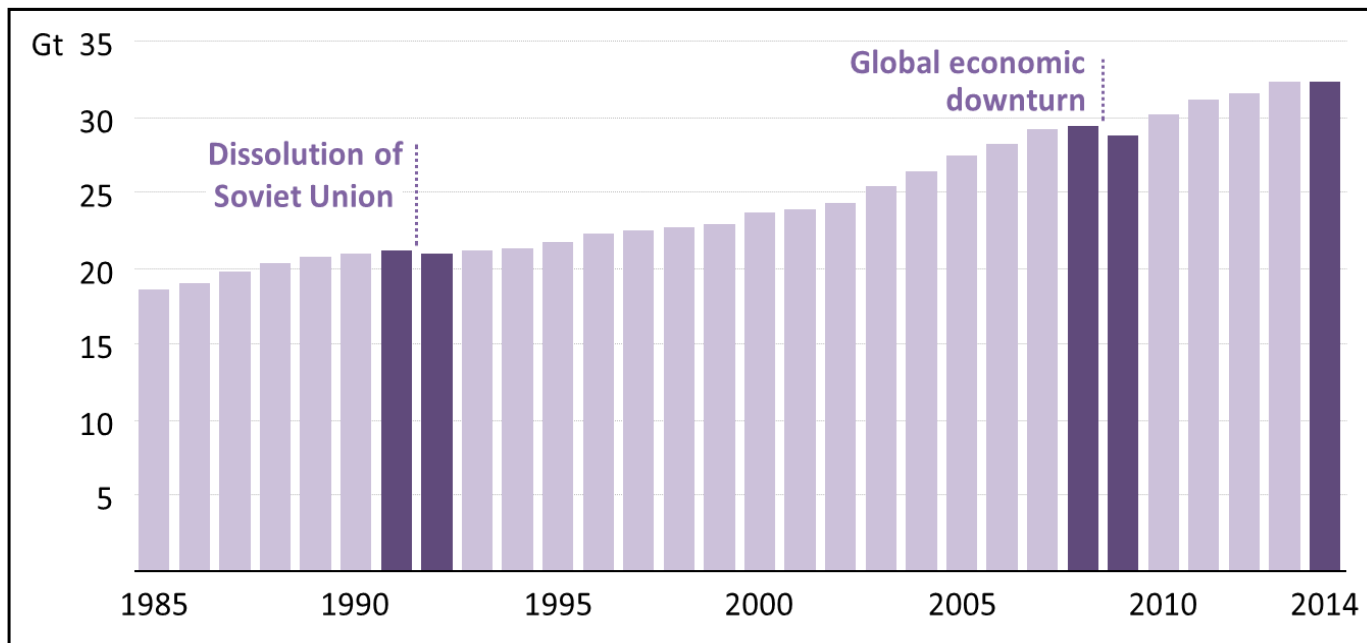


# **Nuclear Energy: Combating Climate Change**

**Prof. Dr. Jan Horst Keppler and Dr. Henri Paillere**  
**OECD Nuclear Energy Agency (NEA)**  
**Nuclear Development Division (NDD)**

# Energy-related CO2 emissions since 1985

- Energy use is responsible for about 70% of total, global GHG emissions.
- Carbon-dioxide (CO2) constitutes 90% of total energy-related emissions, two thirds of total emissions. Nitrous oxide (N2O), methane (NH4) make up remaining 10%.
- In energy sector, CO2 is *exclusively* generated by fossil fuel (coal, oil, gas) combustion.

