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# Tectonic Shifts in Power Generation

## Disruptive Changes to Define a New Era

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**See Appendix A-1 for Analyst Certification, Important Disclosures and non-US research analyst disclosures**

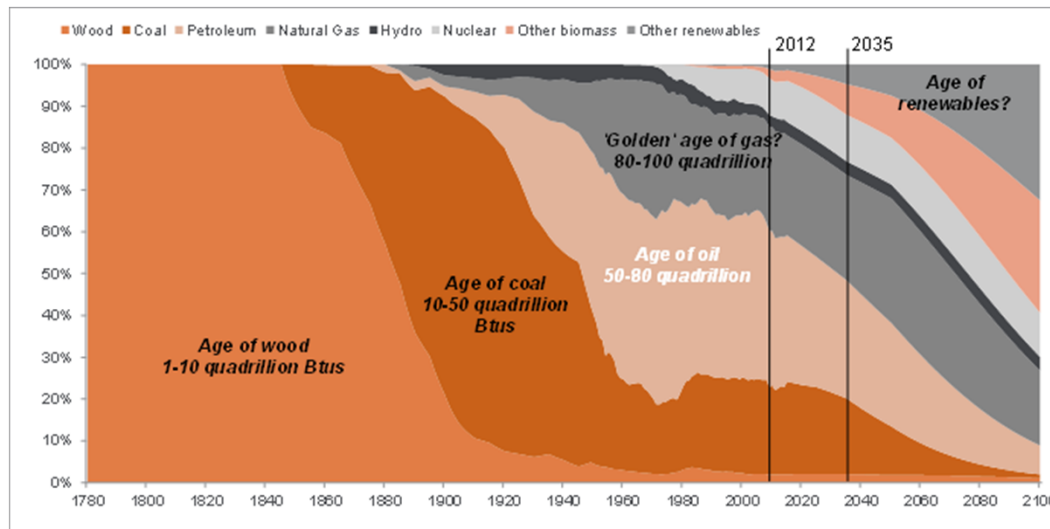
**4/21/2014**

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# Tectonic shifts in global energy

- **A series of transformative forces increasingly assert their influence on global energy.** Disruptive changes in technology costs and fuel markets are now set to ensure that the next ten years look little like the last twenty.
- **Technological advances bring about the shale revolution, rise of renewables and advances in storage, lowering production costs.** US shale oil and gas are just the beginning of tectonic, structural shifts impacting business models
  - Productivity gains and technological diffusion of shale to have substantial global impact
  - Falling costs of renewables and energy storage to transform the way electricity is generated
  - Slowdown of oil and coal demand growth to challenge conventional wisdom of energy

**The ages of energy: History suggests a process of substitution**  
US primary energy demand 1780-2100



Source: Citi Research

# Confluence of underlying forces are driving these shifts

## Technological Change

- Lower barriers to entry
- Drive down costs, scarcity value

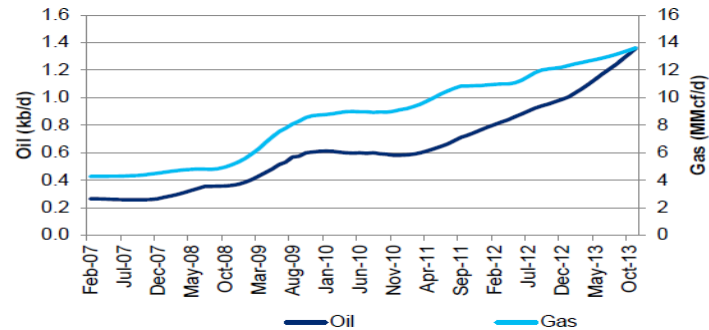
## Substitution

- Helped by technological change
- Reduce market dominance
- Open new markets

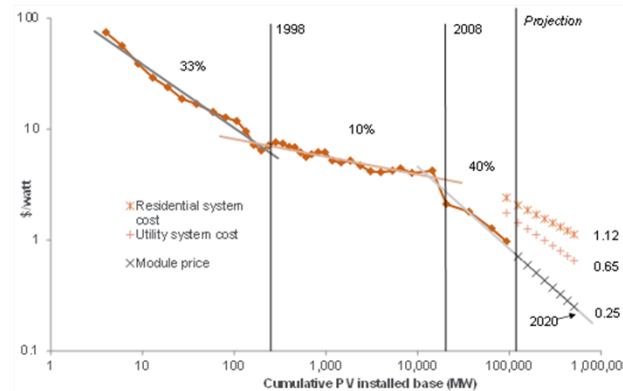
## Slowdown in Demand Growth

- Efficiency, behavioral change
- Reduced energy subsidies
- Where's the next China?

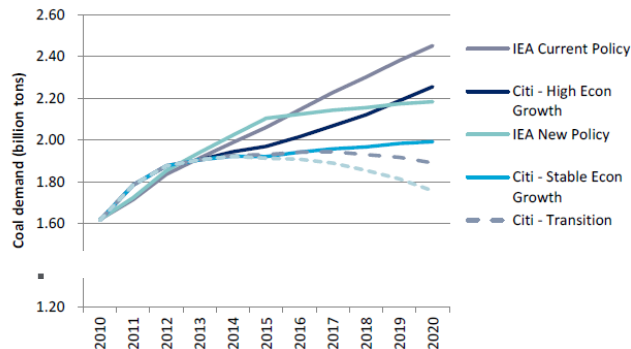
## Rising productivity: production per rig at shale plays



## Rapid fall in solar panel cost due to rising learning rates



## The Peaking of Coal demand in China



## ...with a slowdown in demand growth

### Long-run power demand growth limited by three broad developments:

- Wider use of demand management and load response
- Improvements in energy efficiency standards and
- Behavioral changes across sectors, drastically limiting demand growth.

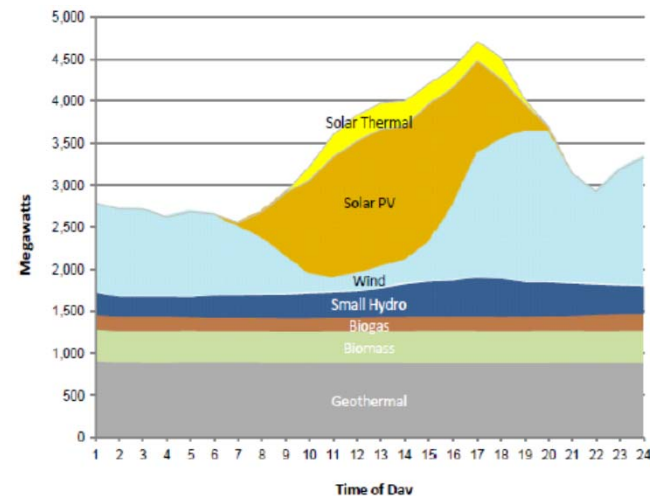
### States with Energy Efficiency Resource Standard – But this is also global



