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Contract design in electricity markets

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Outline

- Requirements for a “good” electricity system
  - The British experience since privatization
- Missing markets and missing money
  - Pricing CO_2 and capacity
- The cost of risk
  - Cost of risk depends on correlations, sharing
- Implications for contract design
  - Incentives vs cost of risk
  - Price and quantity risk, hedging

"Good" electricity system

- Reliable, Sustainable, Affordable electricity
- Reliability – the first priority – adequate capacity
- Investment – right plant in right place at right time
- Least (system) cost dispatch
  - Right plant balances demand and supply
  - **Externalities** properly priced – ***CO_2 priced in EU ETS***
- Simpler with public ownership, otherwise efficient pricing
- Wholesale pricing for efficiency and cost-recovery
  - Price = System Marginal Cost + scarcity

    Scarcity: Loss of Load probability (LoLP) at Value of Lost Load (VoLL)

    = SMC*(1-LoLP)+ LoLP*VoLL = SMC+LoLP*(VoLL-SMC)

    = energy + capacity payment

Competition can work if incentives properly aligned and contracts replace missing markets

Idealized markets

- Complete futures and risk markets reveal all information
  - No market power, no entry barriers, no economies of scale
  - All externalities priced: CO_2, pollutants, learning externalities

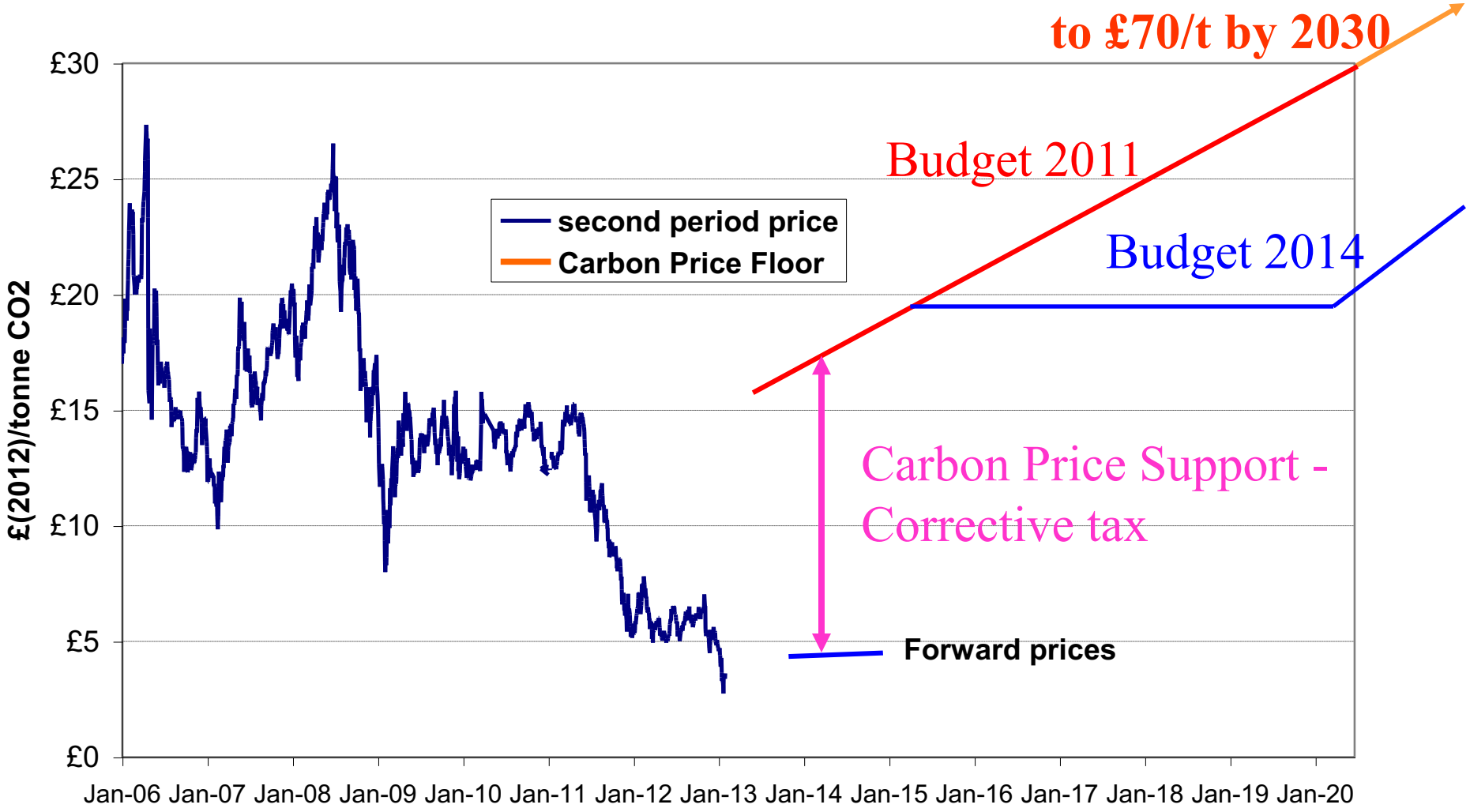
⇒ efficient decentralised decisions for production and investment

- But futures & risk markets ***missing*** from 2-3 years out
- Workable efficient alternatives
  - Stable predictable future, no policy risks, leave to equity market
  - Alternatives to **missing markets**:
    - State-support for low-carbon generation - nuclear power, renewables,..
    - payments to deliver adequate capacity for security of supply
    - vertical integration or suitable contracts between generation and retailers
    - CCGT **+ cheap gas** + long-term contracts facilitated entry/competition

Conditions favoured UK electricity privatization

Pricing externalities – carbon pricing

EUA price second period and CPF £(2012)/tonne



Source: EEX and DECC Consultation

First wave of investment: markets work?

- Privatization: two fossil generators, 12 regional retailers
  - nuclear remains state-owned until 1995, Retailers own grid
- Duopoly sets wholesale price, domestic retail regulated
  - Cheap gas, new modest scale CCGTs available

⇒retailers approached by Independent Power Producers

- IPPs offer 15-yr contracts (PPAs) to retailers
  - Backed by 15 yr gas supply contracts and CCGT guarantees
  - Retailers allowed to pass cost through to captive customers
  - Supply and demand risk hedged => ***cheap finance***

