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ENEDIS L'ELECTRICITE EN RESEAU

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MIT Center for Energy and Environmental Policy Research

Wholesale market designs for future low-carbon electricity systems

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EPRG-CEEPR European Energy Policy Conference

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

Outline*

- Decarbonising power needs a new market design
  - reconciling security of supply with renewables (RES)
- Nuclear, CCS or RES?
  - high capital cost, low variable cost
  - intermittent RES connected to distribution networks
- Criteria for charging and market design
  - ⇒ Capacity payments, long-term contracts, auctions
  - ⇒ new flexibility services required
  - ⇒ Better contracts for RES
- Challenges for network regulators

** Based on joint work with Michael Pollitt and Robert Ritz, Supported by CISL*

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Decarbonising power

- **Electricity** is 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**
- **RES** depresses prices, needs flexible reserves

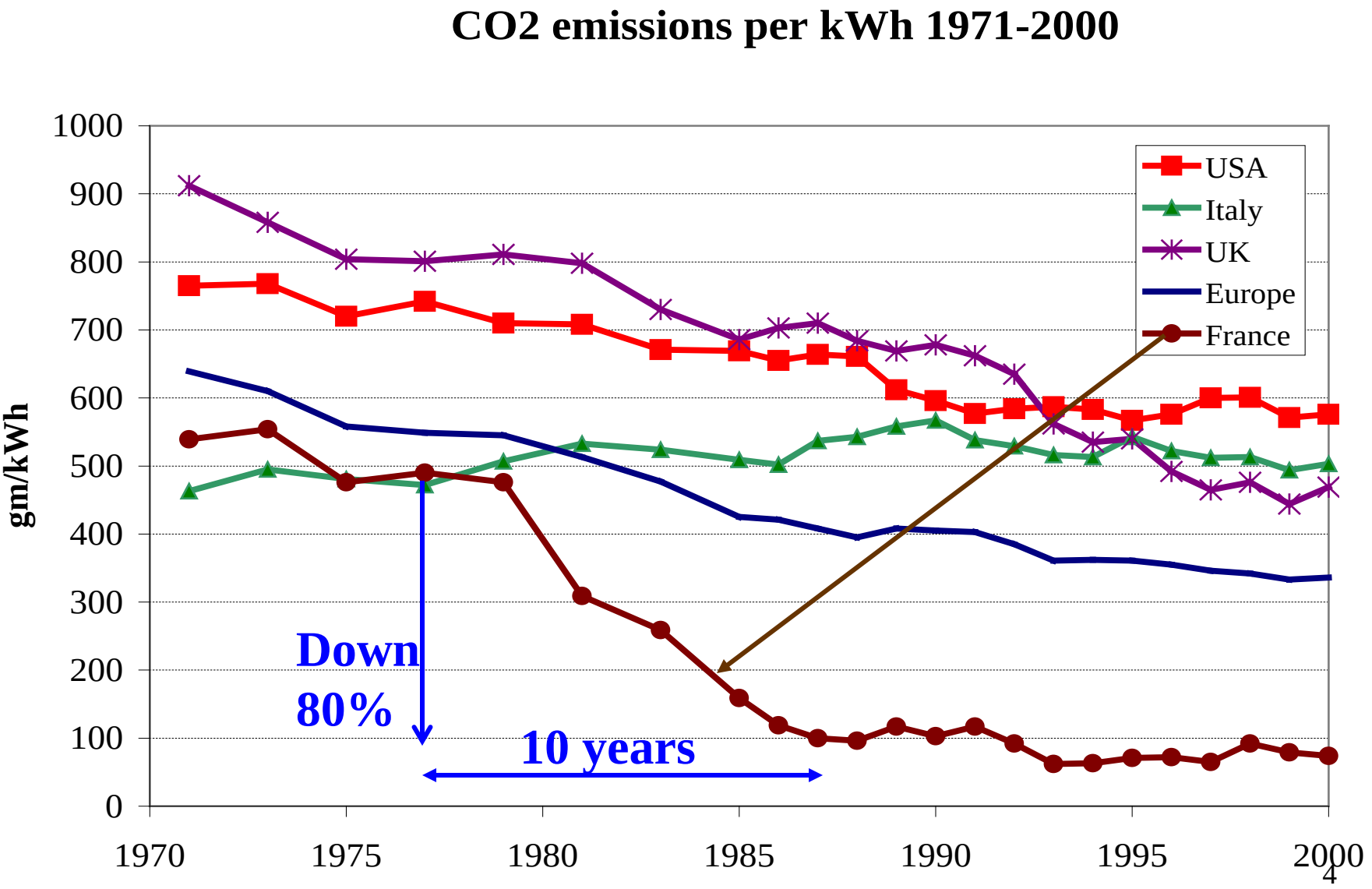
⇒ hard to invest in flexible plant in policy-driven market

