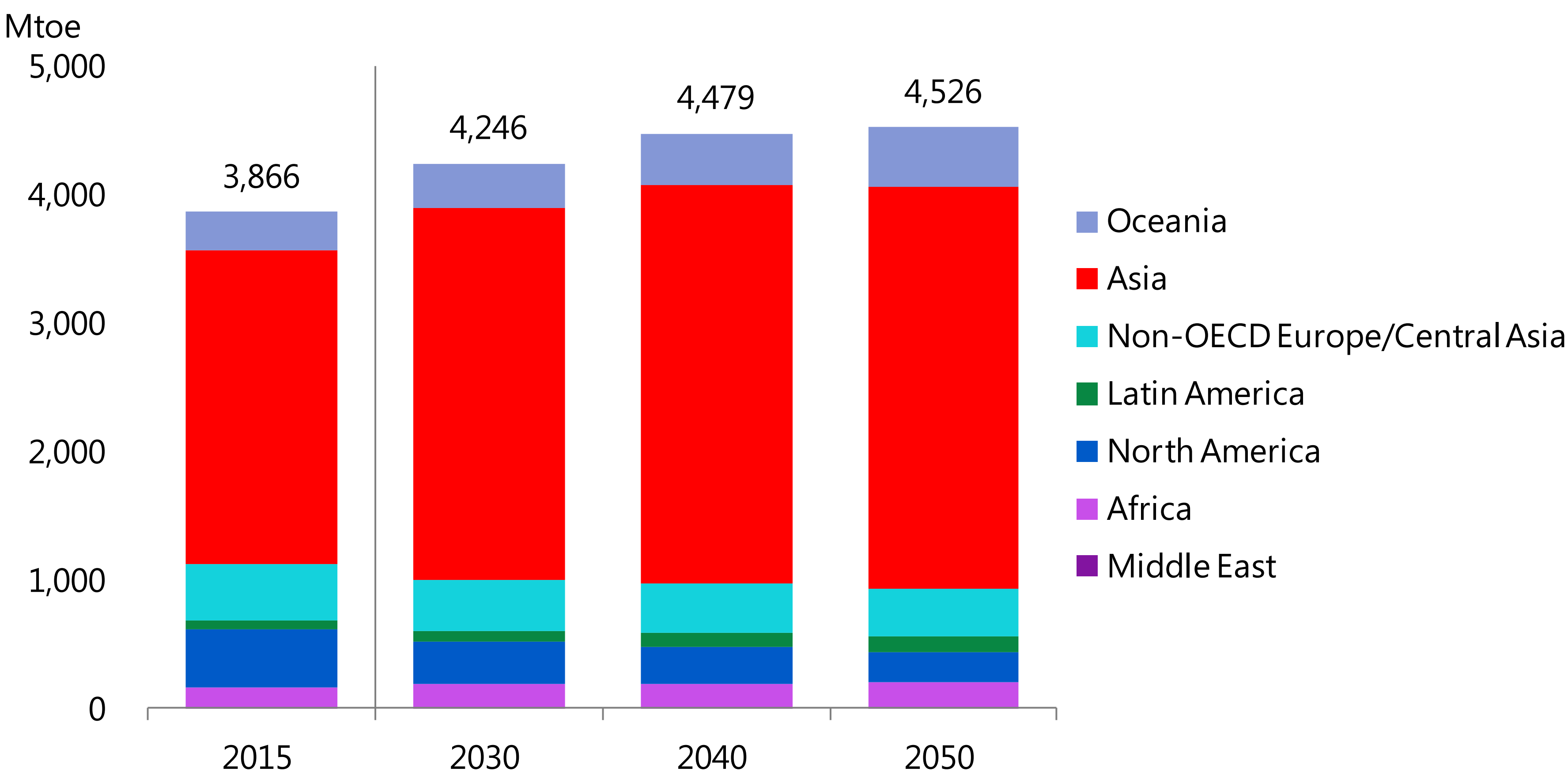



## By sector



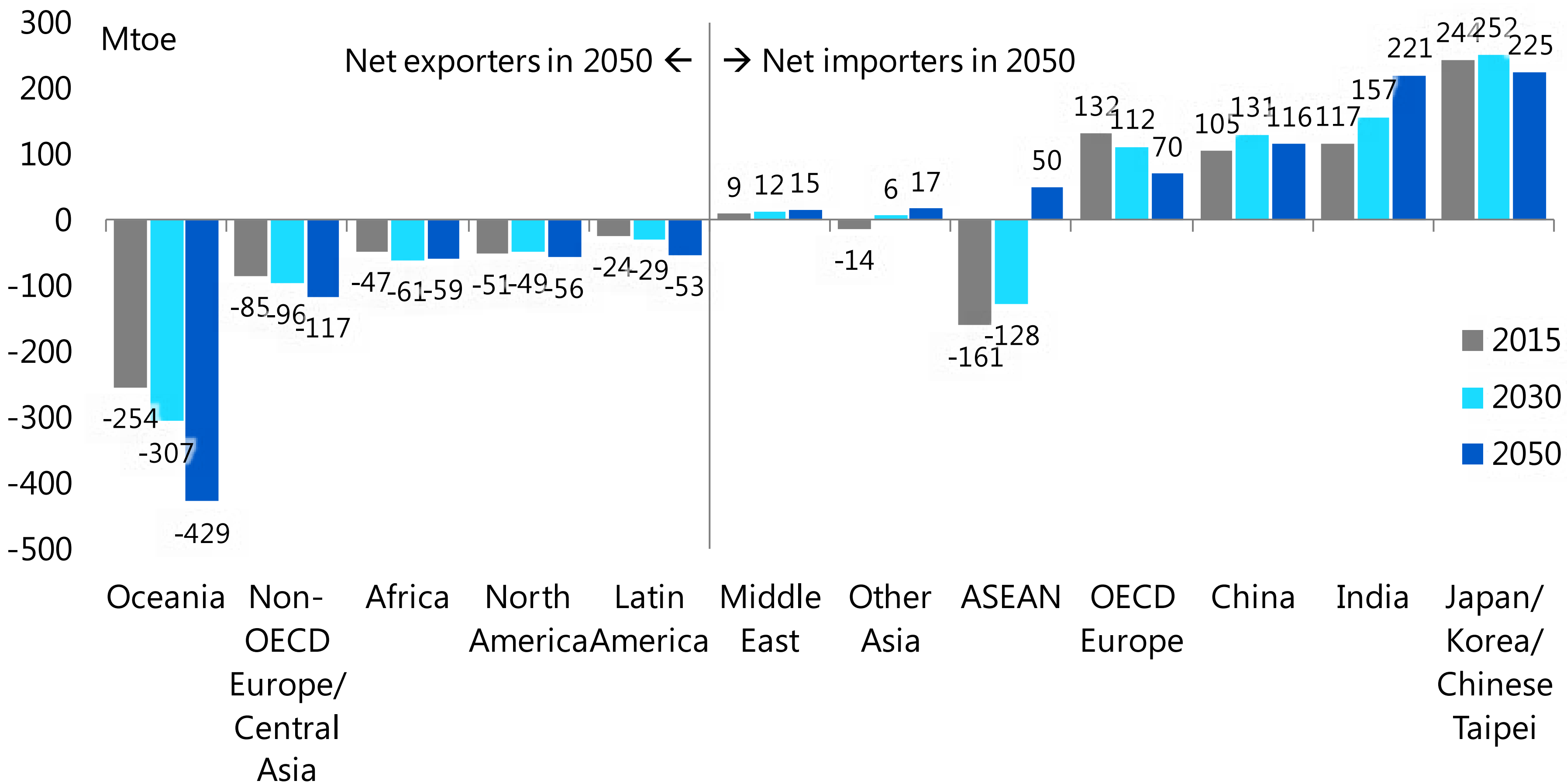
# Coal production

Reference Scenario

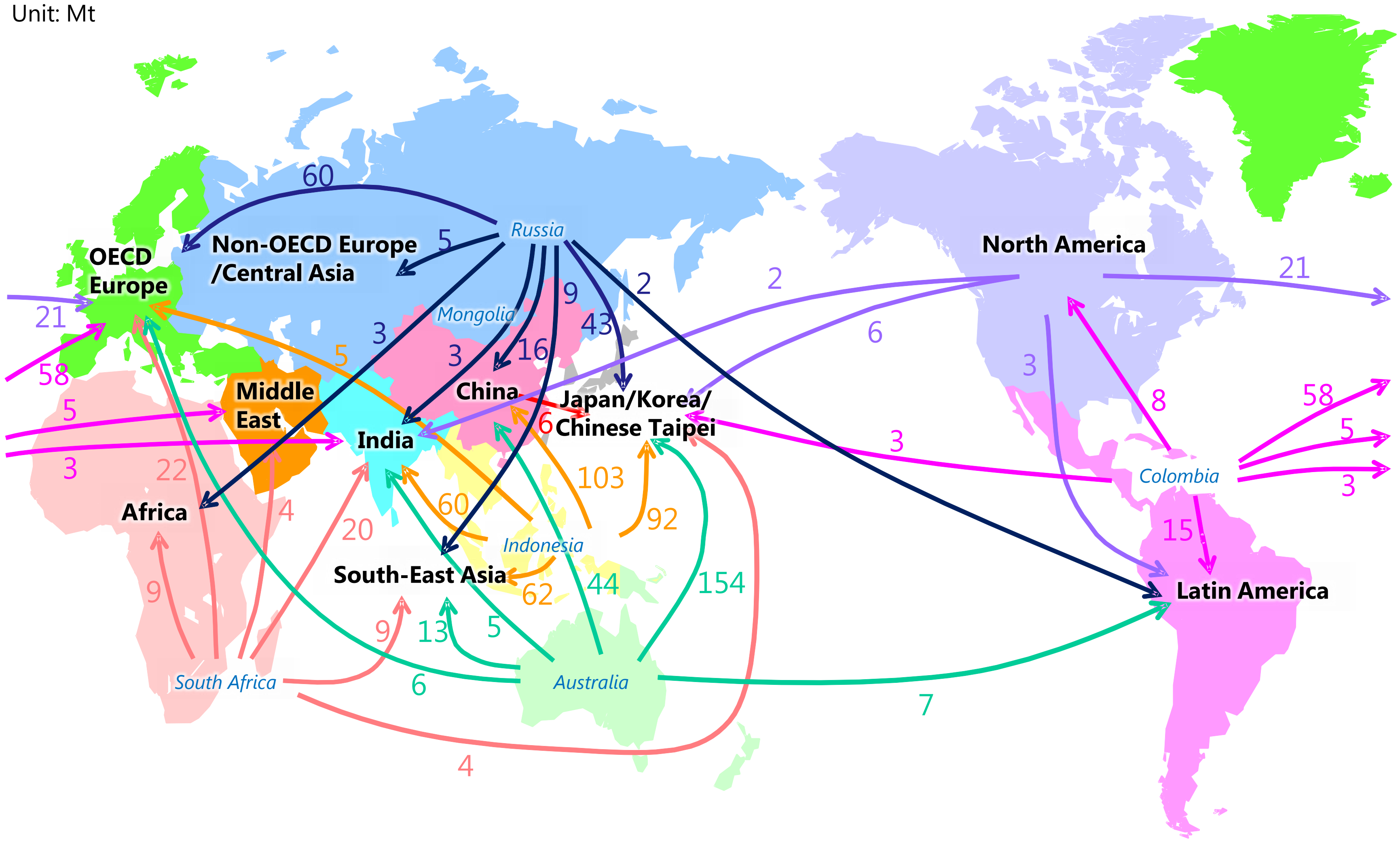


# Coal net imports

Reference Scenario

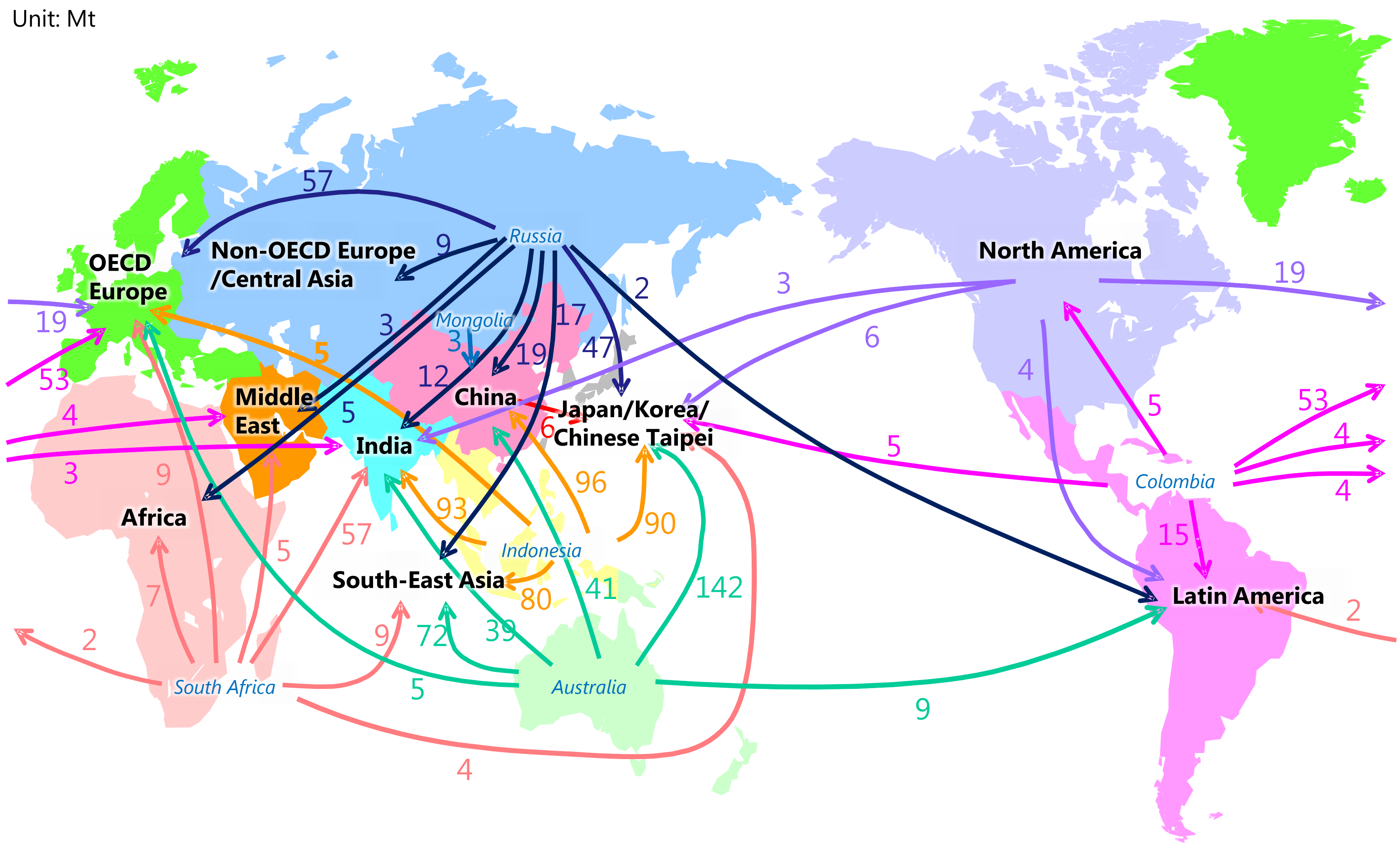


# Major steam coal trade flows (2016)

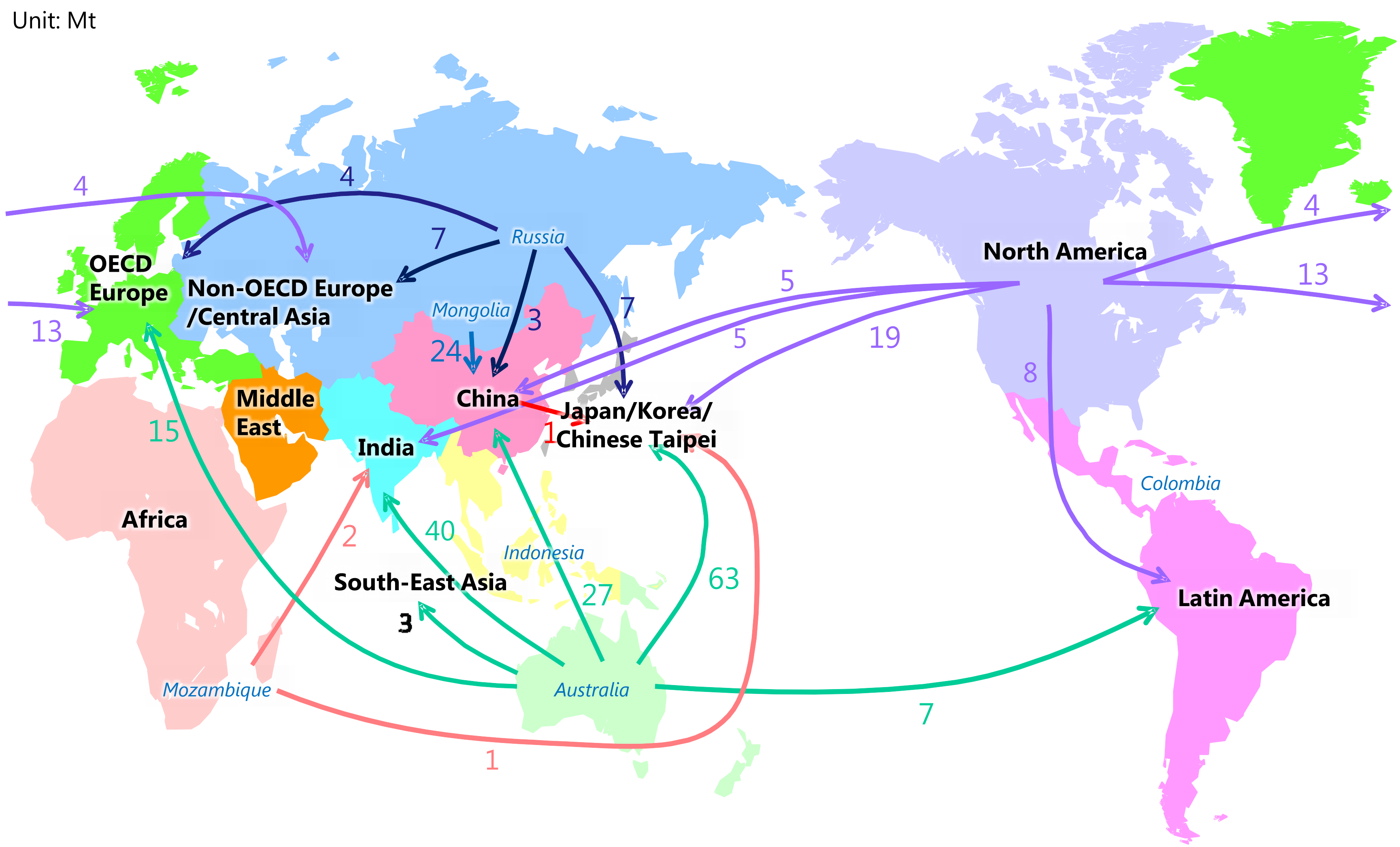


# Major steam coal trade flows (2030)

Reference Scenario



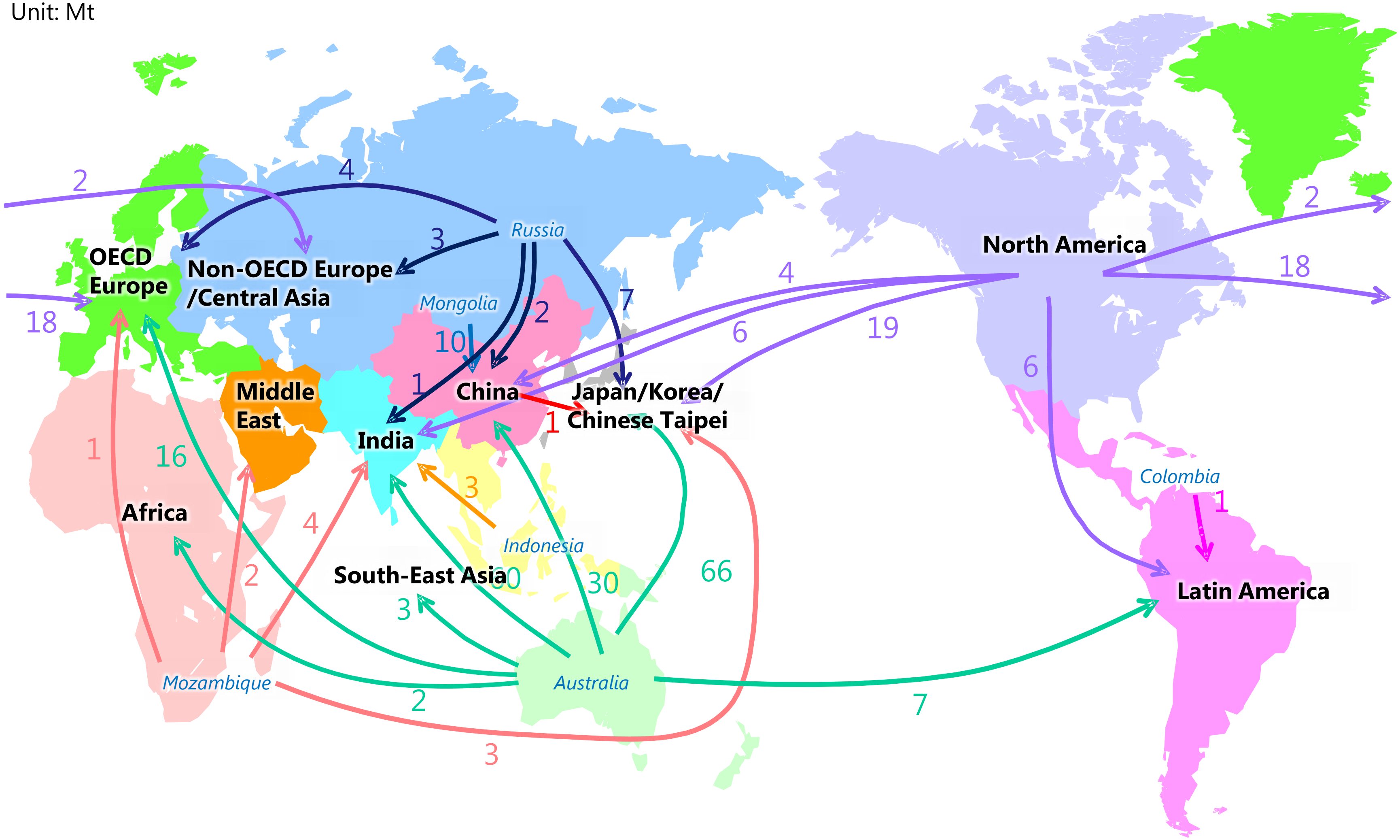
# Major coking coal trade flows (2016)