"market entry" underwritten by long-term contracts

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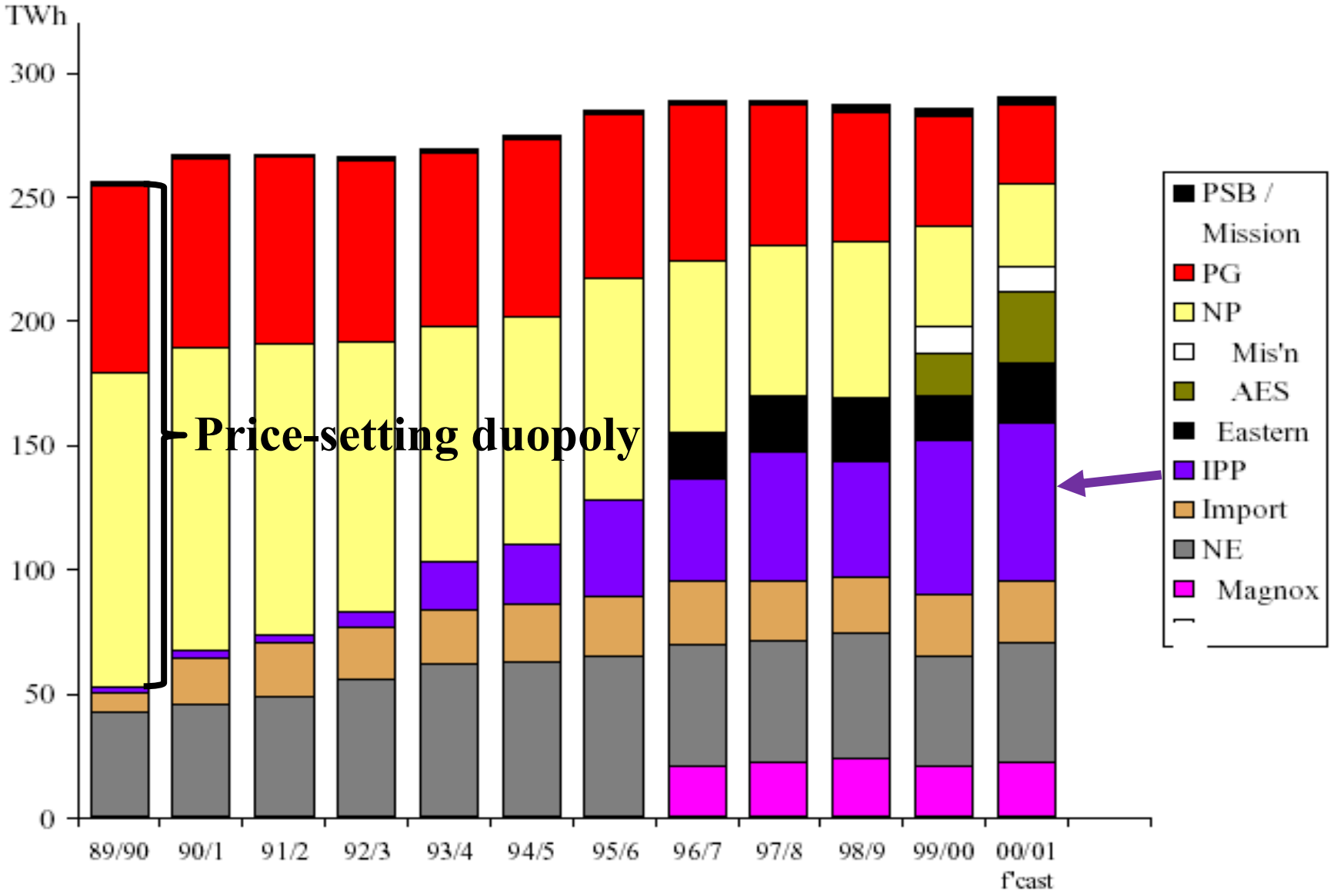
Generation in England and Wales after privatisation



Cost of risk

- Cost of risk proportional to **Variance of return**
- EU(W) ≈ EW - ½AVar(W) where W is existing portfolio
- EU(W+X) – EU(W) = EX - ½A{Var(X) + 2 Cov(W,X)}
- Cost of risk = ½A{Var(X) + 2 Cov(W,X)}

⇒ negative correlations reduce risk

- Spread risk over *n* agents: Total cost of uncorrelated risk
  = ½*n*AVar(X/*n*) = ½AVar(X)/*n*

⇒ Spreading risk reduces ***total*** cost

Balance incentive to manage risk against extra cost

Contracts for different risks

- Short-term for existing assets, long-term for investments
  - Distinguish correlated and uncorrelated price and volume risks
- Dispatchable reliable plant: mainly price risk: CfDs
  - Future flexible plant: capacity contracts
- Variable renewable electricity (VRE): price ***and*** vol risk

  ⇒ suitable short and long-term contracts: yardstick CfDs
- New nuclear (and CCS): construction and carbon risk
  - RAB finance with state as counterparty
  - Cost-sharing of construction risk

Efficient incentives vs least-cost risk sharing

CfD for unbundled industry

- Generators sell, retailers buy in wholesale market
- Retailers sell to consumers (often on fixed prices)
- Upstream and downstream risks negatively correlated
  - High fuel costs reduce upstream profits, low fuel costs raise them
- Vertical integration cancels out these risks
  - So did state ownership

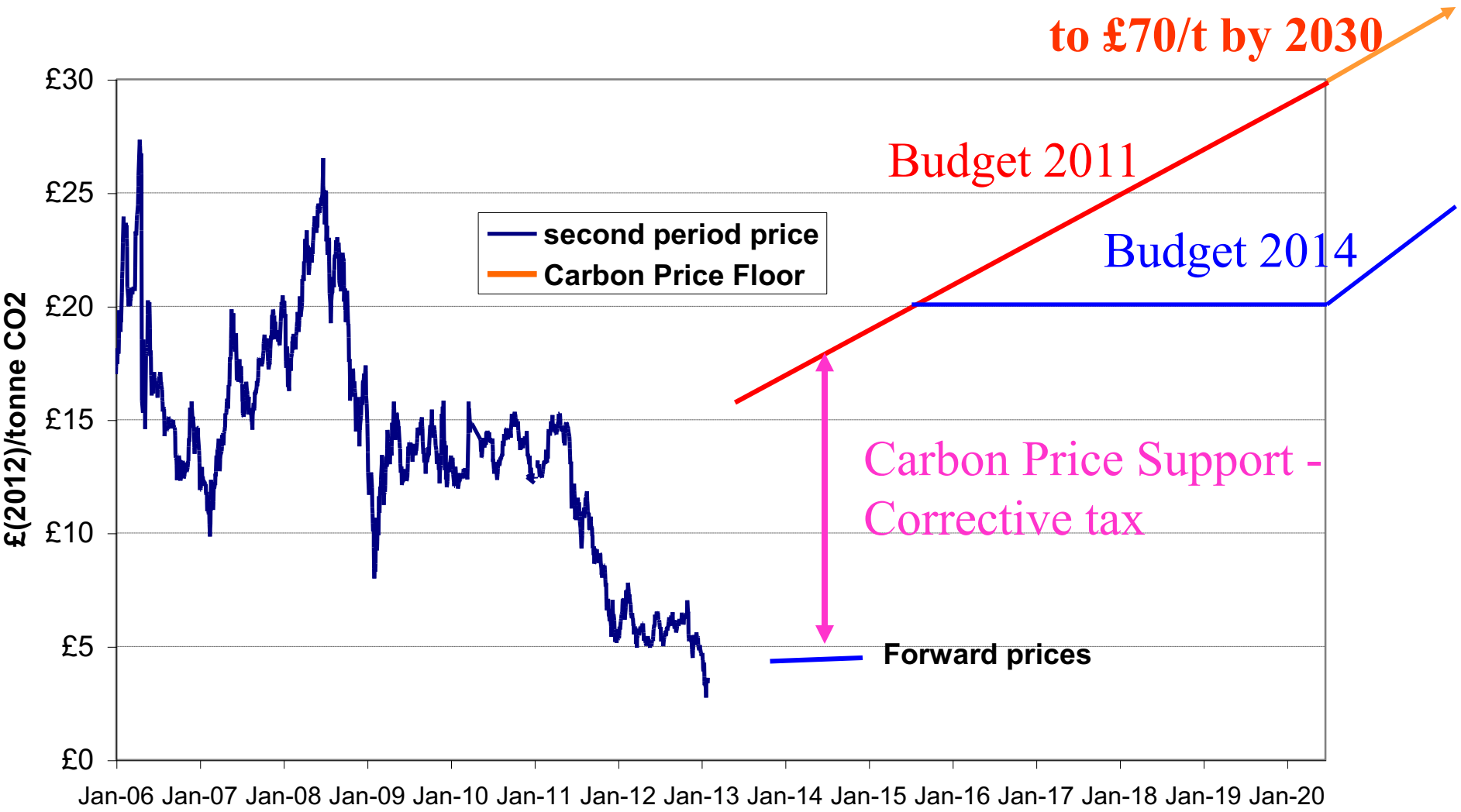
$\Rightarrow$ otherwise hedge risk with Contract-for-difference (CfD)