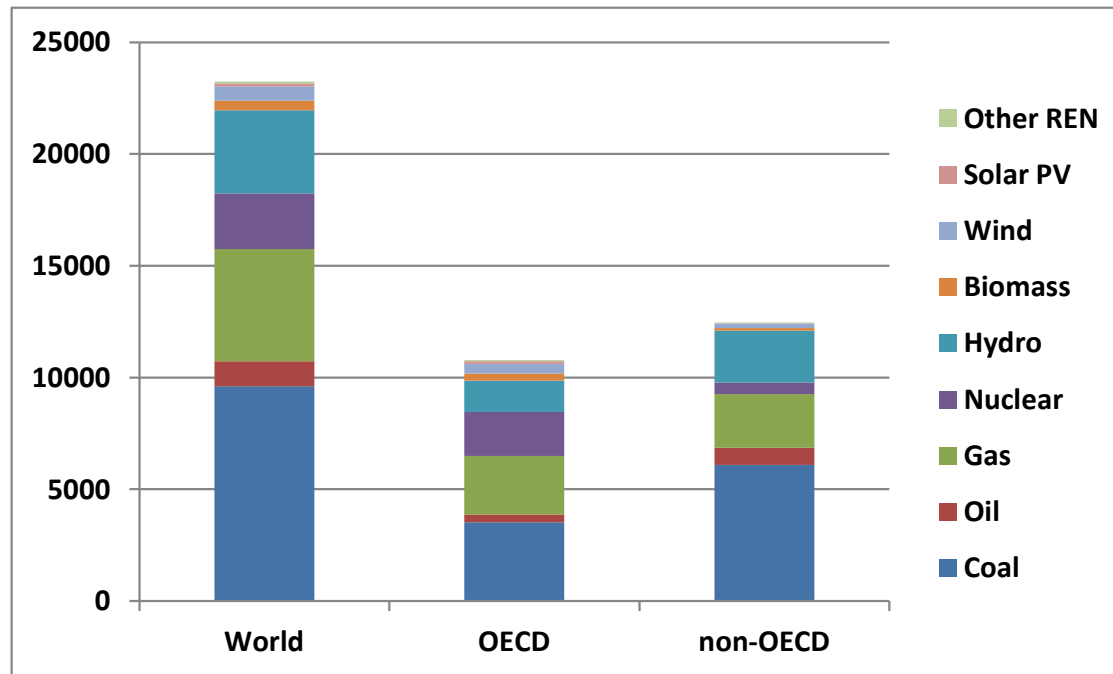


Source: IEA

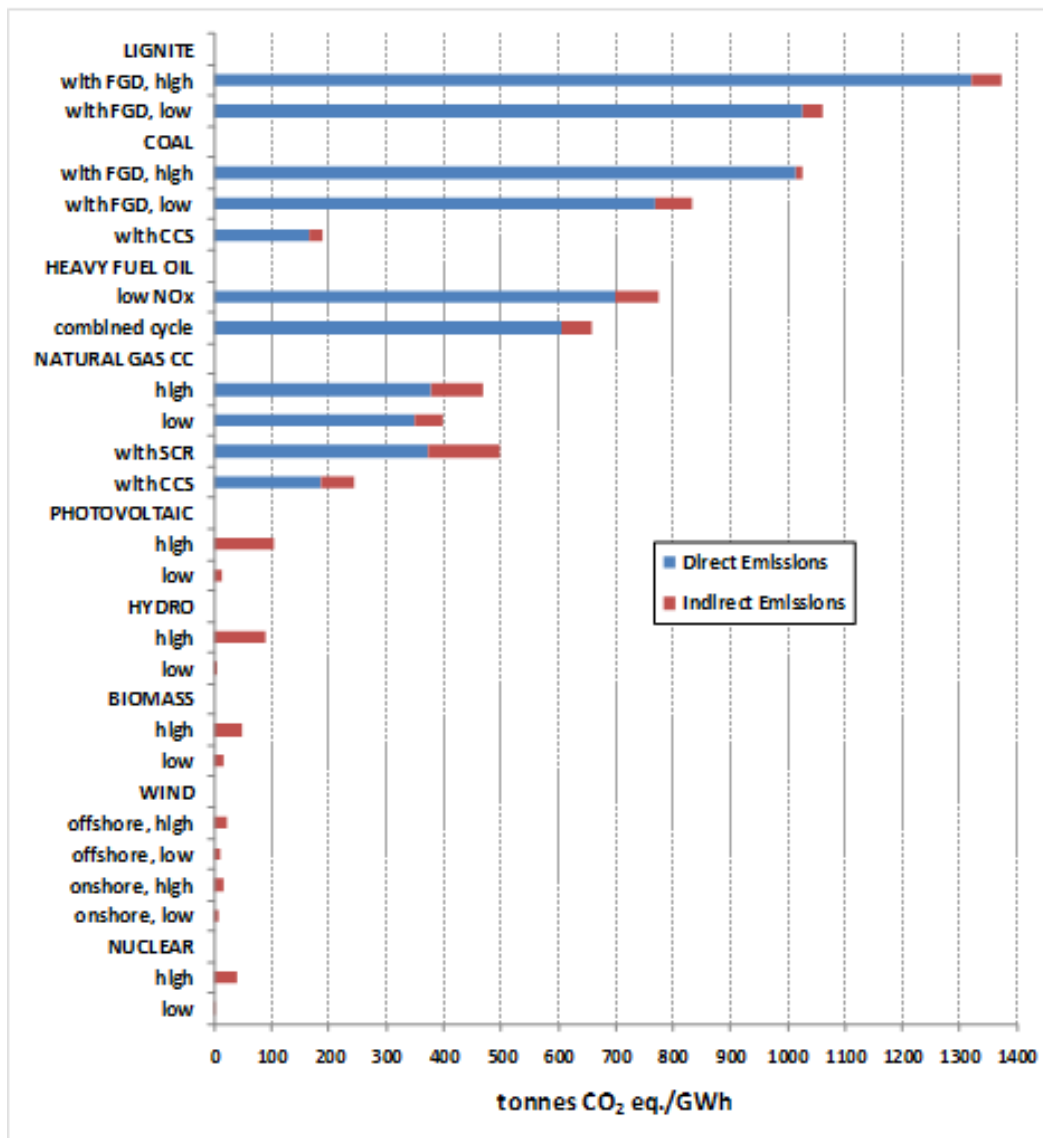
- Coal contributes 44% of energy-related CO2 emissions (29% of energy demand), oil 35% (31%) and gas 20%. (21%).

Electricity produces 40% of CO2 emissions, 30% of total emissions and rising share.

- Coal produced 41% of electricity globally, 33% in OECD and 49% in non-OECD countries. Of ca. 4 000 coal plants in the world, only one is equipped with CCS.
- Gas 22% (26% and 19%)
- Hydro 16% (13% and 19%)
- Renewables (wind, solar PV, biomass, geothermal and marine) 6% (8% and 3%)
- **Nuclear energy 11% (18% and 4%).**



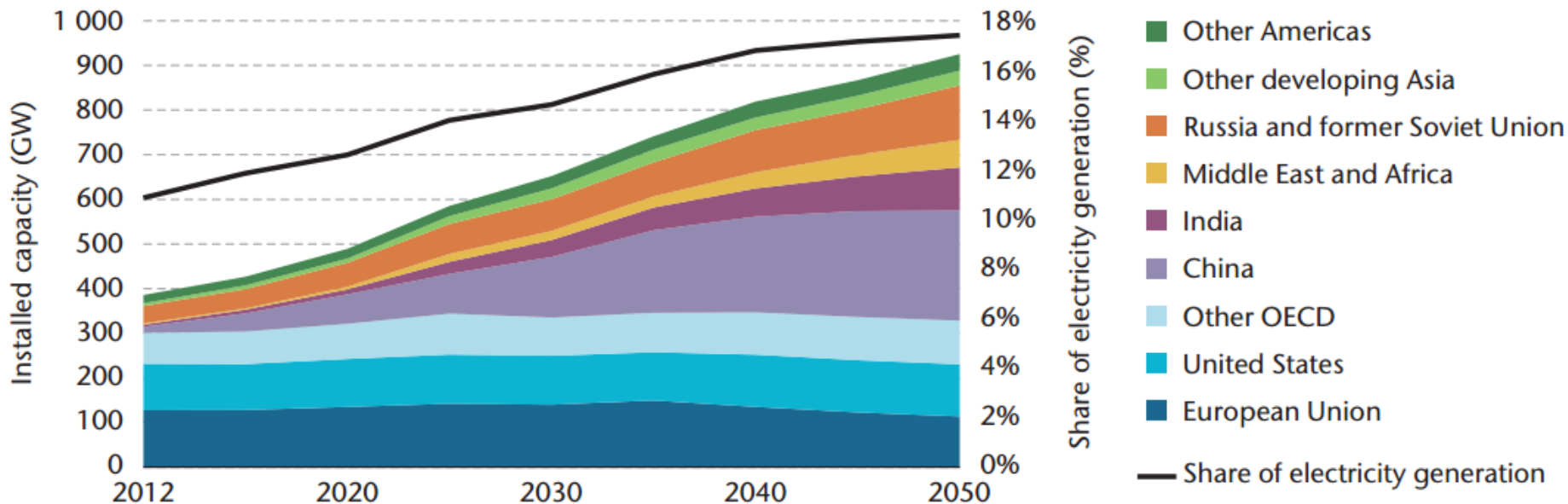
# Carbon Content of Electricity Produced by Different Sources



Source: UNFCCC

- IEA's *Energy Technology Perspectives 2015* expect current nuclear capacity of 376 GW to more than double by 2050 to reach 18% of global electricity supply (see below).
- Compare to WNA's objective of achieving 25% of supply by 2050 (A. Rising, 9/15) and 552 GW by 2035 (WNA Nuclear Fuel report, 9/15).
- IAEA says 385 GW (low growth) or 632 GW (high growth) by 2030.

## Projected nuclear capacity and share of global electricity generation in the IEA's ETP 2015 2 degree scenario

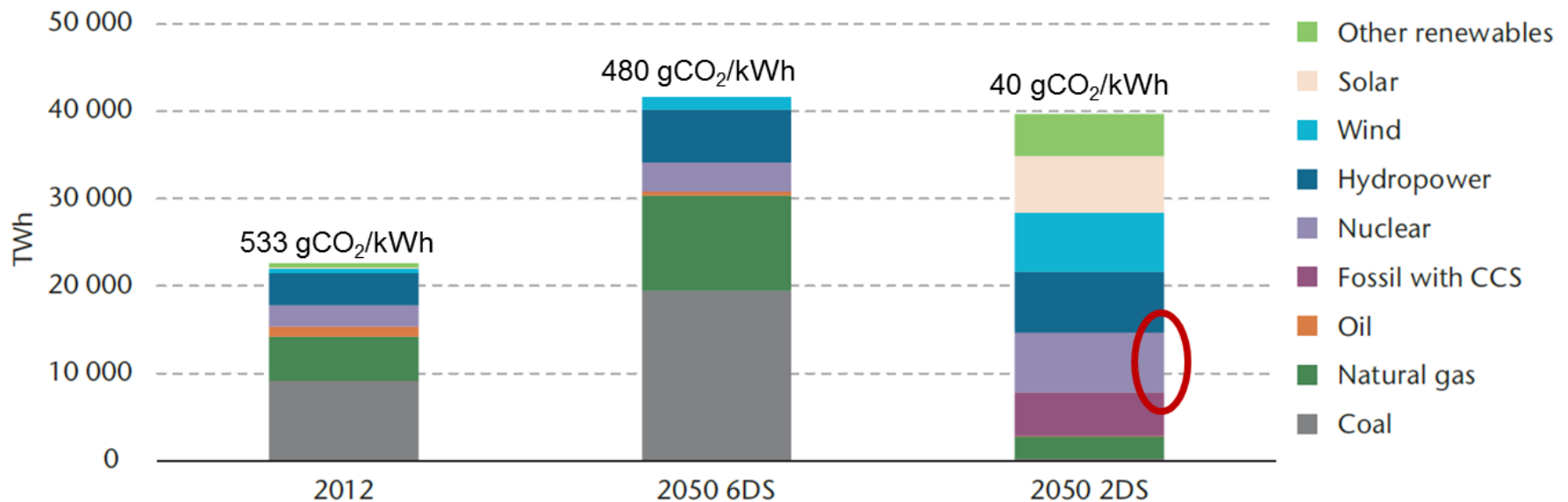


Source: IEA

"Why the Climate Needs Nuclear Energy", NEA/IAEA Side-event at COP21, 10-11 December 2015

- The rise of nuclear would need to be accompanied by a *complete phase-out* of coal and oil, a drastic decrease of gas and a massive increase of renewable energies.

