Delivering the Energy Transition in Theory and Practice

Technology, systems and policy for the 21st Century

Michael Grubb

Prof. International Energy and Climate Change Policy, UCL

Chair, UK Panel of Technical Experts on Energy Market Reform

Combined elements of presentations:
ANU, Canberra, 6 Dec 2016
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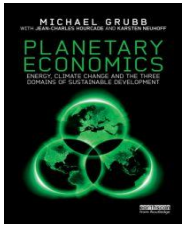
- The broad economic concepts
- Electricity technologies and systems innovations
- Some insights from UK policy experience
- Lessons and elements of transition strategy



The Energy Trilemma

Energy policy needs to address:

- **Security**
  - *System resilience, over-concentration, geopolitical risk*
- **Affordability & competitiveness**
  - *Fuel poverty, the disconnected, 'industrial energy prices'*
- **Environment and sustainability**
  - *Air quality, climate change, mining and water*

Prioritising one too much over the others generates instability

Focus here particularly on electricity, increasingly important in other sectors (transport, buildings)

A *systems* issue .. Requiring multiple policies

Three domains of decision-processes ..

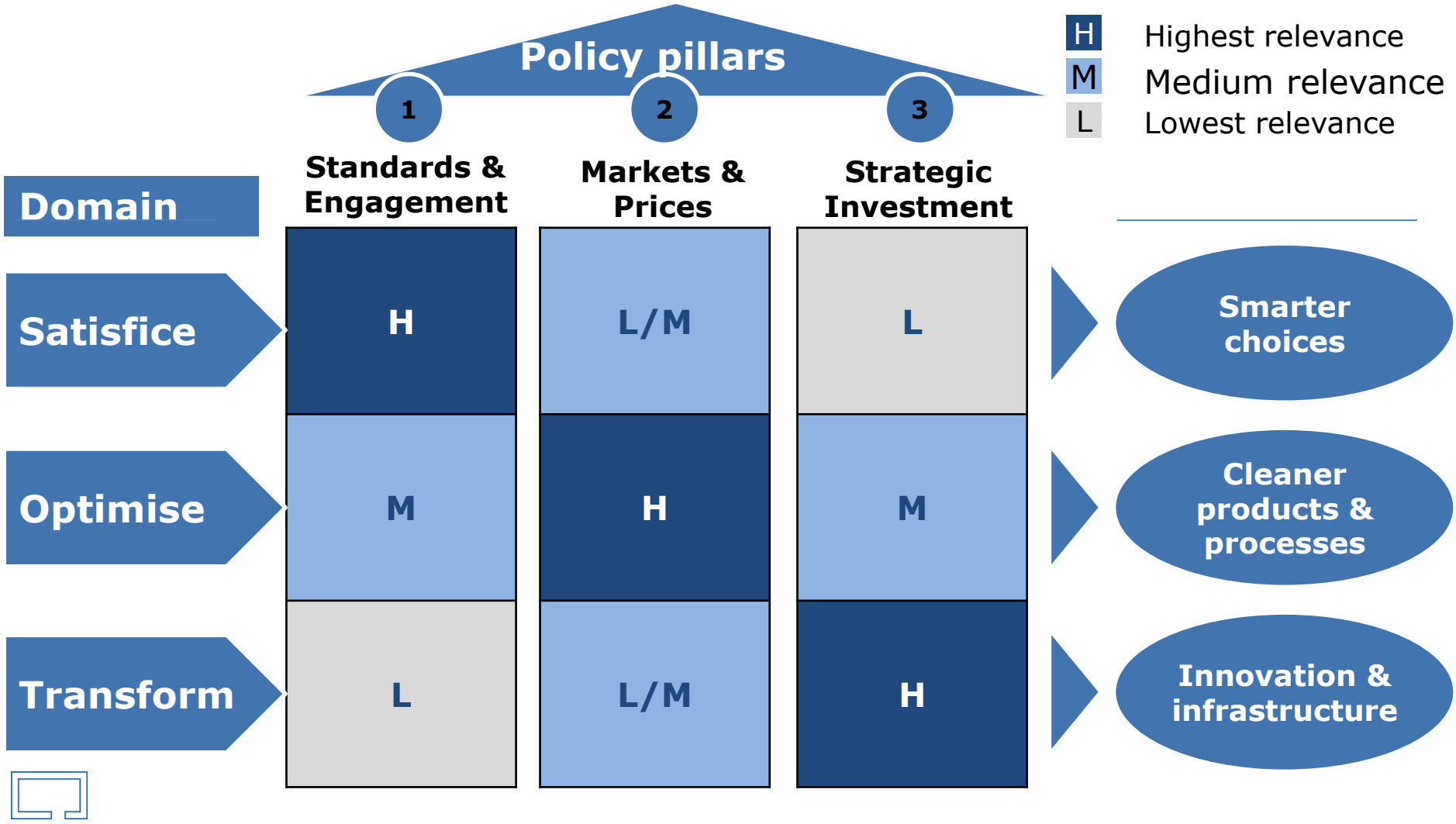
with different characteristics and theoretical foundations, operate at different scales

DOMAIN	Characteristics	Theoretical foundations
Satisficing	Habits, myopia, inattention to incidental / intangible costs; endemic 'contractual failures', principal-agent failures, risk aversion to change or investment	**Behavioural and organisational economics**
Optimising	Economic optimisation based on relative prices, 'representative agents' with 'rational expectations', stable preferences and tech trends	**Neoclassical and welfare economics**
Transform-ing	Technology, structure, institutional and behavioural change, typically from strategising, innovation, infrastructure investment	**Evolutionary and institutional economics**

TIME HORIZON

SOCIAL SCALE

Ideal policy comprises a package which matches the best instrument to the respective domain of decision-making



Affordability – and energy prices

In the long run, countries with higher energy prices do not spend more of their income on energy (the "Bashmakov – Newbery constant")

- Stronger efficiency and innovation policies compensate
- *Indeed countries that subsidised energy to keep it cheap have ended up spending more*

