UNIVERSITY OF CAMBRIDGE | Electricity Policy Research Group

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Supporting off-shore wind without wrecking the market

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Gale Force: Offshore Wind Power

CUEN Conference Cambridge 28 June 2011

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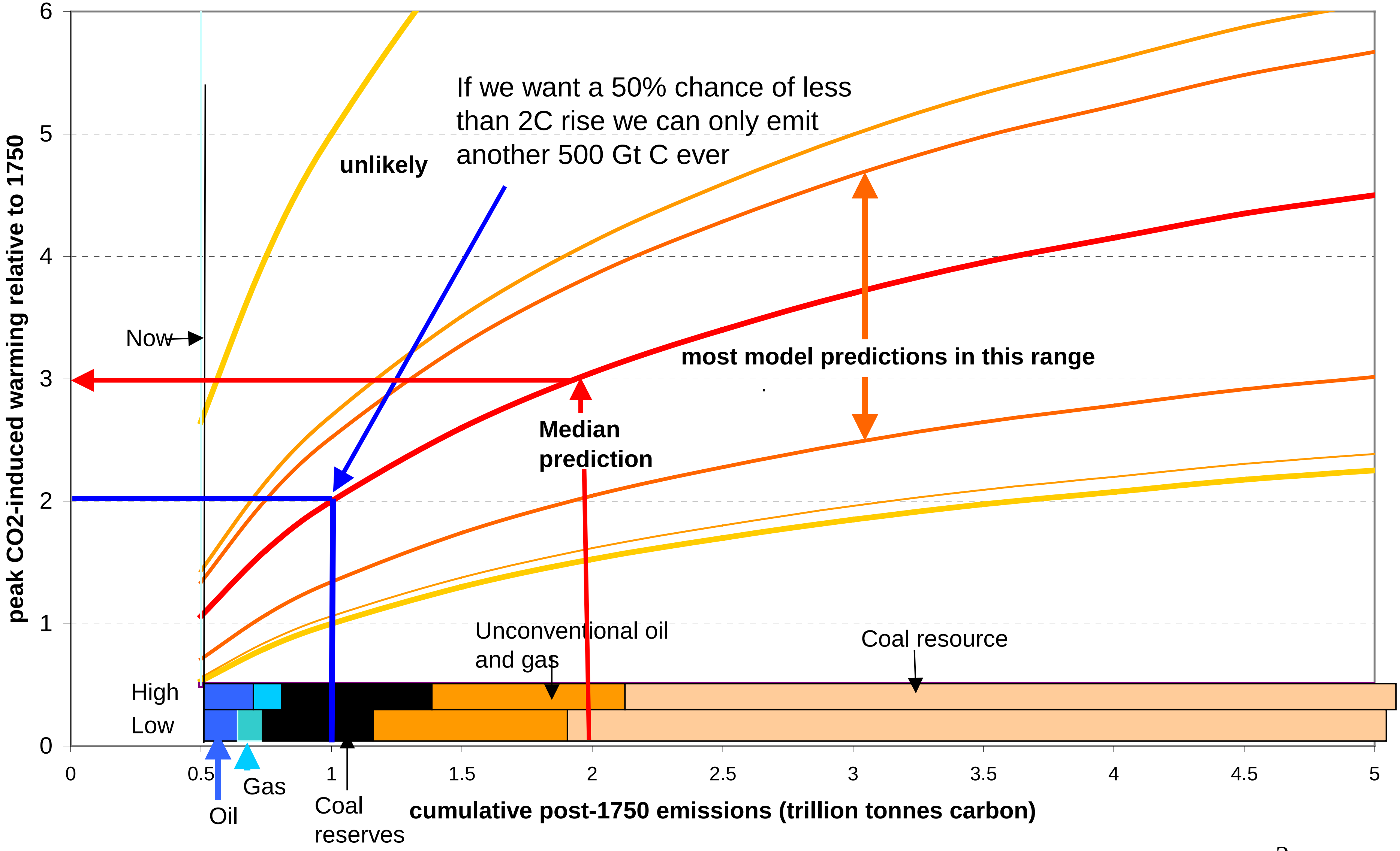
Outline

- Policies for mitigating climate change
- Renewables Directive and the ETS
  - conflicts and problems
- The UK's climate change policy
- Electricity Market Reform
  - what does it mean for wind?
- How best to support off-shore wind

Peak CO_2-warming vs cumulative emissions 1750–2500



After MR Allen *et al.* *Nature* **458**, 1163-1166 (2009) doi:10.1038/nature08019

nature

Mitigating climate change: theory

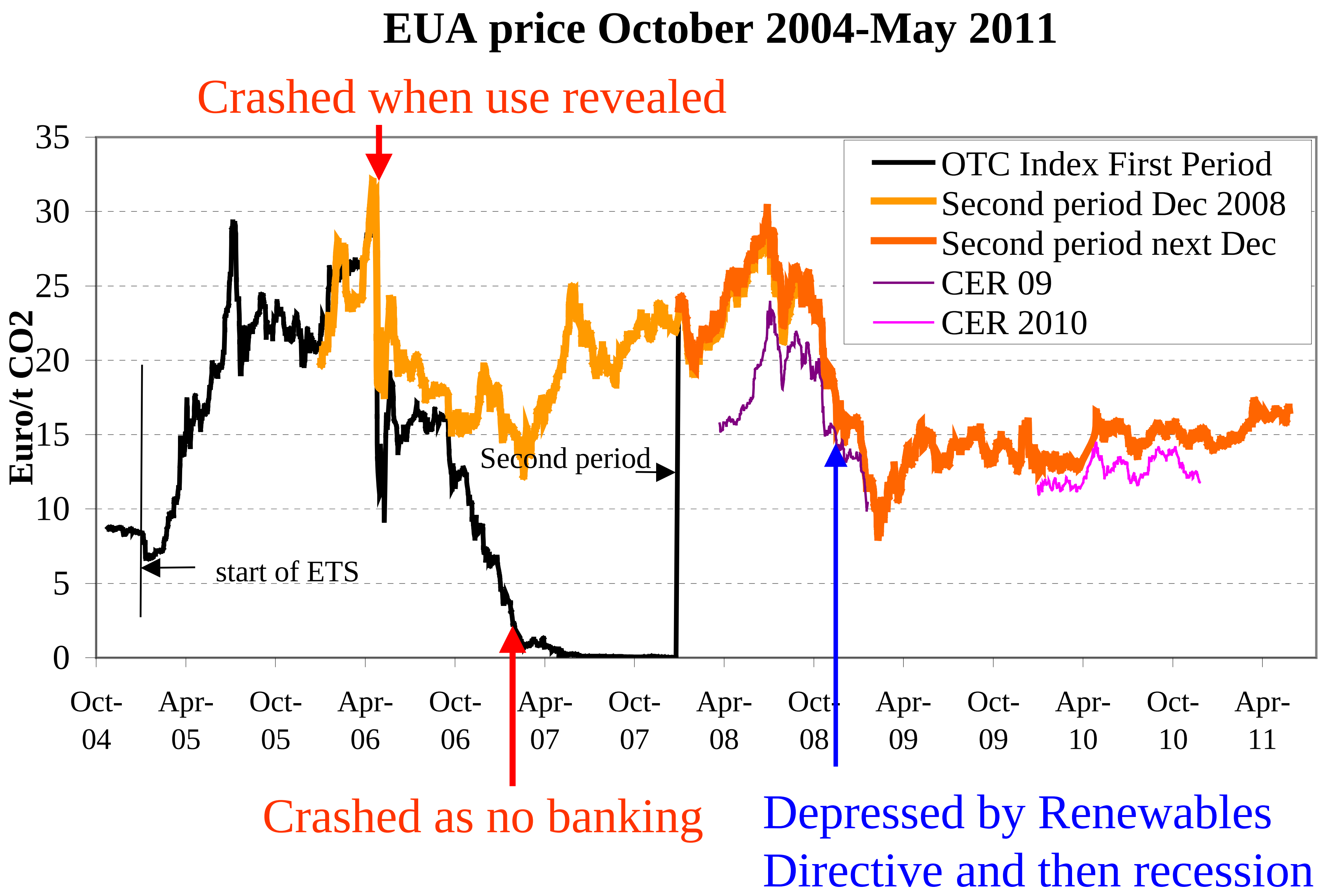
- GHG emissions are a global stock public bad
  - uncertain distant damage with uneven impacts
  - damage regardless of emissions location, persistent
    - => damage moderately independent of date of emission
  - much irreversible over historical time scales
- Solution: uniform charge for GHG emissions,
  - charge rises at discount rate
  - reset in light of new information

EU climate change: policy

- ETS to price CO_2
  - fixes quantity not price => poor guide for low-C
- 20-20-20 Directive: demand pull for renewables
  - justified by learning spill-overs and burden sharing
- EU SET-Plan to double R&D spend
  - to support less mature low-C options

Are these policies effective and consistent?