### Supply side also “limits” demand growth by matching production at peak demand periods

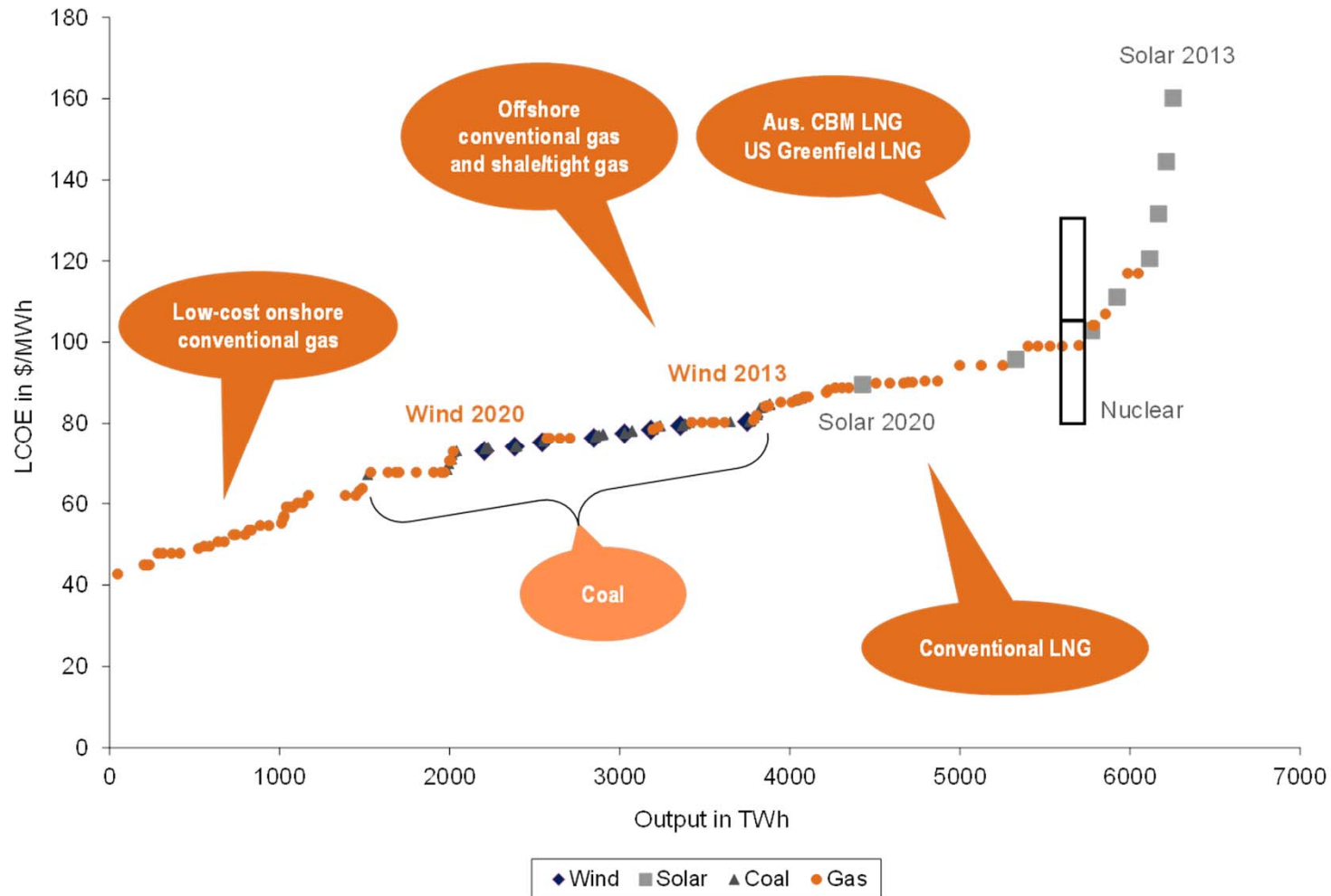
1. Hot summer peak demand typically most 'valuable' part of supply, when electricity prices and solar peak and, causing headache for utilities
2. Solar works well as a distributed (local) source
3. Storage, smart software should cause additional uncertainty for utilities, disruption to fuel markets

### Summer workday in California – with renewables supplying peaking power



# This transformation is driving a change in the energy cost curve...

Citi's Global Integrated Energy Cost Curve\*

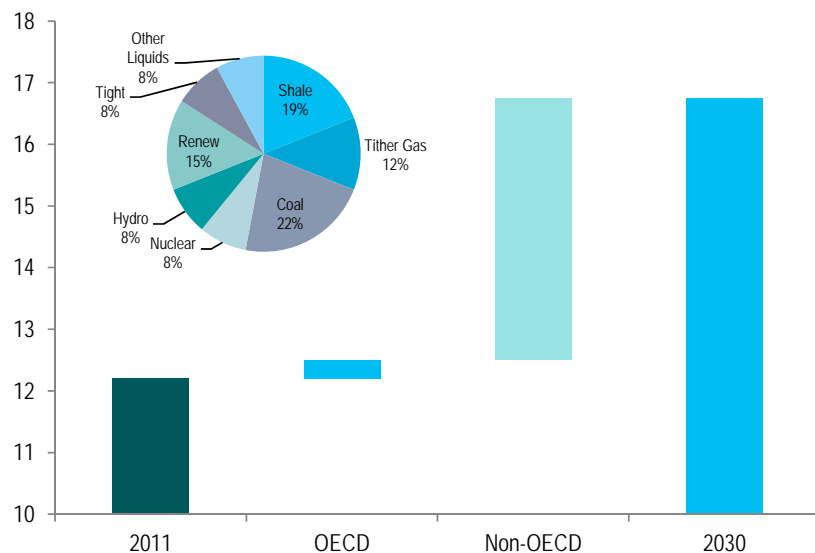


\* LCOE is the 'Levelised Cost of Electricity', which attempts to compare different methods of electricity generation in cost terms on a comparable basis. Different technologies vary materially in the proportion of upfront capital expenditure vs. fuel cost or operating costs. LCOE incorporates all of these costs and calculates the 'price' of electricity needed to give a certain rate of return. The cost curve only includes export-oriented projects: the integrated global energy cost curve is built from 98 gas projects, 48 coal projects, 120 solar and 120 wind projects/scenarios, with nuclear also included.

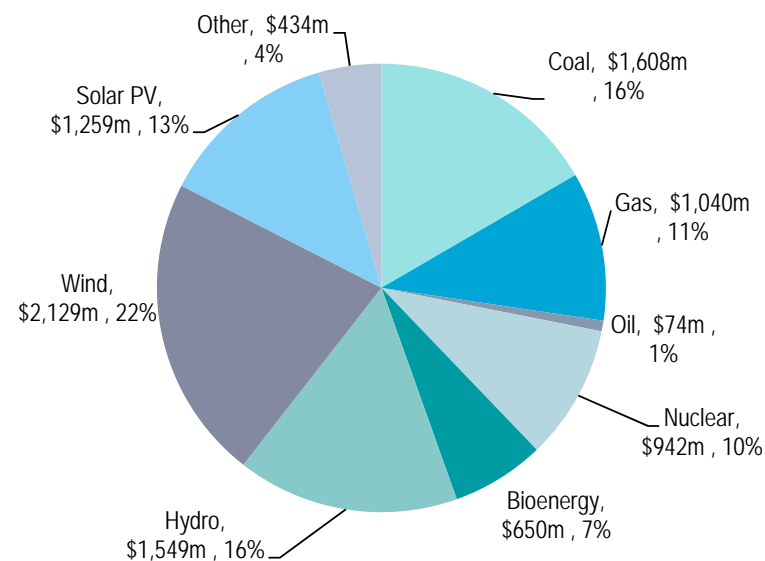
## ... And investments have begun to shift and diversify

