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ECONOMIC BENEFITS FROM AN INTRODUCTION OF CLEAN COAL TECHNOLOGIES IN EAST ASIA

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OUTLINE OF PRESENTATION

I. RISING COAL DEMAND IN EAS REGION

II. CLEAN COAL TECHNOLOGIES

III. ECONOMIC ASSESSMENT OF CTT

IV. ECONOMIC, SOCIAL & ENVIRONMENTAL BENEFITS

V. CONCLUSIONS & IMPLICATIONS

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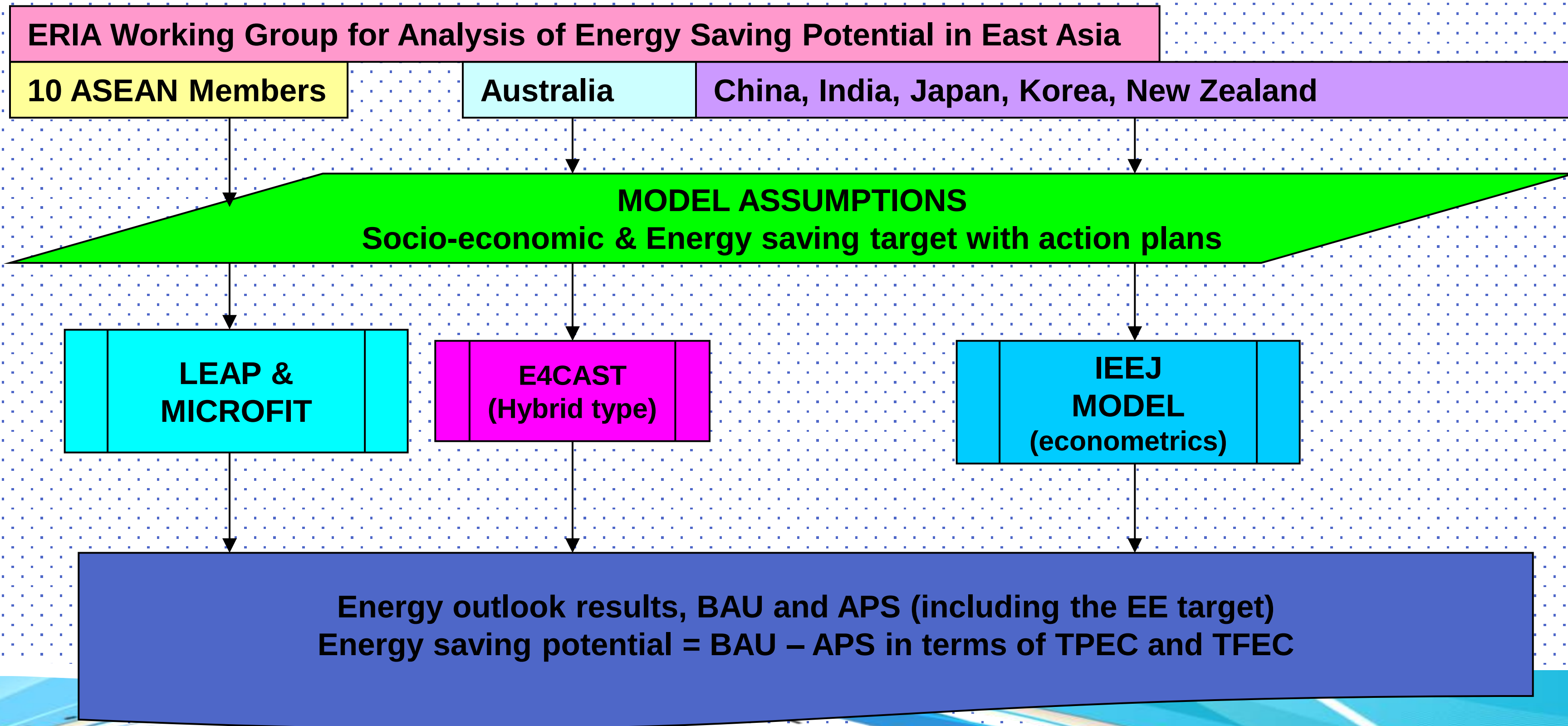
I. COAL DEMAND IN EAS REGION

Source: ERIA Energy Outlook

Research Framework in 2014



Macro Assumptions

Economic Growth

4.0 % P.A. from 2012 to 2035

Population Growth

0.6 % P.A. from 2011 to 2035

3.40 billion persons in 2012 to increase to 3.91 billion in 2035

GDP per capita

4,120 US$/person (constant 2005 price and US$) in 2012 increases to 8,800 US$/person in 2035

Crude Oil Price (nominal price)

Increase to about 200 US$/bbl in 2035 due to tight balance between demand and supply

Car Ownership

0.09 vehicles/person in 2012, increases to 0.18 vehicles/person using vehicle data of 14 countries

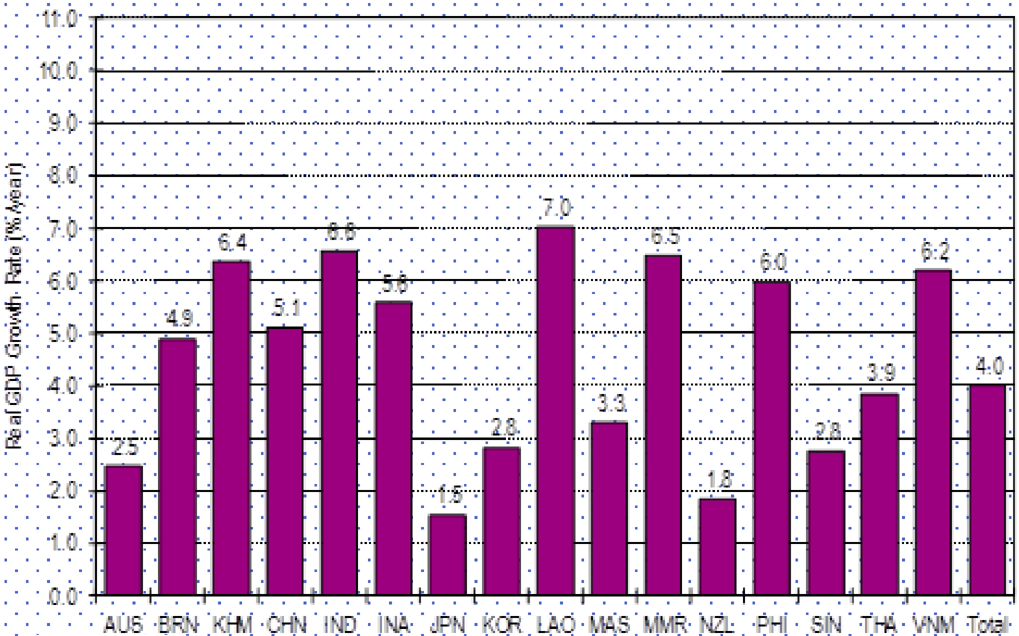
Source: ERIA ESP WG Report 2015

Macro Assumptions

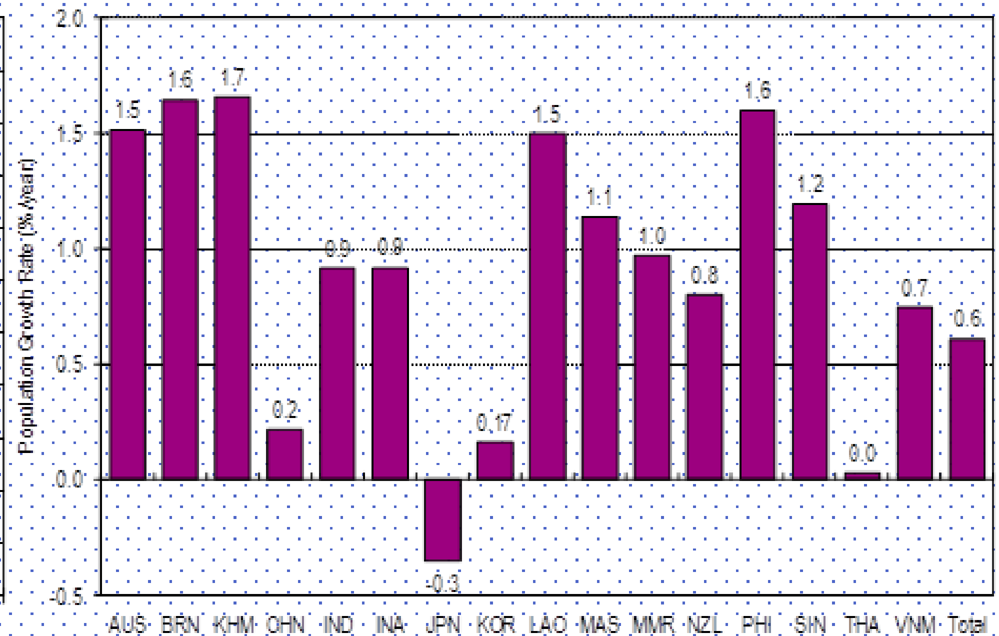
New GDP growth assumption reflect the current government estimated GDP growth.