⇒ 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



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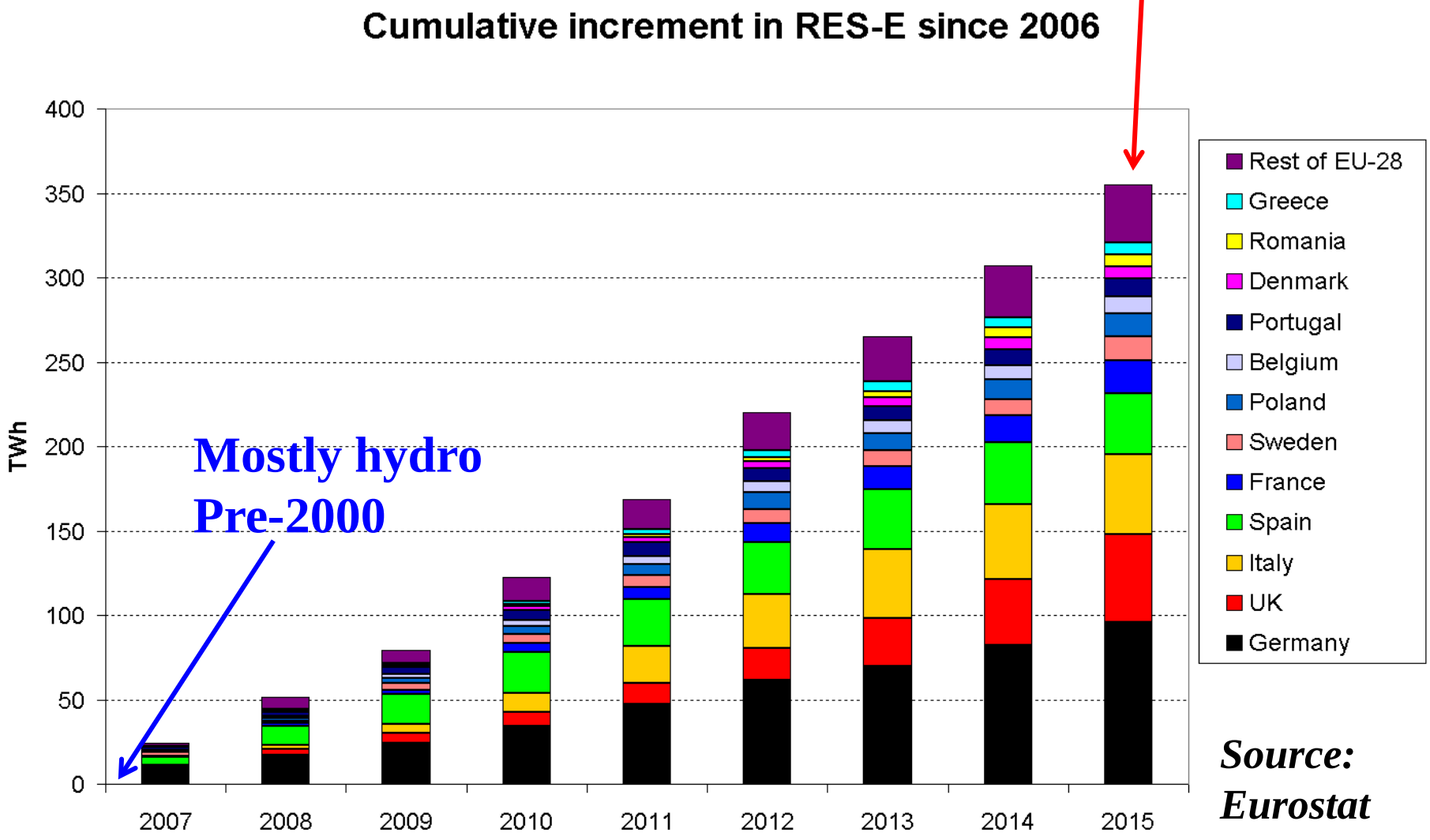
Rapid *increase* in EU renewable electricity to 29% in 2015