- **Fossil CfD**: spot price p, MC = c
- strike price s £/MWh, volume M MW, pays $(s-p)M$:
  - if $p > c$, sell $Y > M$ at p, profit $(p-c)Y + (s-p)M$; if $Y=M$, $\boldsymbol{\Pi = (s-c)M}$: perfect hedge
  - if $p < c$, do not produce, receive $(s-p)M > (s-c)M$ (> 0)

Addressing carbon pricing instability

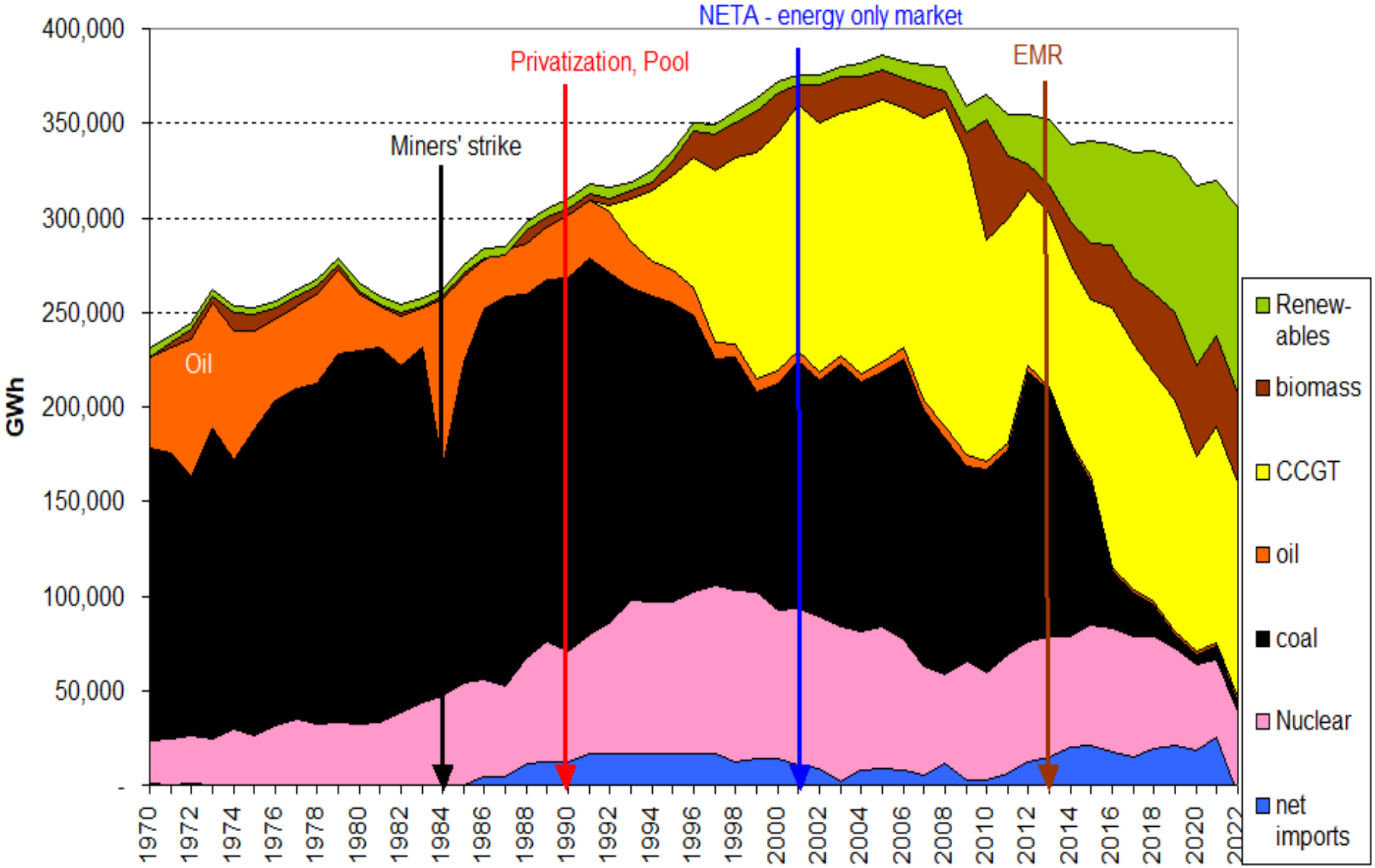
the problem of credible carbon taxes

EUA price second period and CPF £(2012)/tonne



Source: EEX and DECC Consultation

Generation supplied by fuel 1970-2022



Reliability: emerging problem

- Ambitious renewables targets increase intermittency
  - Need flexible reserves
  - Normally came from old high cost plant = coal
    - Emissions Directives threat to coal
    - Budget 2011 carbon price floor => close old coal
  - high EU gas prices and low load factors

  ⇒ gas unprofitable, new coal prohibited
- Future prices now depend on uncertain policies
  - on carbon price, renewables volumes, other supports

