ENERGY & ENVIRONMENT

Bioenergy in power and industry: CCS, BECCS and negative emissions options

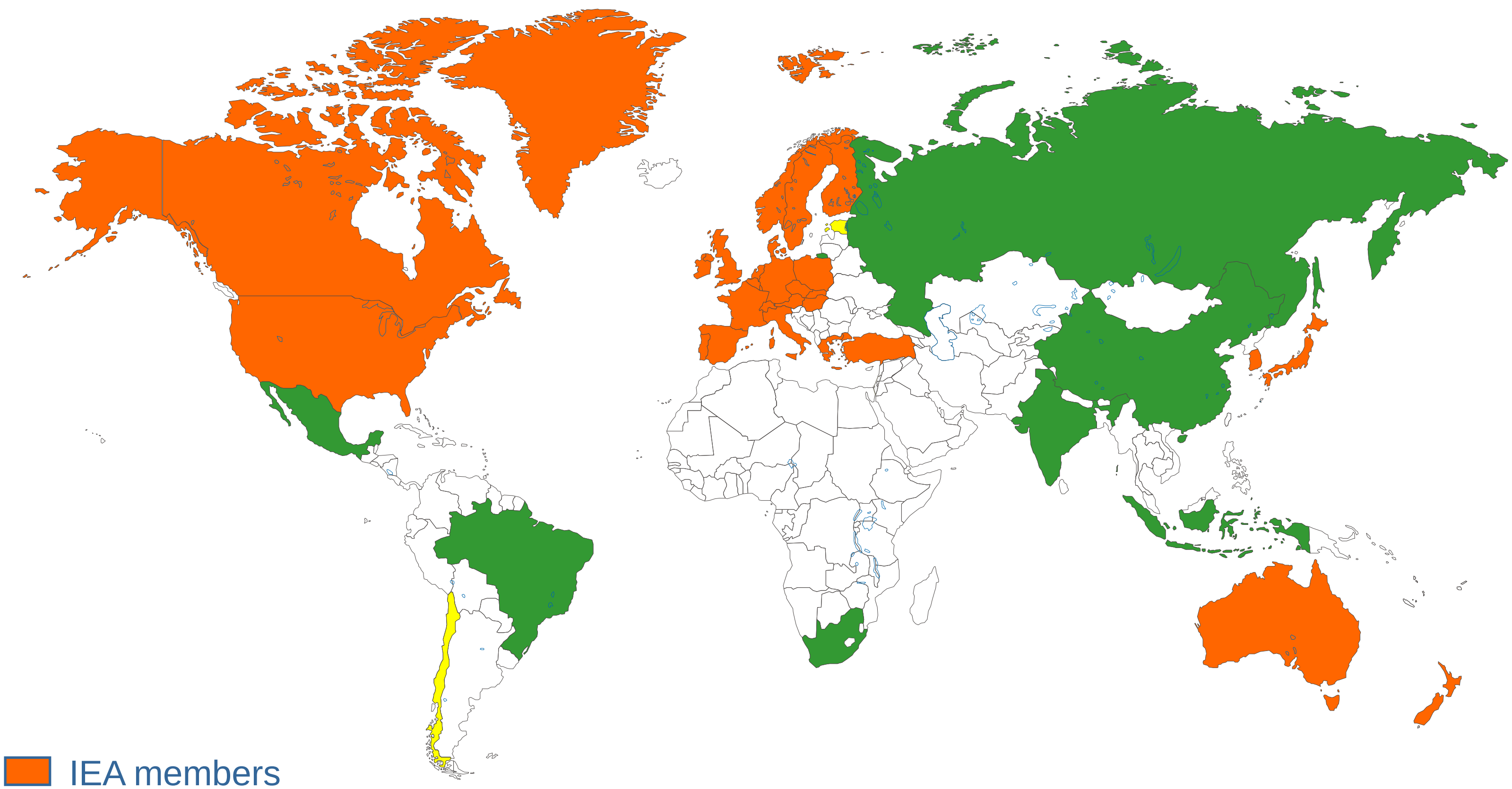
WBS/ICBT 2014, Changsha, China

Dennis Best

Policy Analyst
Sustainable Policy and Technology Directorate

International Energy Agency

Twenty-eight IEA member countries



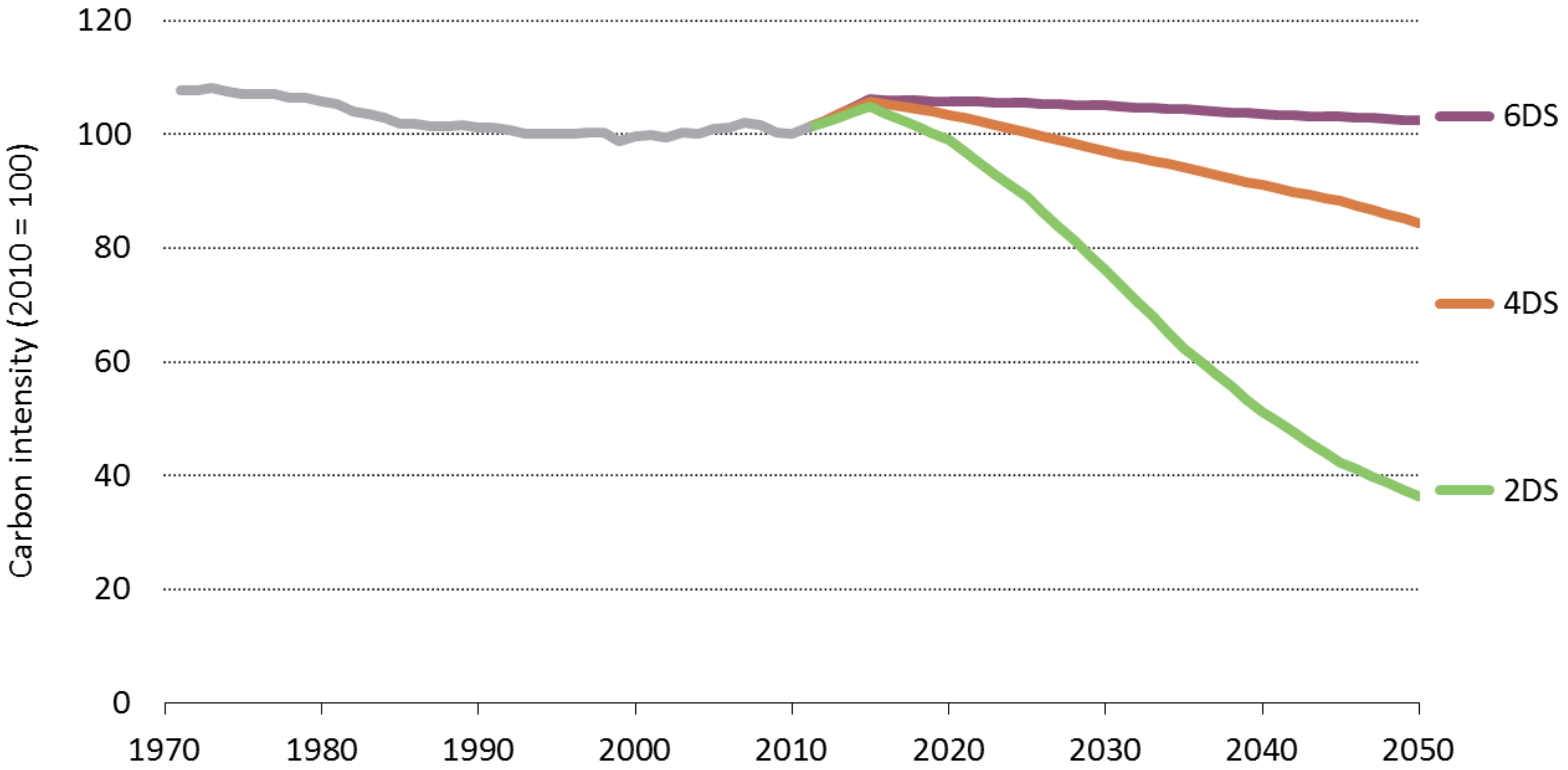
IEA members

Recent accession countries

Partner countries that attended the 2011 Ministerial Meeting

International Energy Agency iea

Carbon Intensity of supply is stuck



The will to make meaningful progress at a global scale has yet to be demonstrated

Bioenergy combined with CCS (BECCS) can provide 'negative emissions'

- **Bio-CCS has the potential to reduce atmospheric concentrations of CO_2**
  - CO_2 sequestered from air as biomass grows is not returned to atmosphere

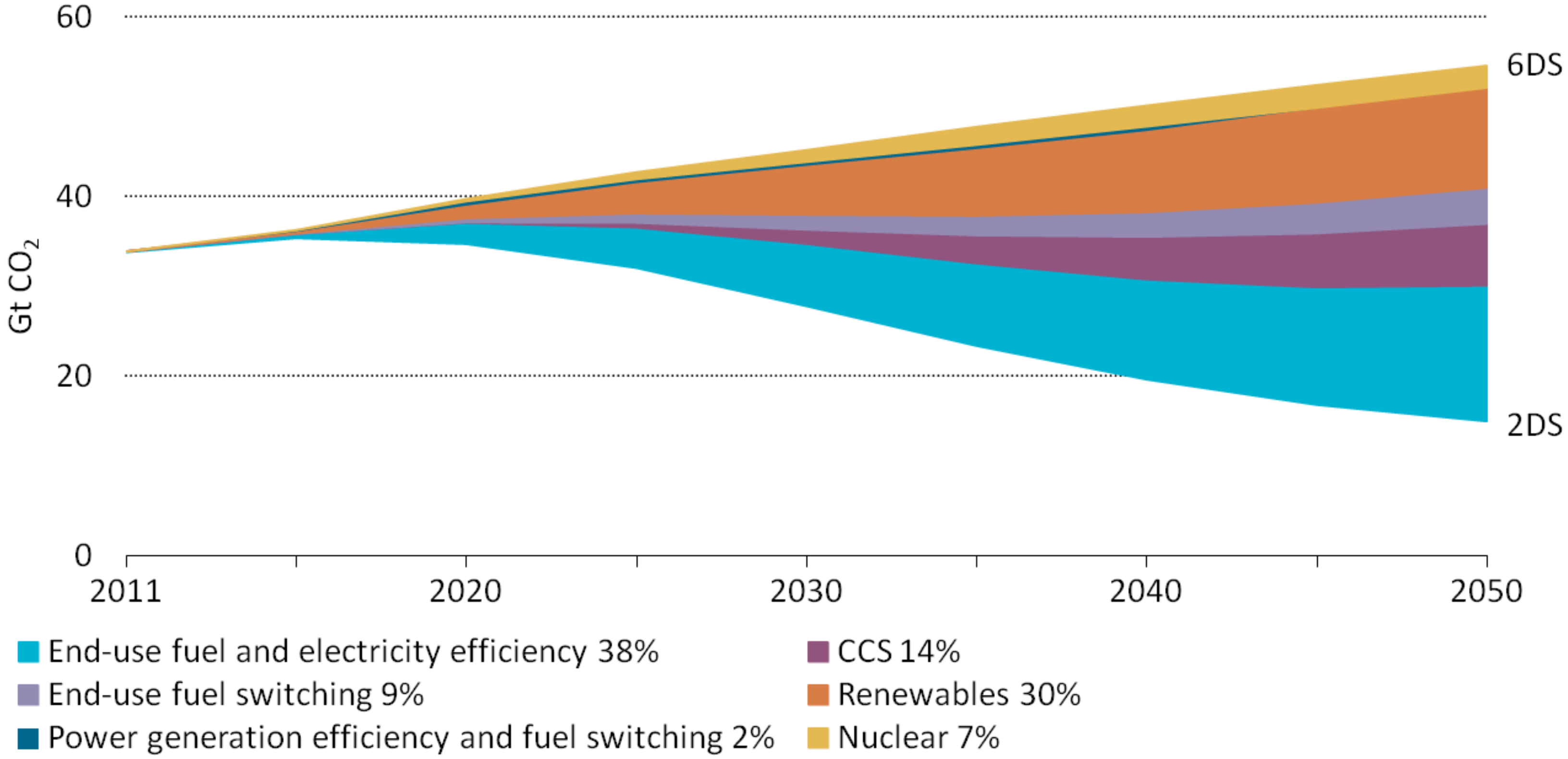
    → **sustainability needs to be ensured**
  - may well be needed for climate stabilisation, in particular looking beyond 2050

Process	CCS	BECCS
Biological sequestration		-1
Combustion	+1	+1
Storage	-1	-1
Lifecycle emissions	0	-1

Note: Table only includes abstract values

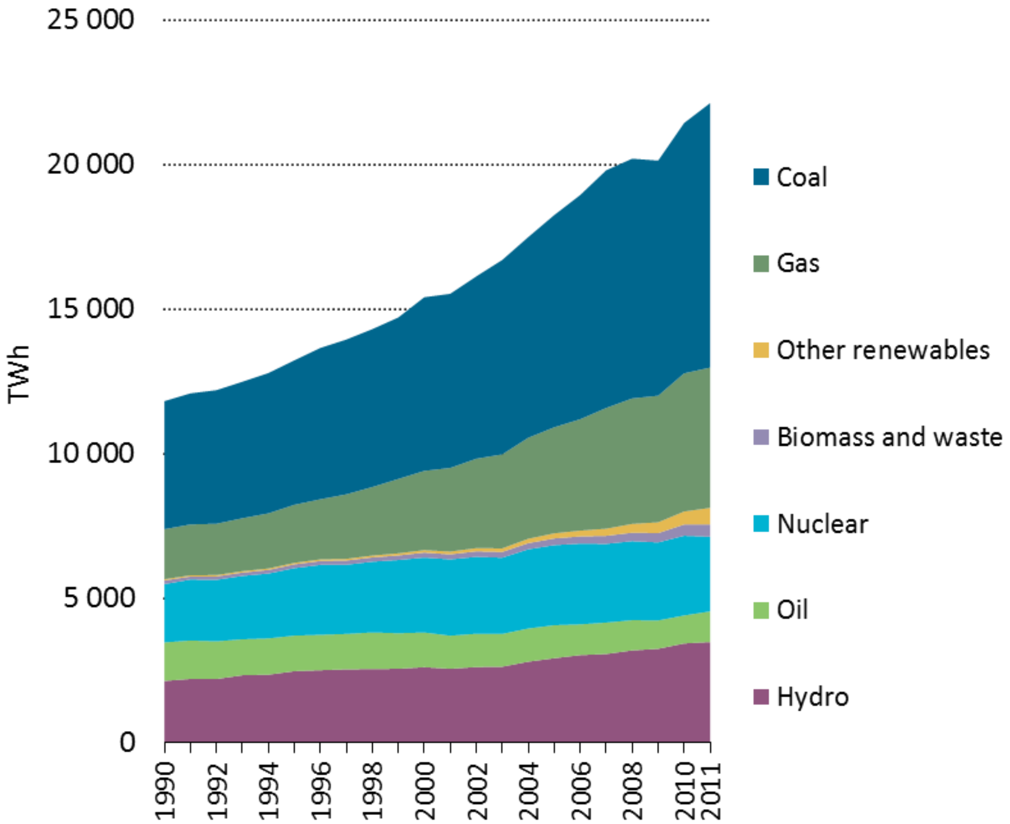
Should be reflected as extra incentive

A transformation is needed…

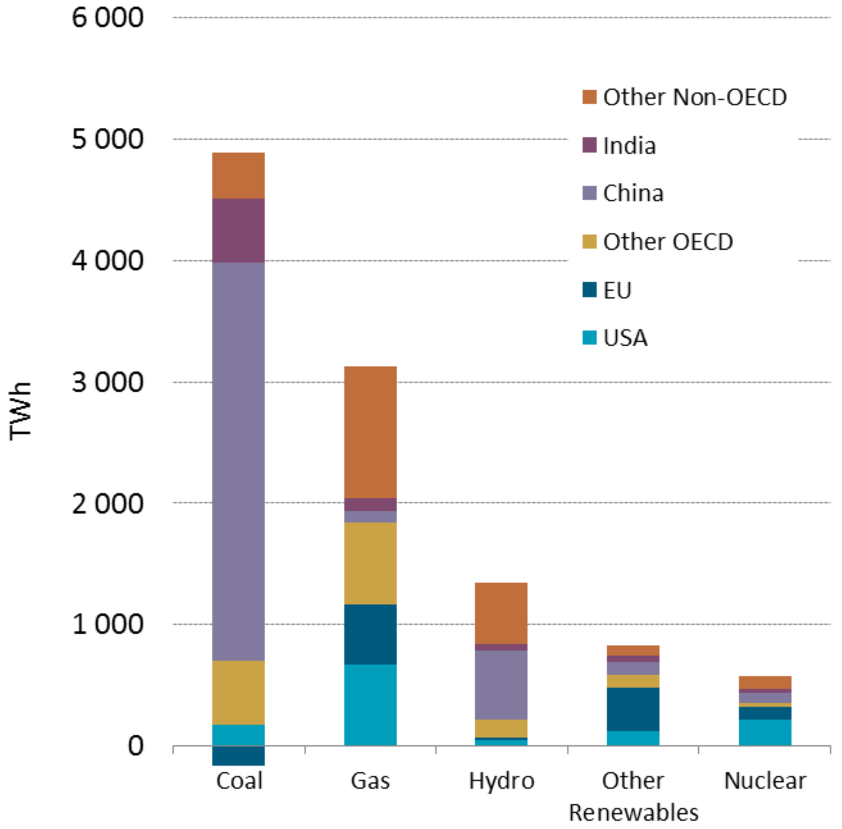


..we have tools to develop a strategy and be proactive.