# Major coking coal trade flows (2030)

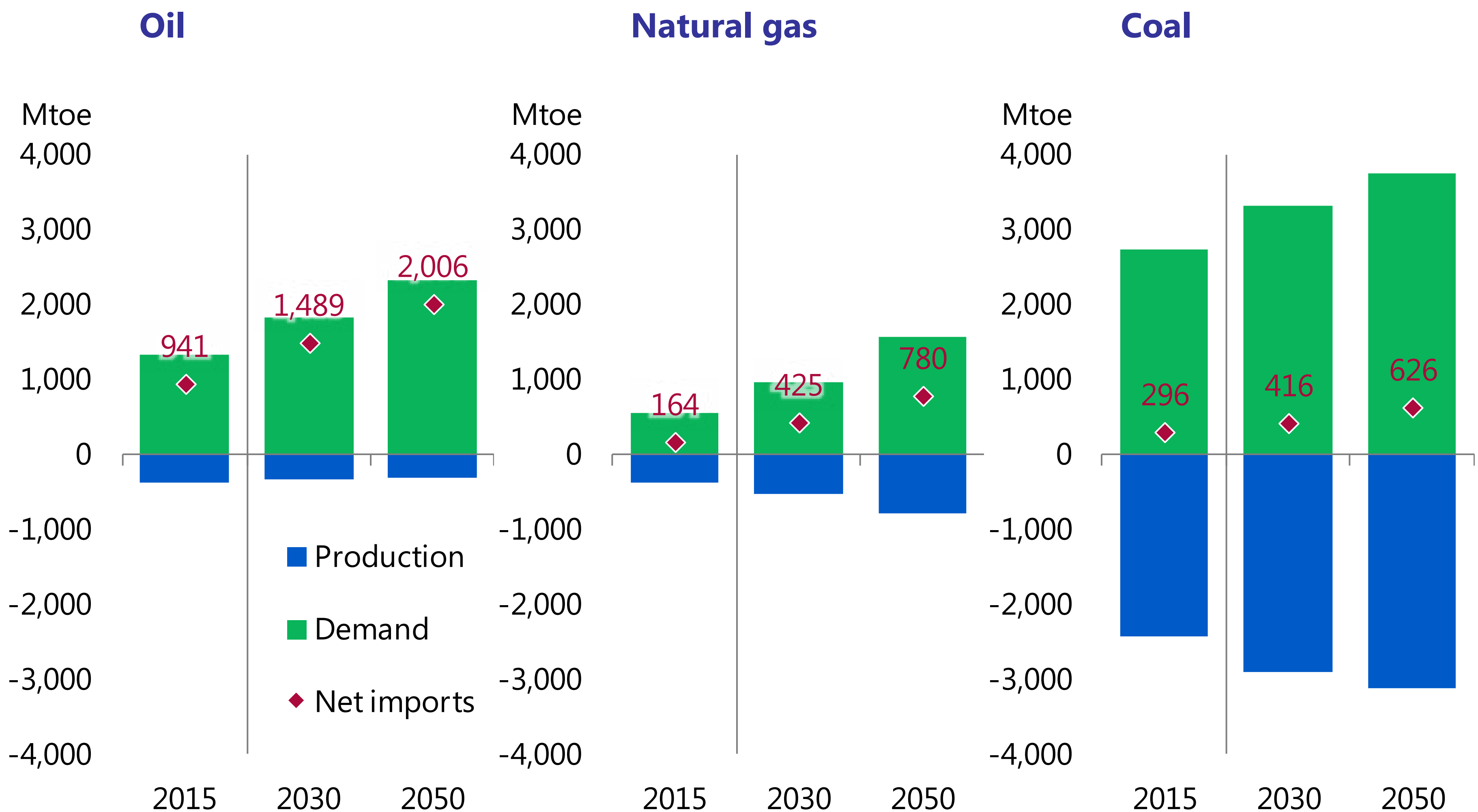
Reference Scenario

Unit: Mt



# Fossil fuel supply/demand balances (Asia)

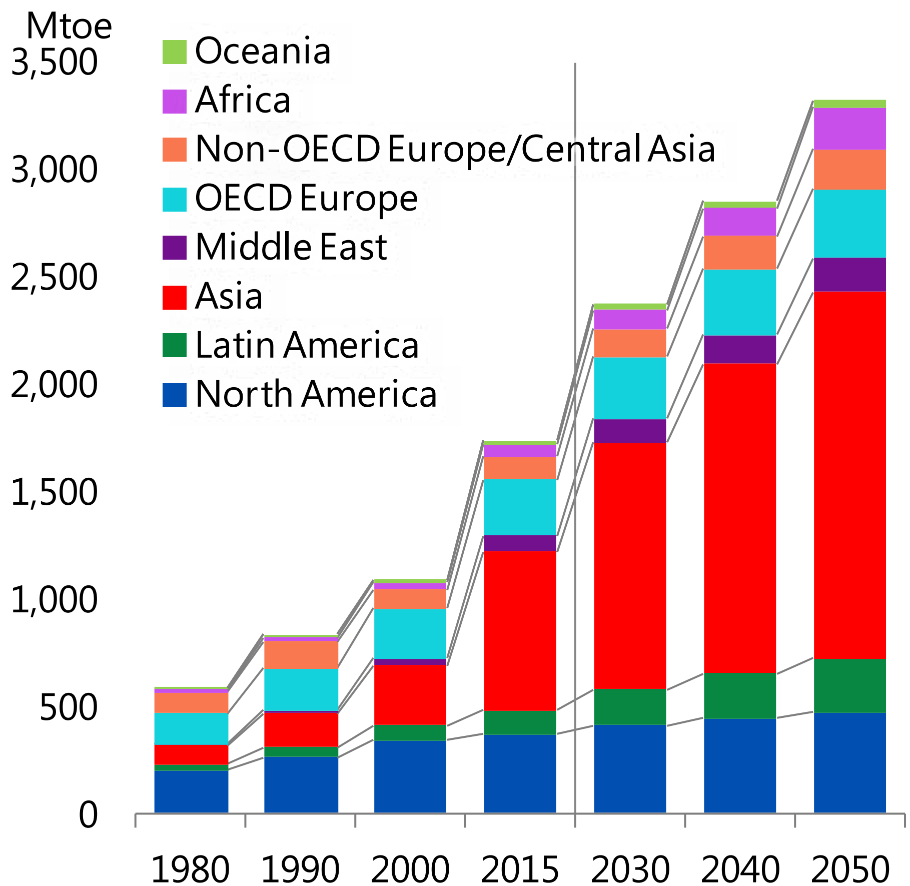
Reference Scenario



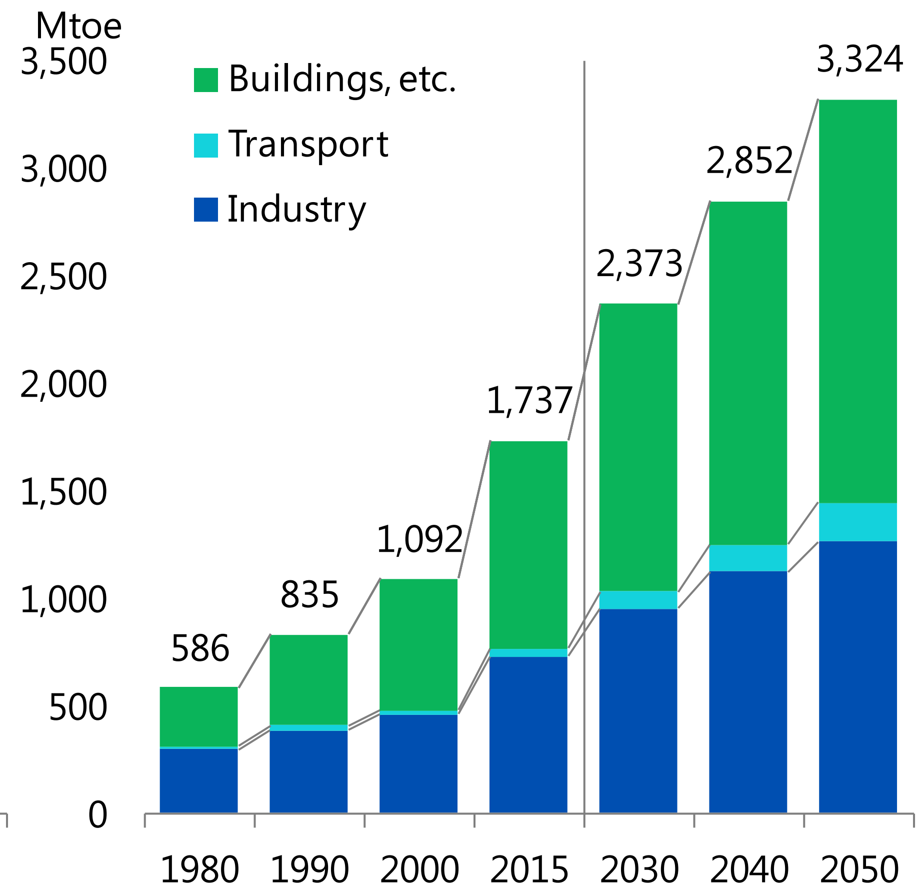
# Electricity final consumption

Reference Scenario

## By region



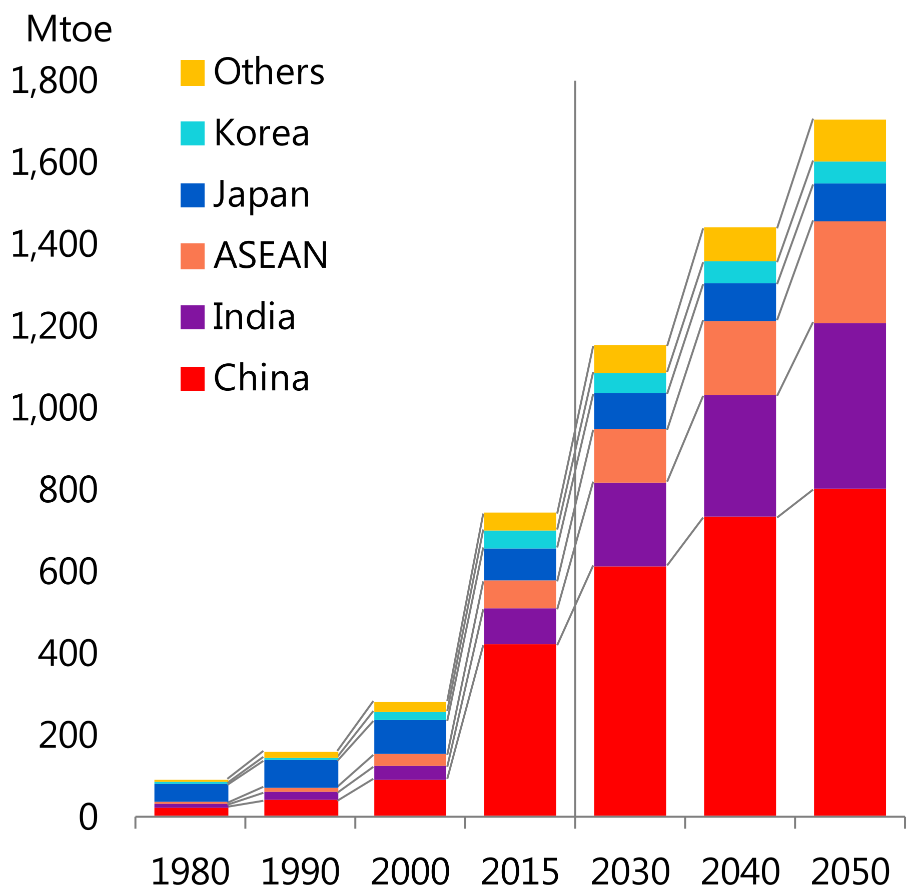

## By sector



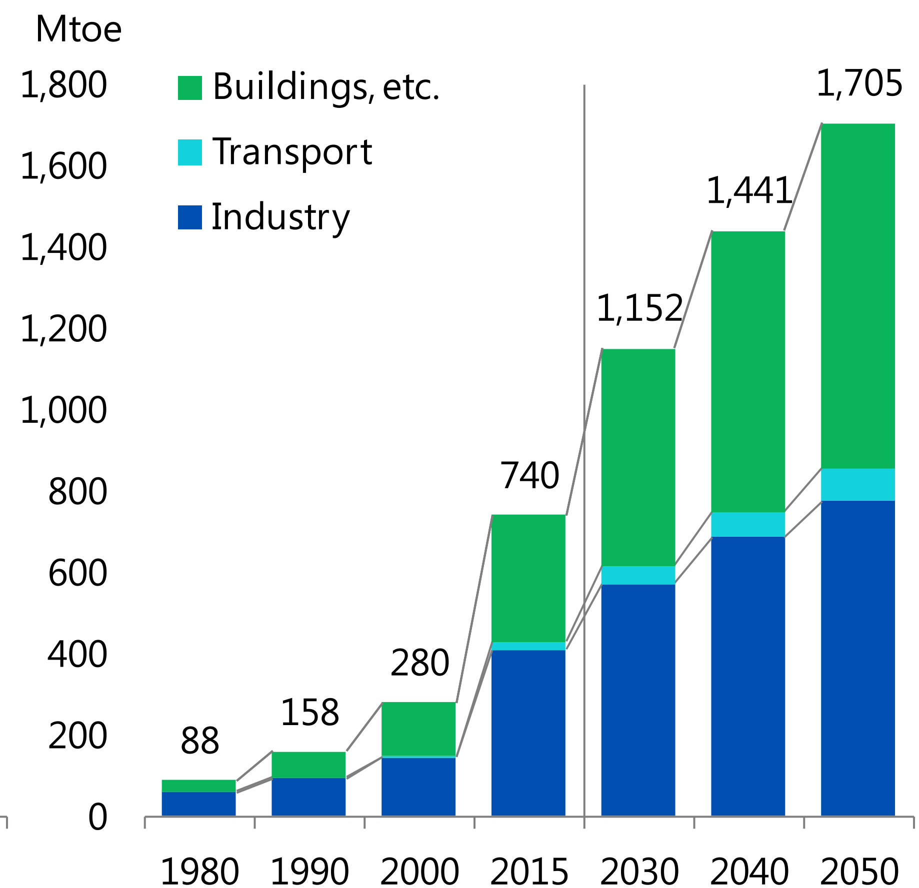
# Electricity final consumption (Asia)

Reference Scenario

## By region



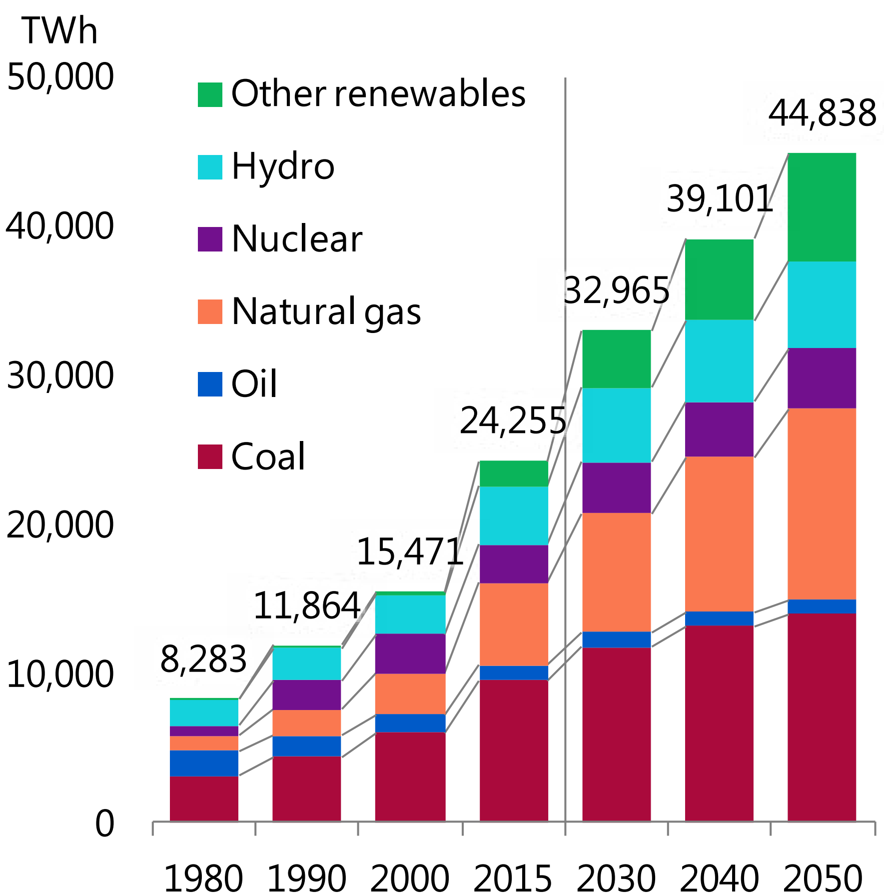

## By sector



# Power generation mix

Reference Scenario

## Electricity generated

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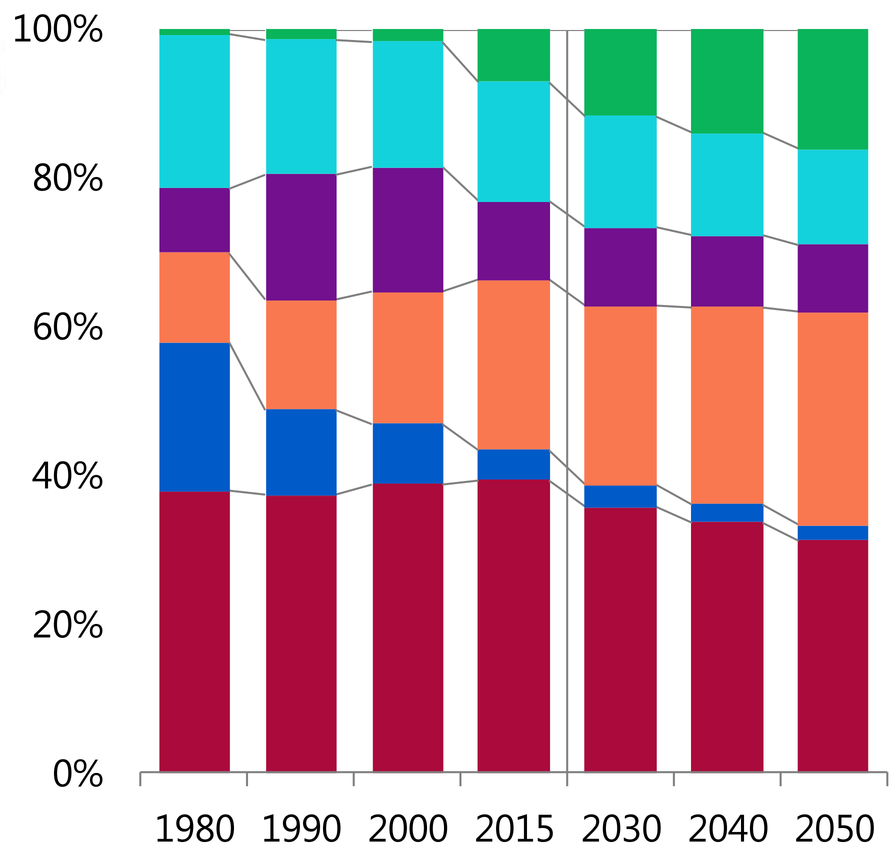
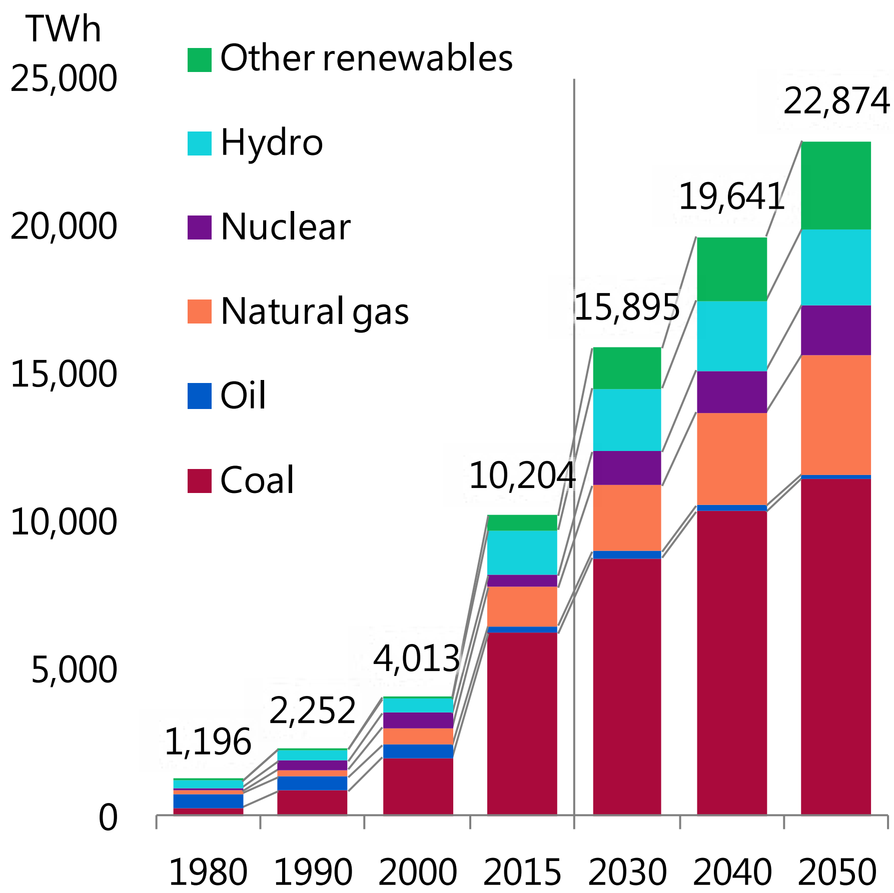


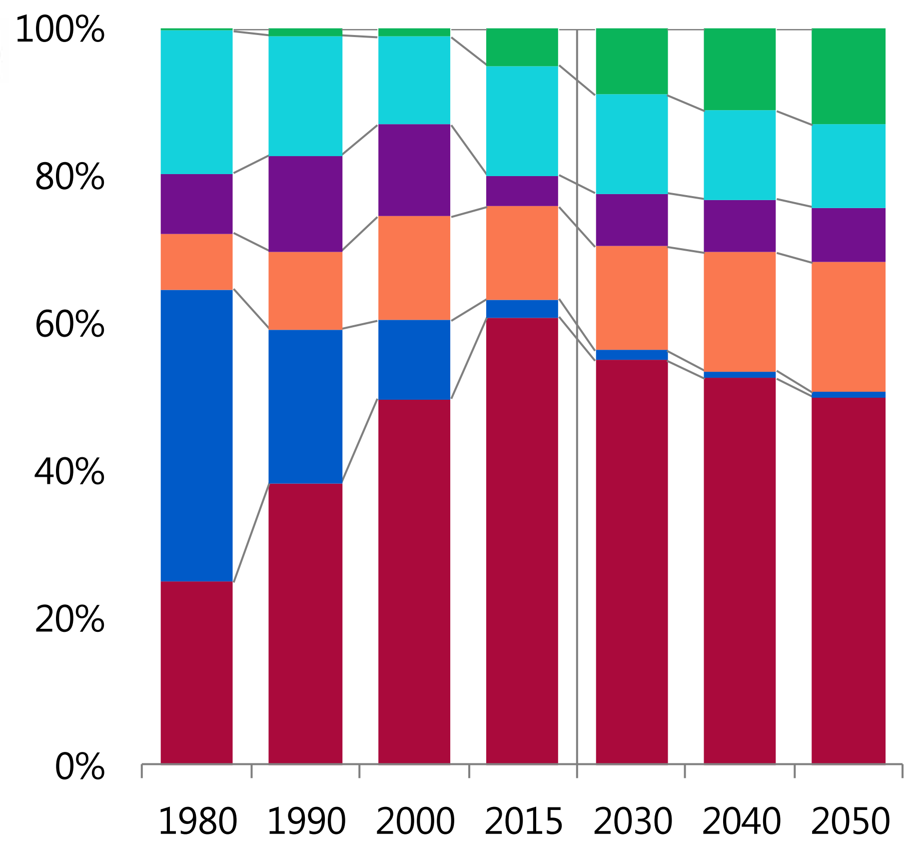
# Power generation mix (Asia)

Reference Scenario

## Electricity generated




## Share

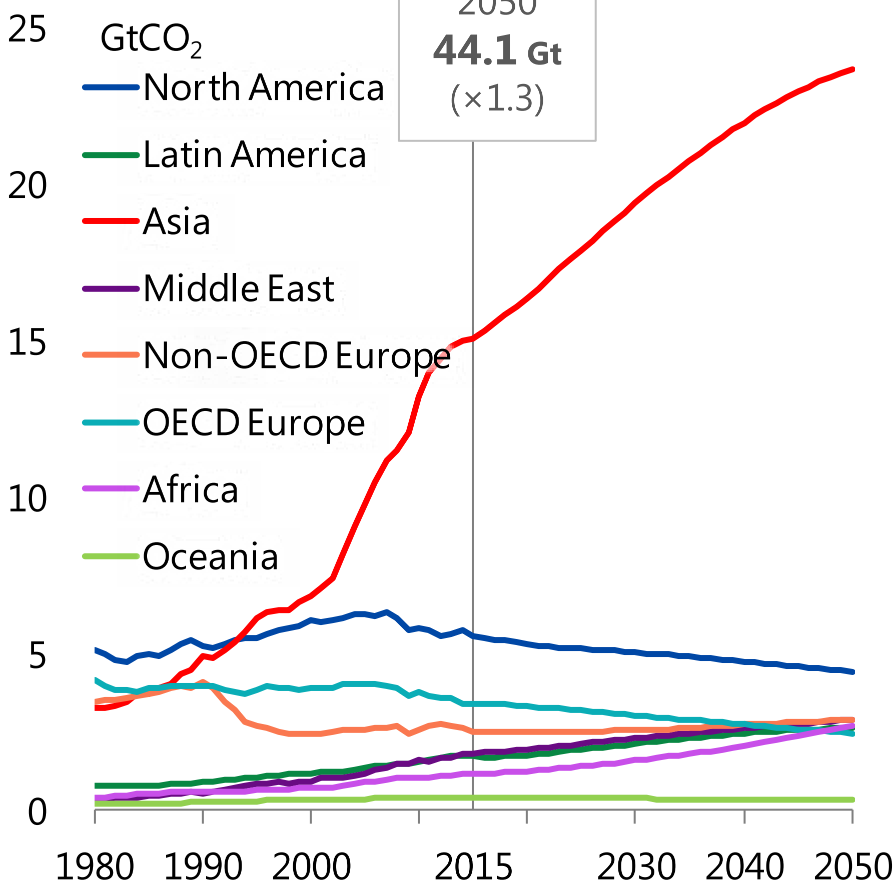


# $CO_2$ emissions

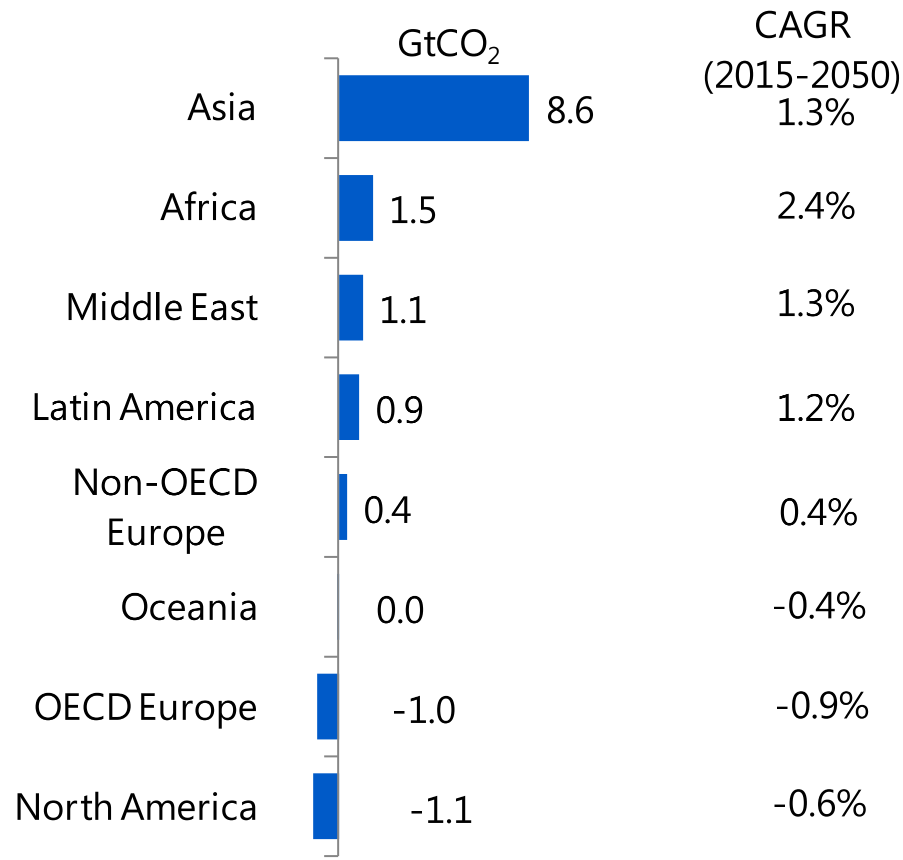
Reference Scenario

World

2015
**32.9 Gt**
↓
2050
**44.1 Gt**
(×1.3)