For example, Thailand average GDP growth rate has been used at 3.9 % to be consistent with the NEW PDP 2015

GDP Growth Rate by Country



Population Growth Rate by Country



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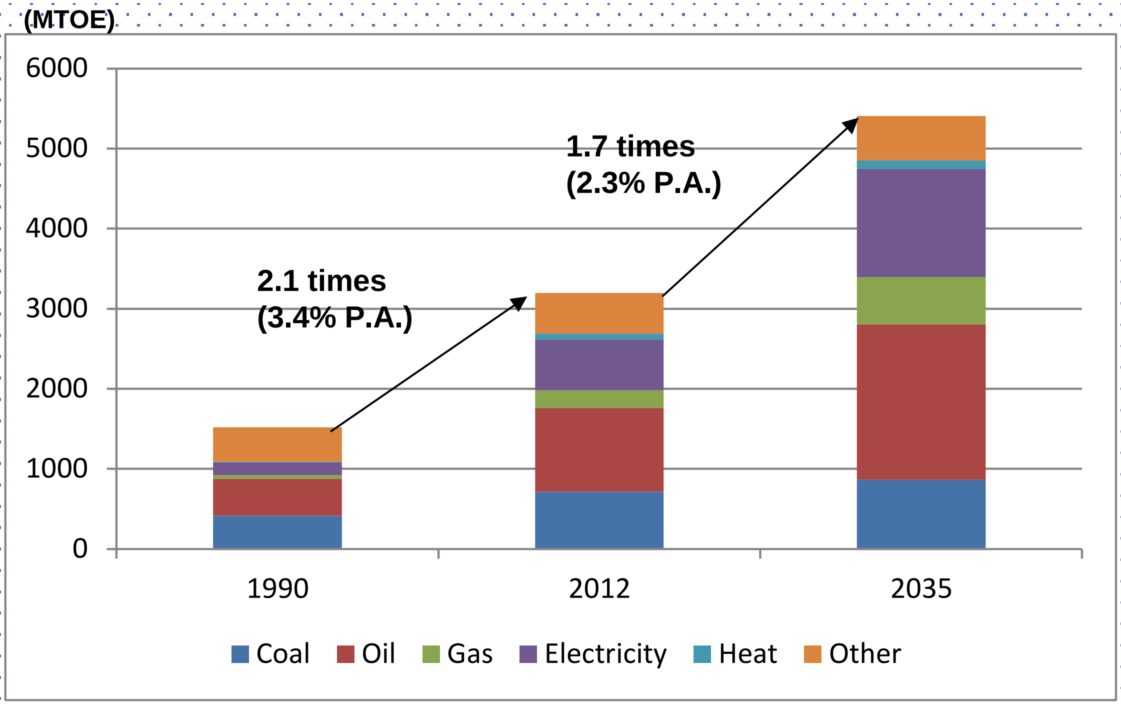
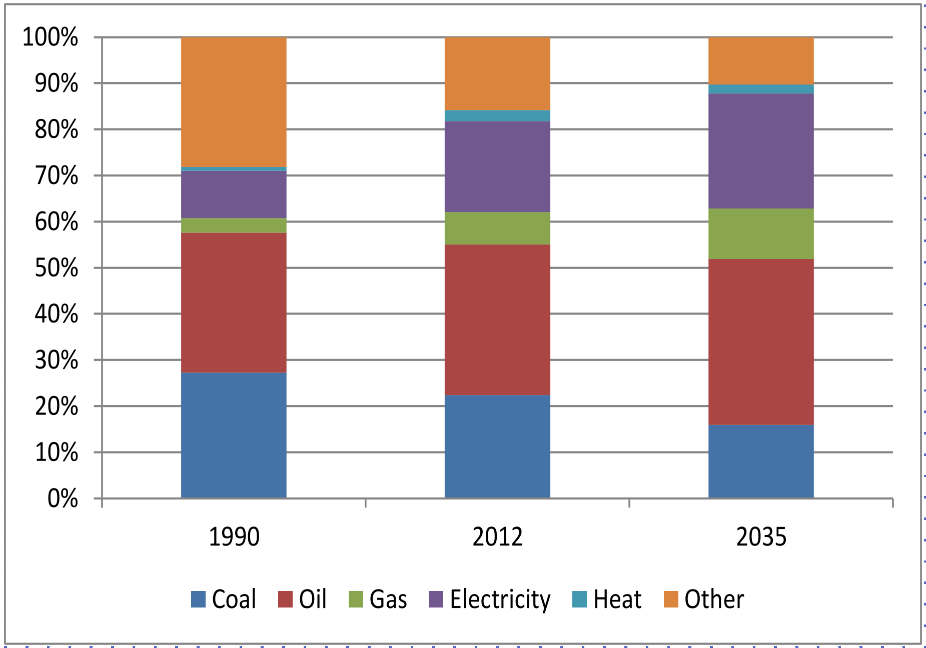
Source: ERIA ESP WG Report 2015

Energy Outlook Result (BAU)

Final Energy Consumption



Share by Energy in FEC



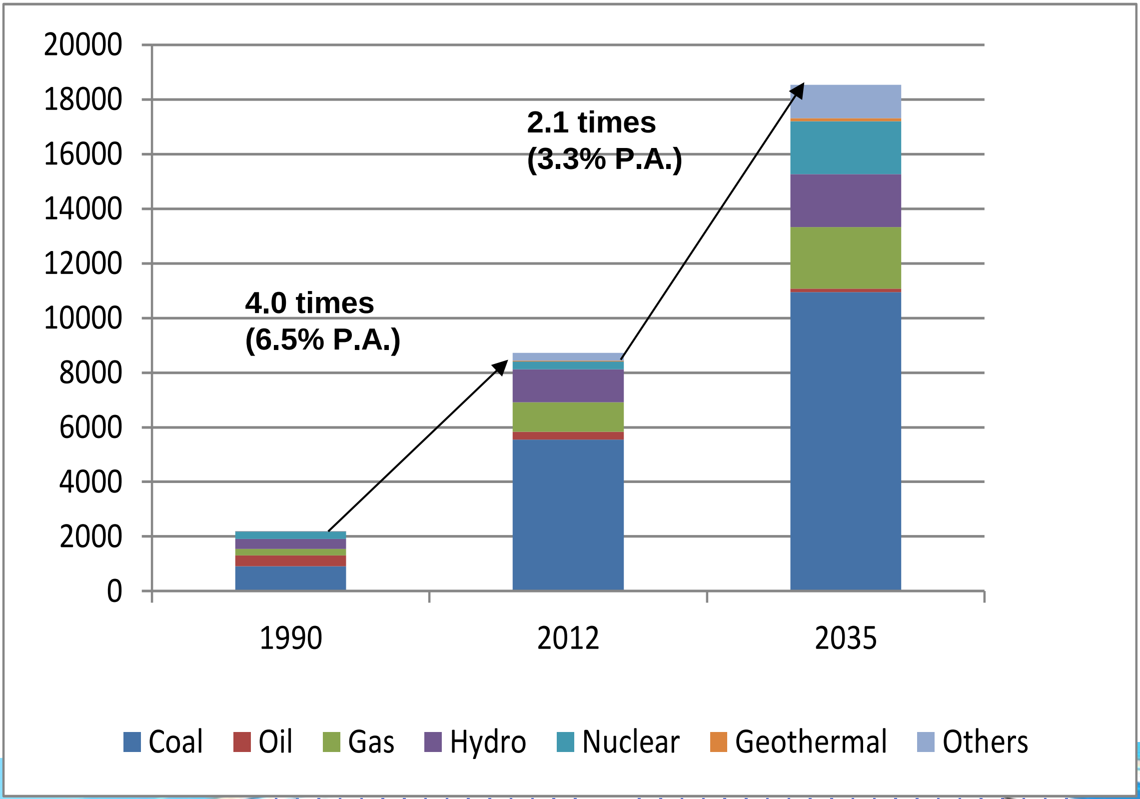
Gas will mark the highest growth at 4.3% p.a., followed by electricity (3.4%) and oil (2.7%).
Consequently gas share will increase from 7% in 2012 to 11% in 2035. Electricity share will also increase from 20% to 25%. On the other hand, coal share will decline from 22% in 2012 to 16% in 2035.

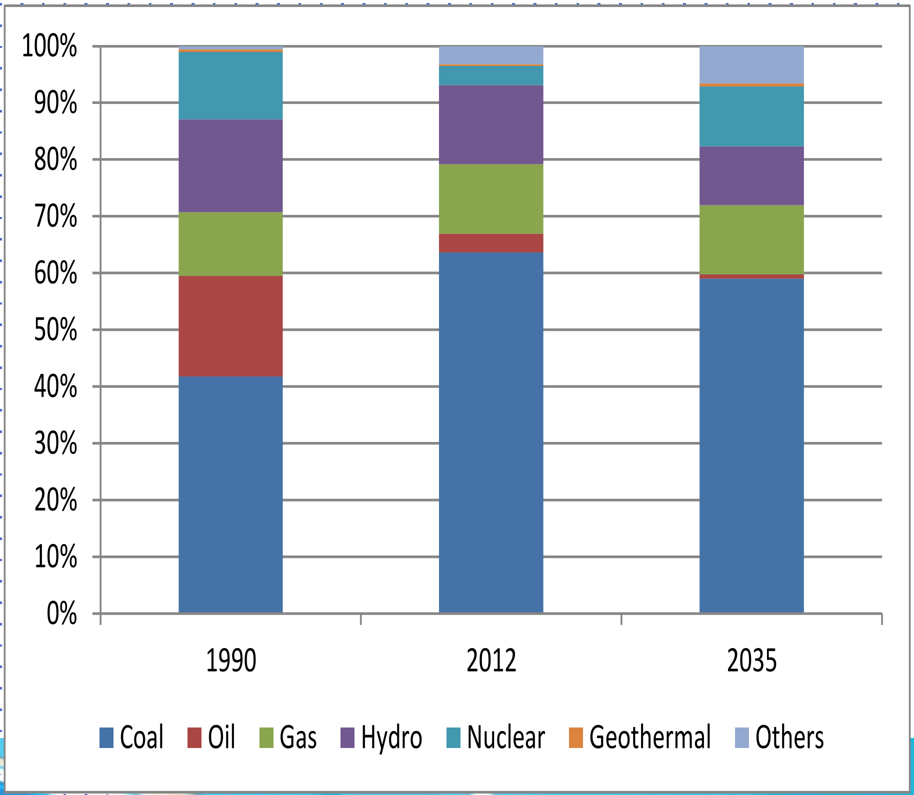
Source: ERIA ESP WG Report 2015

Power Generation

Coal fired generation will still be dominant and its share will be around 60% in 2035.

