

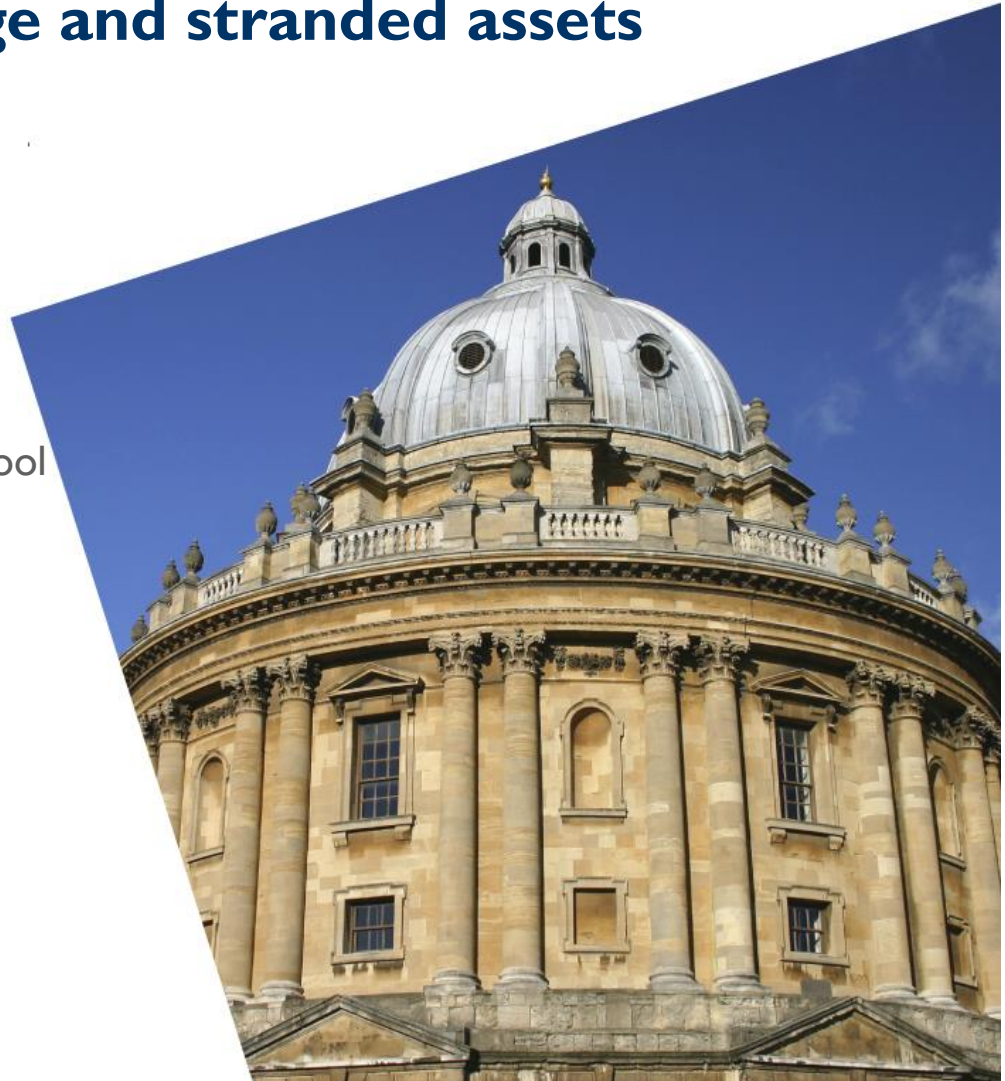
New energy, climate change and stranded assets

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1. Energy scarcity or abundance?
2. Disruptions
3. Divestment and stranded assets
4. Potential economic and geopolitical scenarios
5. Summary

Energy is critical for powering our industry...



...and our cities and towns...



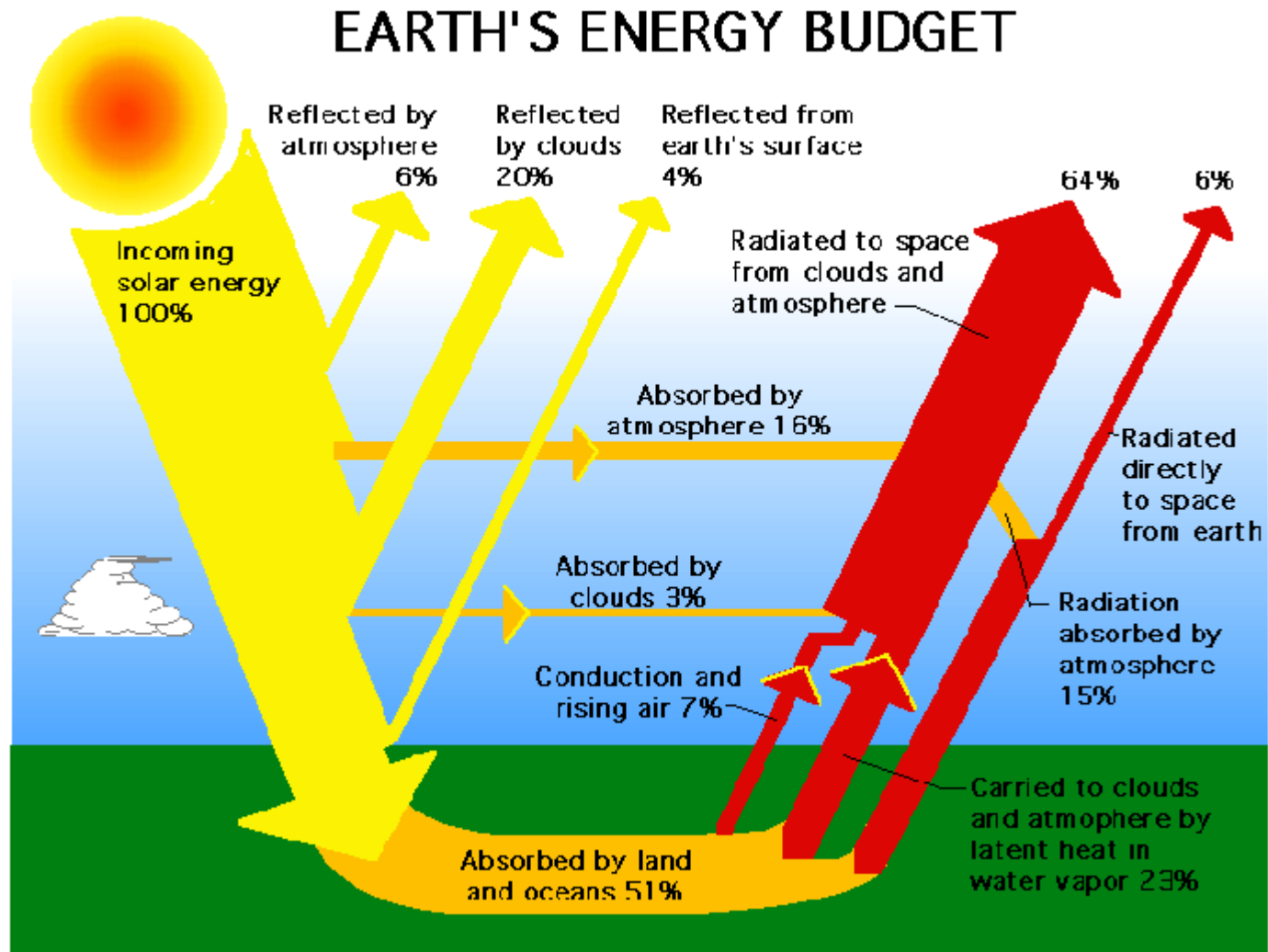
...and is therefore of great strategic importance to the intelligence communities...



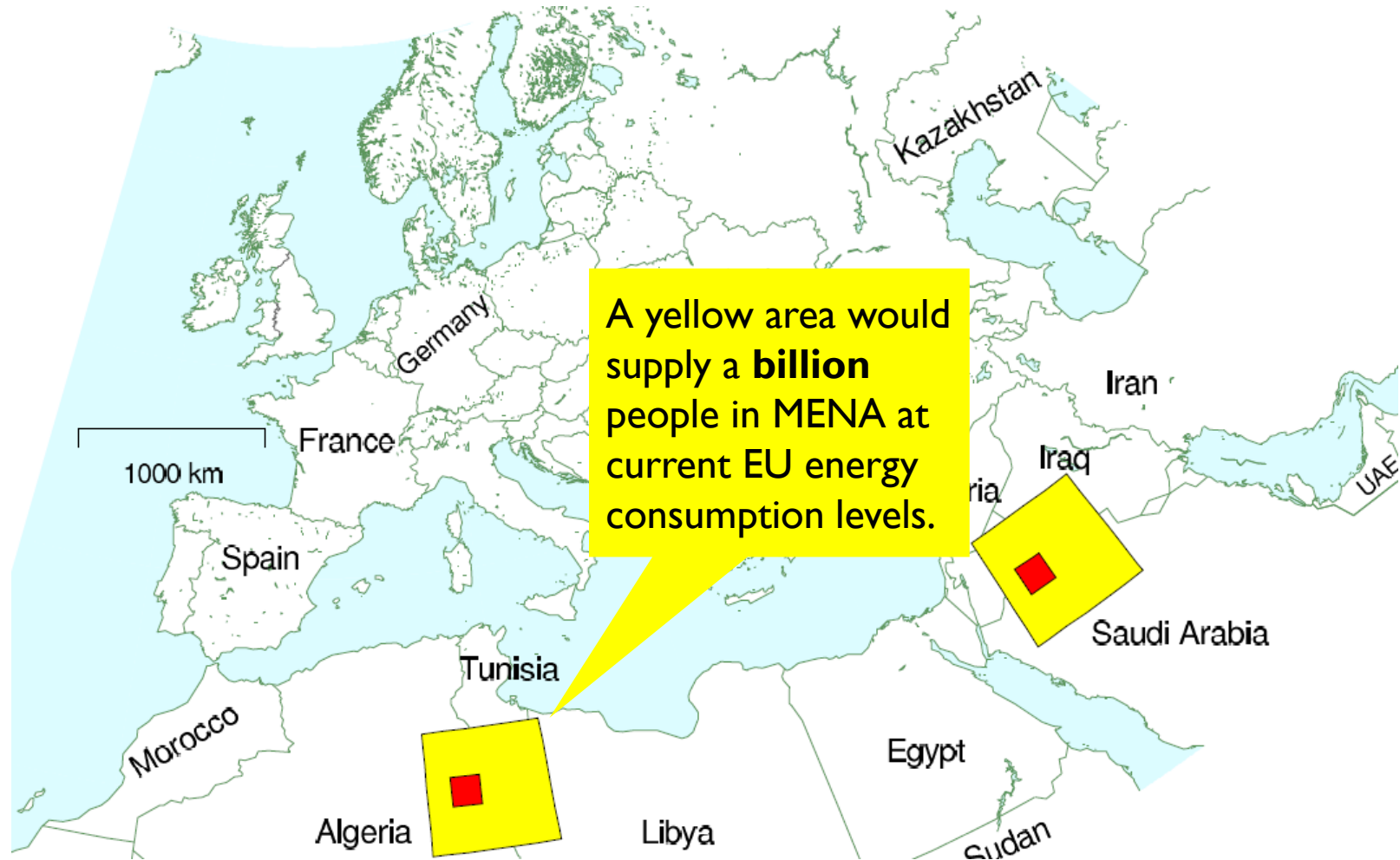
...and ensuring access to energy is of military significance

oil

All of this 'importance' might make you think energy was scarce...but it is actually everywhere...



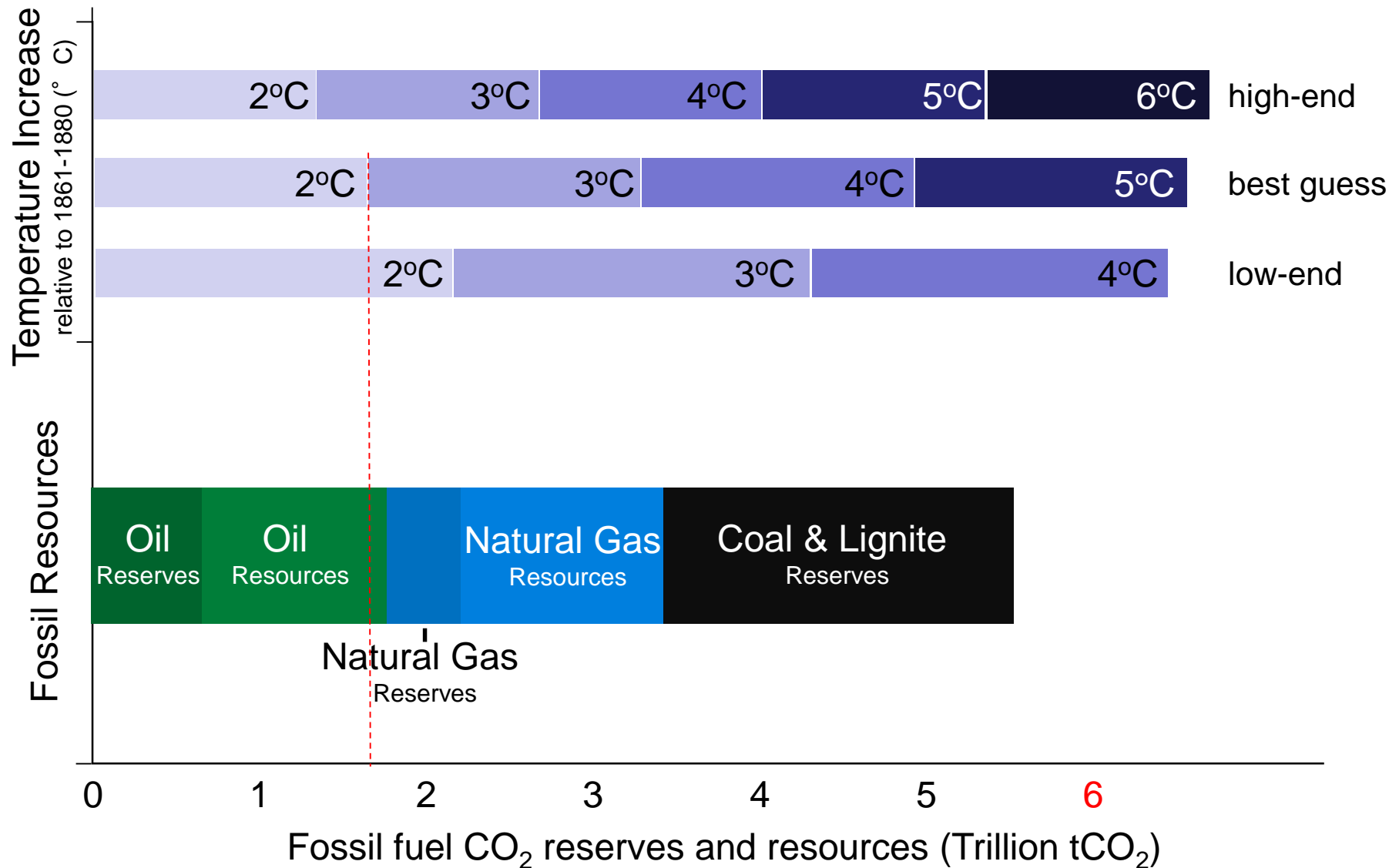
At conservative efficiencies, a small red square could power the entire UK's electricity, heat and transport