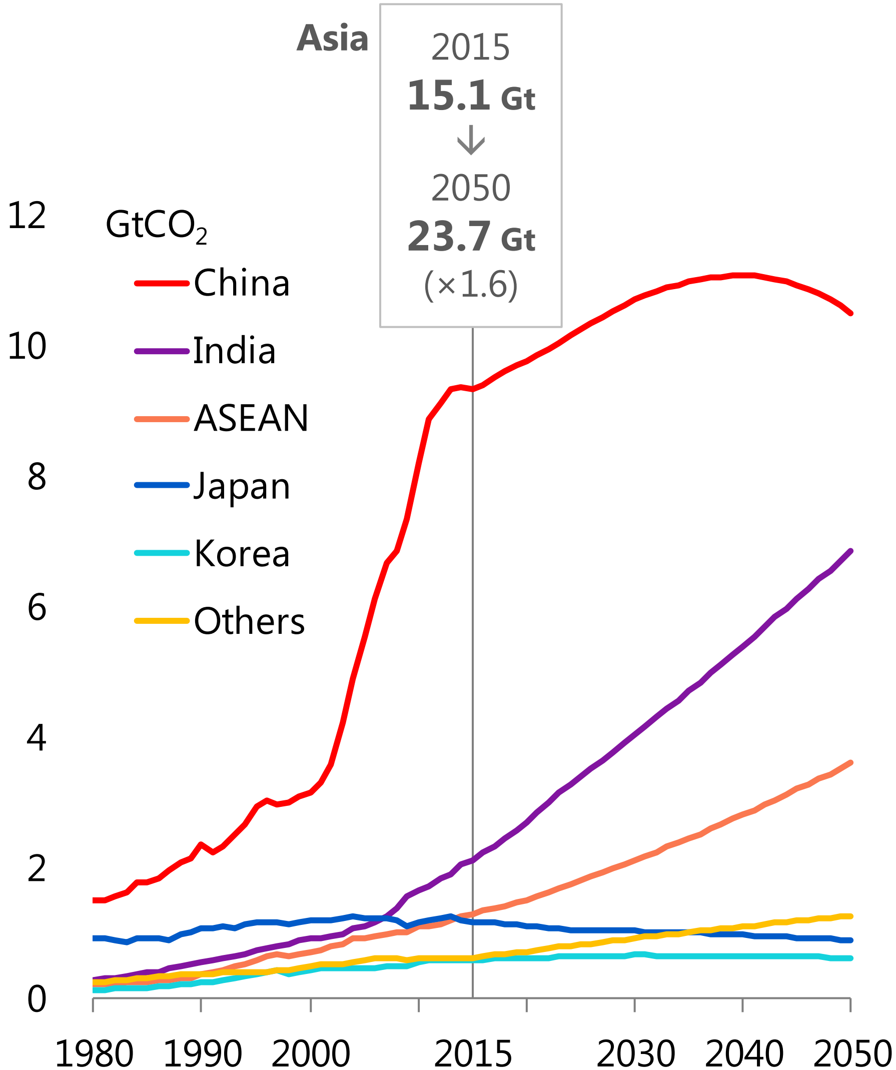


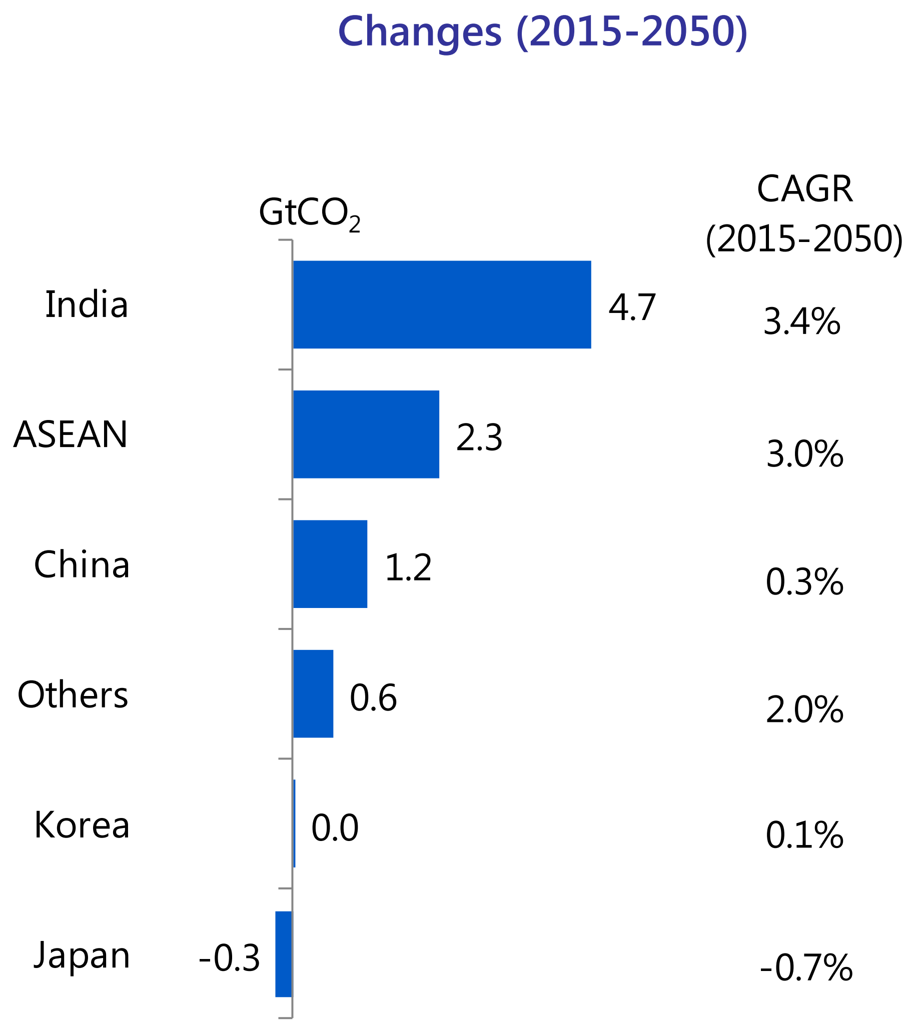

Changes (2015-2050)



# $CO_2$ emissions (Asia)

Reference Scenario



# Advanced Technologies Scenario

# 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 technologies

### ■ 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 technologies

### ■ Renewable energies

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 capacity factor improved.

### ■ Highly efficient fossil fuel-fired power generation technologies

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

### ■ Technologies for next-generation transmission and distribution networks

Lower loss type of transformation and voltage regulator will penerate further

### ■ Carbon capture and storage

*SC: Super Critical, USC: Ultra Super Critical, A-USC: Advanced Ultra Super Critical

# Major assumption: Energy and environmental technologies

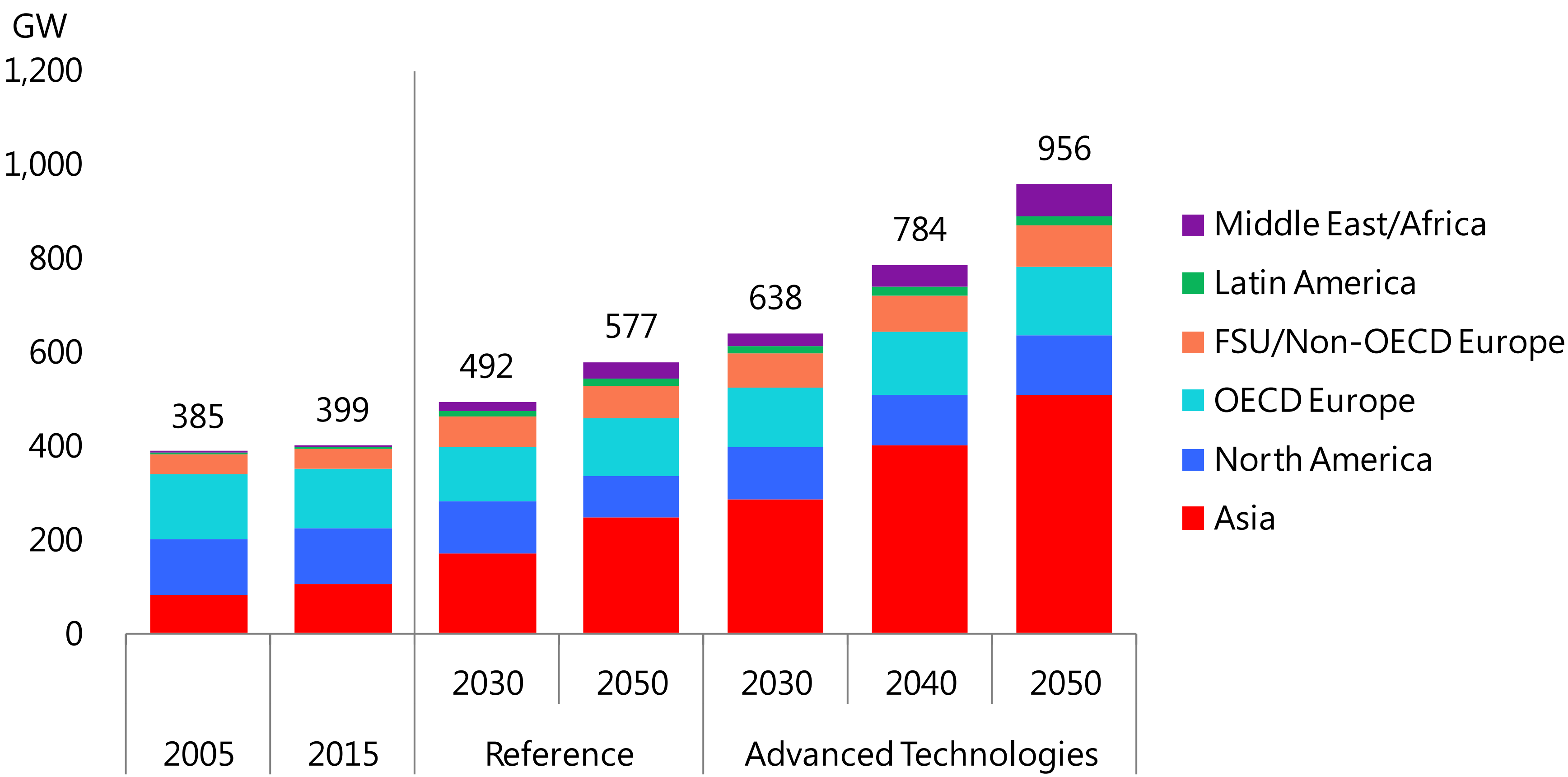
## Advanced Technologies Scenario

2015 → 2050 (Reference, 2050)

| | OECD | Non-OECD |
|---|---|---|
| Thermal power plant | Maintenance of financial scheme for initial investment.<br>Share of IGCC in install 0% → 60% (20%)<br>Installing CCS after 2030 (Countries which have storage potential except for aquifer) | |
| [Thermal efficiency (stock basis)] | Natural gas: 48.5% → 55.7% (56.9%)<br>Coal: 37.3% → 44.4% (45.0%) | Natural gas: 36.7% → 47.3% (44.9%)<br>Coal: 36.5% → 40.2% (41.4%) |
| Nuclear | Maintenance of appropriate price in wholesale electricity market | Maintenance of framework for financing initial investment |
| [Capacity] | 2015: 309 GW → 327 (241) | 2015: 90 GW → 629 (337) |
| Renewables | System cost reduction<br>Cost reduction of power system<br>Efficient operation of power system | System cost reduction<br>Low cost investment<br>Improvement of power system |
| [Capacity] | Wind: 237 GW → 1,091 (718)<br>Solar: 165 GW → 909 (573) | Wind: 178 GW → 1,912 (1,152)<br>Solar: 60 GW → 1,588 (946) |
| Biofuels | Development of next generation biofuel<br>Higher diffusion of FFV | Cost reduction of biofuel<br>Relating to agricultural policy |
| [Consumption] | 50 Mtoe → 107 (68) | 26 Mtoe → 94 (56) |
| Industry | Best available technology diffuses 100% in 2050 | |
| Transportation | Cost reduction of high fuel efficiency of vehicles. Twice of travel distance of ZEV | |
| [Average fuel efficiency of new vehicle sales] | 14.5 km/L → 41.1 (27.8) | 12.9 km/L → 28.6 (20.2) |
| [Share in annual vehicle sales of ZEV] | 0.8% → 66% (35%) | 0.5% → 41% (17%) |
| Buildings | The pace of improvement of efficiency of newly installed appliance, equipment and insulation is twice. 20% improvement in 2050 in ratio of the Reference Scenario<br>Electrification and clean cooking in space heating, water heater and cooking | |