Hard to justify investing in reliable power

Need capacity market to ensure flexible plant enters

Solution: Energy Act 2013: capacity markets, VRE CfDs

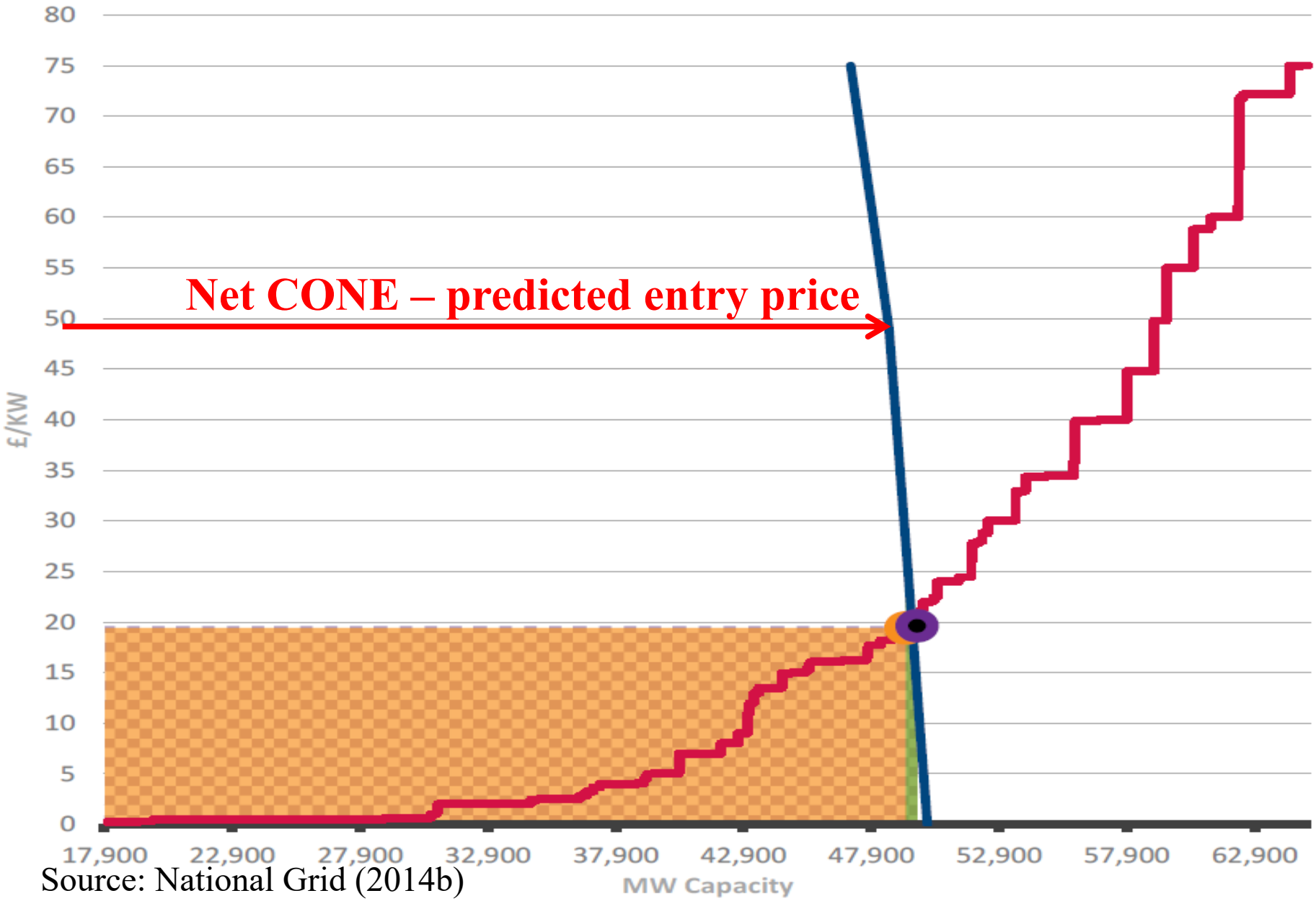
Case for a Capacity Revenue Mechanism (CRM)

- "Missing Money" vs "Missing Markets"
- Missing Money results from price caps

  => address via VoLL caps in markets, hedged by reliability options (ROs)
- Missing Markets
  - Future markets for financing period 15 yrs?
  - Satisfactory carbon price
  - Hedges against regulatory risk, incl price caps
  - For full range of ancillary services
    - Flexibility, fast ramping, frequency response, etc.

Ignore Missing Markets => Missing Money

GB Dec 2014 Capacity Auction



Source: National Grid (2014b)

Reliability Options to deliver flexible capacity

- RO sets strike price, ***s***,
  - **above** variable cost of all controllable generators: $700/MWh?
  - Vary with gas/distillate price? (Texas!)
- RO auction finds required annual payment ***P*** $/kWyr
  - 10 yrs for new, 1 yr for existing capacity to signal exit
- Market price ***p*** reflects scarcity (Voll x LoLP) in stress hours
  - SO sets floor price to reflect spot scarcity

  => price signals efficient cross-border trade
- Generators choose whether to receive ***p*** or bid for RO
- RO holders face wholesale price ***p*** $/MWh
  - receive strike price if available, pay ***p – s***, pay ***p*** *if not.*
- Consumers hedged at strike price ***s*** and pay for RO ***P***

2019:UK Government adopts Net Zero targets

- Net zero requires massive investment
- Low-C is capital intensive and low variable cost
  - **the key to lowering cost is lowering cost of capital**

  ⇒ ***contracts*** reduce risk and lower cost
- Renewables –future price risk & unpredictable output

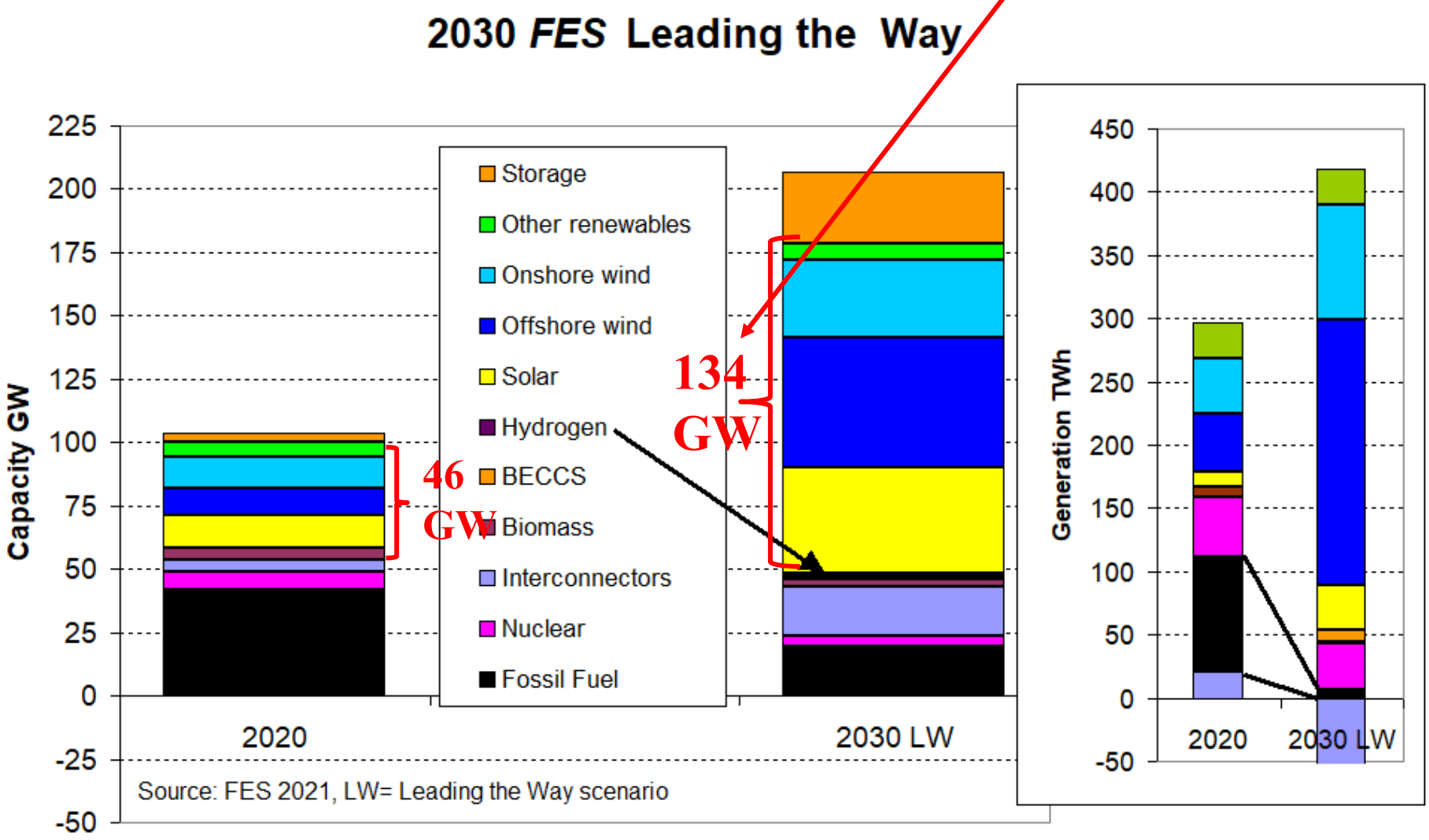
  ⇒ How well do existing contracts perform?
- Flexible gas: future low demand and low prices?