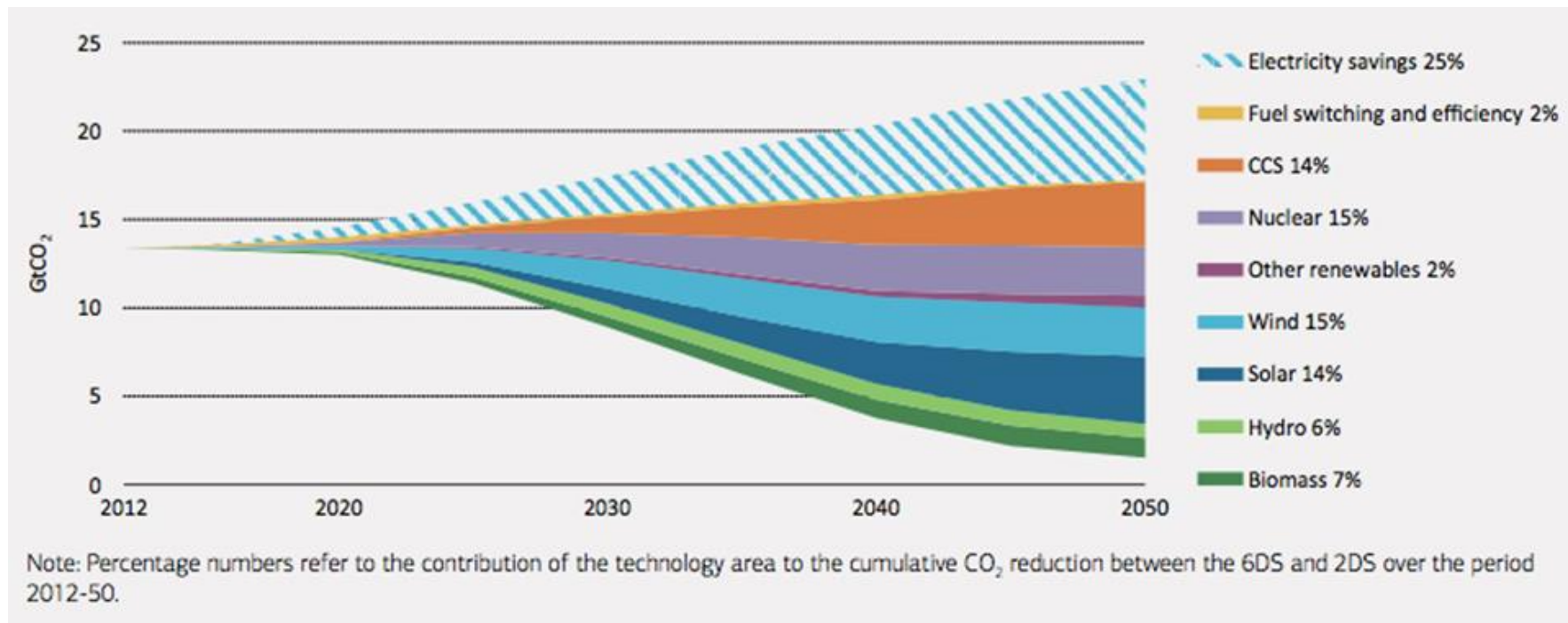
## Shares of different technologies in global electricity production until 2050 in the 2DS



Source: IEA

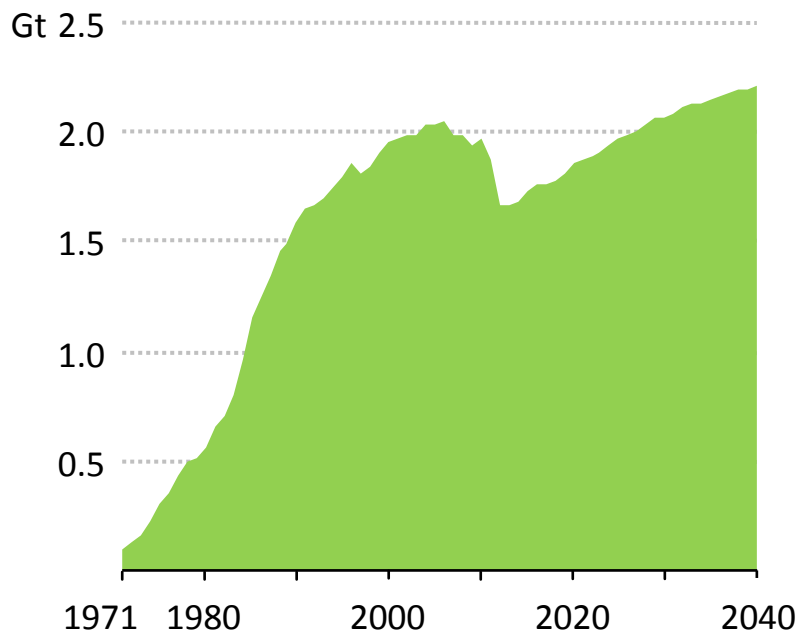
- If the world moved towards a two-degree scenario by 2050 nuclear could be the largest individual contributor to greenhouse gas emission reductions in the electricity sector.

## Emissions reductions in the power sector until 2050 necessary to move from the 6-degree scenario (6DS) to the 2-degree scenario (2DS)



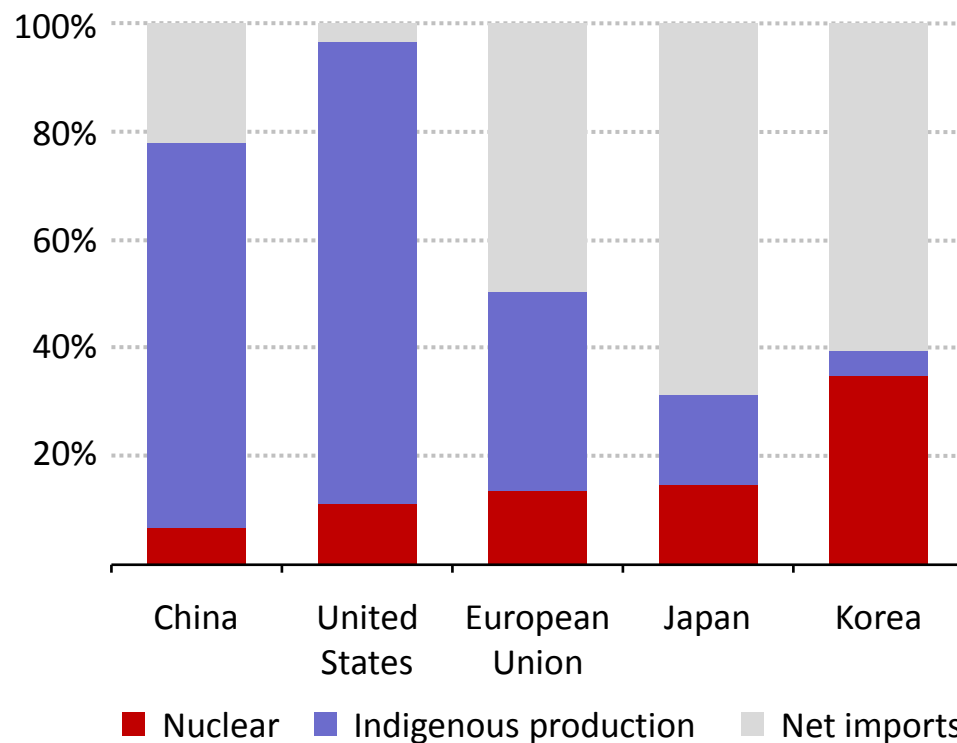
- Under certain assumption, in 2040 nuclear will have provided almost four years of global emissions.