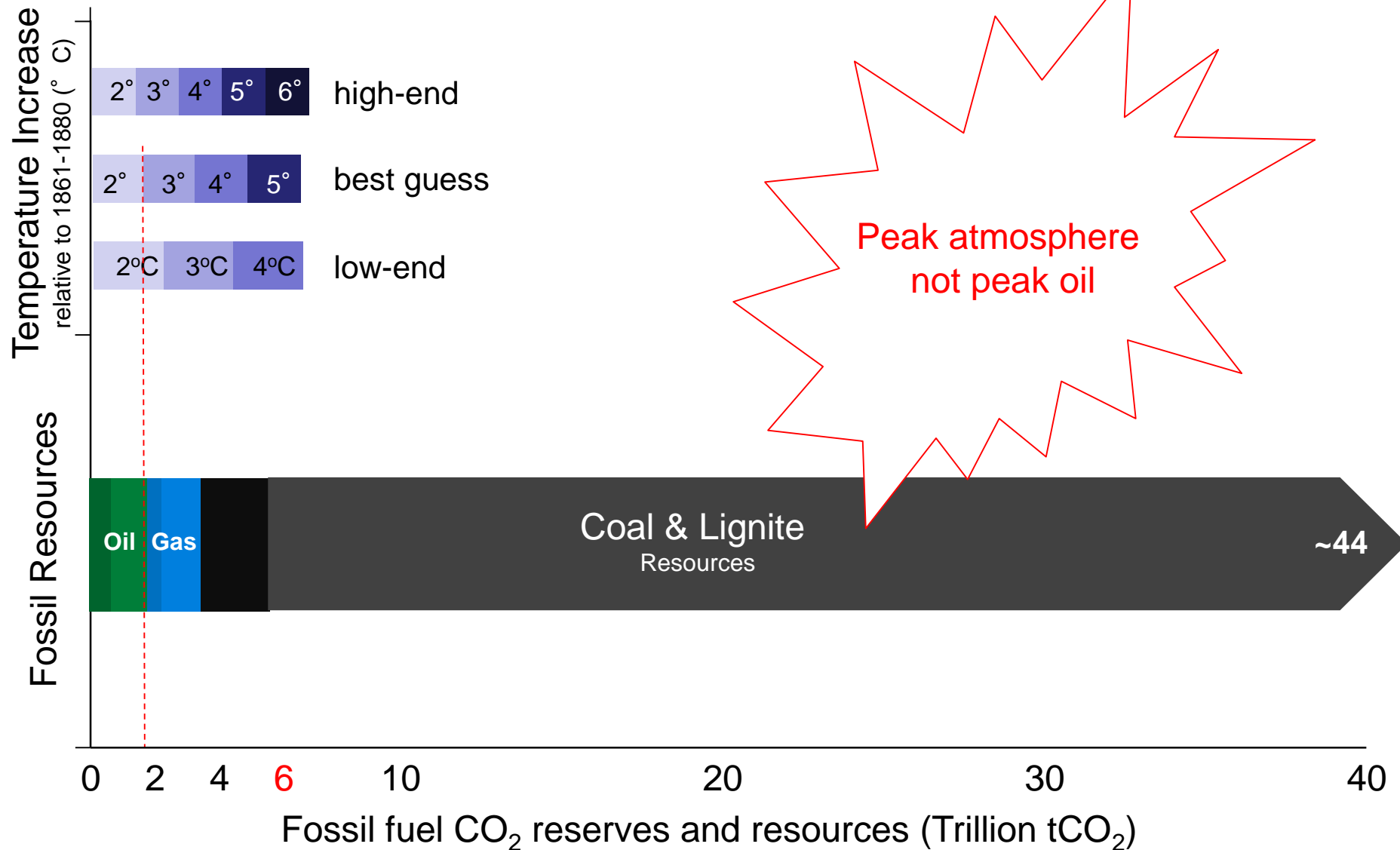
“I’d put my money on the sun and solar energy. What a source of power! I hope we don’t have to wait until oil and coal run out before we tackle that.”

THOMAS EDISON (1931)

We also have more coal, oil and gas in known, economically extractable reserves than we can burn

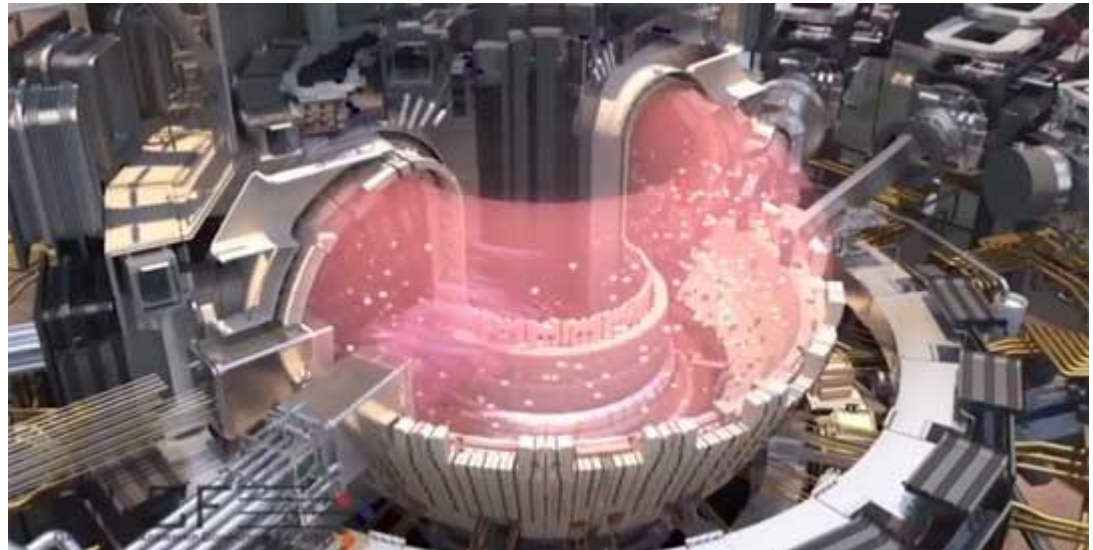


We also have more coal, oil and gas in known, economically extractable reserves than we can burn



If nuclear fusion were ever (?) to get going...we would effectively have limitless energy

$$E = mc^2$$



So why has access to something so abundant held back human civilisation and now threatens it?

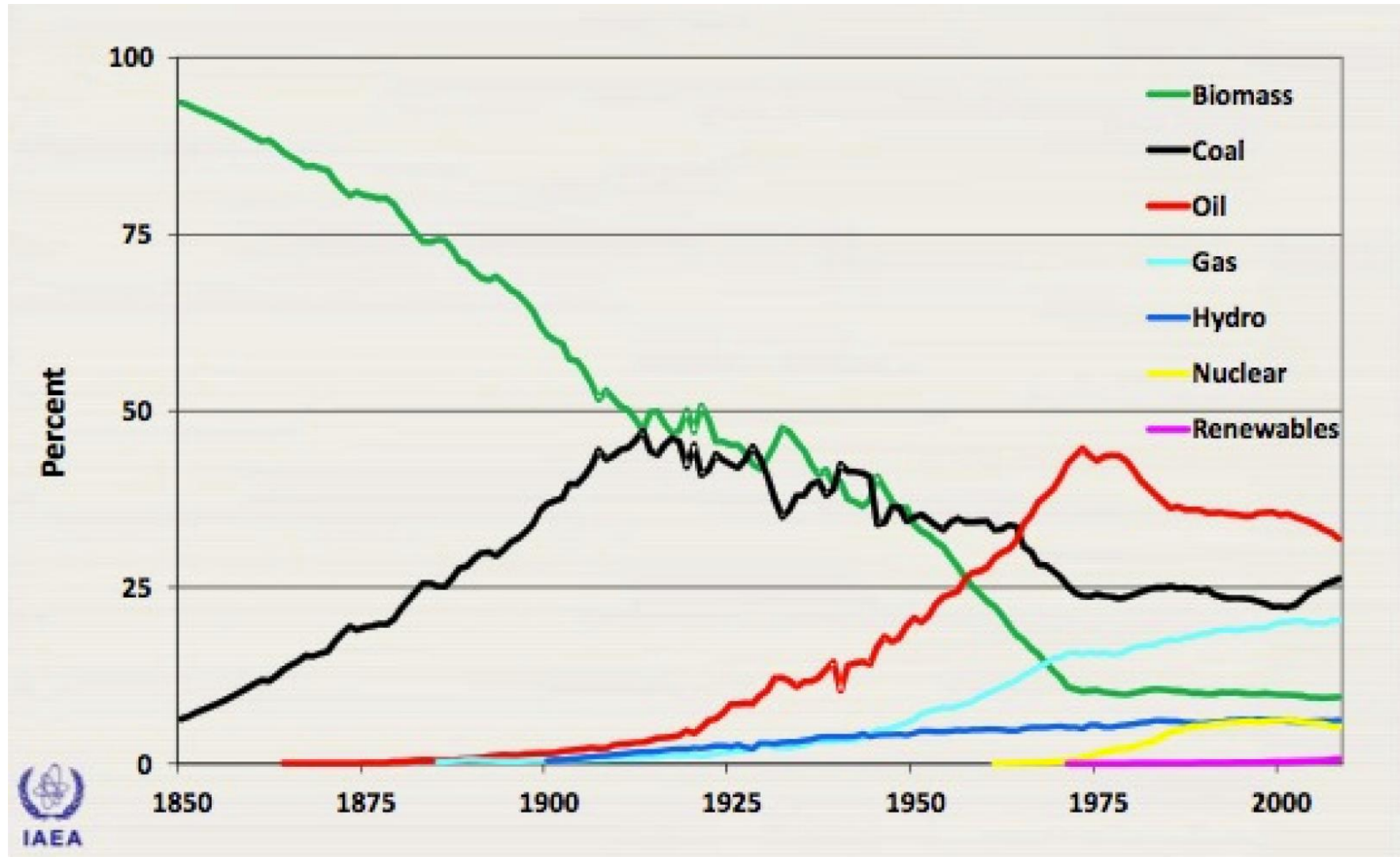
- Energy is super-abundant, but for millennia we had no idea
- Energy has been **economically very expensive** to get into useful forms for human economic activity
- But technological breakthroughs now look likely



