Designing an electricity wholesale market for significant renewables penetration: Adapting the EU model for the UK

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Outline

• European Union commitments to decarbonize
  • A high RES scenario is becoming realistic
    – Falling cost of RES, storage still costly,
    – need to retain options on nuclear, CCS, …
    – improvements in interconnectors – flexibility
  • Need to modify market design and regulation
    – six principles of good market and regulatory design
    • securing flexible plant: capacity auctions
    • auctions for renewables
      – need new auction designs for both

Principles for market/policy design

① Correct market failures close to source
② Allow cross-country variation, not one-size-fits-all
③ Let prices reflect the value of all electricity services
④ Collect regulatory revenue shortfalls with least distortion
⑤ De-risk financing of low-carbon investment
⑥ Retain flexibility to respond to new information

MSs have different resource/institutional constraints

The Electricity Trilemma

• Security of supply trumps other goals
  – Disconnections: high visibility impacts on everyone
• Affordability: a problem of short-run perception
  – Govt: won’t raise taxes but happy to impose charges
• Sustainability: Investment must be low-C
  – Renewables (RES), nuclear and/or CCS
  – Each create challenges for financing and balancing

Can the liberalised electricity market deliver?
Problems of missing markets & missing money
Charging for electricity

• **Networks** are regulated natural monopolies
  – low variable costs, high fixed costs, massive economies of scale
  ⇒ marginal cost below average cost
  ⇒ efficient pricing at marginal cost **fails to recover full costs**
  ⇒ challenge: efficient price signals *and* recover residual
  ⇒ Public finance theory: balance efficiency vs equity
• Low carbon **generation** has similar cost characteristics
  – Low variable costs, high capital/fixed cost
  ⇒ challenge is to develop efficient wholesale/retail prices
  – But not normally a regulated asset
  ⇒ long-term contracts?

*How to charge final consumers?*

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Electricity characteristics

• Electricity characteristics and **cost drivers:**
  – capacity (MW): max demand on links & generation
  – energy (MWh): nodal for each time period: fuel + C
  – quality (frequency, voltage etc.): nodal each second
• Pay networks for **access option** to take capacity
  – Drives investment in T & D
    • Some depends on system peak, some on local max. demand
  – regulated – so need careful design
• QoS bundled with access, energy, capacity
  • paid by final consumers to suppliers of service
  • Procured by System Operator (markets, auctions, …)

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Paying for energy & capacity

• Pay for **energy** at efficient cost of *supply*
  – System marginal cost, SMC
    • variable cost of the most expensive in-merit generator
• Value/cost varies over time and space
  ⇒ locational marginal price varying every 5 mins(?)
    • the US Standard Market Design
• Pay for **capacity** = value of meeting demand
  – Loss of Load Probability x (Value of Lost Load - SMC)
• full price = (1-LoLP)*SMC + LoLP*VoLL
  • reflects probabilities of supply or lack of supply

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Ancillary services for QoS

*Faster* more flexible responses needed with high renewables

*Synchronous inertia* – supplied by fossil generators, not by wind and PV

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**Figure 1:** Frequency Control Services (Source: EirGrid)
Decarbonising power

- **Power sector** key to decarbonising economy
  - Large, easiest, and capital highly durable
- Coal-fired electricity has more than twice the GHG emissions of gas and far higher air pollutants
  - Gas as transition fuel to the low carbon future
  - But there is lots of coal => CCS a long-run priority
- Deployment has dramatically lowered cost of wind, PV
  - Justifies support for R&D and deployment
- Large RES depresses prices, needs flexible reserves
  - Hard to invest in flexible plant in policy-driven market
  - Capacity auctions and new flexibility products
  - Increases case for interconnections paid for security
  - Need better contracts for RES and capacity adequacy

Nuclear power can cut emissions – but we have forgotten how to do it at reasonable cost