ETS is neither stable nor supports adequate carbon price



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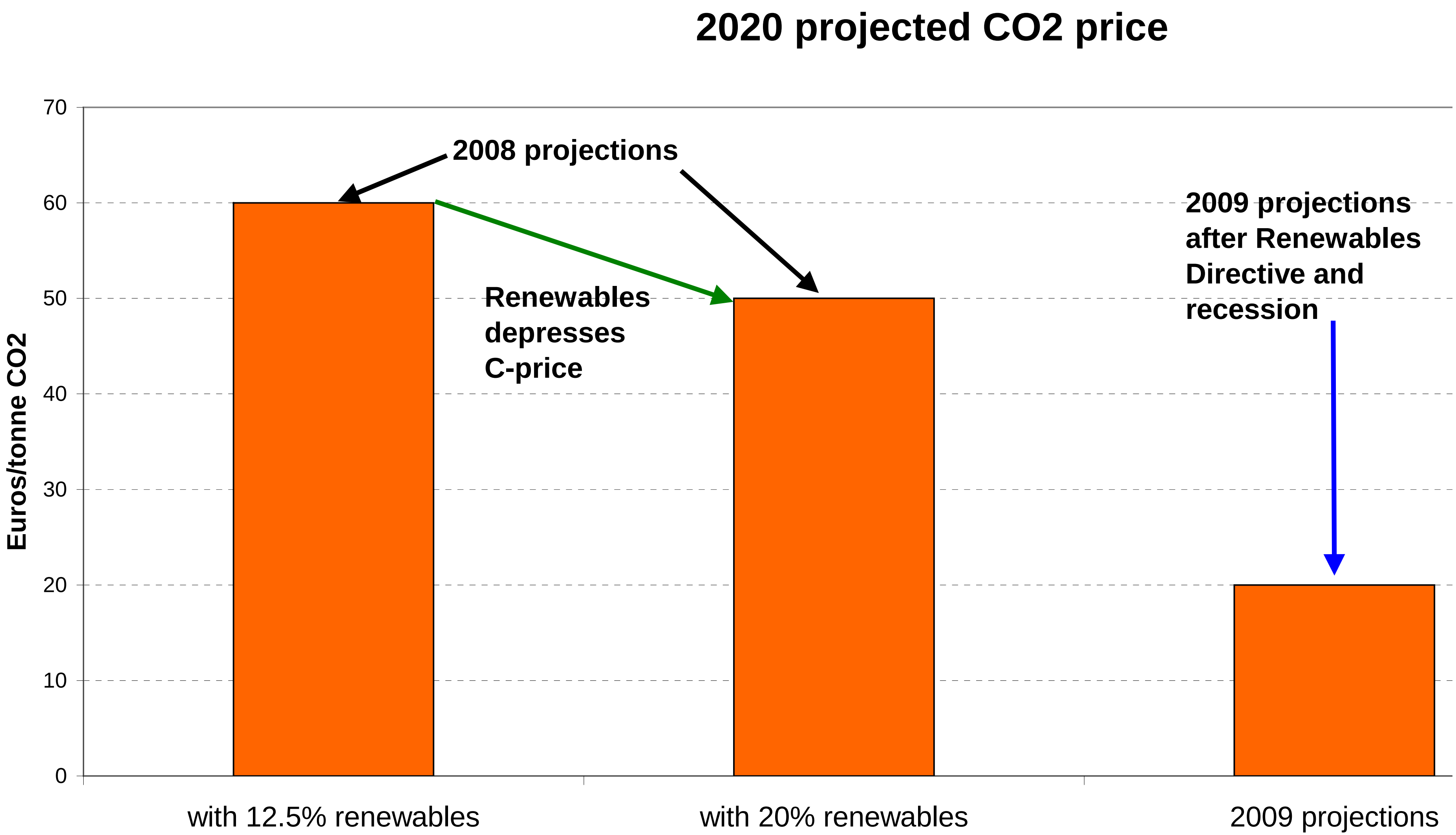
Failures of ETS

- Current ETS sets quota of total EU emissions
  => short-term, unstable and low price discourages long-term investment in low-carbon generation
- Renewables Directive increases RES
  => increased RES does not reduce CO_2
  => reduces price of EUA
  => prejudices other low-C generation like nuclear
- Risks undermining support for RES

Solved by fixing EUA price instead of quota



Source: Committee on Climate Change, 2008 and 2009

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Reforming ETS

- Reform EU ETS to provide rising price floor
  - sufficient for nuclear *or on-shore wind if cheaper*
  - => Carbon Bank trades EUAs to stabilise price
- Commitment to raise CO_2 price at 3% p.a. over life of plant may suffice
  - £24/EUA 2013 => £30 in 2020, £55 in 2040 ...
- Making it credible: write CfD on this path
  - remove uncertainty for low-C generation investment

makes extra carbon savings additional

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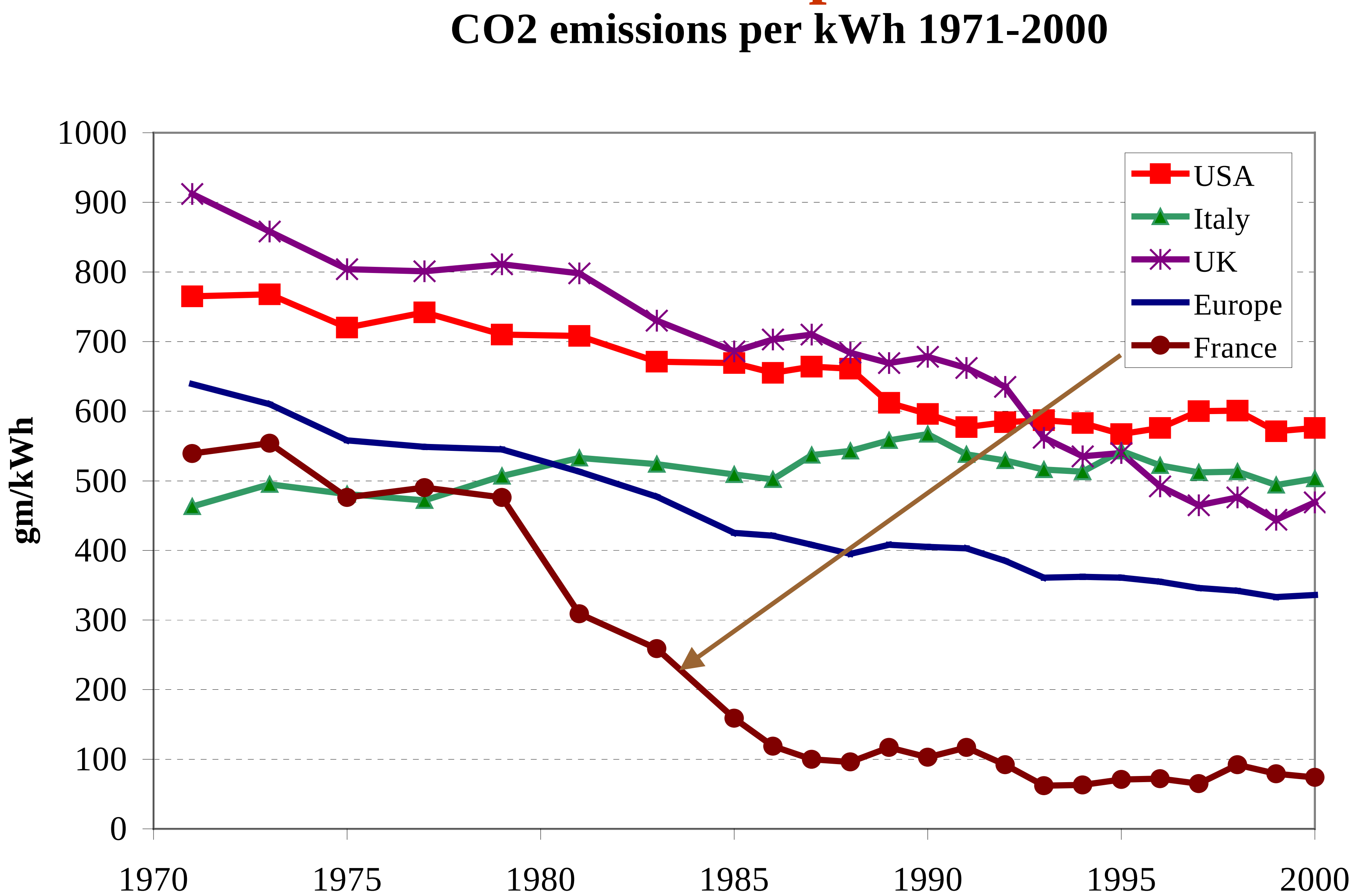
UK climate change policy

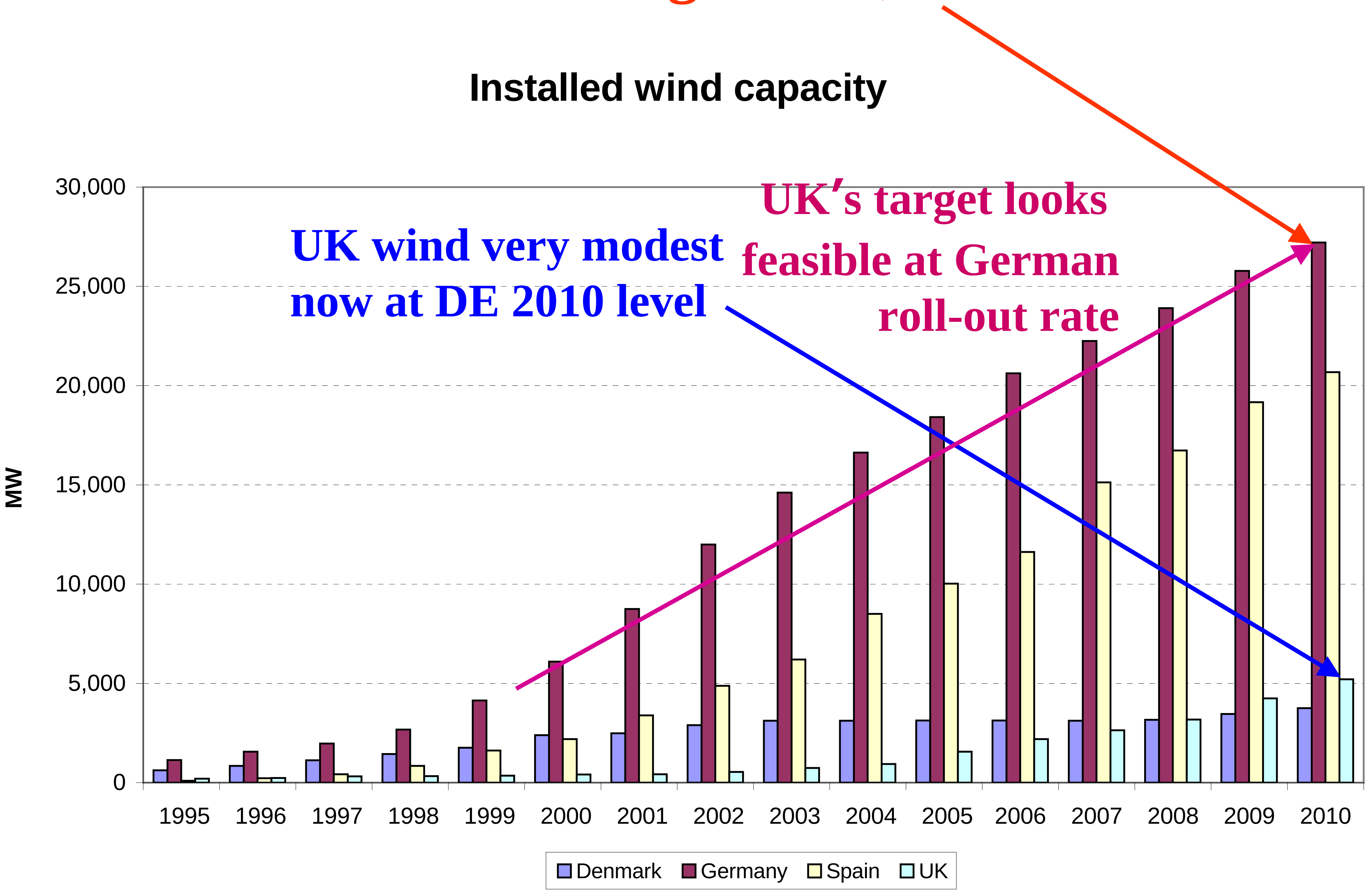
- Electricity is the easiest sector to decarbonise
- current renewables support not delivering
- Zero-C generation faces more risk than fossil
  - electricity price set by gas or coal
- return depends on electricity price
  - set by gas and carbon price
  - and scarcity of ROCs - rewards failure