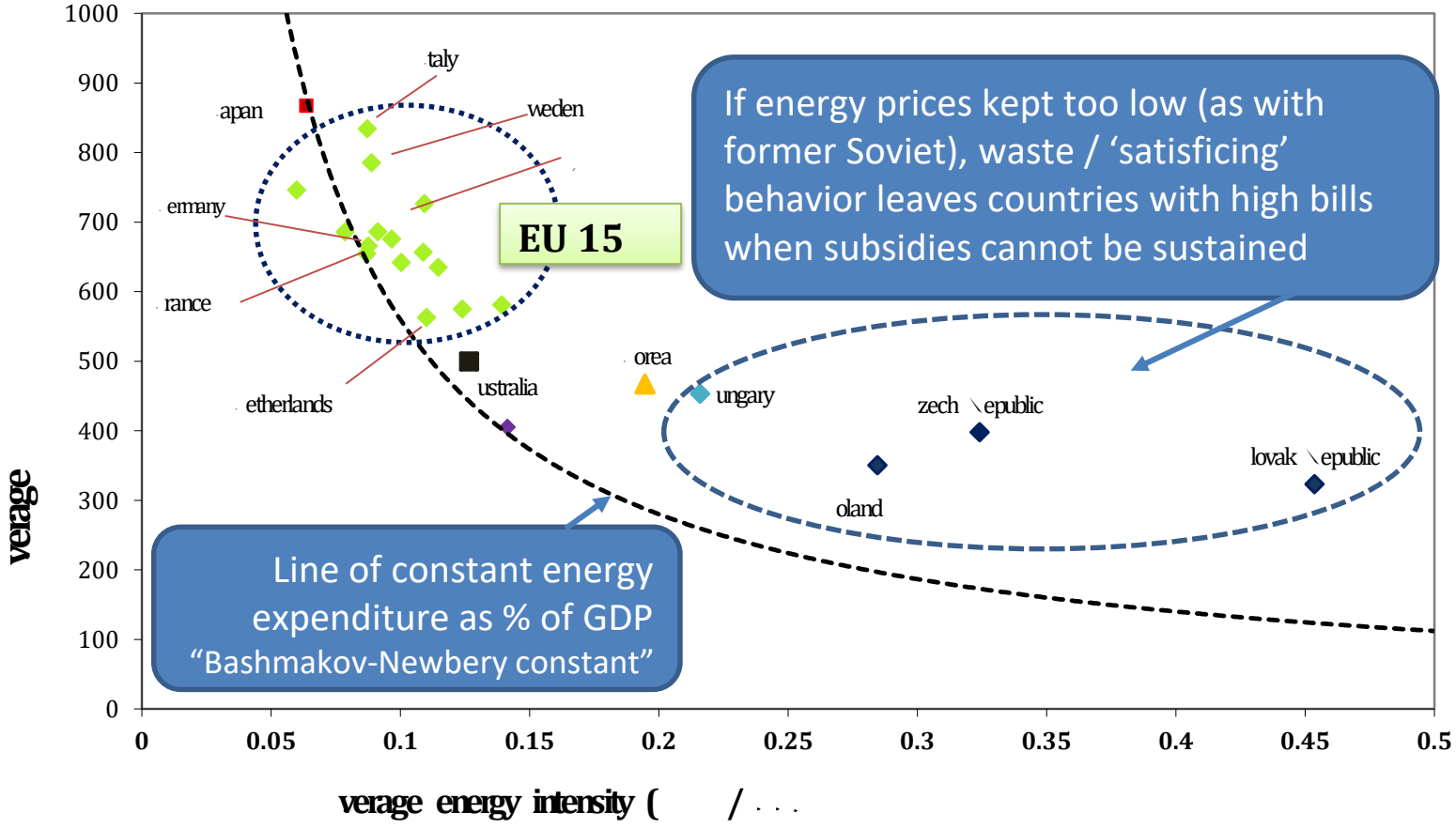
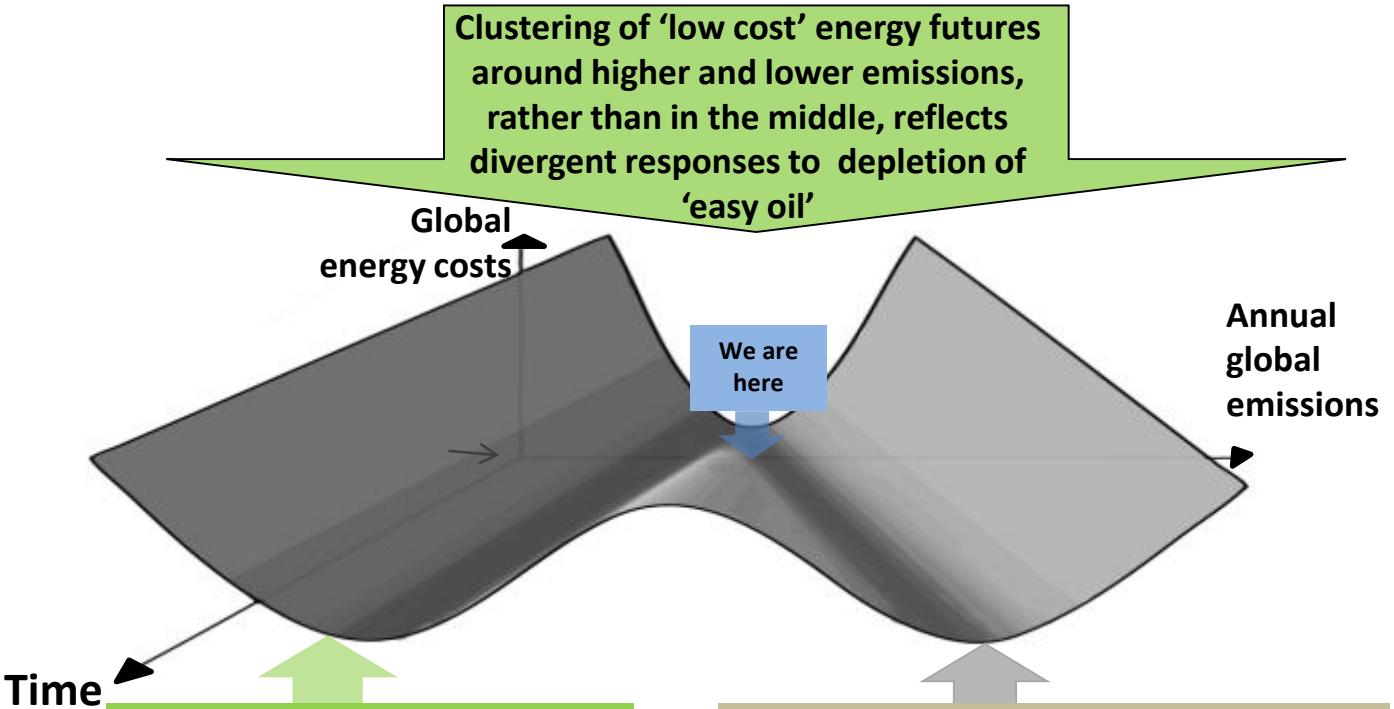


Figure 6-1 The most important diagram in energy economics

Note: The graph plots average energy intensity against average energy prices (1990-2005) for a range of prices. The dotted line shows the line of constant energy expenditure (intensity x price) per unit GDP over the period. *Source: After Newbery (2003), with updated data from International Energy Agency and EU KLEMS*

A sense of direction ….

Need to steer not marginal+ but structural and systemic change



'Green' futures

- Integrated high-innovation system
- Biomass and electricity in transport
- Low-carbon, 'smart electricity'
- High capital costs….
- ……but low operating costs

'Brown' futures

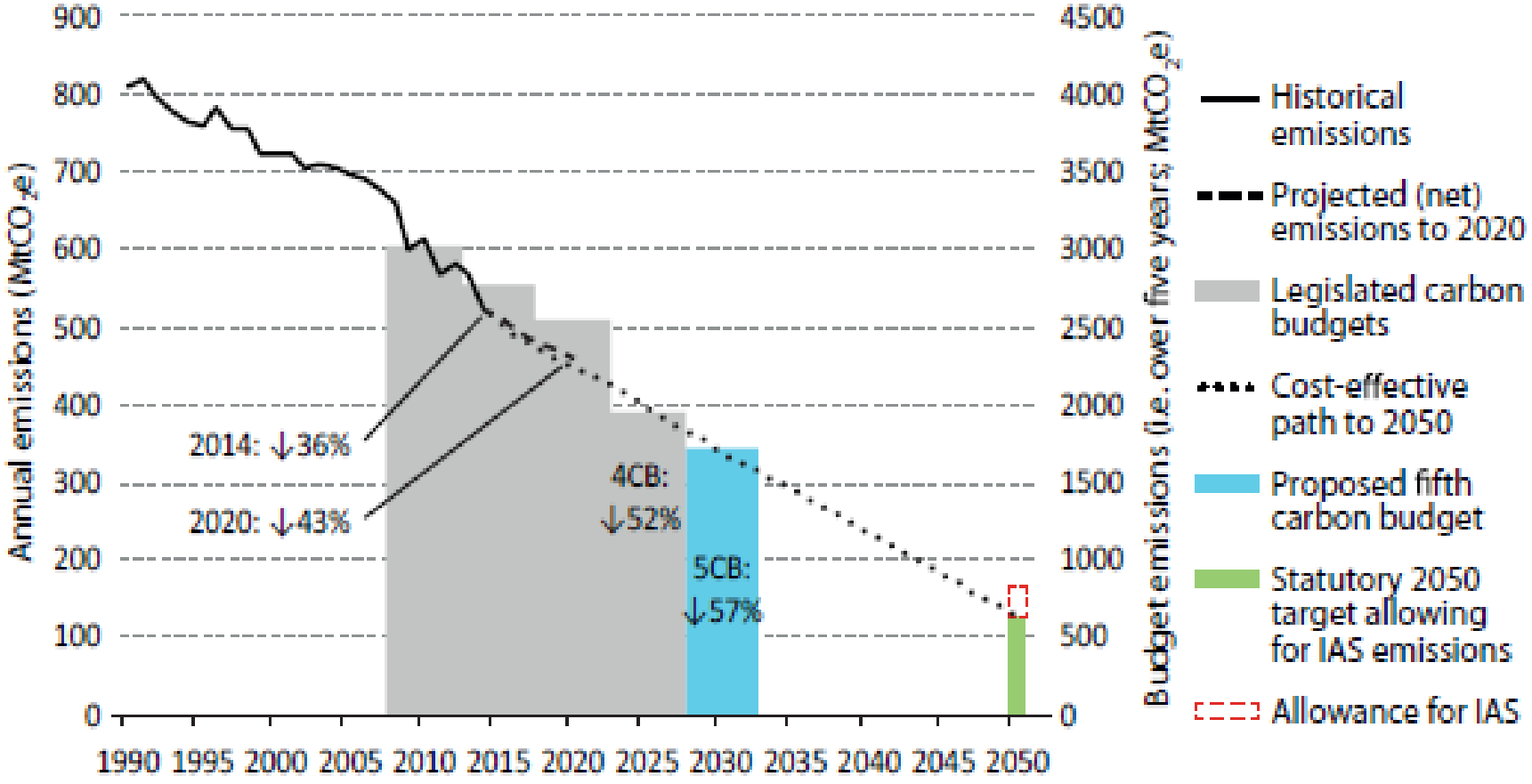
- Continued dependence on fossil fuels
- Unconventional and synthetic oil in transport
- Low capital costs…
- …but high operating costs and a host of environmental issues beyond carbon

"No wind is favourable to those who don't know where they are going"

- Lucius Annaeus Seneca

Figure 10-6: Two kinds of energy future – the carbon divide
Source: **Upper panel: Gritsevskyi and Nakićenović (2000); lower panel: authors**

In UK – once an 'island of coal in a sea of oil and gas' - orientation set by Climate Change Act, with statutory 80%-below-1990 mid-Century



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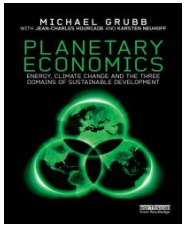