(TWh)

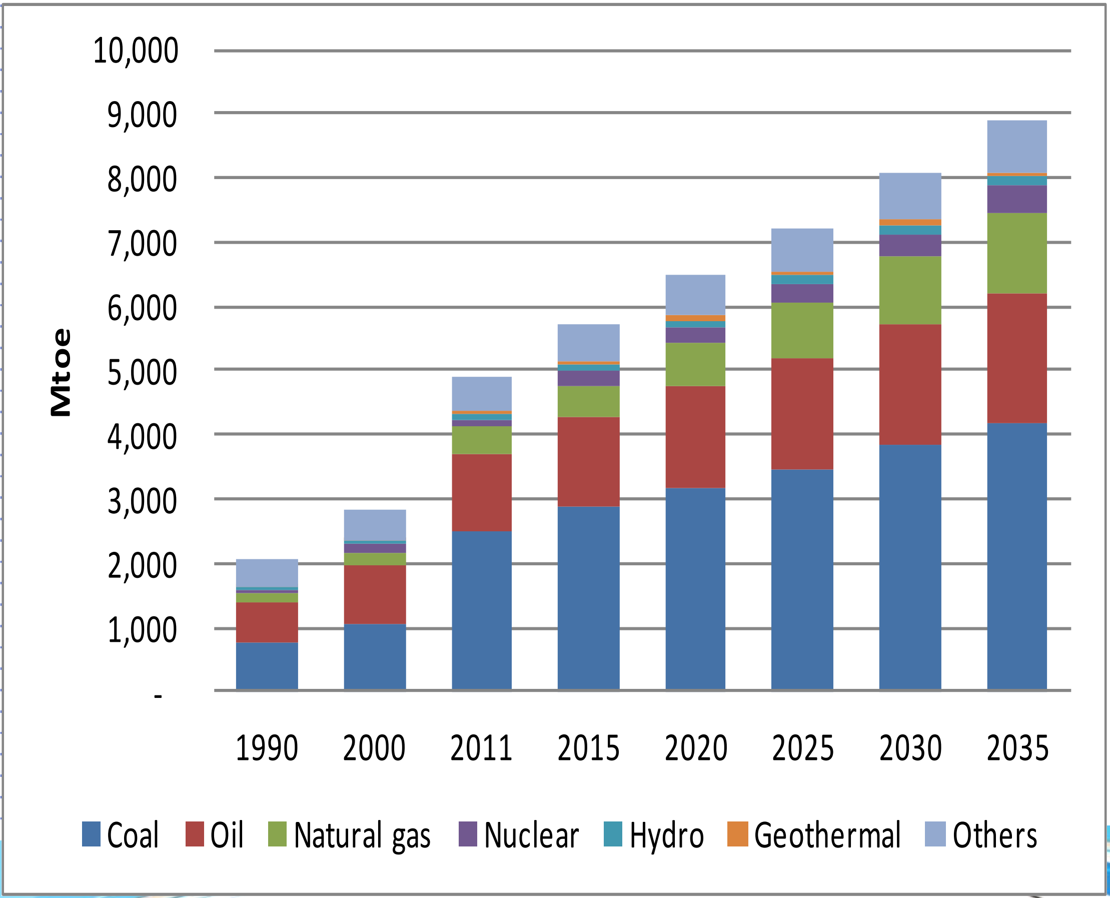




Source: ERIA ESP WG Report 2015

Rising Coal Demand

Primary Energy Demand in EAS (MTOE)



Source: ERIA Energy Outlook, 2014

- ASEAN, together with China and India, has already shifted both economic growth gravity and energy demand to Asia;
- EAS is projected to grow at a faster pace of 2.5 percent per year on average from 4,910 Mtoe in 2011 to 8,912 Mtoe in 2035;
- Coal will still constitute the largest share of primary demand (above 50%).
- In absolute term, coal consumption will increase by almost double from 2,507 Mtoe in 2011 to 4,155 Mtoe in 2035

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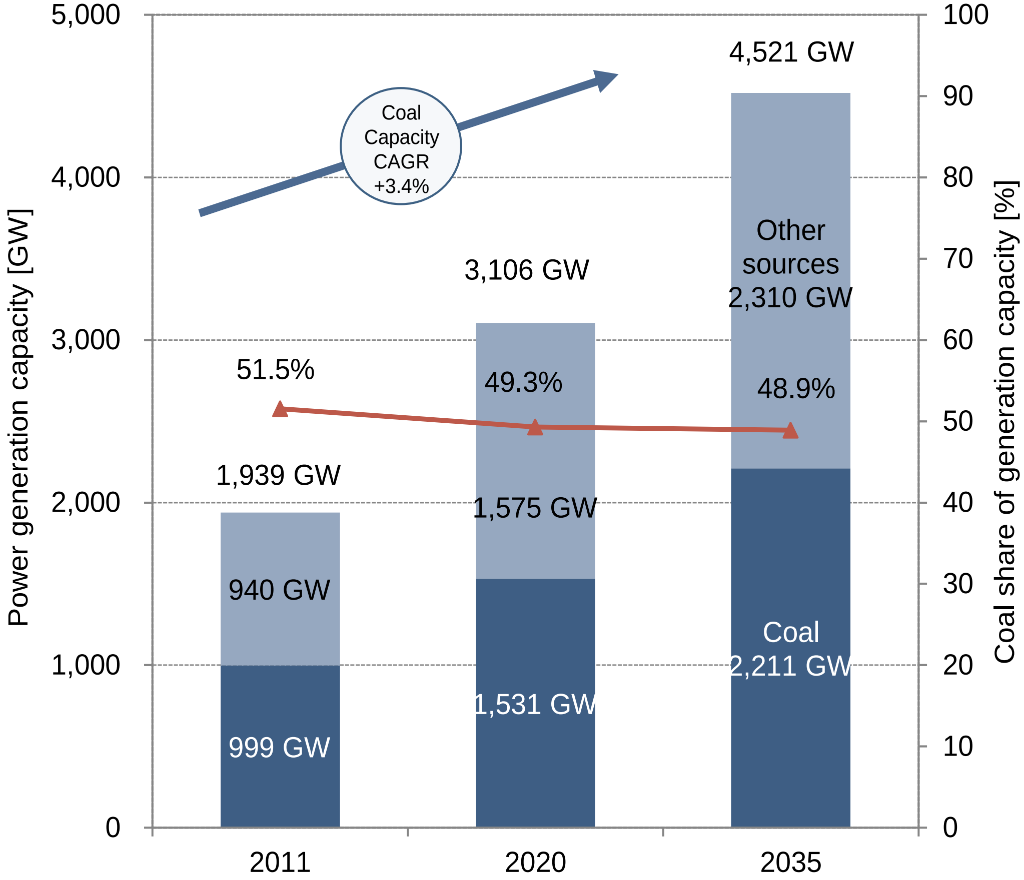
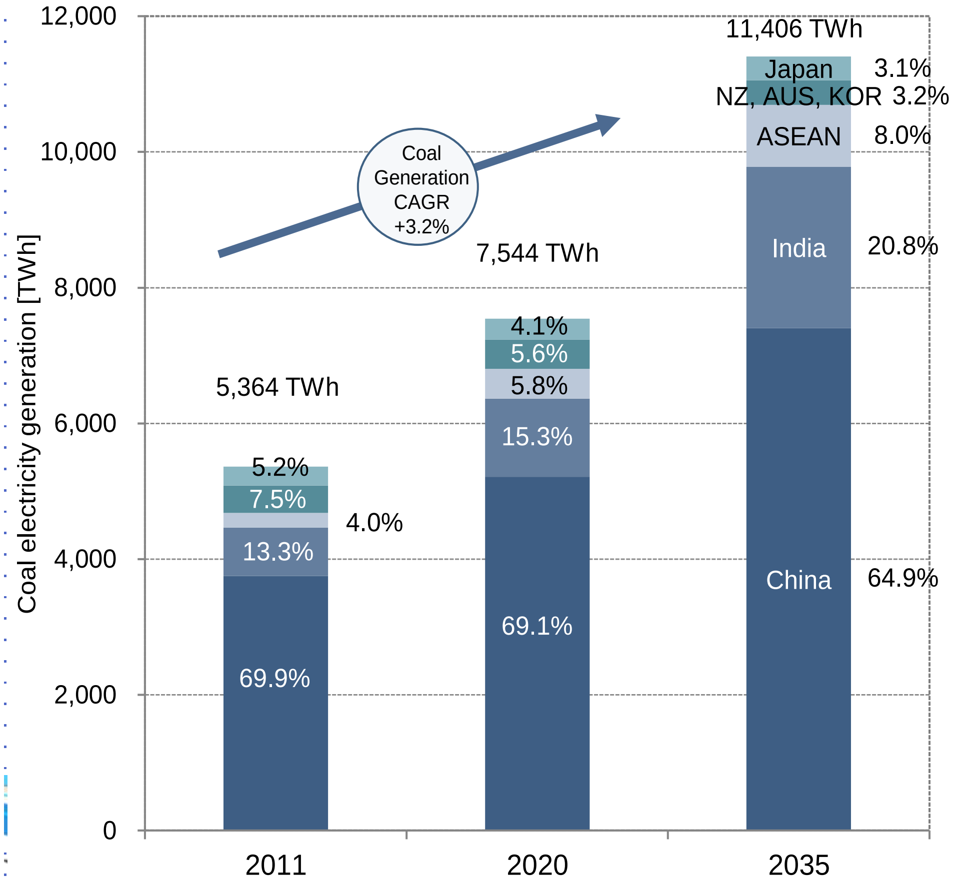
Estimate of Coal-Fired Power Plants in EAS