Annual CO<sub>2</sub> emissions avoided by nuclear



Source: IEA

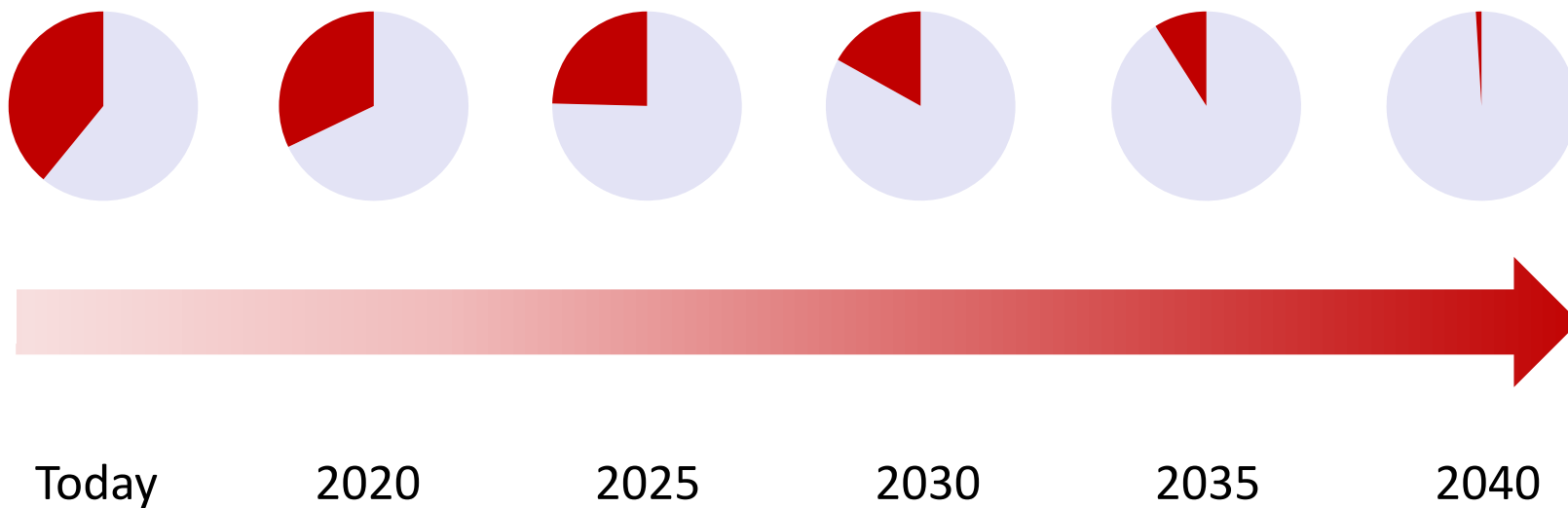
Share of energy demand met by domestic sources and nuclear power in 2040





- If no action is taken the build-up to concentrations 450 ppm of CO<sub>2</sub> in the atmosphere will happen quickly.

## World's remaining carbon budget



Source: NEA/IEA

# Related Issue I: Emissions other than GHGs

- Global climate change is caused by greenhouse gases (GHGs) emitted primarily by burning fossil fuels.
- Depending on technology, GHG emissions are frequently related to emissions of particulate matter (PM), sulphur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>).
- The latter two are precursors for ground-level ozone (O<sub>3</sub>). SO<sub>2</sub> causes acid rain. All three are considered major public health concerns.

	Coal		Natural Gas		Bioenergy	Nuclear
mg/kWh	<i>Hard Coal</i>	<i>Lignite</i>	<i>Combined Cycle</i>	<i>Steam Turbine</i>		
SO <sub>2</sub>	530-7 680	425-27 250	1-324	0-5 830	40-490	11-157
NO <sub>x</sub>	540-4 230	790-2 130	100-1 400	340-1020	290-820	9-240
PM	17-9 780	113-947	18-133	Insufficient data	29-79	0-7

Source: Masanet et al. (2013)

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## Nuclear scare stories are a gift to the truly lethal coal industry

Coal is a much nastier power source than the one we have chosen to fear in a deadly form of displacement activity



George Monbiot  
The Guardian, Monday 16 December 2013 20:45 GMT  
Jump to comments (883)



A man walks past a coal plant in Lingwu, northern China. "Research suggested by Greenpeace suggests that a quarter of a million deaths a year could be avoided if coal power [in China] were shut down." Photograph: Stringer/China/Reuters

Most of the afflictions wrongly attributed to nuclear power can rightly be attributed to coal. I was struck by this thought when I saw the graphics published by Greenpeace on Friday, showing the premature deaths caused by coal plants in China. The research it commissioned suggests that a quarter of a million deaths a year could be avoided if coal power there were shut down. Yes, a quarter of a million.



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**WHO:  
7 million  
deaths/year due  
to air pollution  
(from cooking  
stoves,  
transport, and  
fossil-fuelled  
power and  
industrial plants**

## 7 million premature deaths annually linked to air pollution

News release

25 MARCH 2014 | GENEVA - In new estimates released today, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths - as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

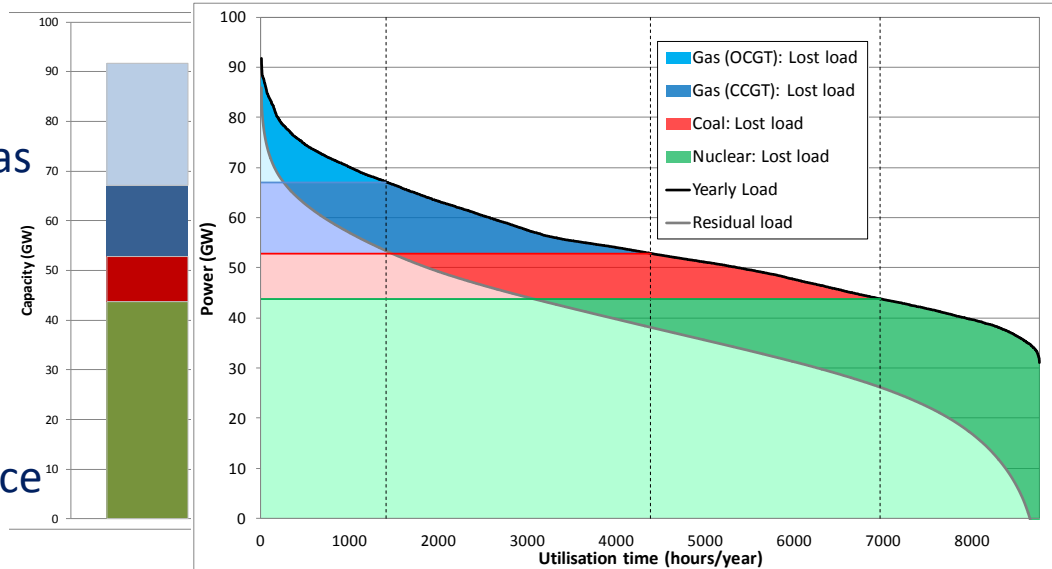
### New estimates

In particular, the new data reveal a stronger link between both indoor and outdoor air pollution exposure and cardiovascular diseases, such as strokes and ischaemic heart disease, as well as between air pollution and cancer. This is in addition to air pollution's role in the development of respiratory diseases, including acute respiratory infections and chronic obstructive pulmonary diseases.