Source: Eurostat

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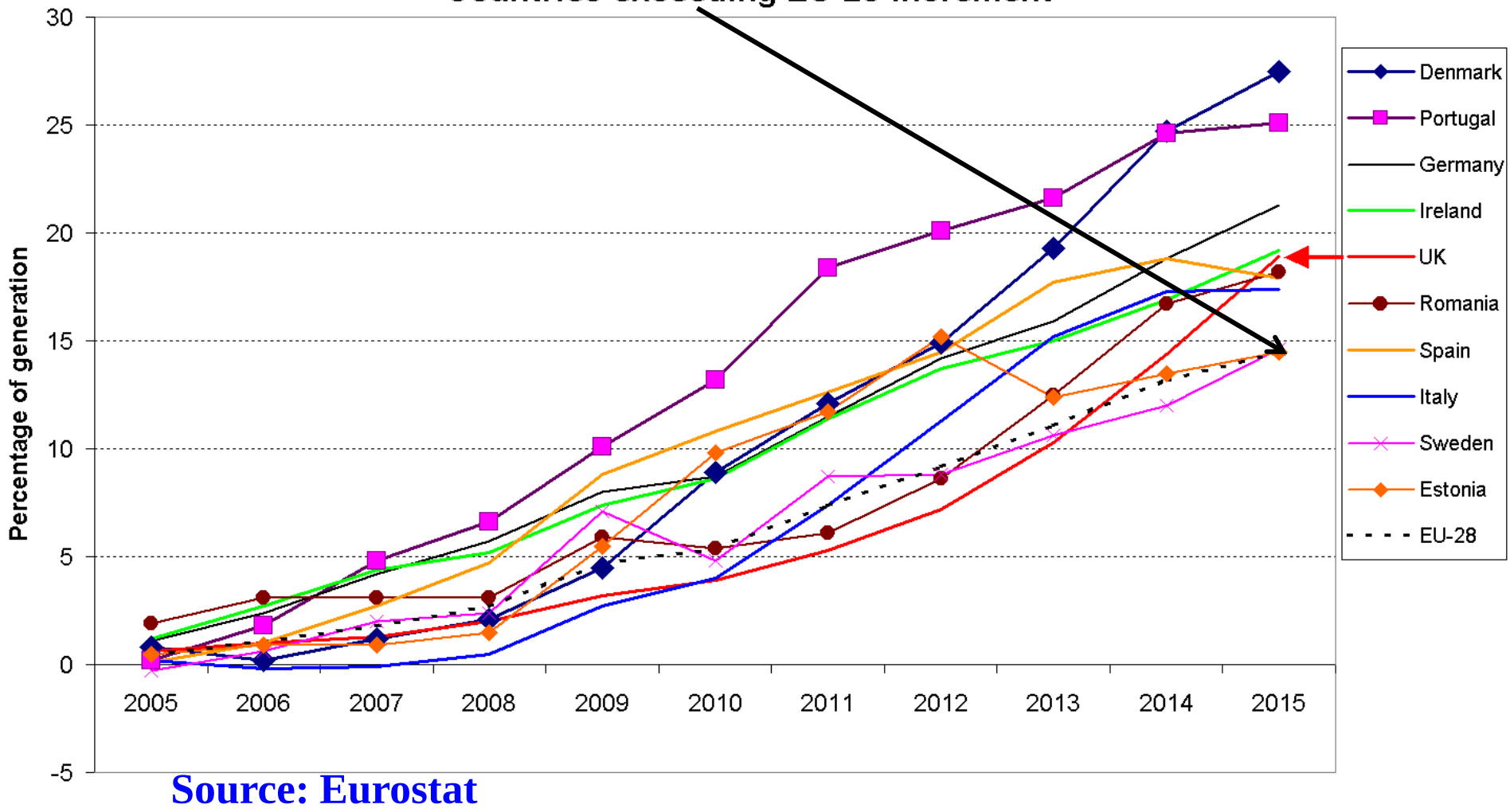