**Energy demand growth should still be dominated by non-OECD countries, but the split of fuels/technology will be relatively even split**

(Energy demand; billion ton oil-equivalent)



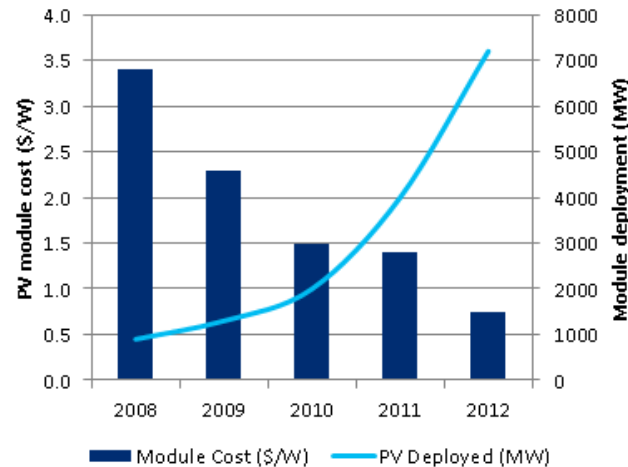
**Split of \$9.7 trillion global investment in power generation by technology**



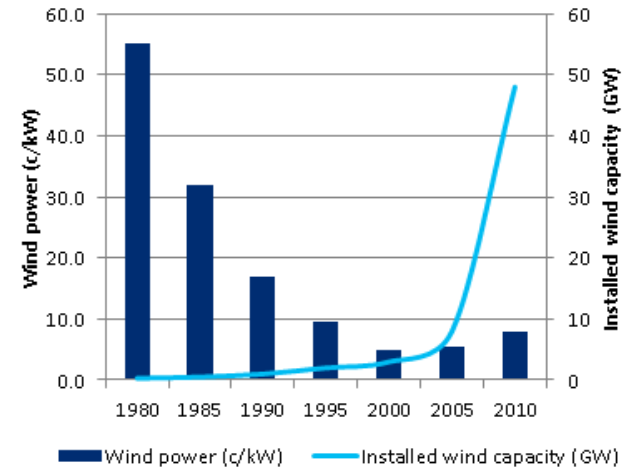
# Technological advances lowering cost, boosting new power deployment

Rising deployment amid falling cost of renewables

Solar PV modules (2008-12)