  ⇒ Capacity market contract

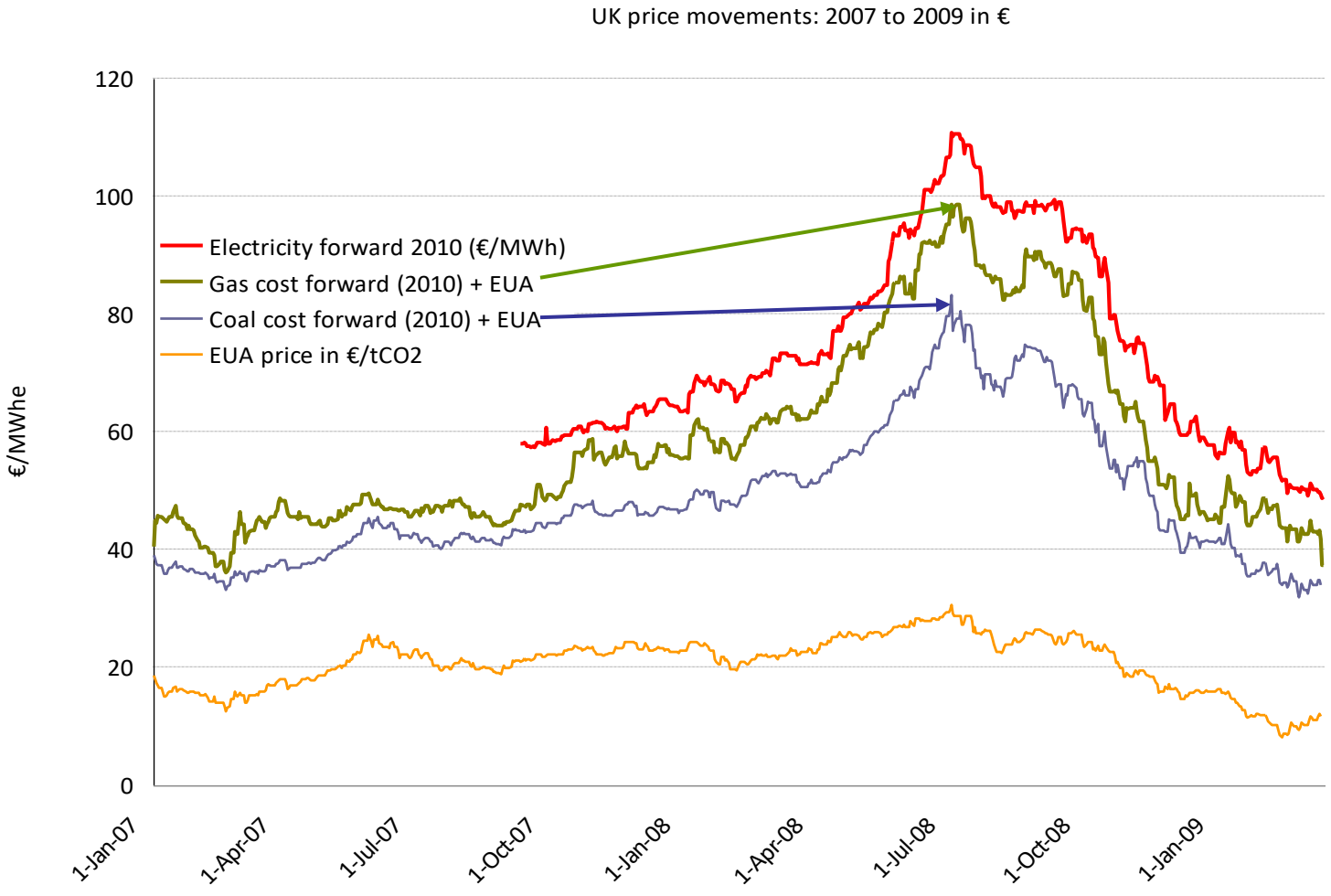
=> **Hybrid markets for new investment**:

- competition **for** the market (auction LT contracts)
- then competition **in** the market to set price

UK renewable electricity capacity nearly *trebles* by 2030



Zero-carbon generation faces more risk than fossil generation



Source: Bloomberg

Designing Renewables Contracts

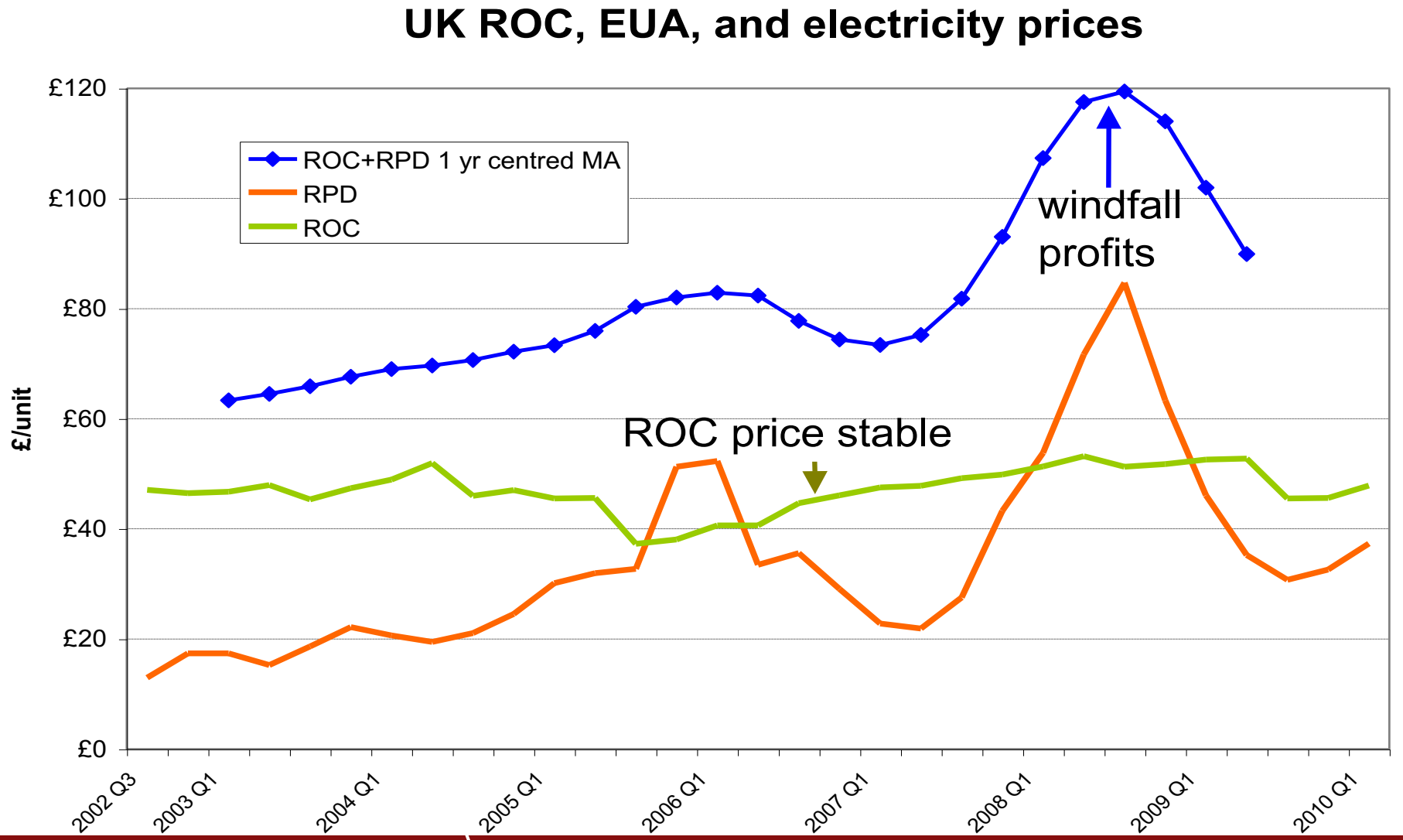
- Missing futures markets and lack of fuel price hedge

⇒ Need long-term contract to transfer risk

  - Feed-in-tariff (FiT) pays fixed price/MWh on metered output
  - Premium FiT on wholesale price: GB - RO certificates
  - CfD with FiT – set strike price, volume = metered output
  - Yardstick CfD – pays on reference output

- Contract length: years or full hours (40,000MWh/MW)?
- How good for:
  - Reducing risk, efficient bidding/operation, location, excess rent
- How to set the strike price?
  - Administratively? Auctions?