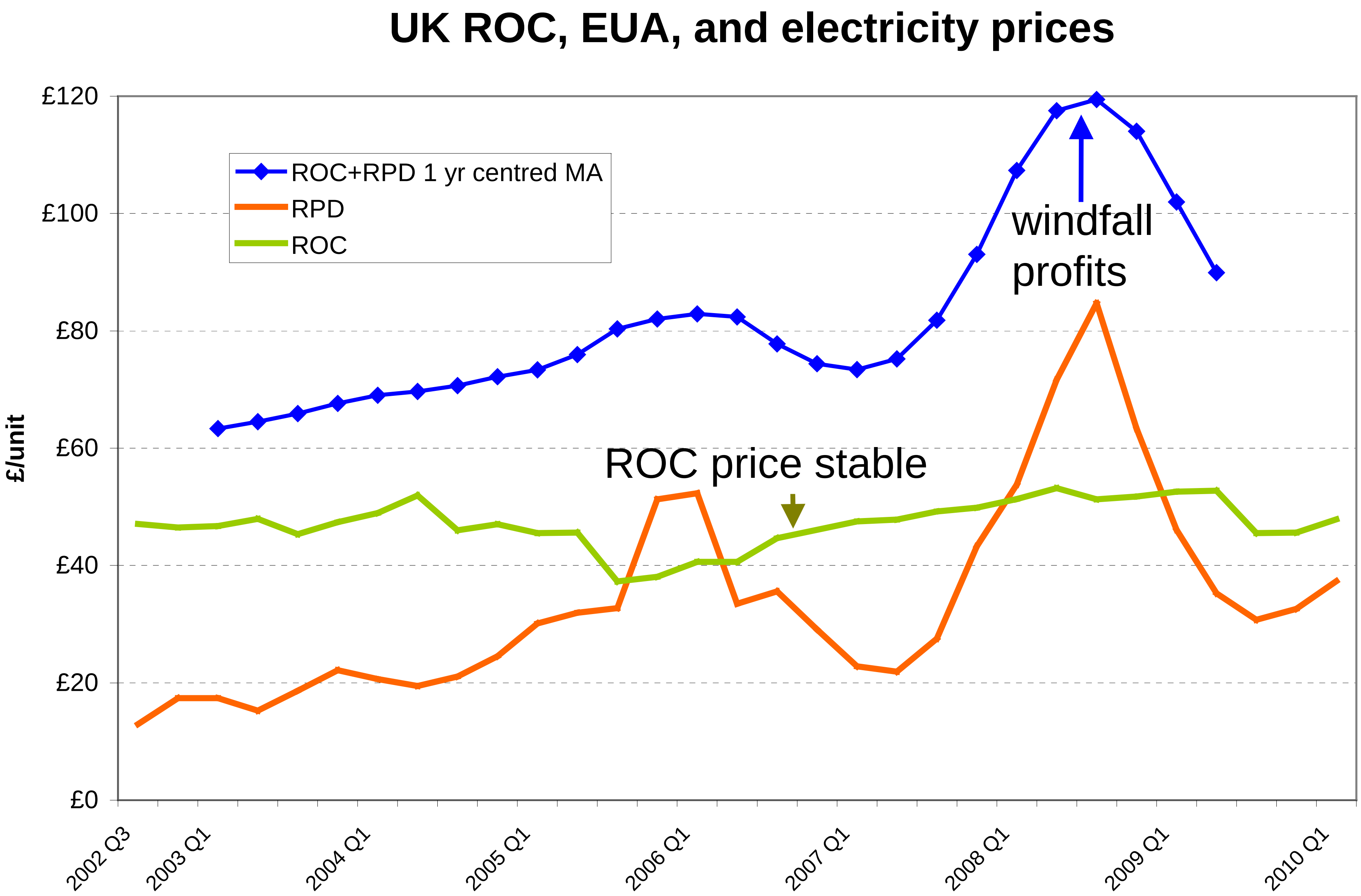
need to de-risk zero C investment

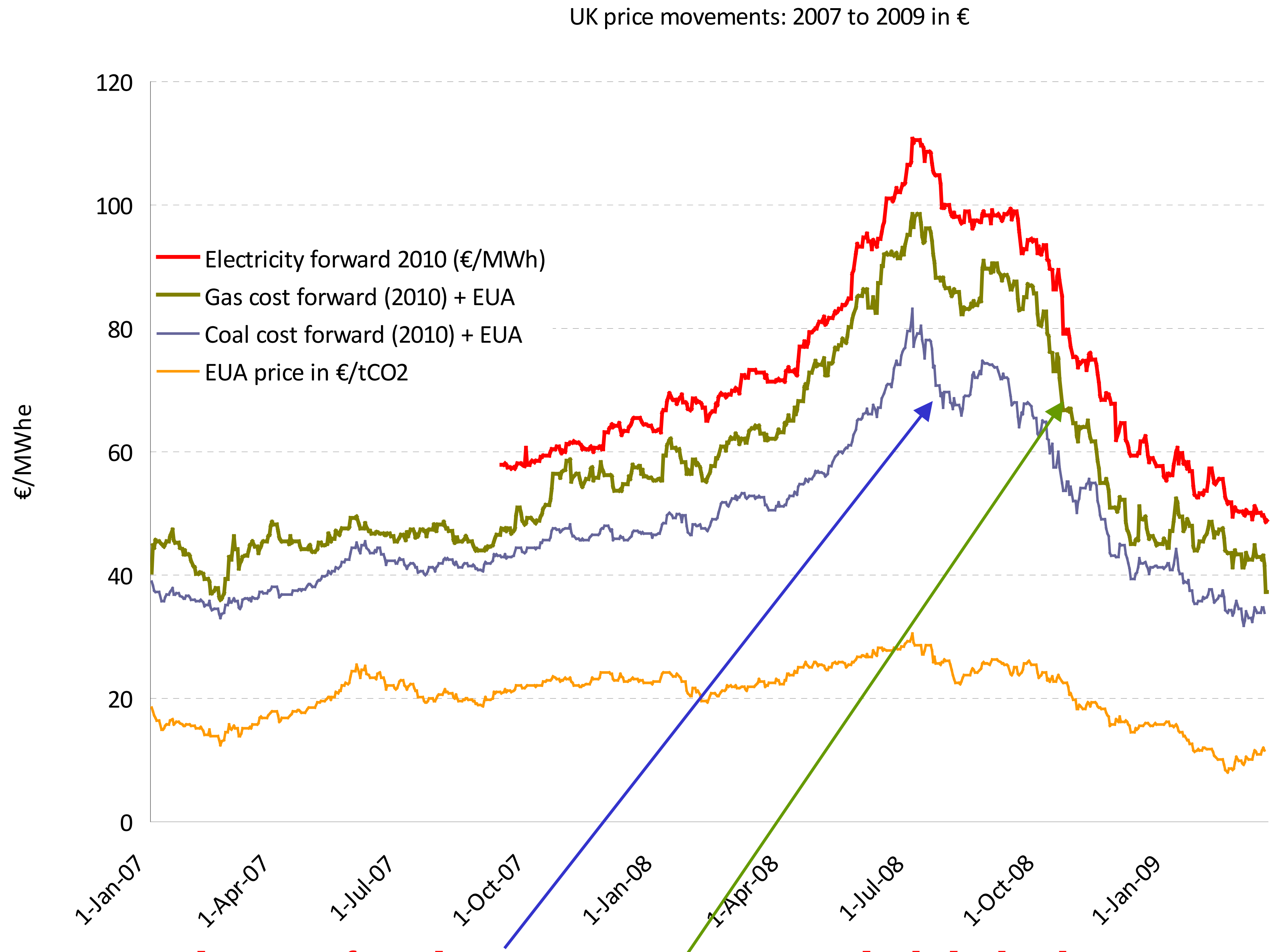
Rapid decarbonisation of electricity is possible - **with nuclear power**



CCC'09 UK 2020 target is 27,000 MW




UK ROC, EUA, and electricity prices
£120
£100
£80
£60
£40
£20
£0
£/unit
ROC+RPD 1 yr centred MA
RPD
ROC
windfall profits
ROC price stable
2002 Q3
2003 Q1
2004 Q1
2005 Q1
2006 Q1
2007 Q1
2008 Q1
2009 Q1
2010 Q1



Correlation of coal+EUA on gas+EUA slightly higher at 96%

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Conclusions pre-EMR

- CO_2 price is too low
  - new coalition supports floor price
- RES Directive undermines ETS
  - and risks bringing ETS into disrepute
  - => make RES additional, set CO_2 price
- UK market hostile to zero-C investment
  - capital costs too high because of risk

Electricity Market Reform

- To de-risk and incentivise low-C investment

=> Long-term contracts for credibility

=> C-price Support to underwrite wholesale price

  – ensures nuclear is not “subsidized”

=> *Capacity payments for peaking plant?*

=> *EPS to deter unabated coal??*

What do these mean for off-shore wind?

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Long-term contracts

- Electricity price is driven by fossil prices
  - – exposes nuclear and renewables to market risk
- CO_2 price unpredictable, not credible

=> long-term contract enforceable in courts

- but technologies differ and so should contracts
  - => simple FiT for on-shore wind (auction sites?)
  - => auctions for off-shore wind?
  - => standard CfD for nuclear, cost-sharing for build?