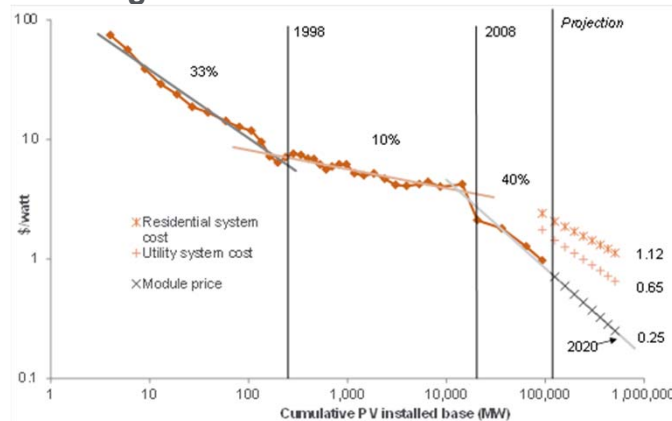


US land-based wind (1980-12)  
60-GW by 2012 already

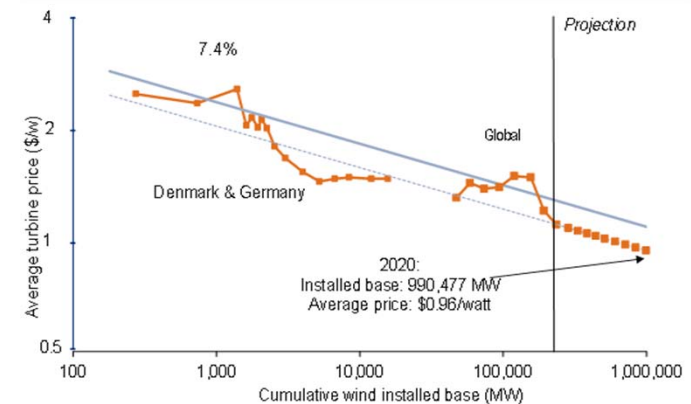


Cost reduction to continue in the future

Solar exhibits potentially rapid learning rates



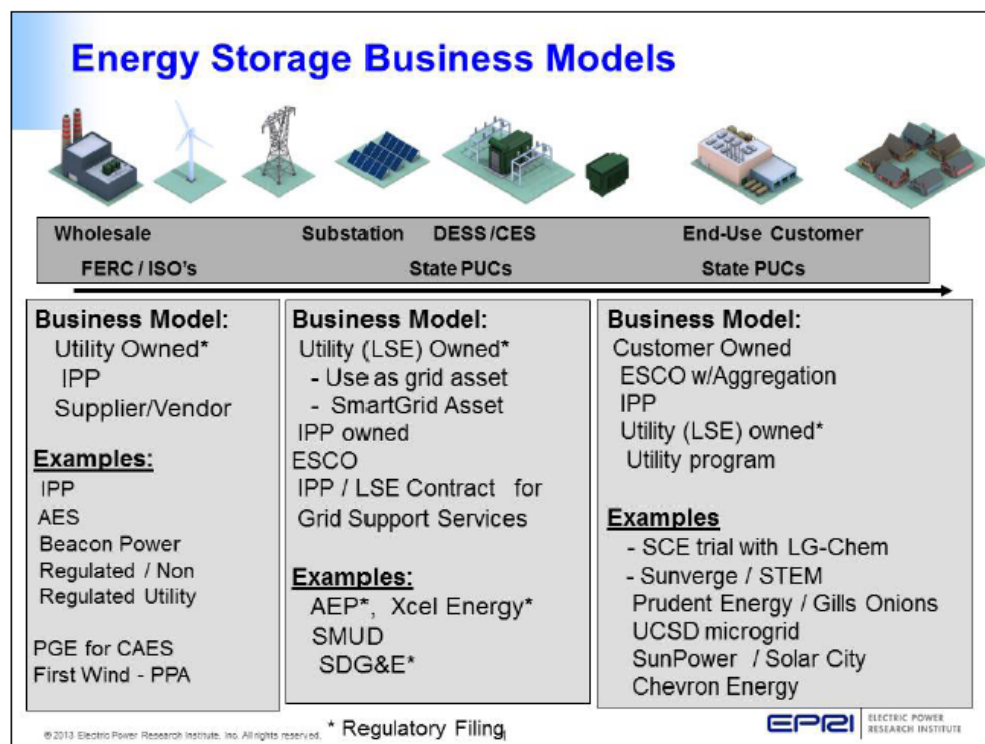
Learning rates of Wind



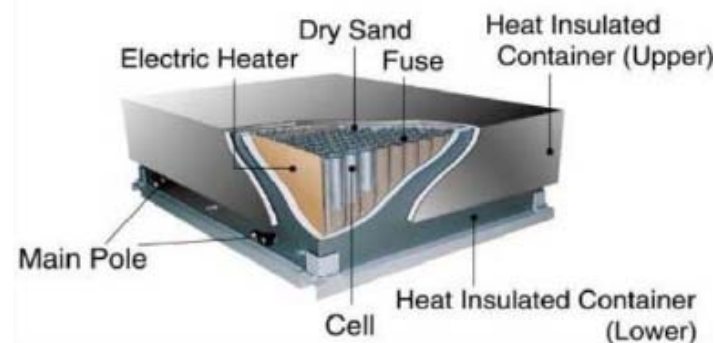
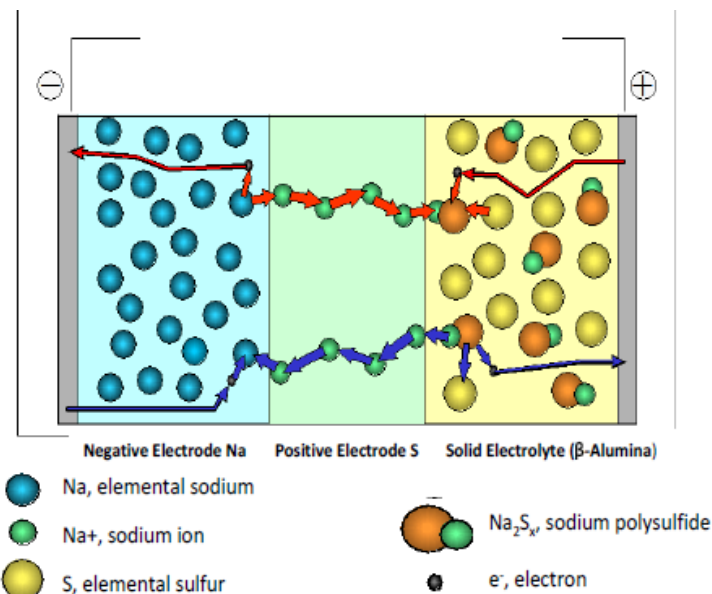
# Energy storage systems are improving: both hardware and software

Hardware has been the focus of innovation...

...But Software controlling how storage systems are used could boost their effectiveness substantially, breaking through barriers that have prevented energy storage from massive deployment



## Example: Sodium Sulfur Battery



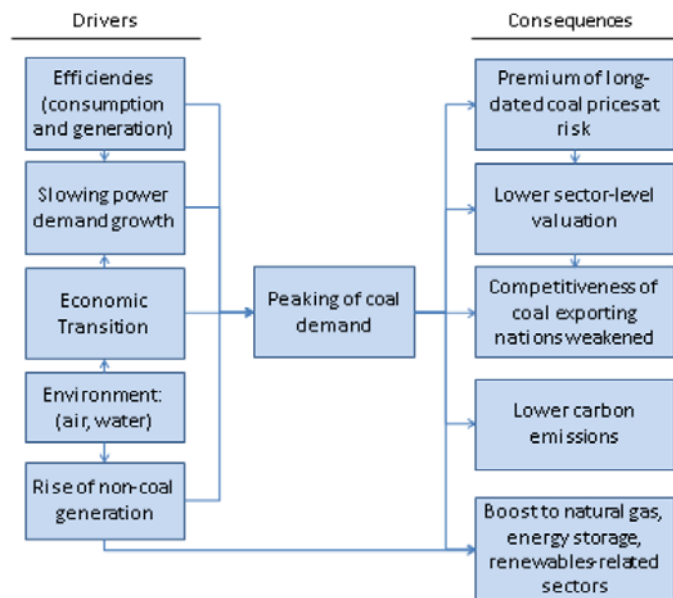


# Utilities across the developed world are facing mounting challenges

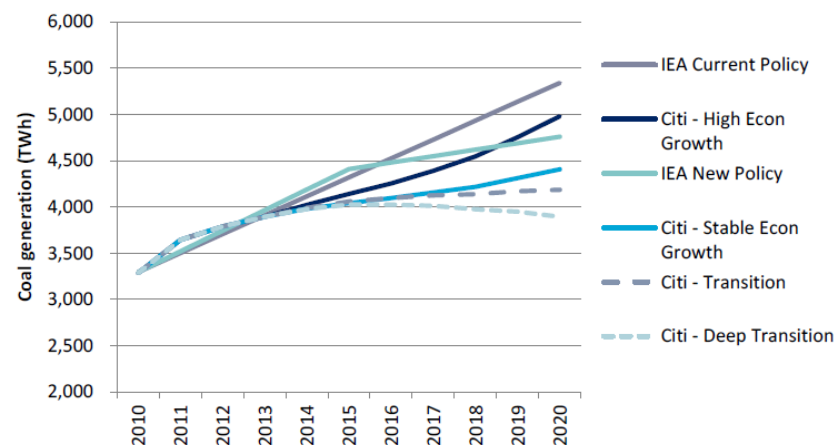
		Europe	US	Japan
Supply-Demand Fundamentals	Weaker demand	<b>Efficiency</b> , demand-side management, lackluster economic growth and rising distributed generation all weaken demand for utility-provided electricity (distributed generation involves off grid customers generating their own power)		
	Fuel prices fluctuations	<b>Now:</b> legacy expensive gas supply, lack of options <b>Future:</b> higher LNG supply to lower global prices	<b>Now:</b> shale gas lowered prices, spark/dark spreads <b>Future:</b> gas price recovery could boost margins again	<b>Now:</b> Expensive LNG imports <b>Future:</b> LNG prices to fall, nuclear restart to help
	Environmental / carbon policies	<b>EU carbon</b> prices too low to reduce high-carbon gen but <b>UK's carbon</b> floor high enough to drive up prices	<b>Coal plant retirements</b>	<b>Abandon “Kyoto”</b> commitment without full fleet of nuclear
	Rising renewables commitment	<b>Government support</b> of rising renewables/distributed generation helps sector growth but at expense of traditional utilities – stagnant demand, fewer customers <b>Cost recovery on infrastructure spending</b> (e.g. to transmit/balance renewables) is limited as authorities still want to support “green” measures first		
Regulatory	Regulatory uncertainty	<b>Regulatory uncertainty</b> with no comprehensive policies on energy/environment affects asset investment/deployment strategy (e.g. EU gas plants, Japan nuclear)		

# Peak coal demand in China to have far-reaching consequences

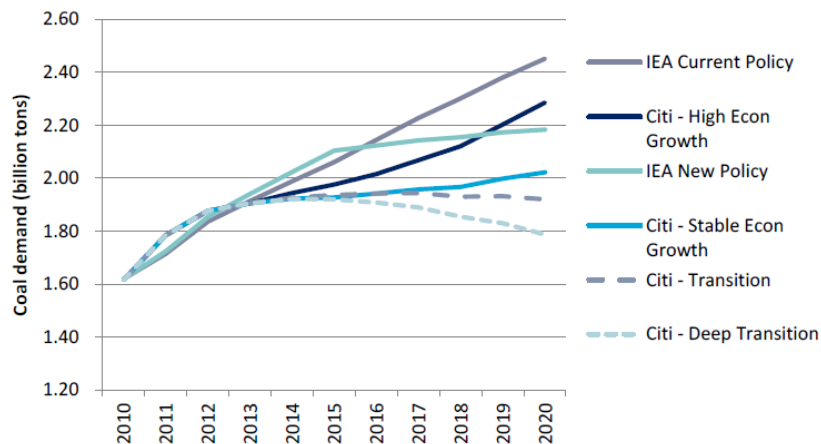
Changes in the power mix, especially in coal demand, have serious ripple effects on: (1) globally traded coal and commodities, (2) countries and sectors reliant on coal production/exports and (3) carbon emissions