Coal/gas fuels of choice over last two decades

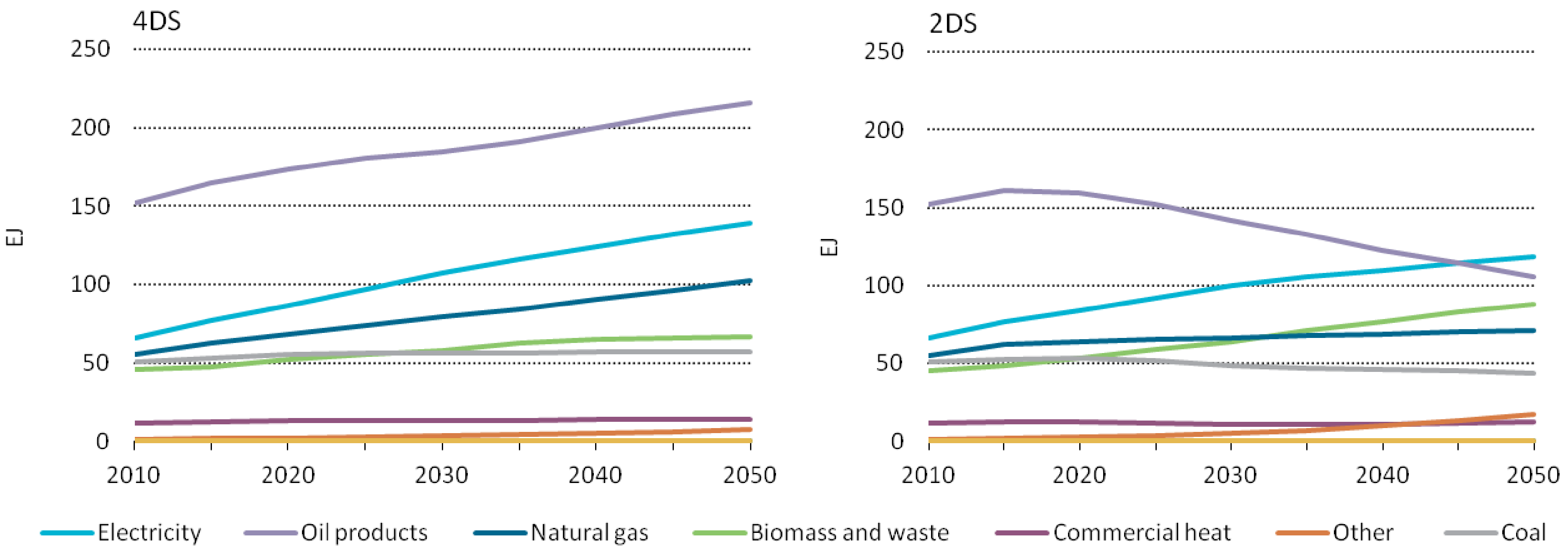


Increase 1990-2011



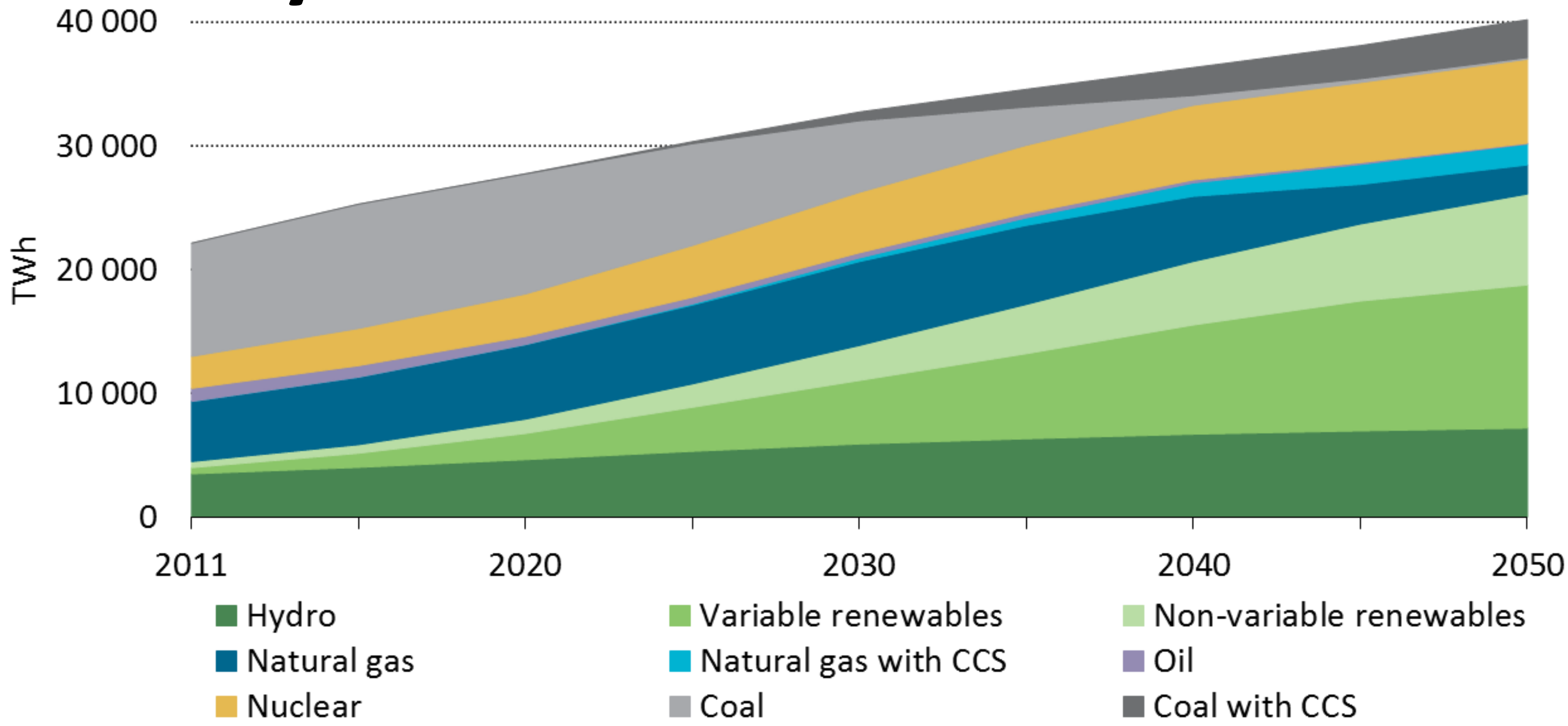
Coal alone covered almost half of the increase in electricity demand between 1990 and 2011.

Electricity/Biomass and Waste in final energy mix increasingly important



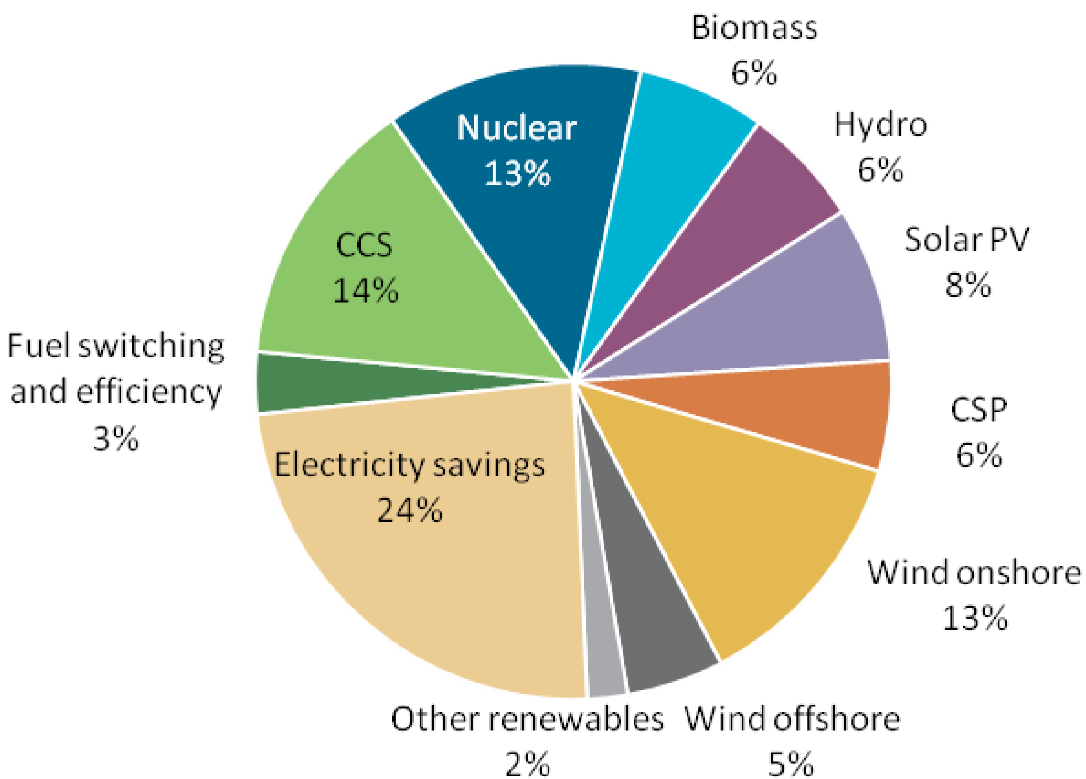
By 2050, in the 2DS, electricity overtakes oil-based products as the largest end-use fuel for meeting the needs of the global energy system.

Electricity Generation: a share reversal



- **Generation today:**
  - **Fossil fuels: 68%**
  - **Renewables: 20%**
- Generation 2DS 2050:
  - Renewables: 65%
  - Fossil fuels: 20%

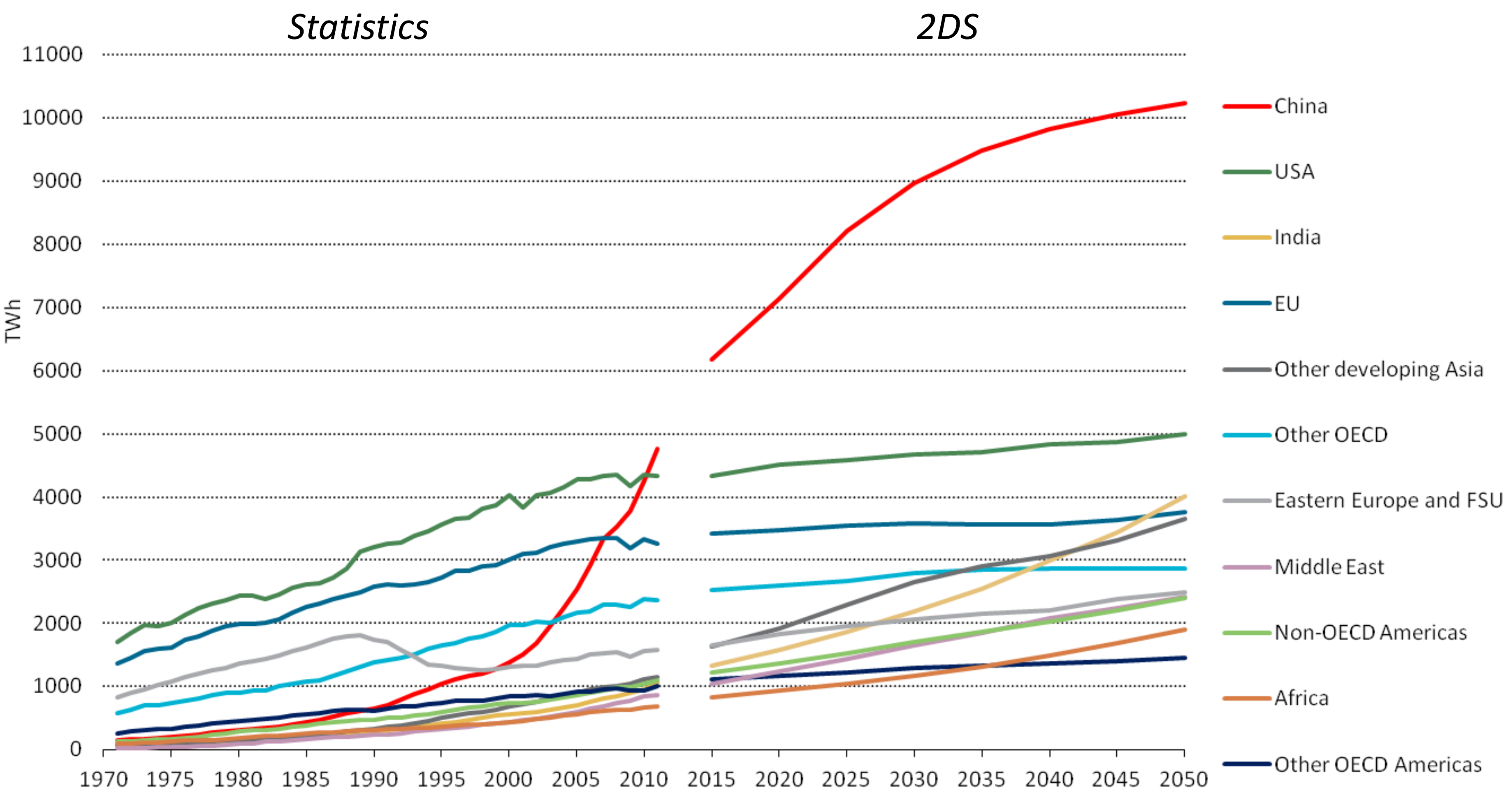
A portfolio of technologies is needed to decarbonise the power sector



Contribution of technologies to cumulative reductions (2011-2050) of 296 Gt in the power sector

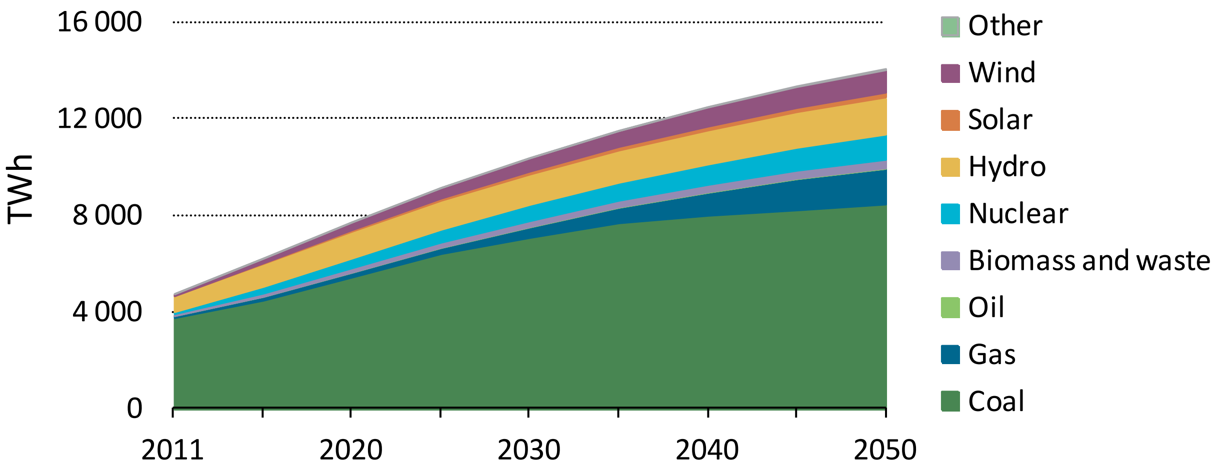
Saving electricity (through efficiency or fuel-switching to renewables) in the end-use sectors accounts for around one quarter of the CO2 reductions, renewables combined provide 45%.