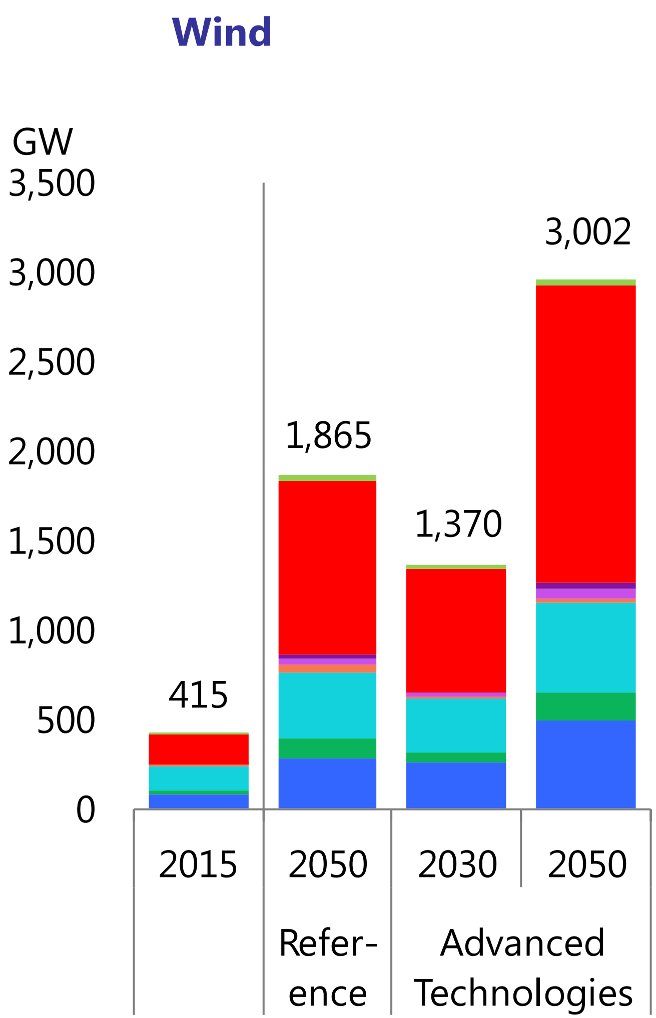
# Nuclear power generation capacities

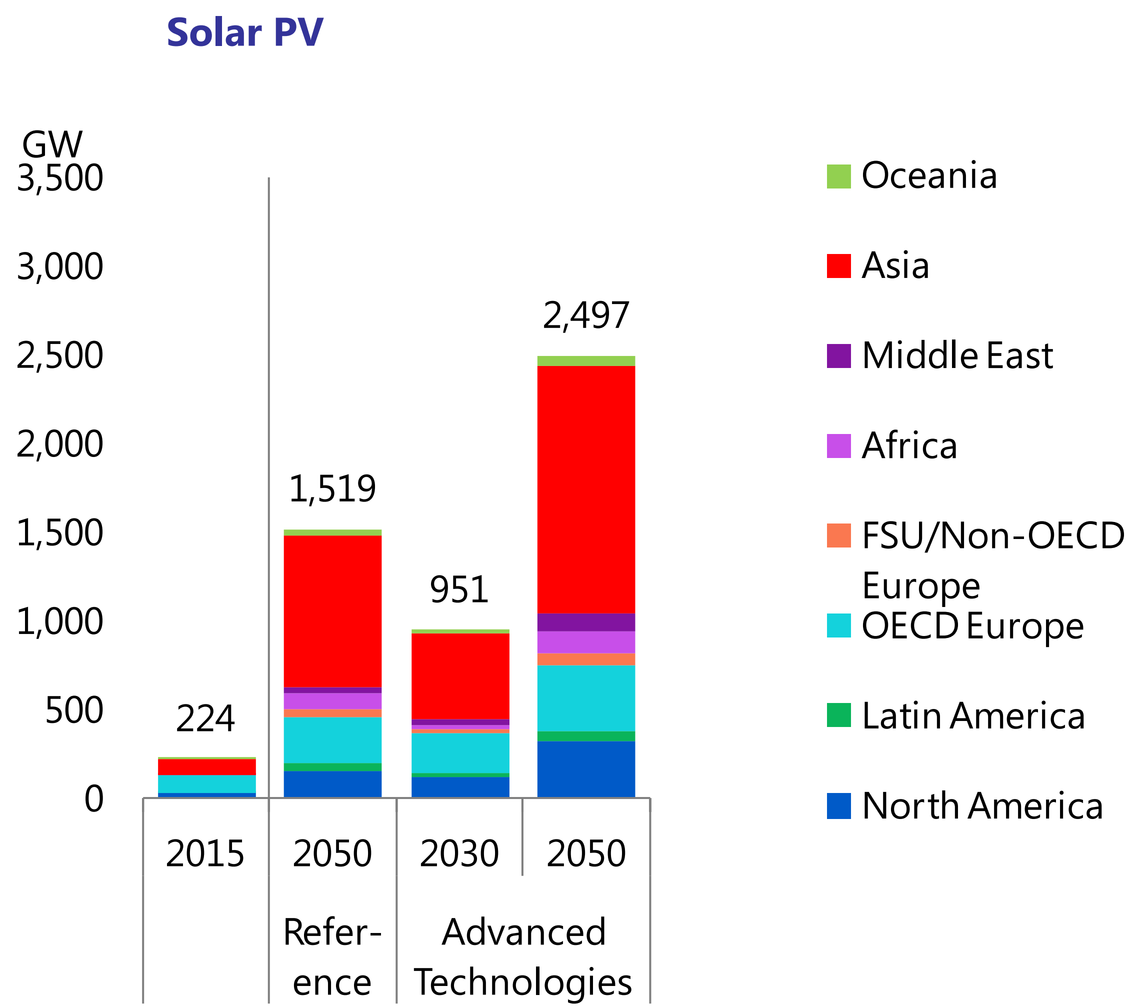
Advanced Technologies Scenario



# Renewables power generation capacities

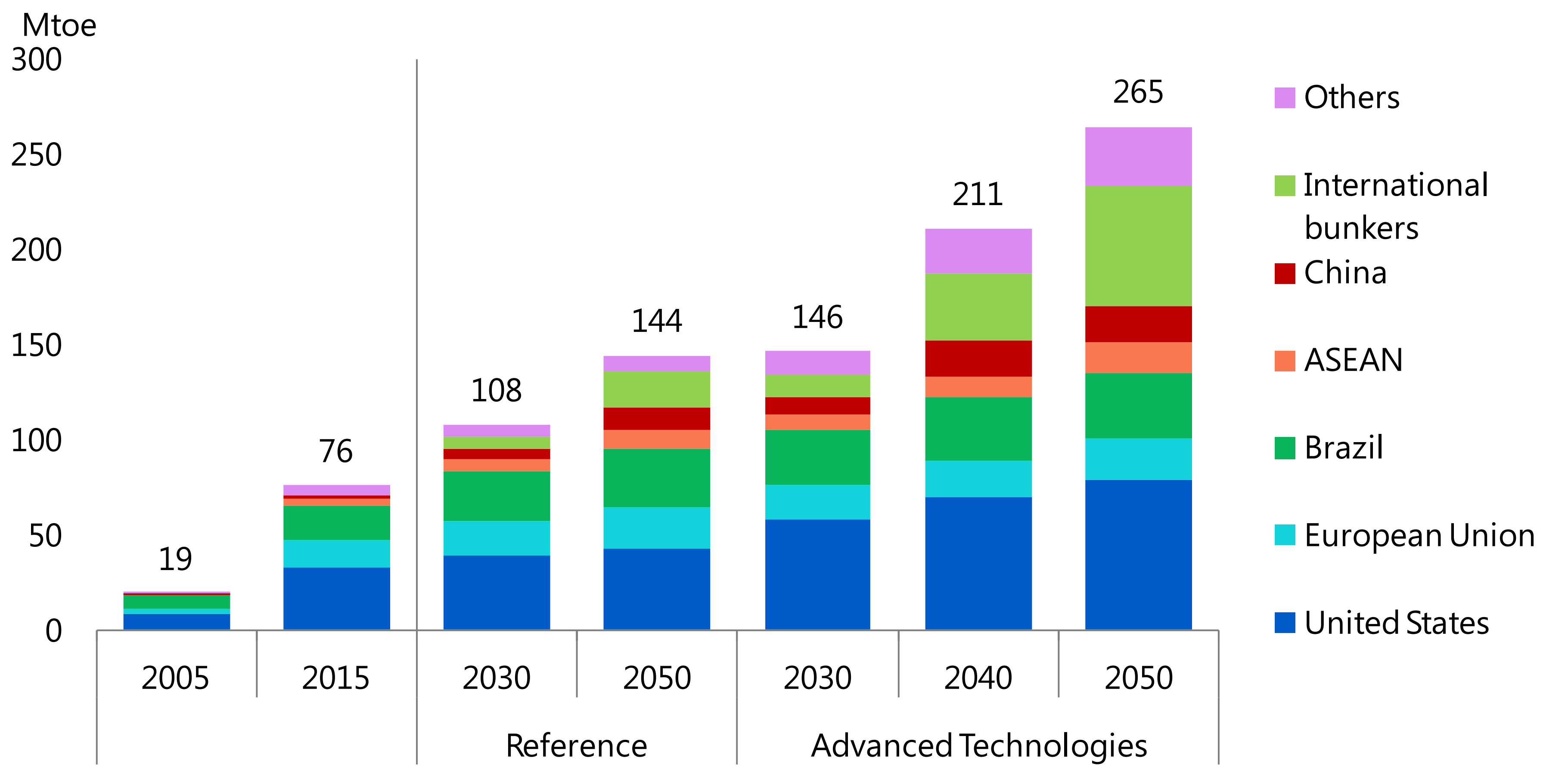
Advanced Technologies Scenario



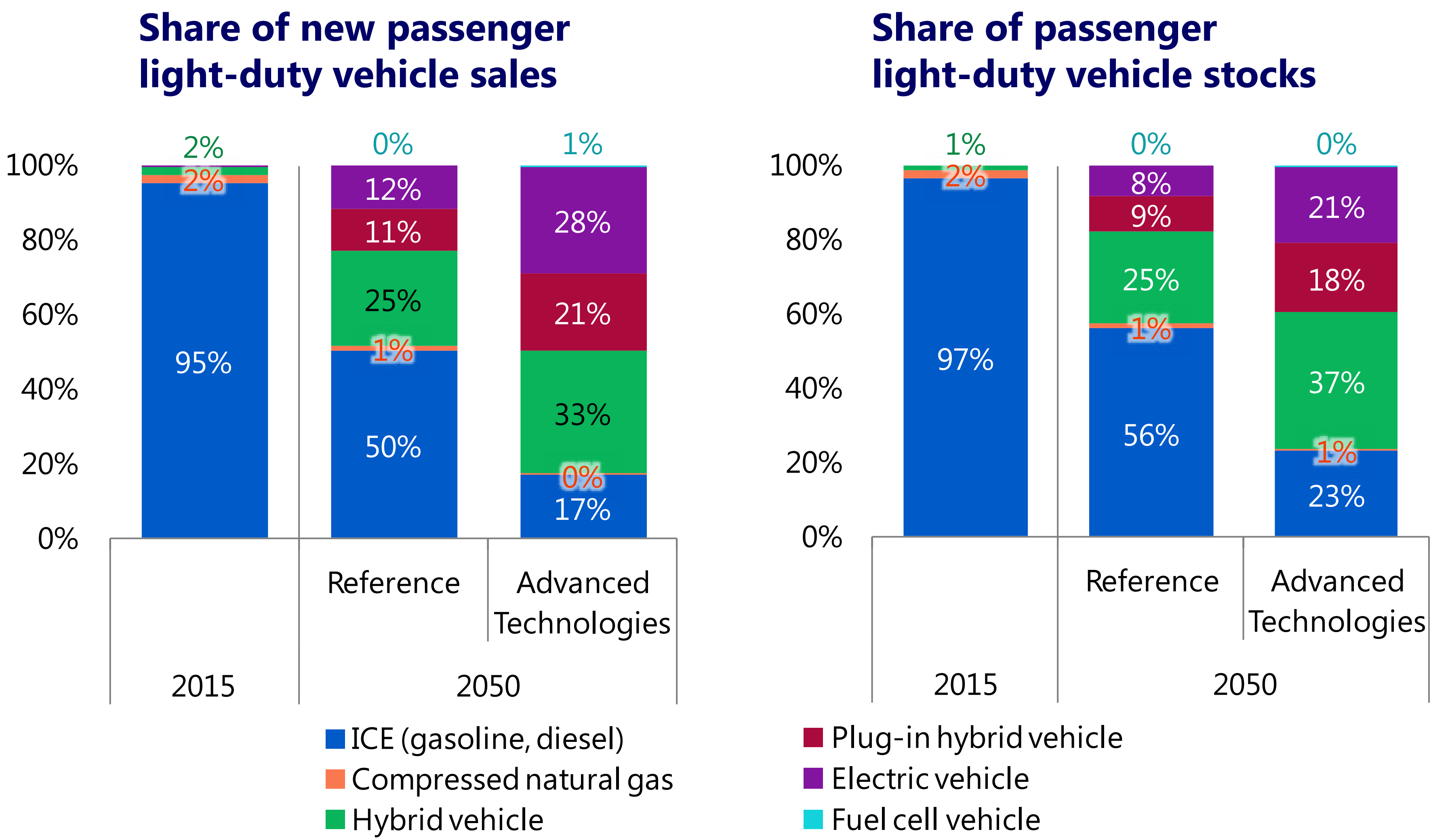
# Biofuels consumption

**Advanced Technologies Scenario**



# Vehicle stock and sales by type

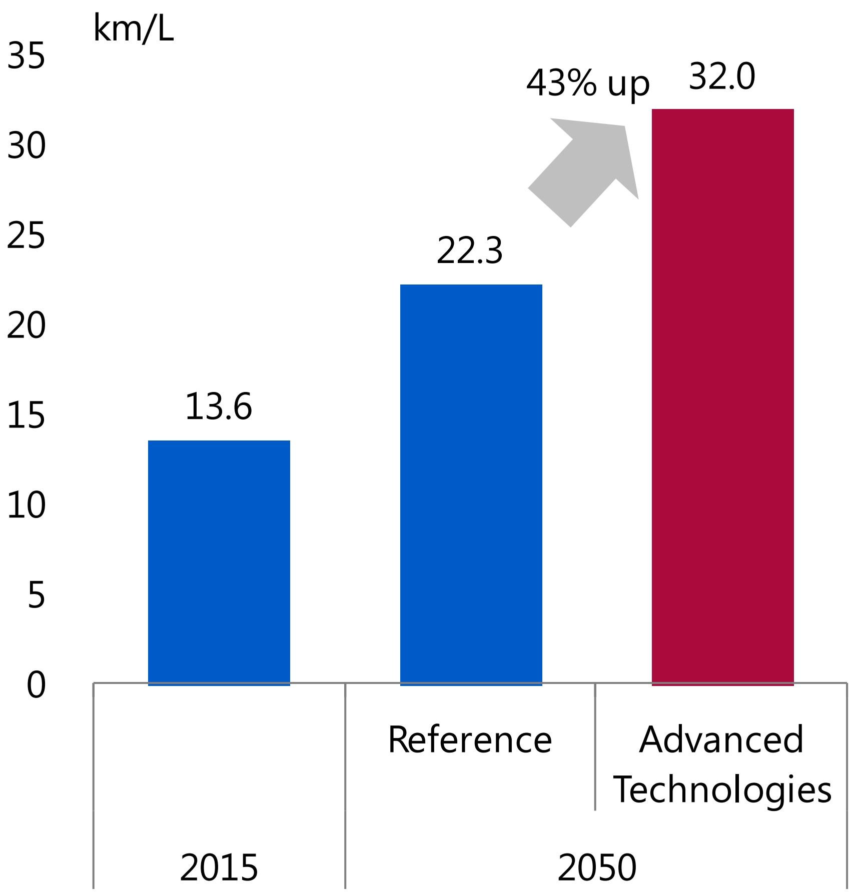
Advanced Technologies Scenario



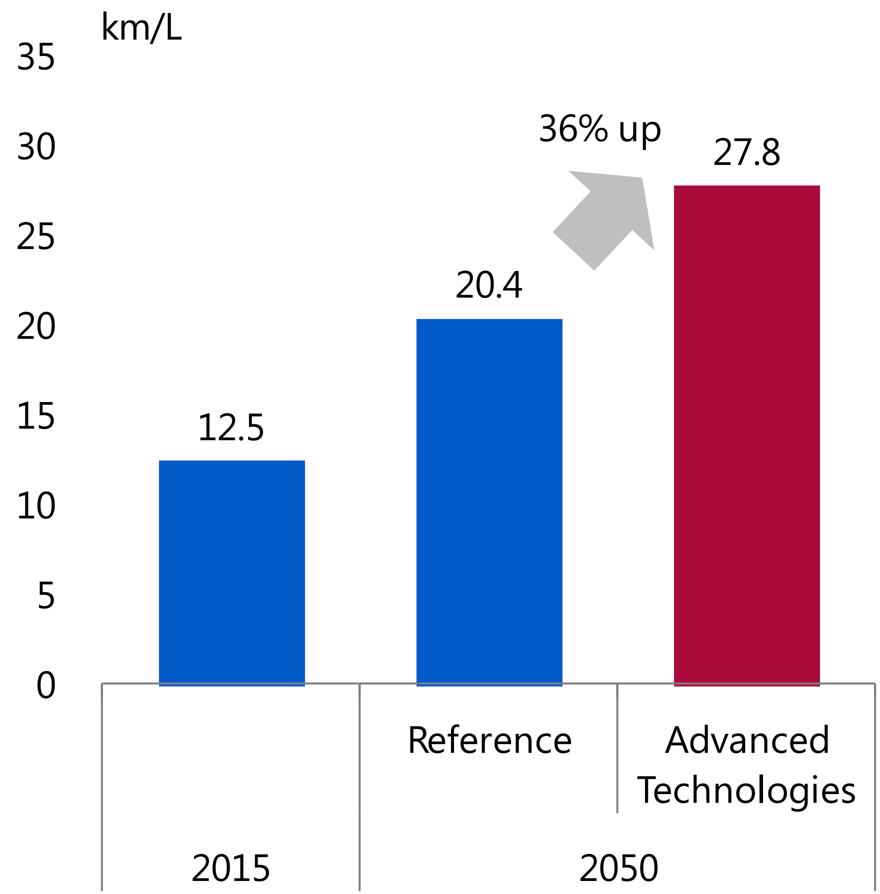
# Fuel efficiency of passenger cars

**Advanced Technologies Scenario**

### Fuel efficiency (New sales basis)

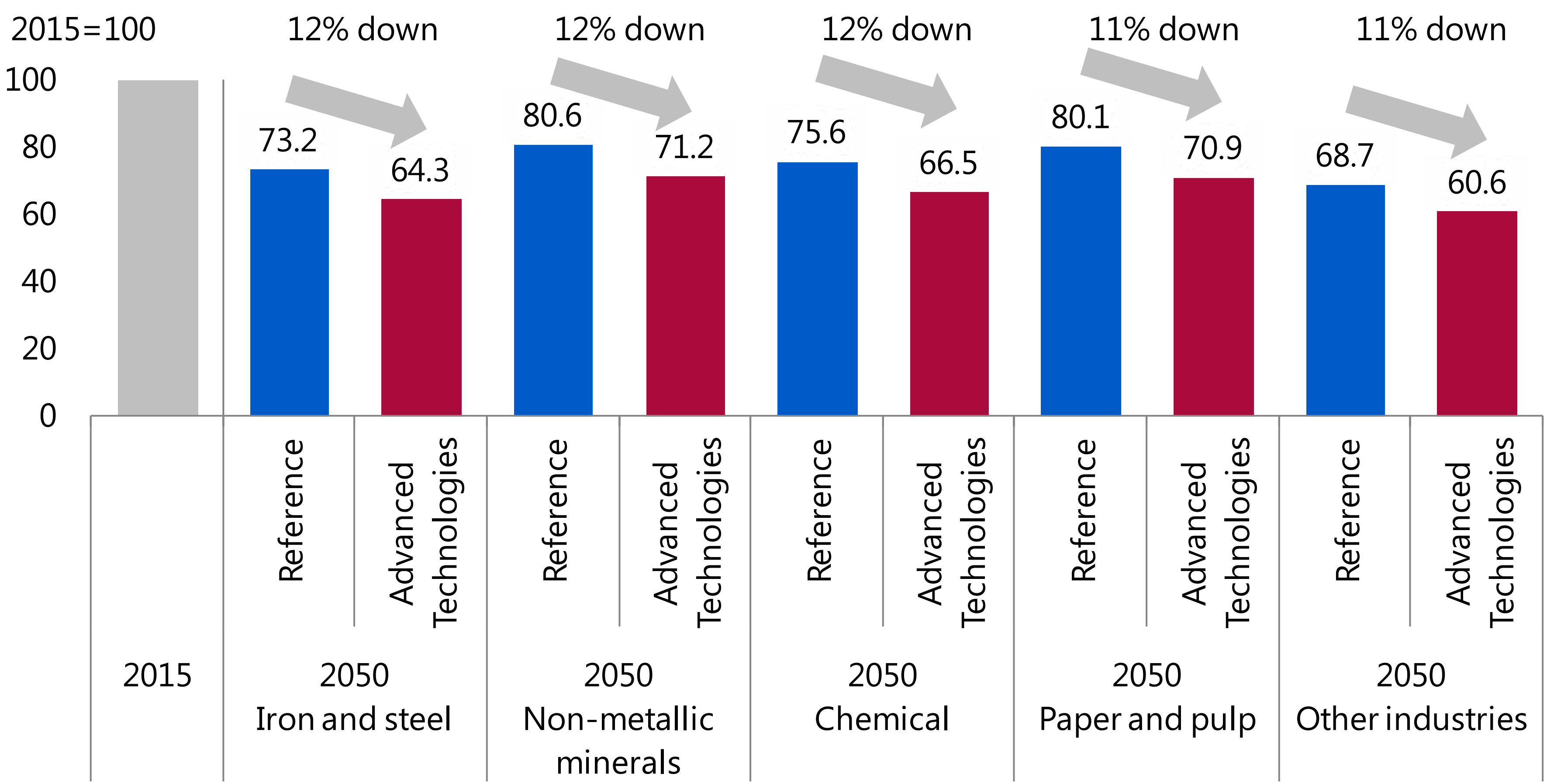



### Fuel efficiency (Stock basis)



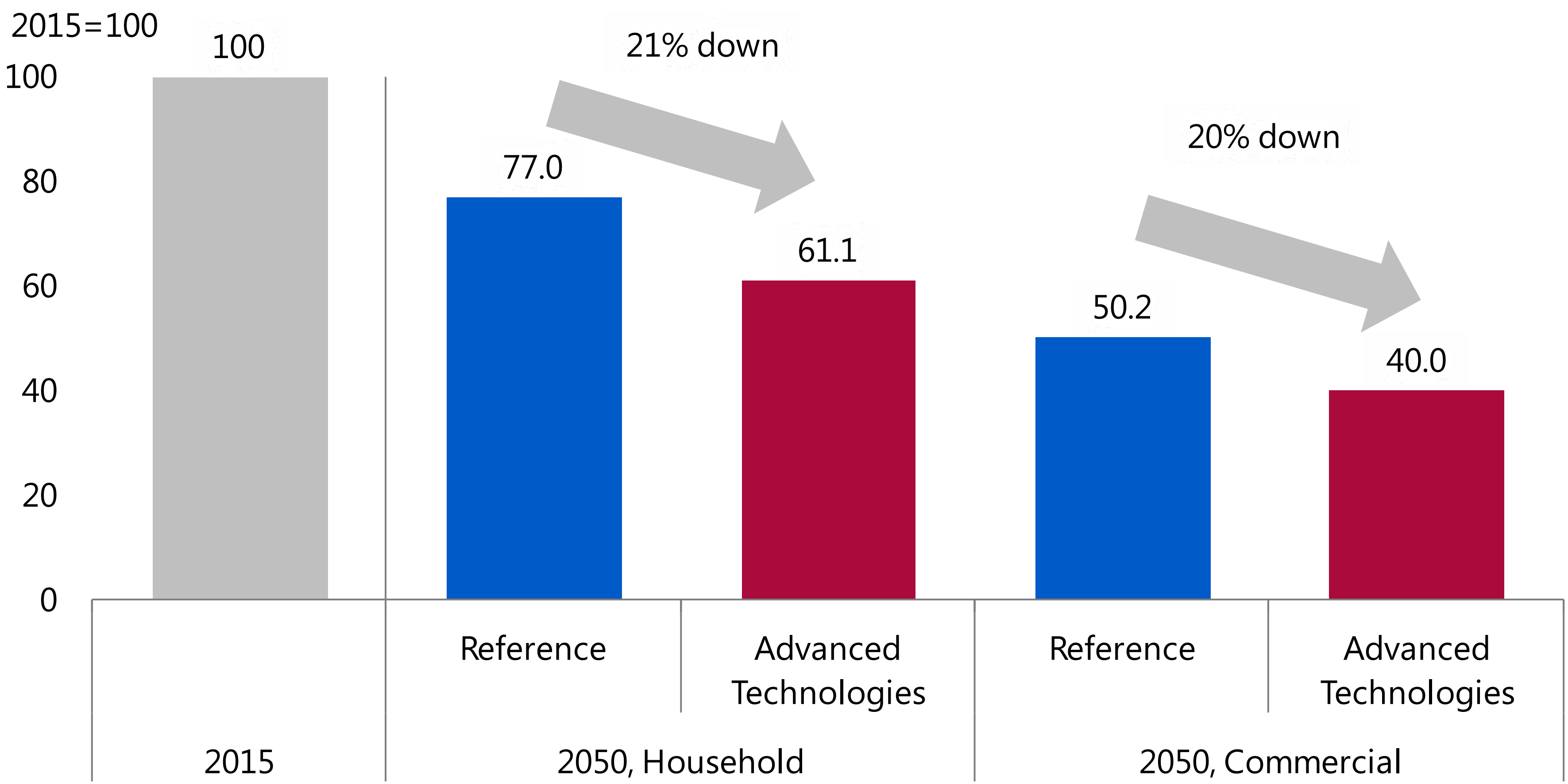
# Energy consumption per unit of output in industry

## Advanced Technologies Scenario



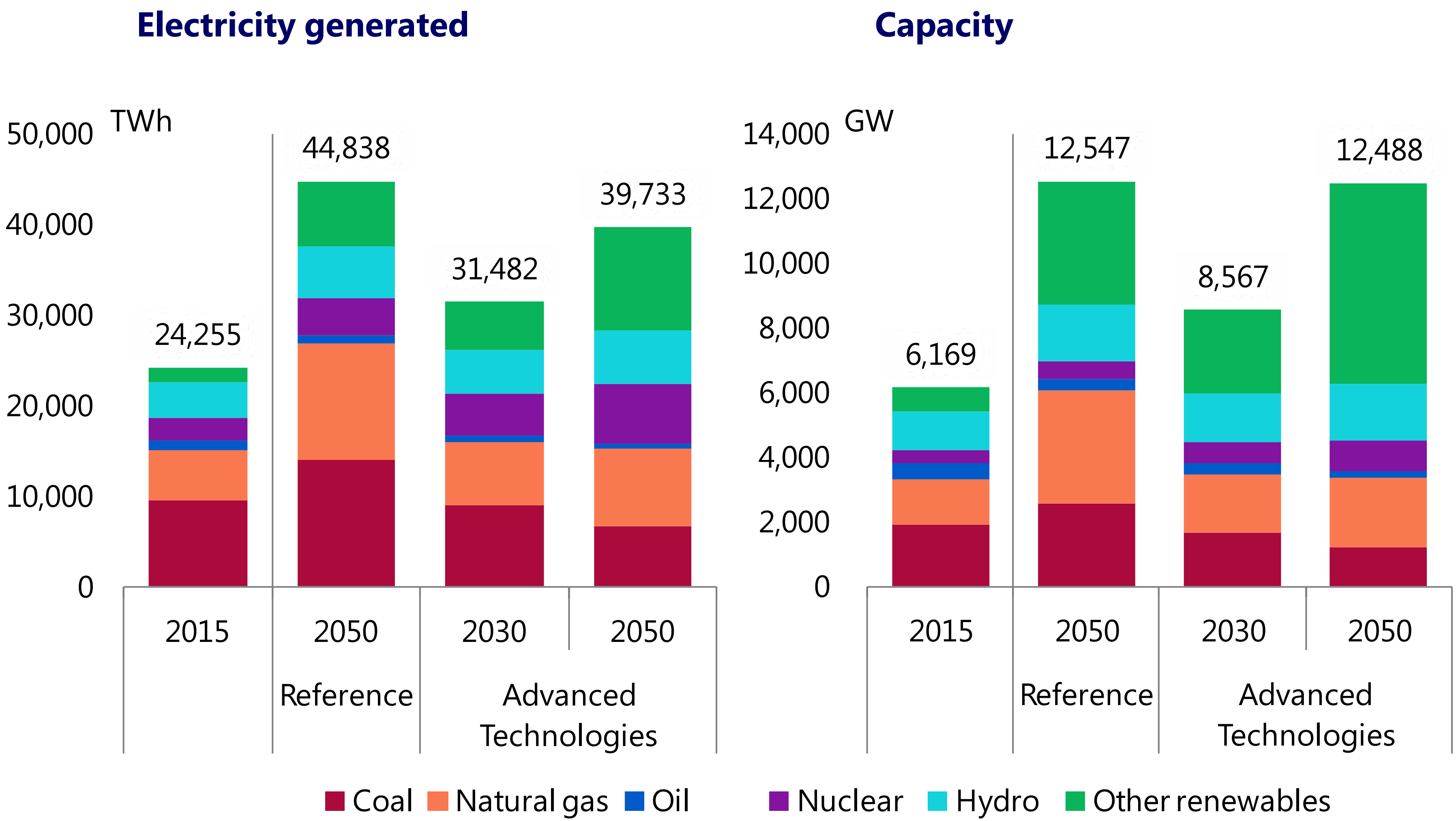
# Total efficiency in buildings

Advanced Technologies Scenario



# Power generation mix

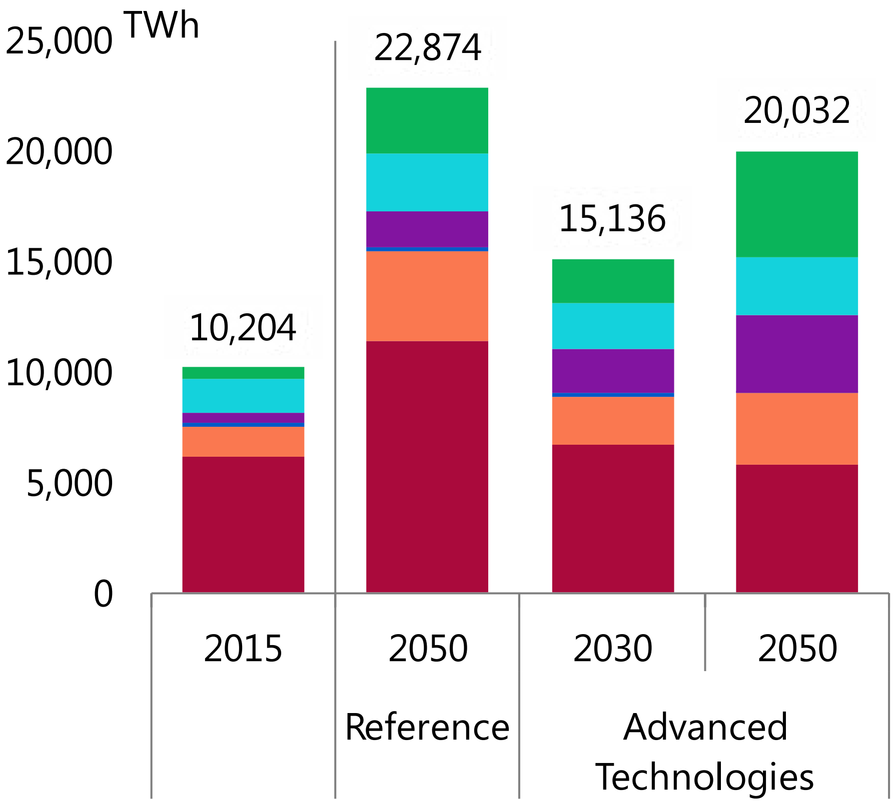
Advanced Technologies Scenario



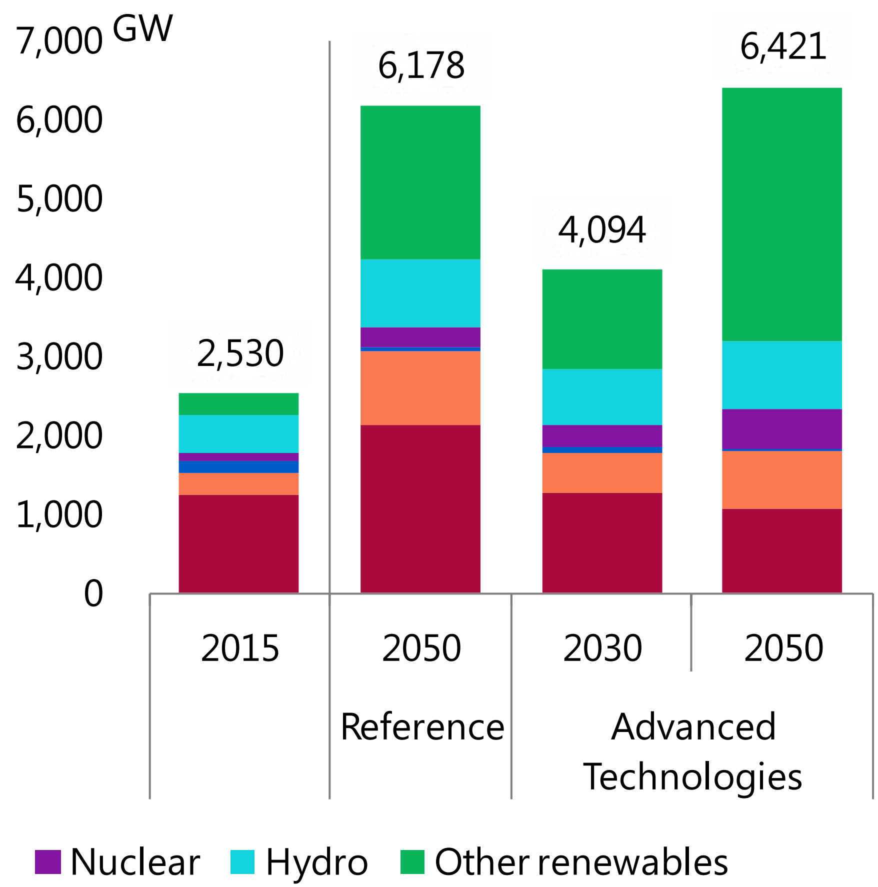
# Power generation mix (Asia)

**Advanced Technologies Scenario**

## Electricity generated

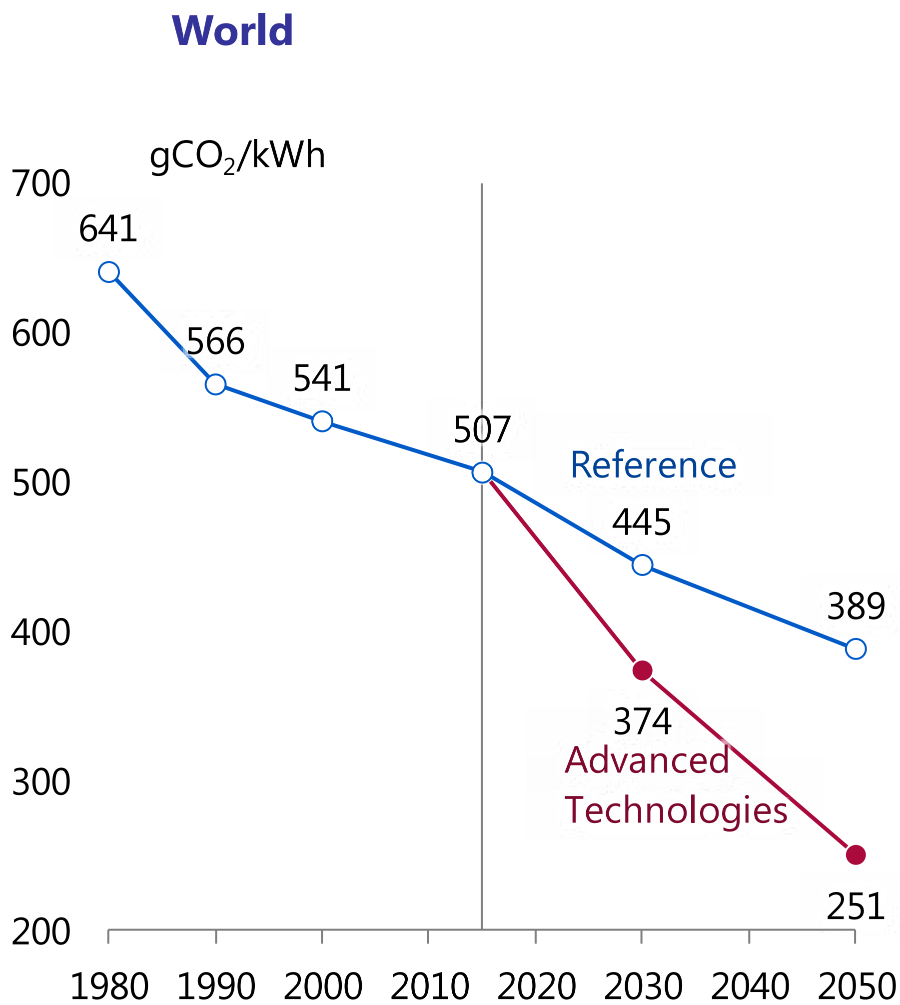


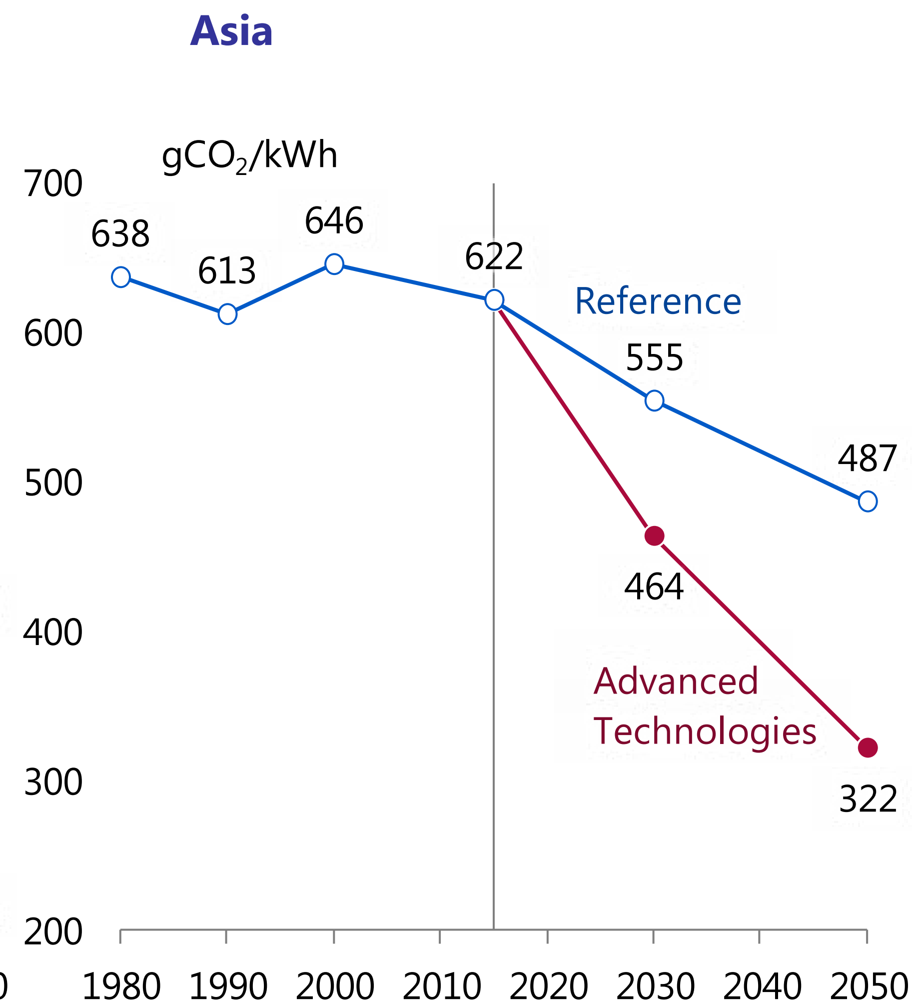

## Capacity



# Carbon intensity of electricity

Reference & Advanced Technologies Scenarios



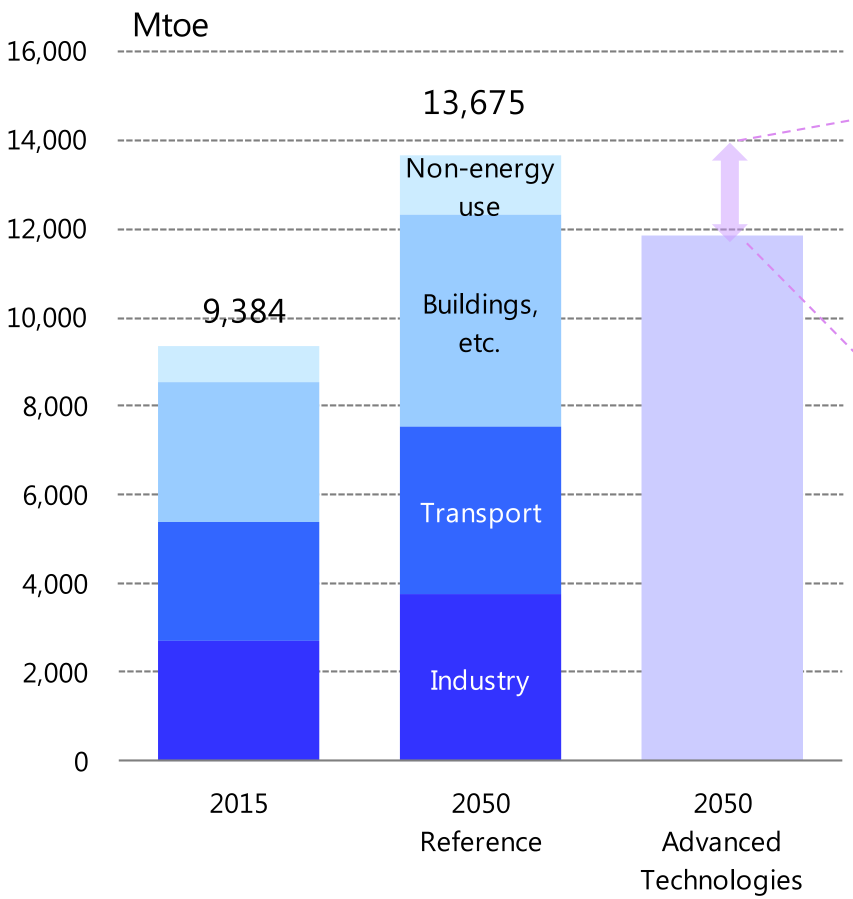




*$CO_2$ emissions per kWh at generation end

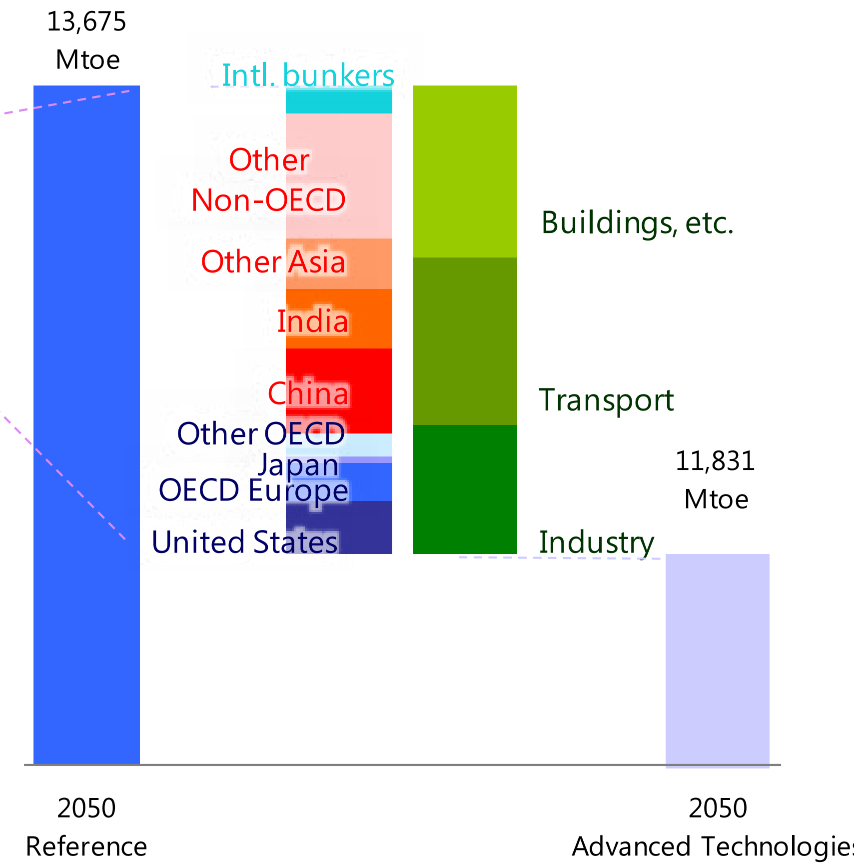
# Energy savings by region and by sector