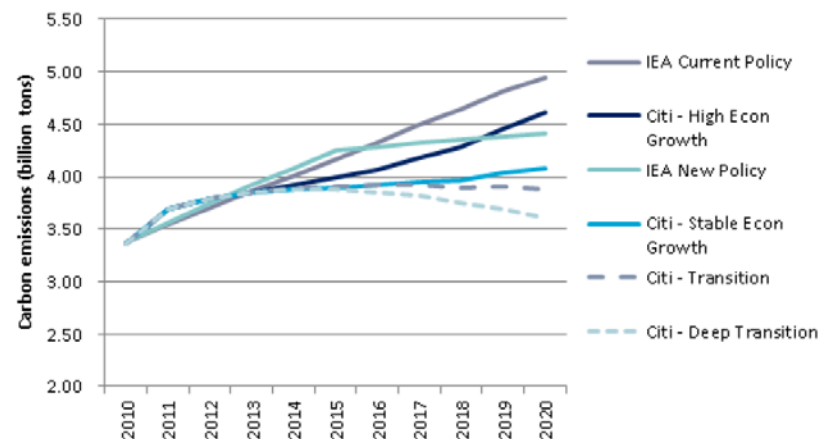
## China power sector coal generation scenarios



## China power sector coal demand scenarios

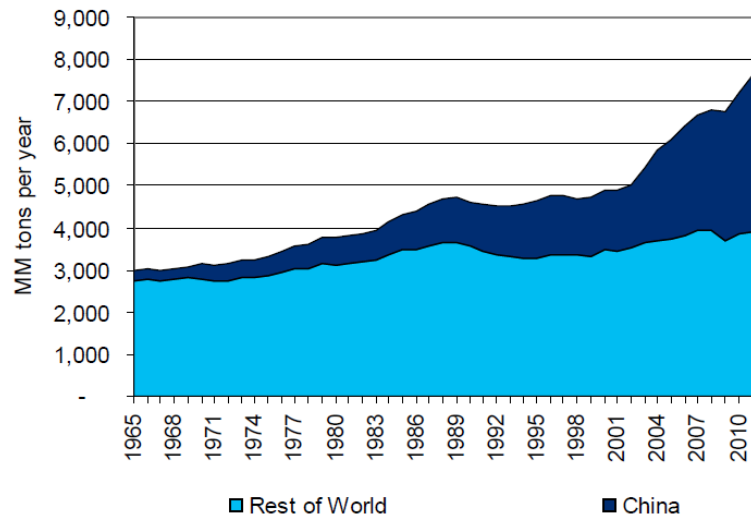


## China's carbon emissions from coal generation

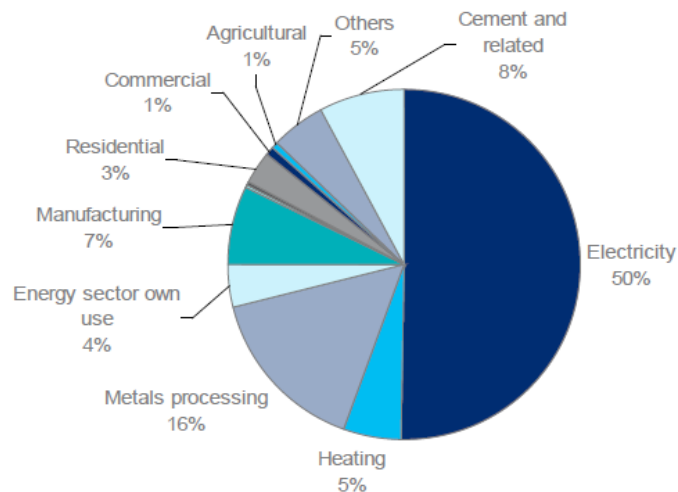


# China uses 50% of global coal, of which 50% is used in the power sector

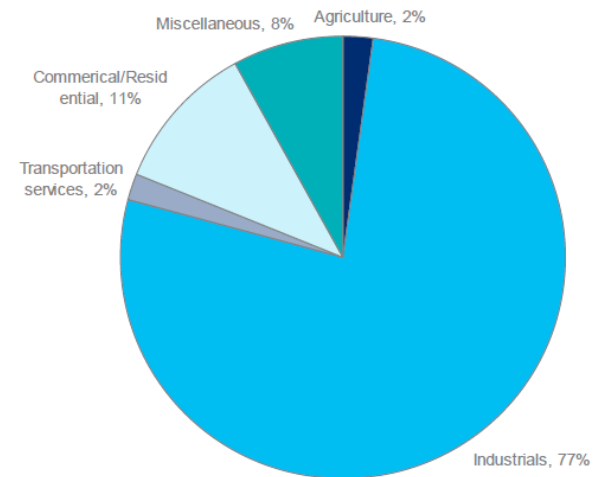
The surge in Chinese thermal coal demand has put it over 50% of world's total consumption



Coal demand for power generation accounts for about 50% of total consumption in China