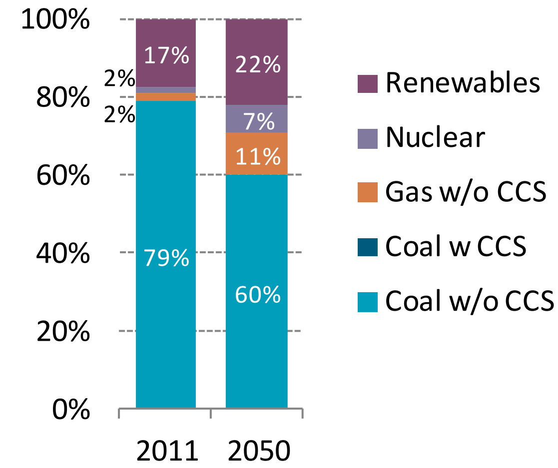
China has become the largest electricity generator…

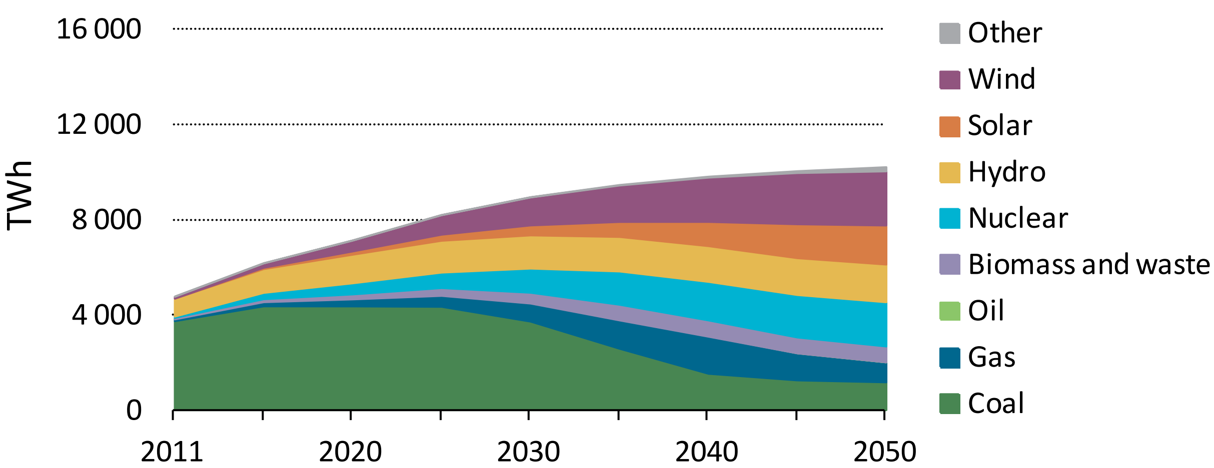


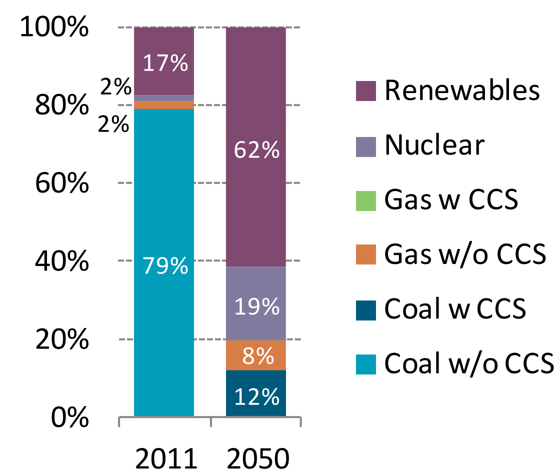
… and continues to do so in the 2DS.

China: Electricity generation mix

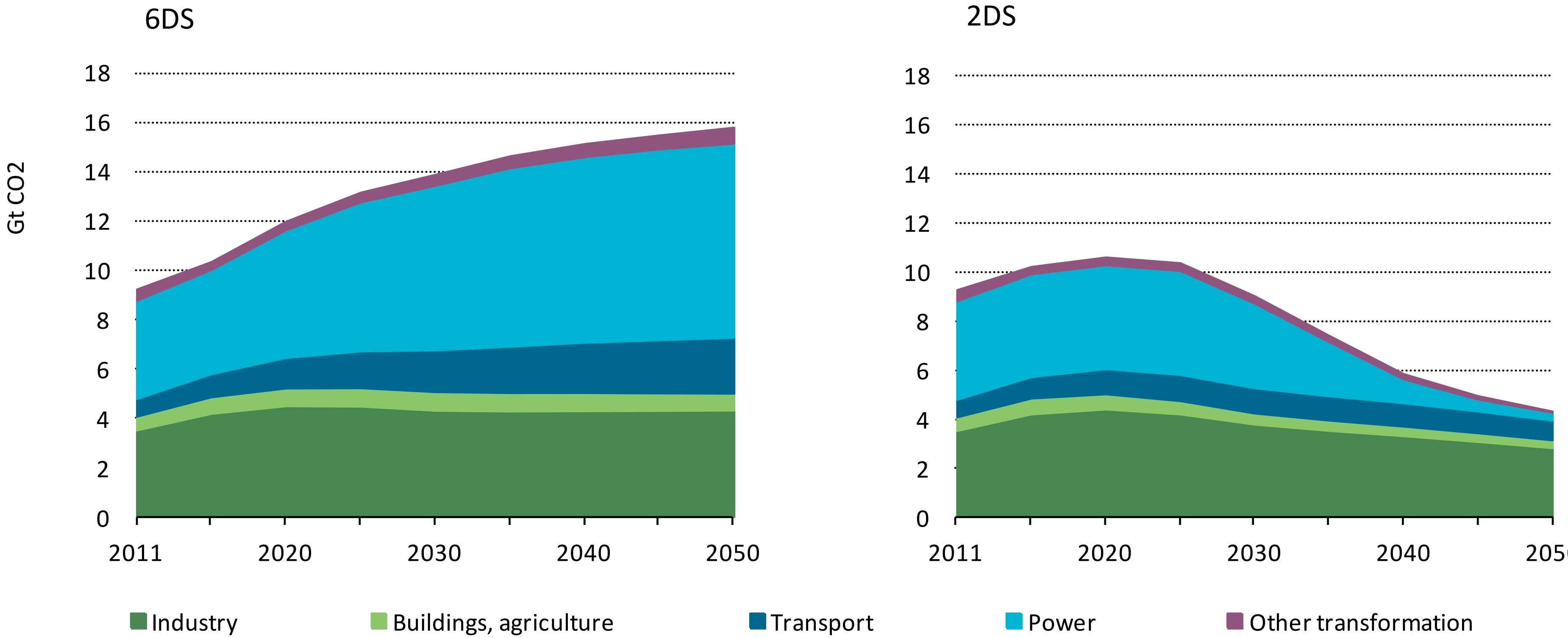








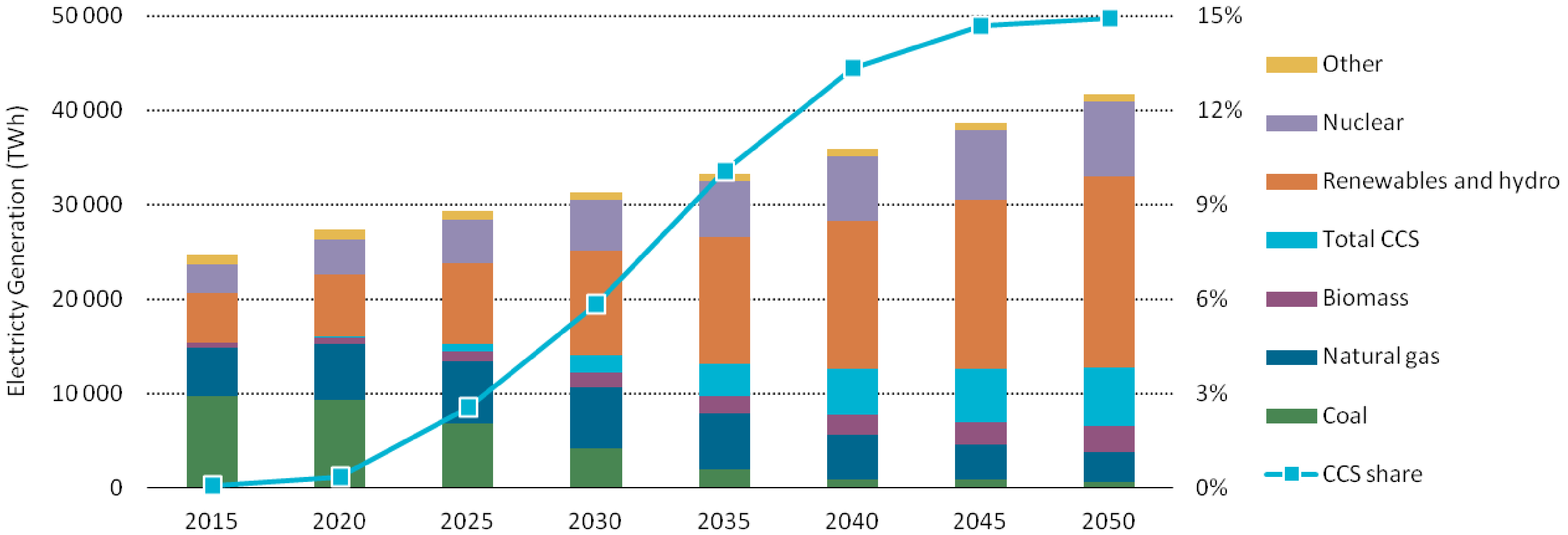
China: CO_2 emissions by sector



Overall CO_2 emissions (energy+process) halved in 2DS by 2050 compared to 2011.

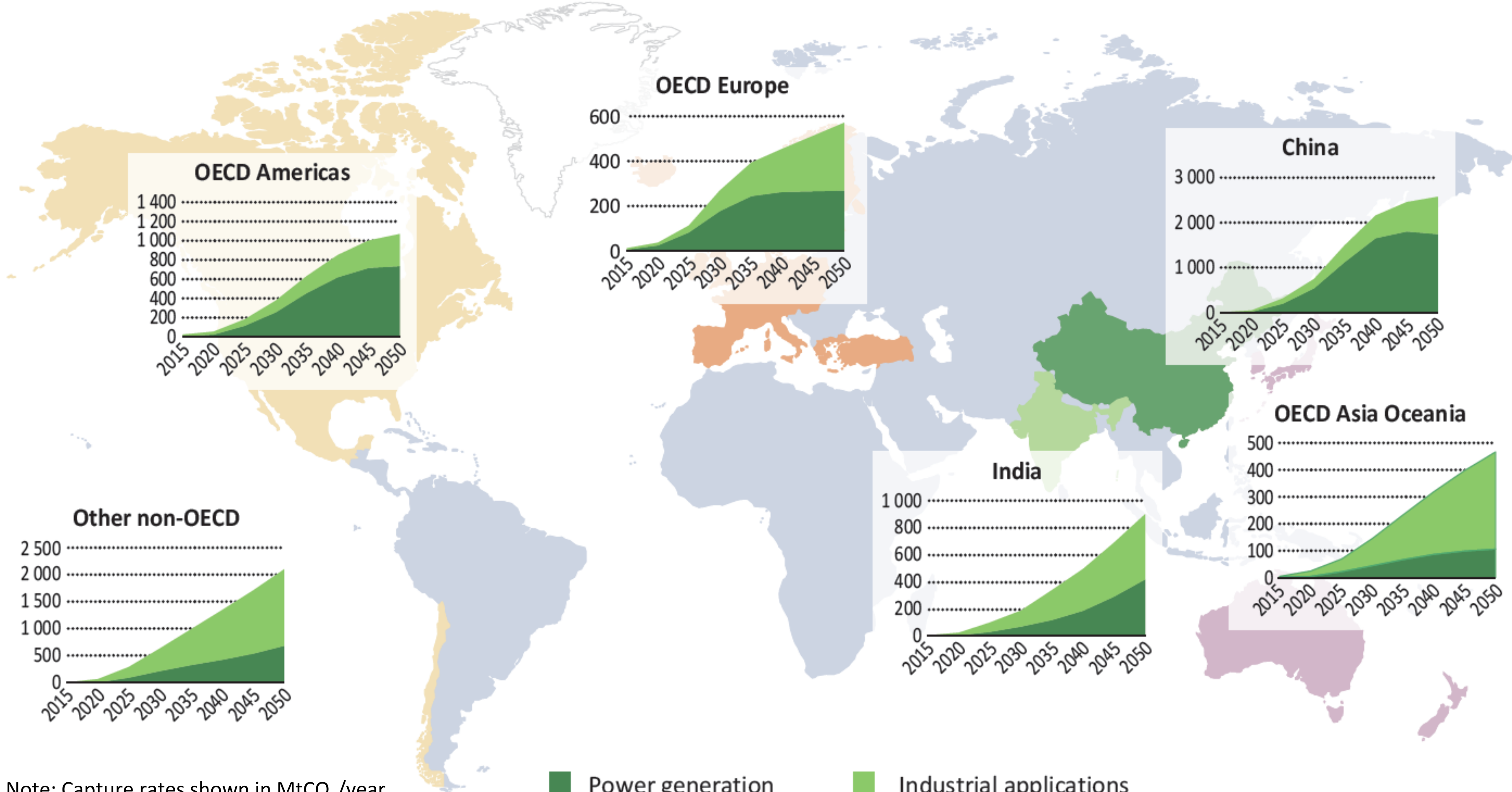
International Energy Agency

Generation from CCS equipped plants grows



Power plants with CCS produce 15% of electricity in 2050, while fossil-fueled plants without CCS produce only 10%