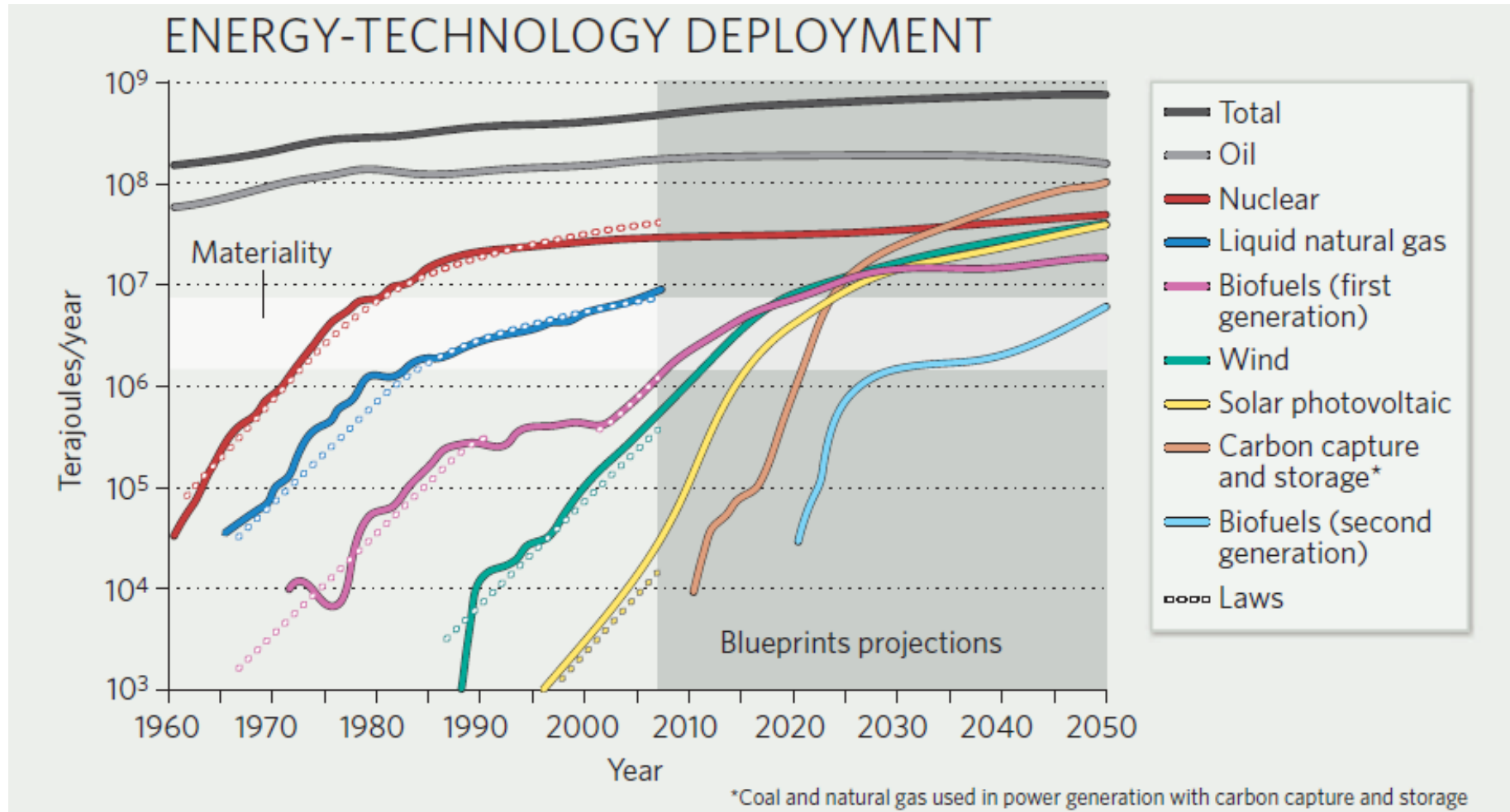
We are probably on the cusp of one of the **most significant energy system transitions** in human history

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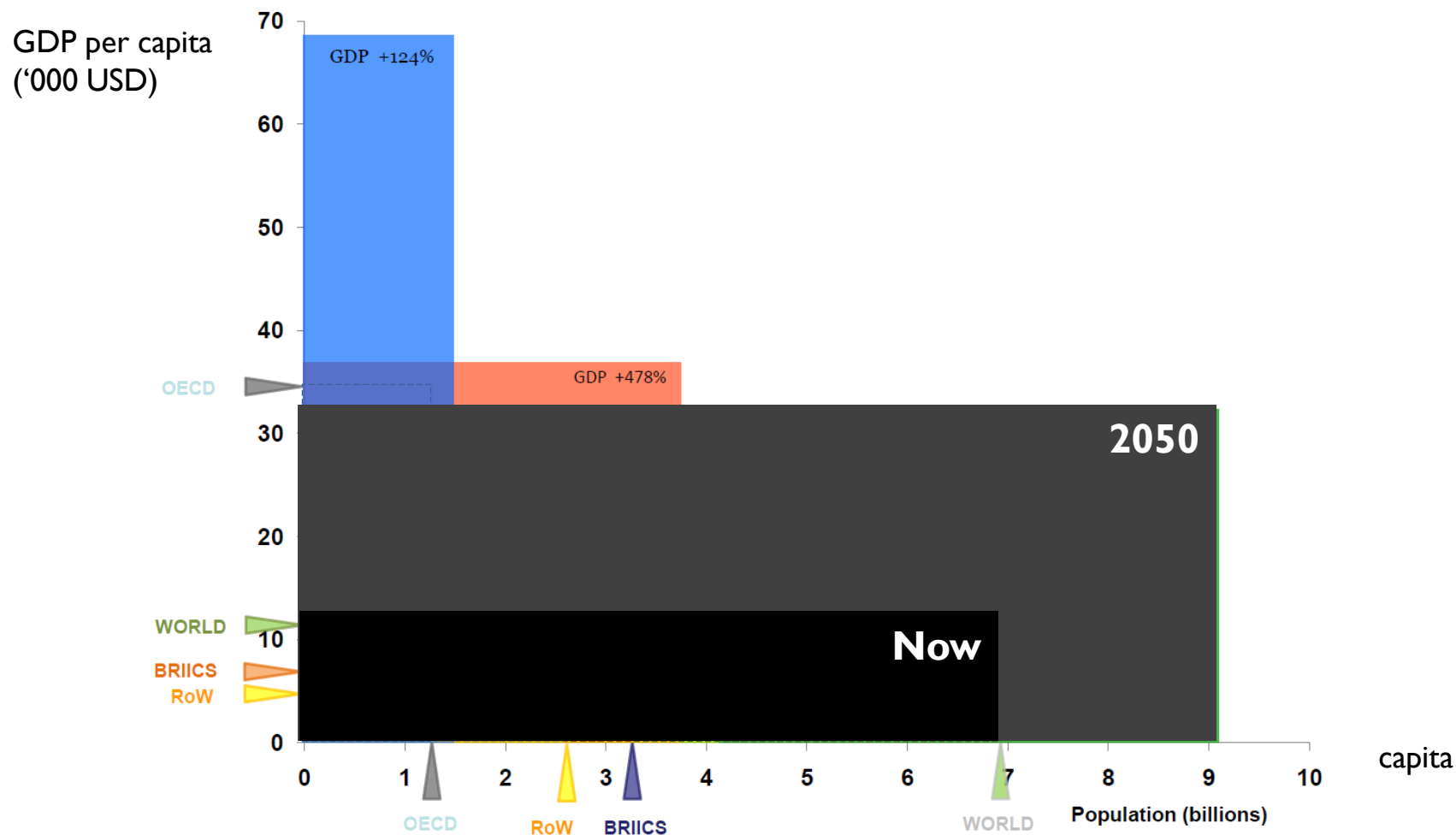
Historically, energy transitions have happened slowly, each one taking many decades



This has been used to suggest that there is a 'law' that constrains how quickly new technologies can enter



But this transition could be faster due to energy demand from billions of new middle class consumers



1. Energy scarcity or abundance?

2. Disruptions

- Markets: fracking, solar, IT

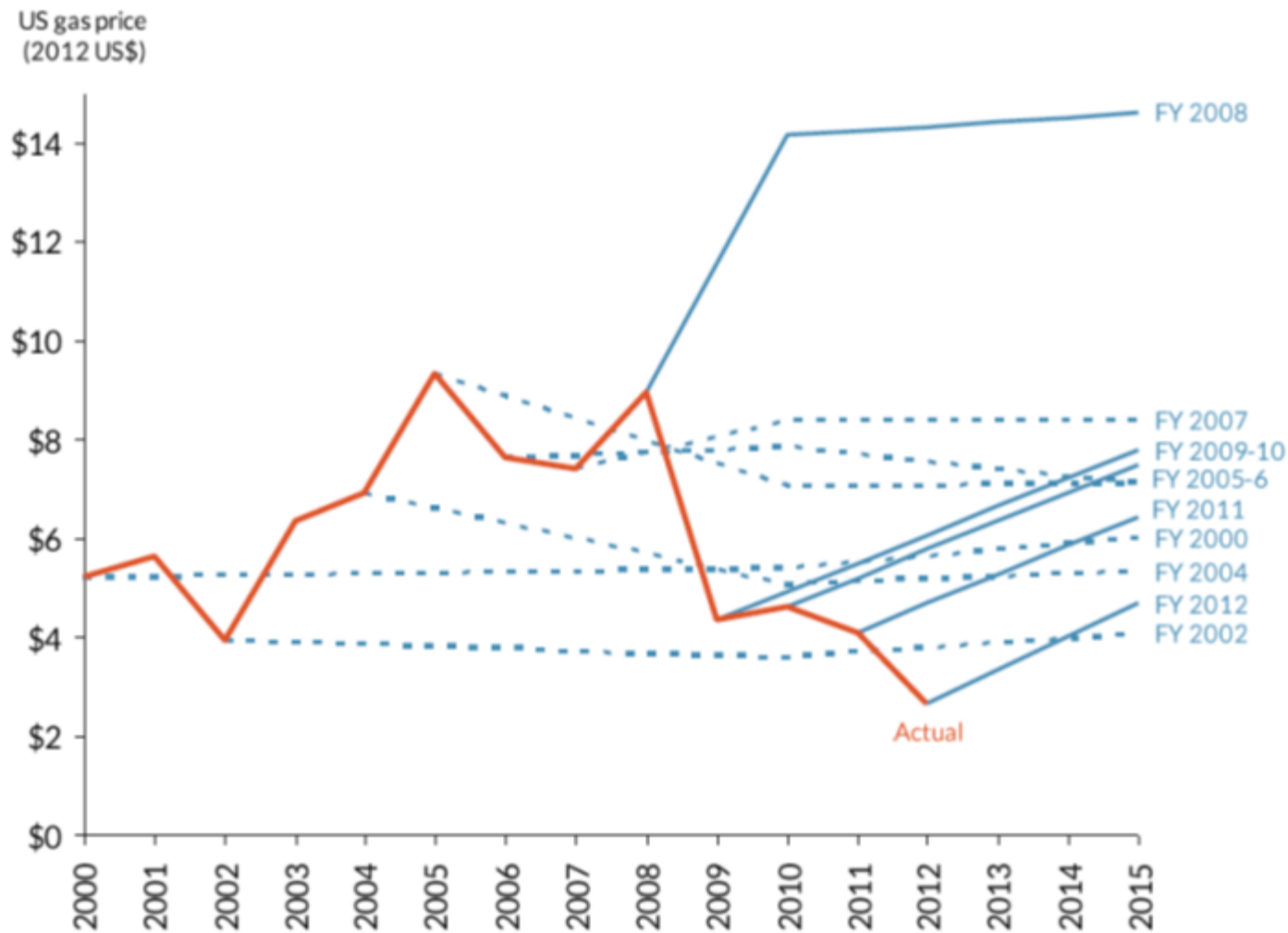
- Government: climate change and renewables

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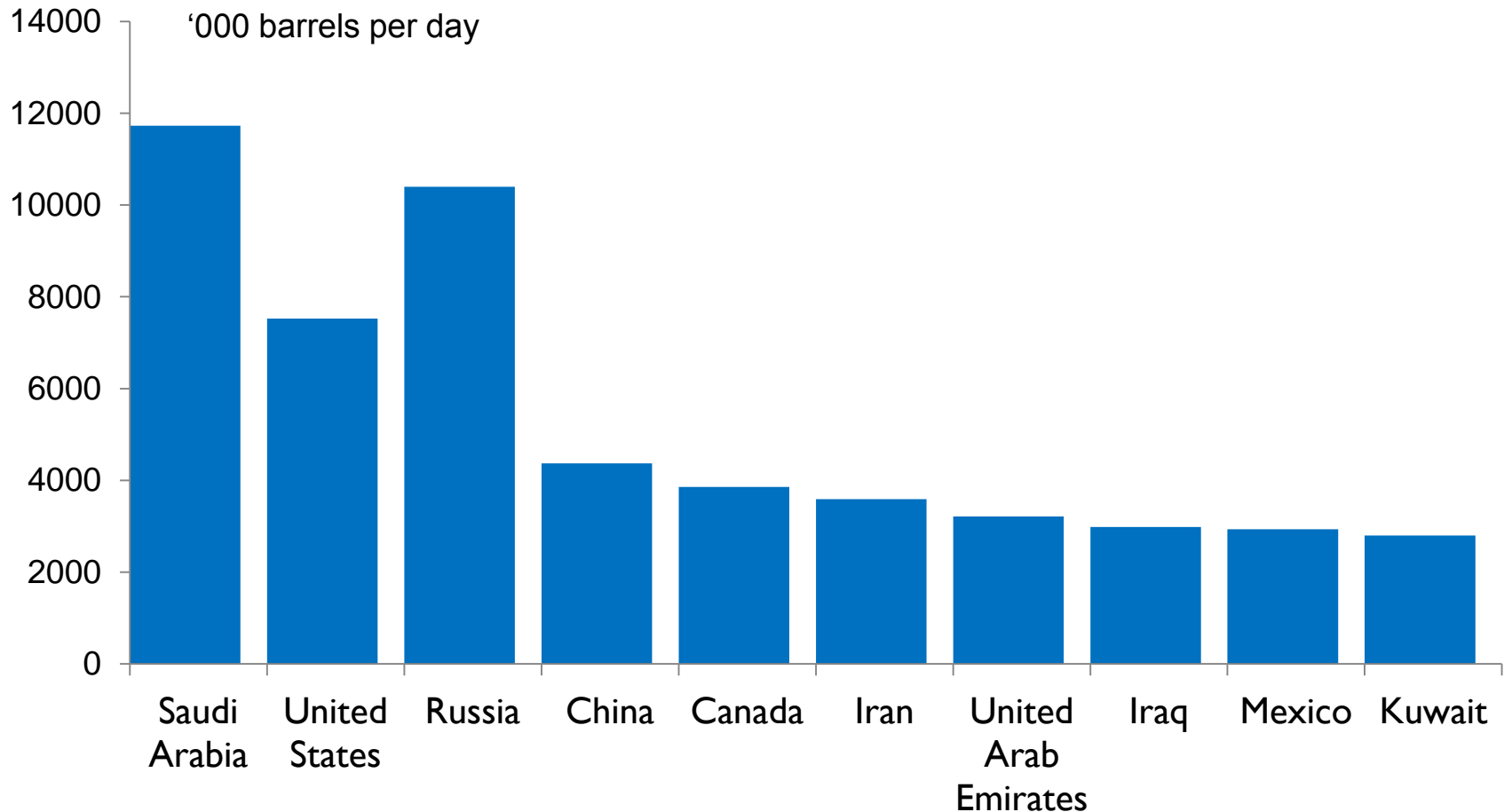
Fracking: Impacts of shale tech appeared rapidly in US gas prices (but unanticipated by forecasters)