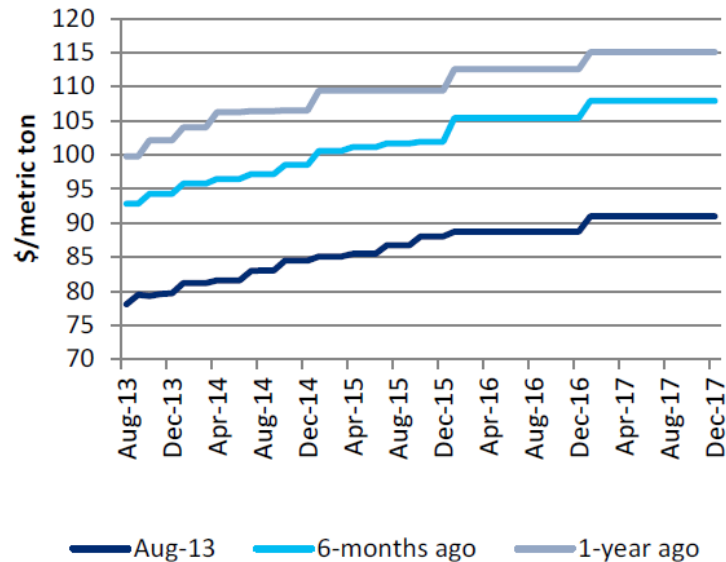


Industrials dominate electricity consumption

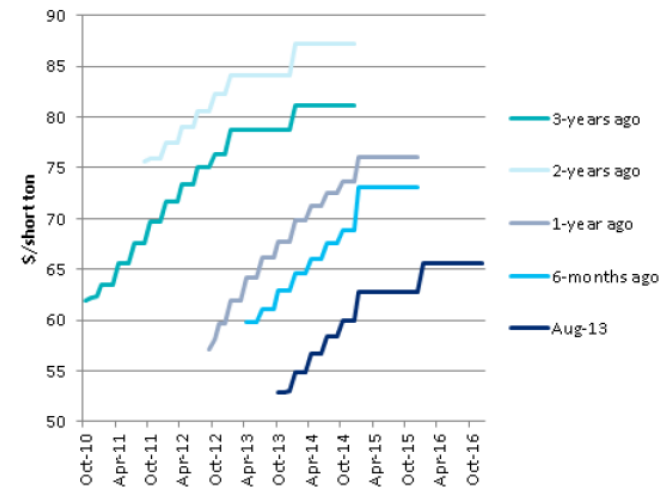


# Dramatic slowing of coal demand to drag prices lower, affecting producers

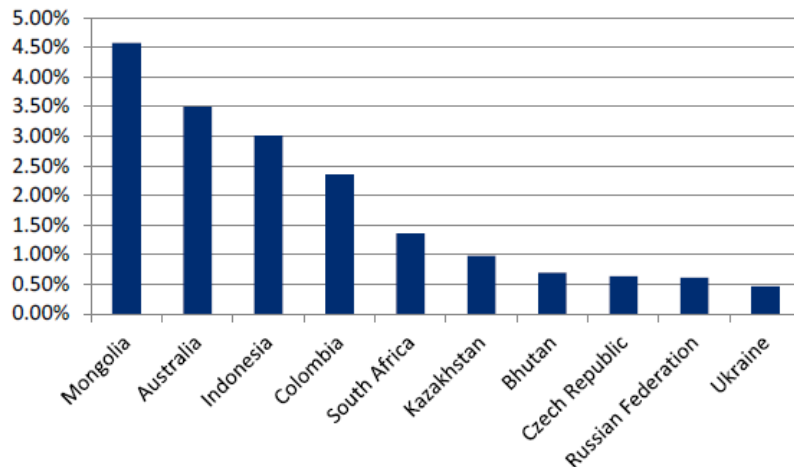
Australian Newcastle coal forward fell on loose supply demand balance, but long-dated prices remain high



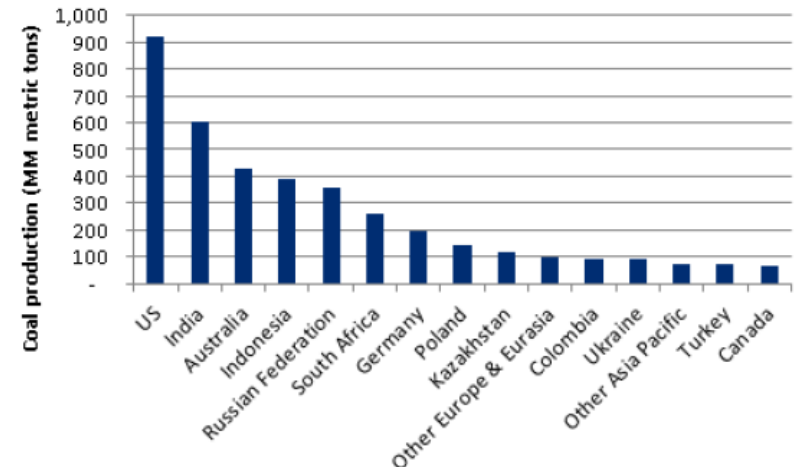
US NYMEX coal forward over the last 3 years: long-dated prices expecting tighter markets ahead often failed to materialize – could global prices follow the same path?



Coal export value as share of a country's GDP in 2011



Top 15 coal producing countries in 2012 (ex-China)



# Coal demand to slow: econ transition, rise of non-coal generation, efficiency

## 1. With economic transition, more modest GDP growth and efficiency to slow power demand growth (GDP growth)

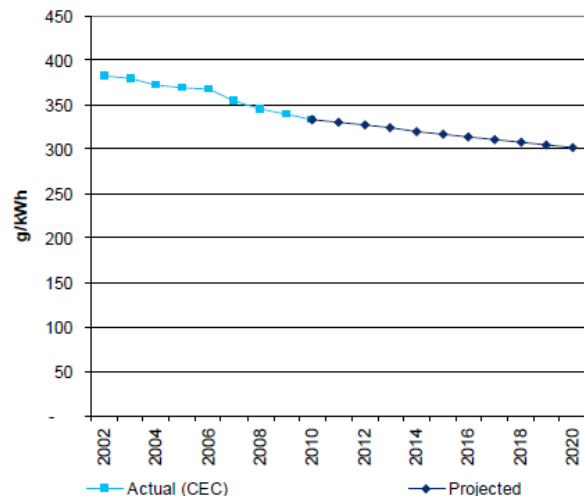
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Actual	9.6%	9.2%	10.4%	9.3%	7.8%								
High Econ Growth	9.6%	9.2%	10.4%	9.3%	7.8%	7.4%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Stable Econ Growth	9.6%	9.2%	10.4%	9.3%	7.8%	7.4%	7.1%	7.0%	7.5%	7.3%	7.3%	7.3%	7.3%
Transition	9.6%	9.2%	10.4%	9.3%	7.8%	7.4%	7.3%	7.3%	7.0%	6.5%	6.1%	5.8%	5.5%
Deep Transition	9.6%	9.2%	10.4%	9.3%	7.8%	7.4%	6.9%	6.4%	5.9%	5.5%	5.0%	4.5%	4.0%
Transition with slow new builds	9.6%	9.2%	10.4%	9.3%	7.8%	7.4%	7.3%	7.3%	7.0%	6.5%	6.1%	5.8%	5.5%

## 2. The rise of non-coal power generation could help to meet much of future power demand growth

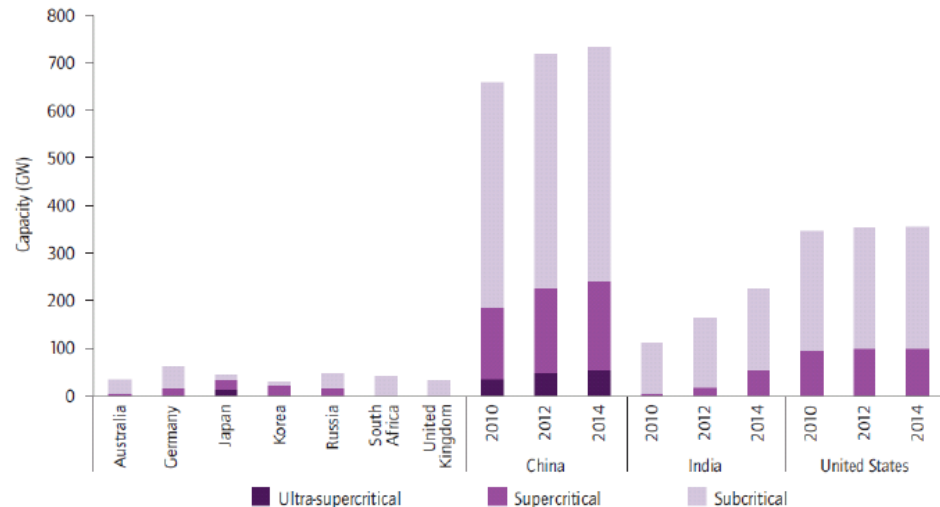
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gas	26	34	37	45	53	56	67	75	83	91	100
Nuclear	11	13	13	15	21	31	36	41	47	52	58
Hydro	213	233	249	270	285	300	320	340	360	370	380
Wind	45	63	76	92	110	129	150	171	193	215	236
Solar	1	4	7	15	25	35	47	58	70	82	94