Current wholesale prices deliver massive windfall gains to RO contracts



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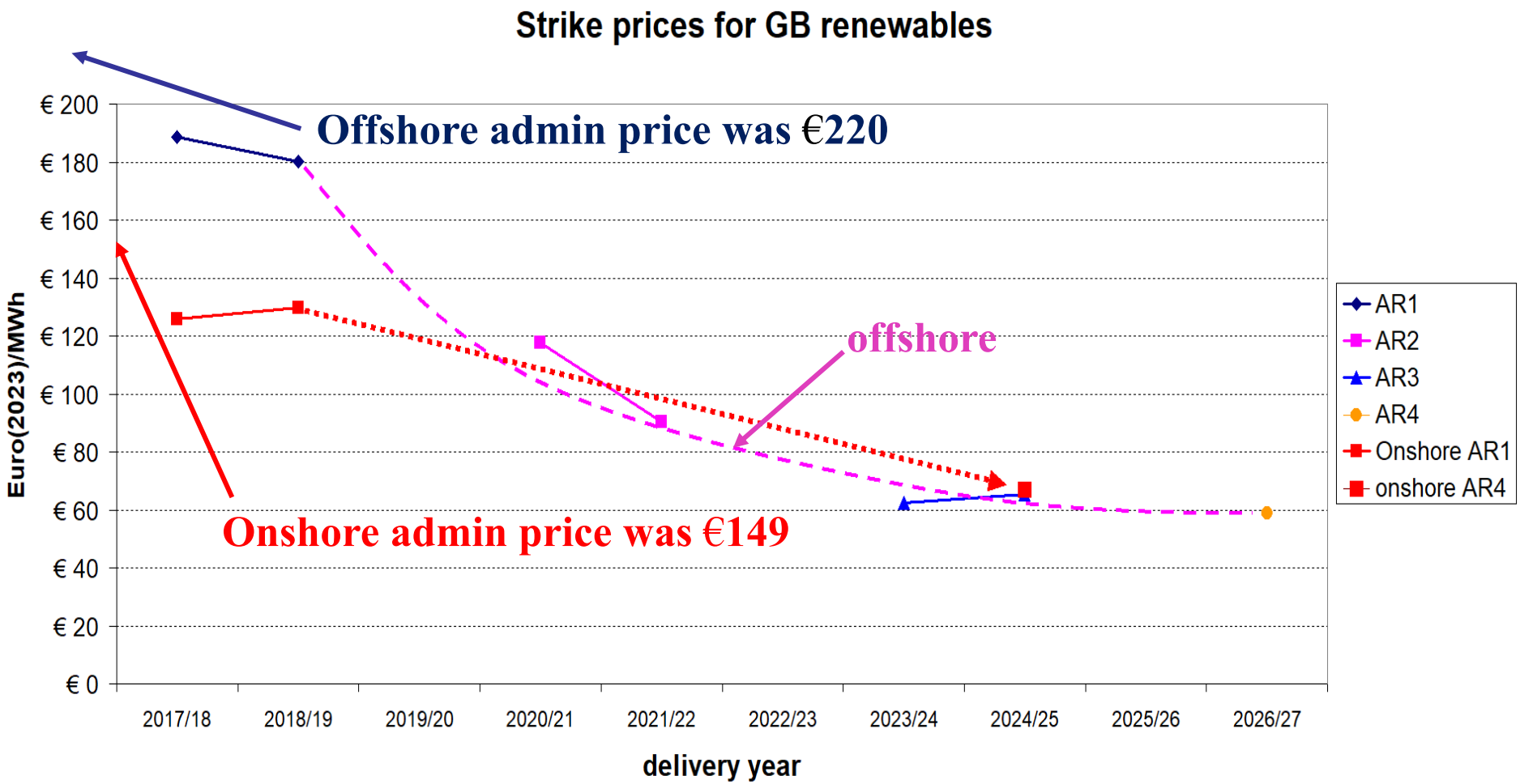
Auctions continue to deliver real GB cost reductions