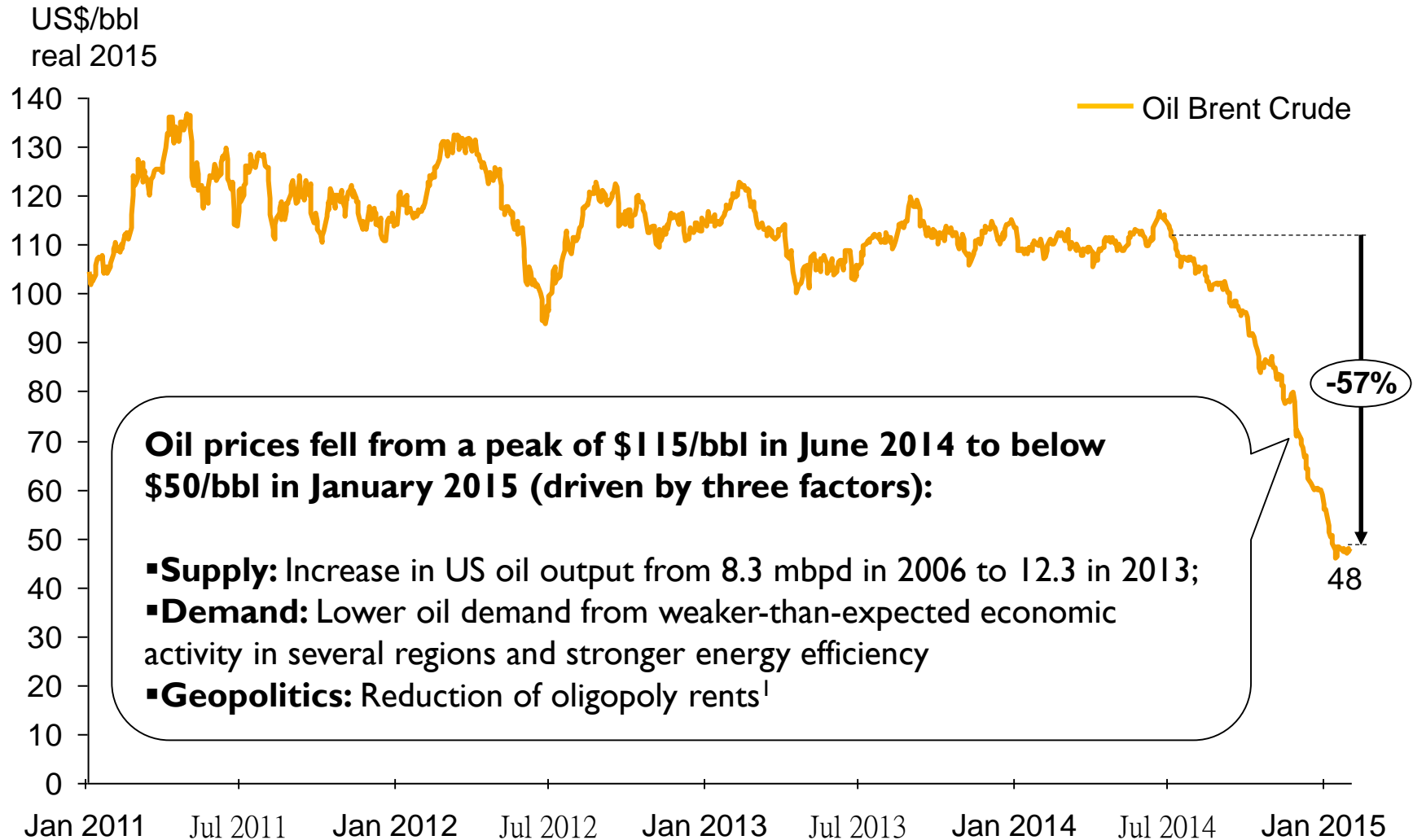
Notes: IEA's US average imported gas price forecast, reference scenario, constant 2012 US\$ per MBtu

Sources: IEA, *World Energy Outlook*, 2000, 2002, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012

Shale then made the USA into the largest oil producer (at least for the moment)...



...triggering the oil price crash...

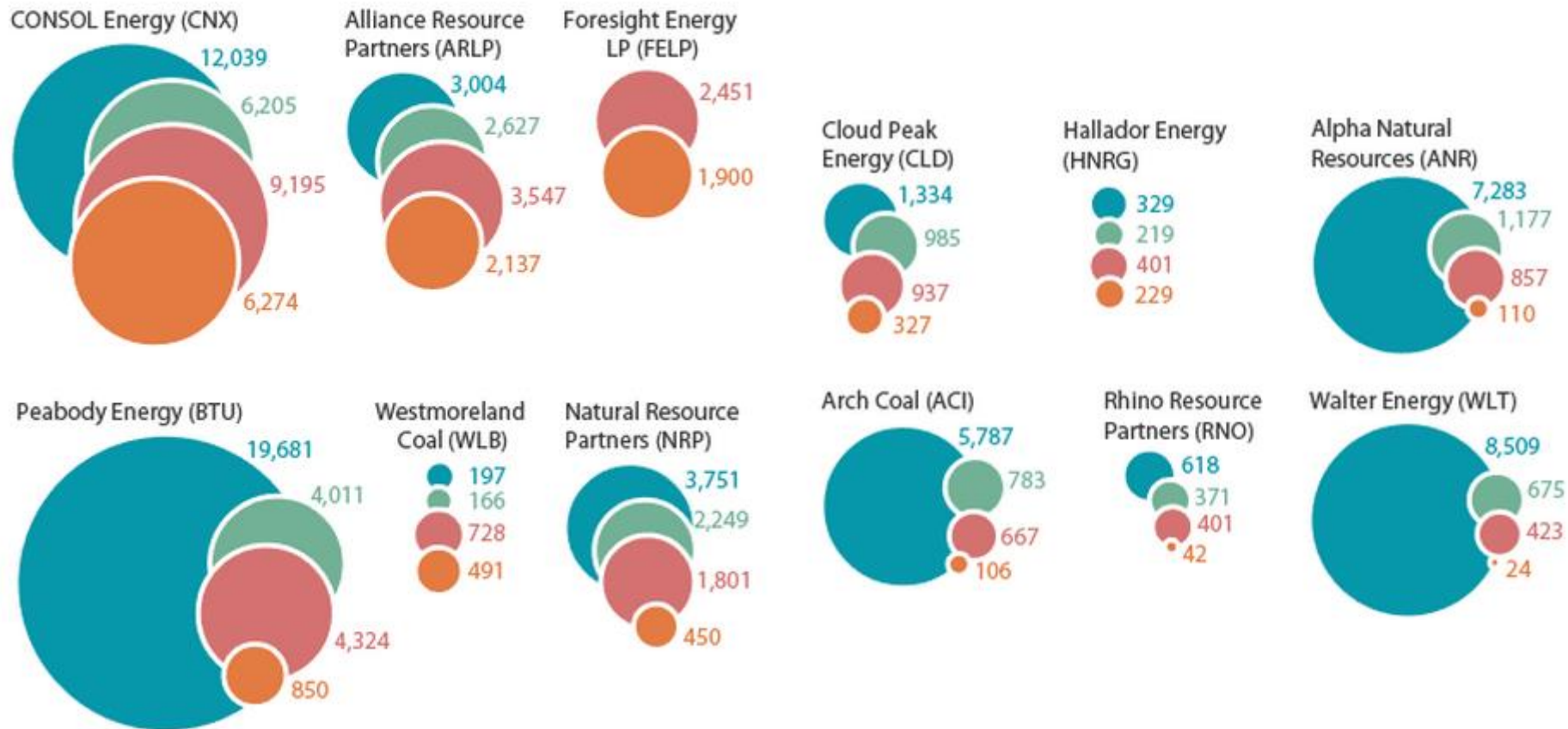


¹ OPEC announced that it would maintain current production levels (Nov. 27th, 2015)

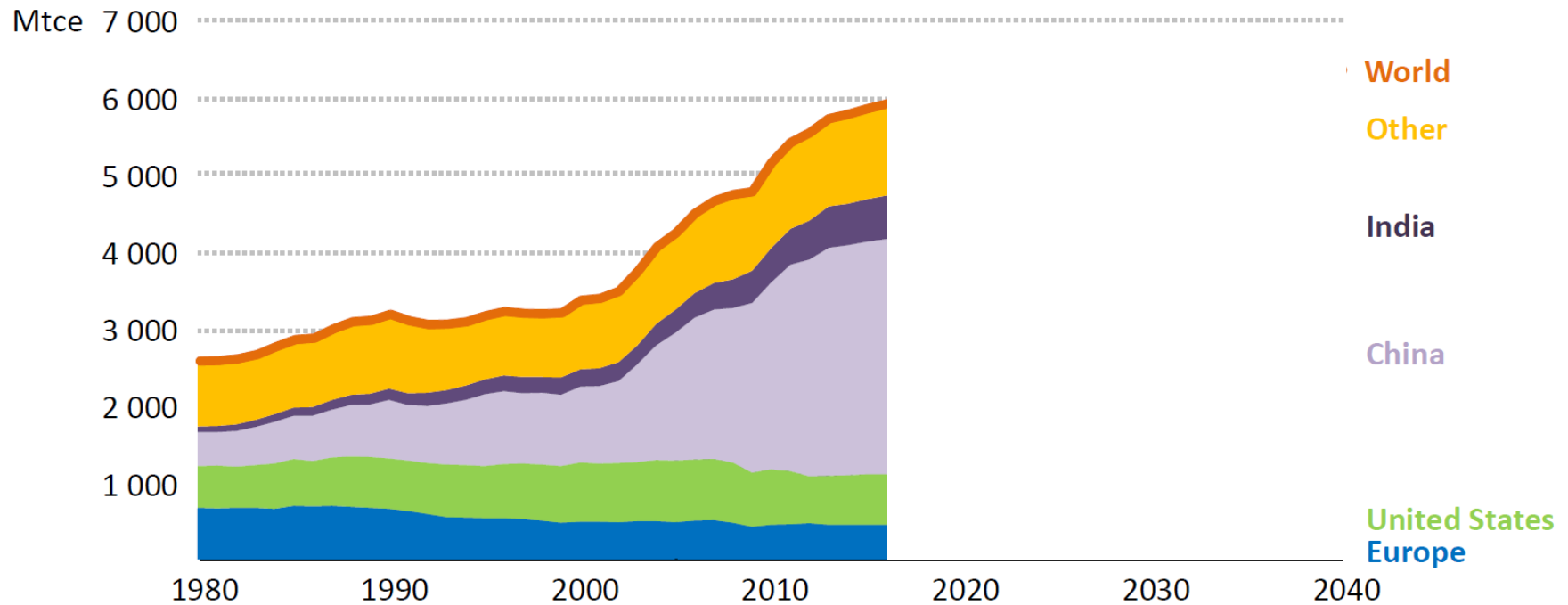
...and hammering US coal players (with the White House putting the boot in)

Coal companies' market capitalization changes (\$M)

As of April 1, 2011
As of Aug. 13, 2014
As of July 2, 2013
As of June 8, 2015



The prospects for growth in coal globally now also look fairly flat.