CCS is applied in power *and* industry

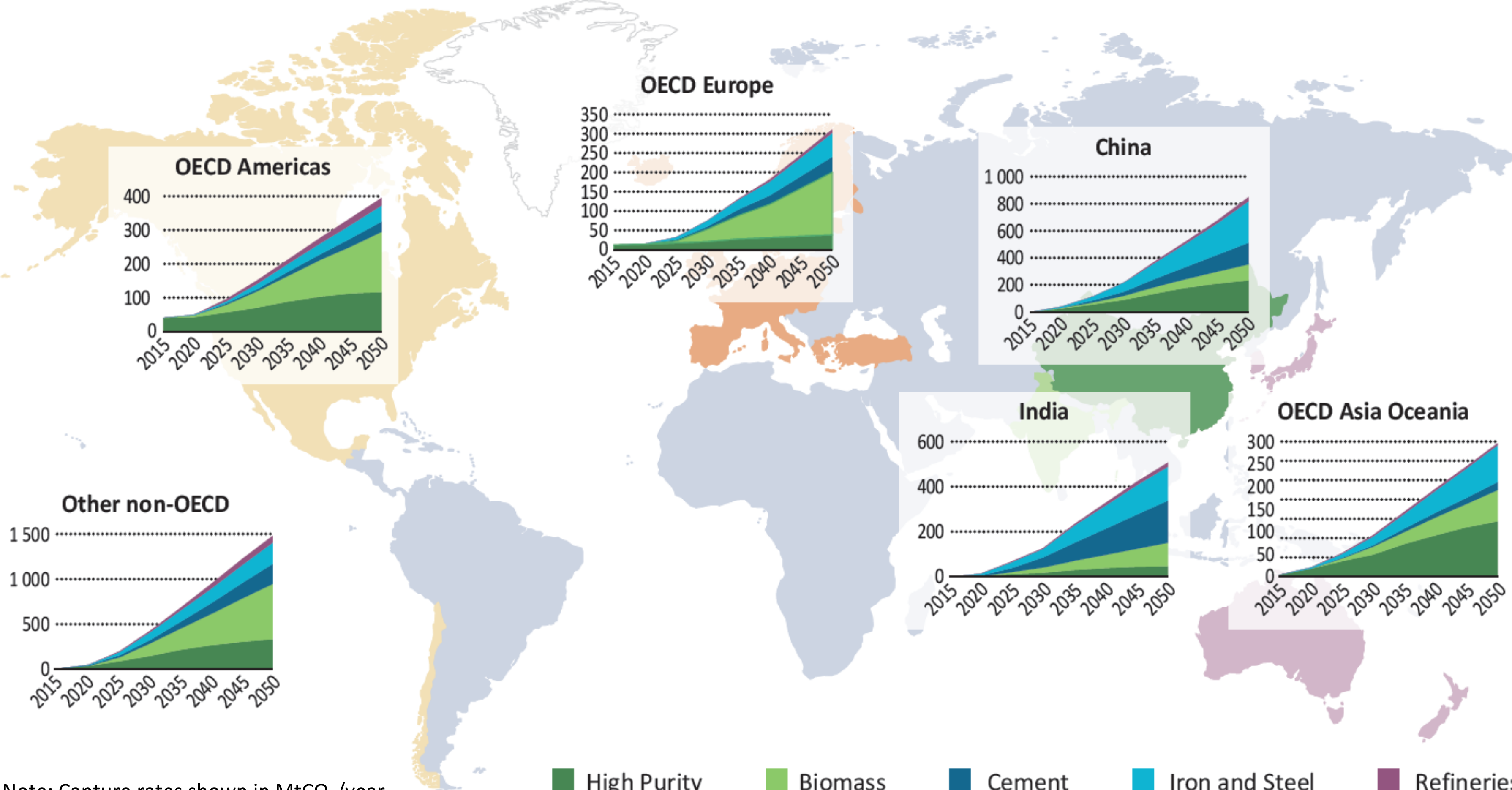


Note: Capture rates shown in $MtCO_2$/year

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The majority of CO_2 is captured from power generation globally, but in some regions CO_2 captured from industrial applications dominates

Industrial applications vary by region



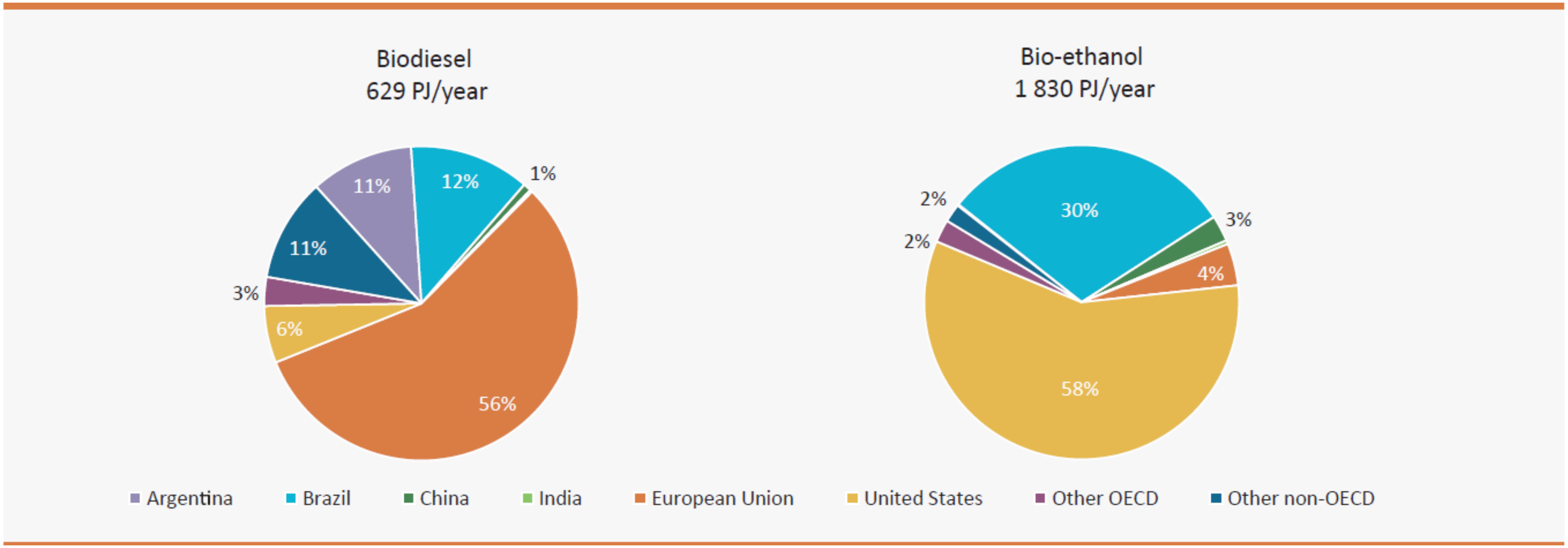
Note: Capture rates shown in $MtCO_2$/year

This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

The predominant industrial application of CCS will vary by region and over time

A closer look at today and near term in bioenergy and CCS

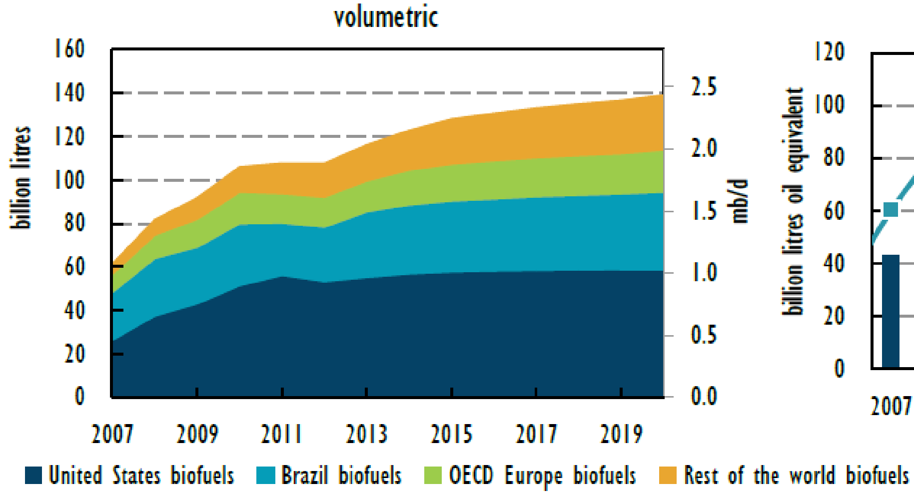
Regional Biofuel production capacity in 2010

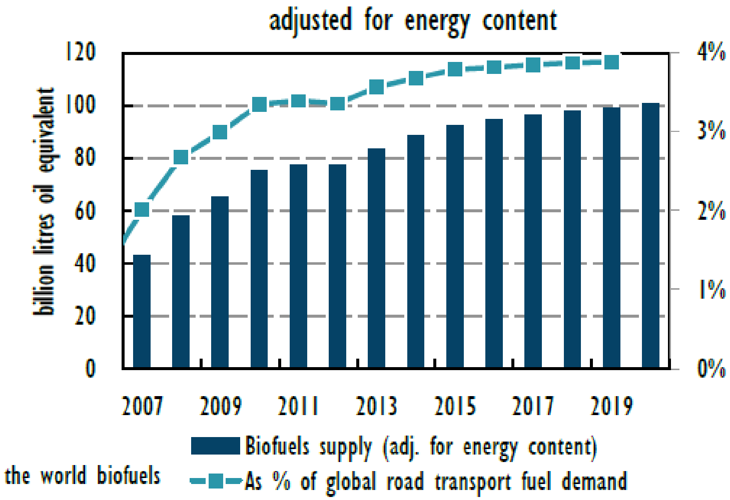


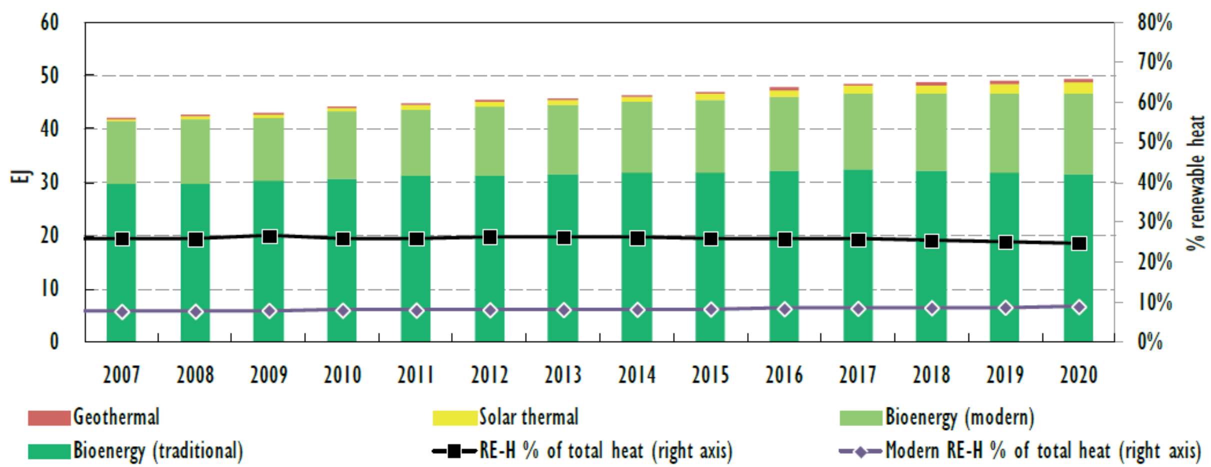
Source: IEA Biofuels Technology Roadmap (2012)

The major share of global biodiesel capacity is installed in Europe, while the United States and Brazil lead in bio-ethanol production

World biofuels production, historical and IEA MRMR projected 2007-20



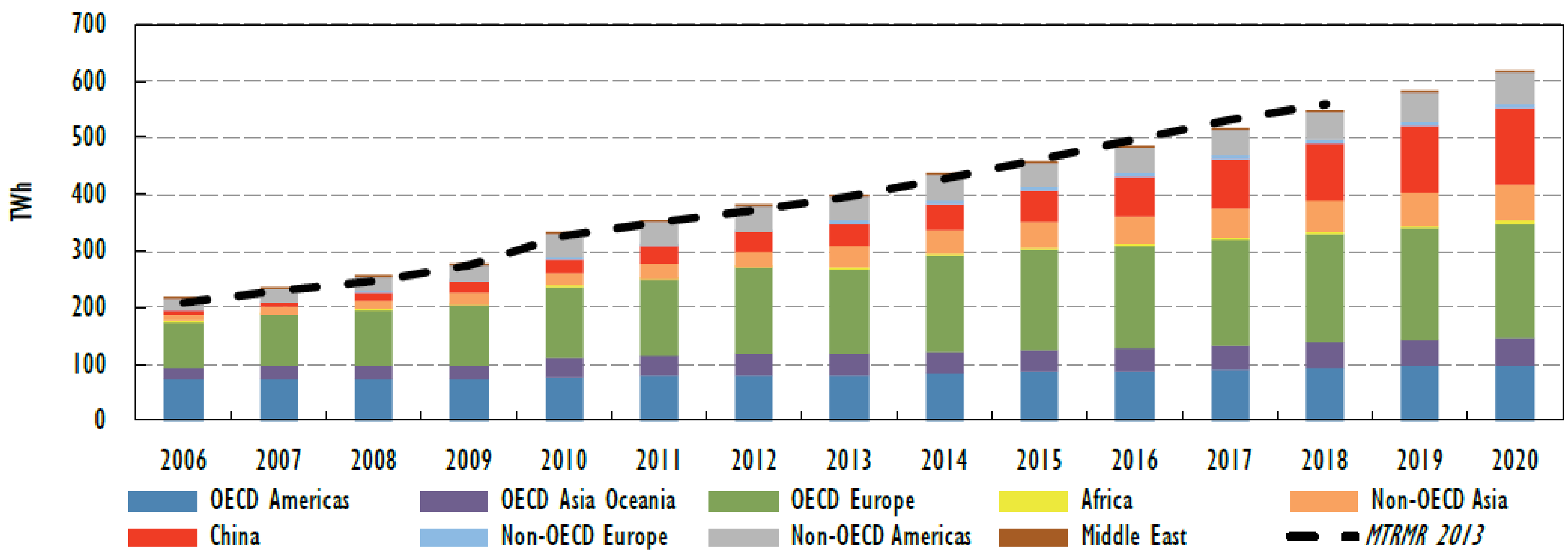




Note: RE-H = renewable heat. Traditional biomass is estimated here – in line with the methodology used in the IEA *World Energy Outlook* (*WEO*) – as the use of solid biomass in the residential sector of non-OECD countries, excluding countries in non-OECD Europe and Eurasia.

In China bioenergy in power was up 5 TWh year-on-year reaching 39 TWh in 2013.

Bioenergy power generation and projection by region

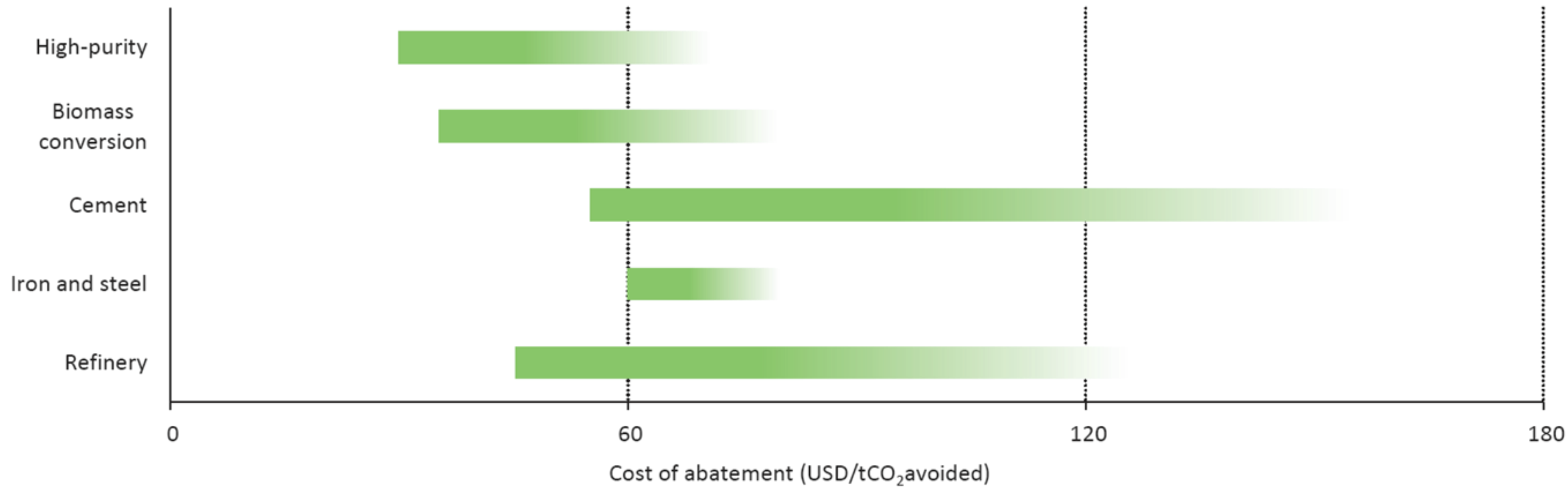


Note: includes generation from renewable municipal solid waste.

