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# Evolving Business Models for Utilities: Key Principles and Emerging Tendencies

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**THE FUTURE OF UTILITIES**

**Paris-Dauphine**

27th September 2017

# Messages

- The 4-D future:
  - Decarbonization – have cost falls shaken the Trilemma?
  - Digitilization – smart everything?
  - Decentralization – on generation and demand response
  - Disruption – does this mean the death of utilities?
- **Efficient market procurement and good pricing principles critical to managing transition**
  - transitions take a long time but anticipation lowers cost
- Good news: groping towards sensible solutions
  - But many business models depend on distorted tariffs

# Recent developments

- GB's RES auction procured off-shore wind at £74.75 (2021/2) & **£57.50/MWh** (2022/3)
  - Was £140, then £120, Govt challenged to sub-£100/MWh
  - less than GB nuclear (£92.5/MWh post 2024)
- Bloomberg NEO 2017 projects:
  - wind & solar 34% elec output world-wide by 2040
  - Europe 50% output from intermittent RES by 2040
    - world PV increases **x 14** by 2040, LCOE falls 66%,
    - world wind x 4 by 2040, onshore LCOE falls 47%, off-shore 71%
- Battery costs continue to fall, EVs improve
  - but decarbonizing heat proving very challenging
  - electric heat pumps massively increase peak electric demand

# Agenda

- European Union **commitments to decarbonize**
- A high RES scenario is becoming realistic
  - Falling cost of RES, storage still costly, some PSP?
  - need to retain options on nuclear, CCS, …
  - improvements in interconnectors – **flexibility**
- Need to **modify** market design and regulation

  => six principles of good market & tariff design
- Implications: generation/retailing businesses:
  - flexible plant: **how to justify needed investment?**
  - aggregators of flexibility services? Price caps?
- Implications for network business models
  - **To avoid the death spiral from DG, change tariffs!**

# Principles for market and tariff 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 revenue shortfalls with **least distortion**

⑤ **De-risk financing** of low-carbon investment

⑥ Retain **flexibility** to respond to new information

***Regulators need to be more agile***

# Charging for electricity

- **Networks** are regulated natural monopolies
  - low variable costs, high fixed costs, cheaper to have single network
  - => 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 balances efficiency vs equity

⇒ Networks as quasi public goods, charge ∝ WTP?

- Low carbon **generation** has similar cost characteristics
  - Low variable costs, high capital/fixed cost

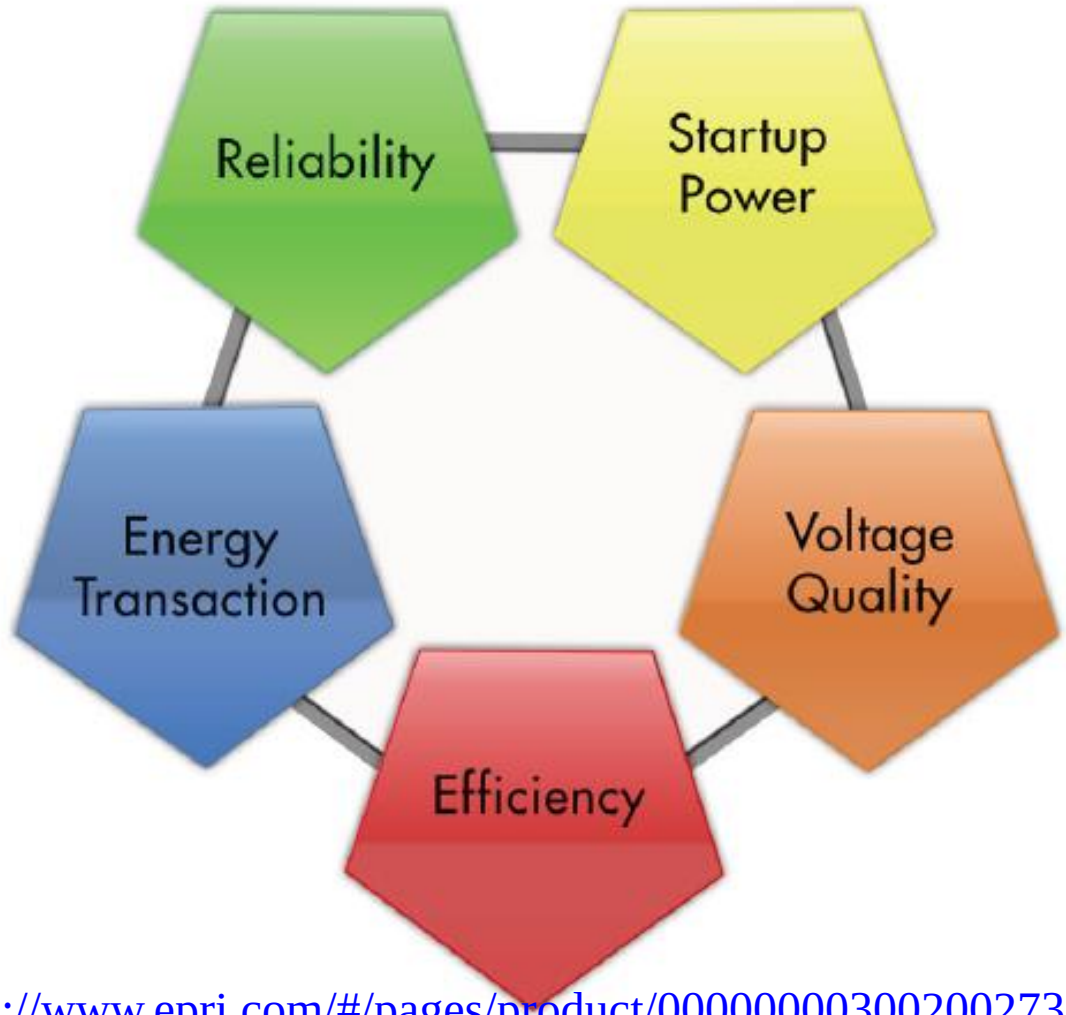
=> challenge is to develop efficient wholesale/retail prices

- But not normally a regulated asset

⇒ long-term contracts?

***How to charge final consumers?***

# Benefits of grid connectivity for DG




https://www.epri.com/#/pages/product/000000003002002733/

# Electricity characteristics

- Electricity characteristics and cost drivers:
  - **capacity (MW)**: max demand on links to Load
  - **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, …)

# Paying for energy & capacity

- Pay for **energy** at efficient price
  - 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**
  - 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**