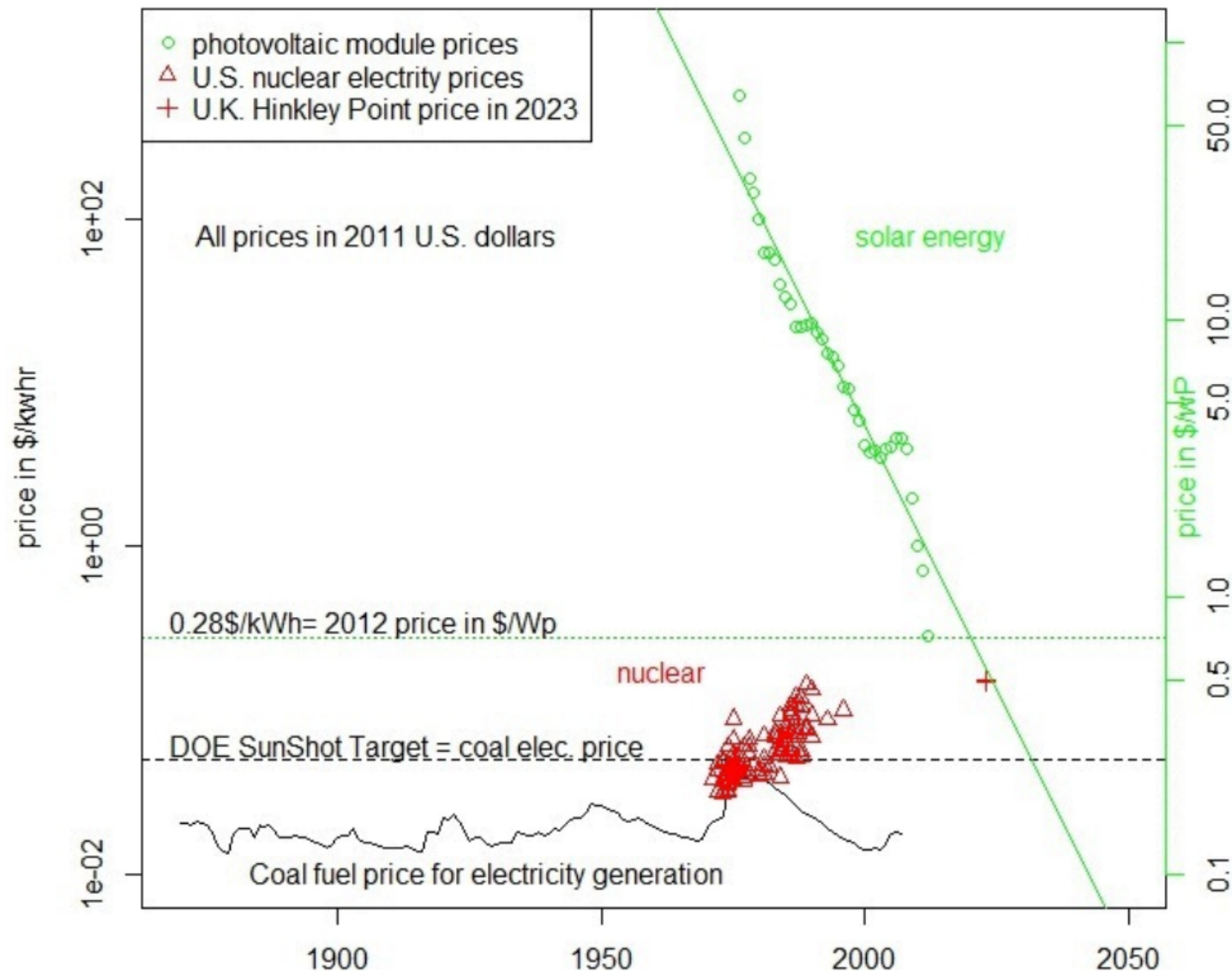
Key questions

Will the shale boom run out of steam?

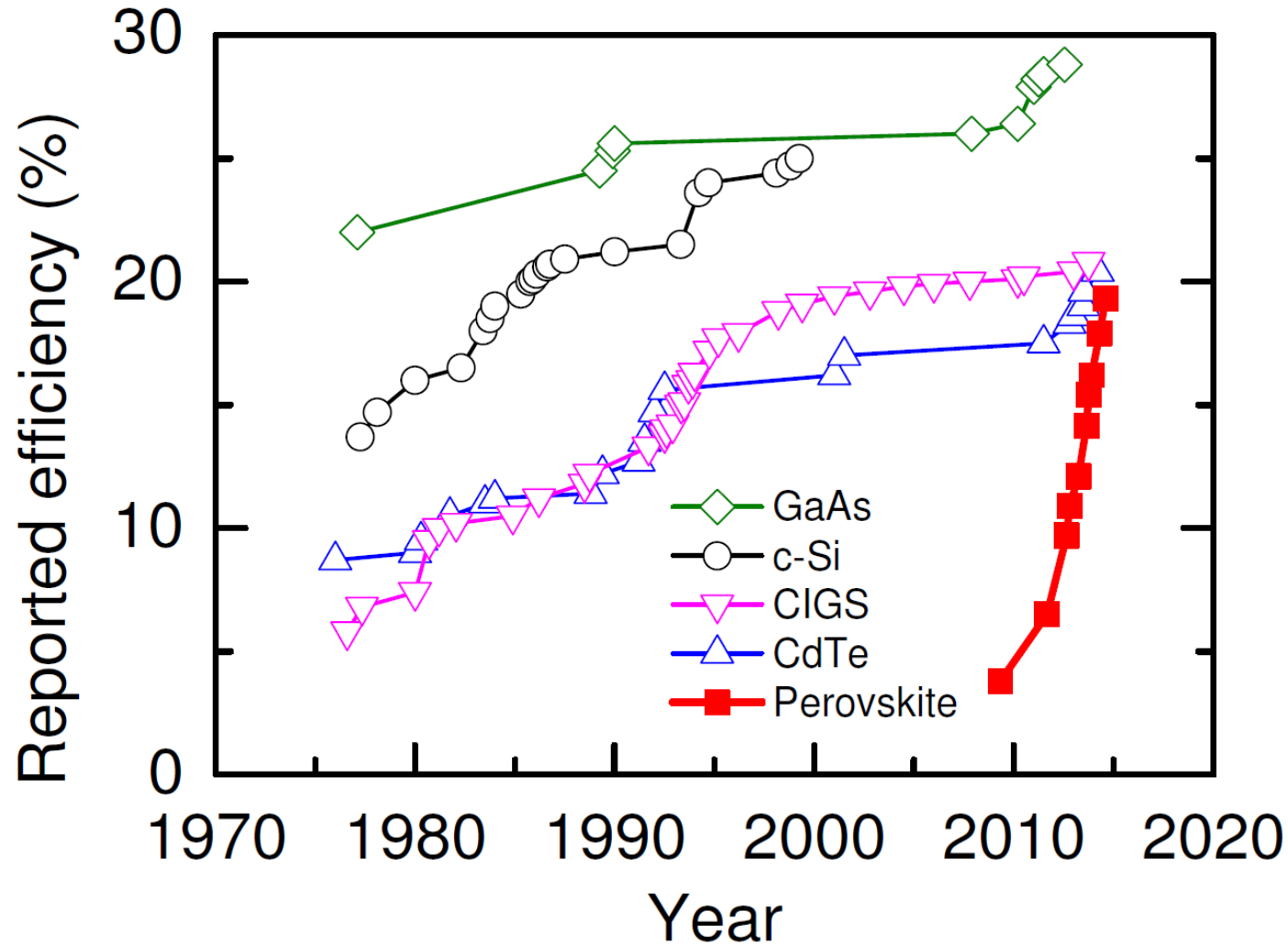
Distinguish three phases:

1. Shale **extraction** in the US (with indirect effects on other markets)
2. Shale gas **exports** (through LNG terminals approved by FERC)
3. Shale gas **technology diffusion** to other countries

Solar PV: Over the long run, the solar PV module price collapse is remarkable compared to coal



And these price declines are based on standard, Silicon-based technology, rather than newer ideas



The prize in solar is now obvious, and innovations in solar are coming thick and fast



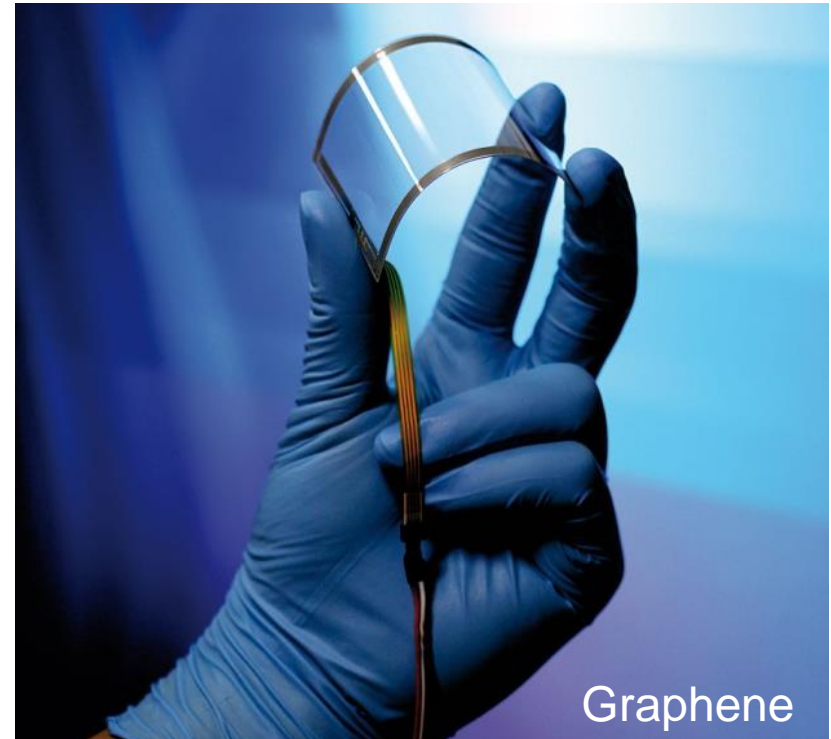
Source: Rob Lavinsky, iRocks.com



Credit: Oxford Martin School

Much of this is based around new materials science to make better practical use of solar physics

- Perovskites (CaTiO_3)
 - High conductivity
 - Increasing efficiency
 - Simple processing
- Graphene (C)
 - High conductivity
 - Very thin and flexible
 - 200x stronger than steel
 - Nearly transparent



Information technology: Disruption happening from new customer relationships...enter Google



Home automation (\$3b)



Data centre energy efficiency



Renewable energy (> \$1b)



Autonomous vehicles

Players like M-KOPA threaten to cut coal's lunch in India (the next logical market as China slows)



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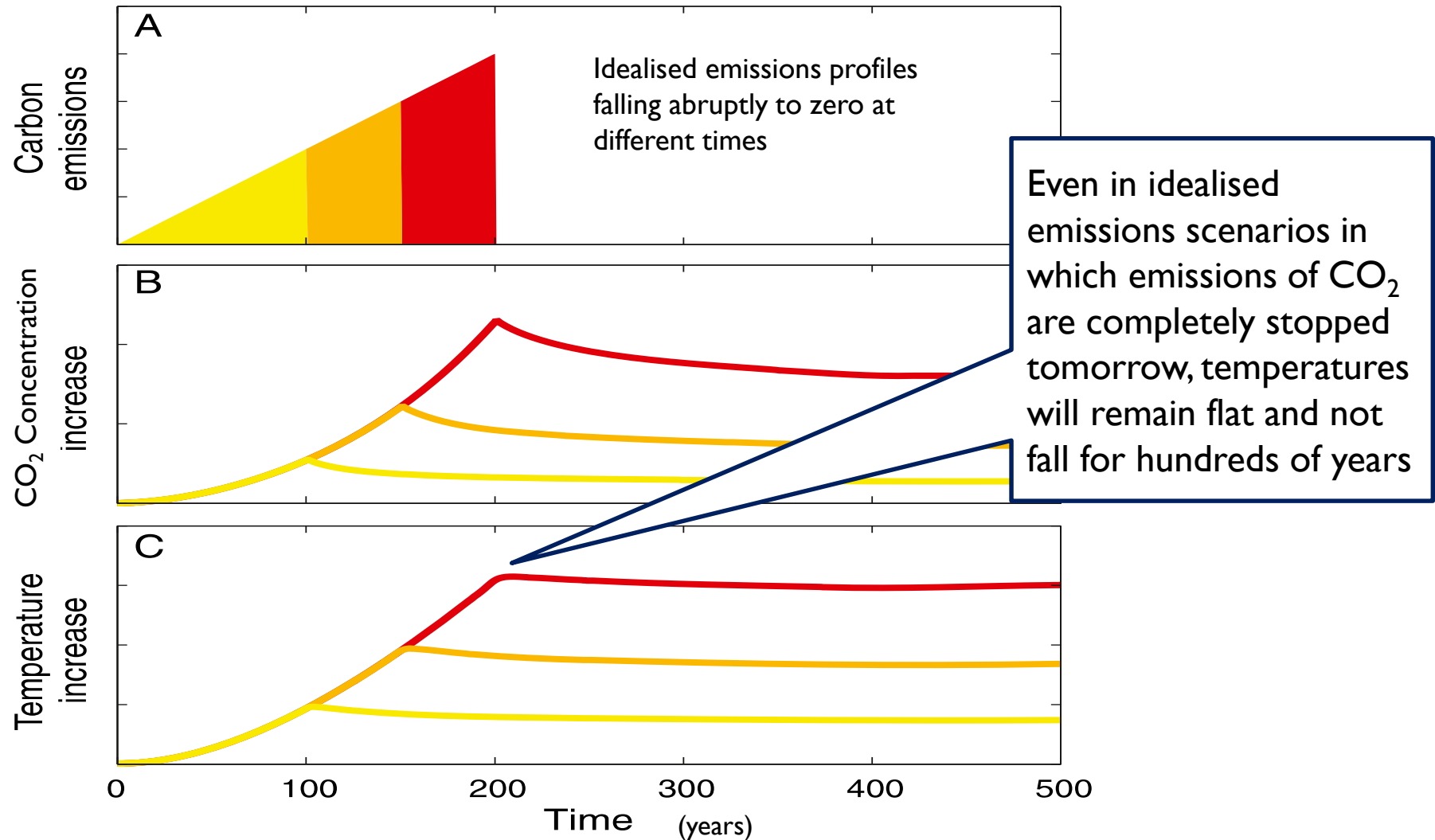
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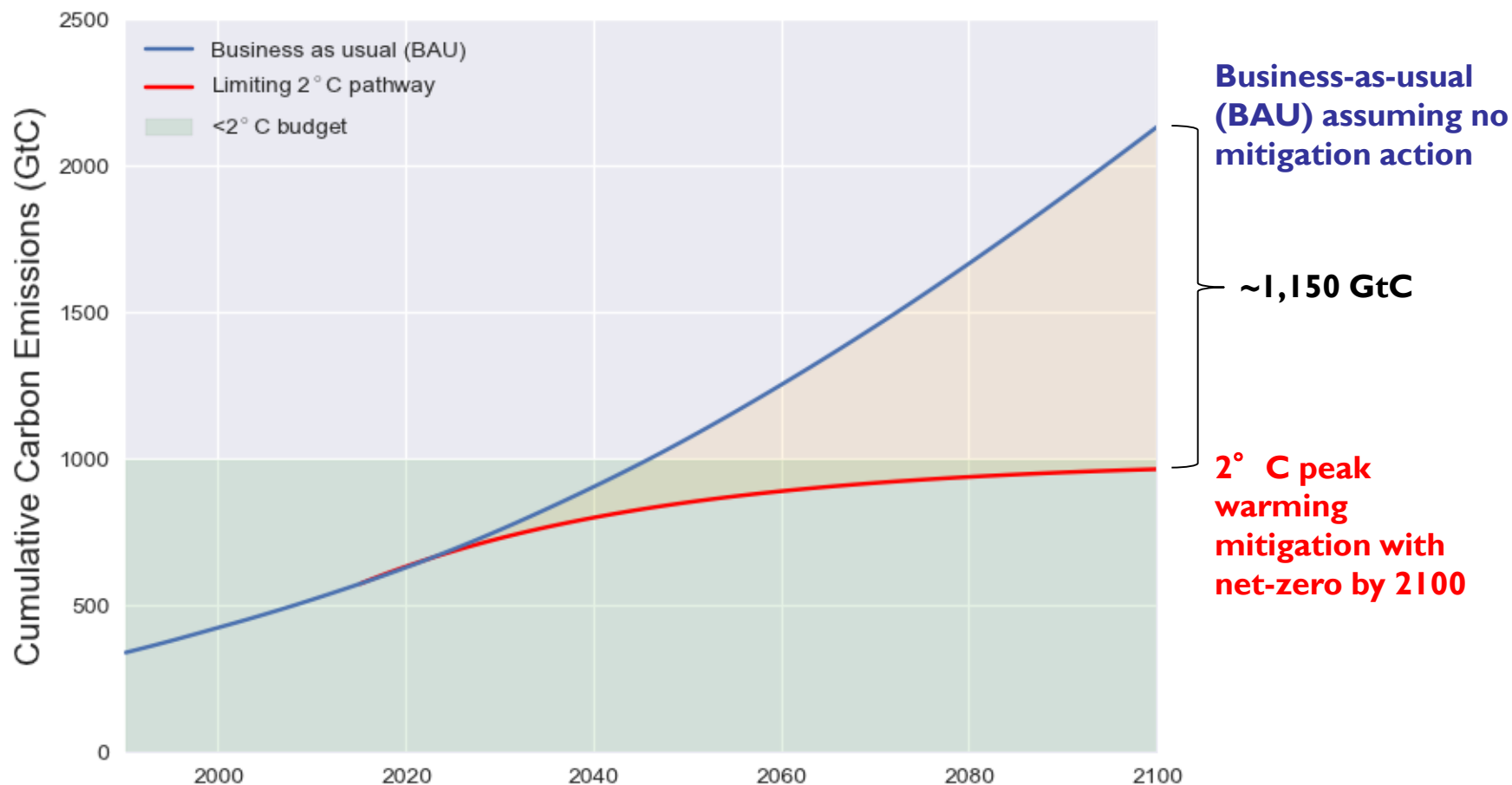
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New science over the last 5 years clarifies the need for **net zero emissions** for *any* stable temperature