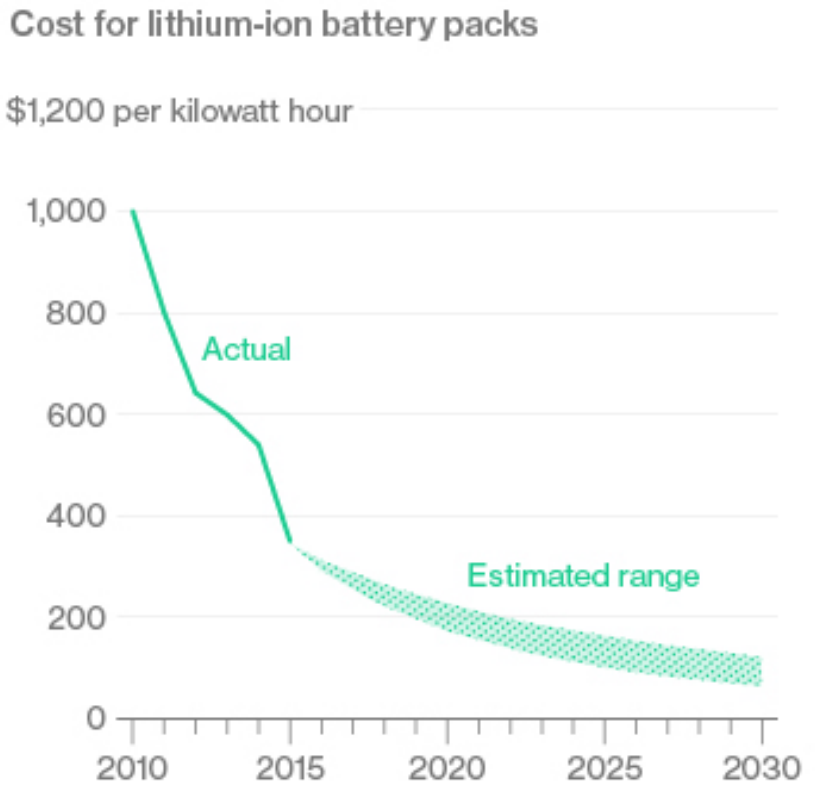
Huge fall in PV and battery costs

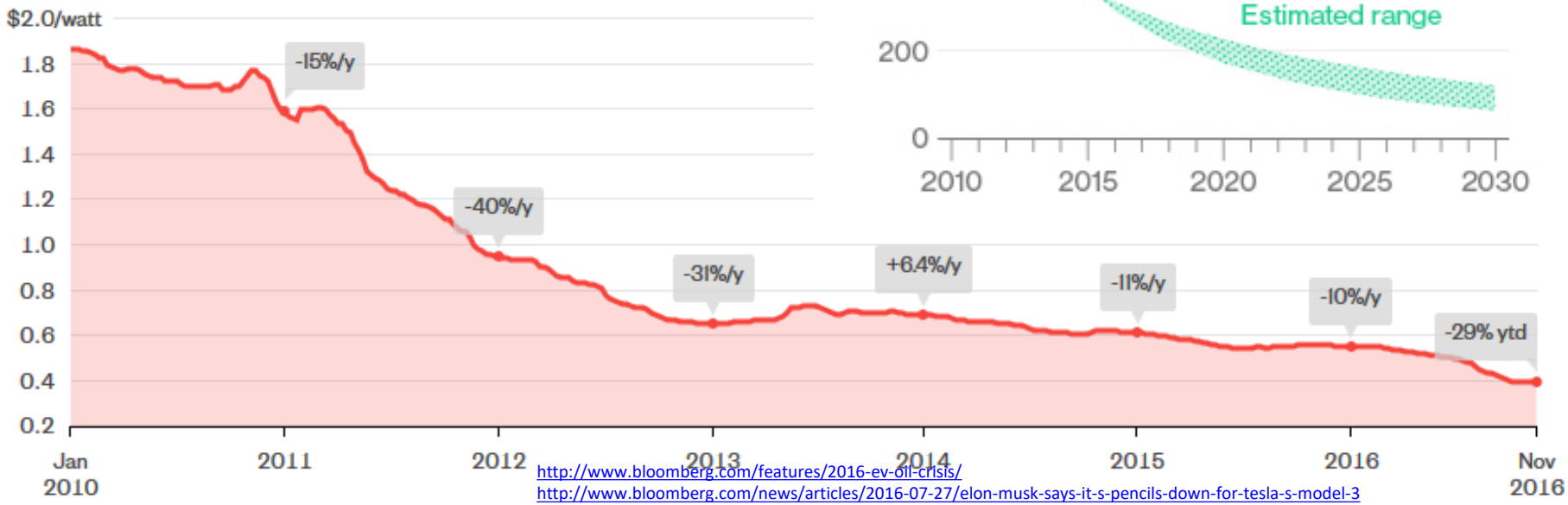
Driven mainly by public policy

PV: New record installed power prices

Chile	= $30/MWh
Masdar	= $25/MWh
Abu Dhabi	= $24/MWh

Module costs: -29% in 2016 to $0.39/Watt





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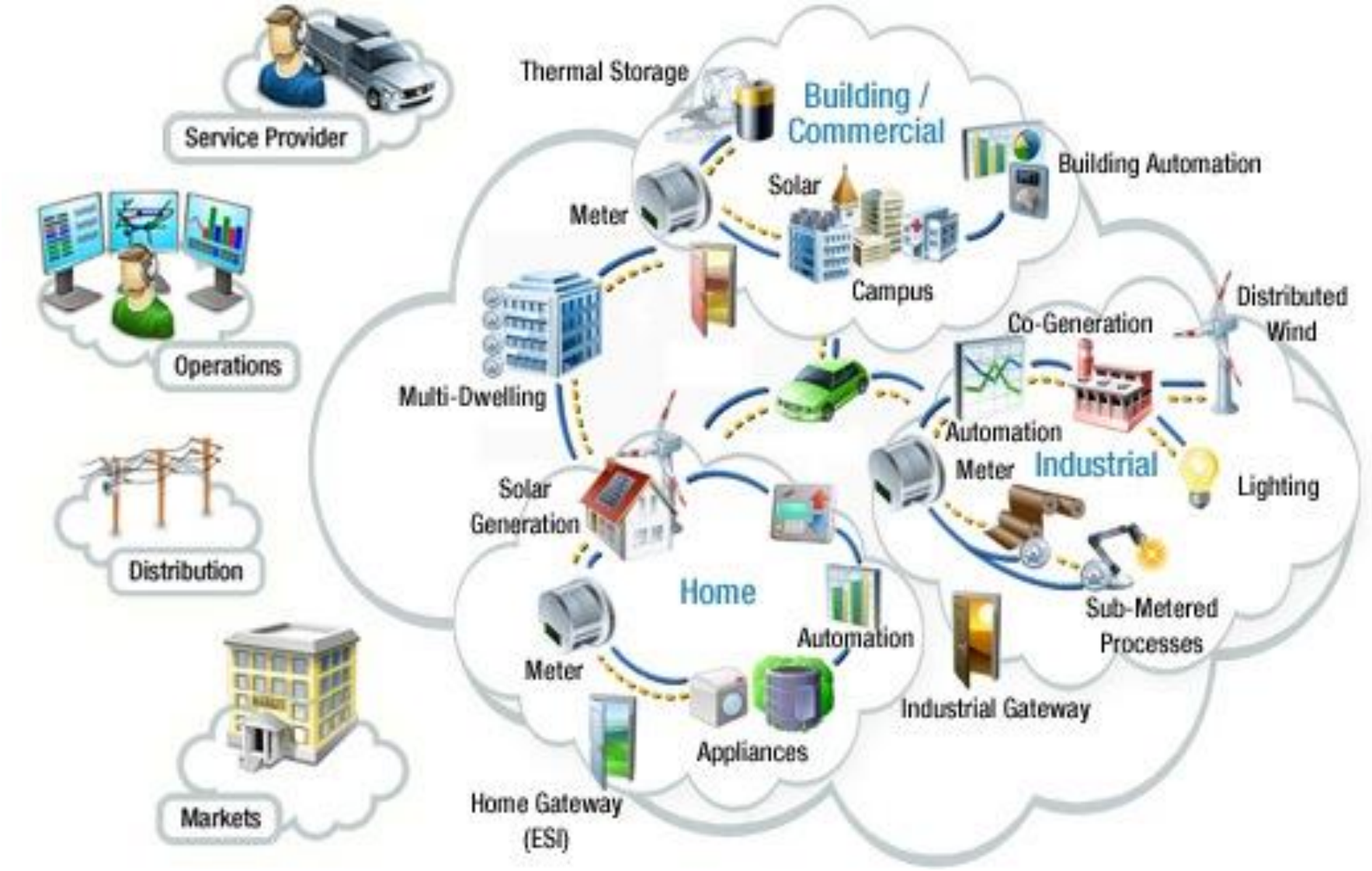
http://www.bloomberg.com/news/articles/2016-07-27/elon-musk-says-it-s-pencils-down-for-tesla-s-model-3

https://www.bloomberg.com/gadfly/articles/2016-11-23/solar-industry-makes-feast-of-price-famine http://reneweconomy.com.au/how-the-jaw-dropping-fall-in-solar-prices-will-change-energy-markets-55160/