The new estimates are not only based on more knowledge about the diseases caused by air pollution, but also upon better assessment of human exposure to air pollutants through the use of improved measurements and technology. This has enabled scientists to make a more detailed analysis of health risks from a wider demographic spread that now includes rural as well as urban areas.

In the *short-run*, renewables with zero marginal costs replace technologies with higher marginal costs, including nuclear as well as gas and coal plants. This means:

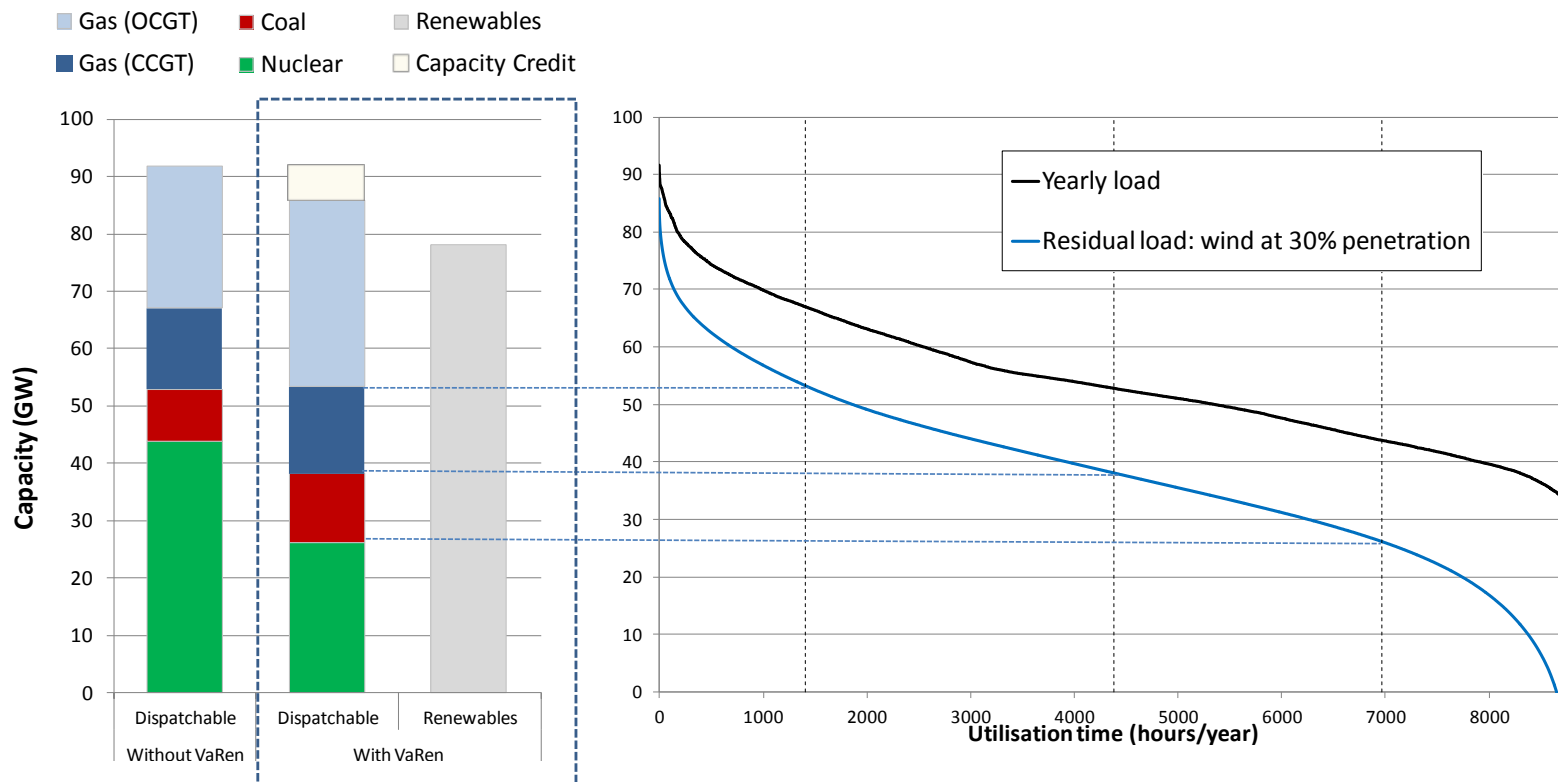
- Reductions in electricity produced by dispatchable power plants (lower load factors, *compression effect*).
- Reduction in the average electricity price on wholesale power markets (*merit order effect*).



		10% Penetration level		30% Penetration level	
		Wind	Solar	Wind	Solar
Load losses	Gas Turbine (OCGT)	-54%	-40%	-87%	-51%
	Gas Turbine (CCGT)	-34%	-26%	-71%	-43%
	Coal	-27%	-28%	-62%	-44%
	Nuclear	-4%	-5%	-20%	-23%
Profitability losses	Gas Turbine (OCGT)	-54%	-40%	-87%	-51%
	Gas Turbine (CCGT)	-42%	-31%	-79%	-46%
	Coal	-35%	-30%	-69%	-46%
	Nuclear	-24%	-23%	-55%	-39%
Electricity price variation		-14%	-13%	-33%	-23%

- Together this means declining profitability especially for OCGT and CCGT (nuclear is less affected).
- No sufficient economical incentives to built new power plants.
- Security of supply risks as fossil plants close.