Emphasise institution for contracting

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Carbon price support

- EUA price volatile, too low, lacks credibility
  – undermined by 20-20-20 Directive and recession
- to bring C-price up to sensible level

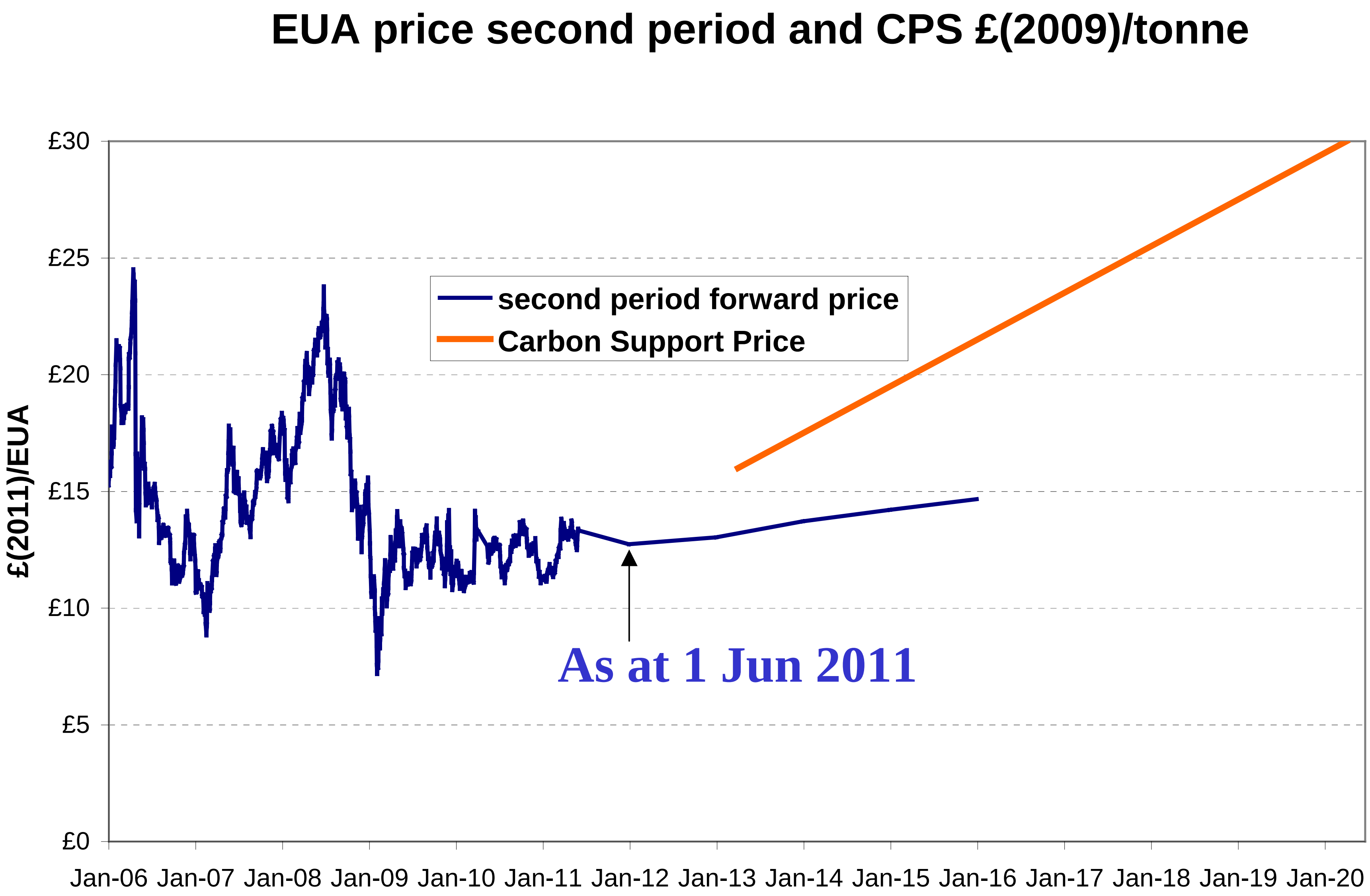
=> ensures wholesale electricity price adequate to support mature low-C investment: i.e. nuclear

- GB wholesale price set by coal or gas

=> nuclear power will not then be subsidized

Useful model to reform ETS

UK's Carbon Price Support plans



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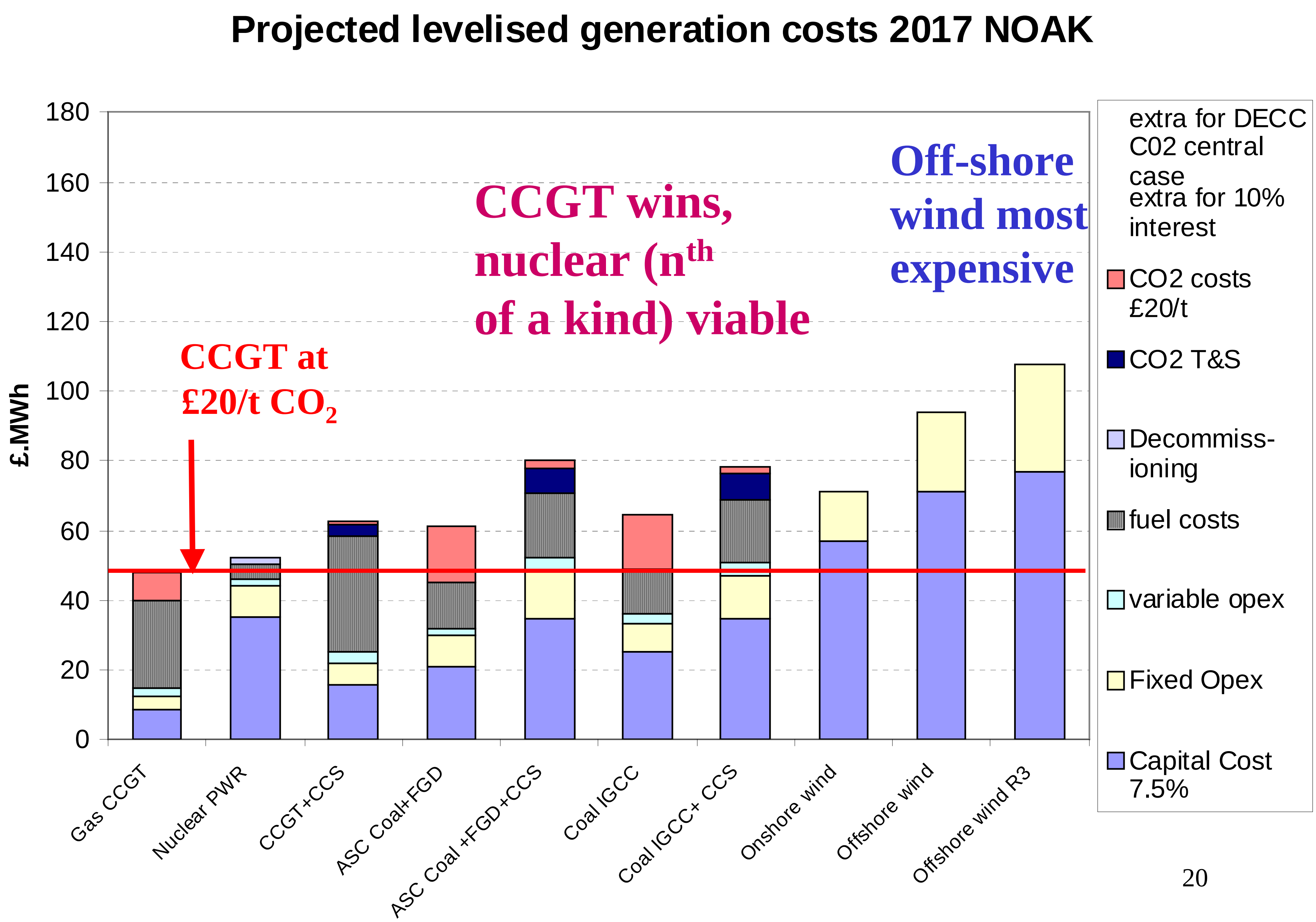
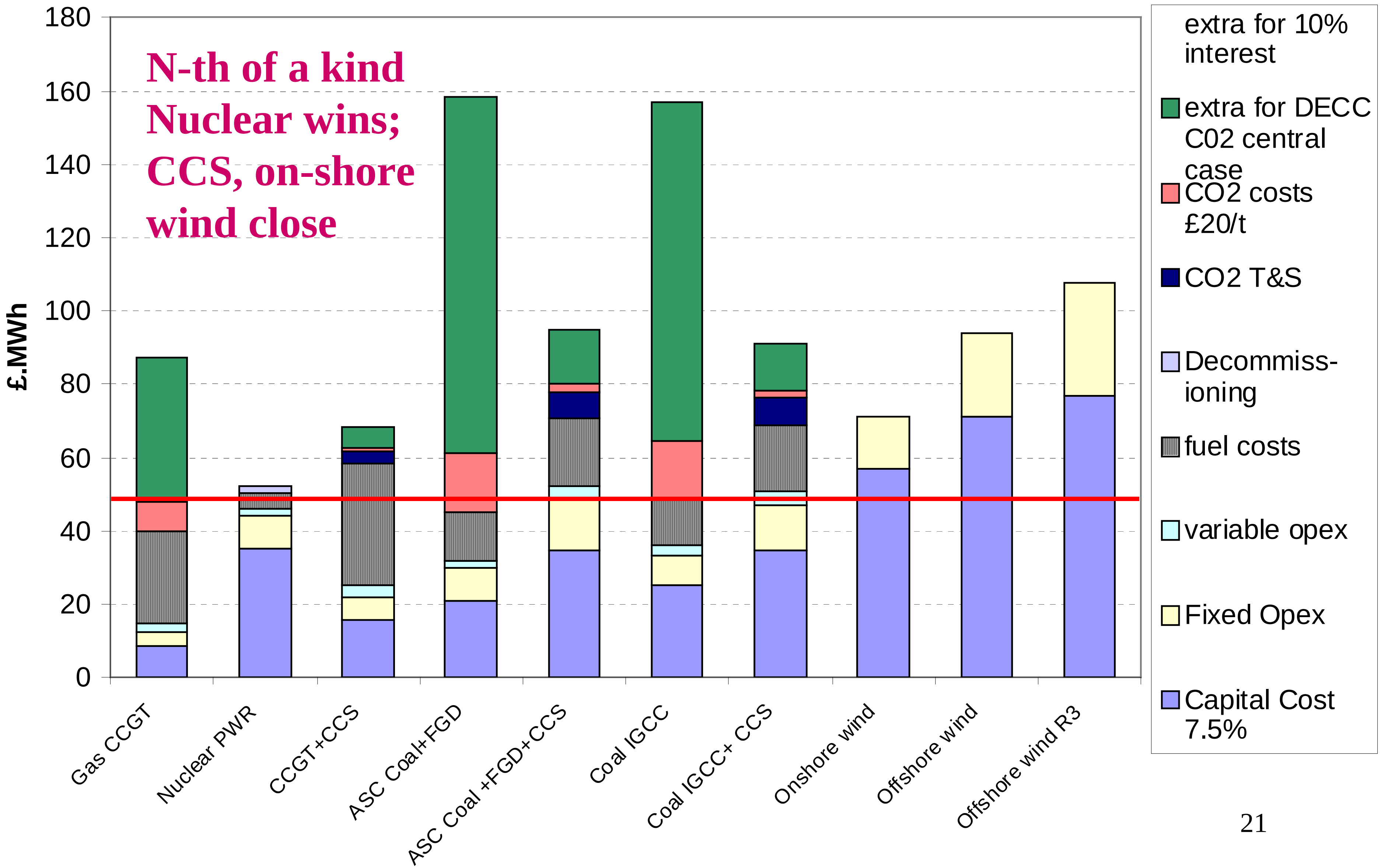
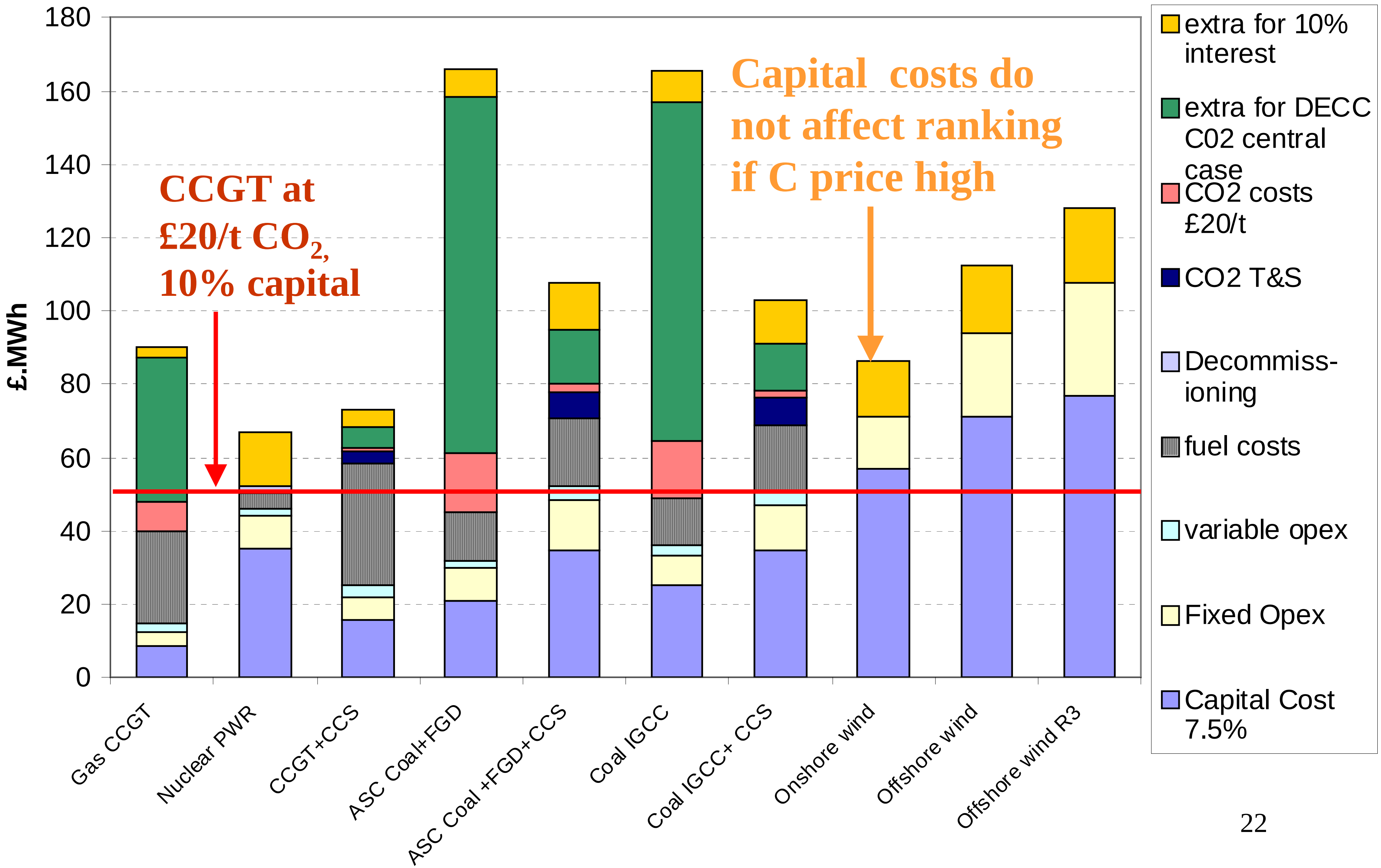