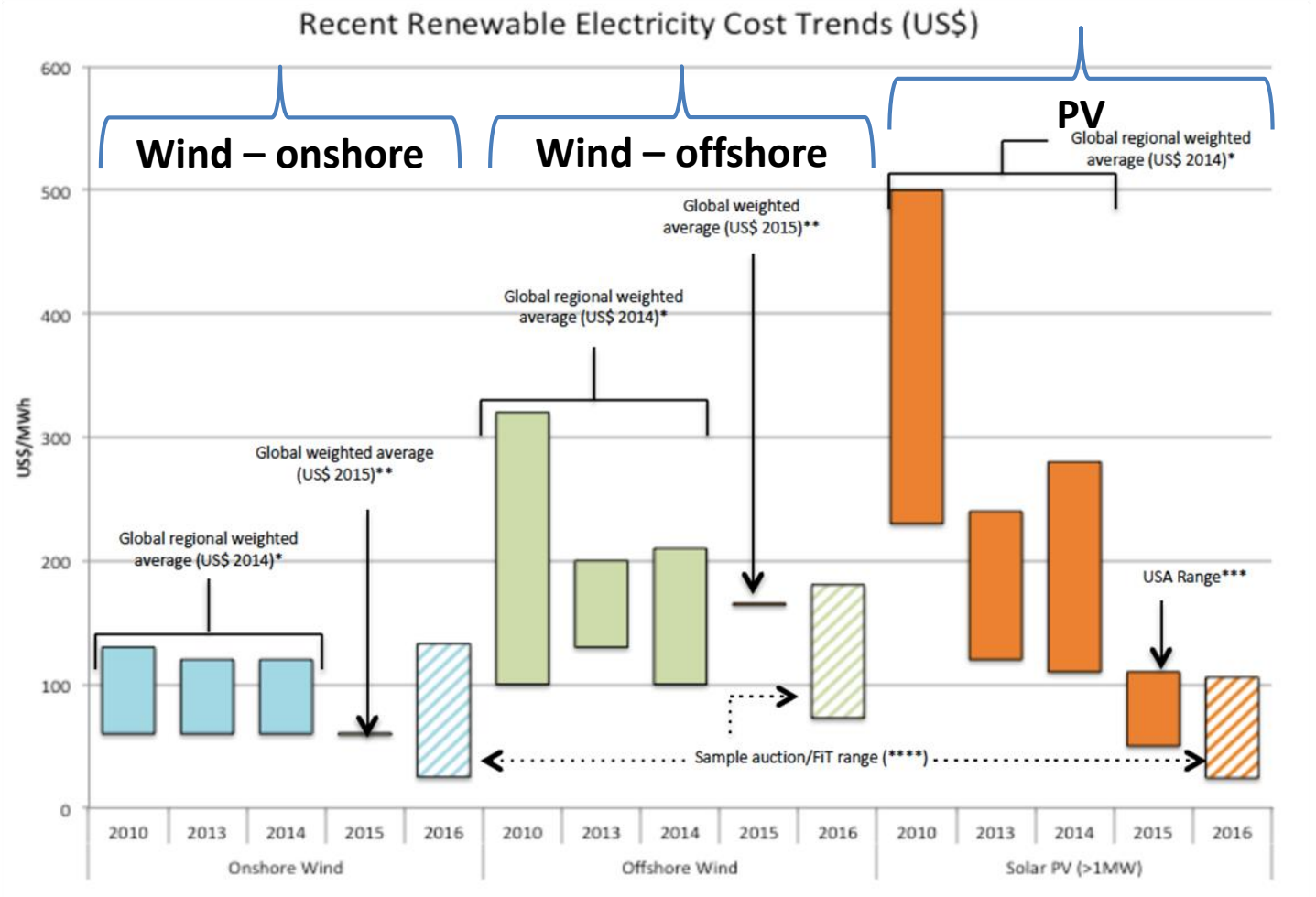
Electricity revolution, Pt.1 – distributed servuces



Source: Prof Jun Dong, North China University of Electric Power

Price trends of the big renewables, 2010-16

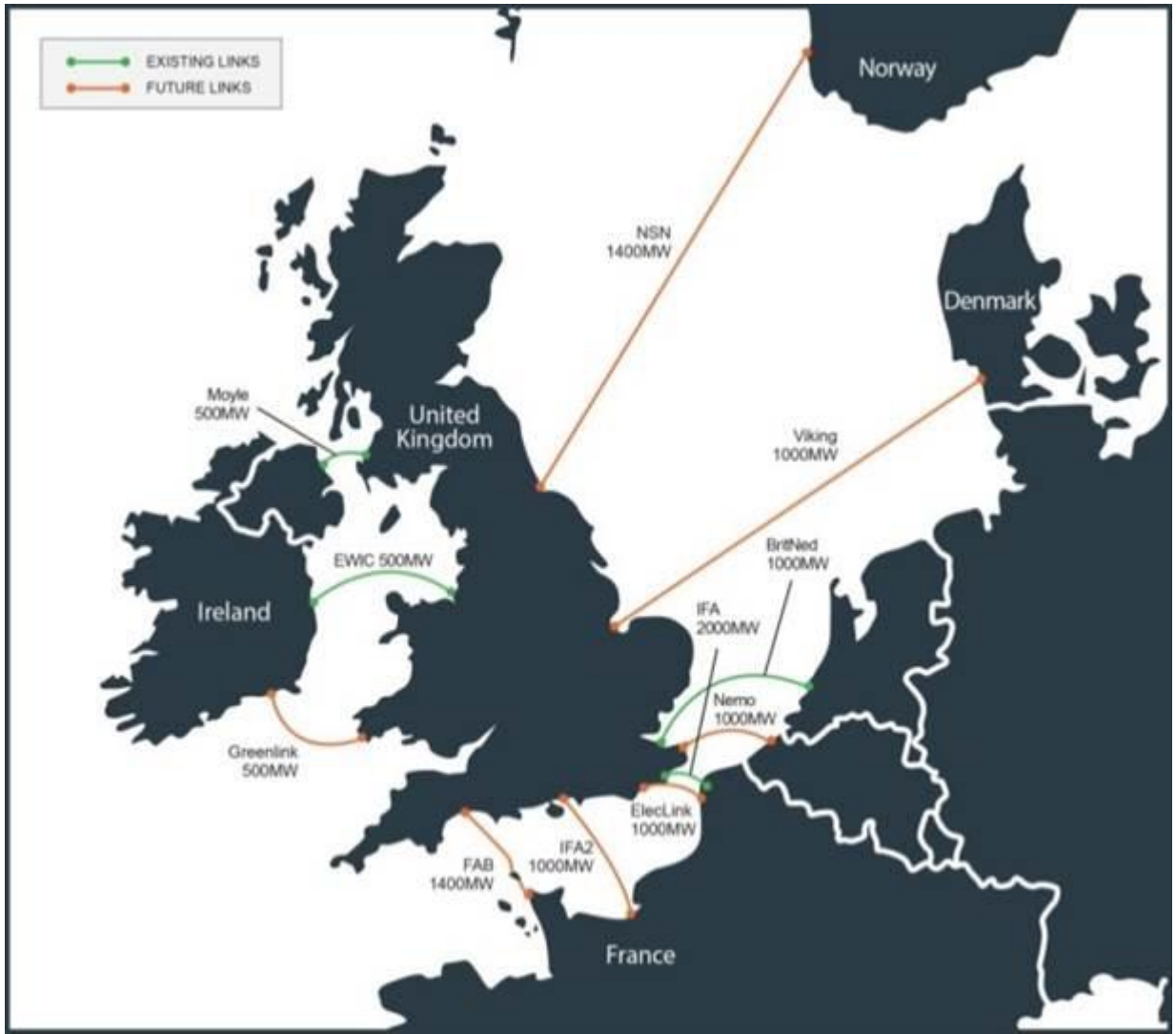
Sharp fall but ranges also show the centrality of policy risk



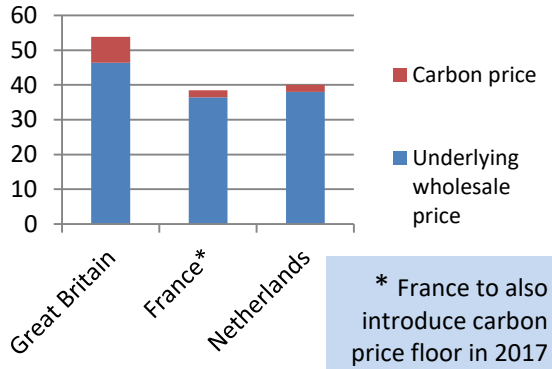
Recent trends in international costs and contracted prices for wind and solar (source: UCL Submission)

More interconnection also valuable – UK rapid increase

- Based on merchant investment with cap-and-floor on returns

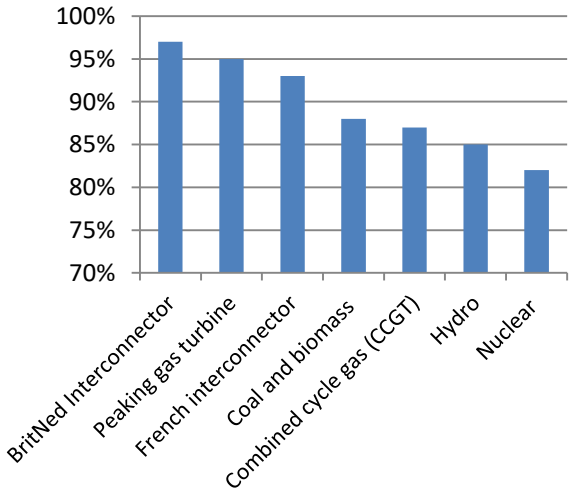


Lower wholesale prices on continent
(2015 average annual prices, €/kWh)



* France to also introduce carbon price floor in 2017

Interconnectors amongst most reliable sources of supply (2015/16 Avg availability, %)