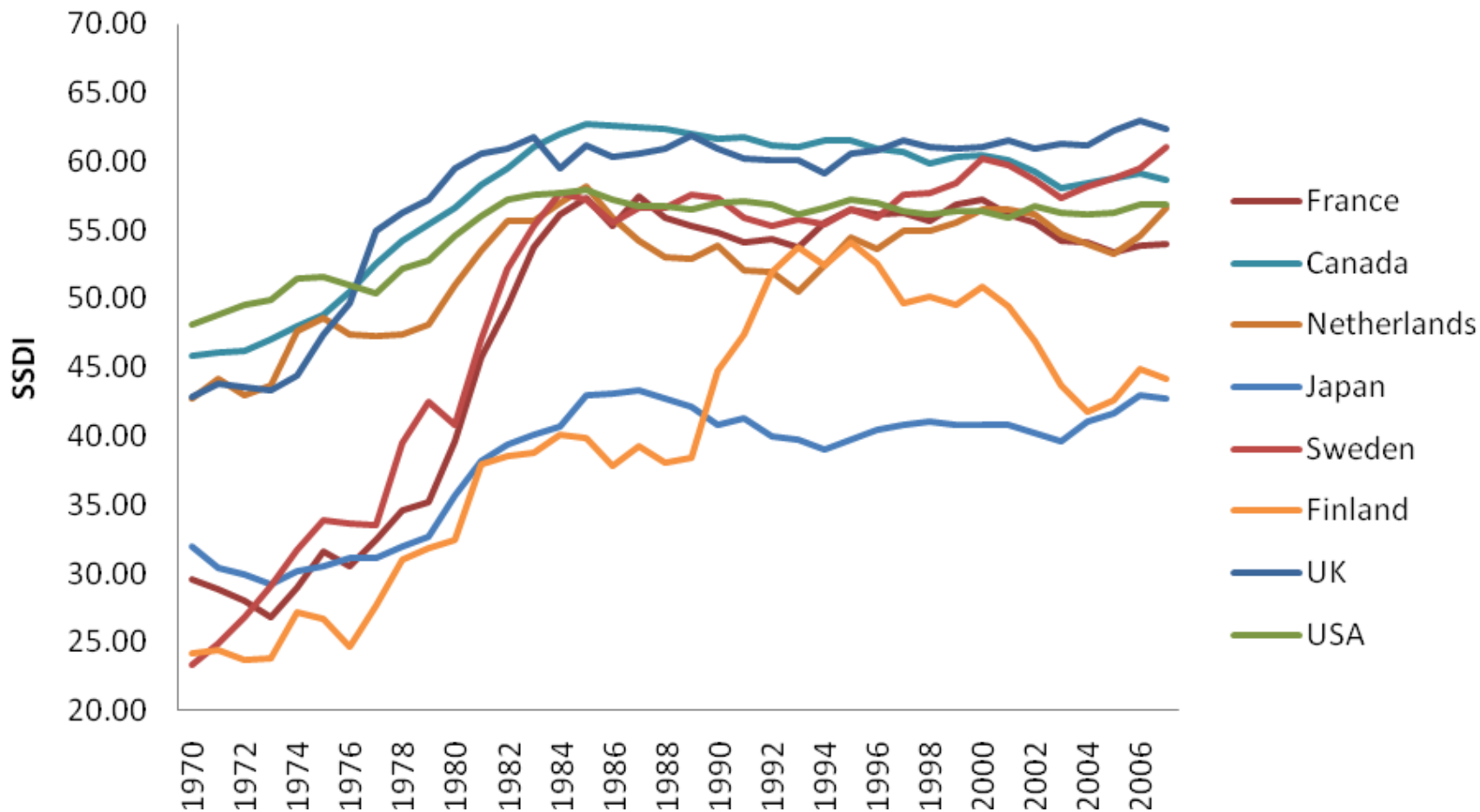
Source: OECD NEA



- Over time renewable production will change residual generation structure.
- Renewables will displace base-load on more than a one-to-one basis, as base-load is replaced by wind **and** gas/coal (**more carbon intensive**).
- Cost for residual load rises as technologies more expensive per MWh are used.
- Impacts and costs increase with the penetration level.