Projected levelised generation costs 2017 NOAK
180
160
140
120
100
80
60
40
20
0
£.MWh
CCGT at £20/t CO_2
CCGT wins, nuclear (n^th of a kind) viable
Off-shore wind most expensive
Gas CCGT
Nuclear PWR
CCGT+CCS
ASC Coal+FGD
ASC Coal +FGD+CCS
Coal IGCC
Coal IGCC+ CCS
Onshore wind
Offshore wind
Offshore wind R3
extra for DECC C02 central case
extra for 10% interest
CO2 costs £20/t
CO2 T&S
Decommiss-ioning
fuel costs
variable opex
Fixed Opex
Capital Cost 7.5%

Projected levelised generation costs 2017 NOAK



Projected levelised generation costs 2017 NOAK



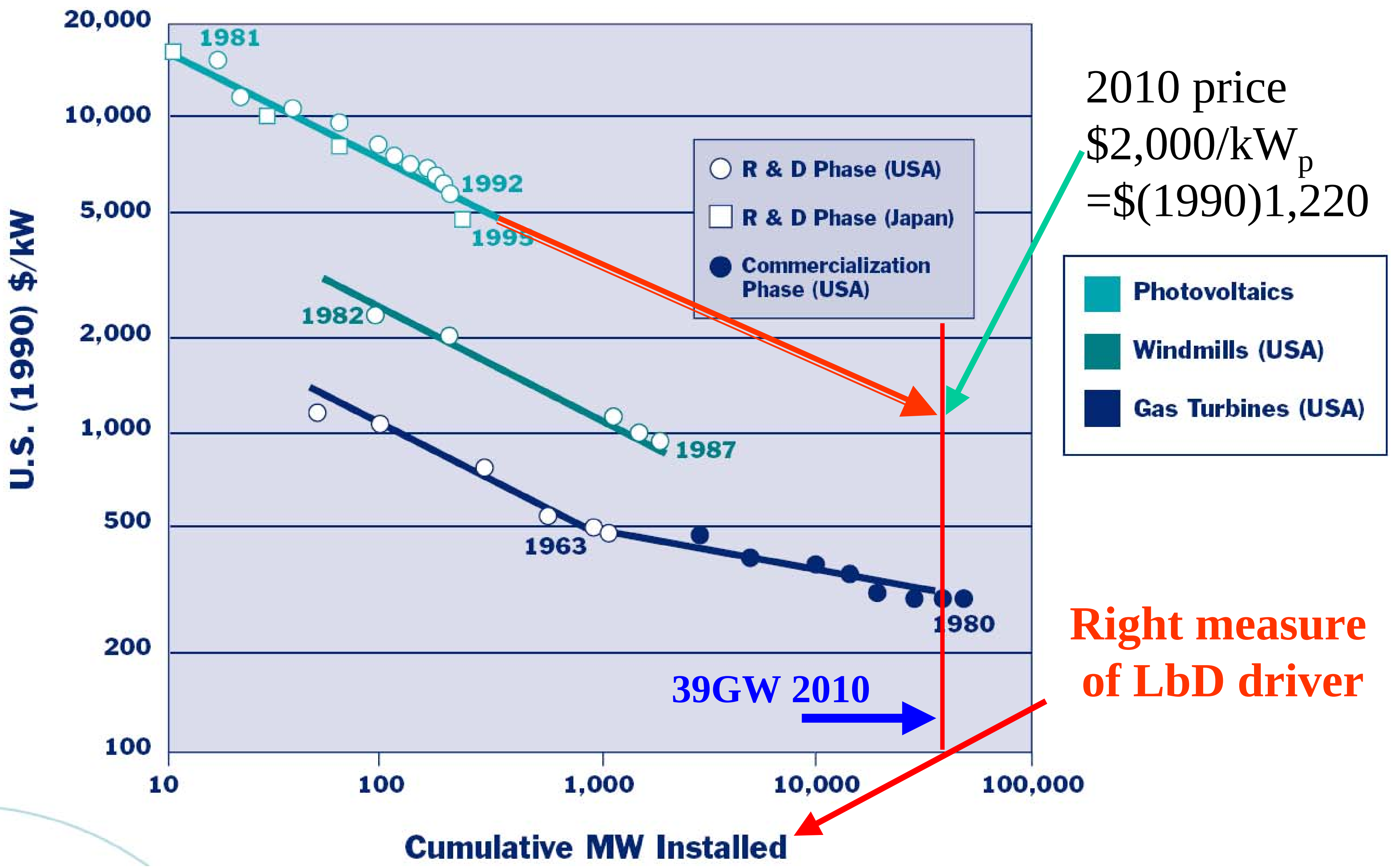
Why support renewables?

- 20-20-20 Directive: demand-pull for renewables
- sets targets for each MS
  - justified by learning spill-overs and burden sharing
  - Each MS chooses its own form of support
- Benefit => lower future RES costs => wide adoption => less climate damage
  - less need for nuclear power

=> NOT judged on current C saving

=> does NOT require “level playing field”

Learning curves for generation technologies



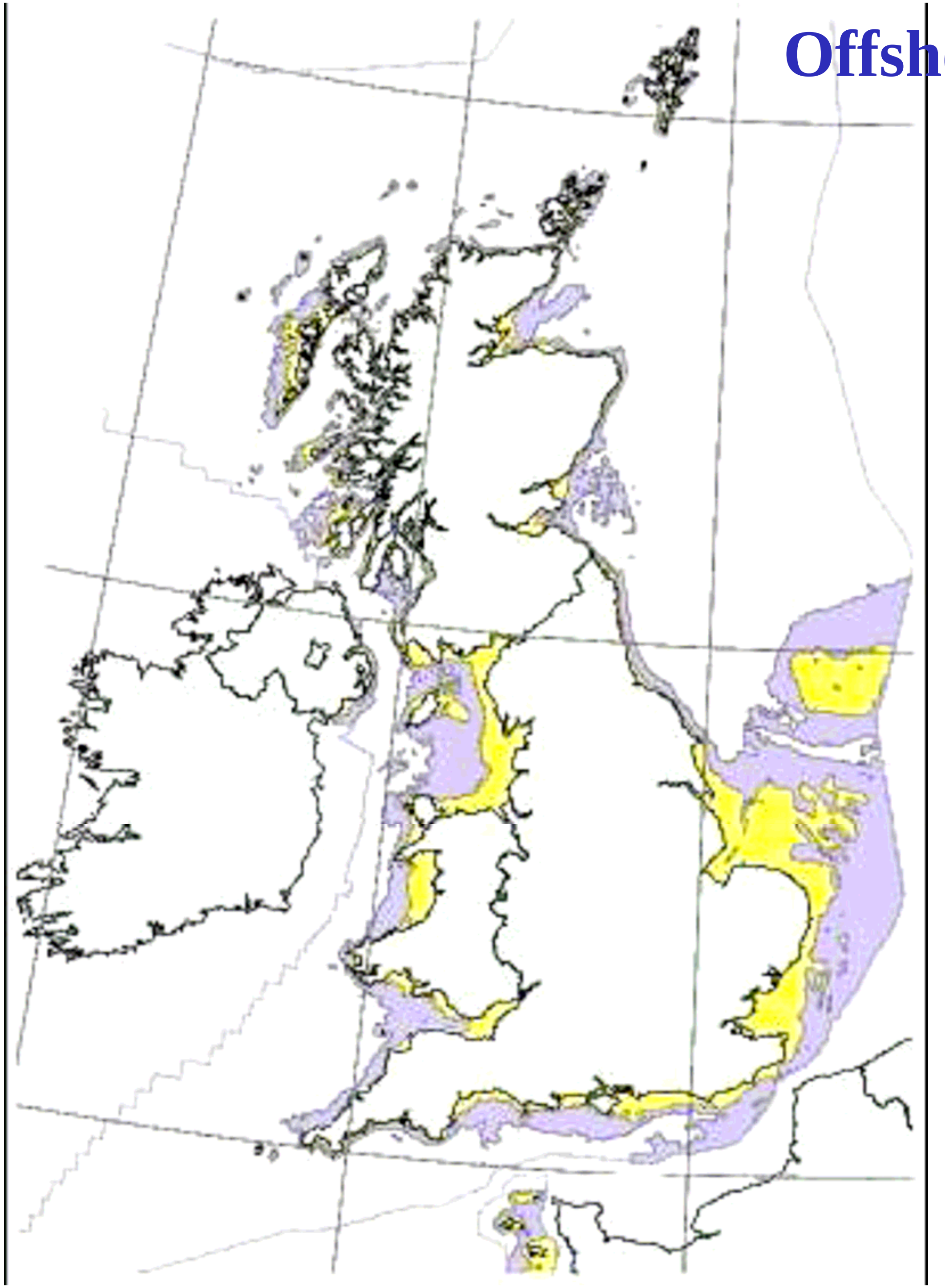
Source: N. Nakicenovic, A. Grübler, and A. McDonald, eds., *Global Energy Perspectives* (CUP, 1998).