**CO2 emissions per kWh 1971-2000**

- **USA**, **Italy**, **UK**, **Europe**, **France**

- **Dash for gas cut UK by 33%**
- **Down 80% 10 years**

- **Premature nuclear retirement makes no economic sense**

- Variable costs of nuclear << average cost
  - But not negligible
  - Low gas prices/ high RES lower wholesale prices
  - Nuclear plants retiring early in US, phase-out in EU
- EU lacks an adequate carbon price
  - Social cost of CO₂ > €40/tonne?
  - At €25/tonne => raises CCGT cost €12/MWh
    - And € 23/MWh if coal at the margin
- But zero-carbon nuclear not adequately supported
  - Unlike renewables

**UK’s Carbon Price Floor - in Budget of 3/11**

- **EUA price second period and CPF £(2012)/tonne**
- **Corrective tax**
- **Budget 2014**
- **To £70/t by 2030**

**Source:** EEX and DECC Consultation
Gas displaces coal at high CO₂ price and low gas price

Coal displaced by RES & gas: carbon price floor working

UK coal policy

• UK adopted a carbon price floor
  – ETS demonstrably unfit for purpose
  – Combined with an emissions performance standard
    • Impossible to meet at baseload on coal, possible on CCGT
• UK Govt: all coal to cease by 2025
  – eligible for annual capacity auction to provide low cost winter peaking capacity (and CO₂ already priced)
• Given COP21 and plans to reform ETS surely no sane utility plans new coal in EU

Revised RES Directive

Revised RES Directive
16. “When designing support schemes and when allocating support, Member States should seek to minimise the overall system cost of deployment, taking full account of grid and system development needs, the resulting energy mix, and the long term potential of technologies.”
26. “…(allow) Member States to count energy from renewable sources consumed in other Member States towards their own”

• Art 3 proposes Union funds (financial instruments) to reduce cost of capital for RES projects; mandatory move towards investment aid
• Art 4: ensure RES responds to market price signals and support is granted in an open, transparent, competitive, non-discriminatory and cost-effective manner
• Art 6: Increase investor confidence: no retroactive changes
Learning justifies support but is on cumulative shipping not RES output.

German wholesale prices fall 50% in 5 yrs, 40% of which due to RES.

Solar PV cost fall 20% for each doubling of cumulative shipments.

Nuclear phase-out exactly offsets RES.

On-shore wind: taller towers give higher capacity factors.

Cumulative investment $647 billion.

Learning rate 7%.

Rapid increase in EU renewable electricity to 29% in 2015.

Dramatic fall in solar PV prices.


Source: IRENA (2016)

Source: Eurostat
UK RES catching up rapidly

Cumulative increment in share of RES in generation from 2004
Countries exceeding EU-28 increment

Reforming RES-E support

• Learning spill-overs need remuneration
  – Almost entirely from making and installing equipment
  ⇒ Contract €X/MWh for (e.g.) 30,000 MWh/MW, auction determines premium €X

Reasons:
• Subsidy targeted on source of learning = investment aid
  – Reduces cost of capital and risk via debt finance
  – Ideally associated with CO₂ credit per MWh
• Could expose RES to current locational spot price
  ⇒ incentivizes efficient location, connection
• Does not amplify benefits of high wind/sun
  – Not over-reward favoured locations with same learning
• Auction better than bureaucrats at minimizing cost

Quantifying the spill-over benefit

RES CfD 2015 auction results

Foolish bid - withdrew
UK Off-shore wind auction prices

Location choices under LMP and spot pricing for wind

With ROCs wind farm inefficiently locates at N

Pay wind for availability + average spot price => efficient E

Supporting flexible back-up

• Ambitious RES targets need flexible back-up
  – Normally comes from old high-cost plant = coal
    • EU Large Combustion Plant Directive 2016 limits coal
    • Integrated Emissions Directive further threat to coal
    • GB Carbon price floor + hostility to coal => close old coal
  – high (pre-2015) EU gas prices and low load factors
    • gas unprofitable, new coal prohibited by GB EPS
• Future prices now depend on uncertain policies
  – on carbon price, renewables volumes, other supports
  – on policy choices in UK, EU, COP21, …

Without a contract new flexible back-up too risky?