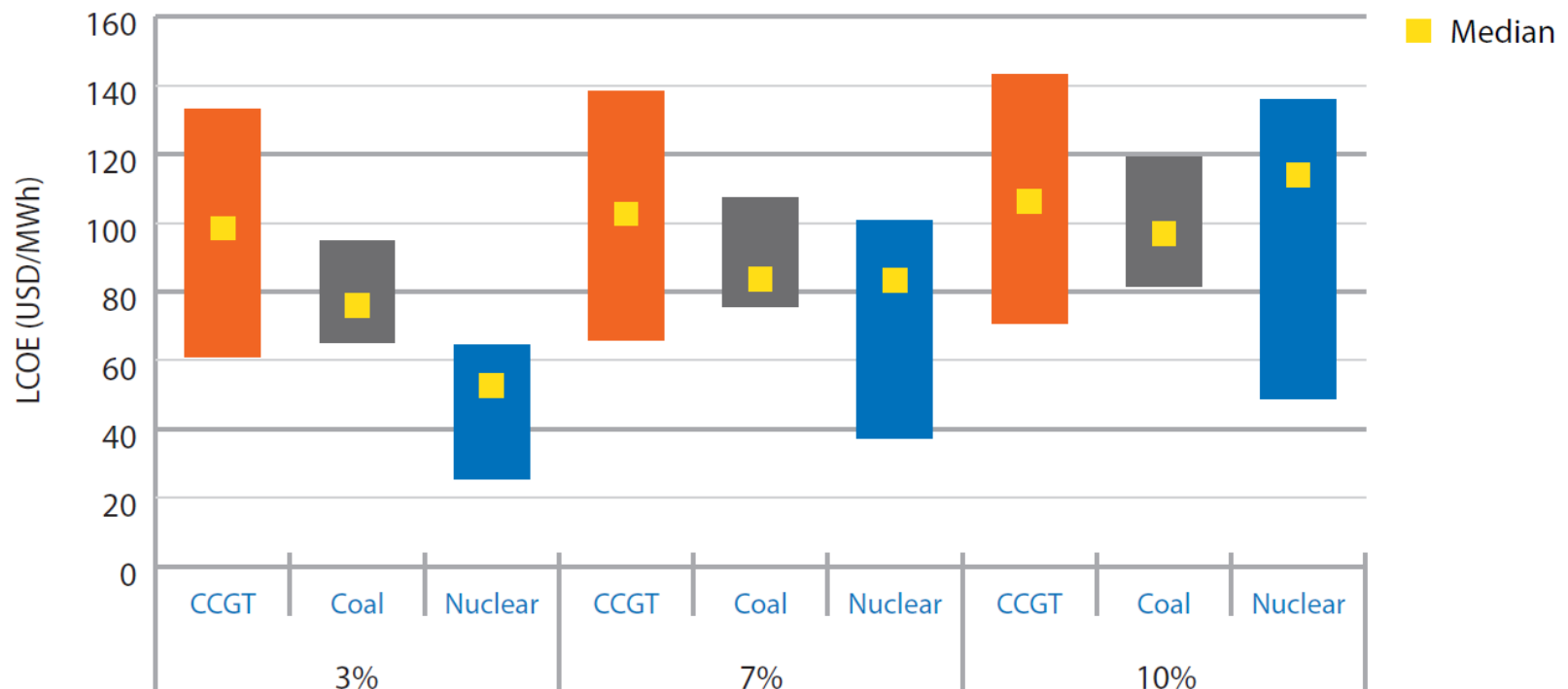
Source: OECD NEA

# Related Issue III: Security of Supply – The Contribution of Nuclear



Source: OECD NEA

## The LCOE (USD/MWh) for dispatchable baseload technologies at different discount rates

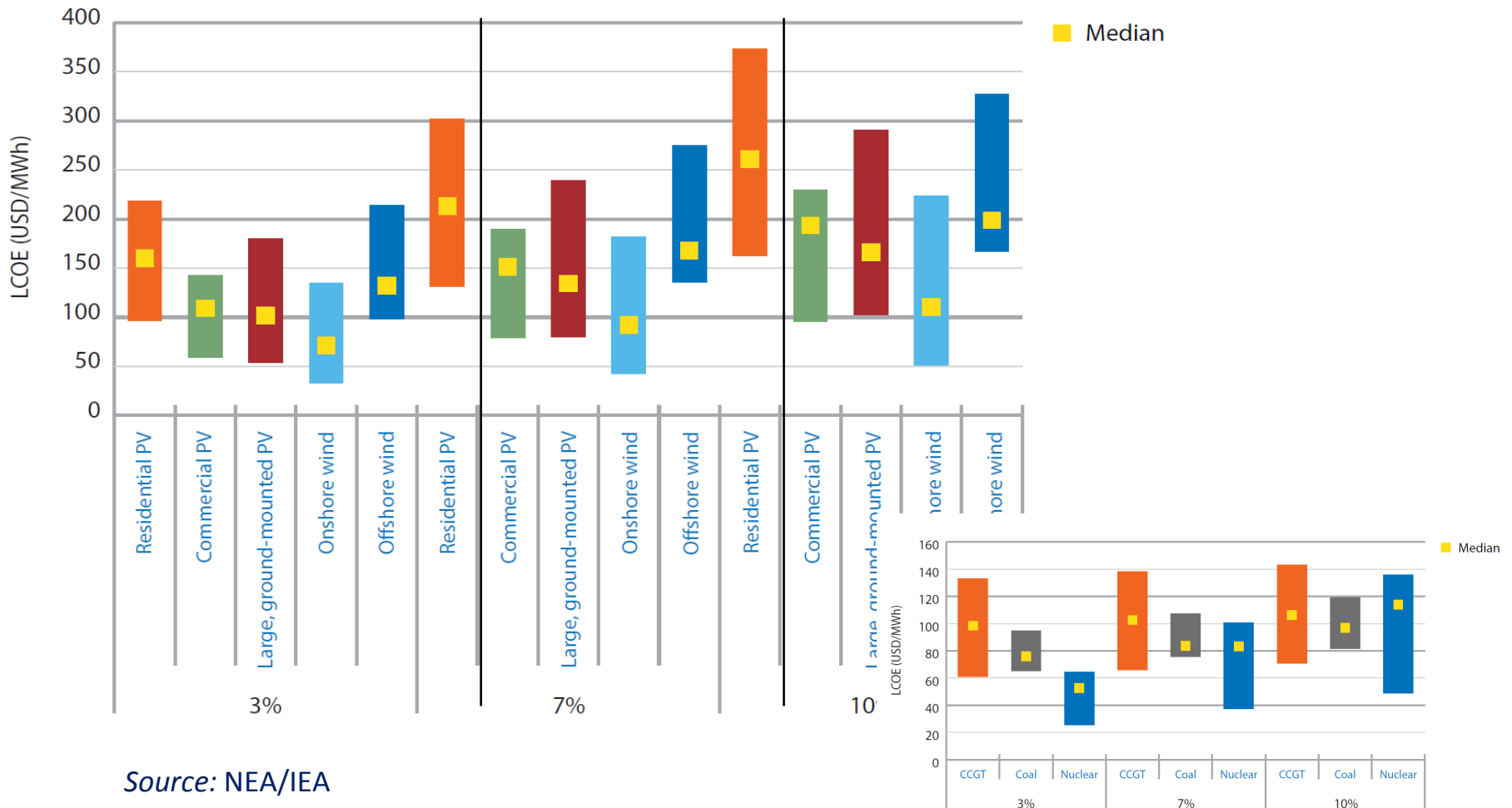


Source: NEA/IEA

Note: Assumes region specific fuel prices for US, Europe, Asia; 85% load factor; CO2 price of 30 USD/tonne

“Why the Climate Needs Nuclear Energy”, NEA/IAEA Side-event at COP21, 10-11 December 2015

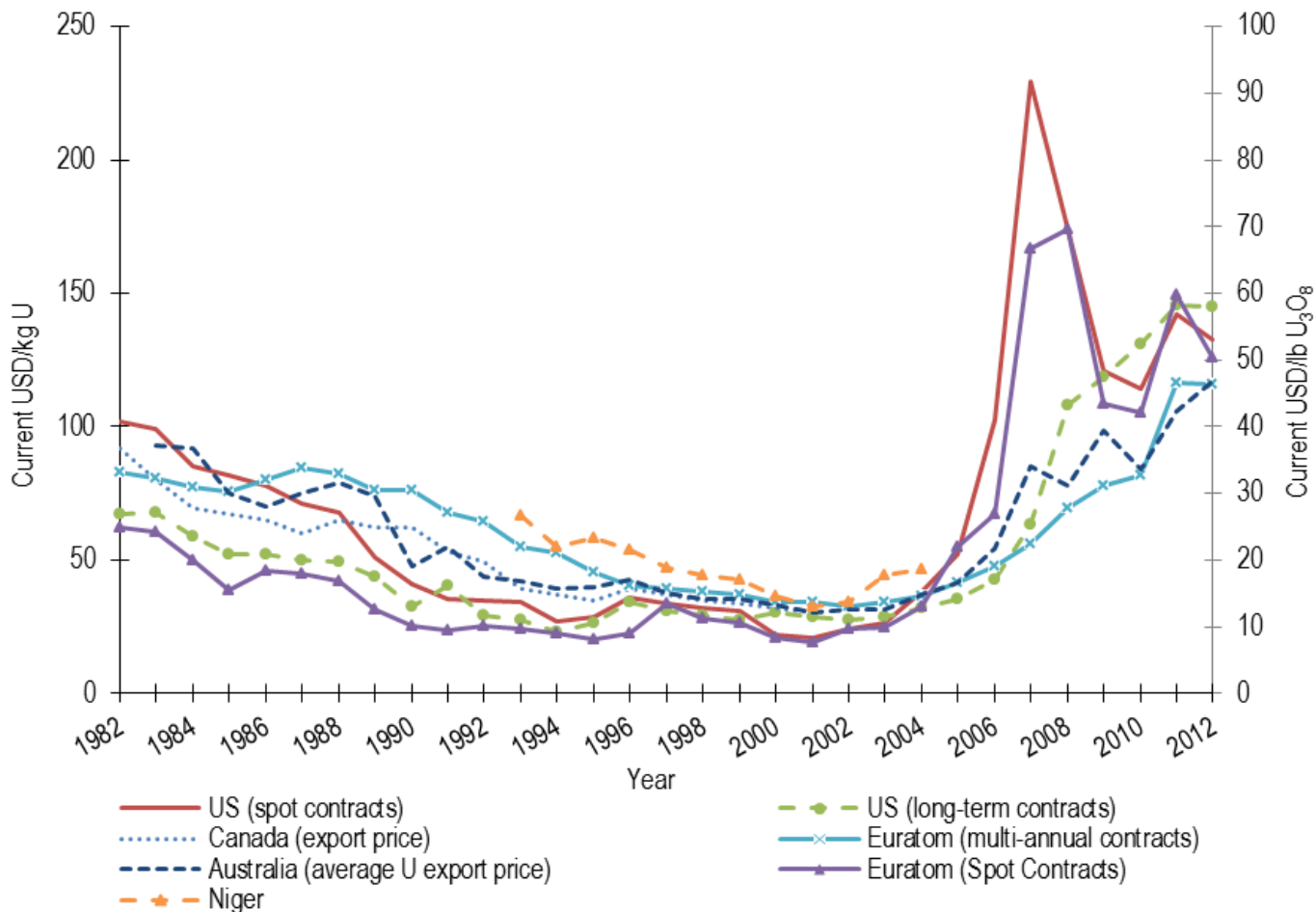
## The LCOE (USD/MWh) for wind and solar technologies at different discount rates



Source: NEA/IEA



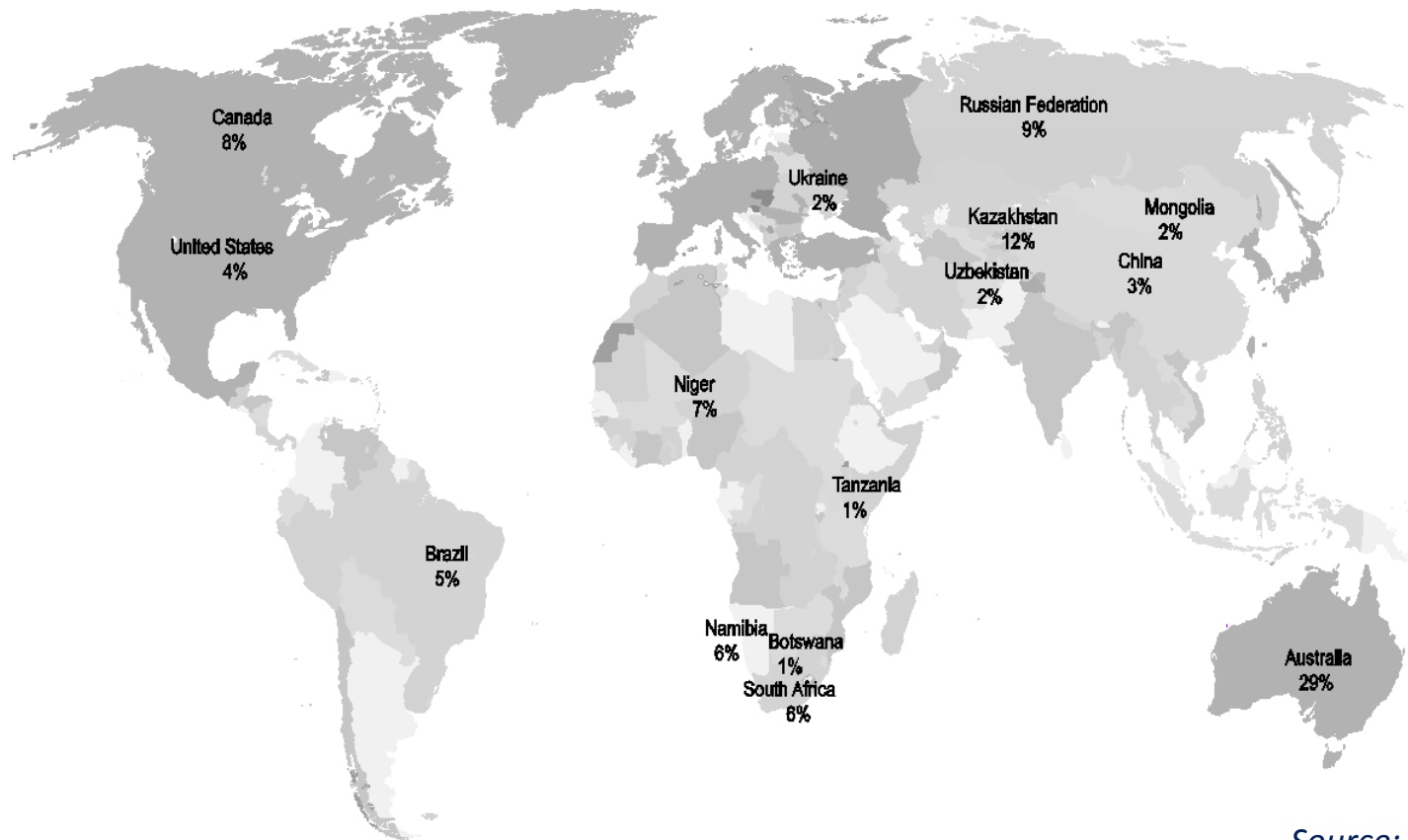
- After a spike in 2007, uranium prices have stabilised in 2010 at around 50 USD/lb and have since come down further.
- Supplies are plentiful at least until 2035 says NEA/IAEA *Red Book*.