# Ancillary services for QoS

***Faster*** more flexible responses needed with high renewables

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

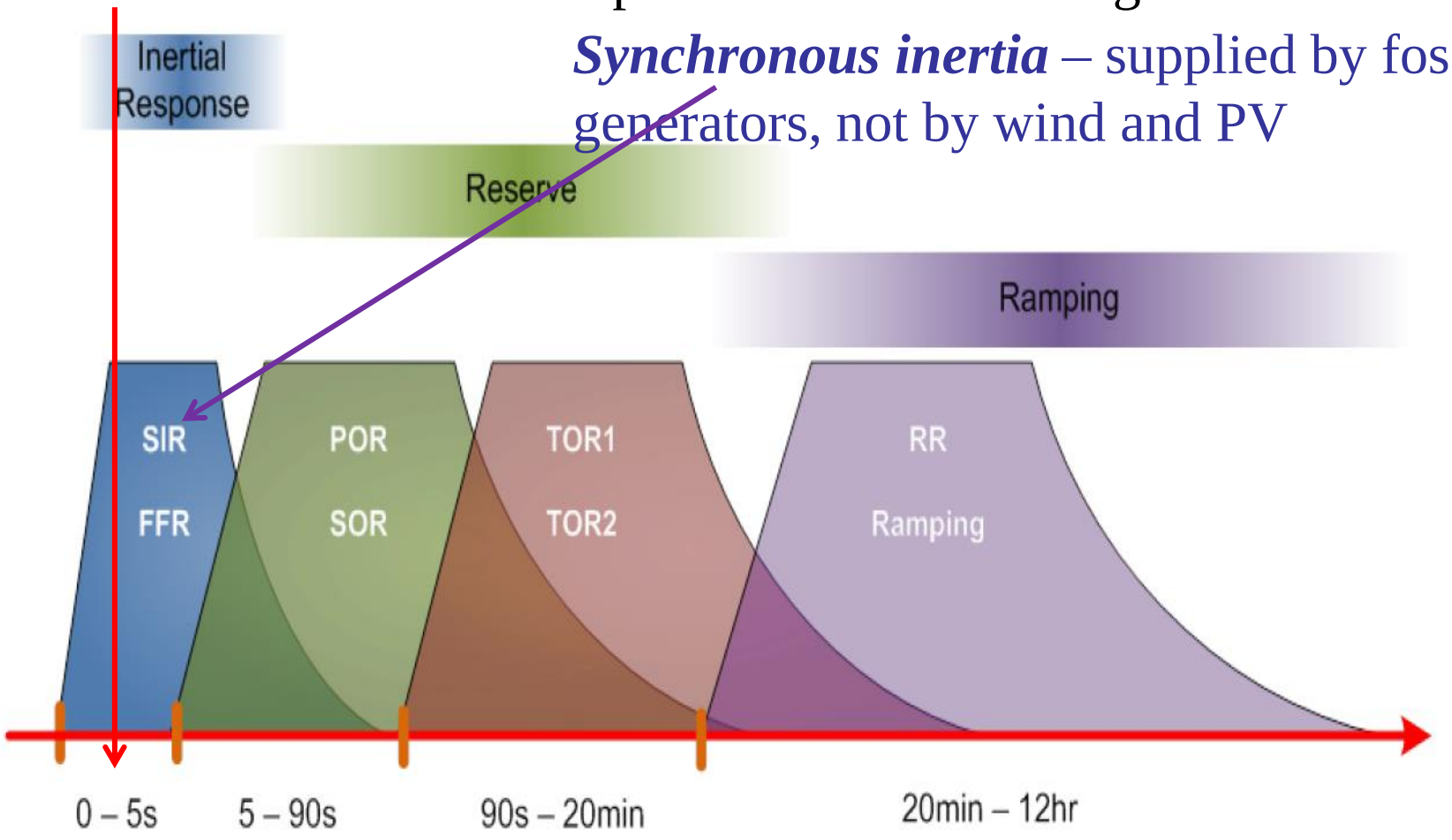


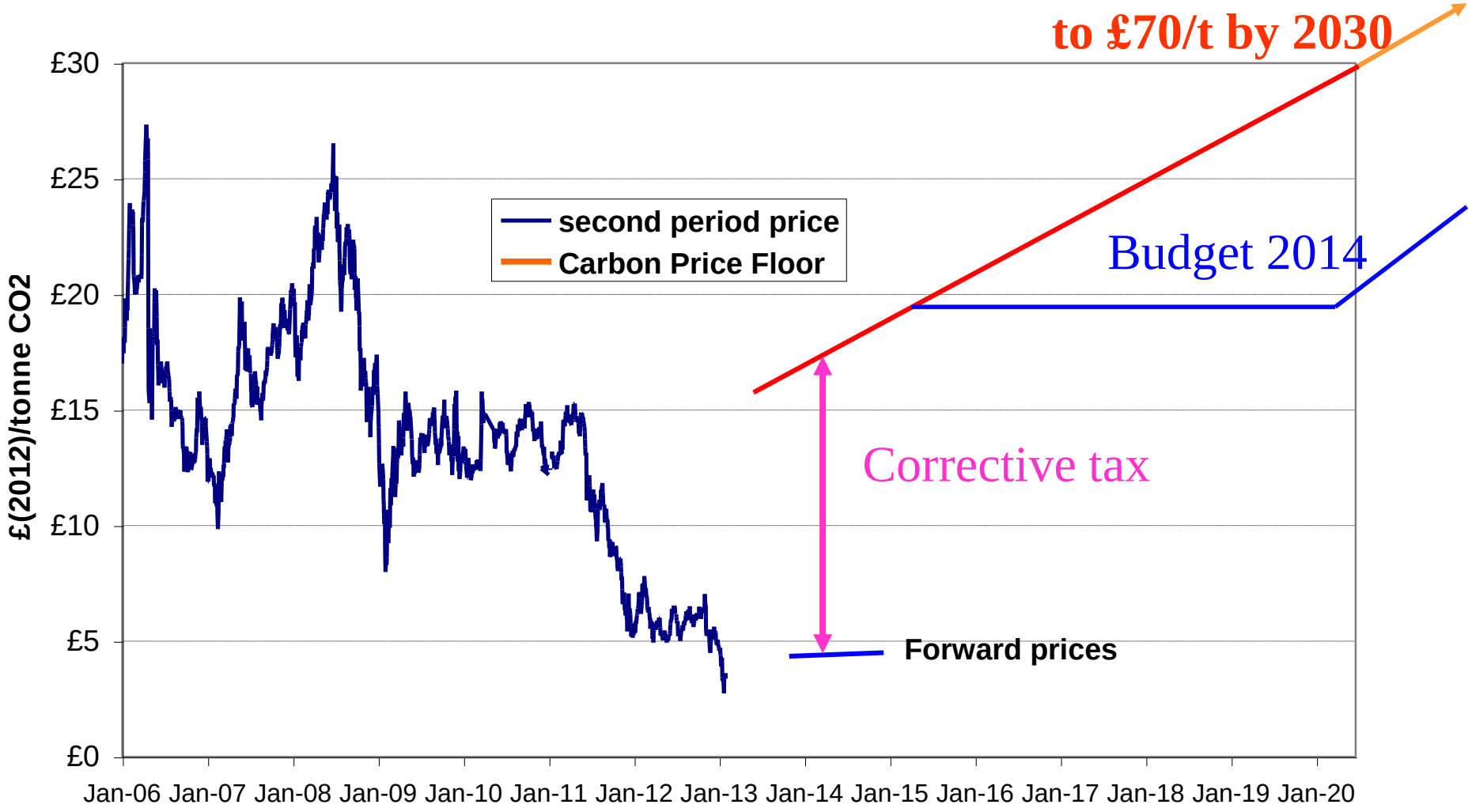

Figure 1: Frequency Control Services (Source: EirGrid)

# Criteria for market design

- Least **system** cost to meet reliability and $CO_2$ targets
  - Coordinate generation, transmission, distribution
  - Generation: timely delivery at right place, size, technology
  - Transmission: built, sized and used for efficient dispatch
  - **$CO_2$ underpriced by ETS, needs carbon price floor**
  - ***Challenging with unbundled liberalised structures***
- Liberalized markets need good price signals
  - ***Many of which are regulated (transmission, distribution)***
- Benchmark efficient spot prices
  - Wholesale price = **SMC + CP** at each node (**LMP**)
  - **CP = LoLP*(VoLL – SMC); ∑LoLP=LoLE**
  - Ancillary service prices to incentivise efficient quality
- Location signals: long-term financial contract on LMP
- **Revenue shortfalls: Ramsey pricing on final consumer**
- **Targeted subsidies, efficient risk sharing**

# UK's Carbon Price Floor - in Budget of 3/11

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






*Source: EEX and DECC Consultation*

# Correcting the $CO_2$ price

- ETS $CO_2$ price is neither adequate, durable nor credible
  - Reforms to date had no impact
- setting the right $CO_2$ price is difficult
  - social cost of future harm hard to estimate
  - break-even price highly sensitive to price of fossil fuel
- Ideally fossil generation should pay corrective tax
  - GB has ***carbon price support-*** brings EUA price up to "right" level
- If not use emissions performance standards (EPS)?
- Or, zero-C subsidy = shortfall in efficient wholesale price
  - perhaps €10/MWh