**Advanced Technologies Scenario**

## Final energy consumption

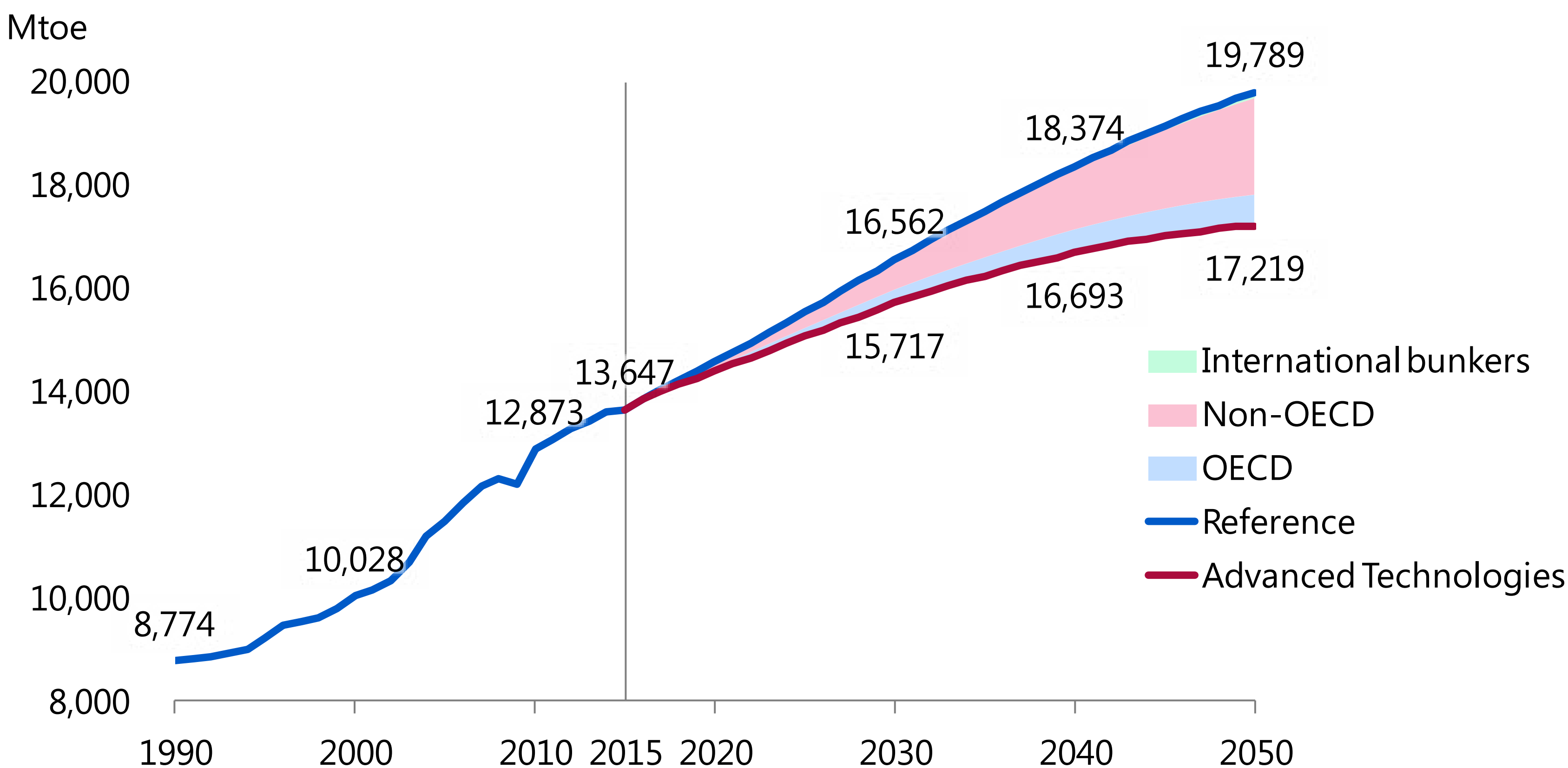



## Energy savings by region and by sector



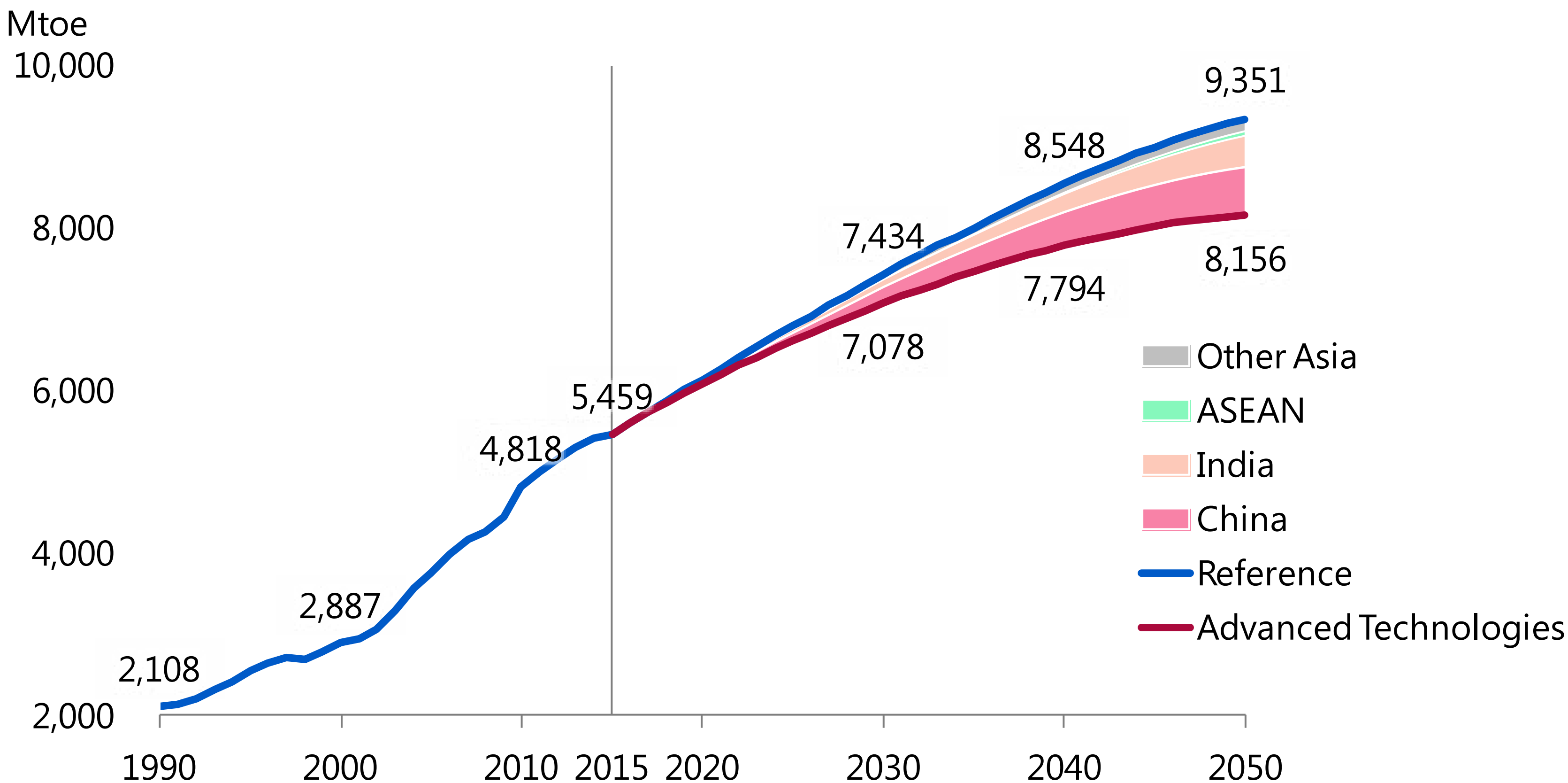
# Primary energy consumption reduction

## Advanced Technologies Scenario



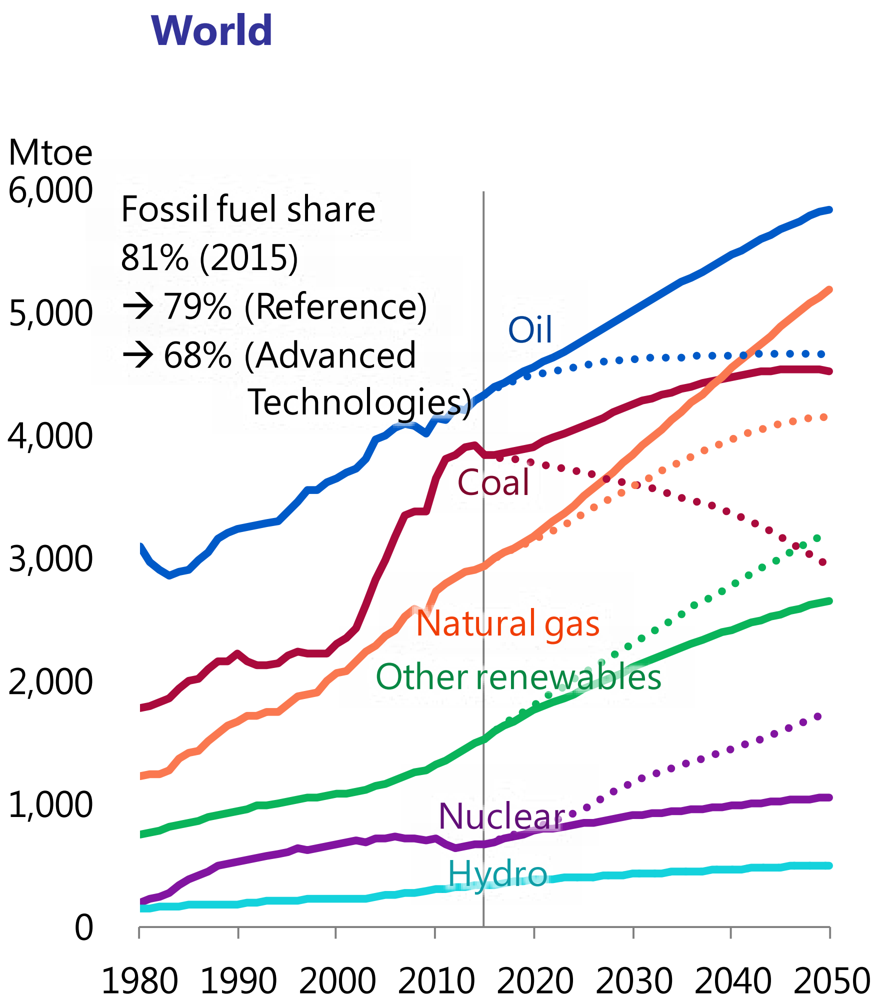
# Primary energy consumption reduction (Asia)

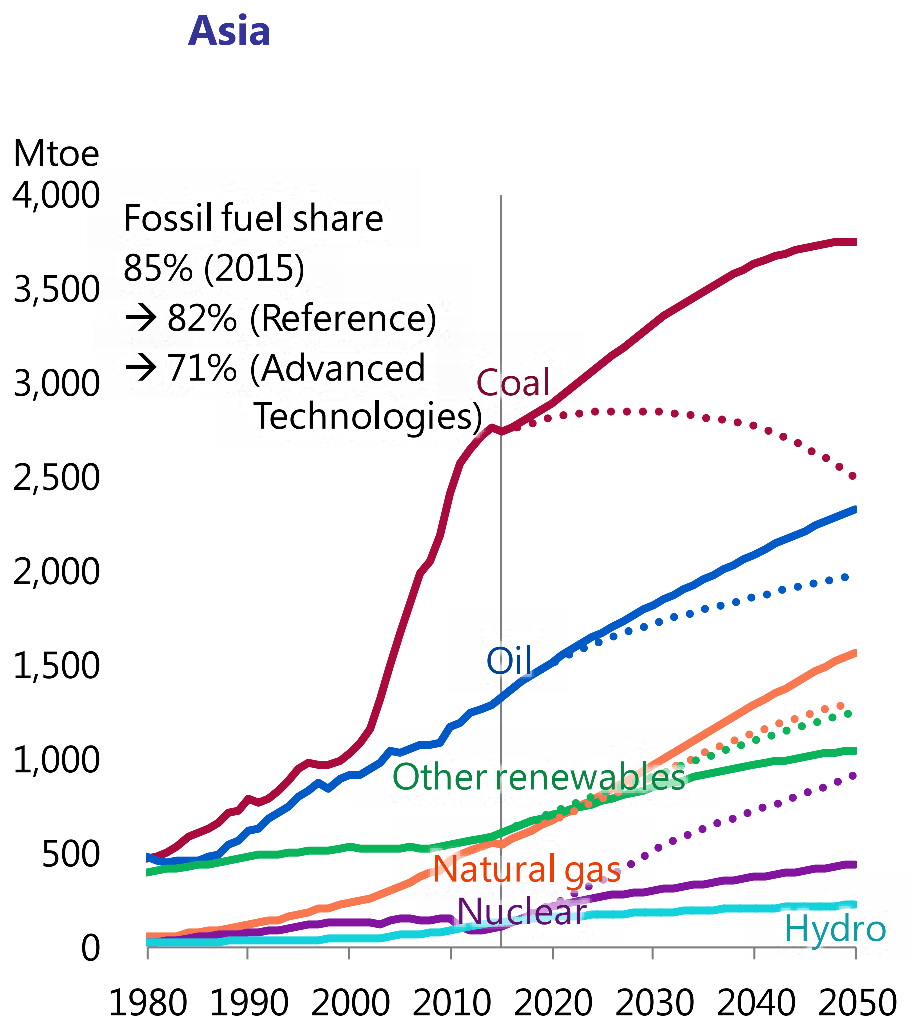
Advanced Technologies Scenario



# Primary energy consumption by source

**Reference & Advanced Technologies Scenarios**

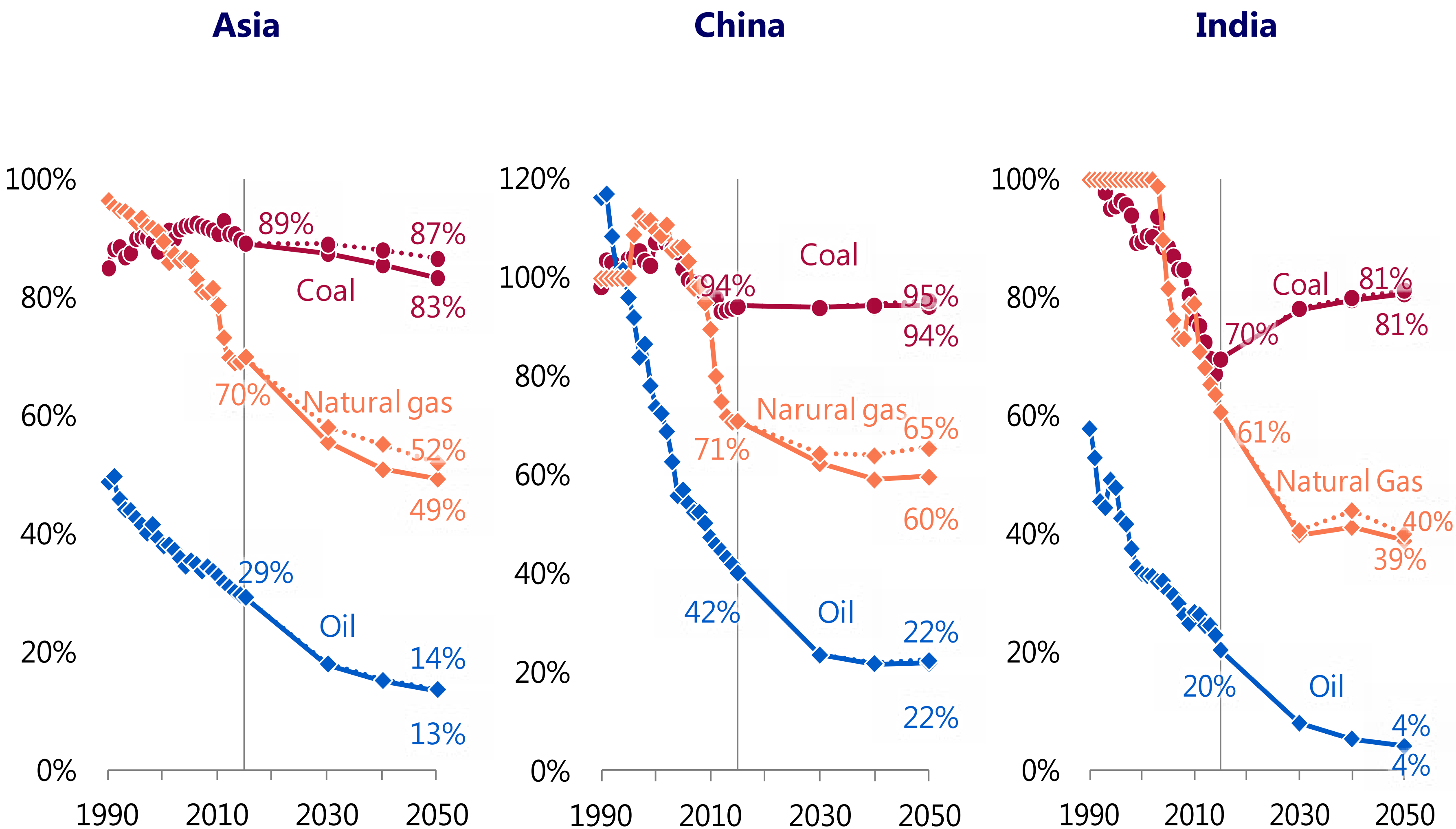



Reference Scenario (solid)
Advanced Technologies Scenario (dotted)

# Energy self-sufficiency ratio

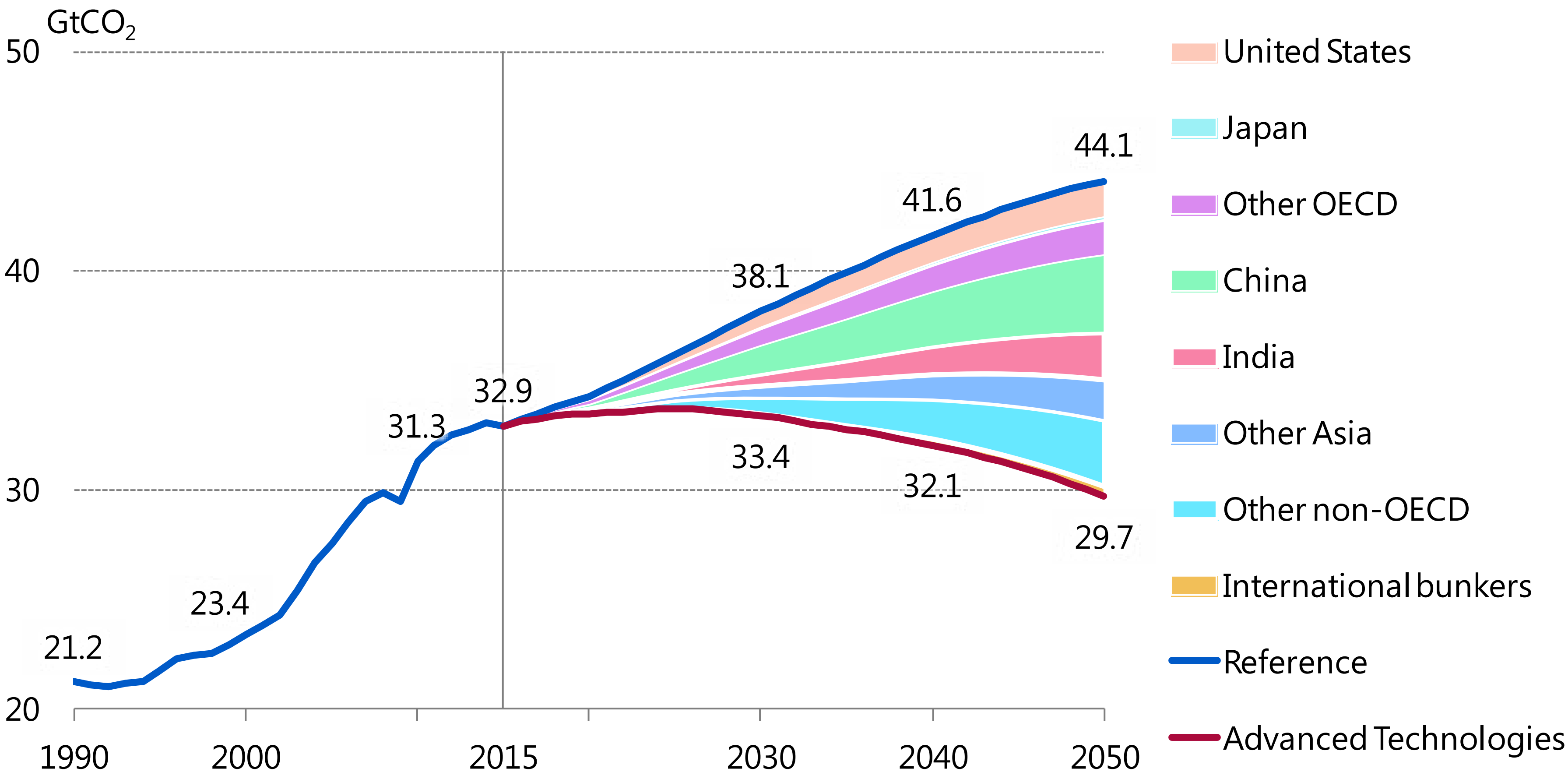
**Reference & Advanced Technologies Scenarios**




Reference Scenario (solid)
Advanced Technologies Scenario (dotted)