Share of coal-fired power stations in the EAS region

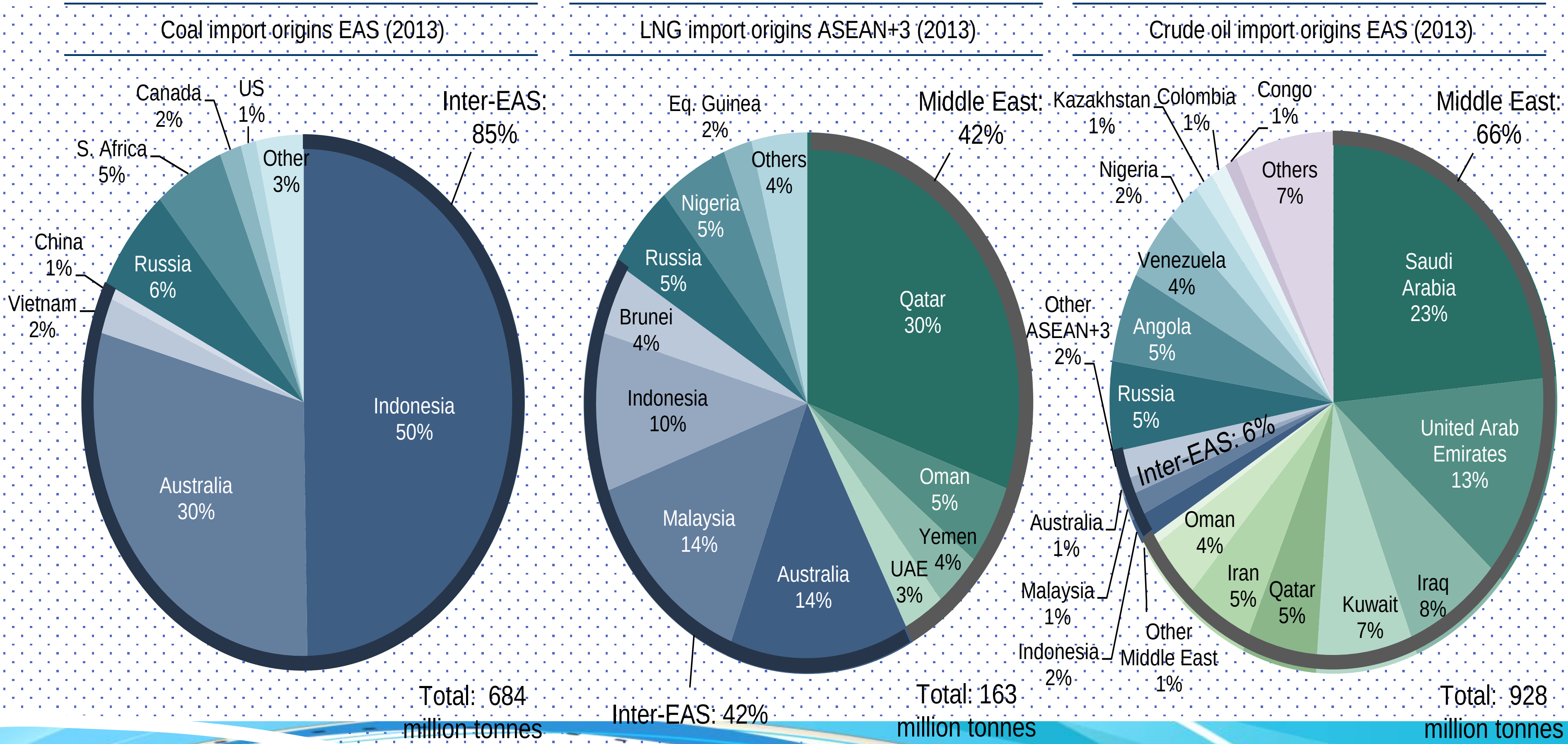


Coal-fired power generation by country



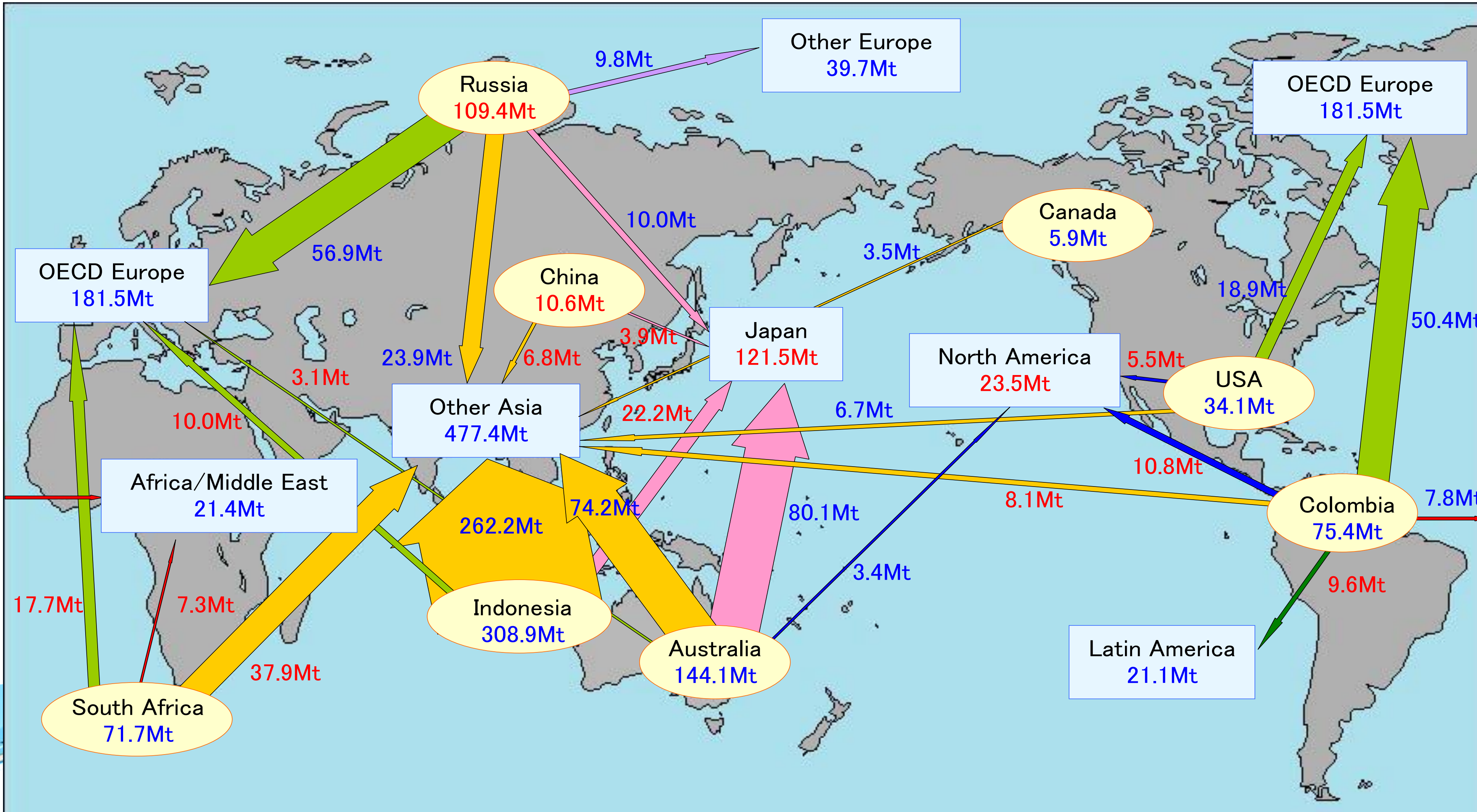
Sources: IEA & ERIA, 2013

Origin of Primary Energy Imports



Sources: ERIA, 2015

Flow of Coal Exports/imports



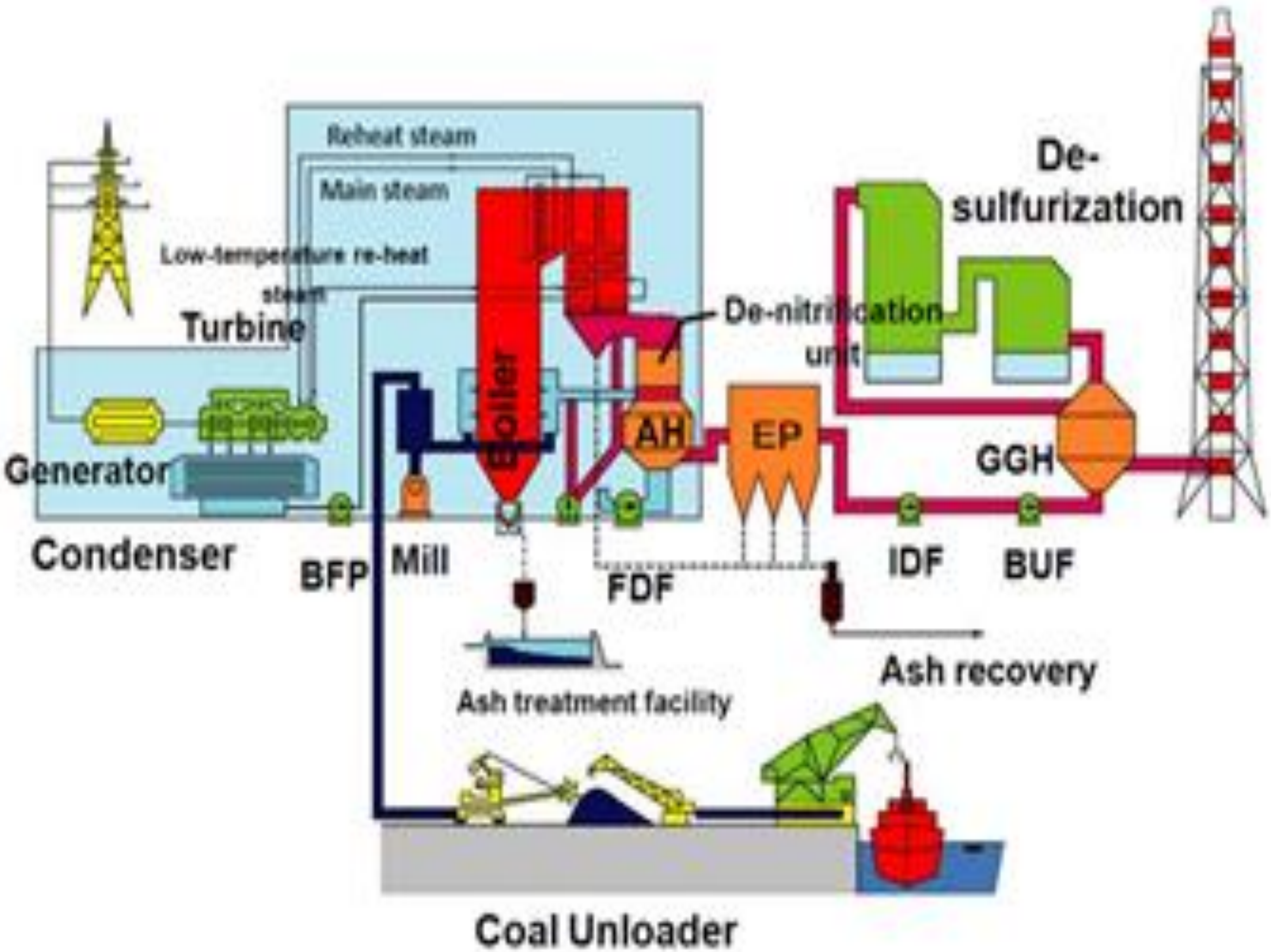
Sources: IEA, 2012

II. CLEAN COAL TECHNOLOGIES

Clean Coal Technologies for power generation

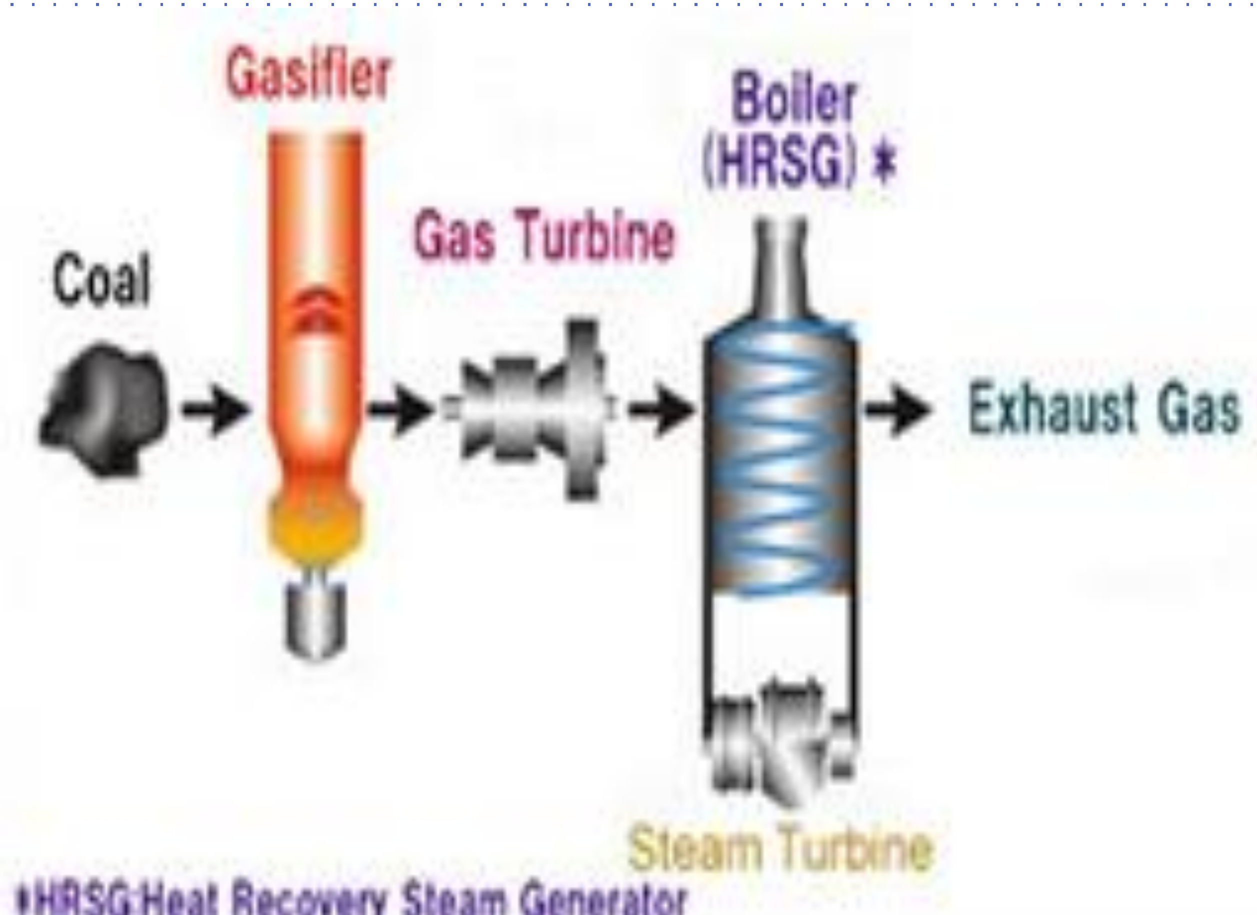
Sources: JCOAL, 2014

Schematic Overview of Typical Power Plant



- De-NOx, De-SOx and Electrostatic Precipitator (ESP)
- Gas-gas heater (GGH) is equipped to avoid white smoke from the stack by the warming-up of the flue gas exhausted from wet type De-sulfurization equipment.

Integrated Gas Combined Cycle (IGCC)



- IGCC has been developed to improve the power generation efficiency using gasifier technology to turn coal into synthesis gas (syngas) for gas turbine power generation.