***Auctioned capacity subsidy simpler for RES***

***Needed for existing nuclear plants to prevent exit***

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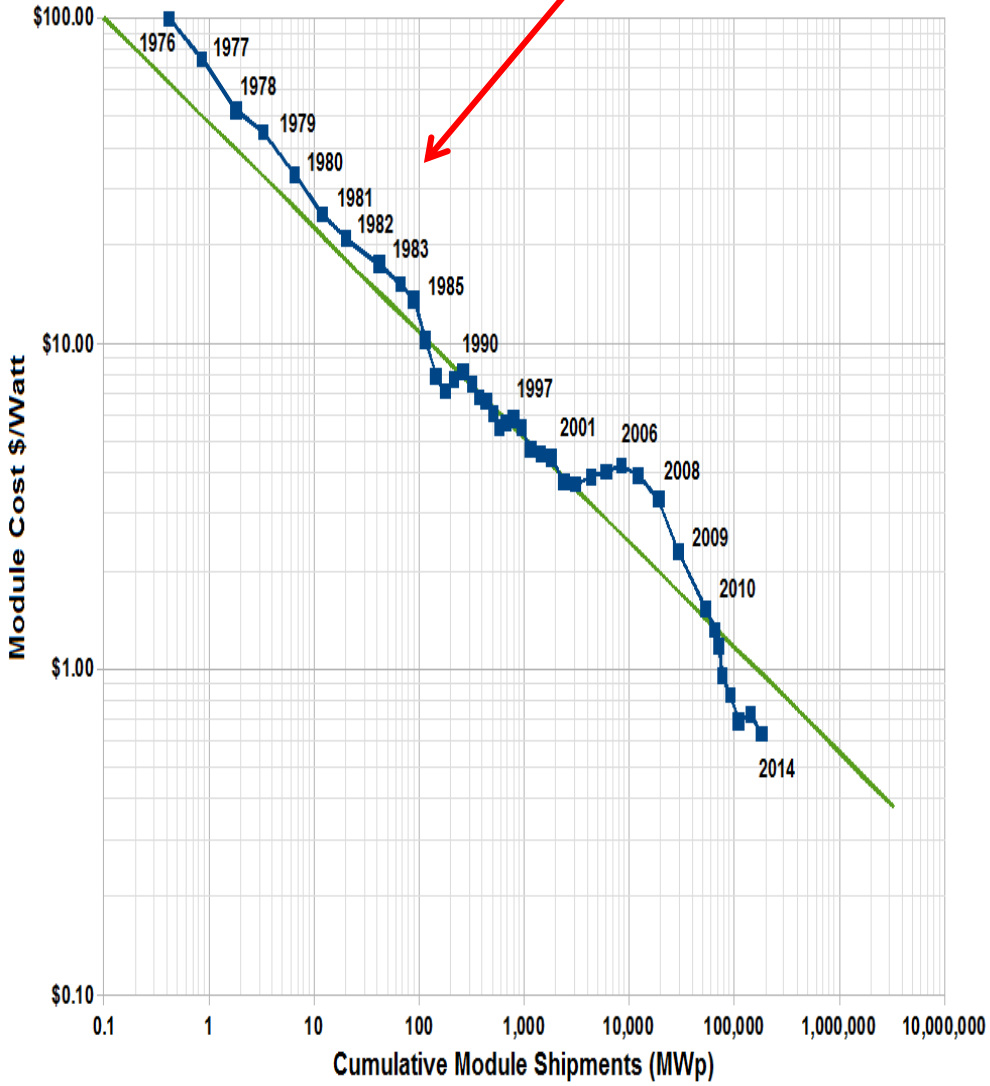
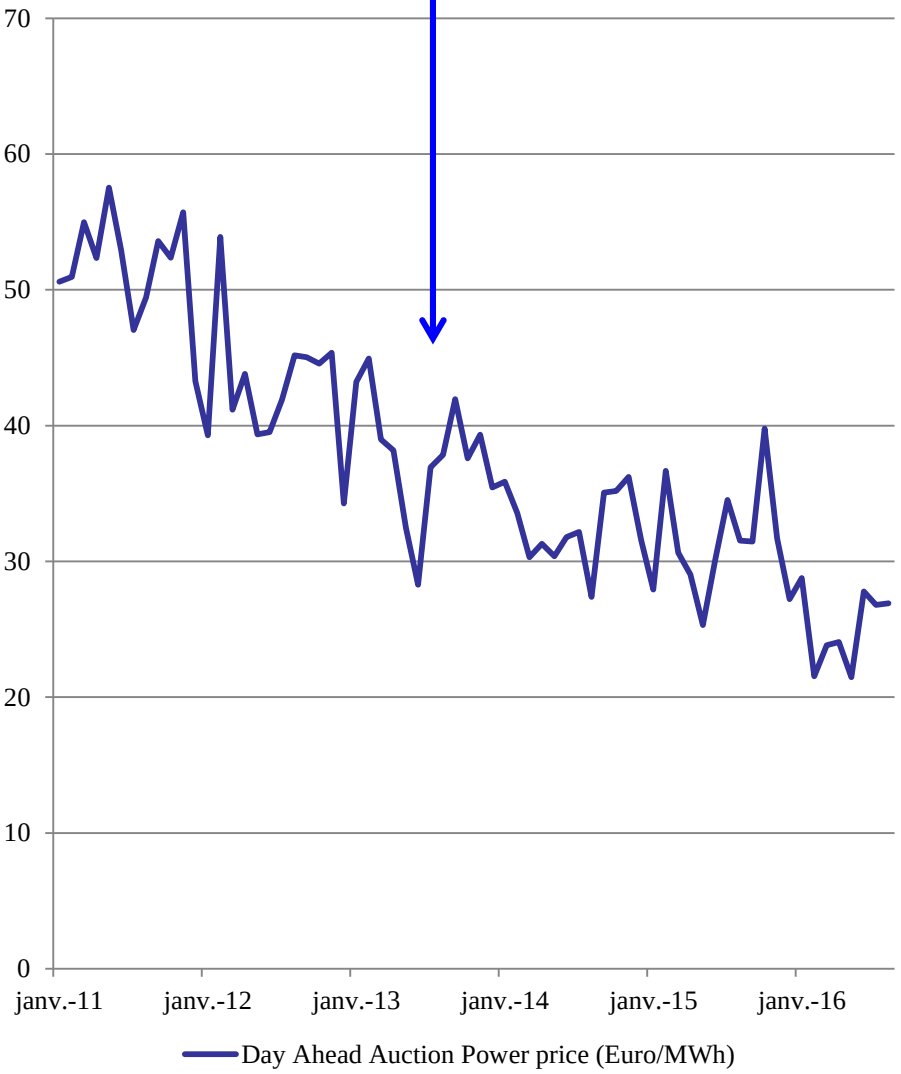
# Solar PV cost fall 20% as capacity x2

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



# Post 2020 RES-E support

- Learning spill-overs need remuneration
  - Almost entirely from making and installing equipment

⇒ Contract ***€X***/MWh for ***N*** MWh/MW, Auction determines ***X***

Reasons:

- Subsidy targeted on source of learning = ***investment aid***
  - Reduces cost of capital and risk via debt finance
  - Addresses failure to set right $CO_2$ price
- Exposes 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

# RES CfD 2015 auction results

Compare 22/23 £74.75

| Technology | | admin price | lowest clearing price | 2015/16 | 2016/17 | 2017/18 | 2018/19 | Total Capacity (MW) |
|---|---|---|---|---|---|---|---|---|
| Advanced Conversion | £/MWh | £140 | £114.39 | | | £119.89 | £114.39 | |
| Technologies | MW | | | | | 36 | 26 | 62 |
| Energy from Waste with | £/MWh | £80 | £80 | | | | £80.00 | |
| Combined Heat and Power | MW | | | | | | 94.75 | 94.75 |
| Offshore wind | £/MWh | £140 | £114.39 | | | £119.89 | £114.39 | |
| | MW | | | | | 714 | 448 | 1162 |
| Onshore wind | £/MWh | £95 | £79.23 | | £79.23 | £79.99 | £82.50 | |
| | MW | | | | 45 | 77.5 | 626.05 | 748.55 |
| Solar PV | £/MWh | £120 | £50.00 | £50.00 | £79.23 | | | |
| | MW | | | 32.88 | 36.67 | | | 69.55 |

Source: DECC (2015)