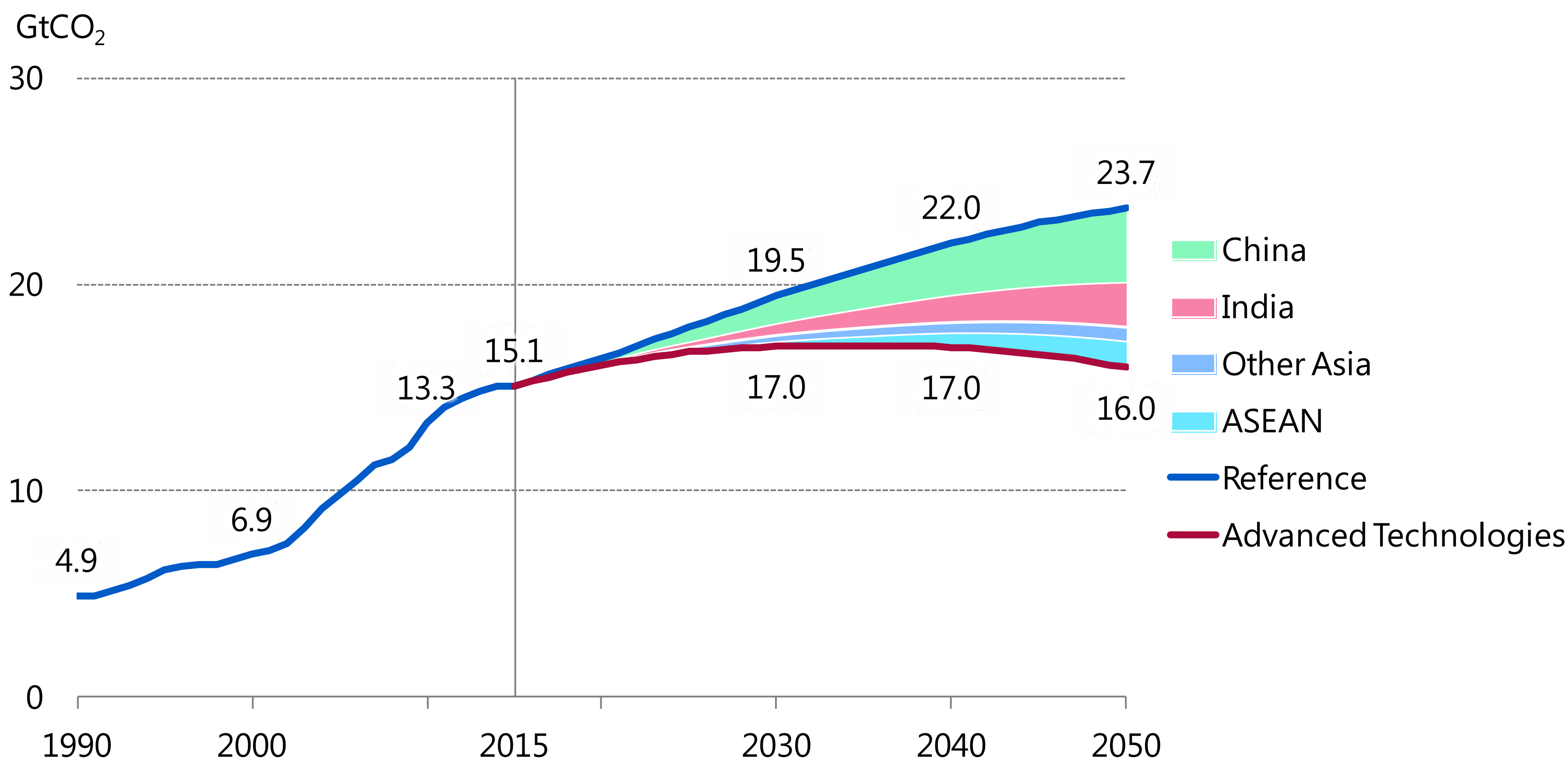
# $CO_2$ emission reduction by region

Advanced Technologies Scenario



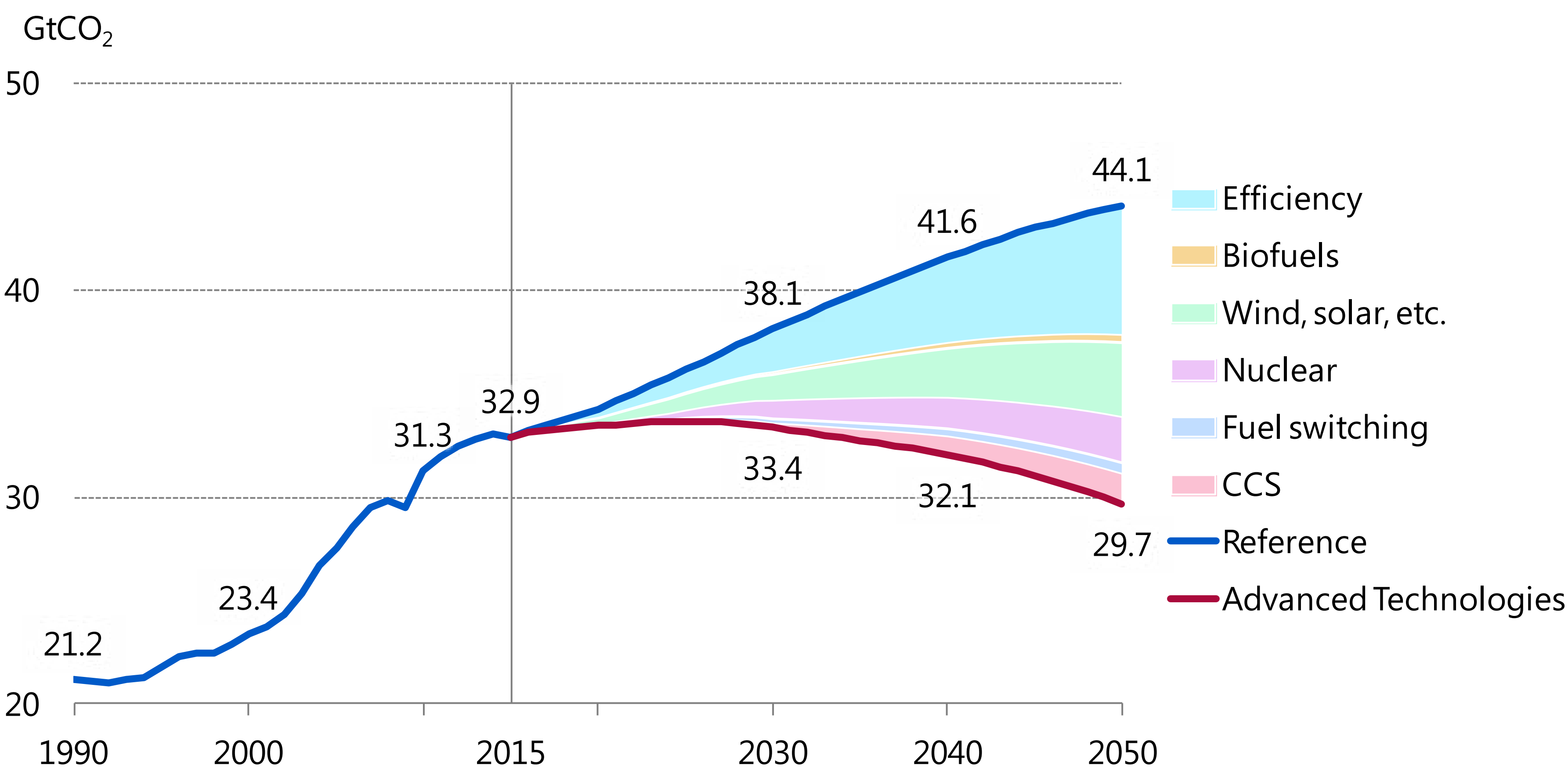
# $CO_2$ emission reduction by region (Asia)

Advanced Technologies Scenario



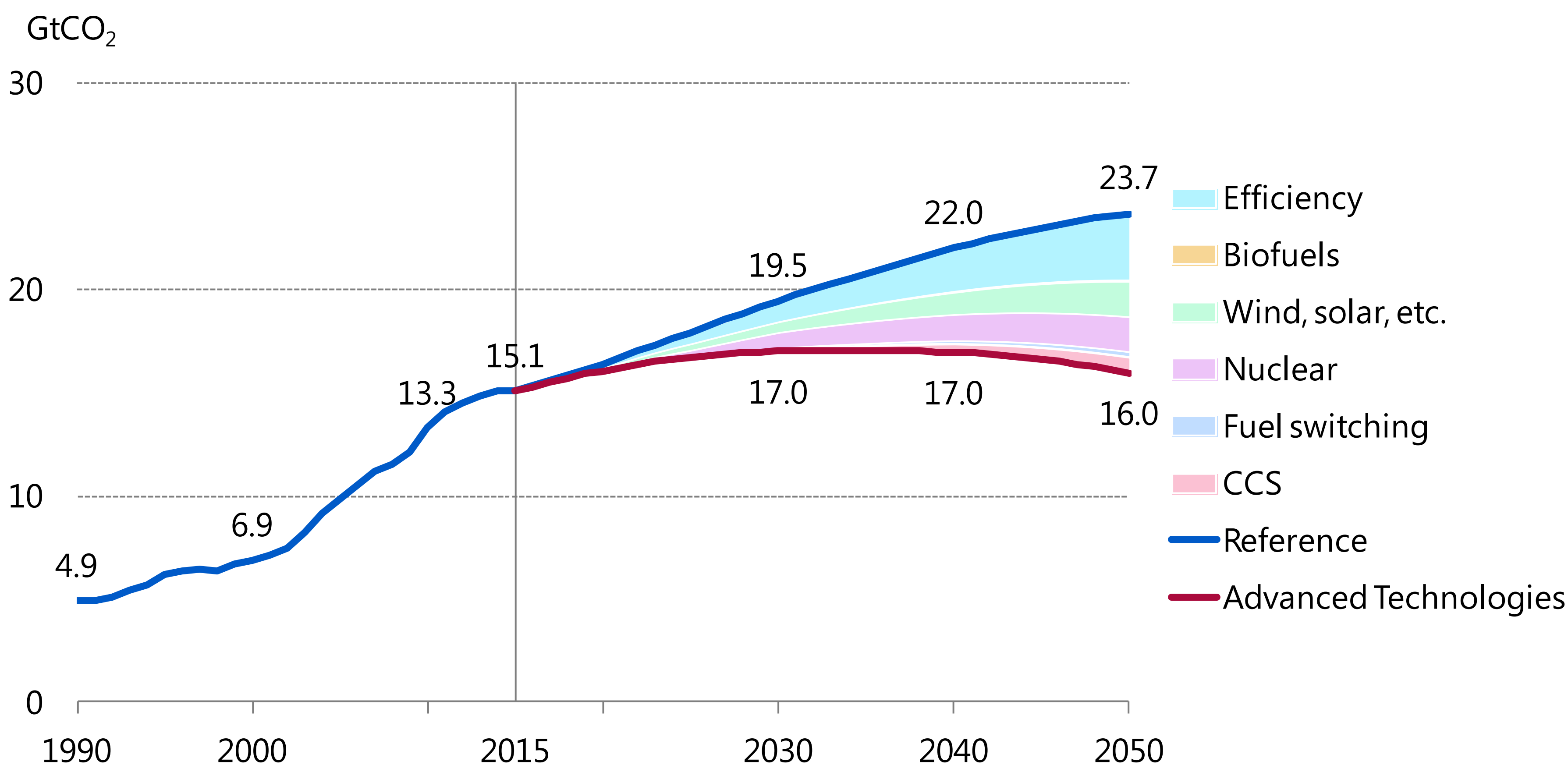
# $CO_2$ emission reduction by technology