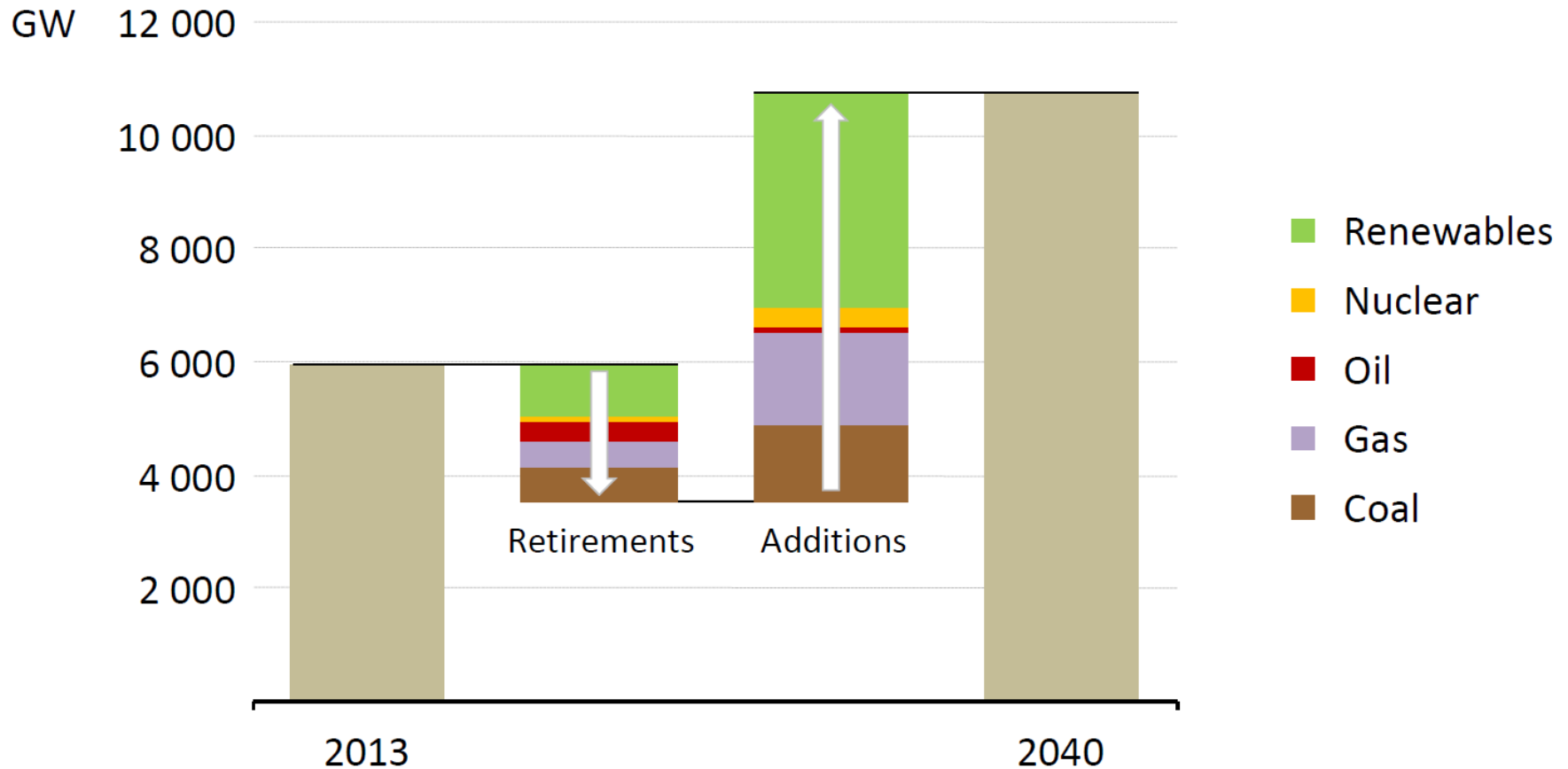
Keeping warming below 2°C requires cumulative carbon emissions under 1,000 GtC before net zero

We need to reach global net-zero emissions before we have emitted **cumulative carbon emissions (CCE)** of about 1,000 GtC to have >50% chance of keeping peak warming below 2°C



~1,150 GtC mitigation from business-as-usual and global net-zero emissions are required before 2100

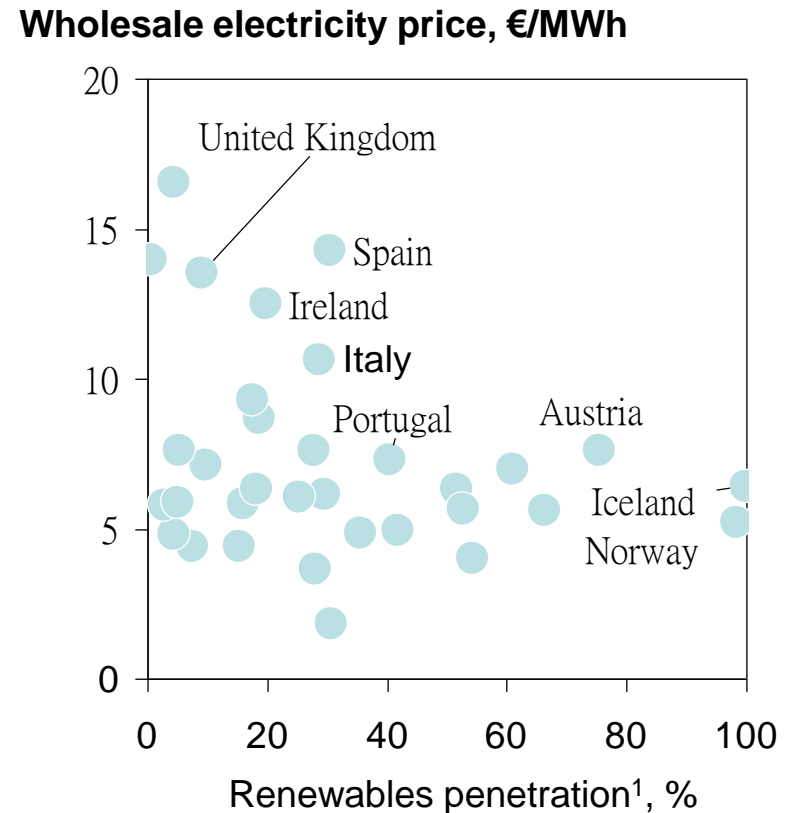
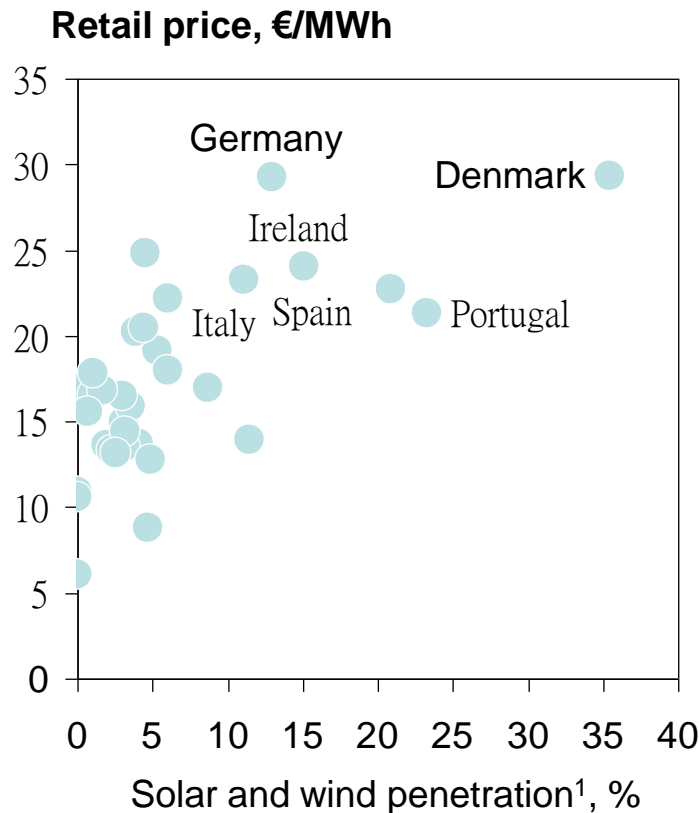
The IEA's guess – over half new global power plant to 2040 will be renewables – might be conservative



Higher renewable penetration is already creating existential threats for conventional thermal plant

Renewables deployment across Europe increases regulatory costs passed on to consumers...

...while depressing the wholesale price and decreasing the profits of traditional generators



1. Most renewable generation in Europe is produced by old hydro plant, most of which has been fully financed and as such this cost is not passed on to consumers. Subsidies for “new” renewables deployment in the form of solar and wind capacity is mostly financed through levies and increases retail price.