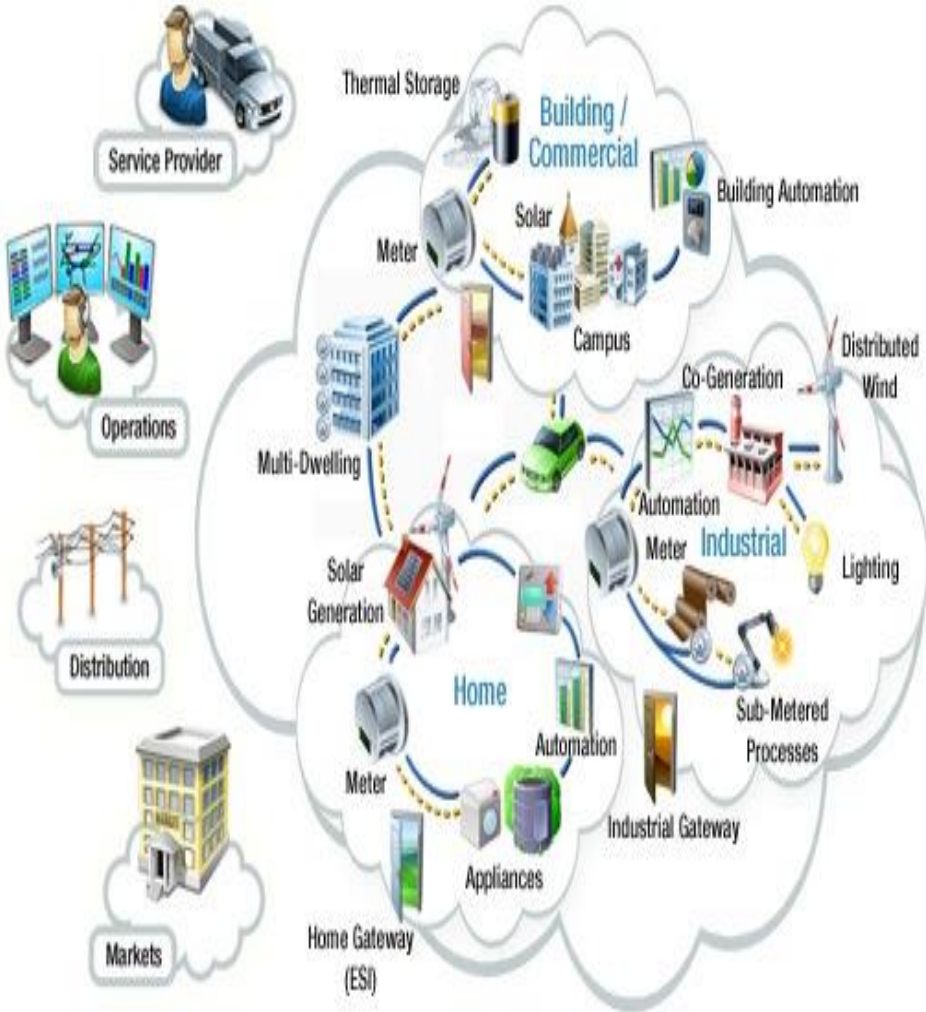


Electricity revolution, Pt.2 ‘hollowed out system’

Distributed Service Providers

Combined with

Big generation developments, such as North Sea



TenneT CEO Mel Kroon commented: *'In Germany and more recently in the Netherlands, TenneT has the role of developer and operator of the offshore grid. From this responsibility we have taken the initiative to establish a realistic and achievable plan for further development of the North Sea.The success of the energy transition depends largely on the extent to which we mount a coordinated joint effort in Europe. Cooperation between national governments, regulators, the offshore wind industry, national grid administrators and nature and environmental organisations is a precondition for achieving Europe's environmental targets. The vision we have presented shows the relevance of cooperation in the North Sea.'*

North Sea Infrastructure: the vision

Solar and wind energy will be necessary on a large scale because attainment of Europe's targets for reducing CO_2 emissions depends largely on the production of renewable electricity. Moreover, wind and solar energy are

Source: Prof Jun Dong, North China University of Electric Power

Source: TenneT

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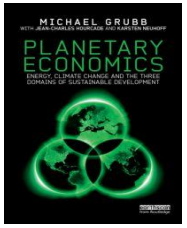
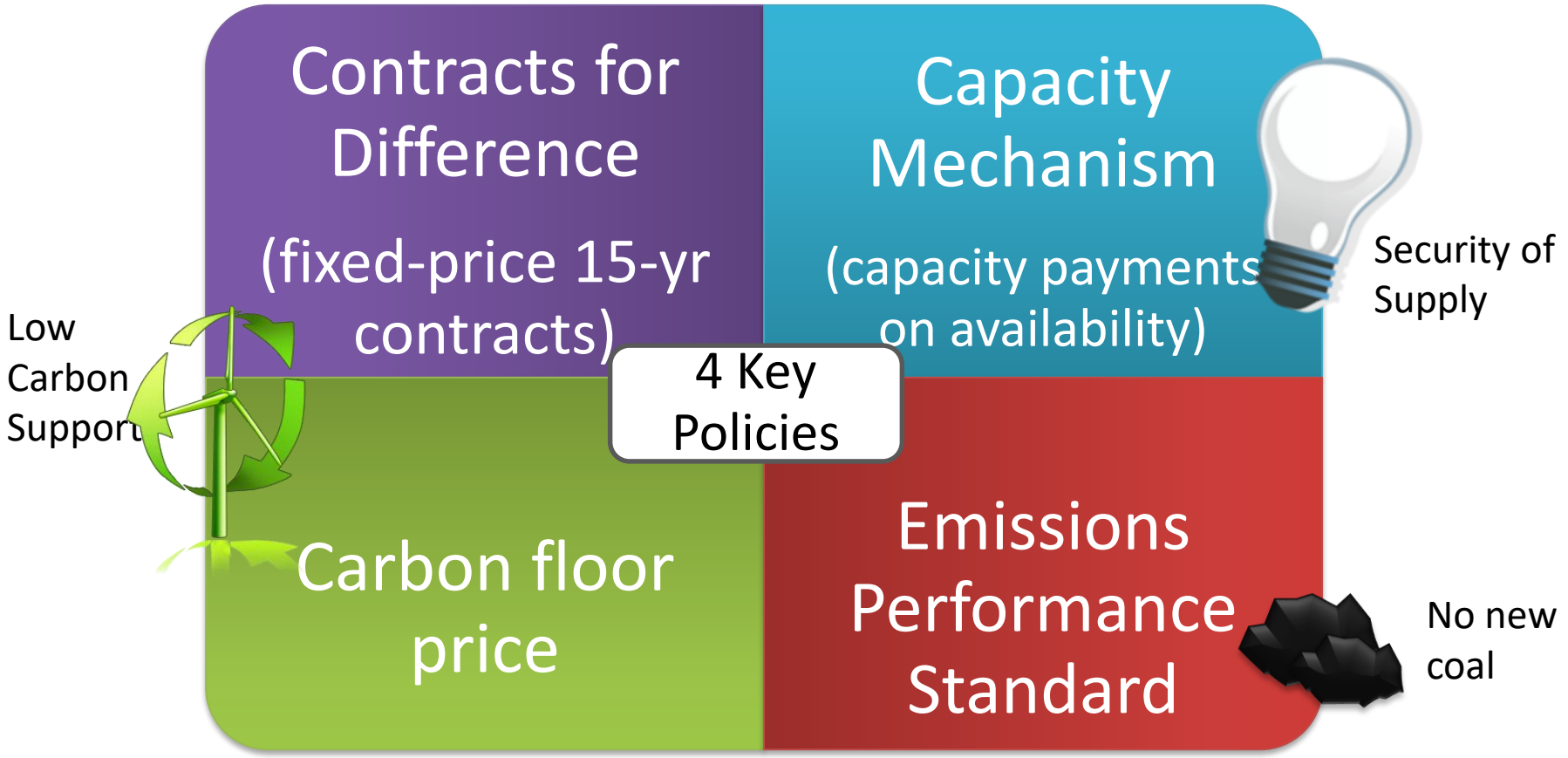