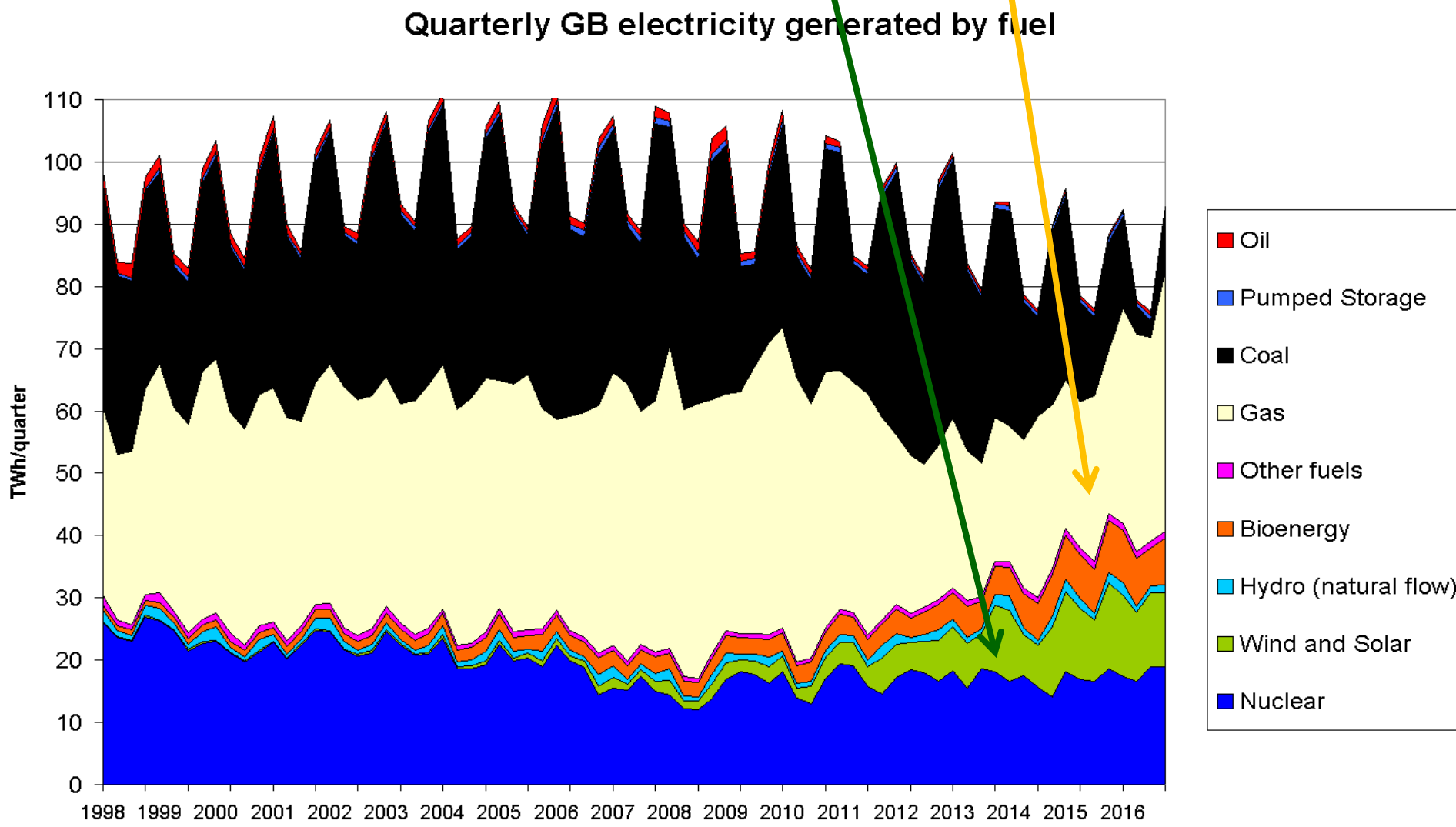
EU-28 *doubled* its RES-E share from 2004-2015