Developments in China continue to be driven by incentives for co-firing of agricultural residues and waste-to-energy projects

Now… a look at CCS

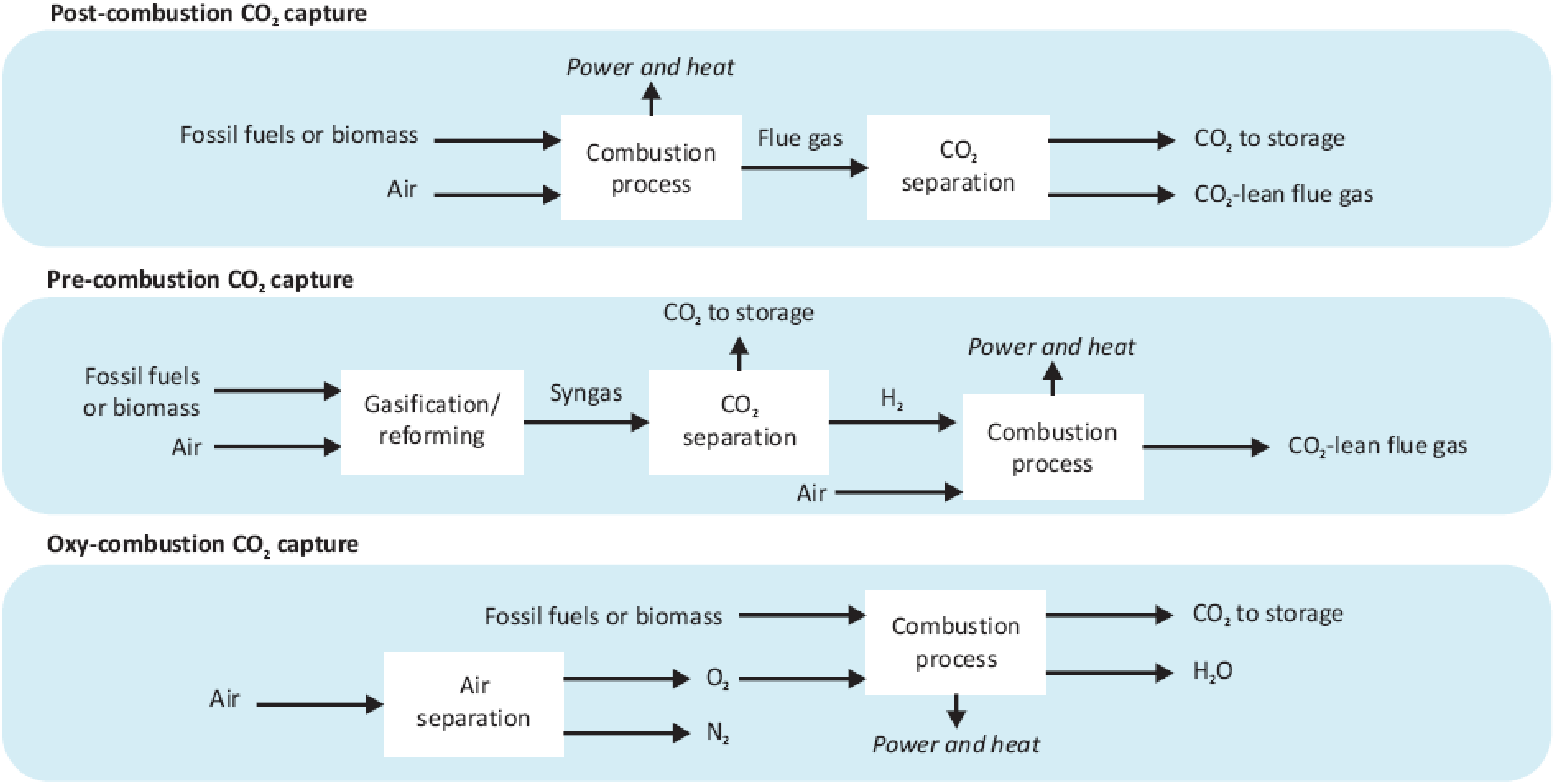
Cost of CCS in industry varies widely



Notes: The range of costs shown here reflect the regional average cost of applying CCS in each sector, and, therefore, the overall cost of abatement in a sector will be affected by the assumed level of CCS uptake in each sector (IEA, 2009 and IEA and UNIDO, 2011). These costs include the cost of capture, transport, and storage, but do not assume that storage generates revenues – *i.e.* CO_2 storage through enhanced oil recovery (EOR) is not considered as a storage option.

A wide range of abatement costs through CCS exists in industrial applications

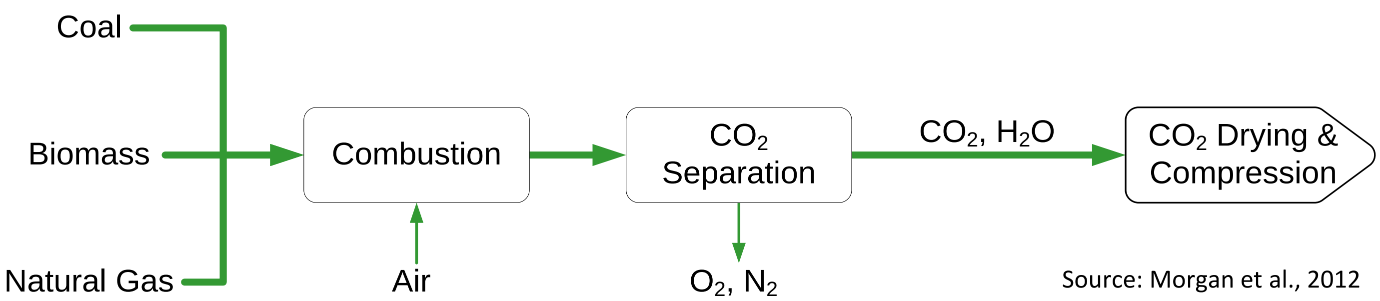
Three CO_2 capture routes



At the present time, no one route is clearly superior to another; each has particular characteristics that make it suitable in different cases of power generation fuelled by coal, oil, natural gas and biomass.

How do you retrofit?
Post-combustion CO_2 Capture for power

Process Layout



Source: Morgan et al., 2012

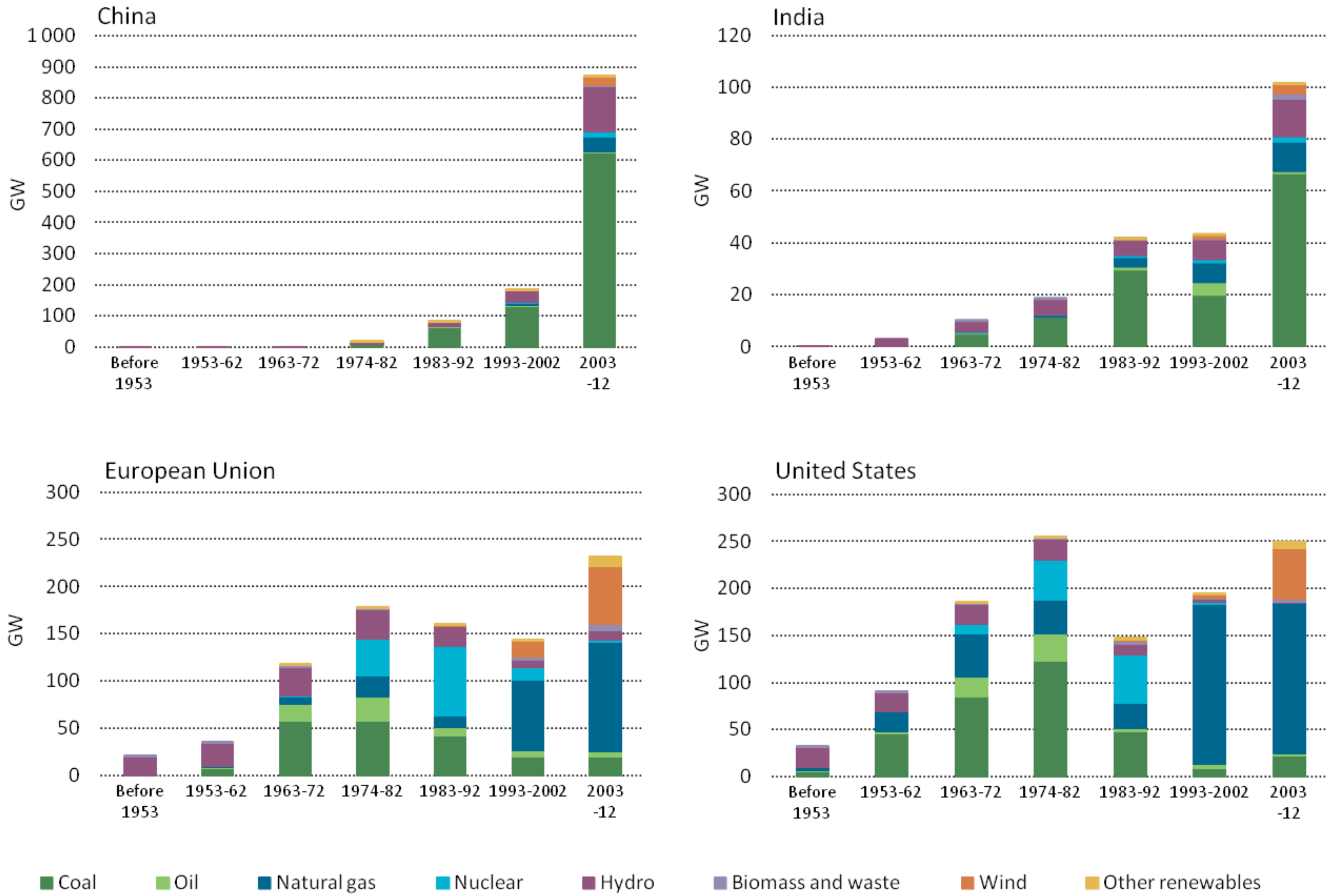
Demo plants

100 MW, Boundary Dam Project, Canada. SaskPower

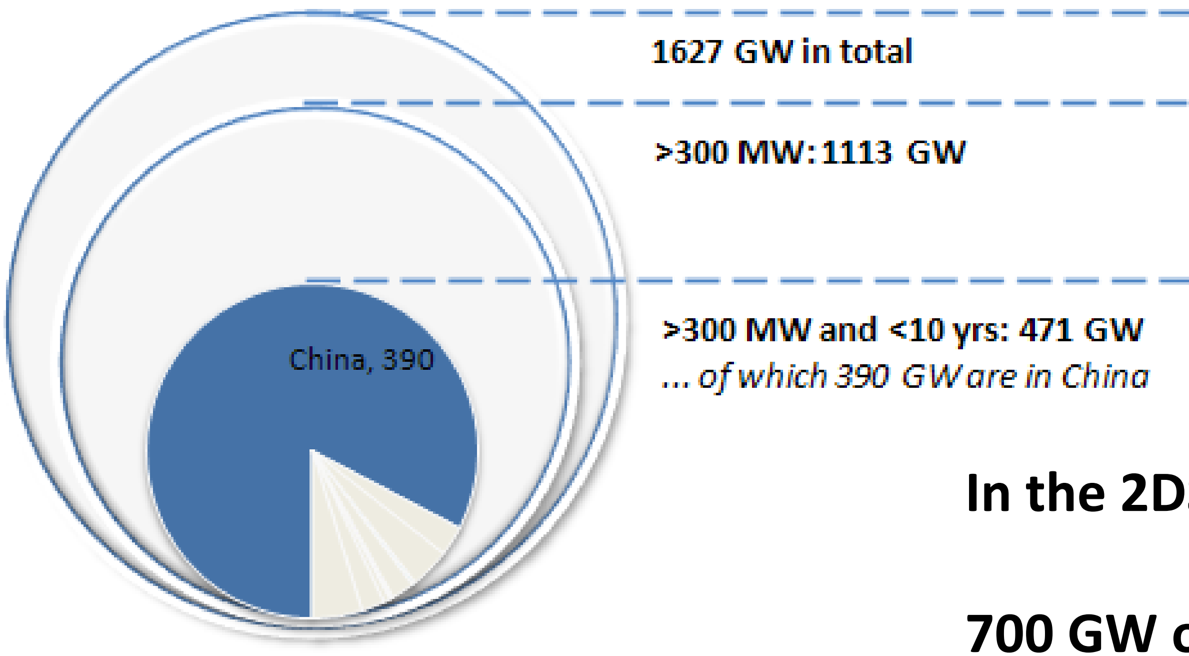
Key challenges & development trends

- Scale-up of capture equipment; prove commercial size application at power plants
- Low-cost absorber designs
- Develop solvents with reduced energy penalty and minimized slip to ambient
- **(needed space)**

Age distribution of existing power plants



Retrofitting CCS to coal-fired generation



In most general terms, larger, more efficient (i.e. younger) plants are suitable for retrofit

Source: IEA, 2012

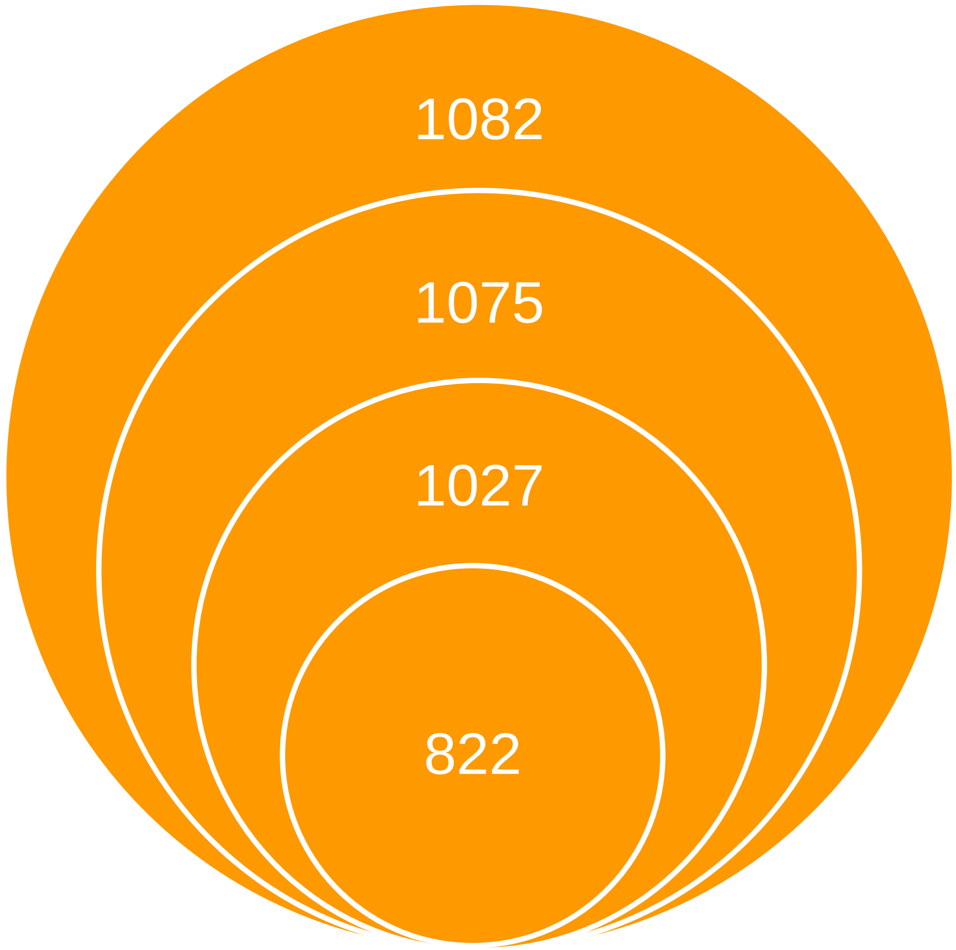
In the 2DS, through 2050:

700 GW of subcritical capacity is retired

150 GW of uneconomic supercritical and ultra-supercritical are retired

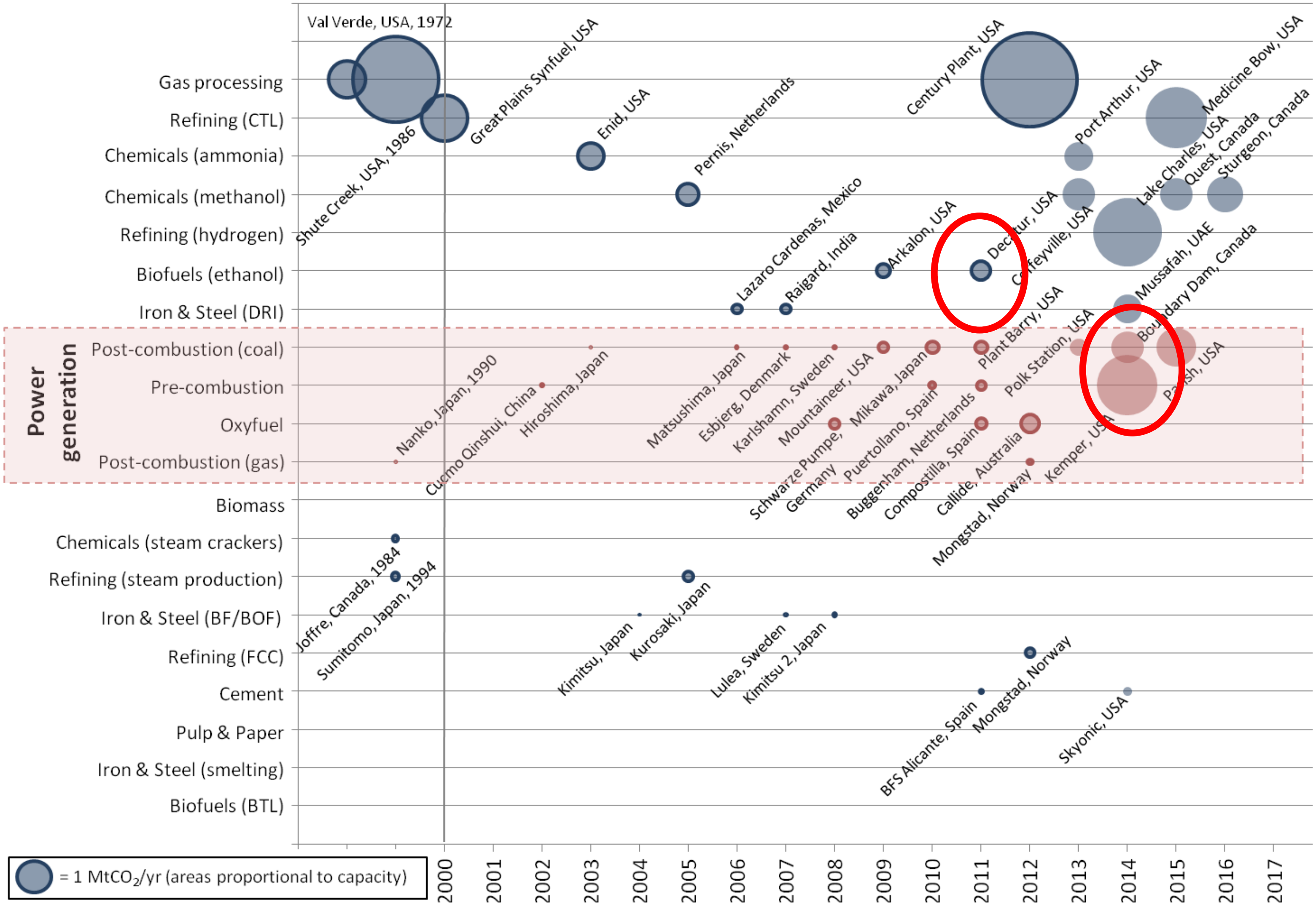
100 GW of coal are retrofitted with CCS

2014 IEA-CEC China Study: Preliminary findings



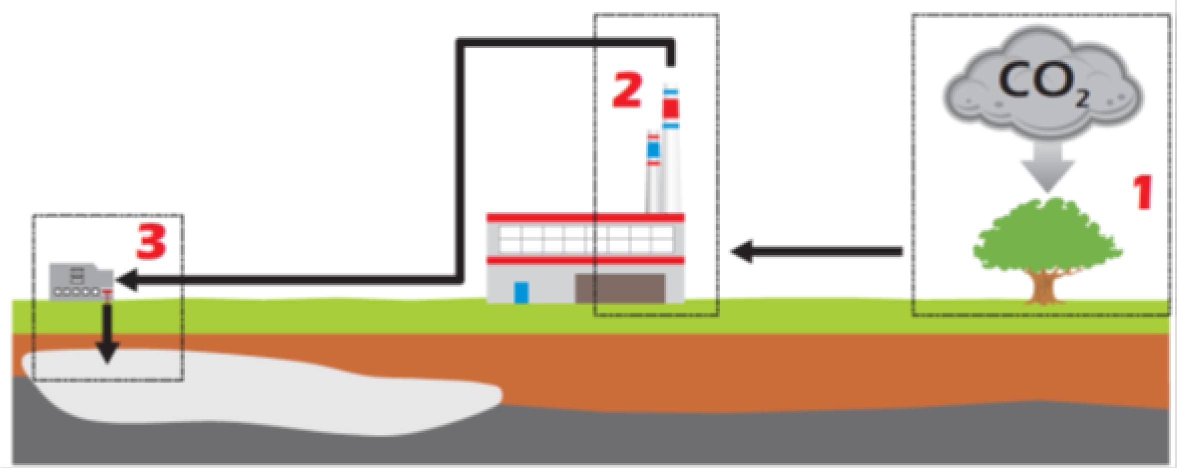
All units >200MW and commissioned after 2000	508 GW
Plus, efficiency >40%	506 GW
Plus, “Wet” FGD	585 GW
Plus, Average load factor >75% in 2012 and 2013	385 GW

Project experience in power and industry-CCS

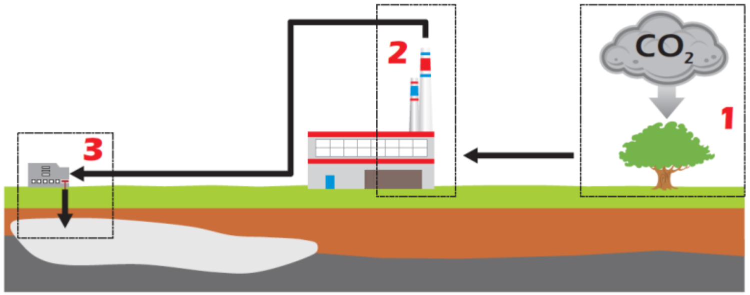


Source: Industry-CCS annex to IEA TCEP report 2013.

A closer look at BECCS and negative emissions



Negative emissions from BECCS by linking the Chain



- Bio-energy with carbon capture and storage (BECCS) can result in permanent net removal of CO_2 from the atmosphere, i.e. "negative CO_2 emissions"
- In BECCS, energy is provided by biomass, which removed atmospheric carbon while it was growing, and the CO_2 emissions from its use are captured and stored through CCS
- BECCS can be applied to a wide range of biomass conversion processes and may be attractive cost-effective in many cases

Biomass must be grown and harvested sustainably, as this significantly impacts the level of emissions reductions that can be achieved

Exploring BECCS potentials in emerging economies: Indonesia, Brazil, …

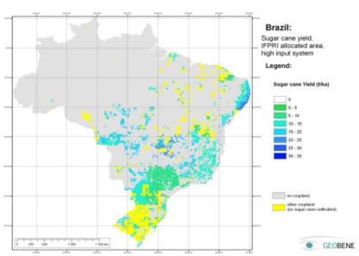
Bioenergy Plus Carbon Capture And Storage Options for Indonesia

Jakarta workshop: IIASA, IEA, the Republic of Indonesia's Ministry of Energy and Mineral Resources (MEMR) and President's Delivery Unit for Monitoring and Oversight (UKP4), the School of Business and Management at Bandung Institute of Technology (SBMITB).

Preliminary Results
– optimal siting and scaling of bioenergy plants

- Methanol production
  - Highest biofuel efficiency (55% energy content)
- Plant capacity: 650,000 t wood/year
- Total biofuel output: ~79,000 toe/year

Similar studies conducted in Europe, Japan, Republic of Korea, Russia



International Institute for Applied Systems Analysis
IIASA

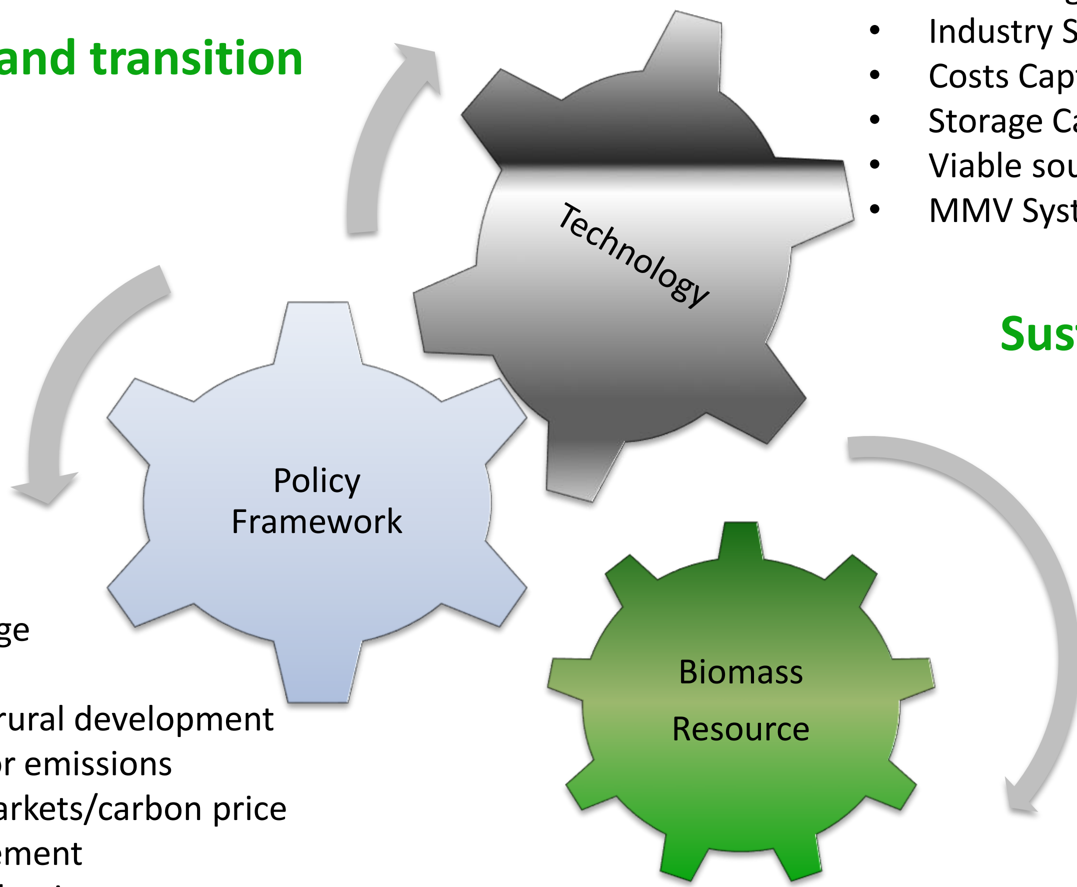
USP
NUPPREC

International Energy Agency
iea

Bioenergy and CCS – A complex technology, resource and policy chain

Innovation and transition

- Technology R&D policy (Biomass/CCS)
- Industry Sectors
- Costs Capture, Transport, Storage
- Storage Capacity potential
- Viable source and sinks (Clustering)
- MMV Systems



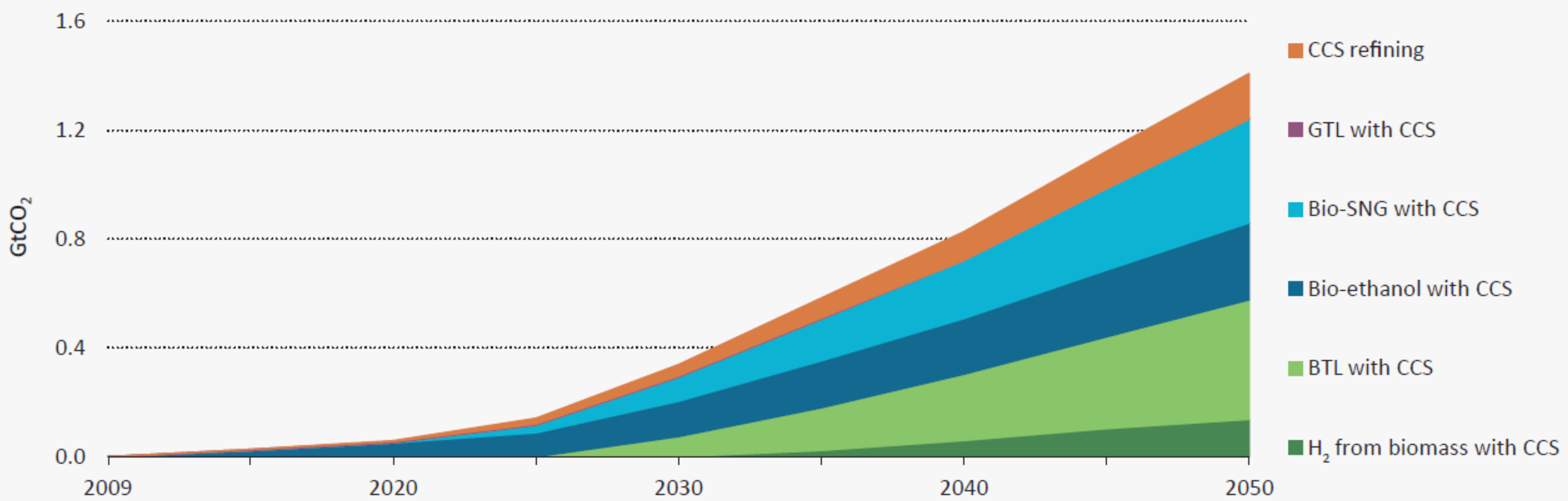
Sustainability

- Resource availability
- Transport/supply
- Lifecycle Costs
- Sustainability/LULUCF
- Scale
- Markets and Trade

- Climate Change
- Economics
- Biomass and rural development
- Accounting for emissions
- Incentives/markets/carbon price
- Public engagement
- financing mechanisms