Four elements of UK *Energy Market Reform*

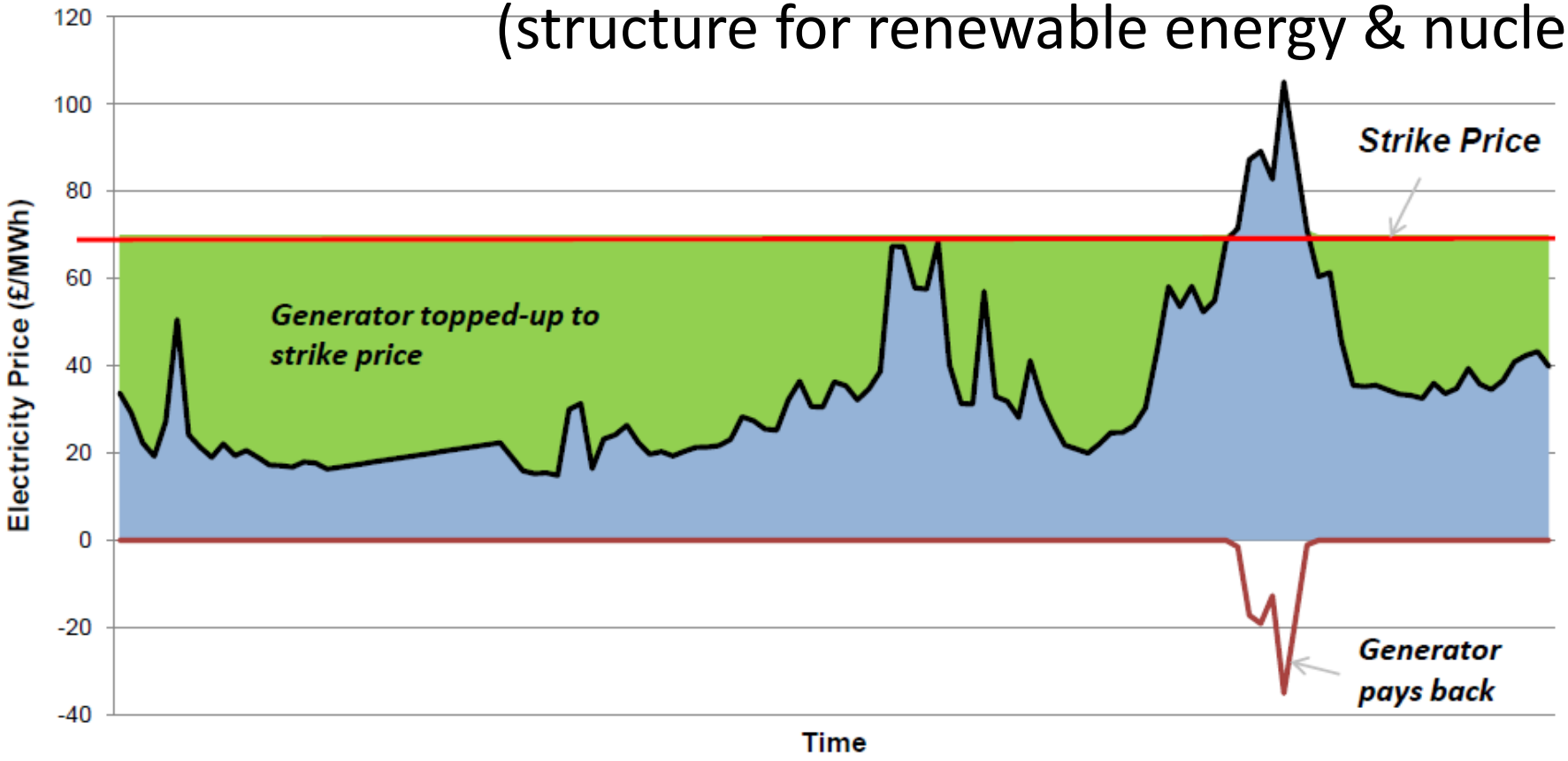


Major changes to UK electricity market, implemented during 2011-15

CfDs to lower the cost of capital

Contracts for Difference (CfDs)

(structure for renewable energy & nuclear)



- Energy price topped up (or reimbursed) to a **"strike price"**
- **Initial contracts** awarded by government; moving to
- **Competitive auction** held by National Grid, sophisticated design
- Over 2GW of new capacity, est cost of capital reduction by 3 percentage points, saving £110m/yr cf administered price – and saving £bns overall

Yielding big cost savings

… when combined with competitive auctions

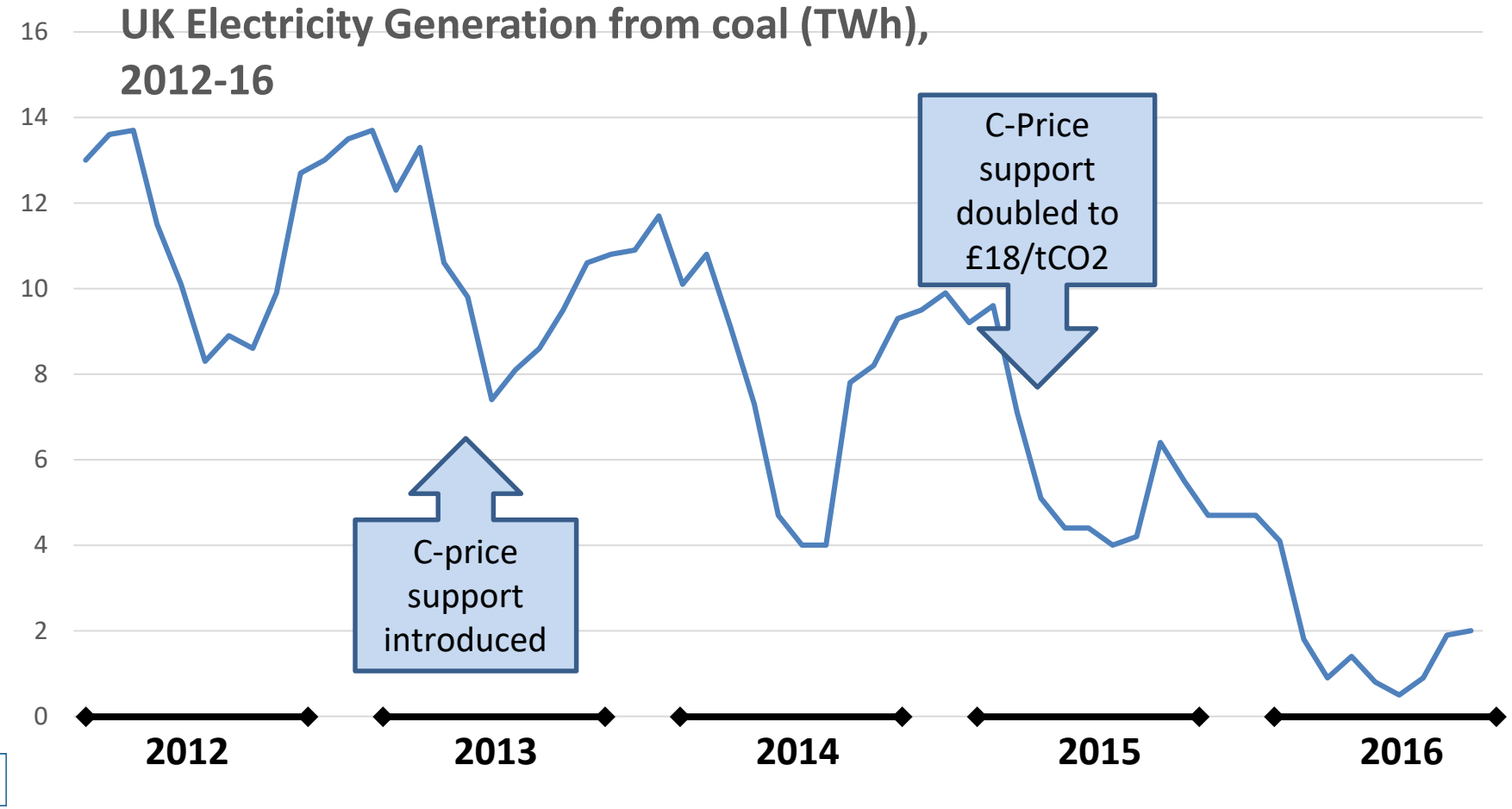
- Administered prices, May 2014 followed by competitive auction, Jan 2015
- Over £315m/yr new contracts offered to five renewable technology classes
- Over 2GW of new capacity with saving £110m/yr cf administered price in 2014
- Estimate cost of capital reduction by 3 percentage points – saving £bns

	Capacity	Admin Strike price 2014 (£/MWh)	Lowest auction clearing price Jan 2015	Maximum % saving
Solar PV	72	120	**79**	**34%**
Onshore Wind	1162	95	**79**	**17%**
Energy from Waste CHP	95	80	**80**	**0%**
Offshore Wind	750	140	**114**	**18%**
Advanced Conversion	62	140	**114**	**18%**

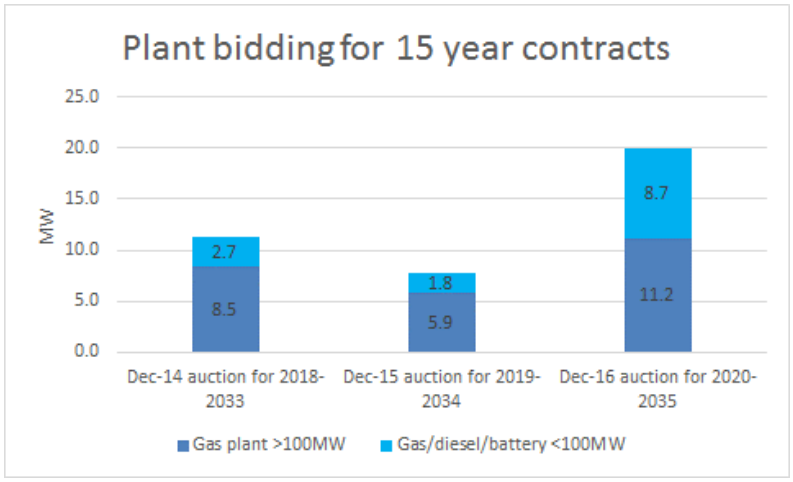
- Other European auctions in 2016 with further (big) cost reductions
- UK electricity renewables exceeding expectations: c.35% by 2020
- Next UK auction announced, expected even offshore wind << £100/MWh
- Now well within the 'BNC' range of affordability, *if & as system evolves*

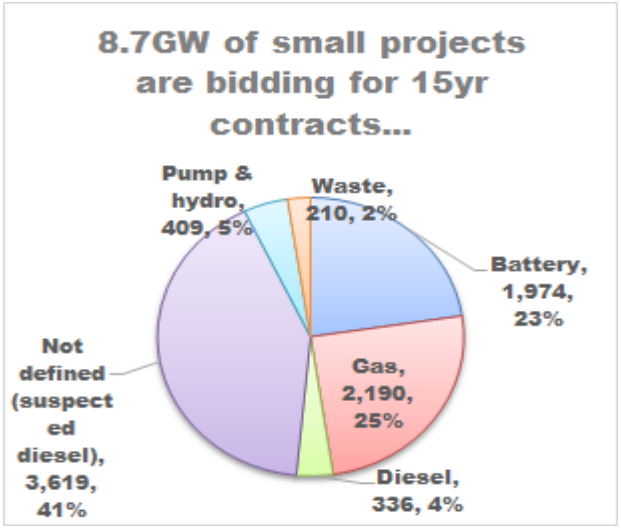
+ Carbon floor price impacts coal

Dramatic (80%) fall since 2012: first hours without coal power for over a Century
Driven as declining gas price meets rising carbon price, and renewables
Falls 2012-15 offset by rising renewables; increased gas in 2016



What will replace 14GW UK coal?