- The plant is called integrated because the syngas produced in the gasification section is used as fuel for the gas turbine, and the steam produced by syngas cooler in the gasification section and heat recovery steam is used by steam turbine in combined cycle

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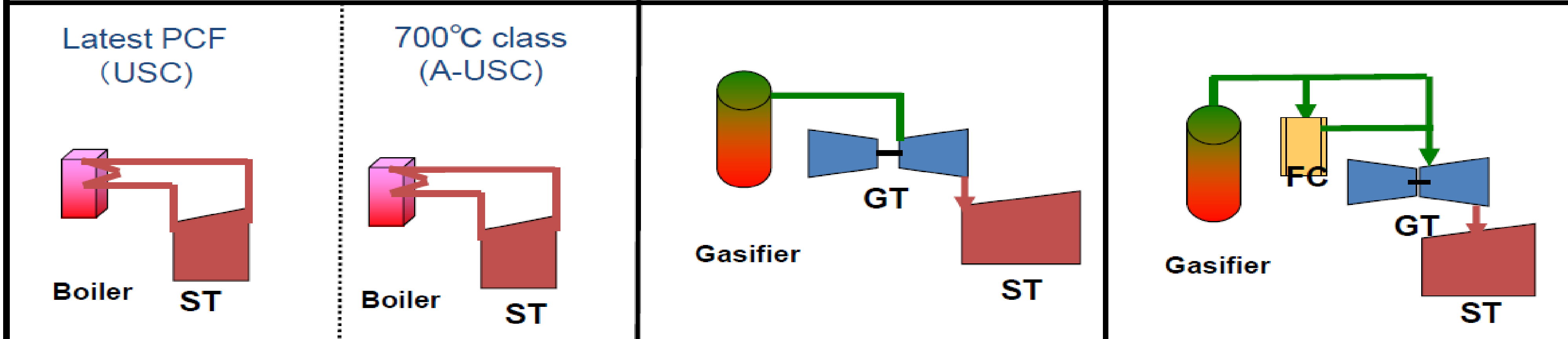
Higher Thermal Efficiency

- **Pulverized Coal-Fired System (PCF)**: Efficiency upgrade by increasing steam temperature and pressure; A-USC (Advanced USC, 700℃ class) is under development
- **Integrated Coal Gasification Combined Cycle System (IGCC)**: Combined Gas turbine (GT) and steam turbine (ST) cycle; Higher thermal efficiency than PCF; Increasing the GT inlet gas temperature is necessary for efficiency upgrade
- **Integrated Coal Gasification Fuel Cell Combined Cycle System (IGFC)**: Triple combined cycle (GT+ST+FC); Higher thermal efficiency than IGCC



① PCF		② IGCC (1500℃ class)	③ IGFC
Latest PCF (USC)	700℃ class (A-USC)		
Gross : 42～43% (HHV) Net : 41% LHV (Basis)	Gross : 48% Net : 46% CO_2 reduction: approx. 11%	Gross : 51～53% Net : 46～48% CO_2 reduction: approx. 13%	Gross : 60%～ Net : 55%～ CO_2 reduction: approx. 25%～