Foolish bid - withdrew

# Supporting flexible back-up

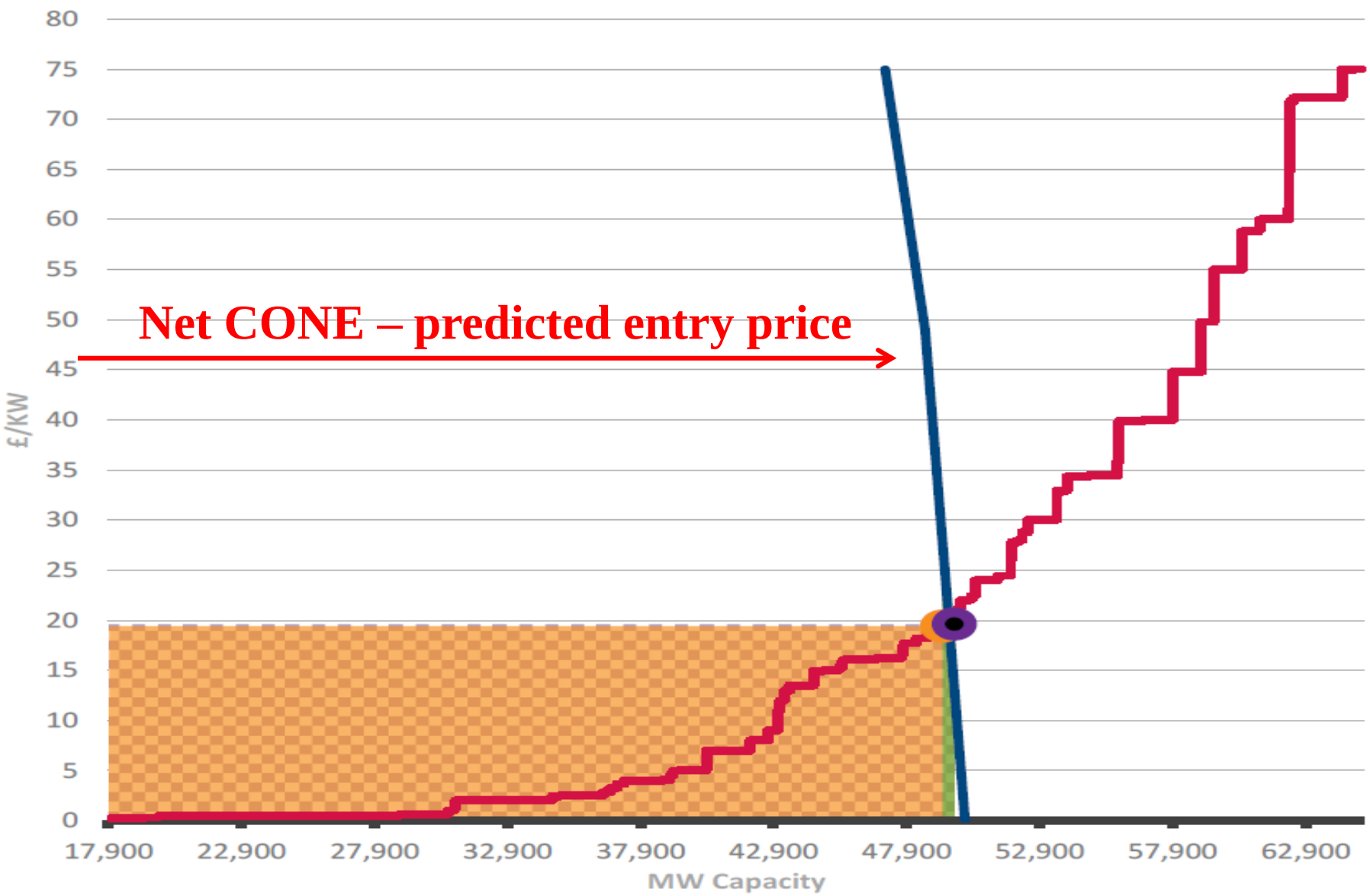
- Ambitious RES targets need flexible back-up
  - Normally comes from old high-cost plant = coal
    - EU Large Combustion Plant Directive 2016 limits coal
    - Integrated Emissions Directive further threat to coal
    - GB Carbon price floor + hostility to coal => close old coal
  - high (pre-2015) 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***

# GB 2014 Capacity Auction



# 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

⇒ represents ***extra*** £50/kWyr embedded benefit in 2018/19

⇒ Auction cleared at £20/kWyr

⇒ DG gets £70/kWyr and TG gets £20/kWyr

⇒ Large number of small (10 MW) diesel and reciprocating engines win capacity contracts on distribution network

***Over-encourages entry of costly subscale plant***

# Efficient network tariffs

- Distinguish efficient price and resulting 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
- Diamond-Mirrlees: tax only final consumers

⇒ T&D revenue shortfall on final consumption ***not*** net demand (at GSP or premises)

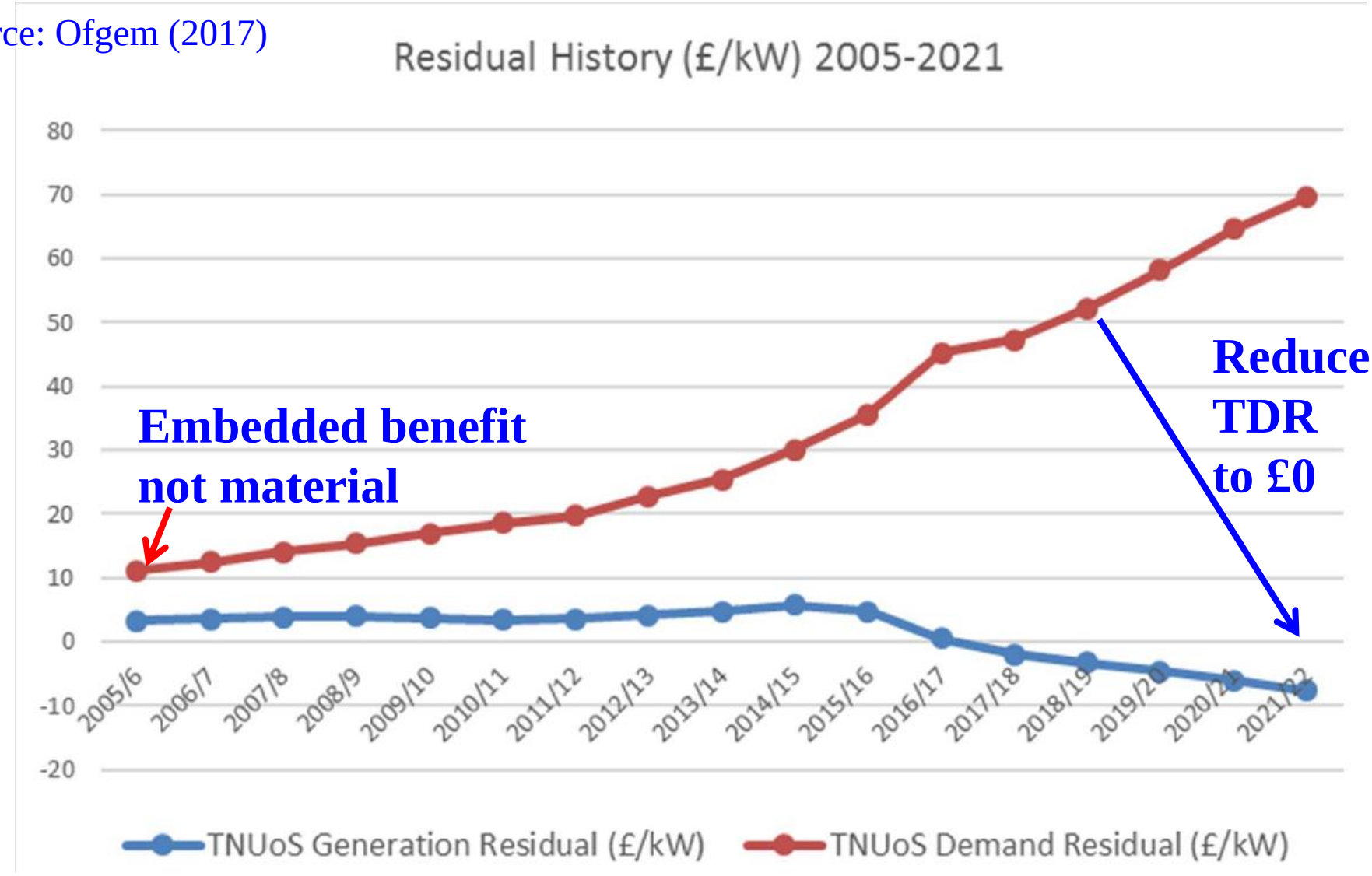
⇒ reduces embedded G benefit from £60 to < £10/kWyr

⇒ **Regulator**s need to compute efficient T&D tariffs

⇒ and move faster. Auction in 1 day grants 15-yr contract

# GB network charges: *residual = extra support to gen on DN*

Source: Ofgem (2017)