What is needed

- Short-run frequency response
- Back-up for windless winter days

What the government wants

- More Combined Cycle (CCGT)

What NGO's want

- Batteries, demand response

What we will get

- Few years of some low load factor coal
- Embedded small gas (+some diesel)
- Batteries & CHP multi-services – with more
- + Interconnectors
- + transport (and maybe heat) integration
- Innovation on distributed service providers

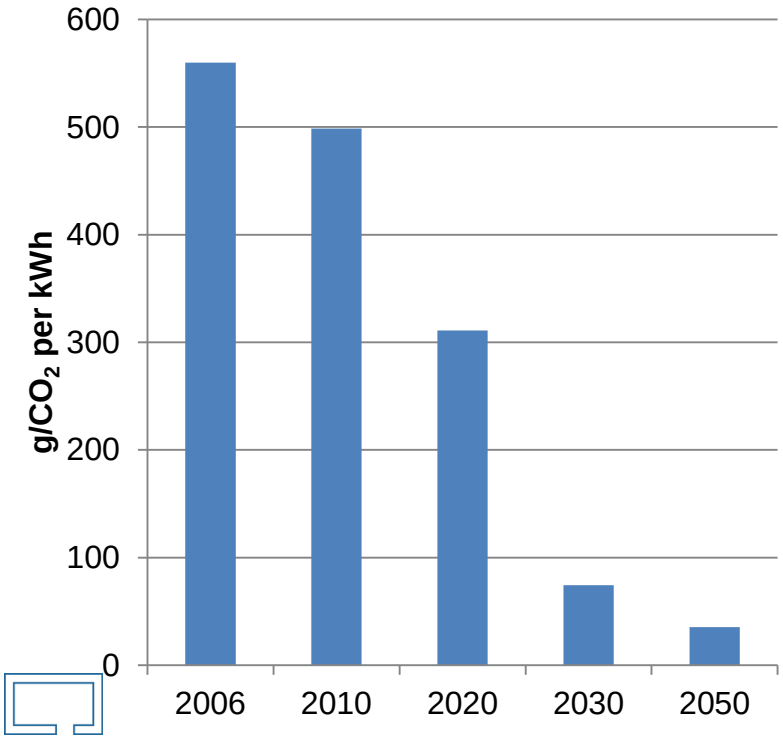
System / consumer costs now well within range of 'Bashmakov-Newbery constant'

Decarbonising power contributes into other sectors

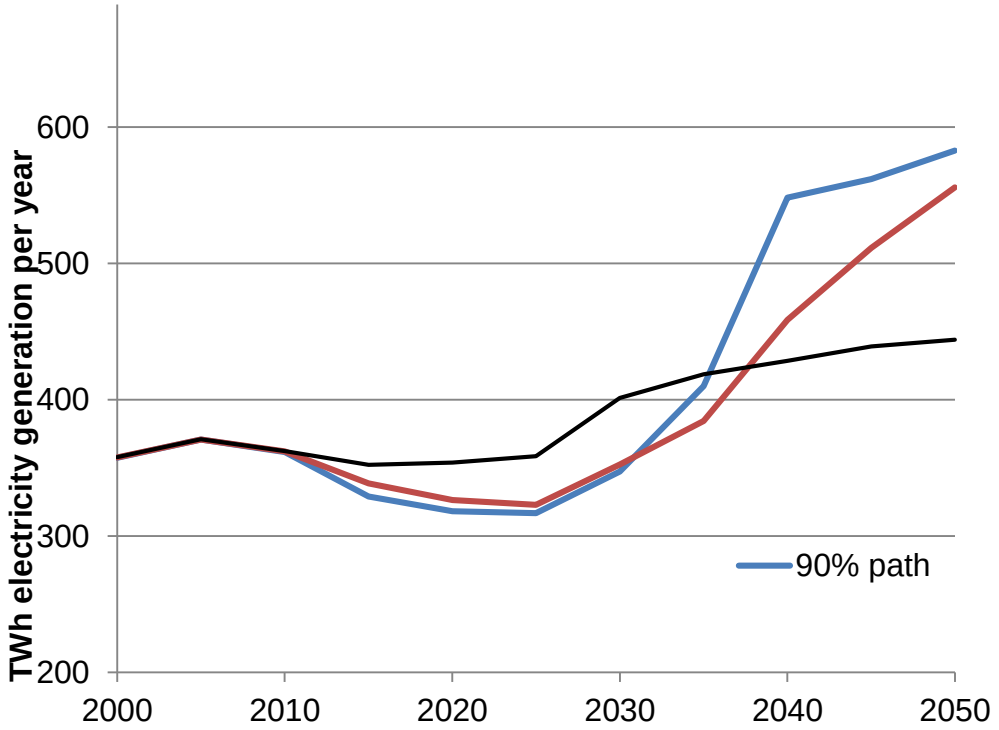
Renewables (Wind, solar, tidal and marine, biomass), nuclear, CCS

Application of power to transport and heat

Electricity emissions intensity to 2050



Electricity demand to 2050



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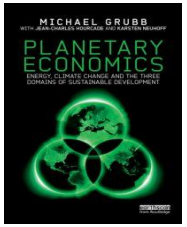


Smart policy includes ..

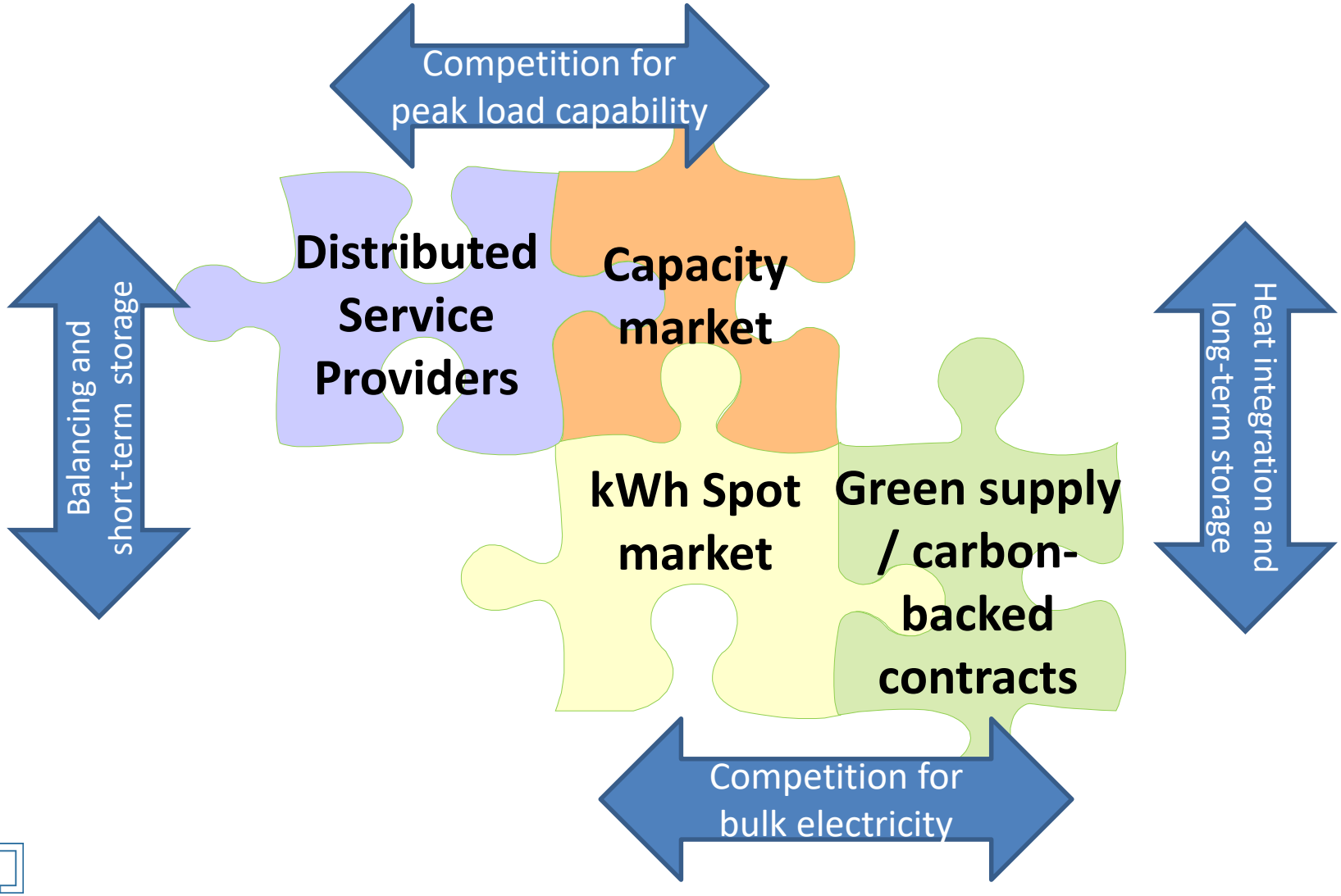
- Balanced approach to deliver all Trilemma goals
- Integration across the three pillars of policy
- A broadened industrial strategy ..
- Whilst using competitive forces
- .. with clear attention to distinctive needs of
  - Operational incentives
  - Efficient networks
  - Generation investment
  - Demand side engagement