Learning rate estimates uncertain!

Table 2.3 Estimated wind power learning rates adapted from (McDonald and Schrattenholzer, 2001)

Country/region	Time period	Estimated learning rate
OECD	1981 – 1995	17
US	1985 – 1994	32
California	1980 – 1994	18
EU	1980 – 1995	18
Germany	1990 – 1998	8
Germany	1990 – 1998	8
Denmark	1982 – 1997	8 (all turbine sizes)
Denmark	1982 – 1997	4 (55kW or larger)

Note: country-based estimates depress learning rate (they double faster than world) these estimates are biased down as they ignore diseconomies of size; Coulomb & Neuhoff (2006) estimate 13%.



Offshore wind

Resource: shallow

3 W/m^2 40,000 km^2 < 25m

- if 30% available = **40 GW**

= 10,000 x 4 MW turbines

=> 16 kwh/d/person

deep:

80,000 km^2 at 30% =

80GW = 32 kWh/d/p

Key:

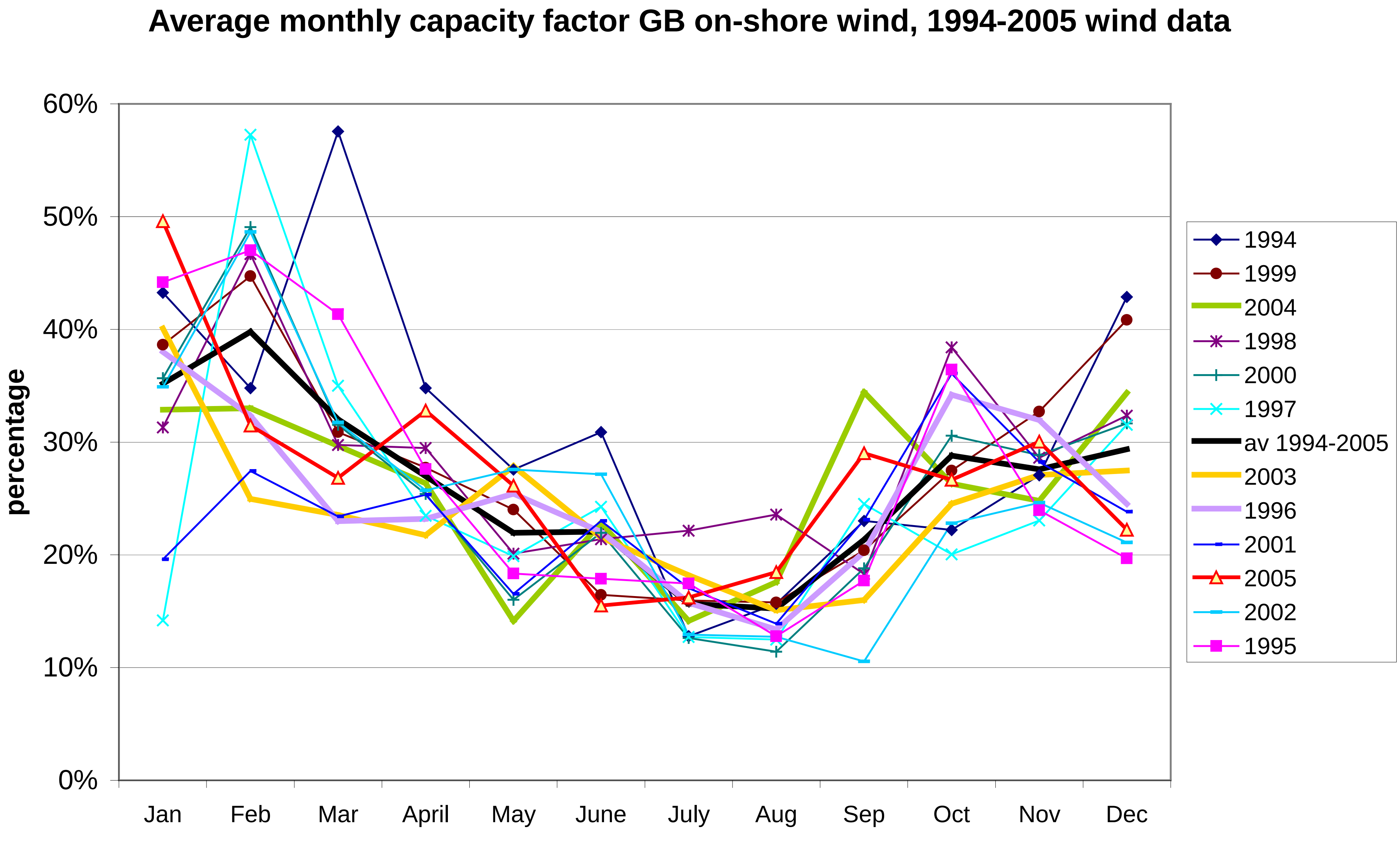
UK territorial waters
with depth < 25m
and < 50m

Source: MacKay (2009) and DTI Atlas of marine resources

Characteristics of wind

- Low capacity factor
  - = 25% on-shore but 36% off-shore
  - – and higher in the winter and day-time
  - – is higher off-shore cost compensated by higher CF?
  - – Depends critically on the value of this power
- High variability
  - – requires considerable flexible dispatchable reserves
- Low predictability day-ahead
  - – hard to contract ahead, risk of imbalance

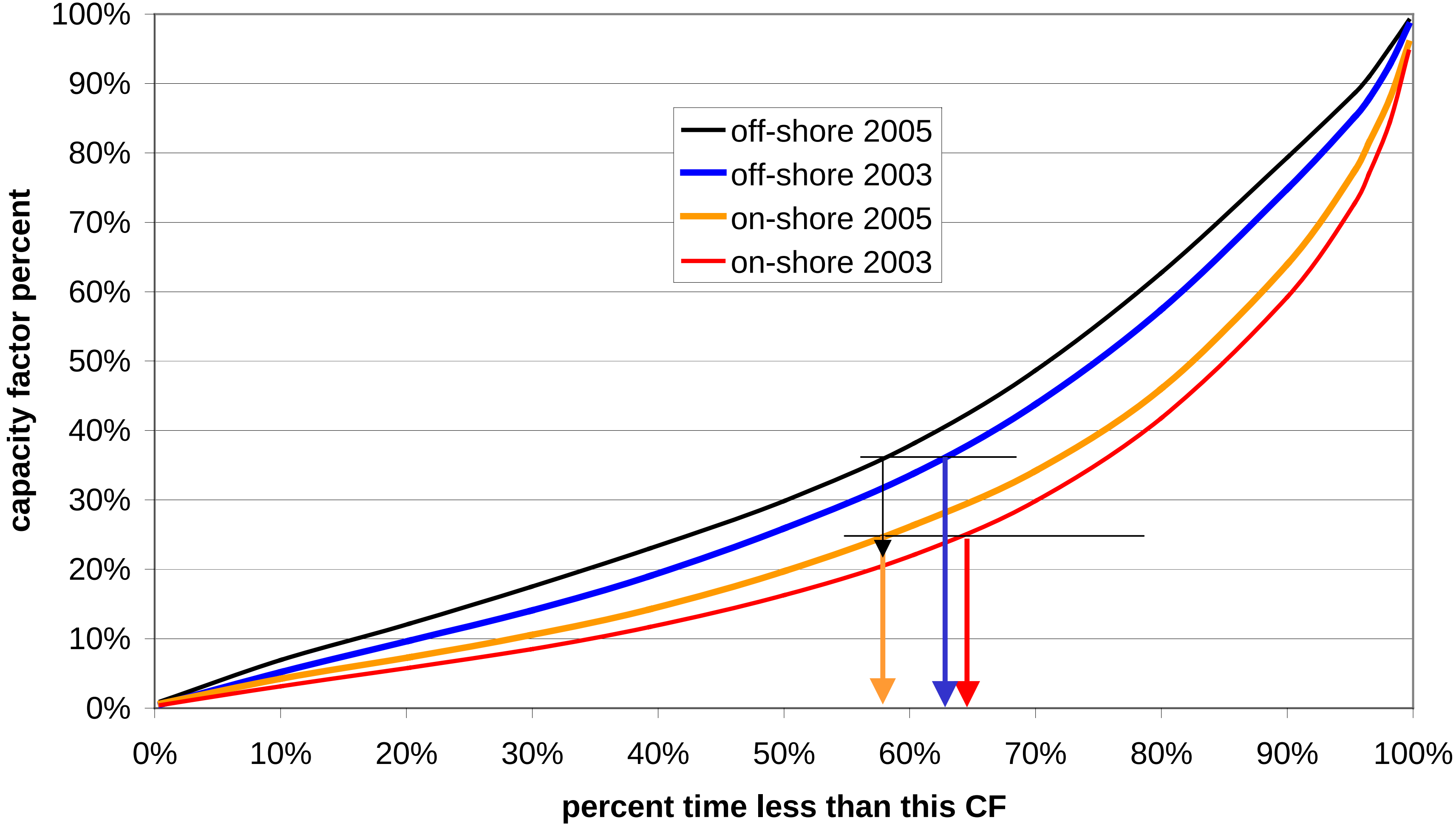
Seasonal capacity factors



Source: Green and Vasilakos (2010)