# Reliability Options

- 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***

# The case for storage

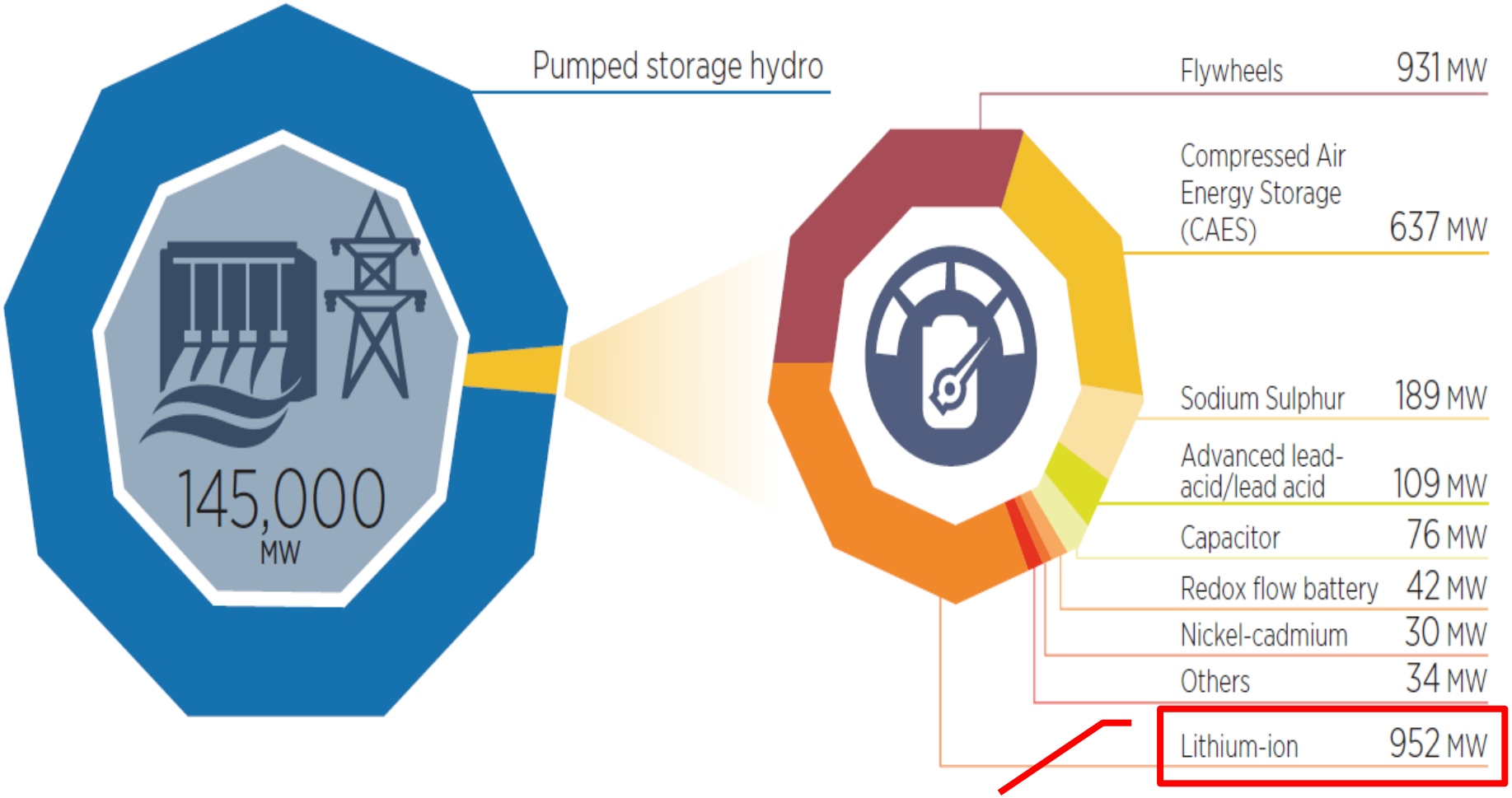
- Increased intermittency – shift supply and/or demand to when/where needed

=> Ancillary services: inertia, fast frequency response, back-up reserves

- Not new: Pumped Storage built to shift nuclear
- Recent developments:
  - Increased wind/solar
  - Reduced battery costs
  - Rise in battery electric vehicles
  - Smart meters and demand side aggregators

**What are the sources of demand/supply shifting?**
**What are their costs?**

# Electric storage vs pumped storage hydro




*Note: Pumped storage data are for 2016; other data are for 2014.*
*Source: IRENA, 2015h; pumped storage data from IHA, 2016*

Less than 1% of PSH

**Source: IRENA (2017)**

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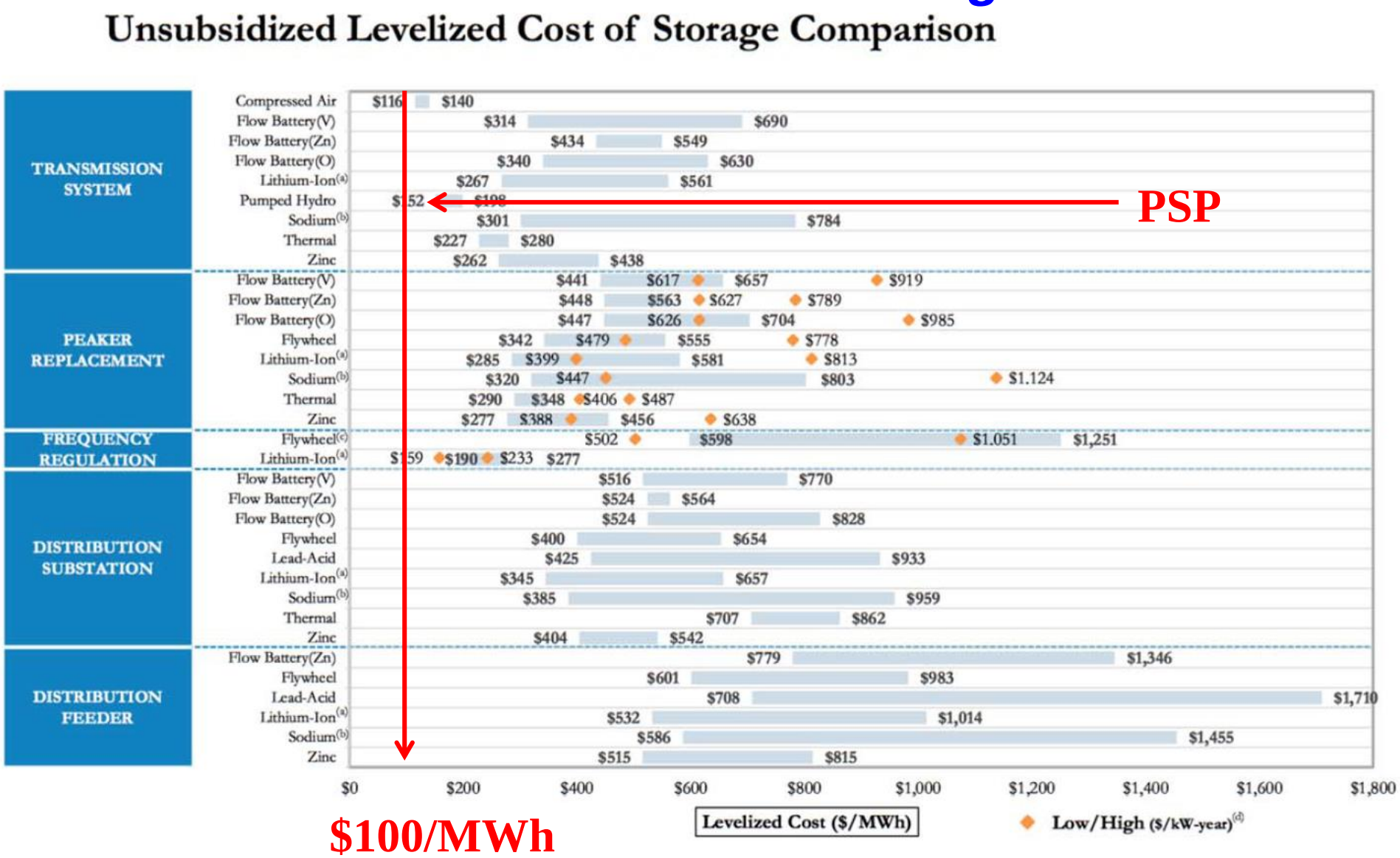
# Lazard's *Levelized Cost of Storage 2.0* $/MWh



# Storage conclusions

- Storage has value but is expensive
  - Can arbitrage prices but flexibility services likely more valuable
- PSP useful, storage hydro far larger

=> **interconnect to Norway**

- Batteries useful for ancillary services
  - And relieving **distribution bottlenecks**
- Supply and demand shifting over time and space cheaper

=> Back-up generation and interconnection usually cheaper than more storage

***The battery revolution has been over-hyped for the ESI***

# Business Models: generators and retailers

- **Generators** face depressed wholesale prices
  - ⇒ **Defer** investment until profitable, prompting
  - ⇒ capacity or reliability option auctions
- **Retailers**: opportunities:
  - – offer innovative use of smart meters?
  - – act as aggregators for flexibility services
- Threats: face price caps?
  - – Resulting from rising levies to finance RES
- damage limitation:
  - –argue for benchmarked cap confined to retailing margin?
  - – or tendering for default supplier?
  - – or accept re-regulation of domestic market?