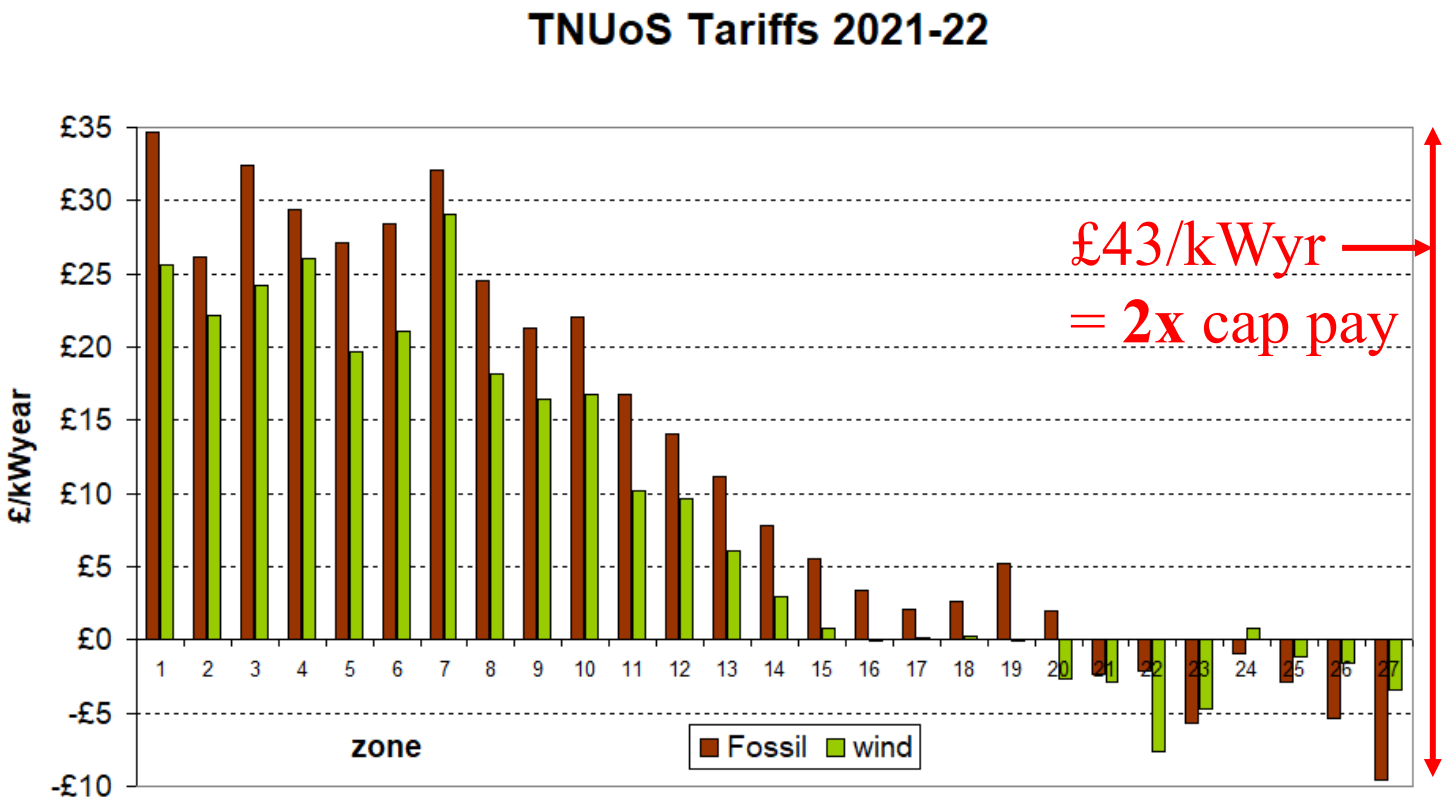


Guiding investment location

Transmission Network Use of System

Problem: **TNUoS** assumes instant incremental adjustments
charges **annually reset**, discourages substantial necessary changes

Solution:
grandfather existing TNUoS, entrants face forward-looking TNUoS



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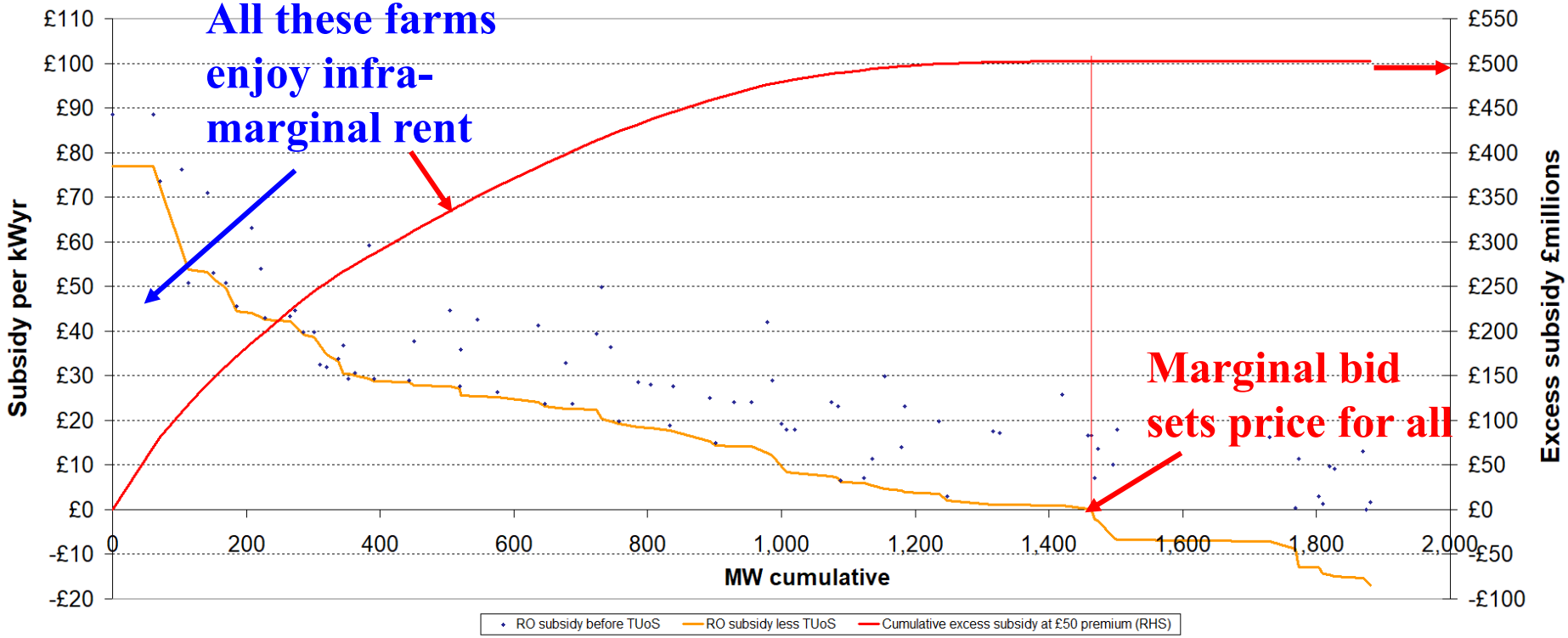
Cumulative excess subsidy from a time-based contract

Subsidy calculated from rolling capacity factors
Auction clears at 25% CF and £50/MWh subsidy for 15yr contract



Reforming VRE support

- Aim: minimise cost of finance while ensuring market responsiveness
- VRE contract should
  - Hedge long-term risks
  - Signal **least system-cost** location for each technology
  - Provide short-term operating signals (congestion, curtailment, flexibility)
  - Minimise infra-marginal rent to favoured locations
  - Maximise competition => **auction** sets single country-wide strike price
- Pay for **capacity** not output for efficient technology choice
  - ⇒ Costs are up-front, running costs independent of market prices

⇒ **Efficient** grid charges guide **location**

⇒ Long-term efficient nodal TNUoS (transmission) charges

- ⇒ 20 yr fixed charge updated for each new contract with new system information
- ⇒ Provides **future cost certainty** before VRE bids in **auction**

An efficient yardstick contract

Assume

- right price for CO_2 (2022 £80 or €90/tonne, now €70/tonne)
- Spot market workably competitive
- Transmission charges are correct spatially (or nodal pricing)

- Efficient dispatch *and* risk-sharing requires CfD for amount ***independent of output***

$\Rightarrow$ Yardstick CfD: strike price s, spot price p_{rh} (in hr h, region r) ***forecast*** capacity factor θ_{rh}, pays $(s - p_{rh})\theta_{rh}K$

Proposition An auctioned yardstick CfD (for the strike price) for a fixed number of full operating hours (MWh/MW) encourages efficient dispatch at least cost

Problems of nuclear power

- Nuclear is large scale, hard to replicate rapidly, long construction period with history of construction cost over-runs (time, budget)
- No examples of private finance for new nuclear in liberalised electricity markets without long-term contracts
  - Auctions for operation deliver cheap finance ***after*** construction risk removed (for offshore wind transmission to shore)
  - CfD (Hinkley Point C) was a costly way of financing construction
- The default model is state ownership bearing all risk
  - Cost of finance to state low, carbon commitment high

Questions to address

- What is the right discount rate?
  - Depends on who bears risk: society or a company
- Who should bear the risks?
  - Of construction, operation, climate risk
- What institution gives the right balance of incentive, risk-bearing and reward
  - State-ownership
  - RAB financing of construction, private management
    - With cost sharing above and below target cost
  - Private financing of whole project
    - With state guarantees against political and catastrophe risk?

What is the right discount rate?