Capacity factors

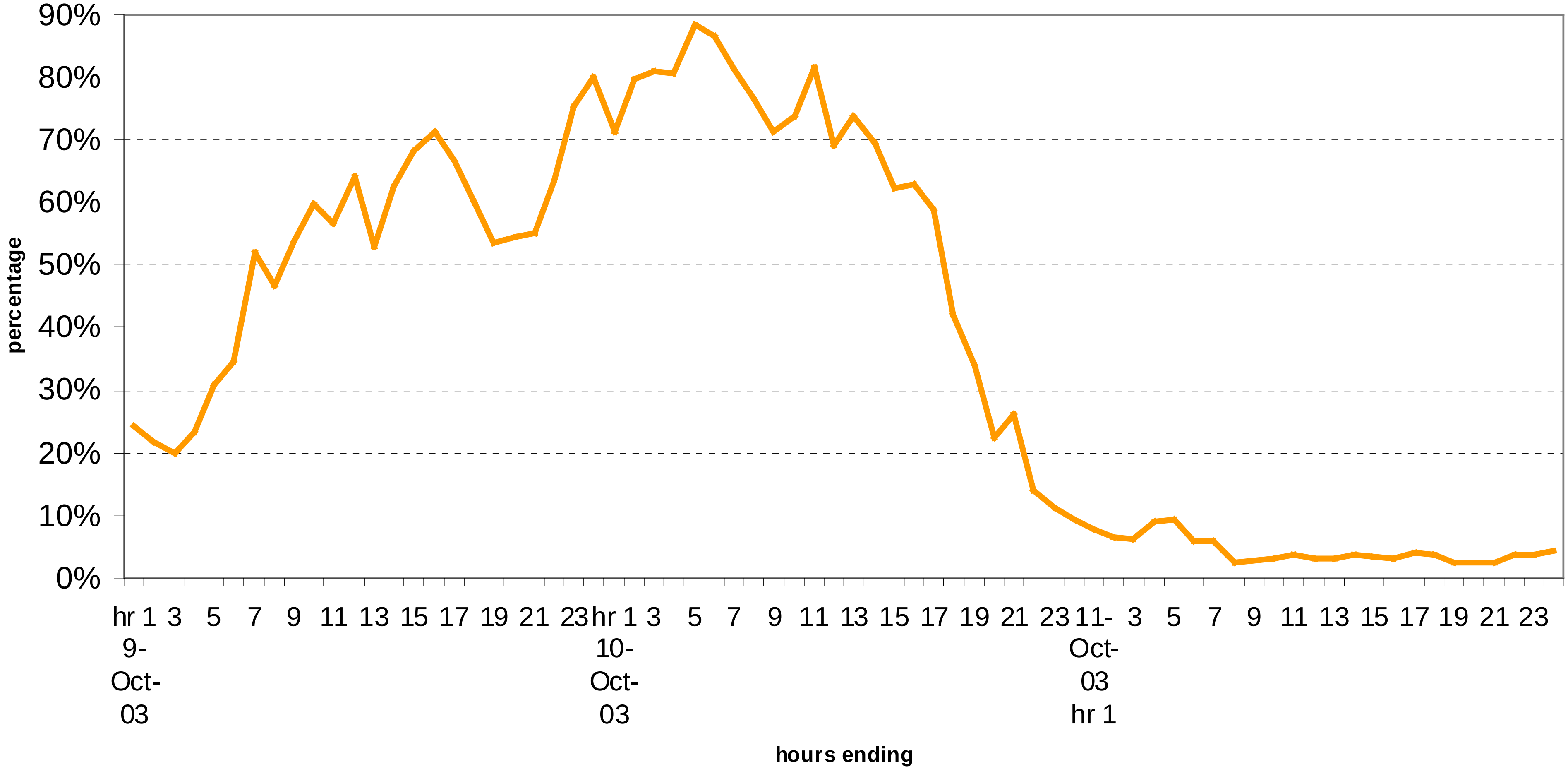
Frequency of on and off--shore GB wind capacity factor



Source: Green and Vasilakos (2010)

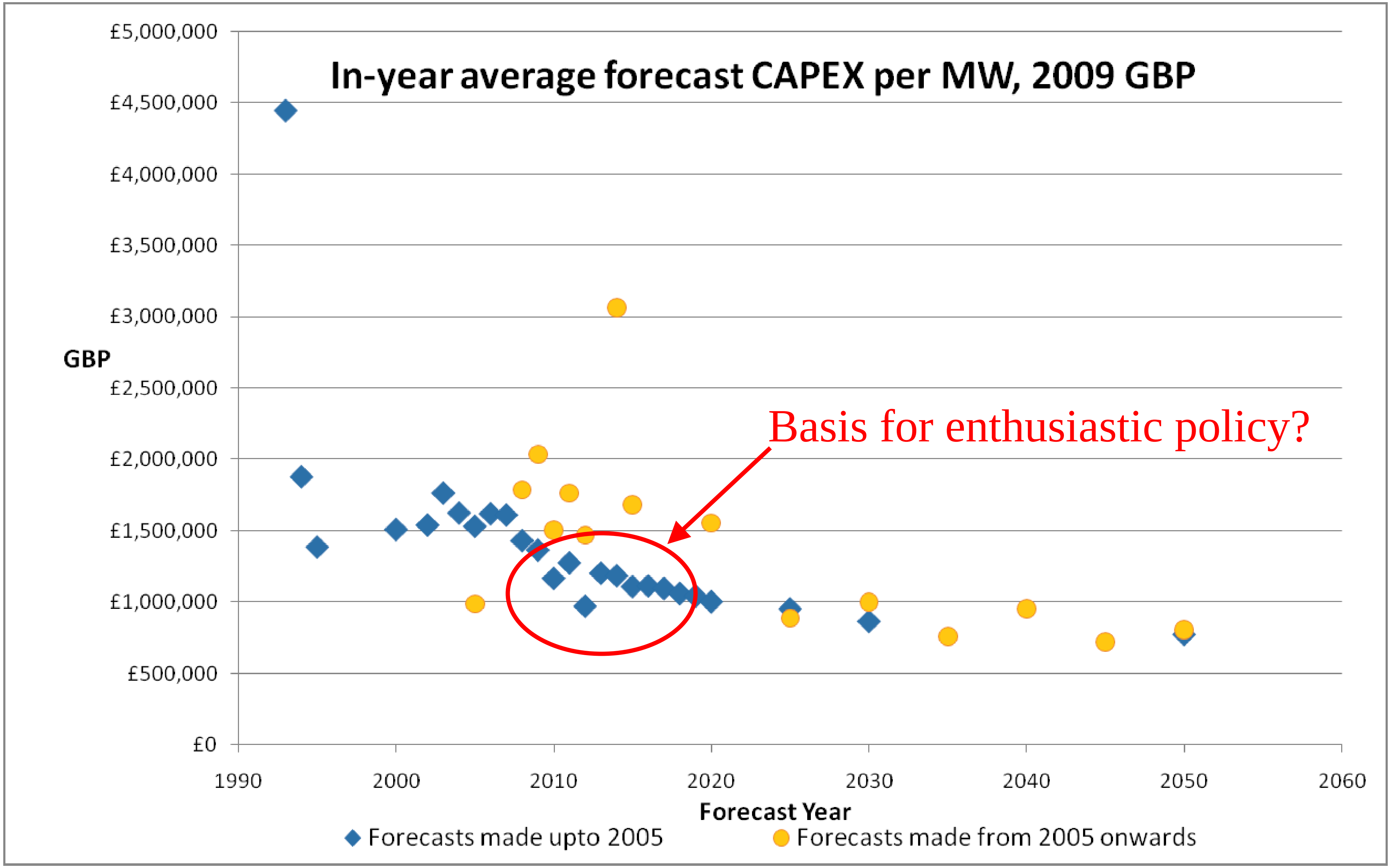
Variability and need for back-up

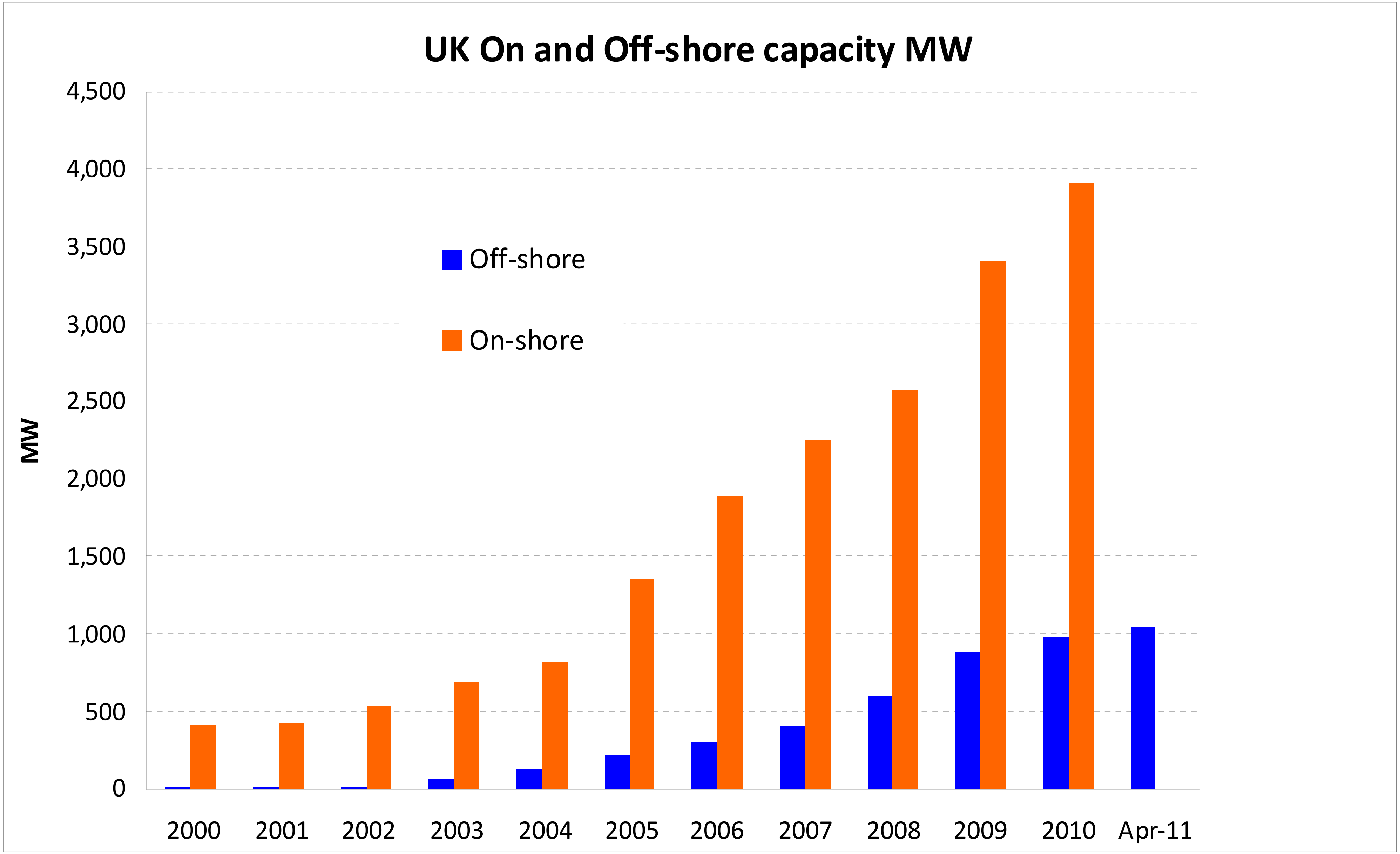
On-shore wind capacity factors 9-11 Oct 2003