The German *Energiewende* provides an indication of the potential challenges coming at utilities

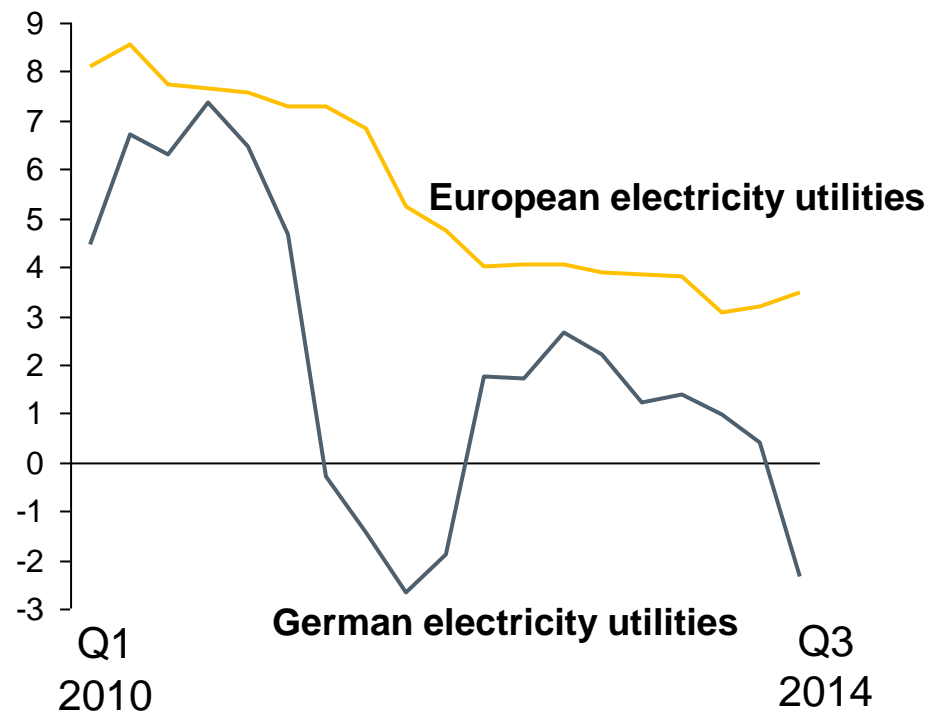
RWE

€3.3 billion:
impairment charge
on fossil plants
in 2013

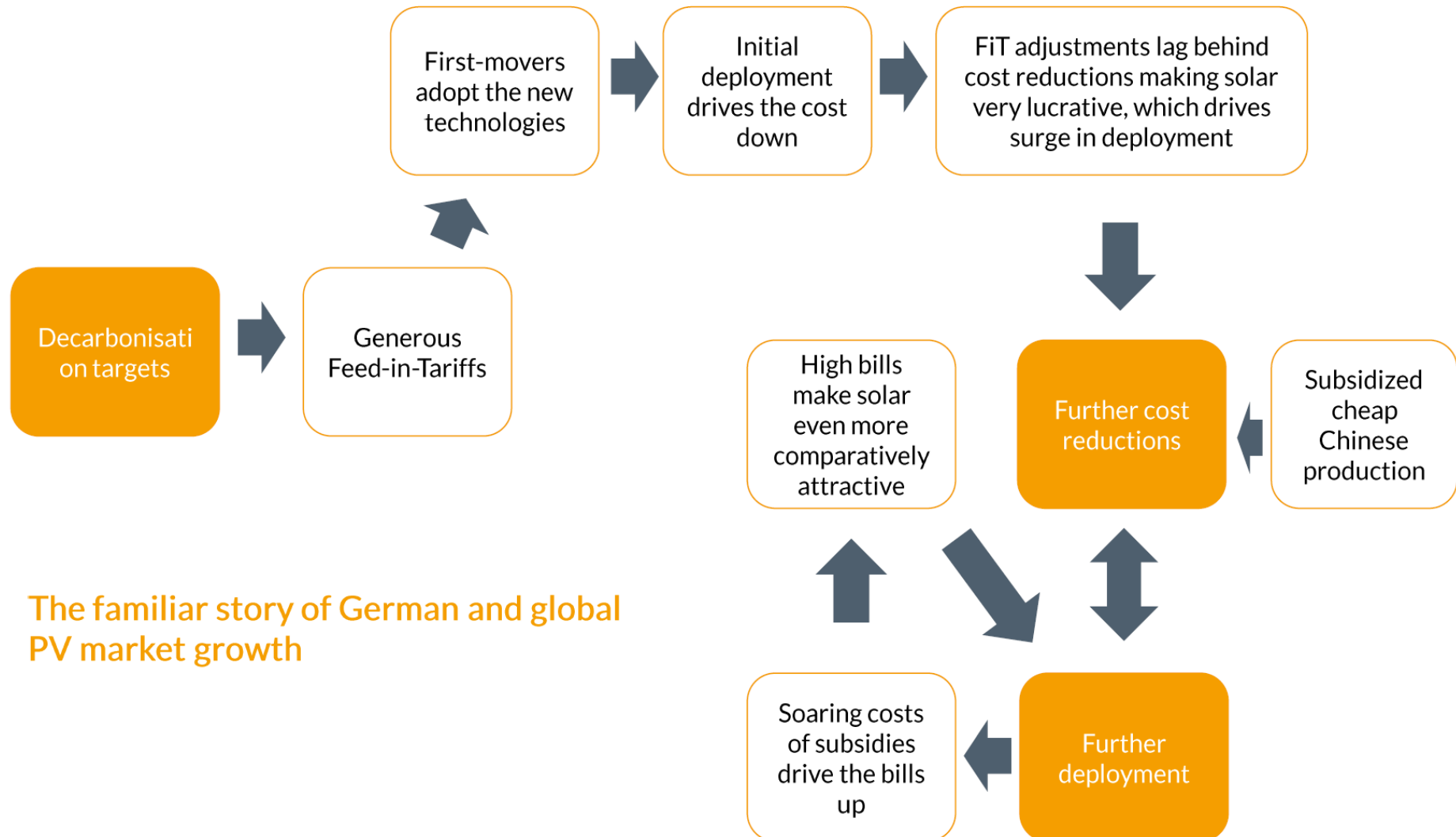
e.on

Corporate
restructure

Profit margin, %



Consumers going offgrid with renewables creates the familiar self-reinforcing feedback loop...



The familiar story of German and global PV market growth

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A fossil divestment movement has grown quickly in response to “peak atmosphere”

Divest for
our
FUTURE



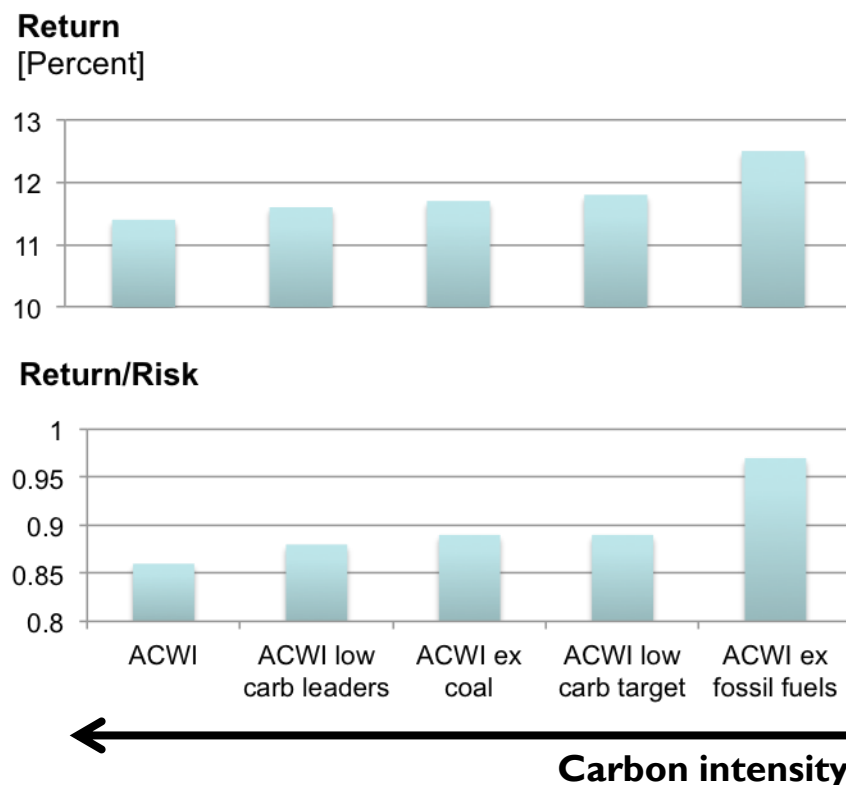
But will it actually do anything? I suspect it is not much more than a good investment strategy

A good investment strategy?

“Free option on high carbon prices”

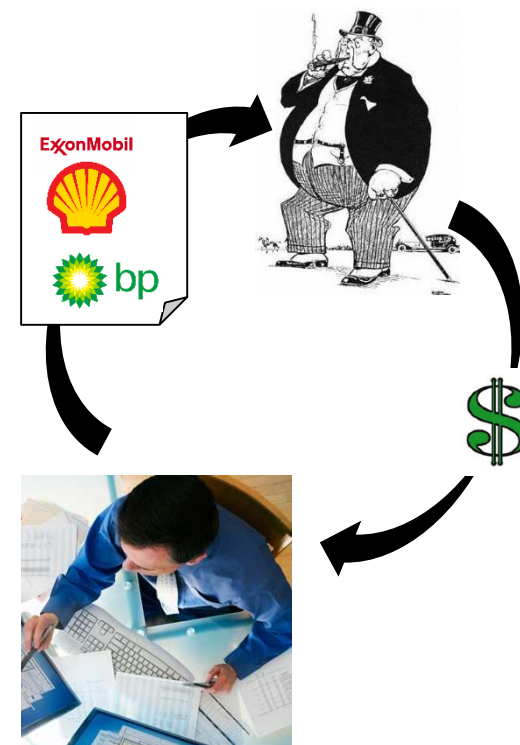
Performance of selected MSCI indices

[Sept. 28, 2010 – Sept. 30 2014]






Socially unproductive?

“Divestment is complicit in the problem; instead use ownership to force positive changes in industry”




At Oxford we are working with fossil fuel owners to develop principles for 'safe' use of the product



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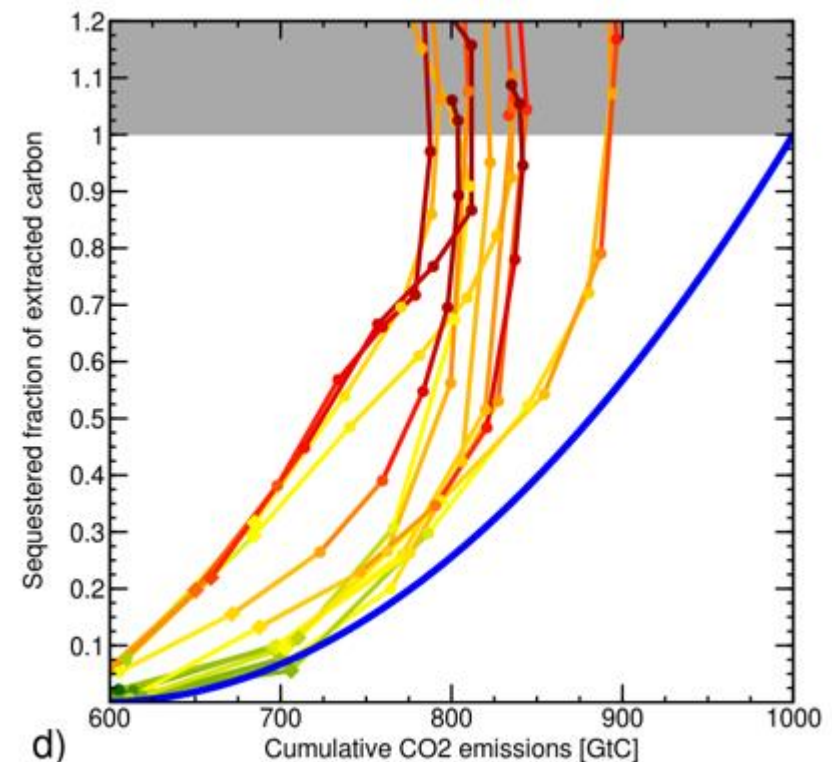
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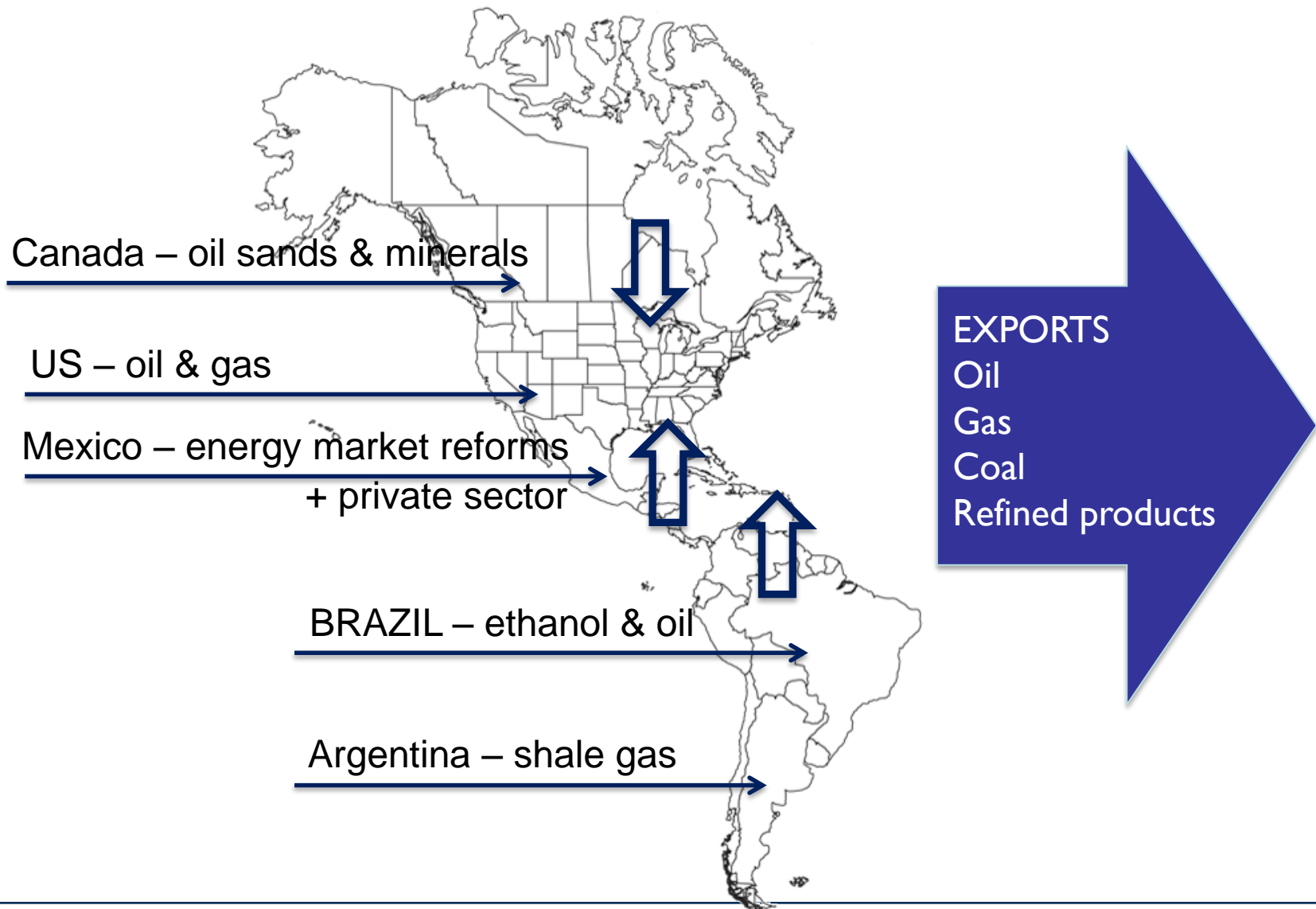
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The distribution of fossil reserves has always had big implications for political and economic power