UK Energy Market Reform

Key lessons

- For Strategic ("Third Domain") investments – eg security and sustainability inc emerging renewables - a role for government is inescapable
  - *The public benefits exceed any risk-adjusted return in spot market*
- Can shifting some risk to government (eg. long term contract) be good? *Yes* if
  - *the risks arise from private perception of policy risk;*
  - *markets (particularly capital markets) are myopic; or*
  - *the benefits are partly public (eg. Due to inadequate environmental pricing, or innovation / learning, etc)*
- Do we need a Capacity Mechanism in addition to low carbon supports?
  - *Yes in UK conditions – but scope is crucial, so too is design*
- Auctions are very valuable – competitive pressures remain important
  - Better than government decision at cutting costs / finding options
- Institutional complexities
  - *contracting bodies and their governance*

To minimise 'state management', the future system could develop competition ***between*** at least four markets



Tools of Regulatory Impact Assessment also need to broaden

Monetised aggregate CBA + Social & distributional impacts + Explicit consideration of strategic & sustainability issues = Impact Assessment

Strengthening analysis of these issues is designed to more systematically represent issues related to the interest of future consumers, complementary to a monetised CBA

- Improved consistency
- Increased transparency

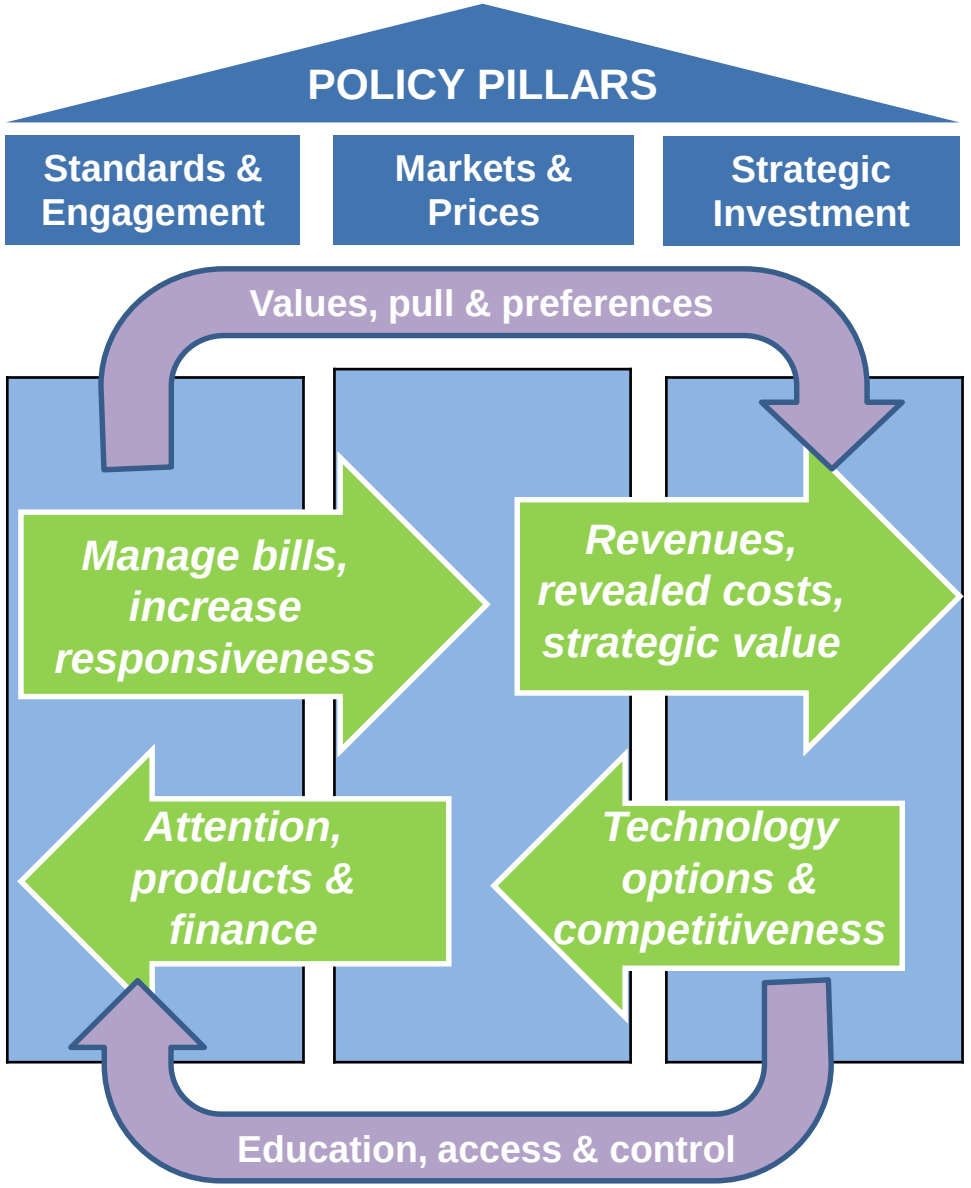
Integrated policies conceptual framework

Need to integrate across all three pillars:

- Enhanced efficiency
- Cleaner products
- Innovation and infrastructure

And harness this for *social and industrial strategy*

- Lower resource costs
- Consider carbon pricing, including *materials consumption & innovation*
- Accelerate innovation for competitiveness

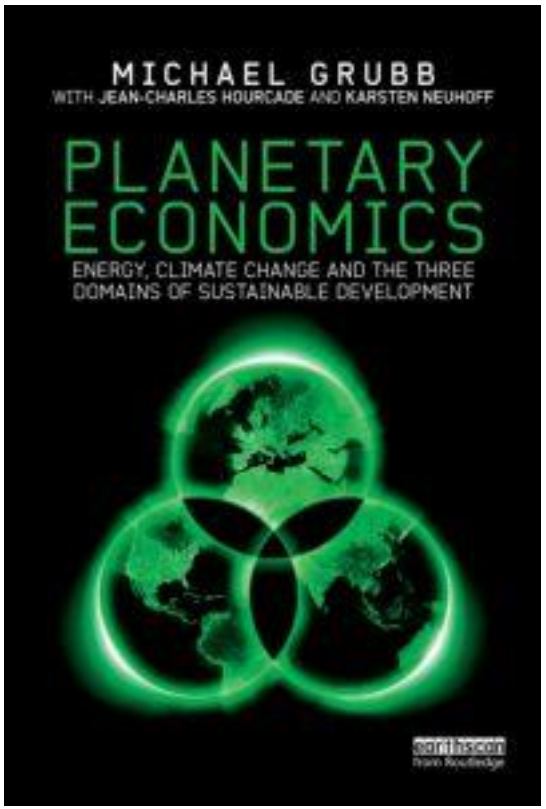


Conclusions: Practice

- 21st Century energy systems will be radically different from 20th Century
- Understanding transition on this scale means broadening economic horizons to all the triads: Trilemma goals, three Domains of decision-making, & associated pillars of policy
- Transition is already under way, so far driven far more by the non-pure-market policies
- Aggregate cost impacts (eg. Germany) pushed to the limit of this approach, but resulting technology cost reductions place the transition within reach of global development and more balanced policy packages
- Clear policy direction can shift risk and lower finance costs
- … including new roles and narrative for carbon pricing

Planetary Economics:

Energy, Climate Change and the Three Domains of Sustainable Development



1. **Introduction: Trapped?**
2. **The Three Domains**

Pillar 1

- **Standards and engagement *for* smarter choice**
- 3: Energy and Emissions – Technologies and Systems
- 4: Why so wasteful?
- 5: Tried and Tested – Four Decades of Energy Efficiency Policy

Pillar II

- **Markets and pricing *for* cleaner products and processes**
- 6: Pricing Pollution – of Truth and Taxes
- 7: Cap-and-trade & offsets: from idea to practice
- 8: Who's hit? Handling the distributional impacts of carbon pricing

Pillar III

- **Investment and incentives for innovation and infrastructure**
- 9: Pushing further, pulling deeper
- 10: Transforming systems
- 11: The dark matter of economic growth

12. **Conclusions: Changing Course**

Published Routledge 2014

6-page 'Highlights' paper available

http://climatestrategies.org/projects/planetary-economics/
for further information #planetaryeconomics

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