## 3. Improved generation efficiency to lower coal demanded per unit of generation

Historical and projected efficiency gains

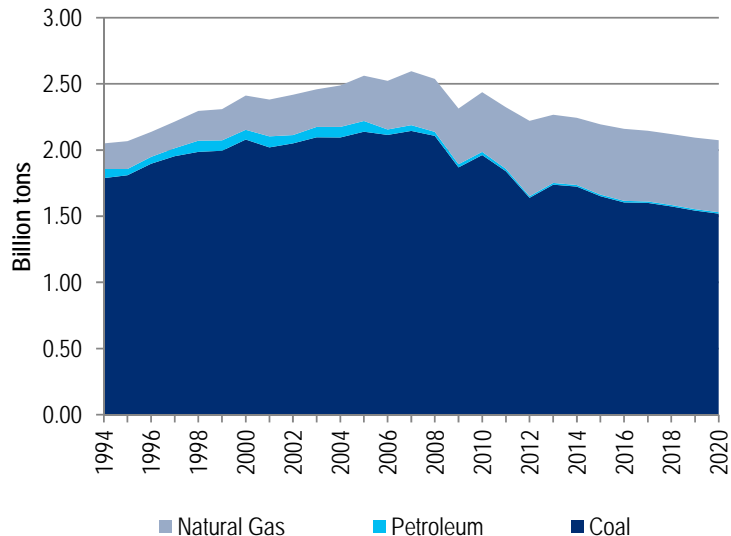


China has majority of supercritical, ultra-supercritical coal plants

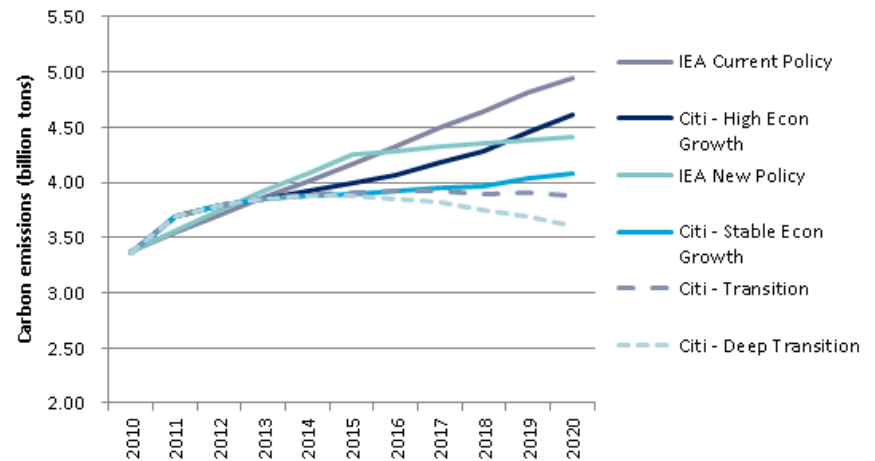


# Carbon emissions reduction from two key emitters: US and China

**US's carbon emissions continue to fall due to the rise of gas and renewable generation in a flat power demand environment**

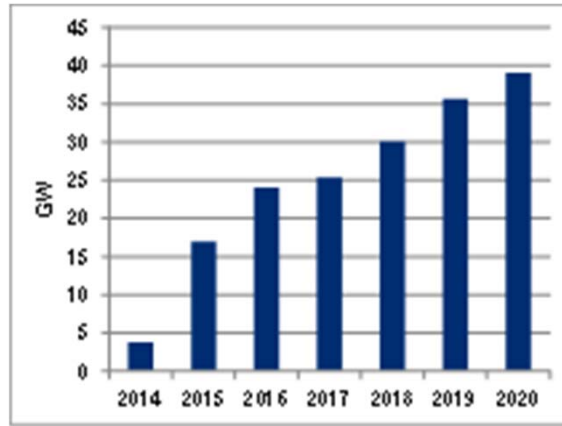


**China's carbon emissions could fall by ~1-billion tons per year by 2020 due to the flattening of thermal coal demand for power generation**

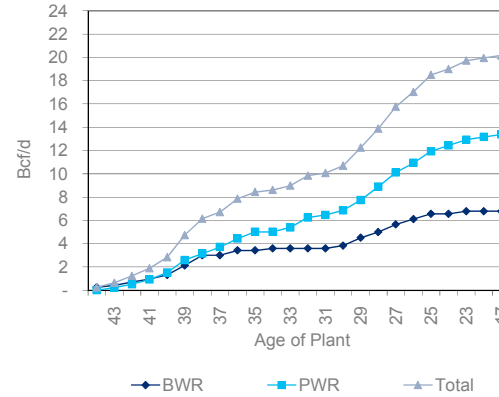


Gas-fired generation should rise by mid-decade due to nuclear units and coal-fired generation retirement, but weak power demand could curb further gas demand growth. Power generation could grow by 2.6-Bcf/d between 2010 and 2020 but only 0.6-Bcf/d between 2013 and 2020.

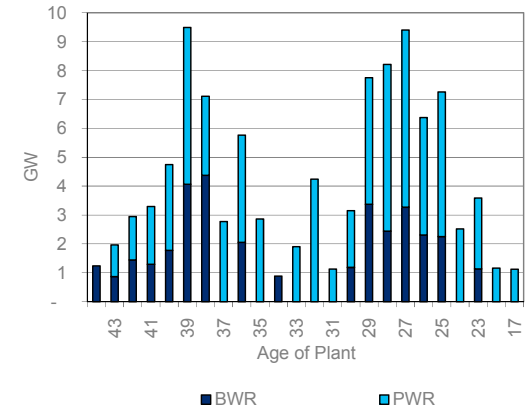
## Cumulative coal plant retirements



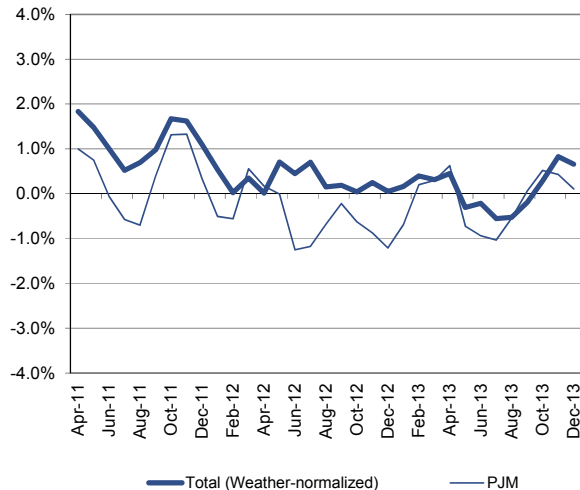
## Cumulative gas demand impact based on the age of nuclear plants