# Disruptions

- Large RES already cost competitive (**with right C price**)
  - grid scale PV, wind farms, off-shore wind in good sites
  - often connected to distribution network
    - risk invisibility, DNO => DSO communicating with TSO
- household PV ***appears*** attractive
  - because of over-generous subsidies
  - and network costs covered per kWh and/or net metering
- Future pricing/management needs to be far more local
  - constraints appearing on local networks from PV, EV, heat pumps
- ICT will be critical for hassle-free management

***consumer propositions will need careful design***

# Business Models: distribution networks

- Old tariff model mostly per kWh no longer fit
  - particularly with net metering
  - over-encourages distributed generation (PV)
  - strands remaining customers paying for fixed costs
- Need to seek innovative network tariffs
  - e.g. high initial charge /kWh with option to move to lower energy charges and higher capacity charge
    - potentially shift fixed costs to higher consumers
  - tariff on final consumption, DG faces different export and domestic tariff – feasible with smart metering
  - large new loads (PV, EVs, heat pumps) to face TOU access or pay for peak consumption (to cover upgrades)

# The good, the bad and the ugly

- **Good**: Auctions can dramatically reduce costs
- Each jurisdiction is facing similar problems
  - ***and trying out a variety of solutions***
- Learning from elsewhere and experimenting essential
  - ⇒ challenge funds to try new ideas and test regulations
  - ⇒ copy **Ofgem's Network Innovation Competitions**
- **Bad**: Bad tariff design + capacity auctions => rapid bad irreversible decisions
  - need smarter, quicker responses to ensure tariffs are suitable
- **Ugly**: tension between efficient and "fair" pricing can led to inefficient ***and*** inequitable outcomes

# Conclusions

- 4-D decarbonize, digitalize, decentralize, disrupt
  - **EC Clean Energy Directive** identifies **good principles**
    **=> clear guidance for good policy instruments**
  - But need adequate **carbon price support**
- Low-Carbon electricity has high capital, low variable costs
  - pricing needs to adjust, distinguish access, capacity, energy, quality
- Support for RES needs change
  - recognise learning benefits by capacity support, **$CO_2$ per MWh**
  - needs better location and dispatch price signals => markets
  - market responsive requires auctions and good network tariffs
  - **reliability auctions and contracts** avoiding trade distortions between MSs
- Utilities will need different business models
  - ***to address threats and make use of opportunities***

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# Acronyms

| | |
|---|---|
| BOS | Balance of system (cost) |
| BSUoS | Balancing Services Network Use of System ≈ €2-5/MWh |
| CCS | Carbon Capture and Storage |
| CfD | Contract for Difference |
| CONE | Cost of New Entry |
| CP | Capacity payment |
| DG | Distribution-connected Generation |
| EPS | Emissions Performance Standard |
| ETS | Emissions Trading System |
| GHG | Greenhouse gas |
| GSP | Grid Supply Point (connection to grid) |
| 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 |
| MS | Member State |
| R&D | Research and Development |
| RES | Renewable energy/electricity supply |
| RES-E | Renewable energy supply in electricity |
| RO | Reliability option |
| ROC | Renewable Obligation (i.e. green) Certificate |
| SMC/P | System Marginal Cost/Price |
| T&D | Transmission and Distribution |
| TG | Transmission-connected generation |
| TNUoS | Transmission Network Use of System, G =Generation, L=Load |
| VOLL | Value of Lost Load |

# References


- http://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition gives links to the various directives
- Clean Energy For All Europeans, COM/2016/0860 final at http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1481278671064&uri=CELEX:52016DC0860
- Ofgem (2017) Impact Assessment and Decision on industry proposals (CMP264 and CMP265) to change electricity transmission charging arrangements for Embedded Generators at https://www.ofgem.gov.uk/system/files/docs/2017/06/cmp264265.docx.pdf
- Newbery, D., M. Pollitt, R. Ritz, & W. Strielkowski, 2017. Market design for a high-renewables European electricity system, EPRG 1711 at http://www.eprg.group.cam.ac.uk/wp-content/uploads/2017/06/1711-Text.pdf

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# Slides on decarbonizing generation

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# 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

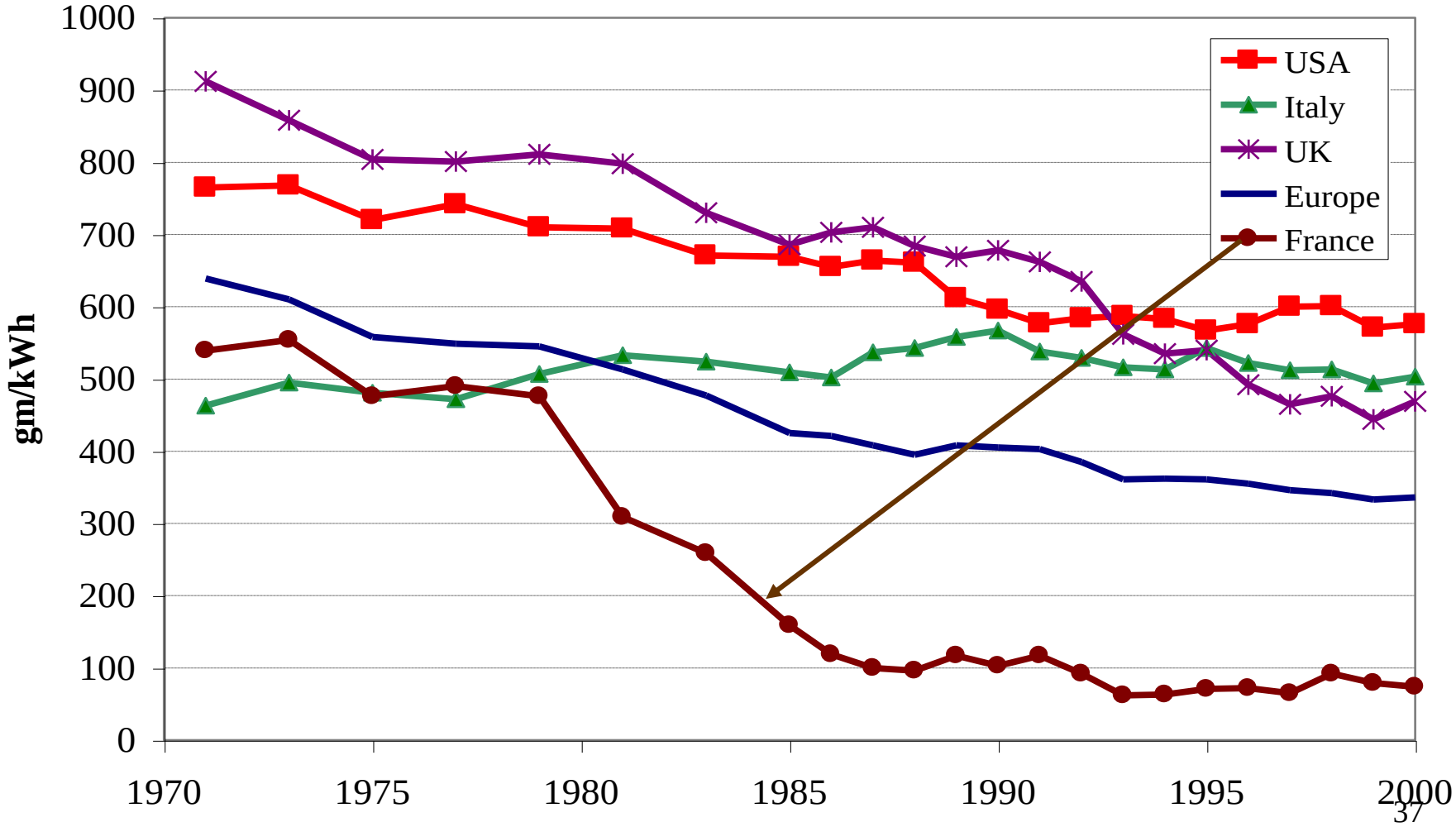
⇒ Increases case for interconnections paid for security