Economics and development

CO2 captured in the fuel transformation sector in the 2DS



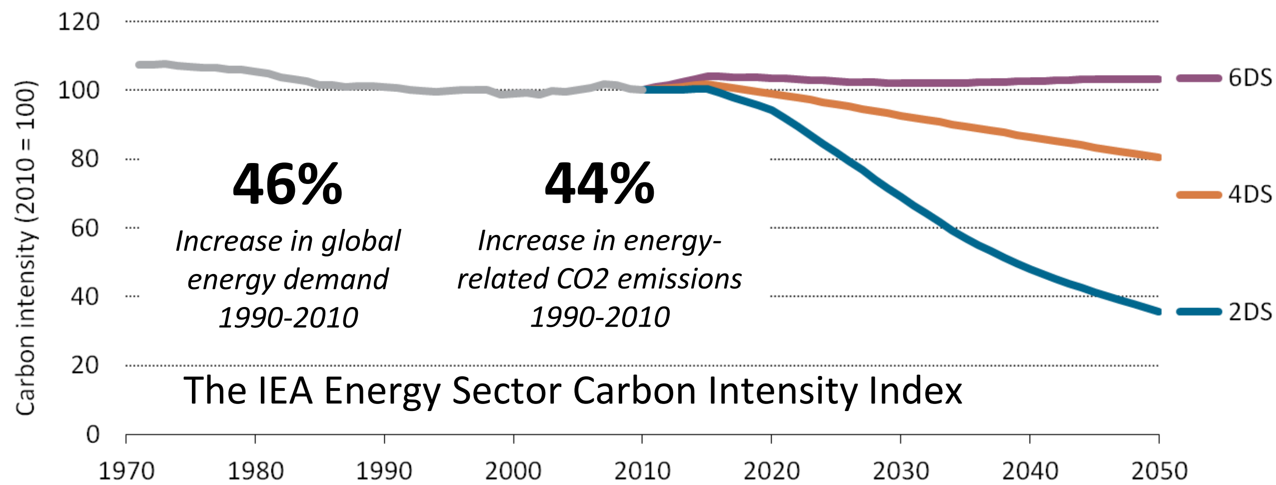
Source: IEA Biofuels Technology Roadmap (2012)

Biofuel production with CCS can lead to “negative”emissions

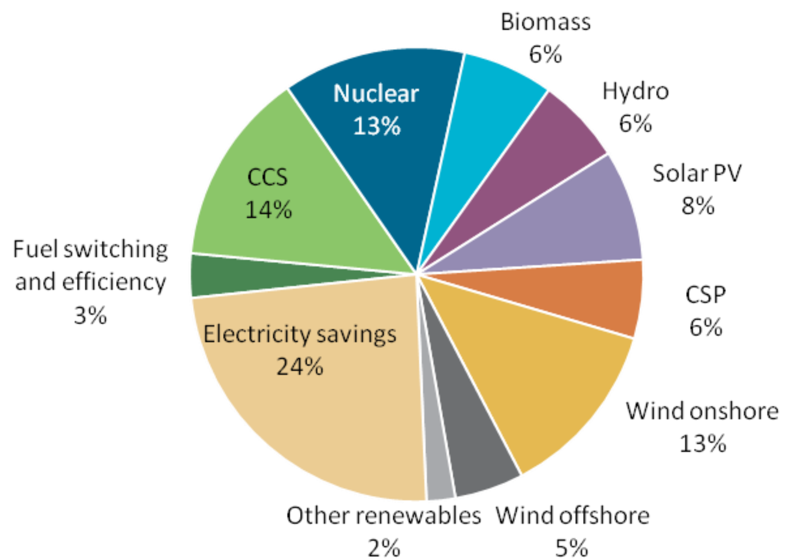
International Energy Agency

- **The World faces a challenge!**

Global energy supply is as carbon intensive today as it was in 1990.



- **But solutions exist!**



Contribution of technologies to cumulative reductions (2011-2050) of 296 Gt in the power sector

A path to negative emissions: key points

- Provides an opportunity to make significant CO2 emissions reductions…
- Impacts rural and economic development priorities
- Air quality impacts, transitioning and unlocking infrastructure

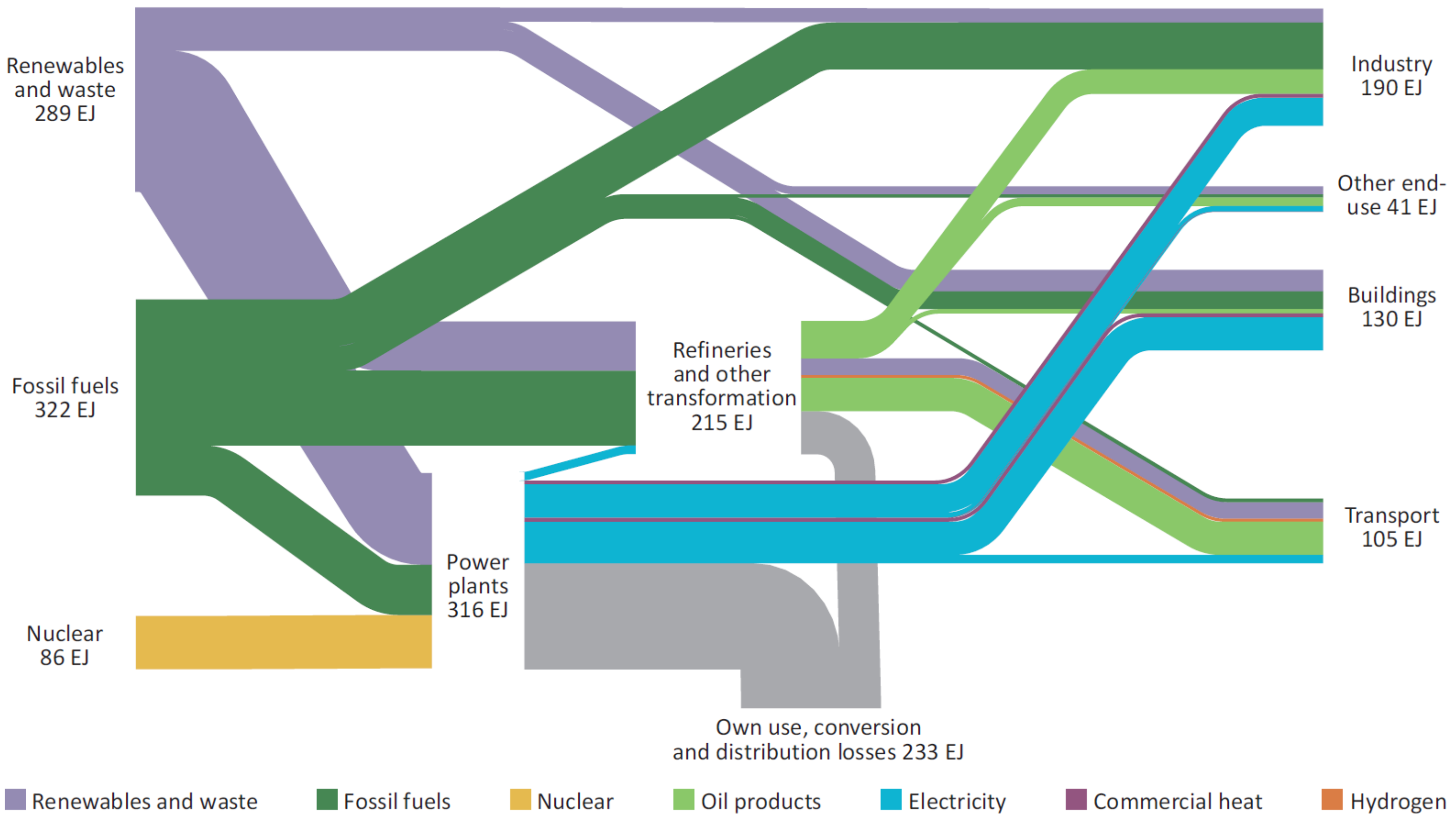
  high carbon → low carbon → carbon negative
- Short term steps in R&D that may lead to long-term actions and negative emission benefits
- Consider long-term feedstock sustainability, impacts to price and availability of commodities and land use change
- Synergies with REDD, forestry, waste utilization and related resource management, demand and distribution

Thanks for your attention!

Dennis Best

dennis.best@iea.org

The future low-carbon energy system



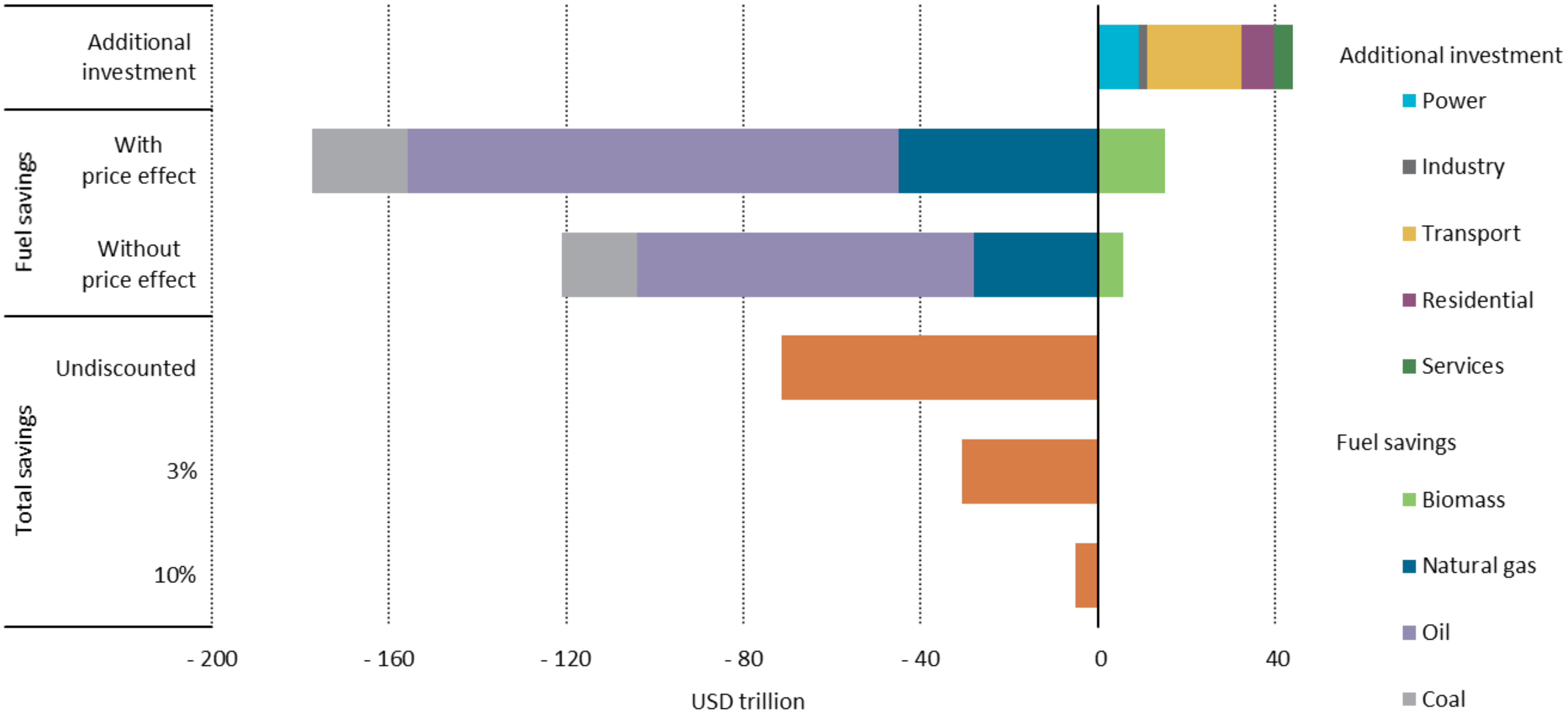
2DS in 2050 shows dramatic shift in energy supply and demand

China's capture pilot and demo projects

Project Title	Scale	Capture Tech	Storage/ Utilization	Status
The pilot project of CO2 Capture, Huaneng Beijing Gaobeidian Thermal Power Plant	Capture Capacity:3,000 T/Y	Post-Combustion	Food Use	Operated in 2008
Demonstration Project of CO2 capture and storage in Coal Liquification Plant, China Shenhua Group	Capture Capacity:100,000 T/Y Storage Capacity: 100,000 T/Y	Coal liquefaction	Saline Aquifer	operated in 2011
Demonstration Project of CO2 capture, Storage and Utilization in IGCC Plant Greengen of Huaneng	Capture Capacity:60,000-- 100,000 T/Year	Pre-Combustion	EOR	Launched in 2011
Small Scale Demonstration Project on CO2 Capture and EOR in Shengli Oil Field, Sinopec	Capture/Utilization:40,000T/Y	Post-Combustion	EOR	Operated in 2010
Demonstration Project of CO2 capture, Shanghai Shidongkou Power Plant, Huaneng	Capture Capacity:120,000 T/Y	Post-Combustion	Food/ Industrial	Operated since 2010
Demonstration project of Carbon Capture, Shuanghuai Power Plant, China Power Investment	Capture Capacity:10,000 T/Y	Post-Combustion	Food/ Manufacture	Operated in 2010
Pilot Plant of CO2 capture in Lianyungang City, CAS	Capture Capacity:30,000 T/Y	Pre-Combustion	N/A	Operated in 2011

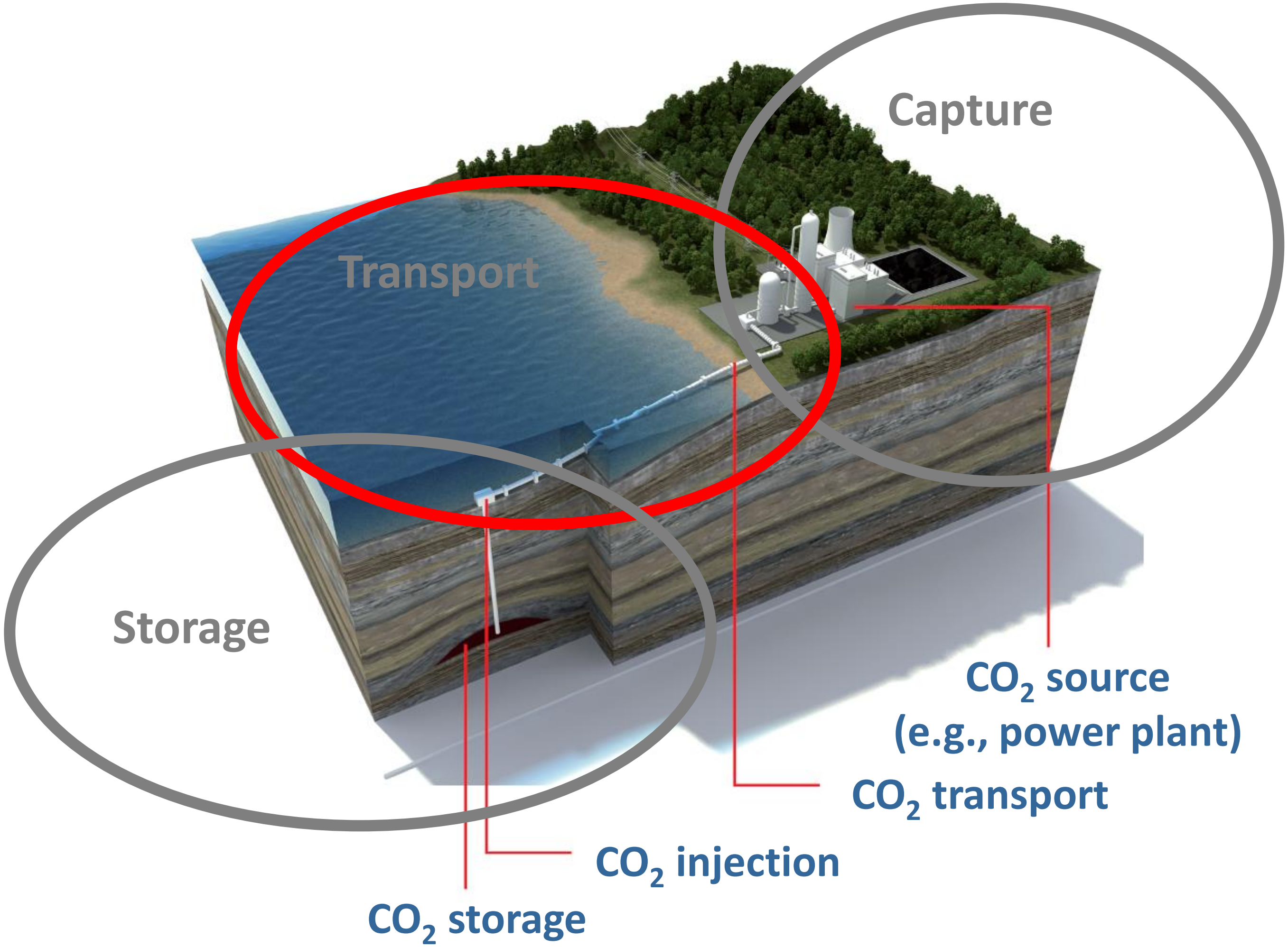
Source: Peng Sizhen, ACCA21, GCCSI Members Meeting , Tokyo, June 20th 2013