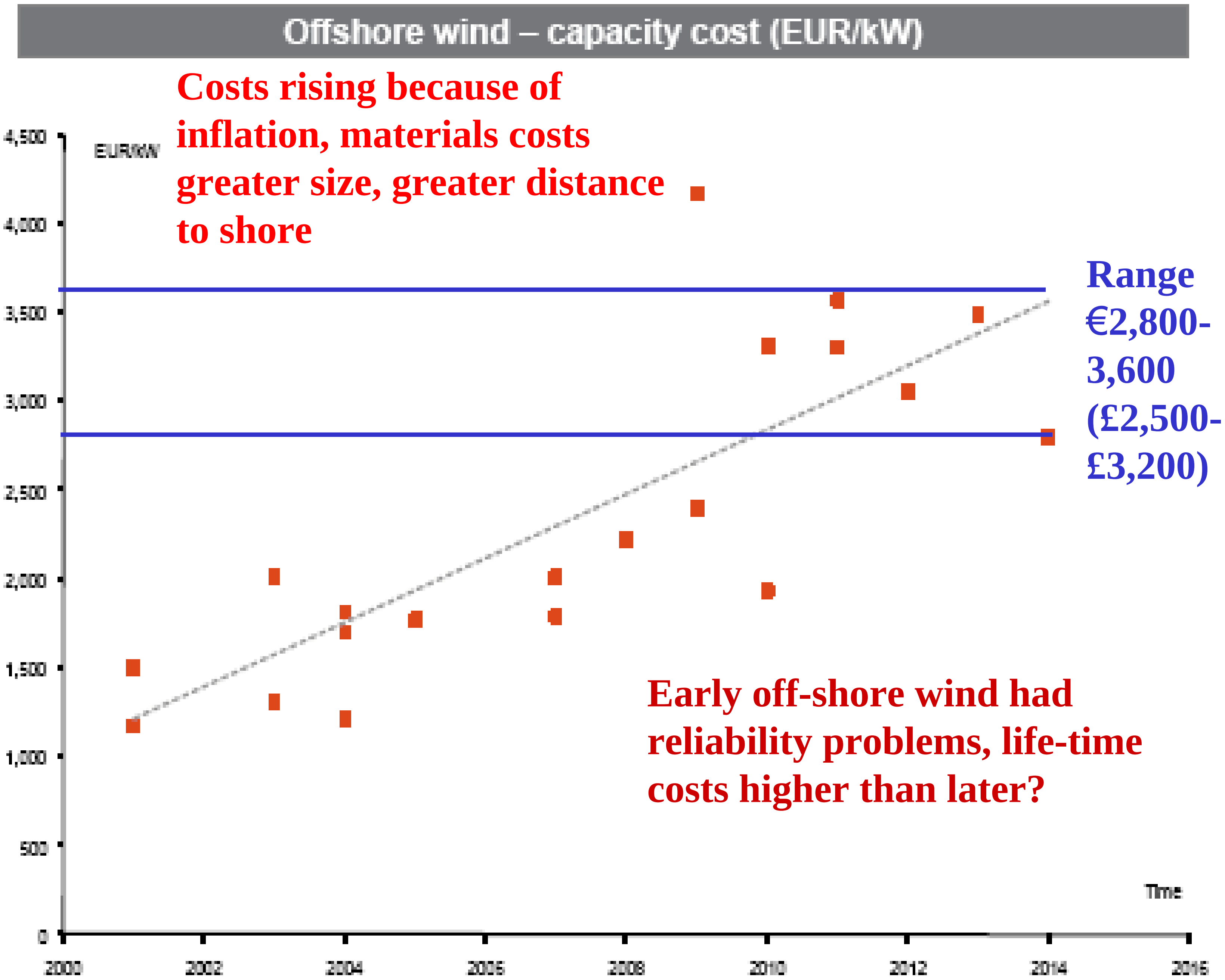
Source: Green and Vasilakos (2010)

Forecast off-shore costs based on LbD





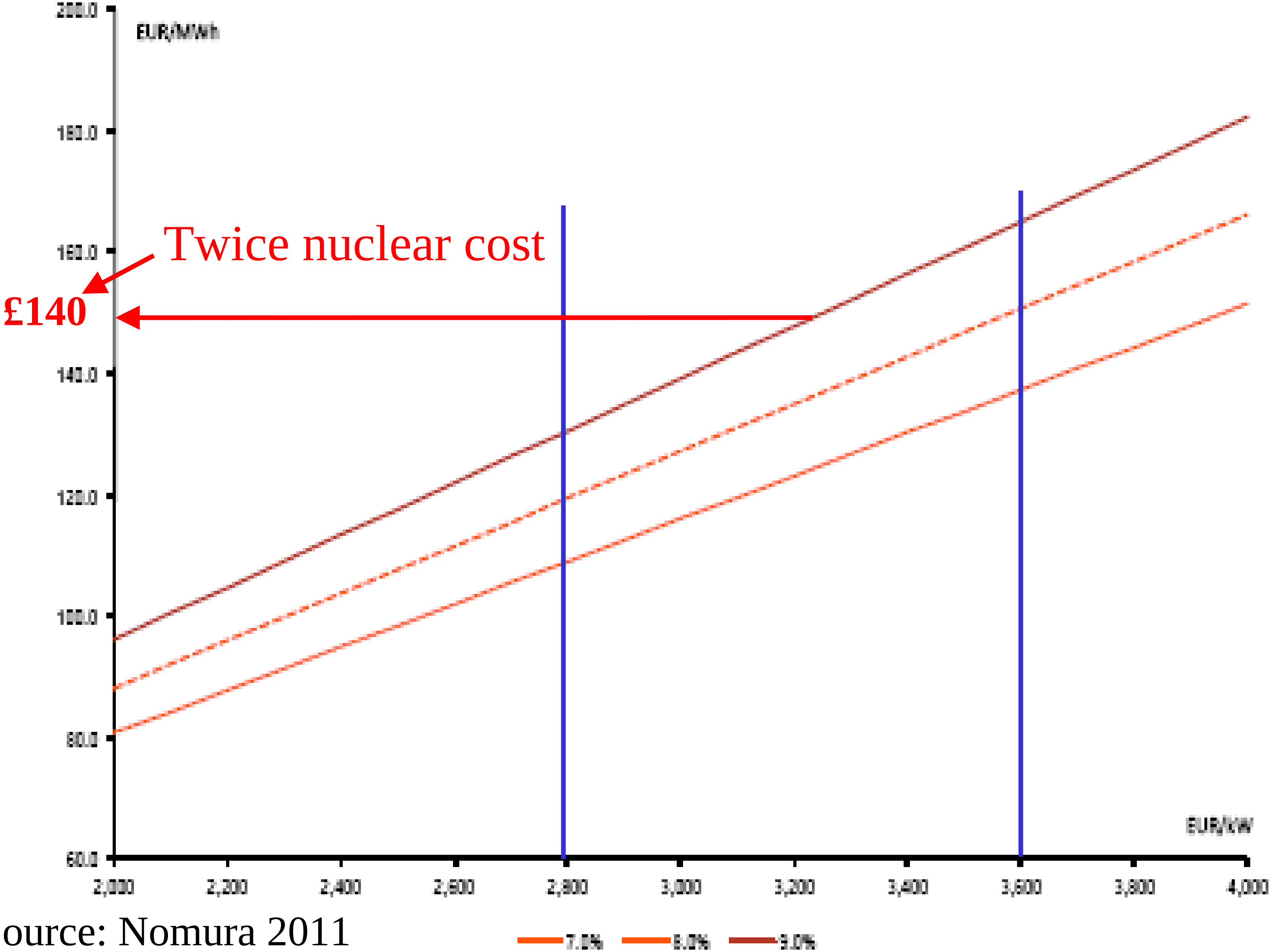
UK On and Off-shore capacity MW
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
MW
Off-shore
On-shore
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Apr-11



Source: EWEA, OceanWind Nomura estimates, Company Data

Source: Nomura 2011

Offshore wind – cost per MWh at various returns



Source: Nomura 2011

Assessment of off-shore wind

- Driven by difficulty of building on-shore
  - given need to meet 20-20-20 target
- Some value in learning by doing
  - how to build, connect and operate reliably
- Unclear scale of world resource that benefits
- Some value if part of N Sea grid?
- But costs likely to exceed on-shore considerably
  - unlikely to be compensated by higher CF

Concerns that costs too high to justify effort

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Conclusions

- Off-shore wind fun for engineers
  - and UK has good off-shore resource
  - and missed the on-shore industrial leadership
- But off-shore is seriously expensive
  - nuclear is half the cost of decarbonising
- Unclear how much resource in rest of world

Danger that "green jobs" and "supporting new green industry" will blind us to economics

Electricity Policy Research Group

Supporting off-shore wind without wrecking the market

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Gale Force: Offshore Wind Power

CUEN Conference Cambridge 28 June 2011

http://www.eprg.group.cam.ac. uk

Acronyms

CCC	Committee on Climate Change
CCGT	Combined cycle gas turbine
CCS	carbon capture and storage
CfD	contract for difference
CF	capacity factor
CPS	carbon price support
ETS	EU emissions trading system
EUA	EU Allowance for 1 tonne CO_2
FiT	Feed-in tariff: fixes price for power
GHG	Greenhouse gas e.g. CO_2
LbD	Learning by Doing
Low-C	Low carbon (e.g. CCS) includes Zero-C (e.g. wind, nuclear)
NOAK	n^{th} of a kind
R&D	Research and Development
RES	Renewable electricity supply
ROC	Renewable Obligation Certificate
RPD	day-ahead price in wholesale electricity market
SET	Strategic Energy Technologies