Advanced Technologies Scenario



# $CO_2$ emission reduction by technology (Asia)

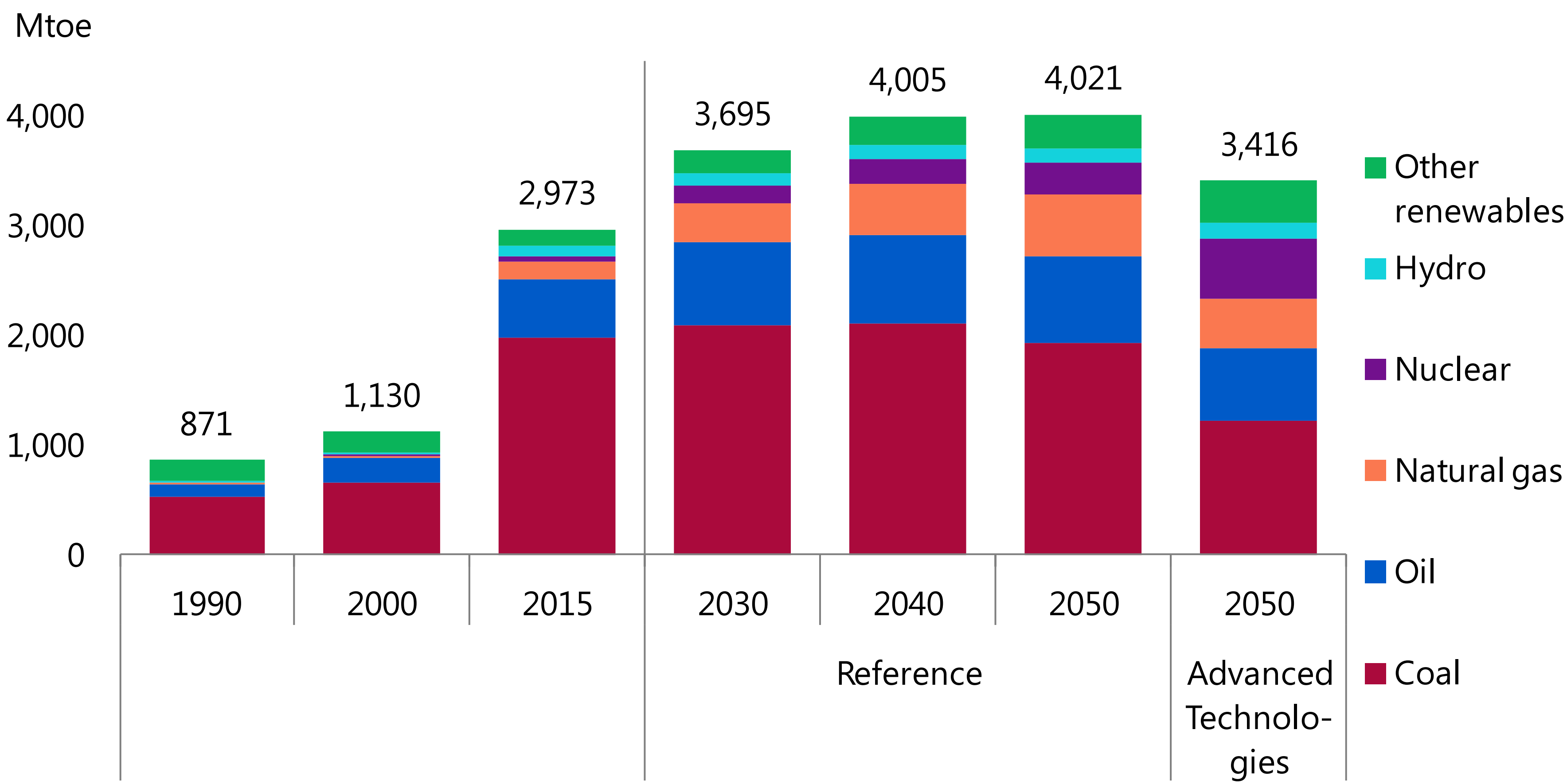
Advanced Technologies Scenario



# Energy outlook in China, India and ASEAN

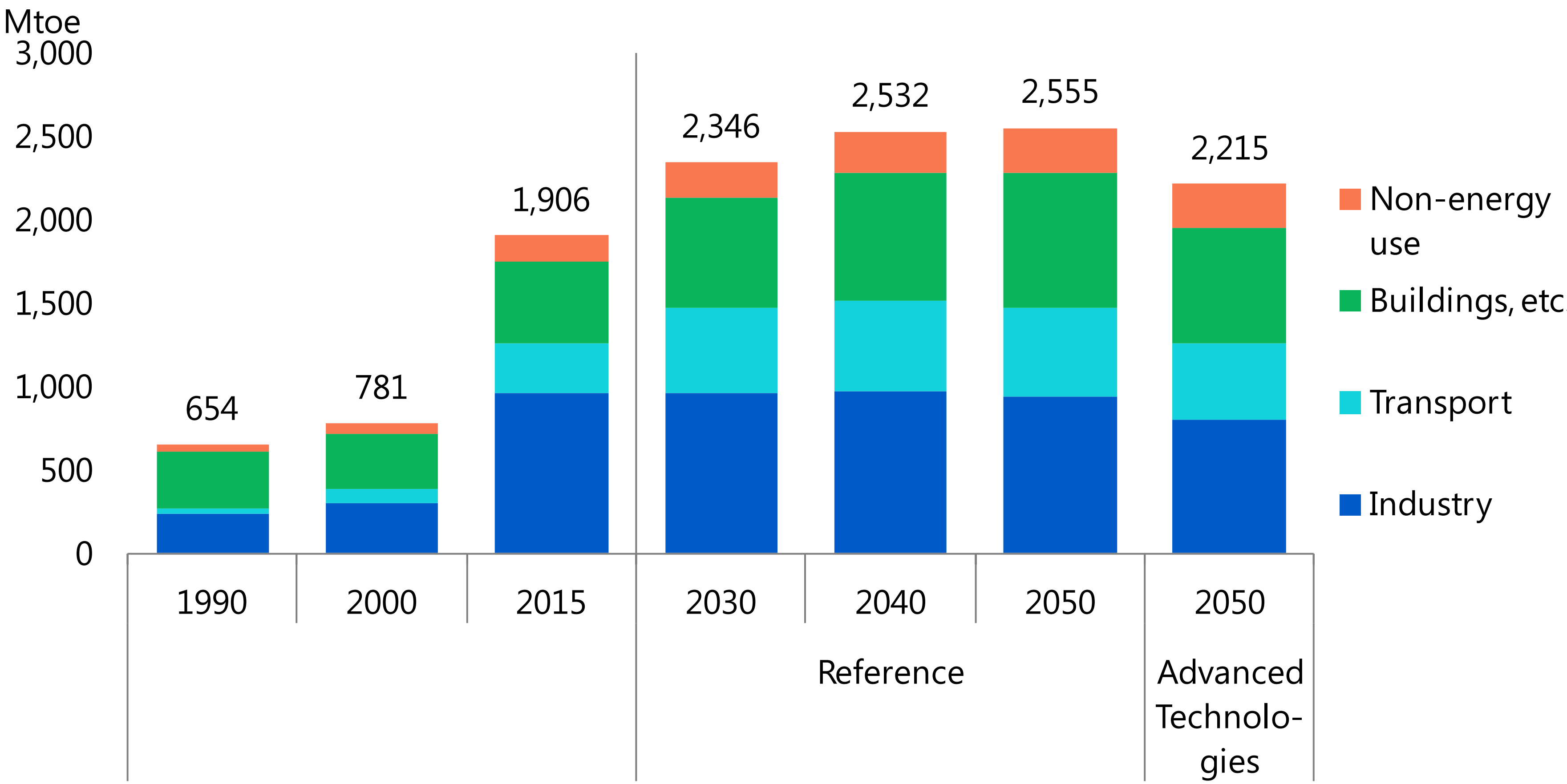
# Primary energy consumption in China

## Reference & Advanced Technologies Scenarios



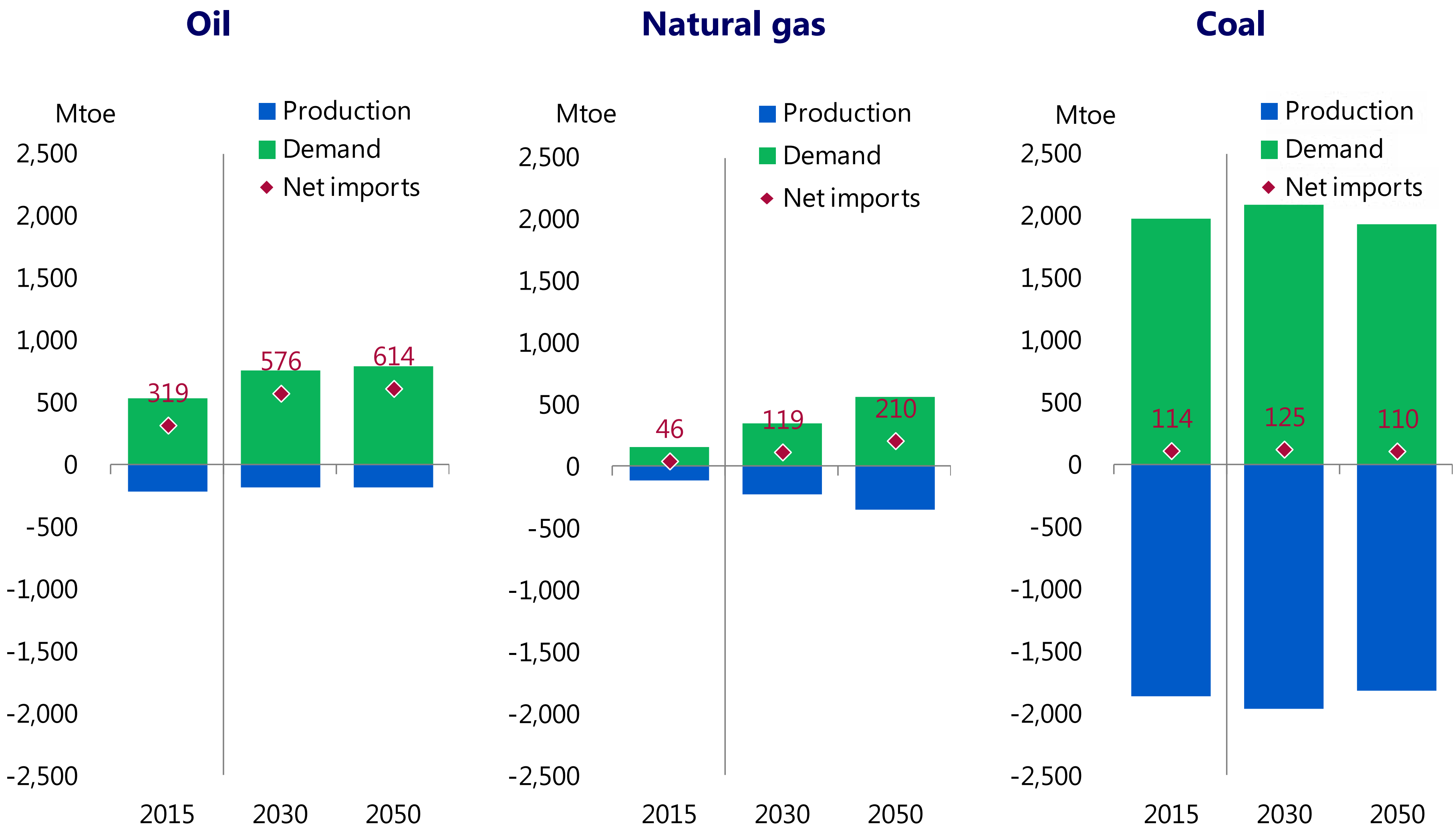
# Final energy consumption in China

Reference & Advanced Technologies Scenarios



# Fossil fuel supply/demand balances in China

Reference Scenario

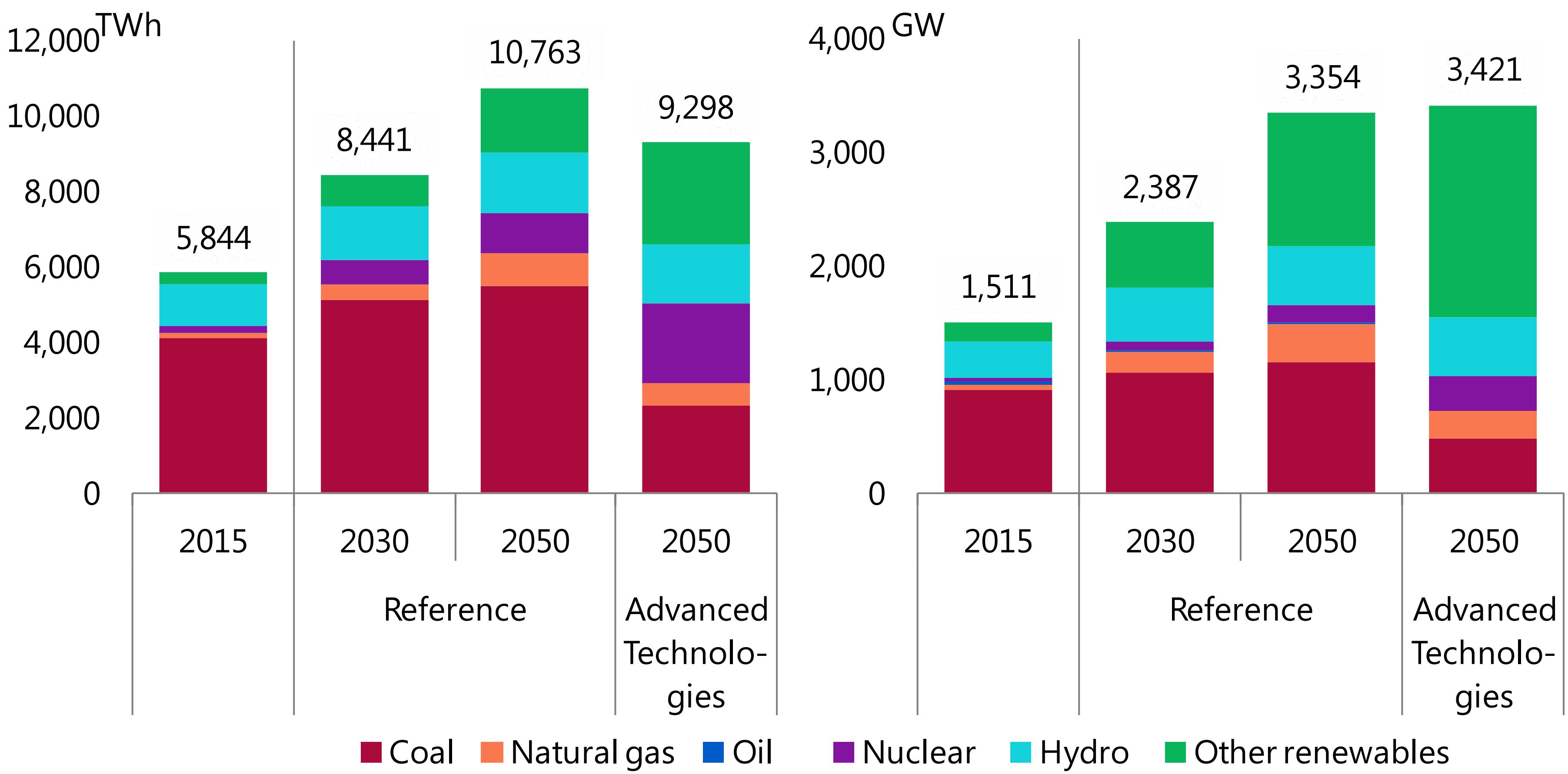


# Power generation mix in China

**Reference & Advanced Technologies Scenarios**

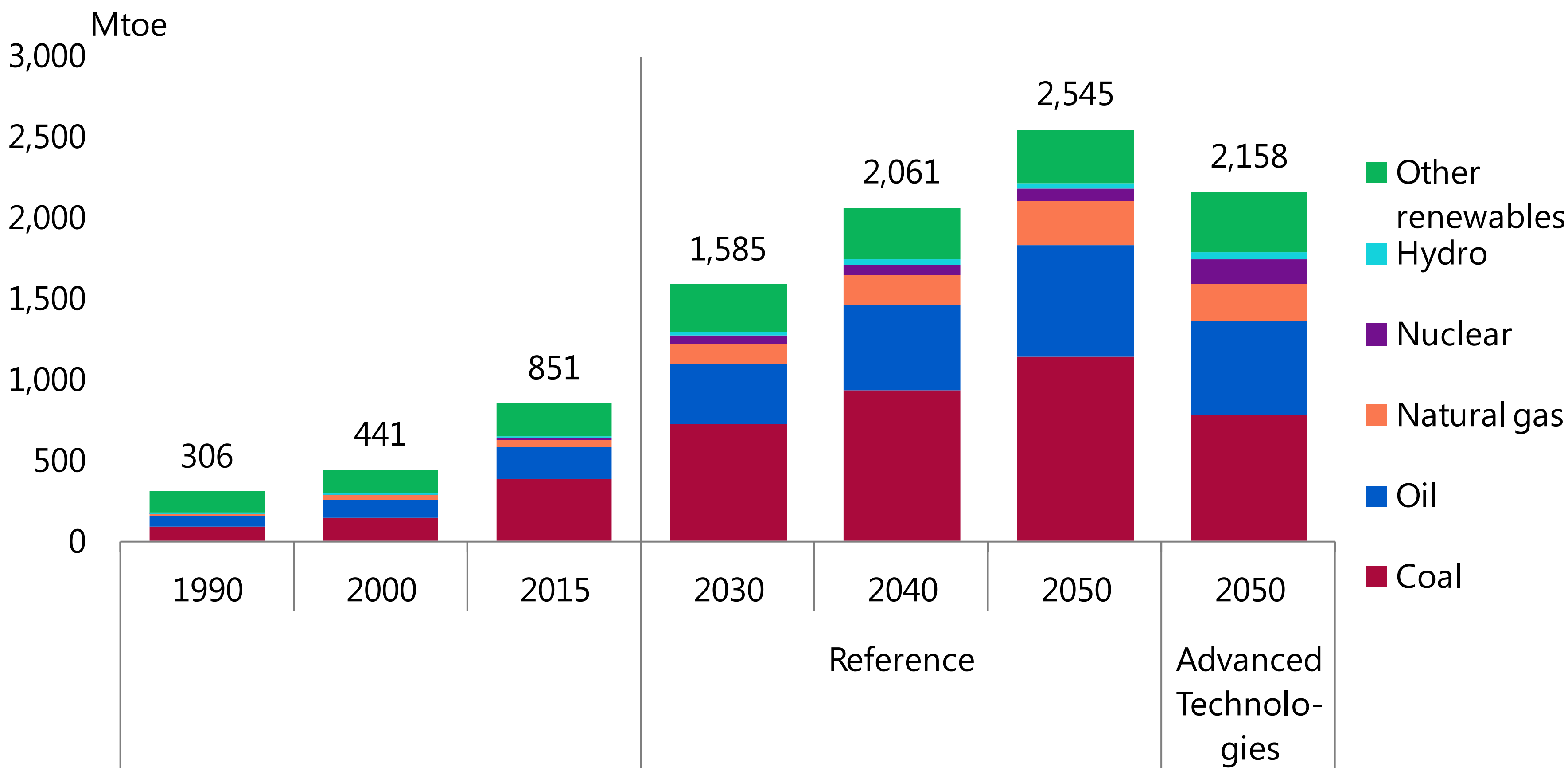
## Electricity generated

## Capacity



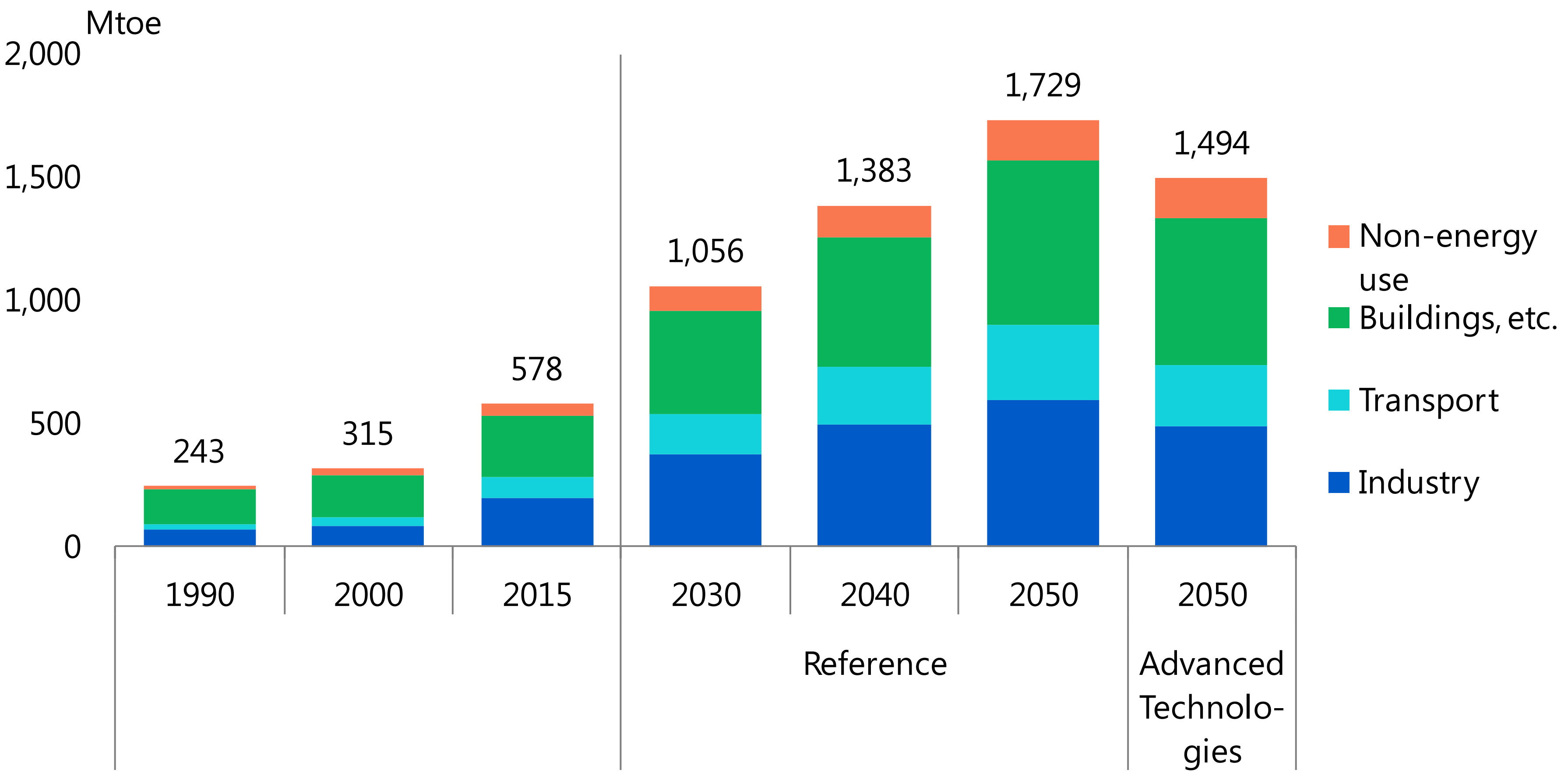
# Primary energy consumption in India

**Reference & Advanced Technologies Scenarios**



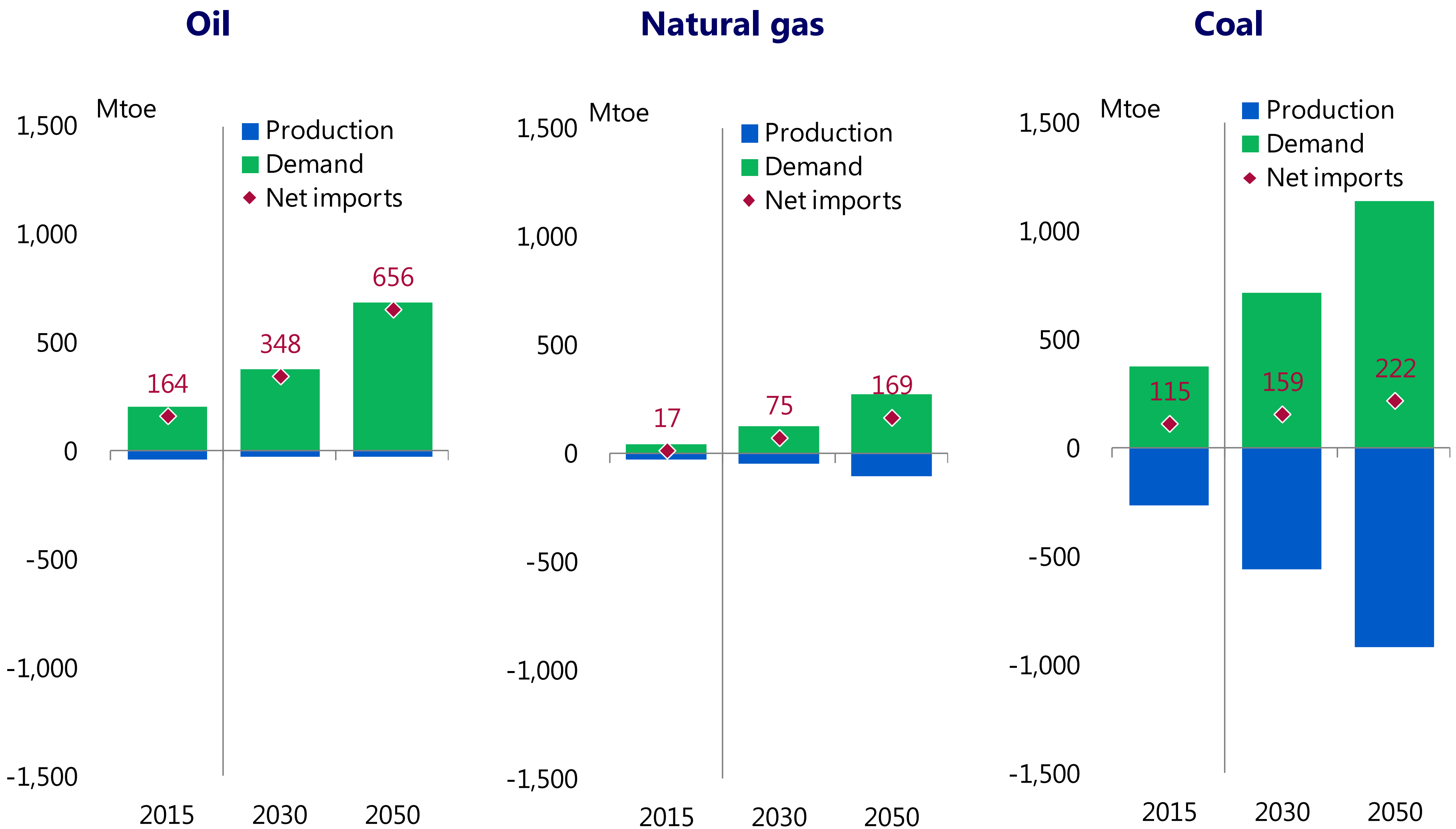
# Final energy consumption in India

Reference & Advanced Technologies Scenarios



# Fossil fuel supply/demand balances in India

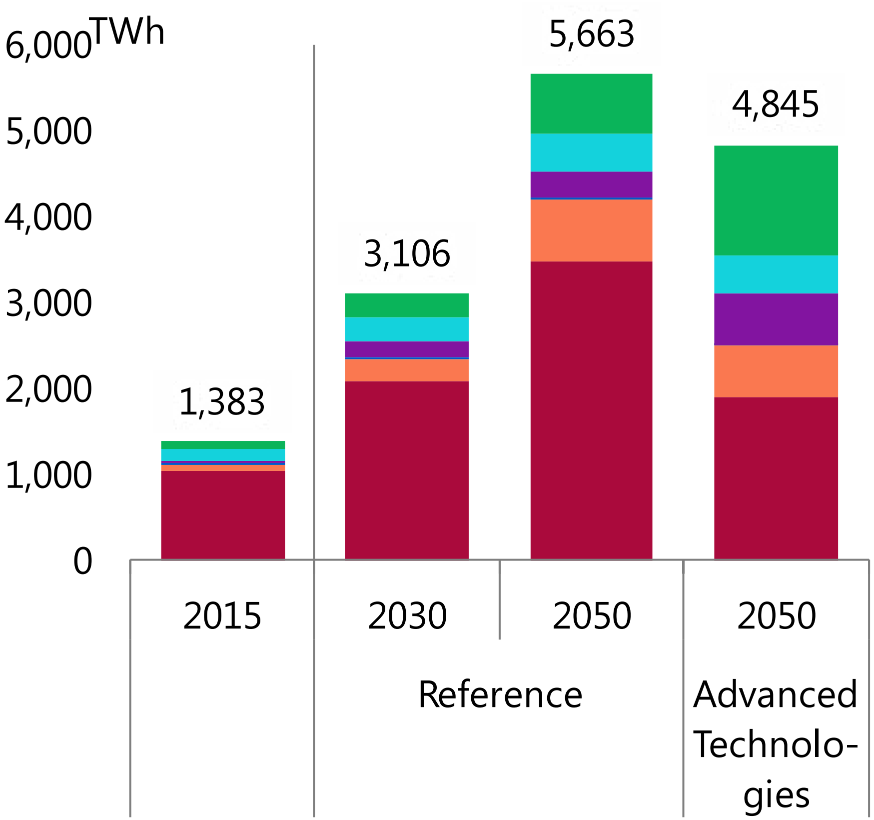
Reference Scenario



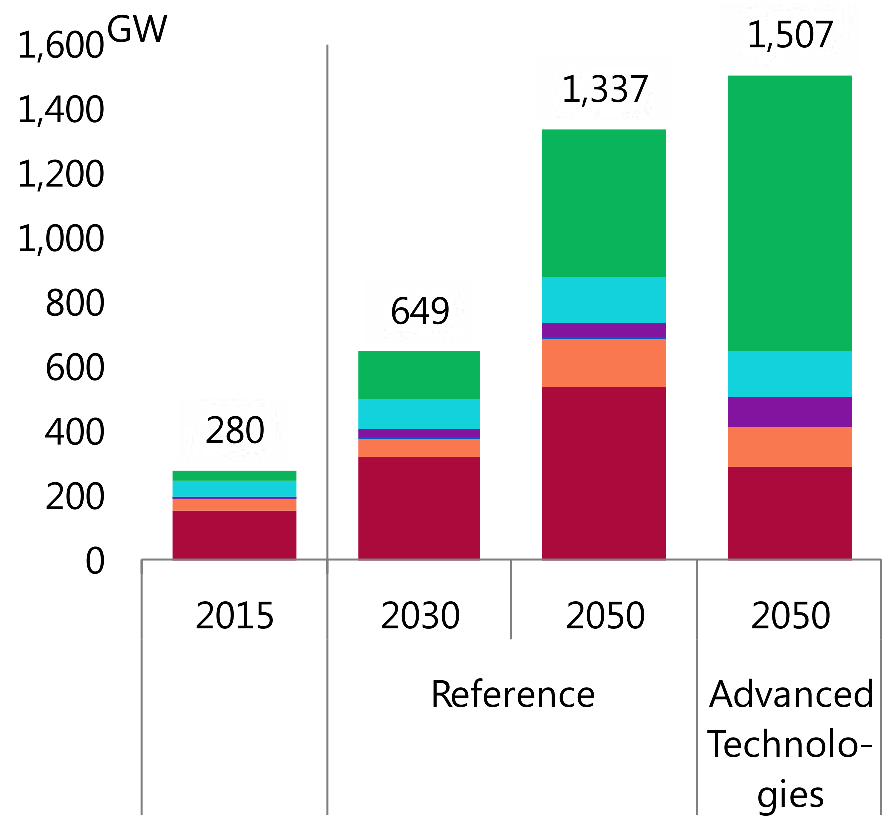
# Power generation mix in India

Reference & Advanced Technologies Scenarios

## Electricity generated



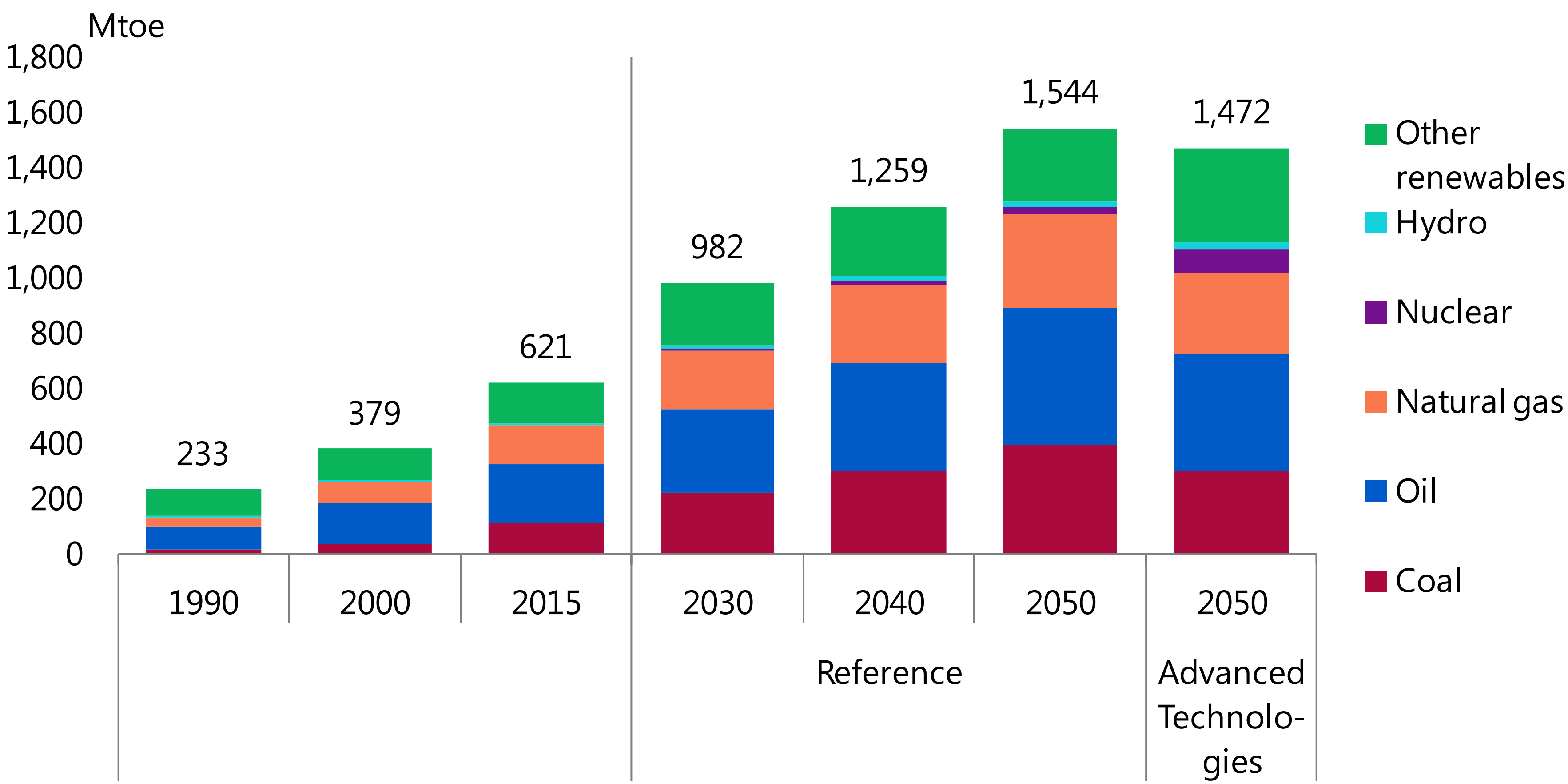

## Capacity




Coal | Natural gas | Oil | Nuclear | Hydro | Other renewables

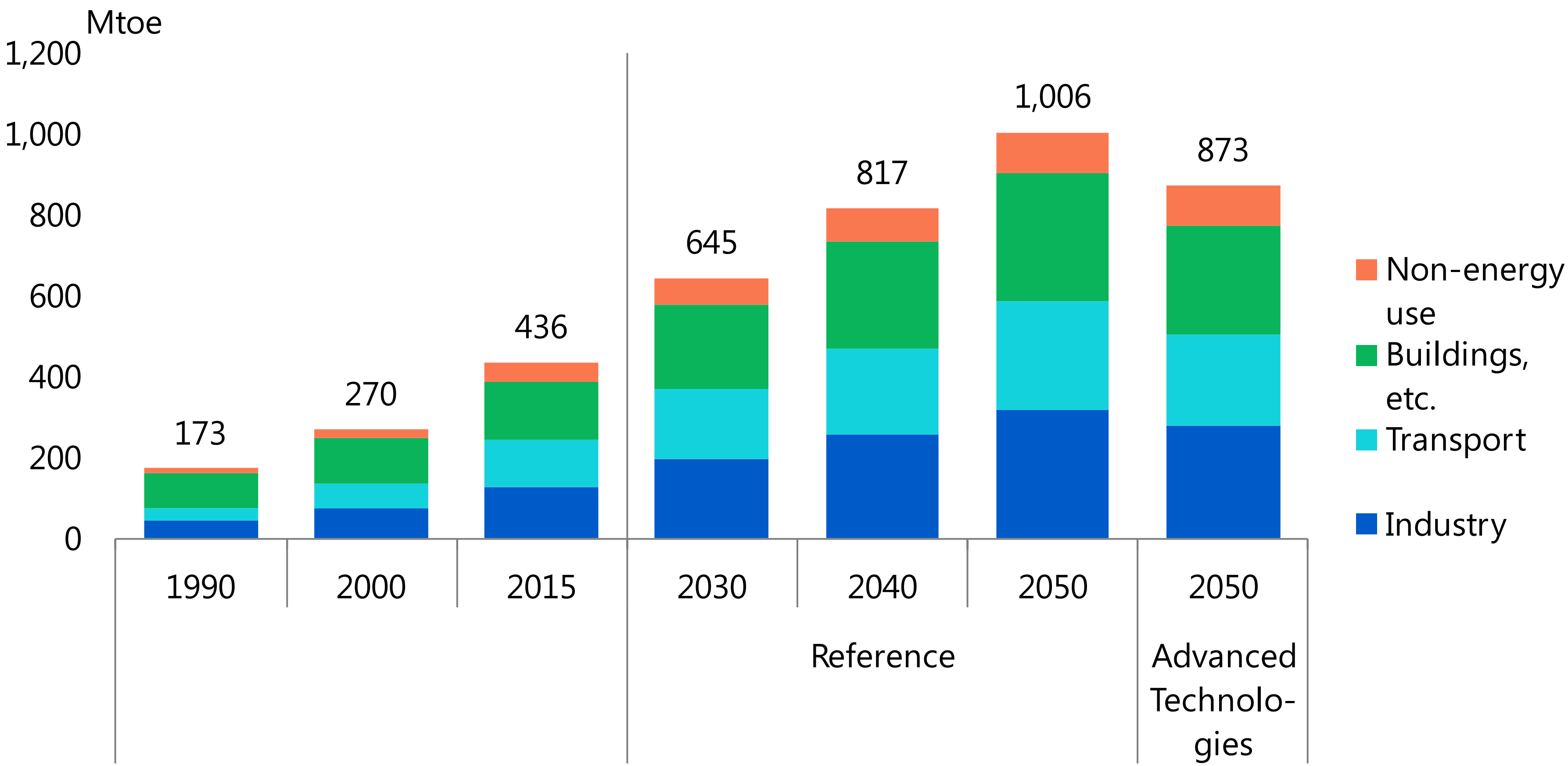
# Primary energy consumption in ASEAN

Reference & Advanced Technologies Scenarios



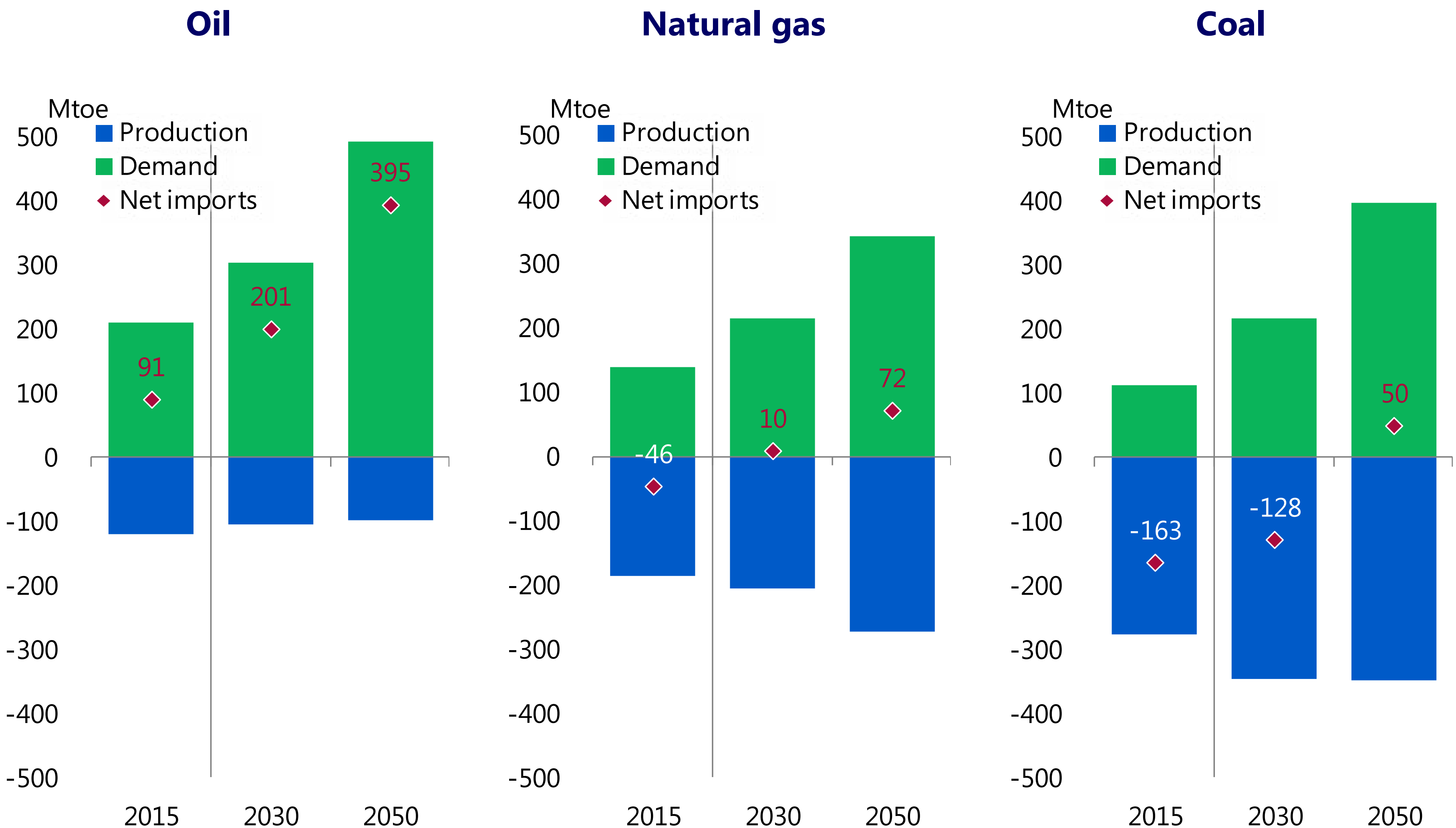
# Final energy consumption in ASEAN

Reference & Advanced Technologies Scenarios



# Fossil fuel supply/demand balances in ASEAN

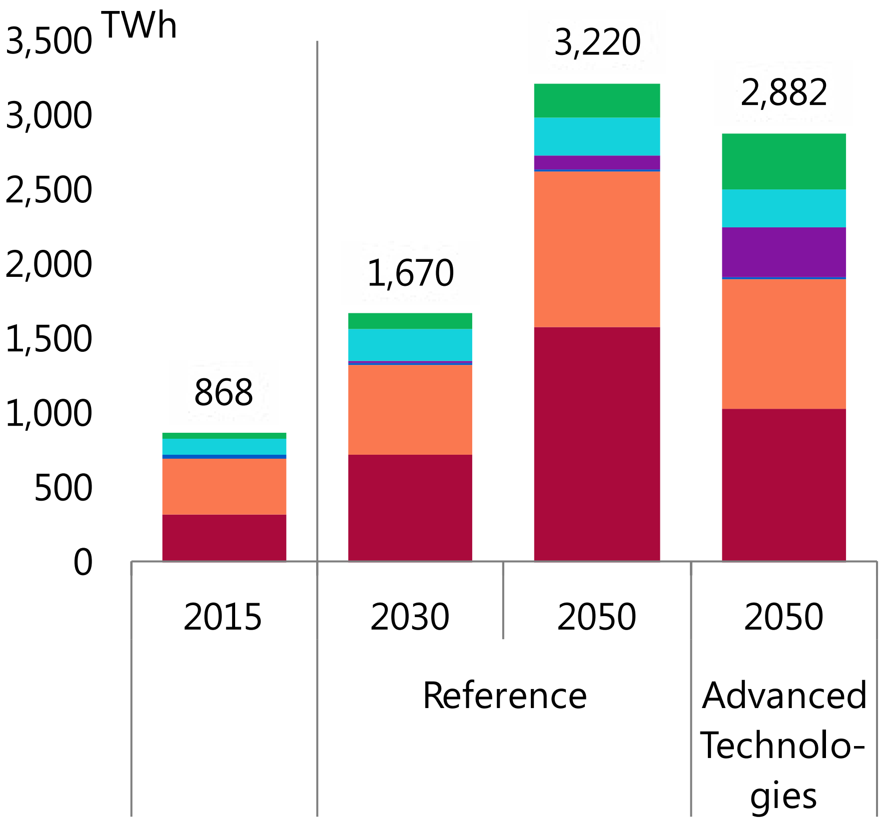
Reference Scenario



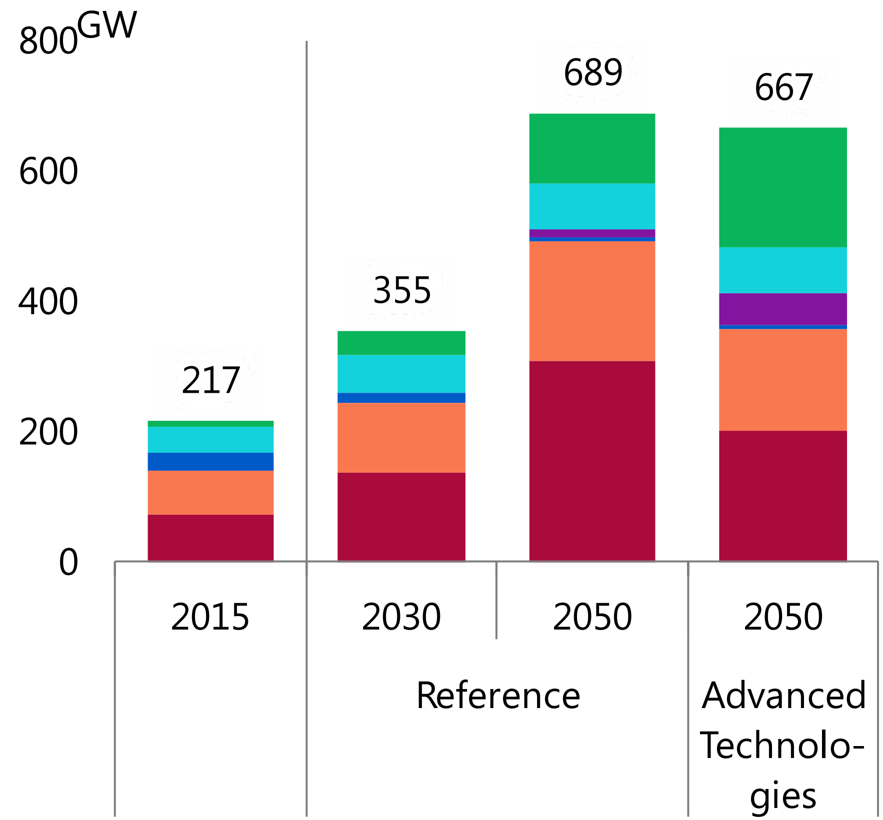
# Power generation mix in ASEAN

**Reference & Advanced Technologies Scenarios**

## Electricity generated




## Capacity




Coal Natural gas Oil Nuclear Hydro Other renewables

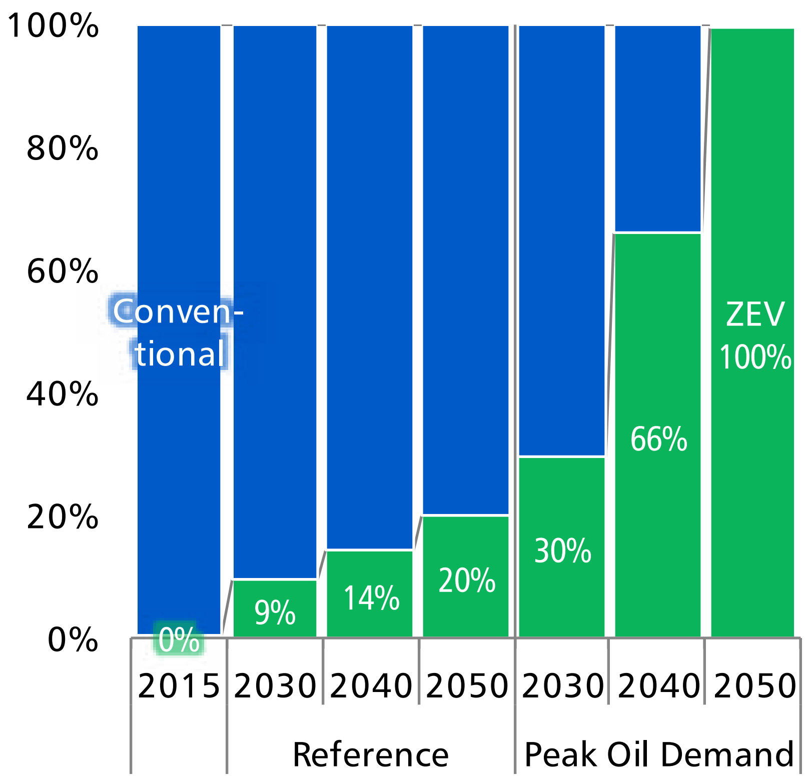
# Peak Oil Demand Case

IEEJ：October 2017 © IEEJ2017

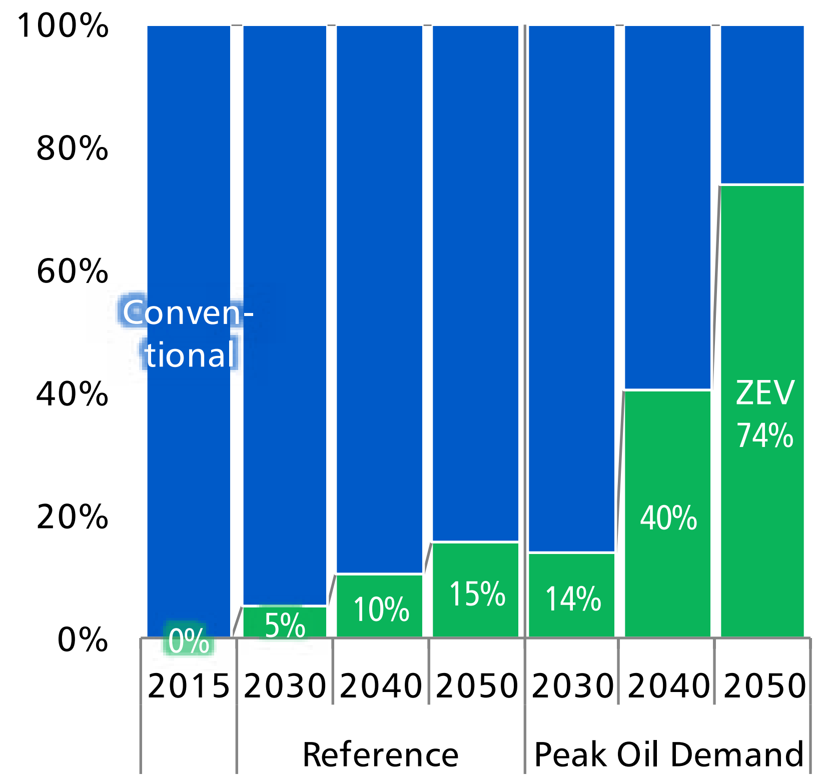
# New car sales and car ownership

Peak Oil Demand Case

## ❖ Assumption of new car sales




## ❖ Car ownership




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

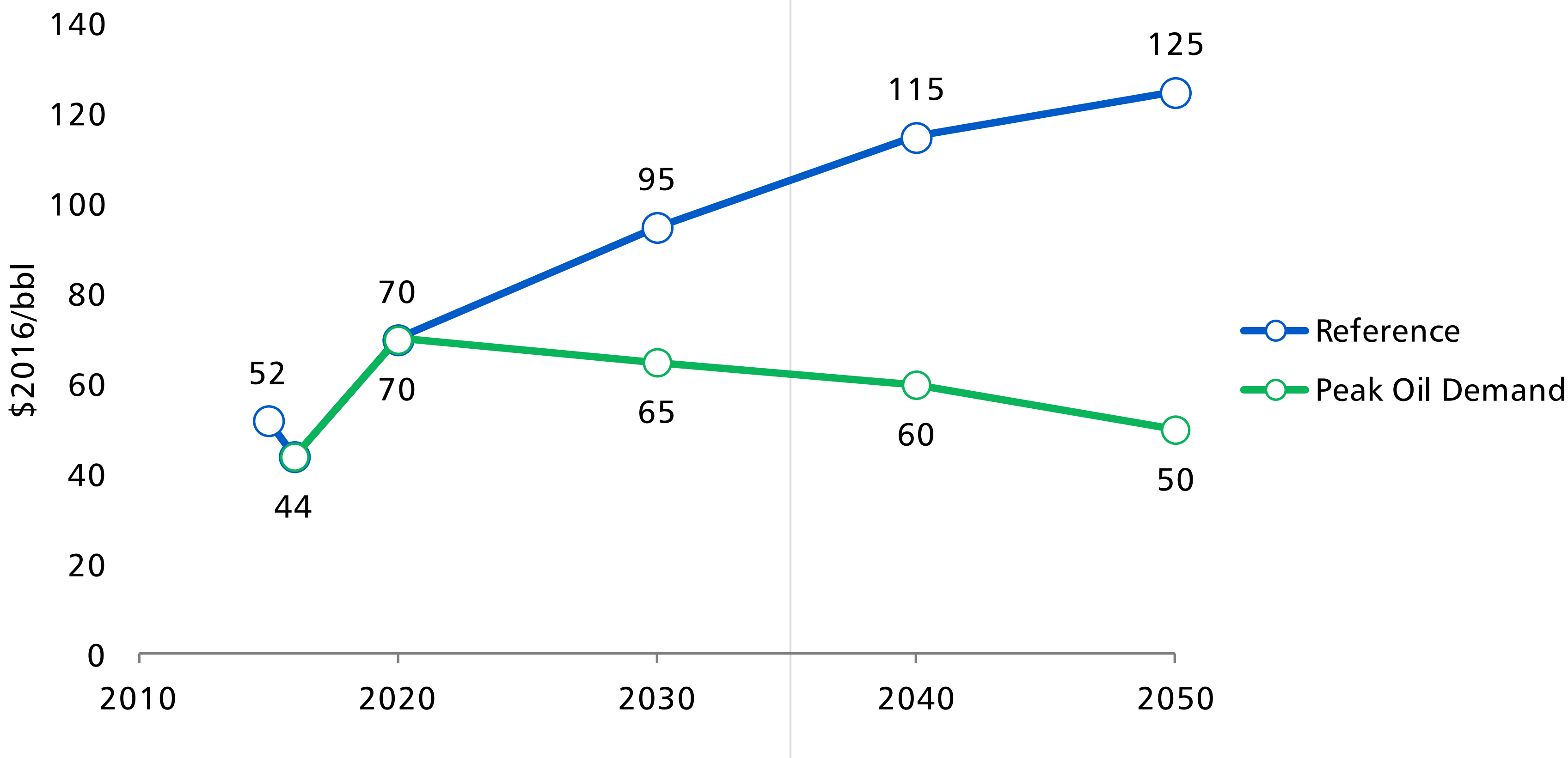
Expectation on penetration speed of ZEVs varies a lot. In the Peak Oil Demand Case, 30% and 100% of global new car (passenger and freight) sales are assumed to be ZEVs in 2030 and in 2050, respectively.

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

# Oil prices

Peak Oil Demand Case

## ❖ Assumption of real crude oil prices



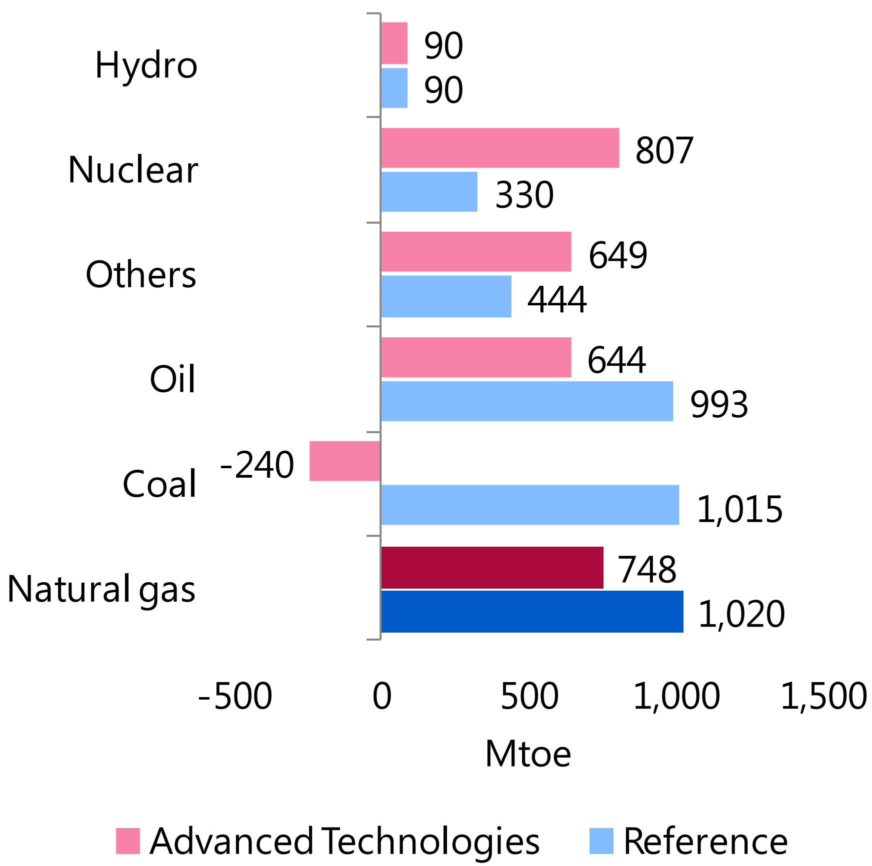

Assuming that the supply and demand relaxation will result in a decline in international oil prices.
In the Peak Oil Demand Case, the prices begin to decline after the 2020s and fall to $50/bbl in 2050.

# Utilisation of natural gas in Asia

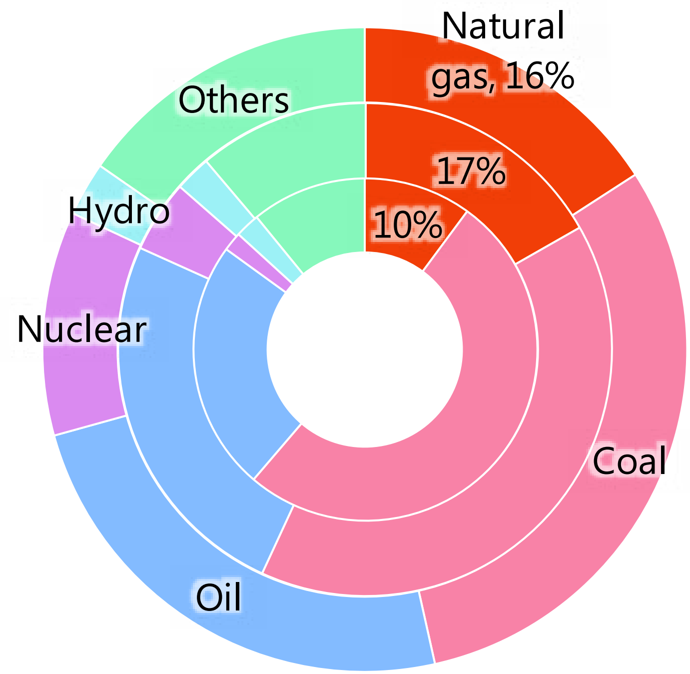
# Golden age of natural gas coming to Asia

**Reference & Advanced Technologies Scenarios**

## Changes (2015-2050)




## Shares (2050)




Inside: 2015
Middle: Reference, 2050
Outside: Advanced Technologies, 2050

While natural gas demand grows at a slow pace currently, it grows at the fastest pace among primary energy sources in long term.

In the Advanced Technologies Scenario, the increases are the largest among fossil fuels and the share increases by 6%p from 2015.

# To ensure golden age of natural gas coming to Asia

IEE JAPAN

In order to ensure increase of natural gas usage, policy implementation by each government and public entity in the following area are important.