Sources: JCOAL, 2014

Note: HHV- Higher Heating Value; LHV; Lower Heating Value

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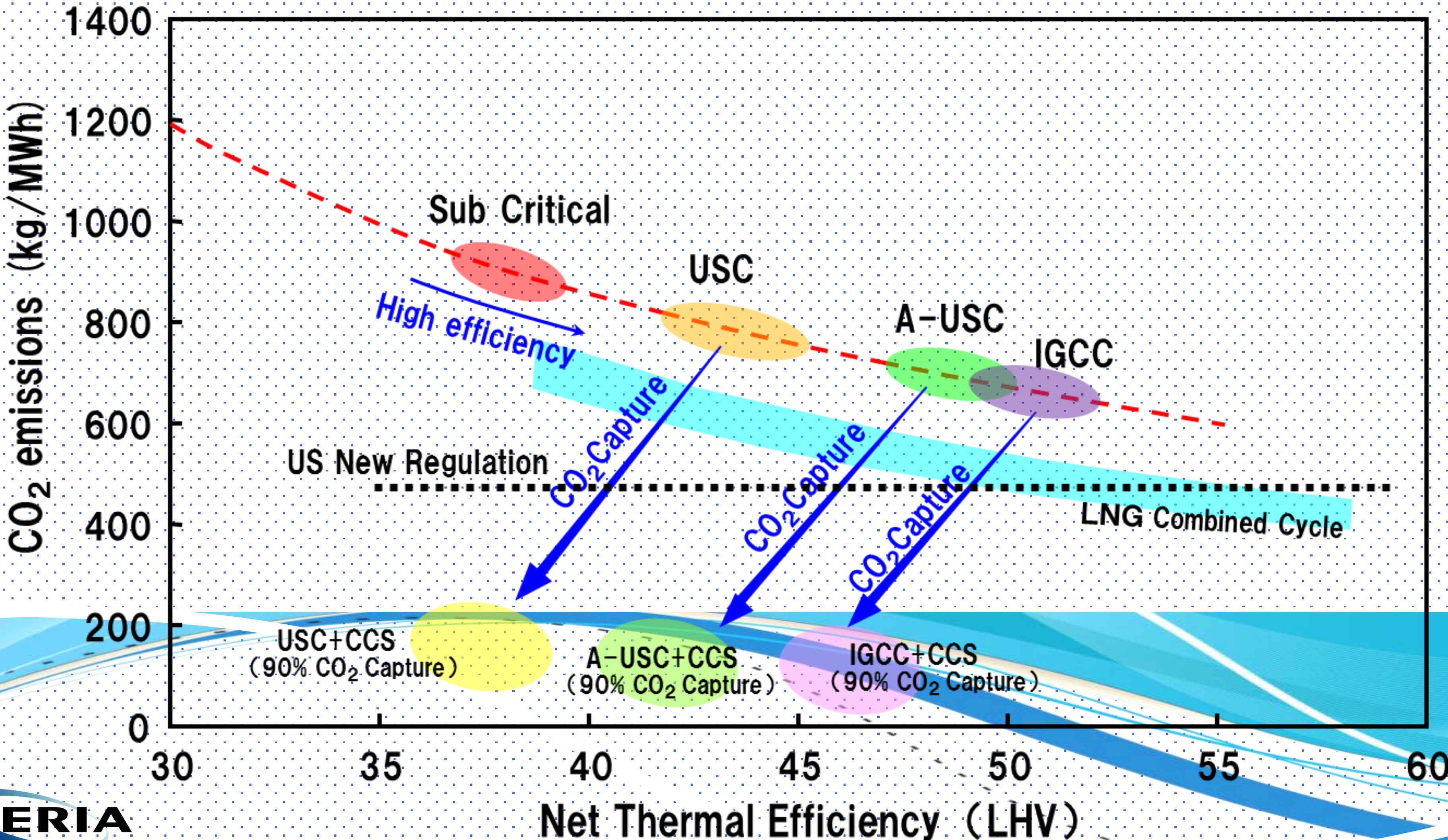
Relationship b/t power plat efficiency & CO2 emission



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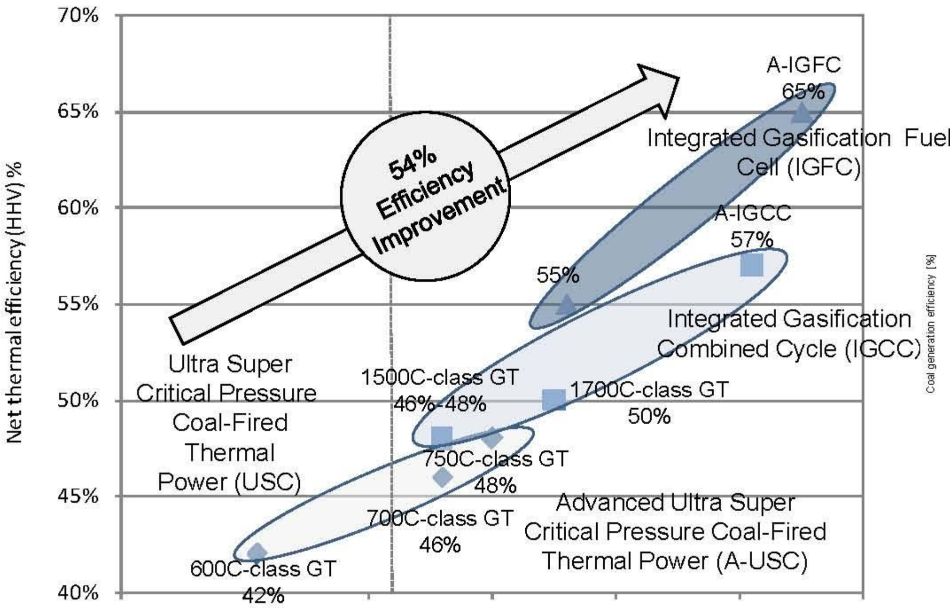
A REGIONAL TREND- ASEAN & EAS

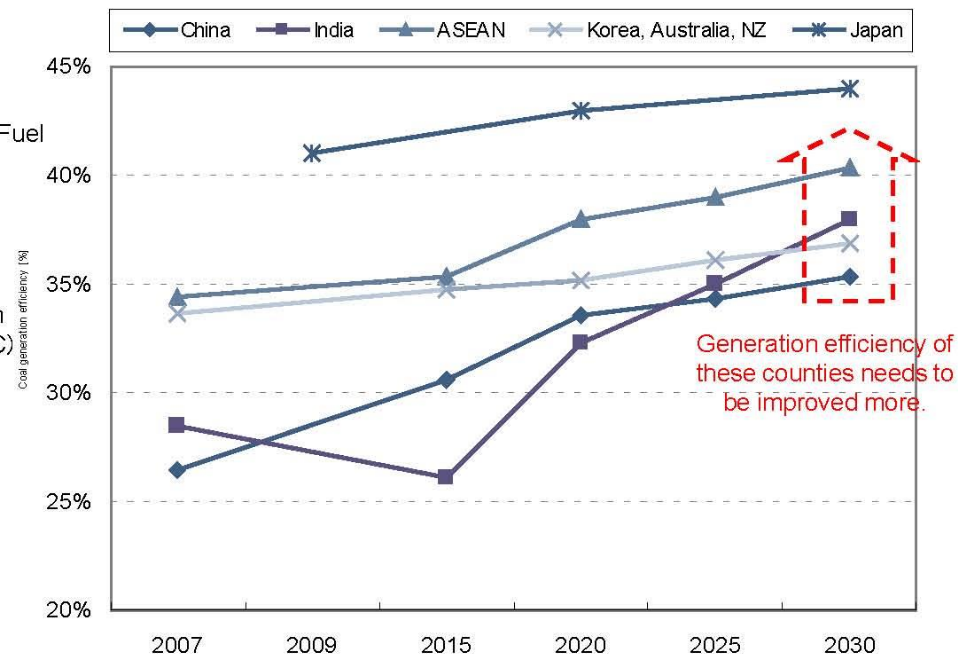
- Even with current USC, efficiency can be raised to over 40%
- With deployment of next-generation technologies like IGCC, power generation efficiency of over 50% can be attained.

Roadmap for efficiency improvement of coal fired power generation



Source) Created based on the "Action Plan for Achieving a Low-carbon Society" and "Cool Earth-Innovative Energy Technology Program"

Power generation efficiency forecast



Source) Compiled from IEA statistics

III. ECONOMIC ASSESSMENT OF THE CCT

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General assumptions for cost-benefit analysis

		Values	Remarks
Plant	Capacity	1,000 MW	
	Operation	25 years	For cash flow purposes
	Operation rate	80%	
	Thermal efficiencies	42.1% (USC), 41.1% (SC), 38.2% (subcritical)	LHV value from NEDO study “Promotion of high-efficiency coal-fired power stations in Indonesia”
	Annual generation	7,008 GWh	
Coal specifications	Heating value	4,000 kcal/kg	
	CO2 emissions	1.43 kg-CO2/kg coal	Based on IPCC 2006 default emission factors for stationary combustion in the energy sector.

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Cost Components

- LCOE consists of: base plant costs, desulphurization and denitrification costs, financing & CO_2 emission costs.
- Plant costs are divided into following costs:
  - Engineering, procurement and construction (EPC),
  - Operation and maintenance (O&M), and
  - fuel costs.
- Financing costs are calculated to generate 9.5% IRR and 15% IRR. To calculate cash flows over operation, electricity sales are set equal to annual generation at 7,008 GWh for a period of 25 years,
- CO_2 emission costs were calculated at USD 10/ton-CO_2.