Rank	Coal	Oil	Gas
1	US	Saudi Arabia	Russia
2	Russia	Canada	Iran
3	China	Venezuela	Qatar
4	Australia	Iran	Turkmenistan
5	India	Iraq	Saudi Arabia
6	Ukraine	Kuwait	US
7	Kazakhstan	UAE	UAE
8	South Africa	Russia	Venezuela
9	Poland	Libya	Nigeria
10	Brazil	Kazakhstan	Algeria
Total of top 10	91.5%	82.9%	76.8%

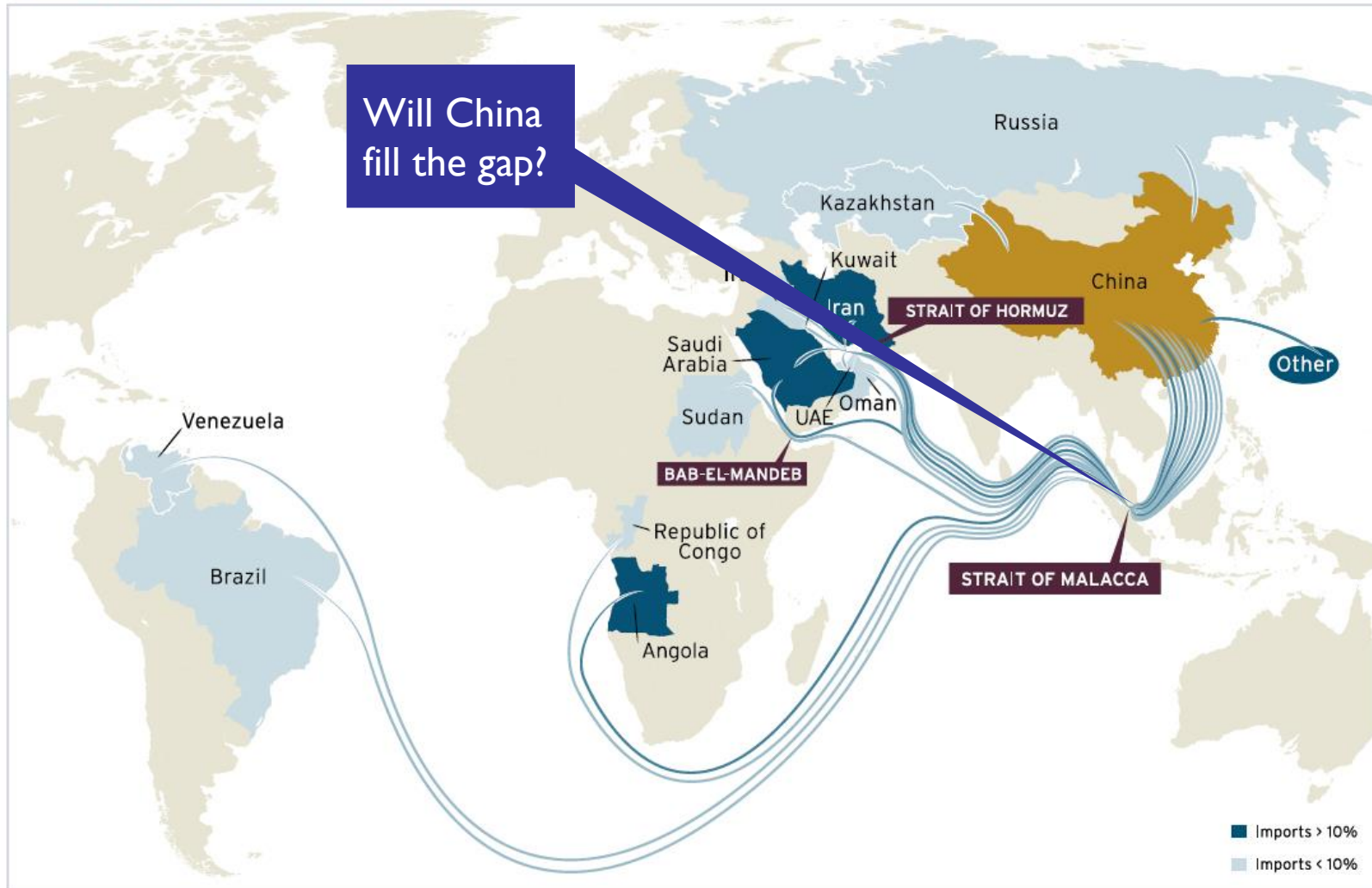
* 200 largest coal and oil & gas companies listed on stock exchanges around the world

The USA is now in a position of energy abundance, reshaping power balance globally



This is already raising political questions...so
imagine what happens when solar really gets going

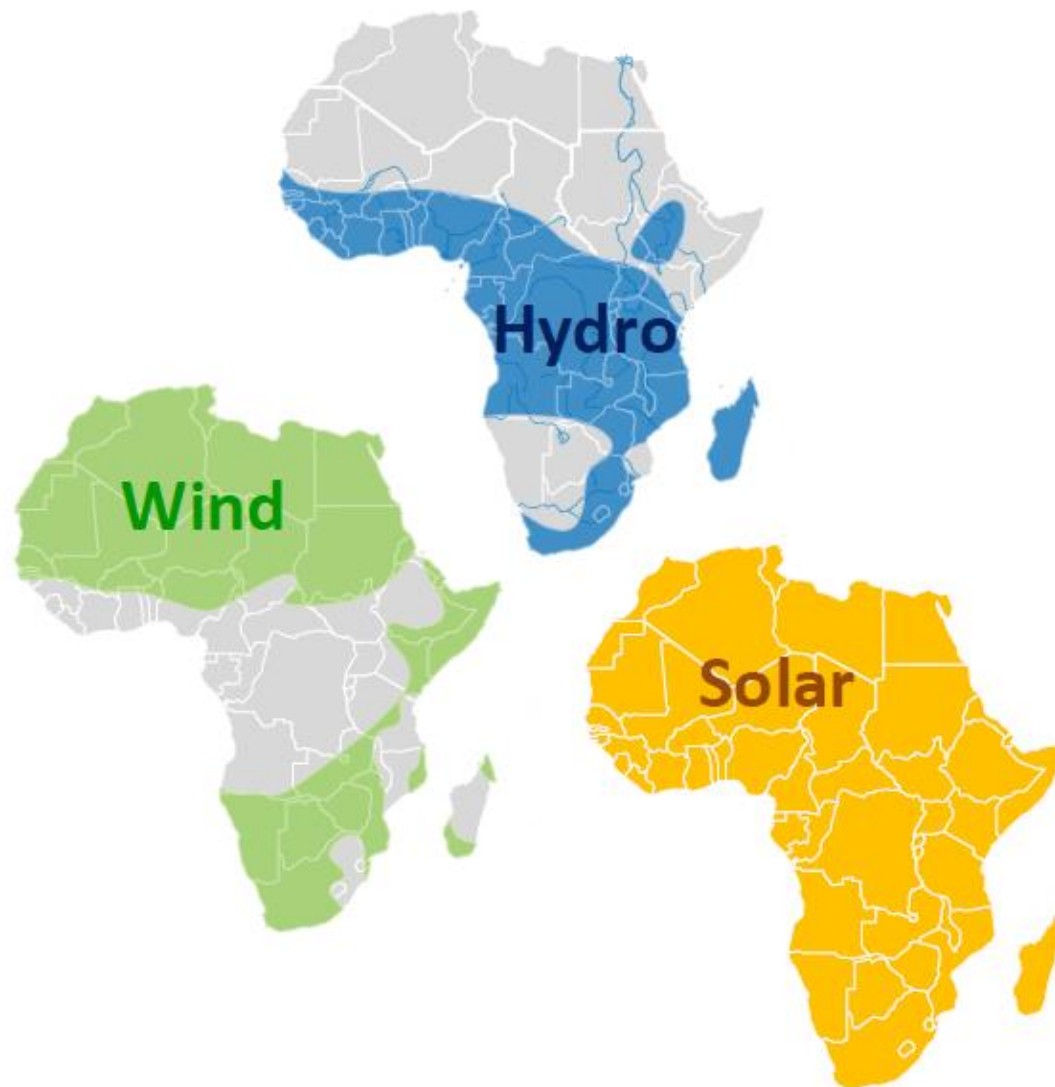
China Import Countries, 2011



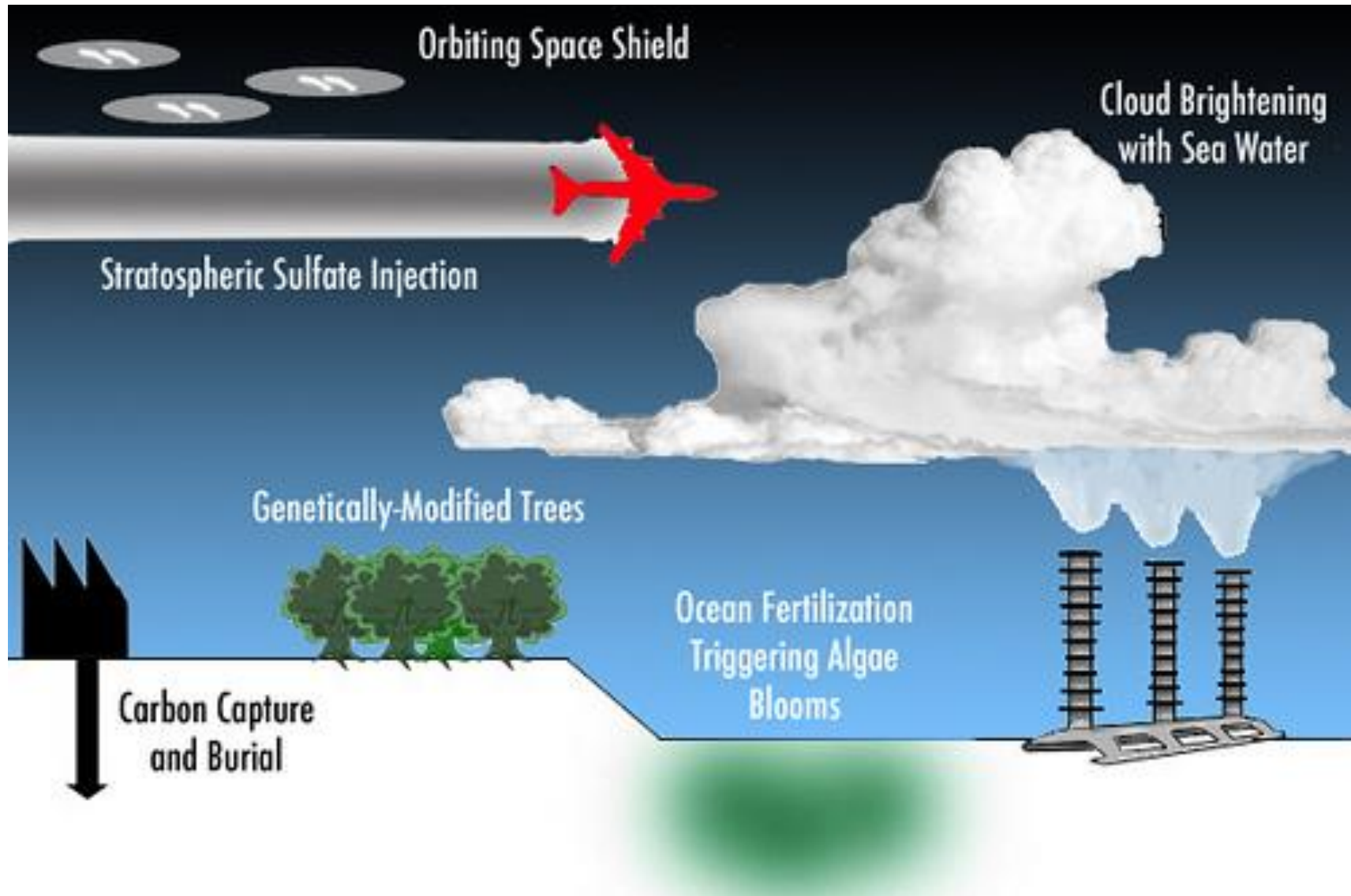
A clean, cheap, and unlimited supply of energy is no longer implausible within several decades



The beneficiaries might not necessarily be the usual suspects and energy powers



But not fast enough for the climate; once impacts hit, panic responses are likely, increasing risks of conflict



Agenda

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Concluding remarks

1. Energy is not a scarce resource on Earth; it is extremely abundant.
2. Humans are just starting to work out how to harness it cheaply
3. Technological progress in energy is finally starting to accelerate
4. We have ample fossil fuels, but very little atmosphere left
5. Government responses to climate change (too little, too late) will lead to fundamental changes in the energy sector
6. Signs of the bumpy ride ahead can be seen in the impacts on US coal, EU gas, OECD utilities, divestment campaigns, frugal innovation in Africa

Thank you

Pumped hydro is so dominant because of its combined power & discharge times (log scale)