⇒ Auctions for capacity
  ⇒ Better still for Reliability Options

Reliability Options to replace Capacity agreements

• RO sets strike price, s (e.g. at €500/MWh)
• Market price p reflects scarcity (Voll x LoLP)
  – SO sets floor price to reflect spot conditions
  – Wholesale price signals efficient international trade
• RO auctioned for annual payment P
  – 7-10 yrs for new, 1 yr for existing capacity
• Gen pays back wholesale price p
  – less strike price if available (p – s)
  – G chooses whether to be paid p or s + P
• Suppliers hedged at strike price s for premium P

Trade over interconnectors efficient
No need to pay foreign generators
GB 2014 Capacity Auction

- Net CONE – predicted entry price £49
- Auction clearing price £19.40/kW

New build 2014 T-4 auction

- Cleared at £19.40/kWyr
- Average Size 11 MW

T-4 by technology Dec 2016 for 2020/21

- Of which 500 MW battery storage derated as pumped storage!

Flaws in GB Capacity Procurement

- Transmission-connected generation TG pays full G TNUoS
- Distribution-connected generation DG receives L TNUoS
  - But avoided cost at most the transmission demand residual
  - = extra money to pay full cost less efficient charge of transmission
  - \( \Rightarrow \) represents extra £50/kWyr embedded benefit in 2018/19
  - \( \Rightarrow \) Auction cleared at £20/kWyr
  - \( \Rightarrow \) DG gets £70/kWyr and TG gets £20/kWyr
  - \( \Rightarrow \) Large number of small (10 MW) diesel and reciprocating engines win capacity contracts on distribution network

Over-encourages entry of costly subscale plant
Conclusions

- Support for RES needs change
  - recognise learning benefits by capacity support, CO₂ per MWh
  - needs better location and dispatch price signals => markets
  - market responsive requires auctions and good network tariffs
- Efficiently pricing externalities and system impact key for efficient entry and exit decisions
- Tariffs and market design need reform to guide decisions
  - network tariffs to avoid distorting embedded benefits
  - reliability options better than capacity auctions for market
- Consumers can help if they make efficient decisions
  - need to face efficient tariffs for networks – largely fixed charges
  - and efficient electricity prices => lower off-peak; higher peak
  - then can decide on PV, batteries, Electric Vehicles, etc.

Efficient tariffs

- Distinguish efficient price and short-fall in required revenue
  - Efficient peak T price is marginal expansion cost
  - At best 30% average cost, less if demand falling
- Ramsey-Boiteux pricing => “tax” inelastic demand
  => equi-proportional reductions in all types of demand
    - incl. option to take up to NkW
- Diamond-Mirrlees: tax only final consumers
  => T&D revenue shortfall on final consumption not net demand (at network connection)
  => reduces embedded G benefit from £60 to < £10/kWyr
  => Regulators need to compute efficient T&D tariffs
  => and move faster. Auction in 1 day grants 15-yr contract

Acronyms

- CfD Contract for Difference
- CONE Cost of New Entry
- CP Capacity payment
- DG Distribution-connected Generation
- DN Distribution Network
- G, L Generation, Load
- LMP Locational Marginal Pricing (Nodal pricing)
- LoLP Loss of Load probability
- LoLE Loss of load expectation in hrs/yr = reliability standard
- QoS Quality of service
- RES Renewable energy/electricity supply
- RO Reliability option
- ROC Renewable Obligation (i.e. green) Certificate
- SMC/P System Marginal Cost/Price
- T&D Transmission and Distribution
- TDR Transmission demand residual
- TG Transmission-connected generation
- TNUs Transmission Network Use of System, G =Generation, L=Load
- VOLL Value of Lost Load