- Social discount rate r from Stern Report derived from social welfare

  $W = \Sigma_t N_t U(c_t) e^{-\delta t}$, N = pop, δ = pure time preference

  $U(c_t)$ utility of c_t, Stern: $U(c_t) = (c_t^{1-\eta})/(1-\eta)$

  $r = \eta g + \delta$, g = growth rate of c_t

- η requires intergenerational equity judgements

  Strong case for $\eta=1$ (otherwise poorer lives are worth less than richer lives) => $U(c_t) = \log c_t$

- Stern takes g = 1.3%, δ = 0.1% (extinction risk)

  $r = g + \delta$ = 1.4%

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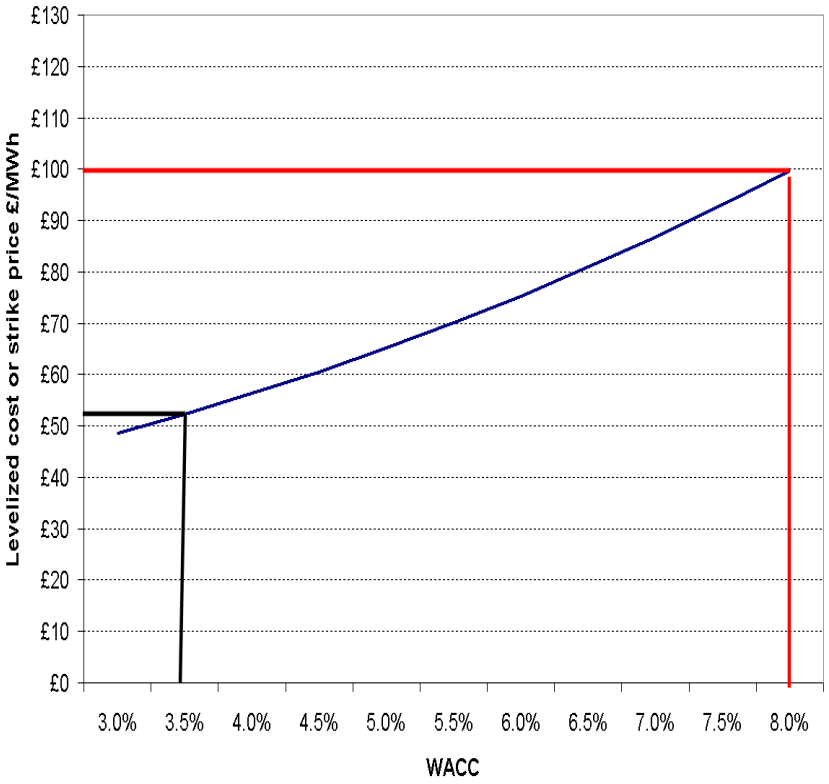
Financing nuclear with regulated revenue is *much* cheaper

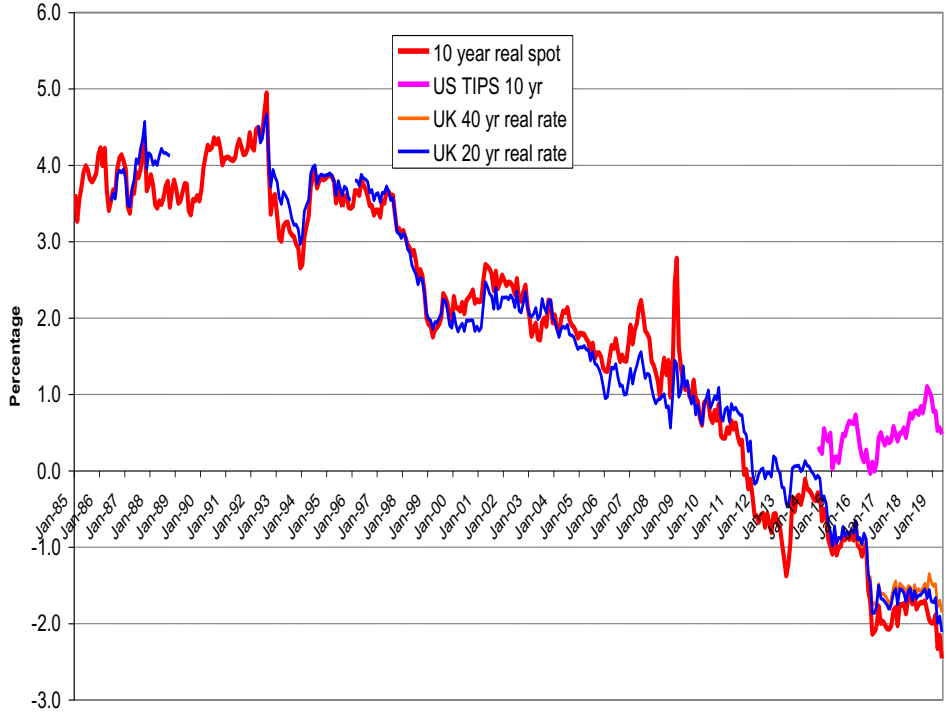
Nuclear : time to recover cost >> willingness to lend without guarantee

Cost of finance falling and **very low**

A commercial rather than regulated WACC almost doubles the cost



Real interest rates for UK indexed gilts and US TIPS



Conclusions

- The low-carbon transition throws up new risks

⇒ Requires suitable contracts designed to address risks

  - Provide incentives for right investment, location and operation

- Fossil CfDs are purely financial => efficient dispatch
  - Enjoy natural hedge with fuel prices that set market price
  - But future price risks of high VRE => capacity/RO auctions?
- Non-fossil generation lacks fuel price hedge
- VRE contracts – make them financial and limit rent
  - Yardstick CfD on reference output for limited hours not time
- Nuclear power – state or regulatory (RAB) finance

=> **Hybrid markets for new investment**:

  – competition **for** the market (auction LT contracts)

  – then competition **in** the market to set price

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References

- *BEIS Review of Electricity Market Arrangements: Consultation Document,* https://www.gov.uk/government/consultations/review-of-electricity-market-arrangements
- Kröger. M. and D. Newbery, 2024. Renewable electricity contracts: lessons from European experience, *Papales de Energiá*, 24, https://www.funcas.es/revista/papeles-de-energia-24/
- Newbery, D., 2021. Designing efficient Renewable Electricity Support Schemes, at https://www.eprg.group.cam.ac.uk/eprg-working-paper-2107/
- Newbery, D., 2021. The cost of finance and the cost of carbon: a case study of Britain's only PWR. *Economics of Energy & Environmental Policy*, 10 (2), 229-247. https://doi.org/10.5547/2160-5890.10.2.dnew
- Newbery, D.M., 2016. Towards a green energy economy? The EU Energy Union's transition to a low-carbon zero subsidy electricity system - lessons from the UK's Electricity Market Reform, *Applied Energy*, 179, 1321–1330. http://dx.doi.org/10.1016/j.apenergy.2016.01.046
- Newbery, D.M. 2016. Missing Money and Missing Markets: Reliability, Capacity Auctions and Interconnectors, *Energy Policy*, 94, 401–410. http://dx.doi.org/10.1016/j.enpol.2015.10.028

Acronyms

CCGT	Combined cycle gas turbine
CCS;	Carbon capture and storage
CfD:	Contract for Difference
FiT	Feed-in Tariff (paid on metered injection)
FTR:	Financial Transmission Right
IPP	Independent Power Produce
LMP:	Locational marginal (nodal) price
LoLP	Loss of Load Probability
PPA	Power Purchase Agreement
RAB:	Regulatory Asset Base (the value on which the regulated return is paid)
RO(C):	Renewable obligation (certificate) or Reliability Option (in capacity auction)
SMC	System marginal cost – MC of most expensive plant
TNUoS	Transmission Network Use of System
VRE:	variable renewable electricity
WACC:	weighted average cost of capitalTNUoS Transmission Network Use of System
VoLL	Value of Lost Load
VRE:	variable renewable electricity
WACC:	weighted average cost of capital