## ● Improving flexibility in LNG market

Demand in new LNG importing countries in Asia has high uncertainty, thus more flexible supply system is required.

Survey on LNG Trades published by Japan Fair Trade Commission in June 2017 point out that providing destination clauses under a fixed-term FOB contract is likely to be in violation of the Antimonopoly Act. Not only new contracts or timing of renewal contracts but also existing contracts are required to be reviewed for destination restrictions. If Fair Trade Commission in other Asian countries have the same announcement, lifting destination restrictions

## ●Developing and implementing natural gas usage policies (energy mix)

The advantage (clean, geographical dispersal, and ease of usage) of natural gas has is scarcely reflected to the price and political support is required.

To reduce uncertainties of new investment of infrastructure as much as possible, political commitment by the government is required and implementing energy mix target is recommended.

## ●Supporting finance

While natural gas supply requires large investments, private finance cannot afford the investment amount. Public support is essential.

Financial support from each government, the Export Credit Agencies which have the companies in the country which are interested in infrastructure building and multilateral development bank such as the World Bank and the Asian Development Bank in financial arrangements are important.

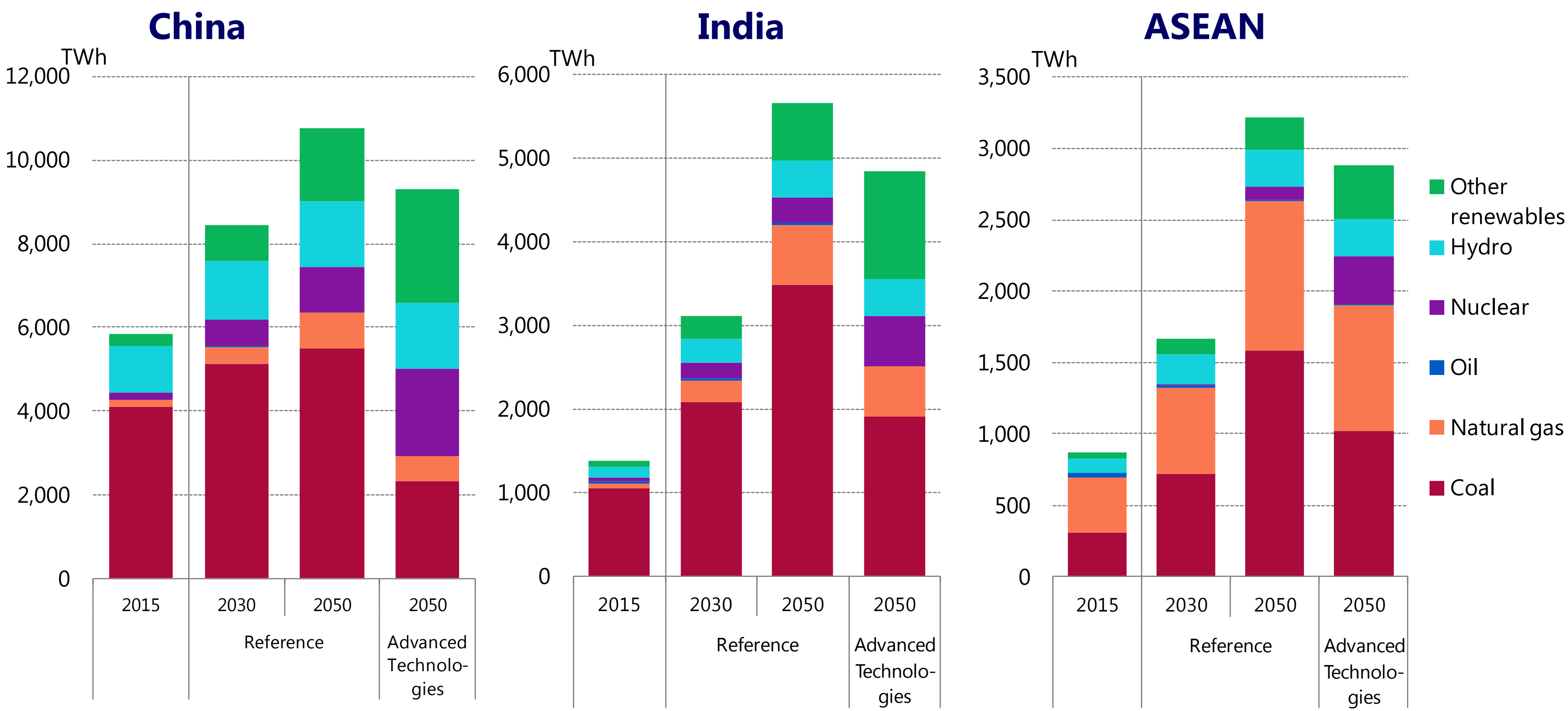
## ●Human capacity building

The shortfall in human resources for rapid development of natural gas and LNG demand in both of the governments and industries is likely to hinder swift decision-making.

LNG requires more expertise for deal, security, and environment more than other energy. If the countries which have been consuming LNG such as Japan play an active role, it would help increases the LNG usage in Asia significantly.

# Role of coal and its efficient use

# Share of coal in power generation



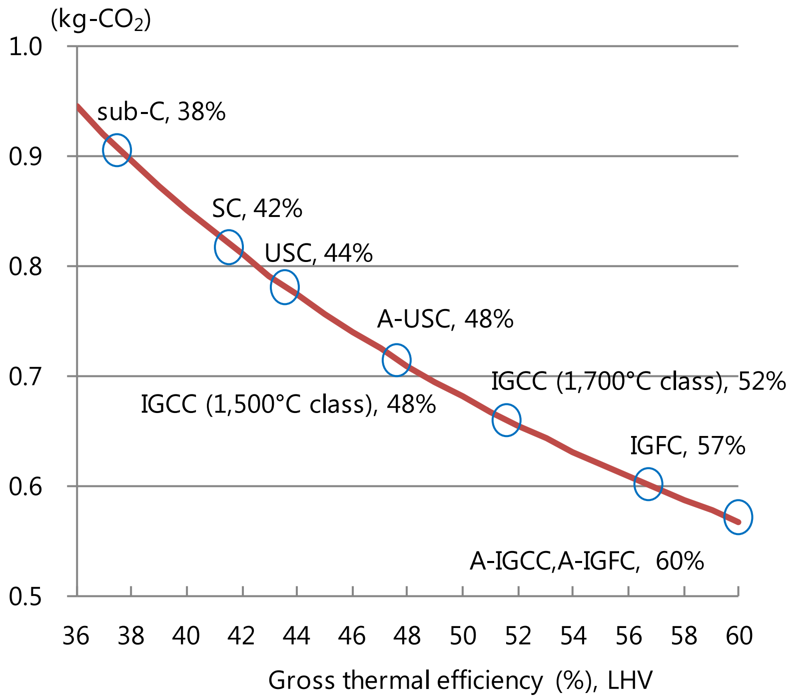

In the Reference Scenario, most of the increase of coal-fired power generation occurs in Asia, especially in India and ASEAN.

In the Advanced Technologies Scenario, electricity generated from coal declines significantly even in Asia, due to the lower electricity demand with the further progress of energy conservation, and the shift from coal to other sources in power generation.

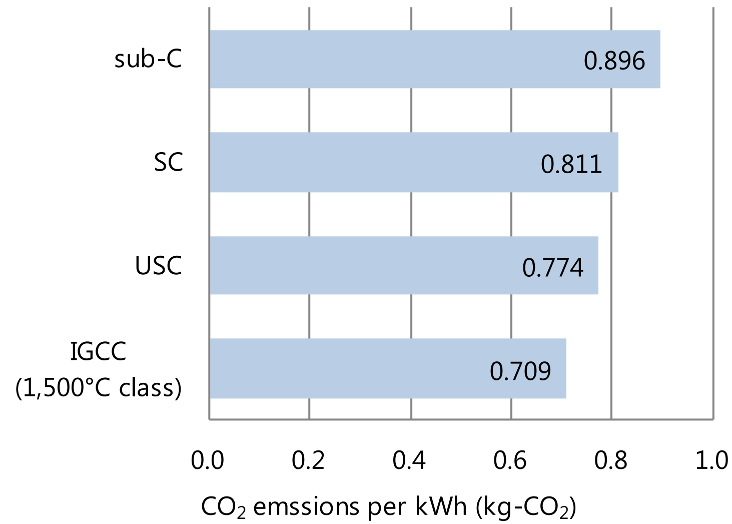
However, in India, Indonesia and other ASEAN countries with abundant coal resources, the construction of coal-fired power plants continues from the viewpoint of energy security and economic efficiency.

# High efficiency coal-fired power plant and $CO_2$ emissions

## Thermal efficiency and $CO_2$ emissions per kWh




## $CO_2$ emissions per kWh by plant




## Cost of coal-fired power plant

| | sub-C | SC | USC | IGCC |
|---|---|---|---|---|
| Plant cost ($/kW) | 1,422 | 1,689 | 1,867 | 2,144 |

Source: estimated from IEA, "World Energy Outlook 2016"

With the improvement of the thermal efficiency, $CO_2$ emissions per kWh in SC, USC and IGCC are respectively 90%, 86%, 79% of that in sub-c coal fired plants. On the other hand, their plant costs are more expensive, about 1.2, 1.3, 1.5 times of that of sub-c plant.

Though high thermal efficiency do reduce fuel costs, financial support remains necessary for the introduction of high-efficiency power plants. To ensure future commercialisation and wide utilisation of IGCC, cost reductions are required.