LCOE, excluding financing and CO_2 costs

- 2009 to 1st quarter 2014, coal prices for 4,200 kcal/kg coal ranged from USD 35/ton to USD 63/ton. Thus, price scenarios were chosen at: USD 40/ton (low scenario), USD 50/ton (medium scenario), and USD 60/ton (high scenario)
- Without financing cost, USC is more competitive in every coal price scenario

		Ultra-Supercritical (42.1%)			Supercritical (41.1%)			Subcritical (38.2%)		
		High EPC (USD 2,076 million)	Medium EPC (USD 1,941 million)	Low EPC (USD 1,867 million)	High EPC (USD 2,043 million)	Medium EPC (USD 1,908 million)	Low EPC (USD 1,796 million)	High EPC (USD 1,925 million)	Medium EPC (USD 1,796 million)	Low EPC (USD 1,688 million)
Coal prices	High (USD 60/ton)	5.39	5.27	5.20	5.46	5.34	5.23	5.68	5.55	5.45
	Medium (USD 50/ton)	4.87	4.74	4.68	4.93	4.80	4.69	5.10	4.97	4.87
	Low (USD 40/ton)	4.35	4.22	4.15	4.39	4.26	4.16	4.52	4.39	4.29

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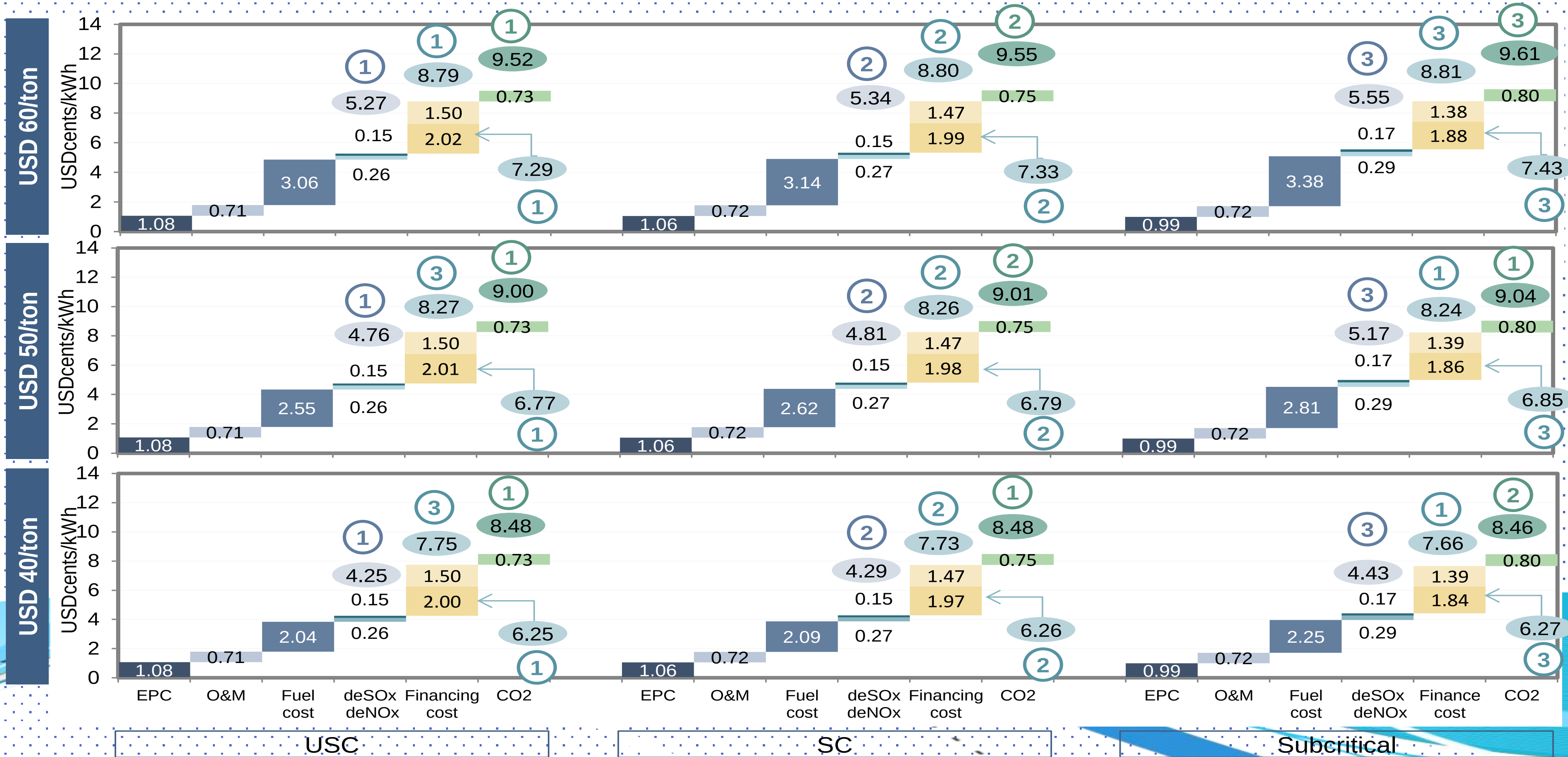
LCOE, with financing and CO_2 costs

- If financing costs are set to generate 9.5% IRR, USC is again most competitive, even at USD 40/ton coal price;
- However, as initial capital costs are higher, USC is less competitive when financing costs to generate 15% IRR are considered



Generation Cost by Boiler Type & Coal Price

- Financing costs also account for a significant share of total generation costs, depending on IRR.
- USC loses cost-competitiveness when IRR is higher. For example, at coal prices of USD 50/ton, USC is most cost-competitive when IRR is 9% (USDcent 6.77/kWh).
- However, when IRR is increased to 15%, USC is less cost-competitive than SC and subcritical (USDcent 8.27/kWh).
- Therefore, USC may be less viable in countries which do not have access to low-interest loans.

		Boiler Type		
		Ultra Super Critical (USC)	Super Critical (SC)	Sub-critical
Capacity		1,000 MW		
Coal CV / Price		4,000 Kcal/kg (GAR) / 50 USD/ton		
Thermal Efficiency (LHV)		42.1%	41.1%	38.2%
Initial Cost (million USD)		1,931	1,897	1,787
Coal Consumption (tons/year)		3,578,263	3,665,326	3,943,583
CO2 Emission (tons/year)		5,102,914	5,227,073	5,623,893
Generation Cost (USD cent/kWh) (@USD60/ton)	IRR= 9.5%	7.29	7.33	7.43
	IRR=15.0%	8.79	8.80	8.81
Generation Cost (USD cent/kWh) (@USD50/ton)	IRR=9.5%	6.77	6.79	6.85
	IRR=15.0%	8.27	8.26	8.24
Generation Cost (USD cent/kWh) (@USD40/ton)	IRR=9.5%	6.25	6.26	6.27
	IRR=15.0%	7.75	7.73	7.66

IV. ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS

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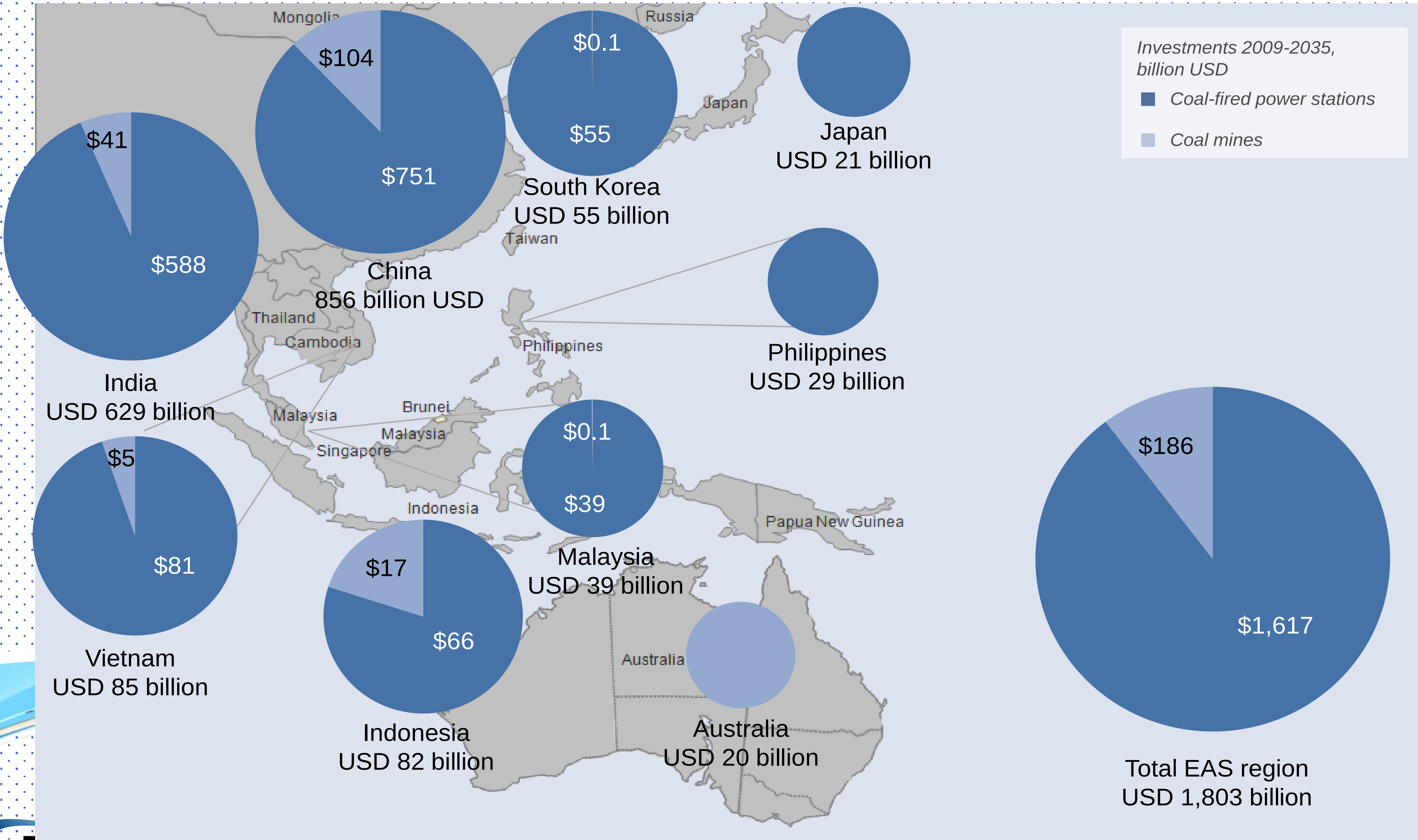
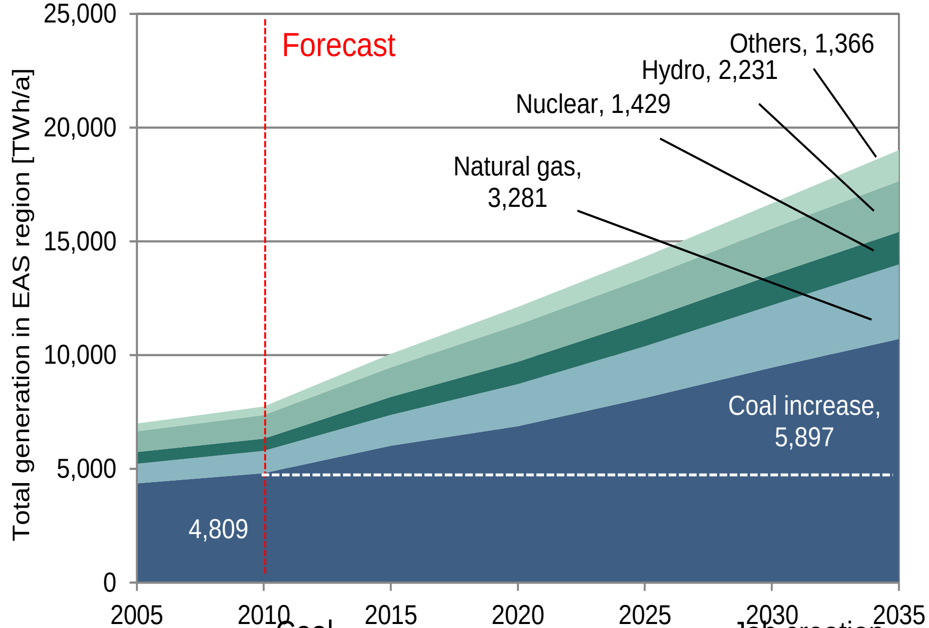
Potential investment benefits