⇒ Need better contracts for RES and capacity adequacy

# Rapid decarbonisation of electricity is possible

## - with nuclear power

**CO2 emissions per kWh 1971-2000**



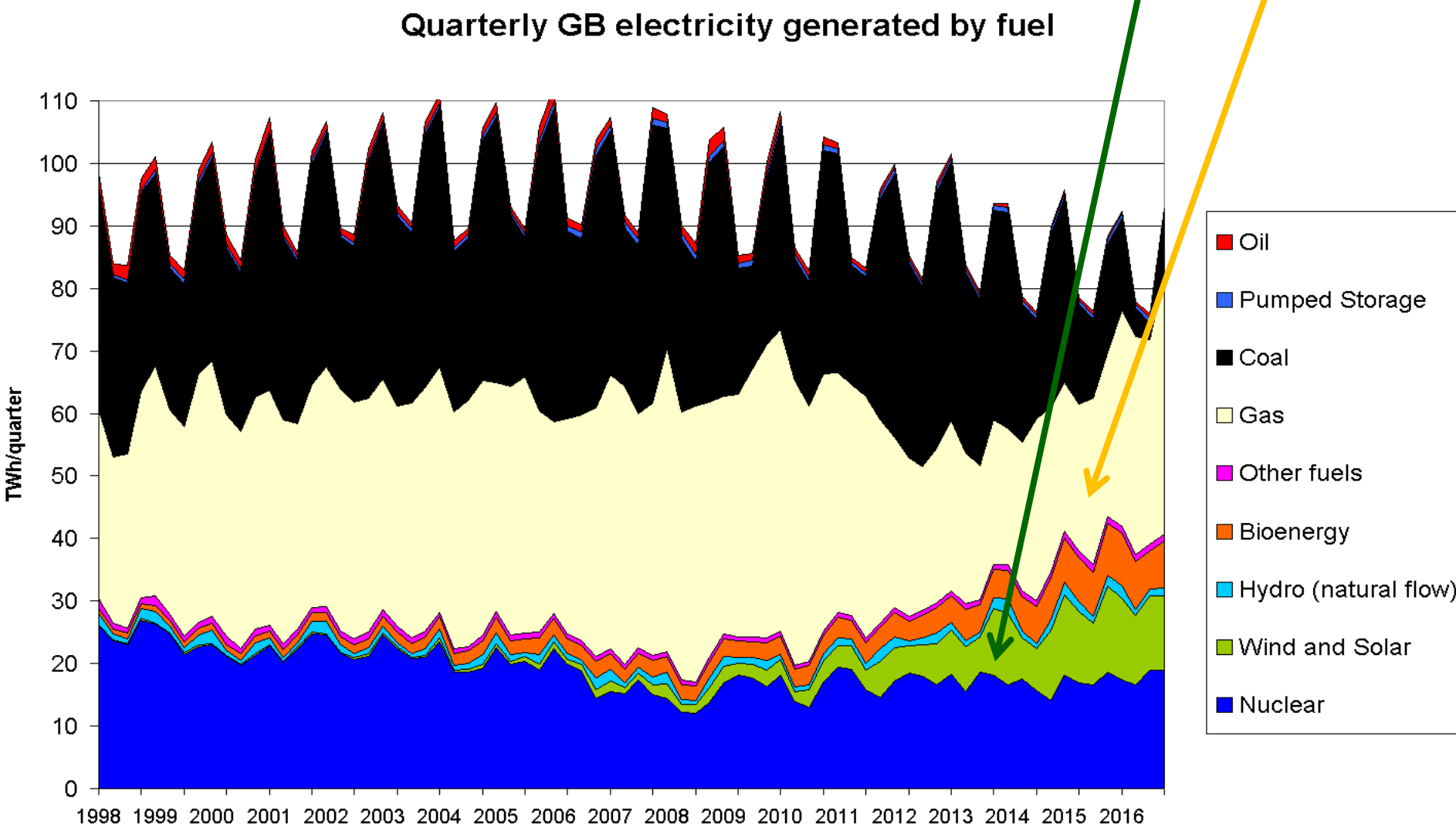
# Premature nuclear retirement makes no economic sense

- Variable costs of nuclear << average cost
  - But not negligible
  - Low gas prices lower US wholesale prices

  => nuclear plants retiring early
- US lacks a carbon price impacting on electricity
  - Social cost of $CO_2$ $40/tonne?
  - At $25/tonne => raises **CCGT cost $12/MWh**
    - **and > $20/MWh if coal at the margin**
- But zero-carbon nuclear not supported in US
  - Unlike renewables

***Case for a $CO_2$ price or equivalent subsidy***

# Coal displaced by RES & gas



# 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 $CO_2$ already priced)
- Given COP21 and plans to reform ETS surely no sane utility plans new coal in EU

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# Spare slides on RES, storage

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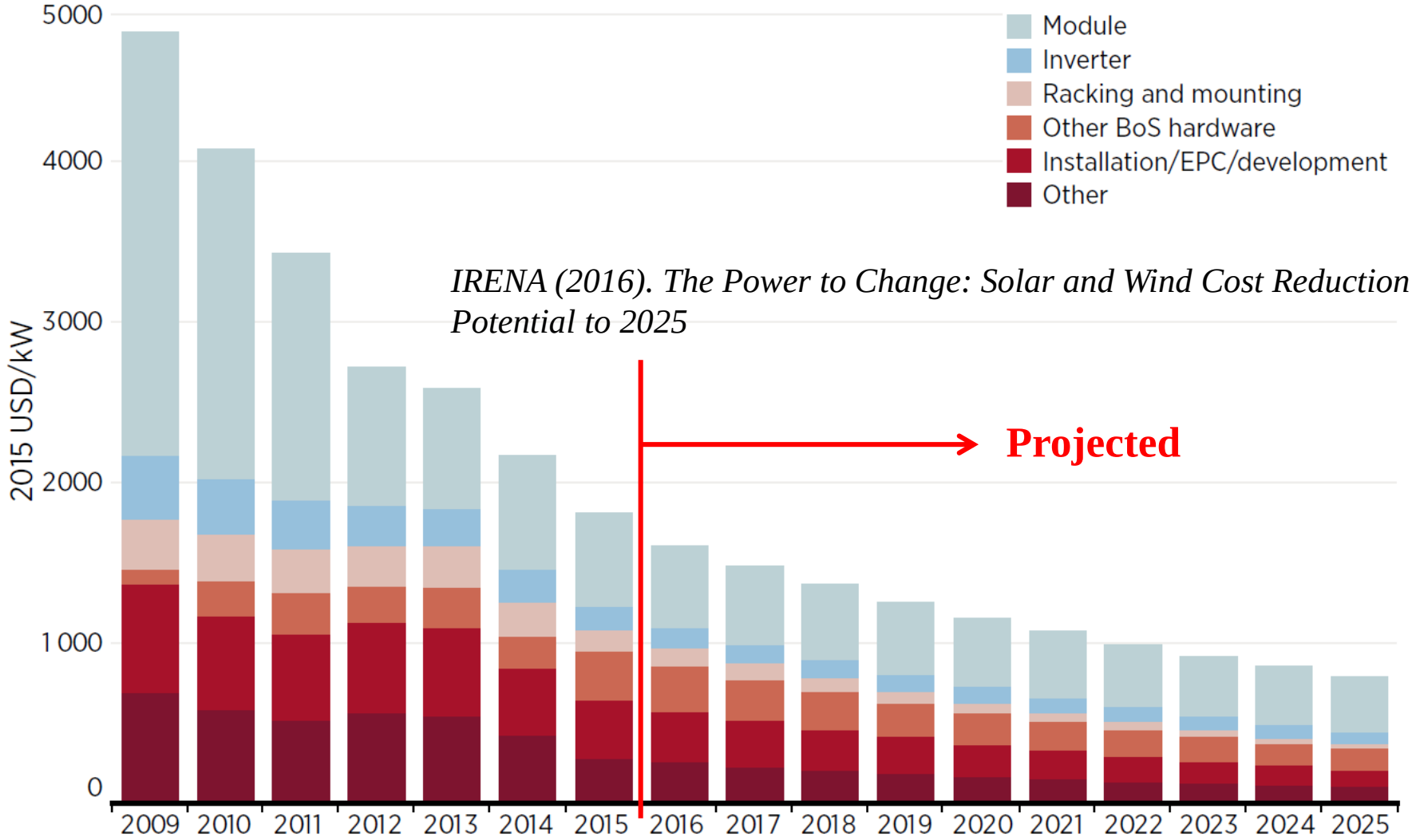
# Dramatic fall in solar PV prices