Source: NEA/IAEA

- Uranium resources are well diversified.

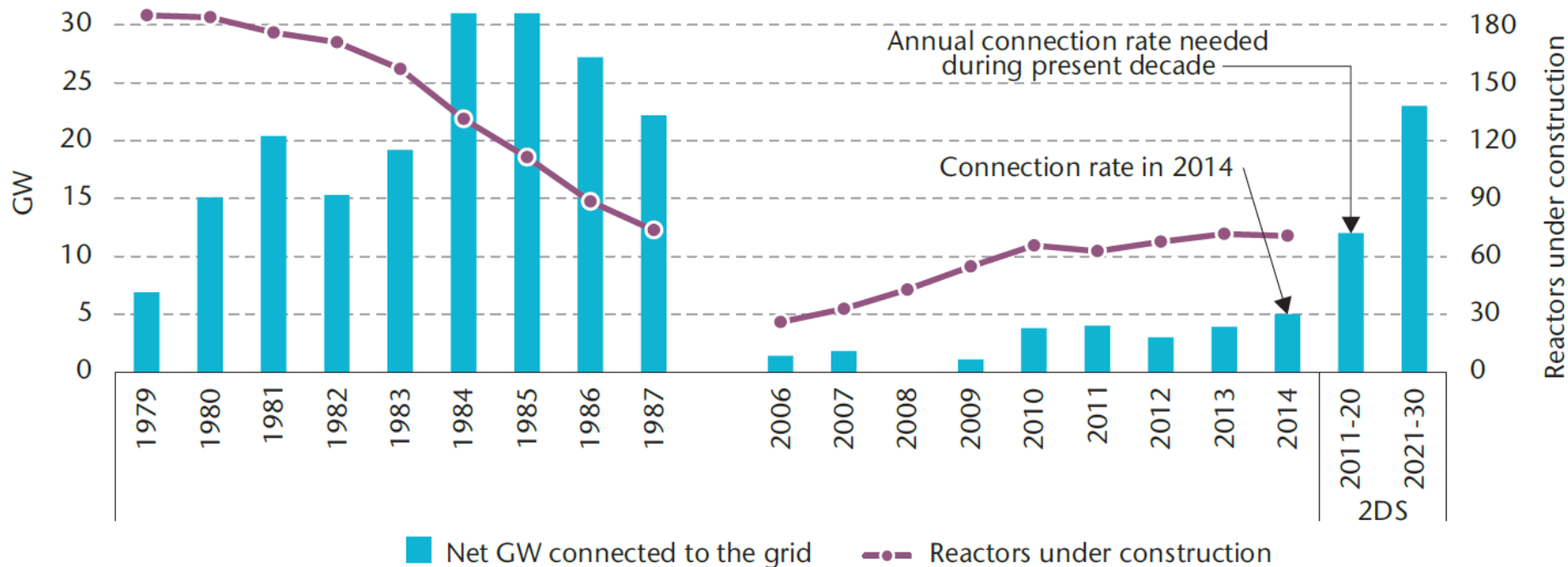
**The global distribution of uranium resources  
at production costs of less than 130 USD per kg**



Source: NEA/IAEA

# Could the Nuclear Construction Industry Cope?

- Connection and construction rates needed to reach nuclear’s full contribution to the 2DS scenario are below those achieved in the early 1980s.
- The difficulty lies in the long-timeframes and the sustained favourable political and financial framework conditions required to rebuild a global nuclear supply industry.



Source: NEA/IEA

In recent years a growing number of journalists, environmentalists and climatologists such as Robert Stone, George Monbiot, Mark Lynas, Michael Shellenberger or Gwyneth Cravens have spoken out in favour of nuclear power as a means to combat climate change.

**“There is no credible path to climate stabilization that does not include ... nuclear power”**

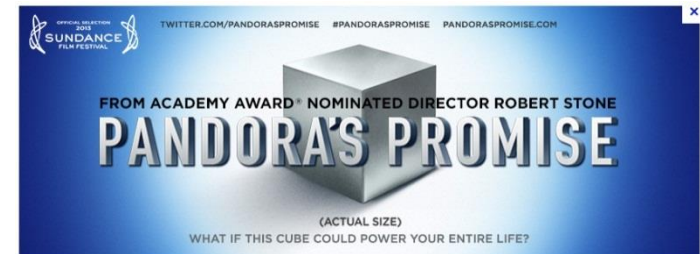
**“With the planet warming and carbon dioxide emissions rising faster than ever, we cannot afford to turn away from any technology that has the potential to displace a large fraction of our carbon emissions. Much has changed since the 1970s. The time has come for a fresh approach to nuclear power in the 21st century (Nov. 2013)”**

Ken Caldeira, Senior Scientist, Carnegie Institution

Kerry Emanuel, Atmospheric Scientist, MIT

James Hansen, Climate Scientist, Columbia University Earth Institute

Tom Wigley, Climate Scientist, University of Adelaide and NCAR



**On the documentary “Pandora’s Promise”:** It’s no easy thing for me to have come to the conclusion that the rapid deployment of nuclear power is now the greatest hope we have for saving us from an environmental catastrophe (Film Director Richard Stone).

- 1. Avoiding the worst of climate change and achieving a two-degree scenario will demand massive structural change in the electricity sector.**
- 2. Nuclear, hydro and renewables will have to bear the brunt of electricity generation by 2050.**
- 3. Due to their intermittency, variable renewables such as wind and solar will not be able to ensure carbon-free electricity around the clock on their own.**
- 4. Together with additional hydro resources in short supply nuclear power is an indispensable part of future low-carbon electricity systems.**
- 5. Nuclear is well-placed to respond to this challenge:**
  - At favorable financing costs and modest carbon prices it is cheaper than coal or gas.
  - Uranium fuel is plentiful and widely distributed.
  - Required build rates are in line with historical experience.
  - Additional benefits in terms of local environmental impacts and security of supply.
  - Public attitudes are changing precisely among those most concerned about greenhouse gas emissions and climate change.