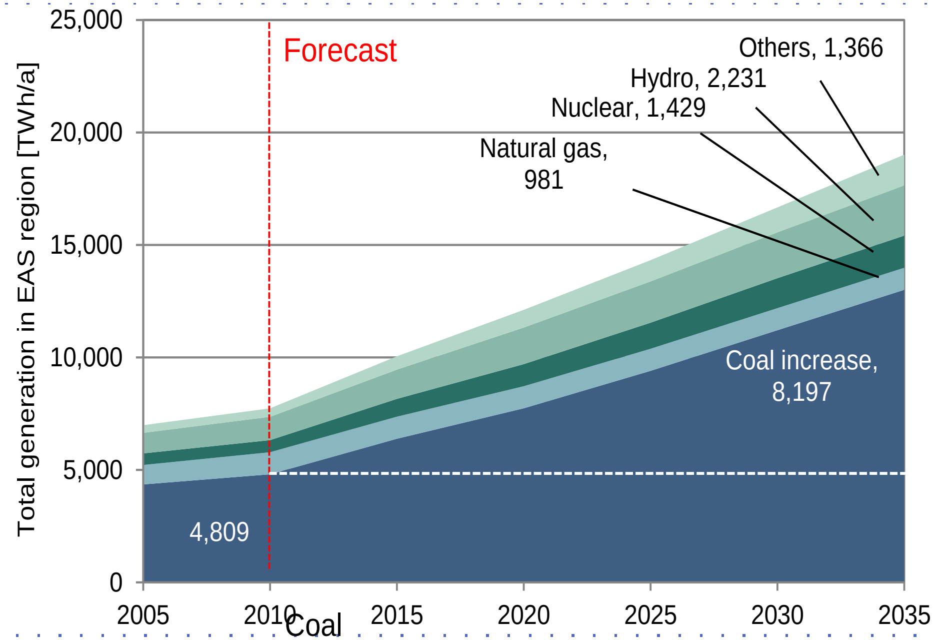


Employment creation

Electricity generation EAS region BAU case



Electricity generation EAS region natural gas replacement case



2009 - 2035	Coal generation increase	Employment per TWh	Job creation in power stations	Employment in coal mines	Coal demand increase	Employment per MT	Job creation in coal mines
BAU case	5,897 TWh	42 persons	246,457 persons		1,943 MT	39 persons	75,767 persons
Gas replacement case	8,197 TWh	42 persons	342,568 persons		2,700 MT	39 persons	105,315 persons

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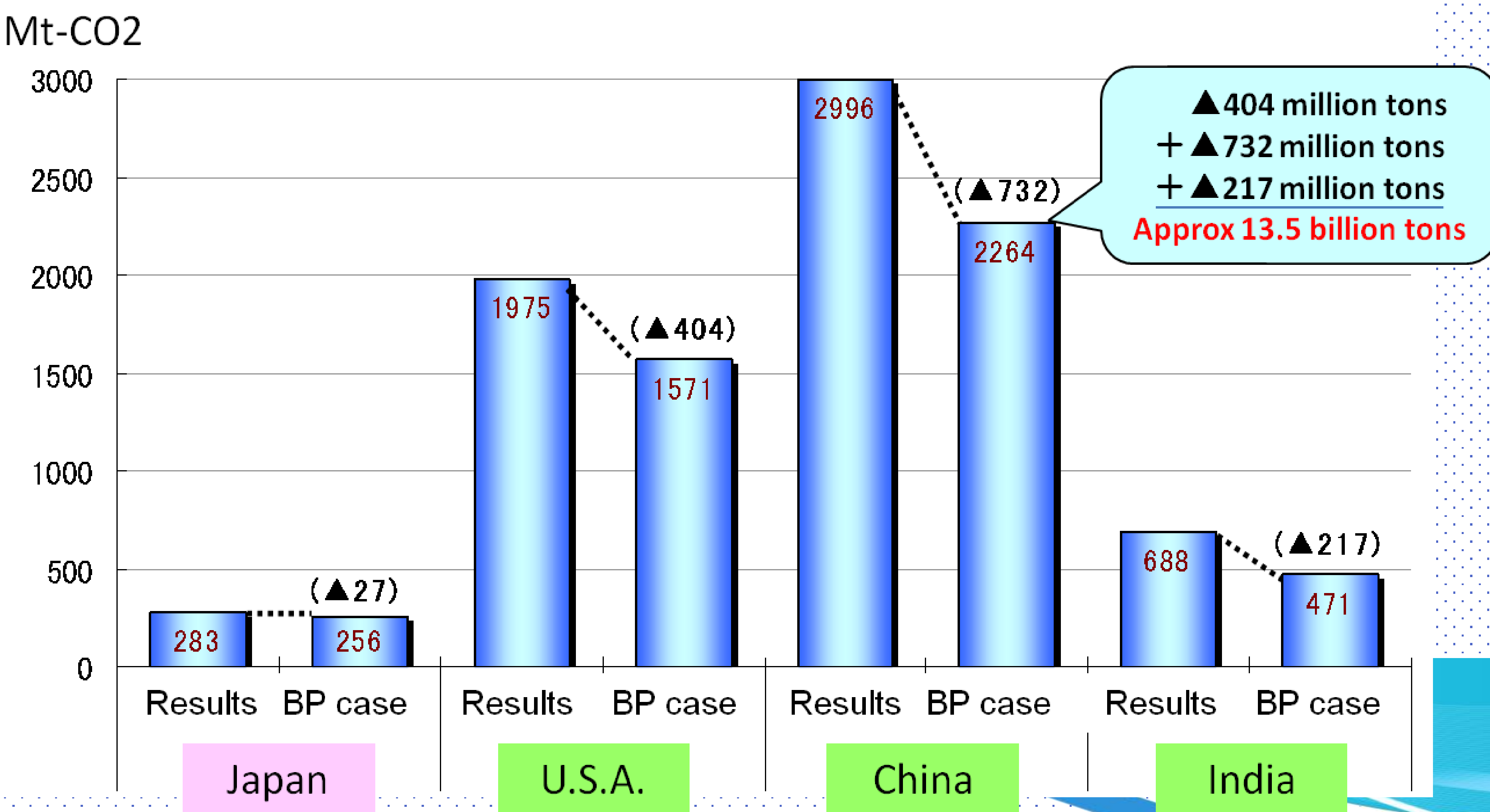
Potential CO2 reduction by CCT



V. Conclusions

- CCT is an useful technology to be able to use low ranked coal, which has a plenty reserve in this region;
- CCT needs large investment; thus lowering upfront cost will make CCTS competitive;
- About $US 1,803 billion investment potential from the introduction of CTT & Coal Mines
- Around haft million job will be created
- About 13.5 billion tons of CO2 reduction potentials
- Strengthen environmental standard is key to the up-take of CCT technologies and deployment;
- Energy efficiency is vitally crucial for policy measures to save energy and use it effectively.

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