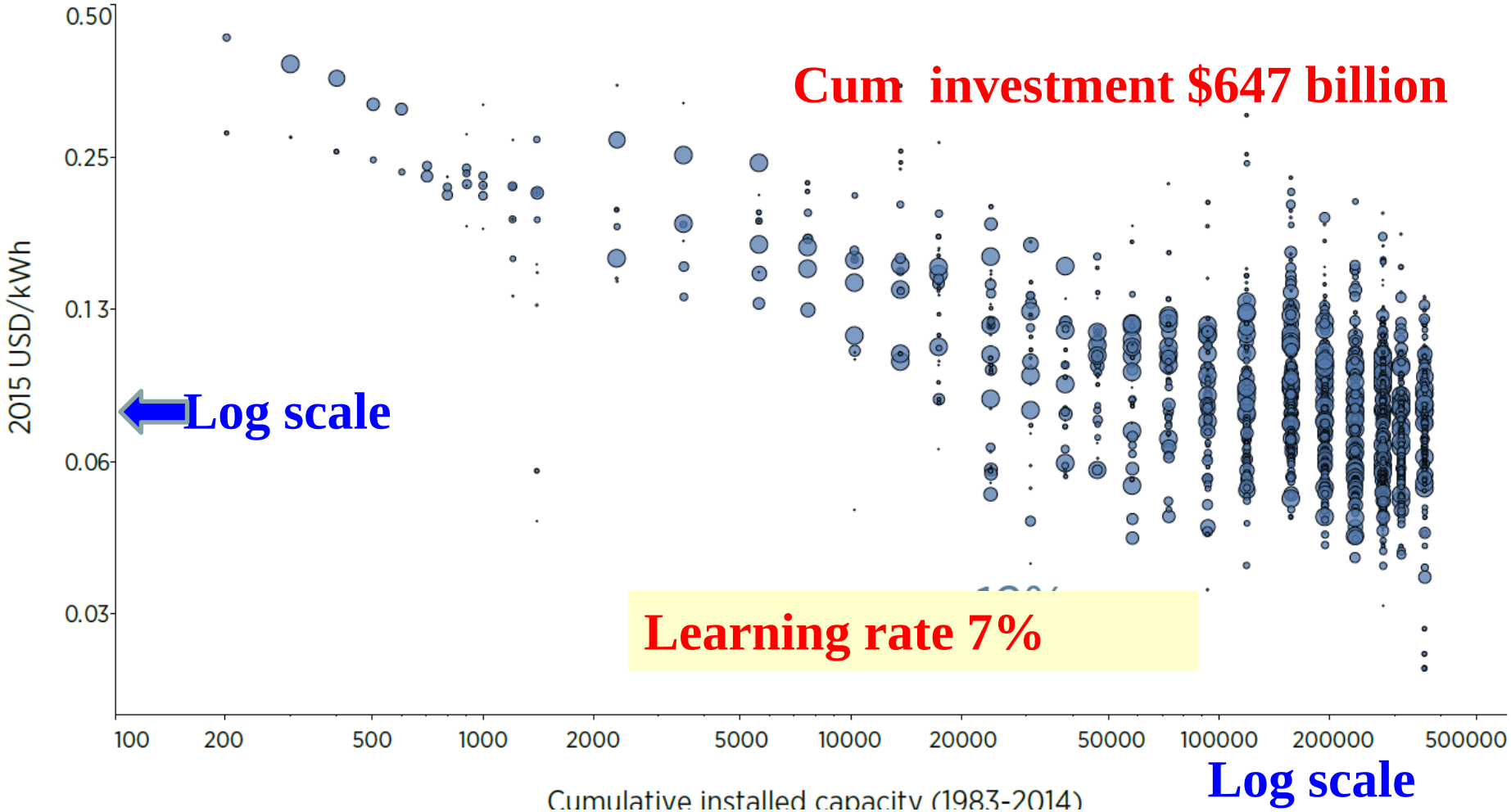
FIGURE ES 1: GLOBAL WEIGHTED AVERAGE UTILITY-SCALE SOLAR PV TOTAL INSTALLED COSTS, 2009-2025




*IRENA (2016). The Power to Change: Solar and Wind Cost Reduction Potential to 2025*

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

FIGURE ES 3: GLOBAL ONSHORE WIND LEARNING CURVE ANALYSIS, 1983-2014




Source: *IRENA (2016*

# Sep 2017 GB CfD auction

2012 prices

| Project Name | Developer | Technology Type | Capacity (MW) | Strike Price (£/MWh) | Delivery Year | Homes Powered | Region |
|---|---|---|---|---|---|---|---|
| Drakelow Renewable Energy Centre | Future Earth Energy (Drakelow) Limited | Advanced Conversion Technologies | 15.00 | 74.75 | 2021/22 | 27,190 | England |
| Station Yard CFD 1 | DC2 Engineering Ltd | Advanced Conversion Technologies | 0.05 | 74.75 | 2021/22 | 90 | Wales |
| Northacre Renewable Energy Centre | Northacre Renewable Energy Limited | Advanced Conversion Technologies | 25.50 | 74.75 | 2021/22 | 46,220 | England |
| IPIF Fort Industrial REC | Legal and General Prop Partners (Ind Fund) Ltd | Advanced Conversion Technologies | 10.20 | 74.75 | 2021/22 | 18,490 | England |
| Blackbridge TGS 1 Limited | Think Greenergy TOPCO Limited | Advanced Conversion Technologies | 5.56 | 74.75 | 2021/22 | 10,080 | England |
| Redruth EfW | Redruth EFW Limited | Advanced Conversion Technologies | 8.00 | 40.00 | 2022/23 | 14,500 | England |
| Grangemouth Renewable Energy Plant | Grangemouth Renewable Energy Limited | Dedicated Biomass with CHP | 85.00 | 74.75 | 2021/22 | 148,880 | Scotland |
| Rebellion | Rebellion Biomass LLP | Dedicated Biomass with CHP | 0.64 | 74.75 | 2021/22 | 1,120 | England |
| Triton Knoll Offshore Wind Farm | Triton Knoll Offshore Wind Farm Limited | Offshore Wind | 860.00 | 74.75 | 2021/22[1] | 893,690 | England |
| Hornsea Project 2 | Breesea Limited | Offshore Wind | 1,386.00 | 57.50 | 2022/23[2] | 1,440,300 | England |
| Moray Offshore Windfarm (East) | Moray Offshore Windfarm (East) Limited | Offshore Wind | 950.00 | 57.50 | 2022/23[3] | 987,220 | Scotland |

# How much storage?

- World **pumped storage** capacity 2016 = **164 GW**
  - **Estimated at 99.7% of global bulk electric storage**
- **PSP Storage capacity** at 12 hrs = **2.9 TWh**
  - GB 2.9 GW PSP, **27 GWh** storage = **9.3 hrs**
  - Germany 6.8 GW PSP, **50 GWh** storage = **7.4 hrs**
- World **hydro** 2012 = **979 GW, 3,288 TWh/yr =16% total**
- **Hydro storage** at 3 mths = **2,144 TWh = 700+ times PSP**
  - **Norway 23.4 GW storage hydro, 70 TWh = 2,400+ time GB PSP**
- Global electro-chemical **batteries 2016**:
- **1.6 GW, 3 GWh, 0.1% of pumped storage**

# EES overhead costs

| | cost/kWh capacity | DoD | O&M /kW.yr | cycles/ day | Life yrs. | levelized cost/MWh |
|---|---|---|---|---|---|---|
| Leighton Buzzard Li-ion NOAK | £850 | 100% | £10 | 1 | 9 | £251 |
| Leighton Buzzard Li-ion NOAK | £850 | 75% | £13 | 2 | 10 | £264 |
| Tesla 2018 Low | $475 | 100% | $15 | 1 | 12 | $207 |
| Tesla 2018 High | $1,050 | 60% | $20 | 2 | 14 | $323 |
| Li-Ion 2020 Low | $385 | 100% | $15 | 1 | 12 | $175 |
| Li-Ion 2020 High | $525 | 100% | $20 | 2 | 6 | $179 |
| Na-S Low | $420 | 100% | $15 | 1 | 7 | $256 |
| Na-S high | $700 | 80% | $20 | 2 | 6 | $287 |
| Lead-acid low | $196 | 100% | $15 | 1 | 1 | $617 |
| Lead-acid high | $280 | 100% | $15 | 1 | 3 | $334 |

| PSP | interest | cost/kWh capacity | DoD | O&M /kW.yr | cycles/day | Life yrs. | levelized cost/MWh |
|---|---|---|---|---|---|---|---|
| Dinorwig | 5% | £162 | 60% | £20 | 1 | 75 | £58 |
| Turlough Hill IE | 5% | £50 | 60% | £20 | 1 | 75 | £32 |
| Cruachan | 5% | £100 | 60% | £20 | 1 | 75 | £43 |
| LEAPS CA | 8% | $183 | 60% | $40 | 1 | 75 | $107 |
| DECC 2050 default | 5% | £260 | 60% | £20 | 1 | 75 | £81 |

# What about Electric cars?

- 2016 world car fleet 1.2 bn; 1.2 m BEVs @ 25kWh = **30 GWh**
  - IEA Paris accord calls for 100 m BEVs by 2030 = **2.5 TWh**
  - C.f. dams have **2,000+ TWh**
- UK: if 5 million BEVs by 2035 (13% fleet)
  - 20kWh each => 100 GWh; 30 km/day = 6 kWh/day
  - 50% charging at 3 kW at 5.30 p.m. = **8 GW extra load at peak**
  - 8% charging at any moment = **1.2 GW shiftable load**
- Really good idea to control time of charging
- Helpful (but modest) ability to demand shift
- Fast frequency response also useful

***BEVs can harm a lot or help somewhat***