Investment in our future pays off…

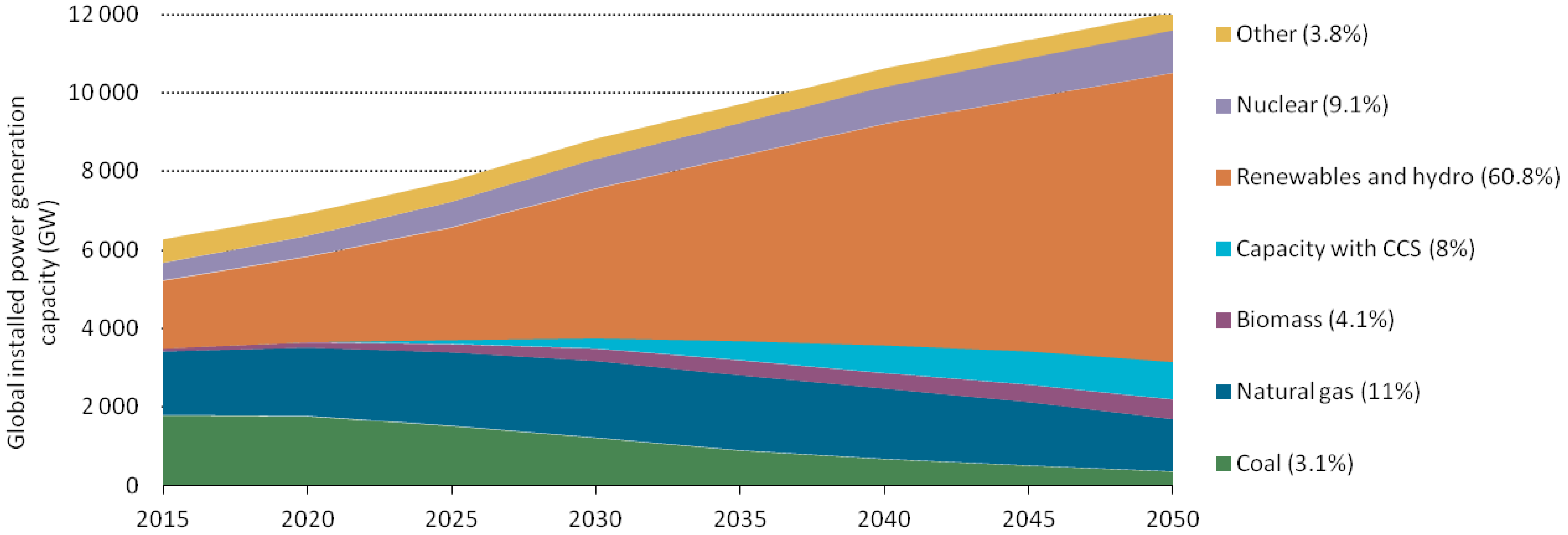


…and it is cost effective to make the transition

CCS Technology Chain

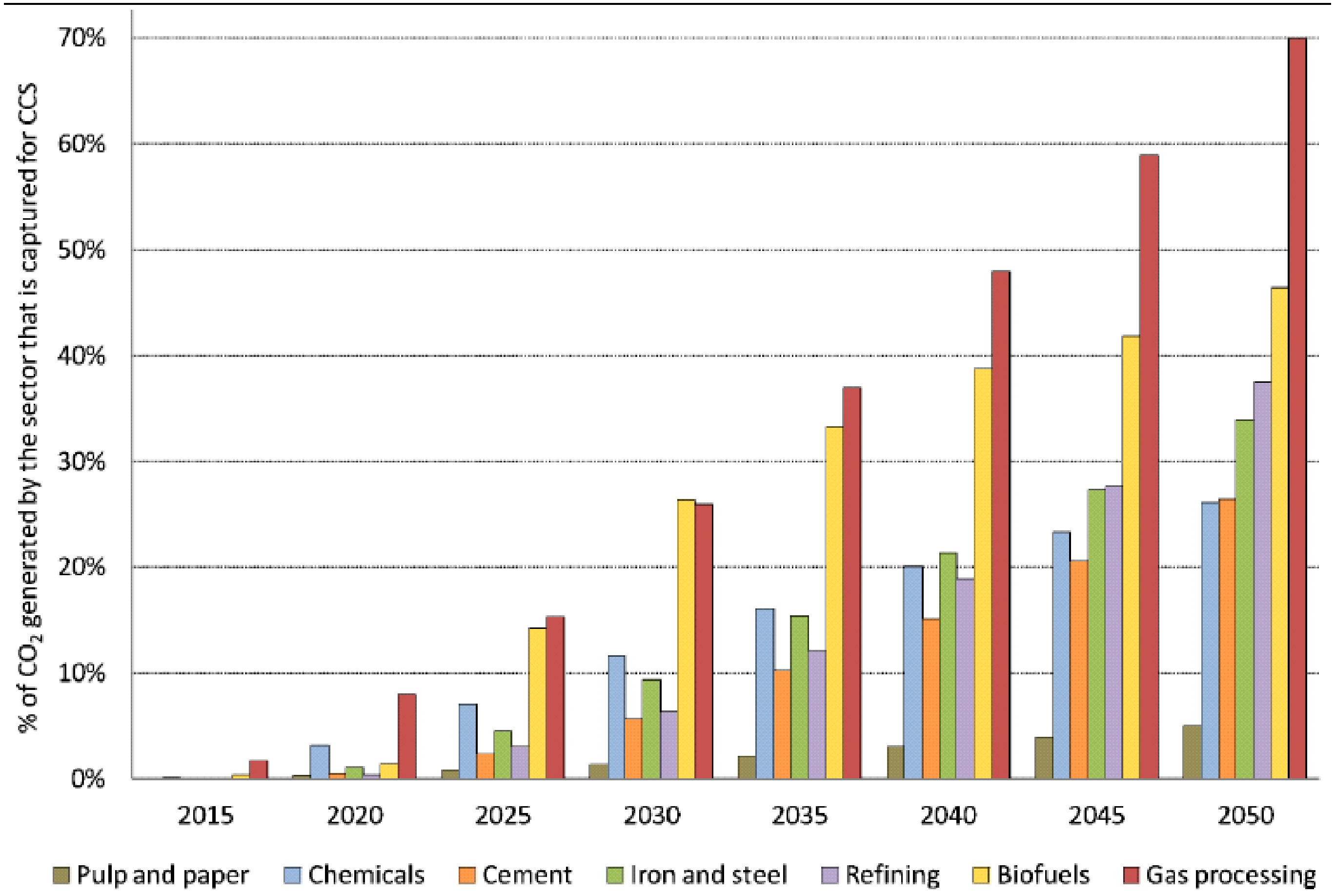


CCS is applied to coal, gas and biomass



In 2050, 63% of coal-fired electricity generation (630 GW) is CCS equipped, 18% of gas (280 GW) and 9% of biomass (50 GW)

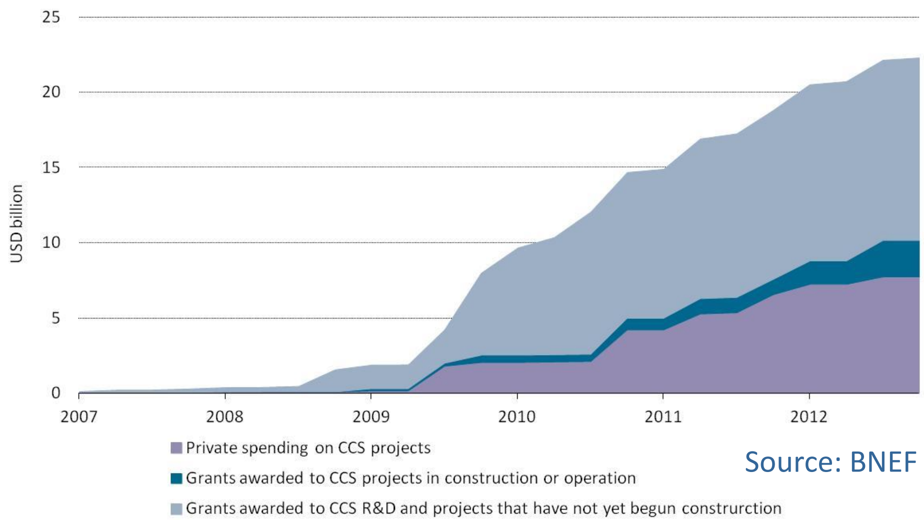
Proportion of CO2 generated globally that is captured and stored through CCS in the sectors analysed in the 2DS



Source: IEA (2012b).

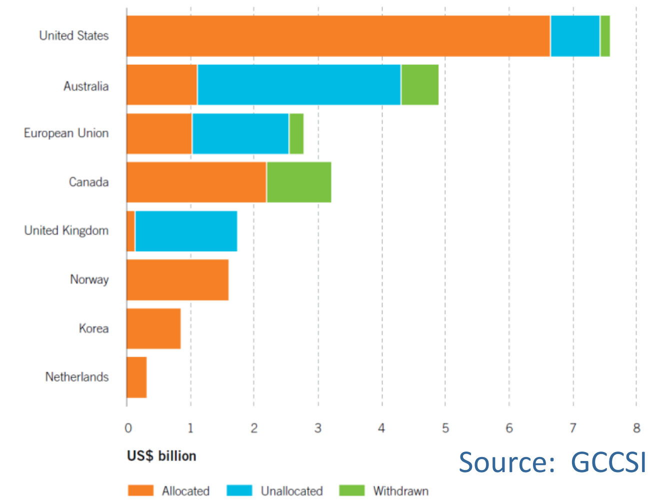
Inputs into CCS are not negligible...

Money spent on CCS projects globally



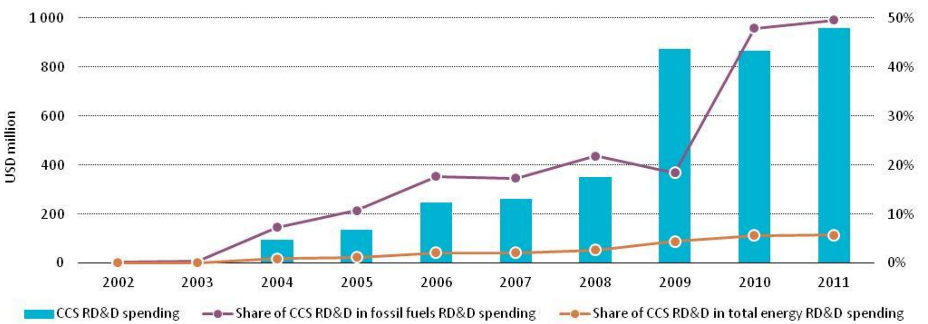
Source: BNEF

Government pledges for CCS support



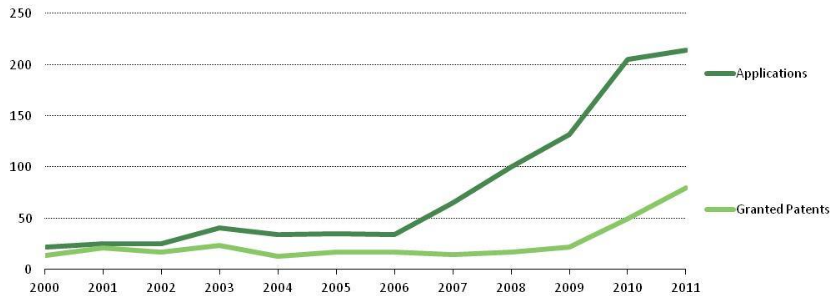
Source: GCCSI

R&D spending on CCS technologies by IEA countries



Source: IEA

Numbers of CCS-related patents



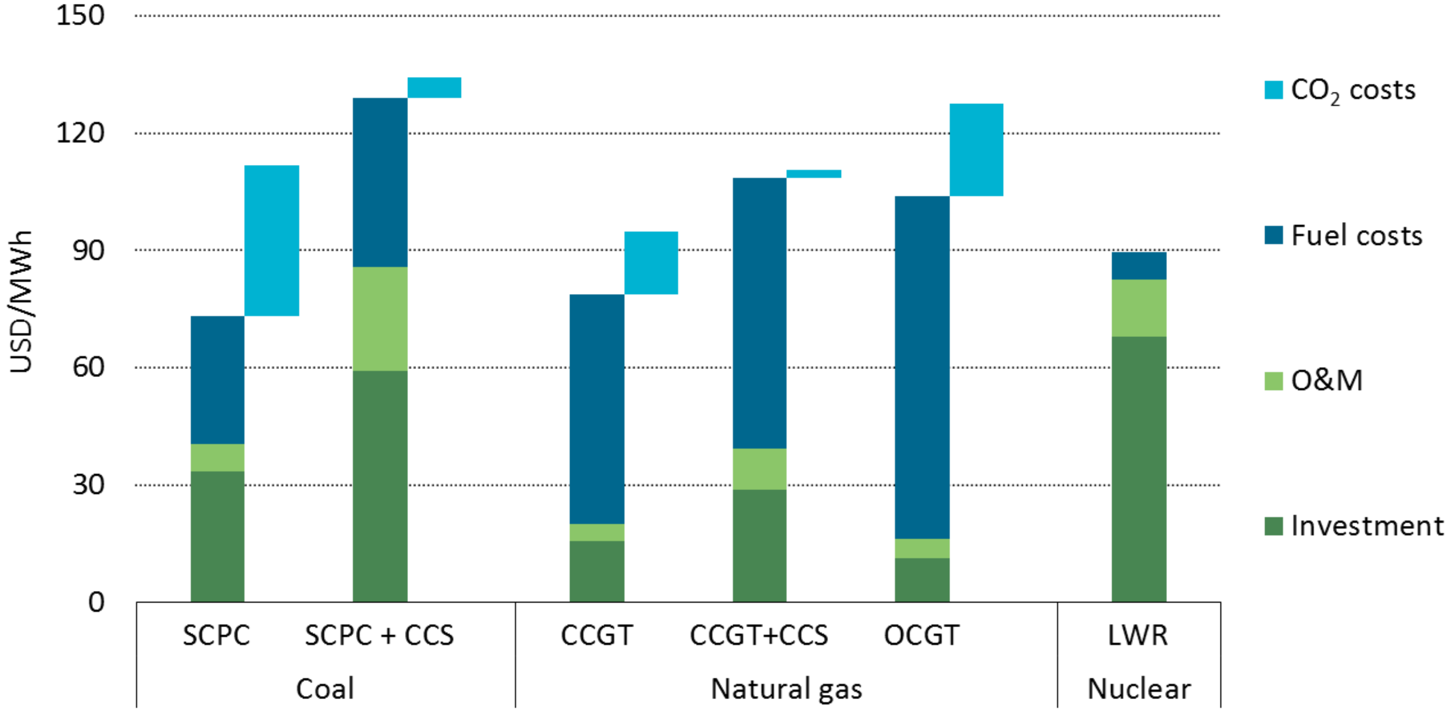
Source: IEA

International Energy Agency

Without CCS natural gas power generation is not carbon free

EU, 2020

46 USD/t CO_2



Gas w/o and w CCS can become cheaper than coal w CCS; under high CO_2 prices (100 USD/t CO_2) CCS for natural gas is less expensive than CCS for coal.