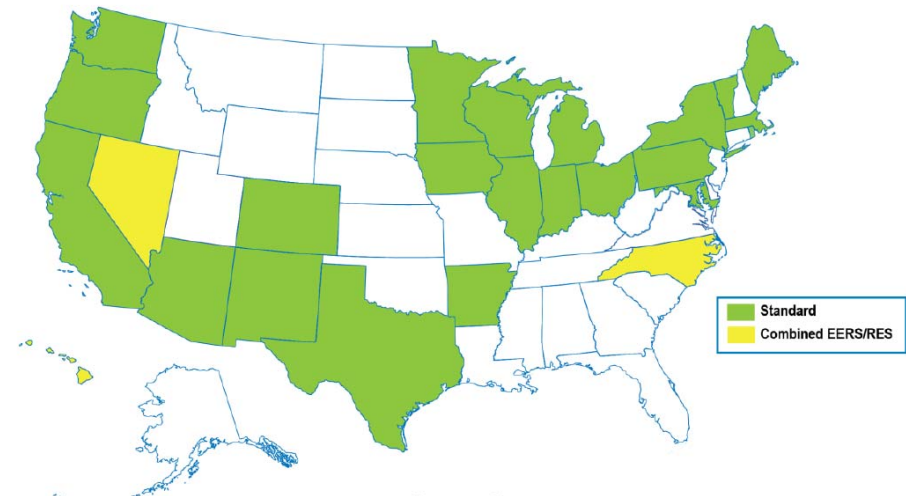
## Size and age of nuclear plants



## But weather-normalized power demand growth has been flat in North America and the key power market PJM



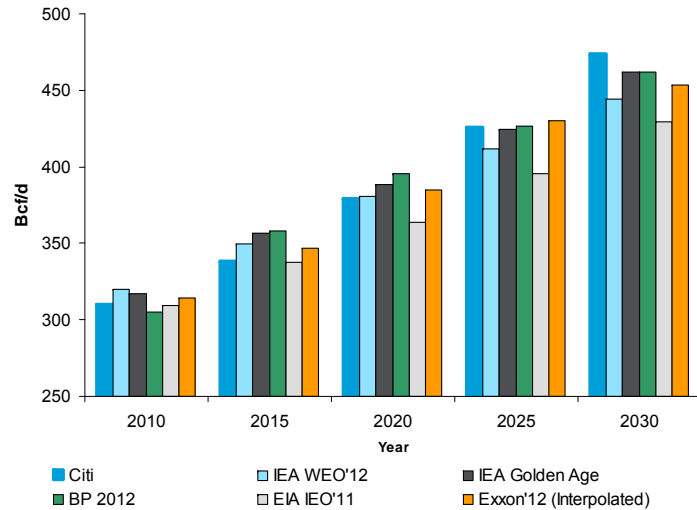
**Many states also have binding Energy Efficiency Resource Standard, curbing demand growth**



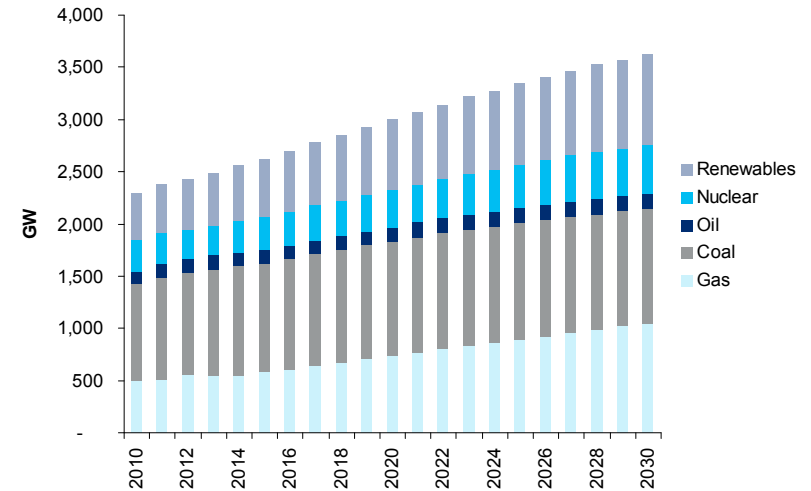
# Putting it all together: a remaking of global energy landscape

## Gas: Rising global supply to meet demand needs

Estimates from different forecasters

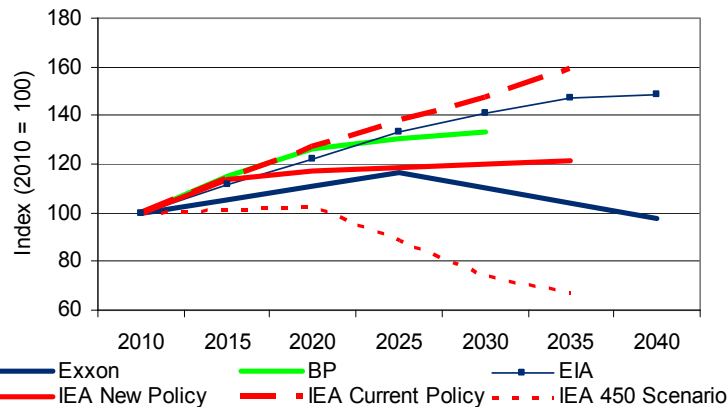


## Power: Renewables and gas to power rising demand



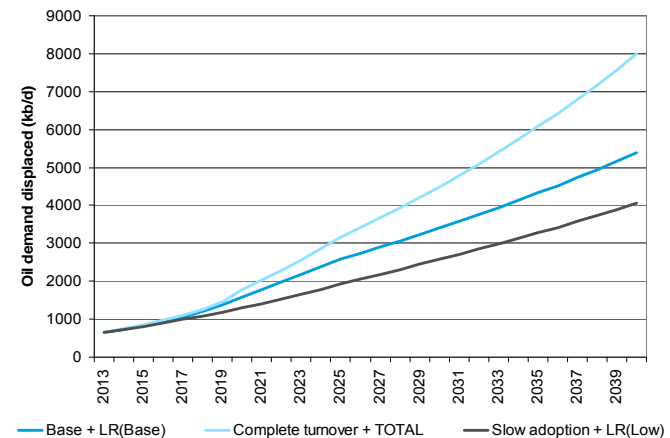
## Coal: Demand should peak, led by China's slowdown

Scenario could follow IEA's New Policy and Exxon's cases



## Oil: Displacement to slow global demand growth

Gas-for-oil substitution in transportation, but substitution in power generation could cut an additional 5-mb/d of demand





# Ongoing/potential disruptive trends to remake the energy market

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- **The last decade saw the emergence of disruptive technology and significant change on the supply side**
- **How and when new technology emerges is always a surprise but improvements of current technology could be just as impactful**
  - Over the past five decades, the hardware industry built on the semiconductor concept developed in the 1960s. Improvements in current technology, such as gas plants, can leverage existing infrastructure and be more impactful
  - Technology can have a large impact on the market if infrastructure is not a hurdle. Shale gas was able to leverage off the existing network, with incremental improvements elsewhere. Storage technology still has to undergo years of massive commercialization before they will have a market-wide impact.
  - But being nimble in response to emerging trends is always a key success factor.

# Appendix A-1

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