Source: Eurostat

GB: RES & gas displace coal



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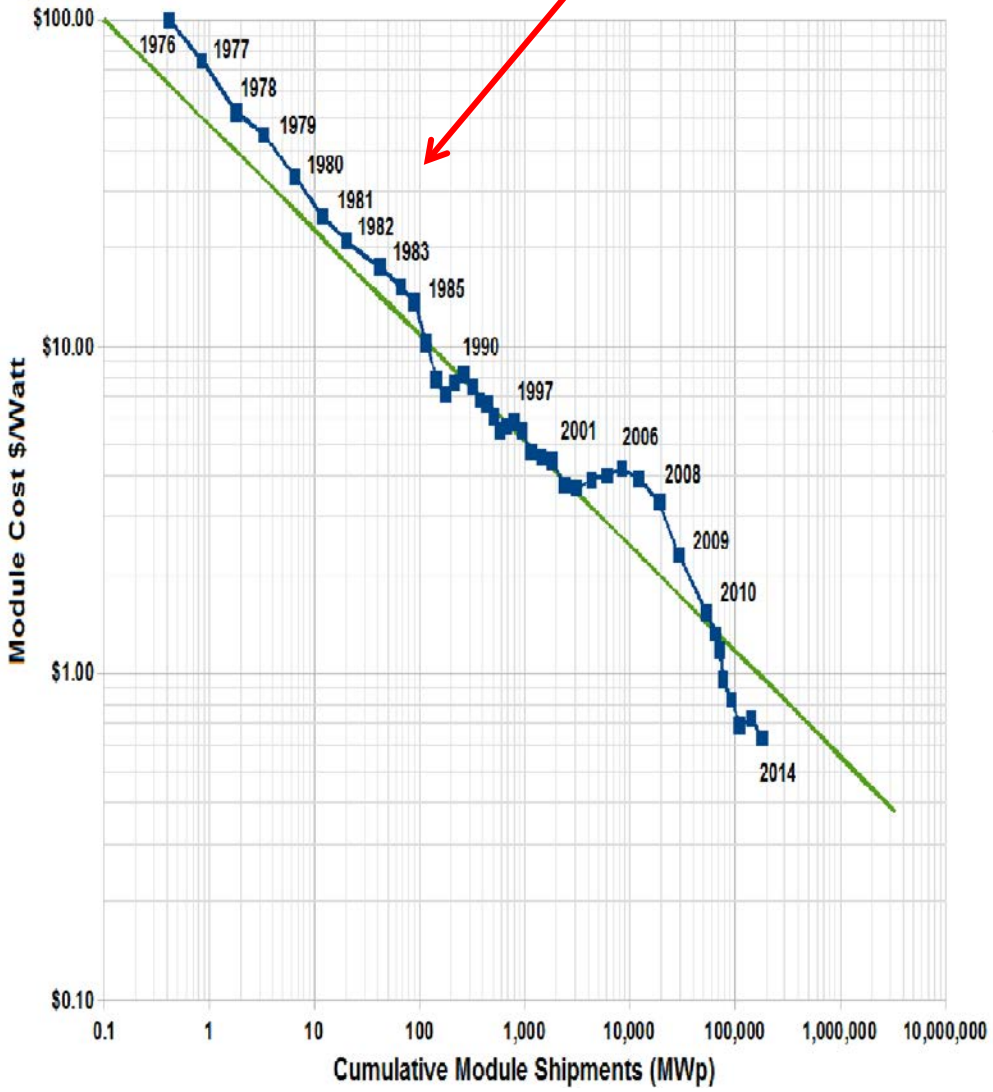
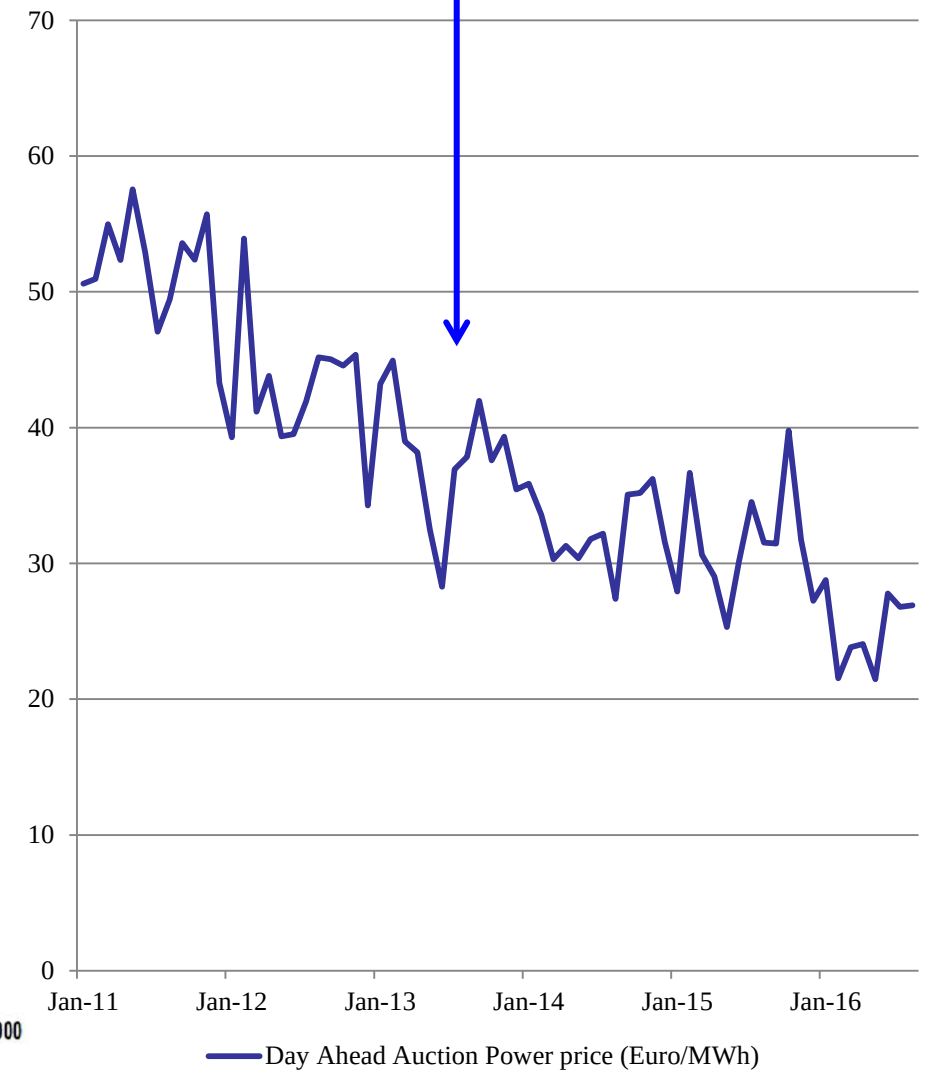
Solar PV cost fall 20% as capacity x2

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





Charging for electricity

- **Networks** are regulated natural monopolies
  - marginal cost pricing **fails to recover full costs**
  - efficient grid pricing may recover **< 30%** of cost

=> challenge is to give efficient price signals and recover balance from optimal taxes (**efficiency vs equity**)

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

=> challenge is to develop efficient wholesale/retail prices

- But not normally a regulated asset

$\Rightarrow$ long-term contracts?

How to charge final consumers?

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 for ***access option*** to take capacity
  - Drives investment in T & D
    - Some depends on system peak, some on ***local*** max. demand
  - Pay for **energy** at efficient price (SMC)
  - Pay for **capacity** at LoLP x (VoLL-SMC)
  - QoS bundled with access, energy, capacity
    - paid by final consumers to suppliers of service

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Ancillary services for QoS

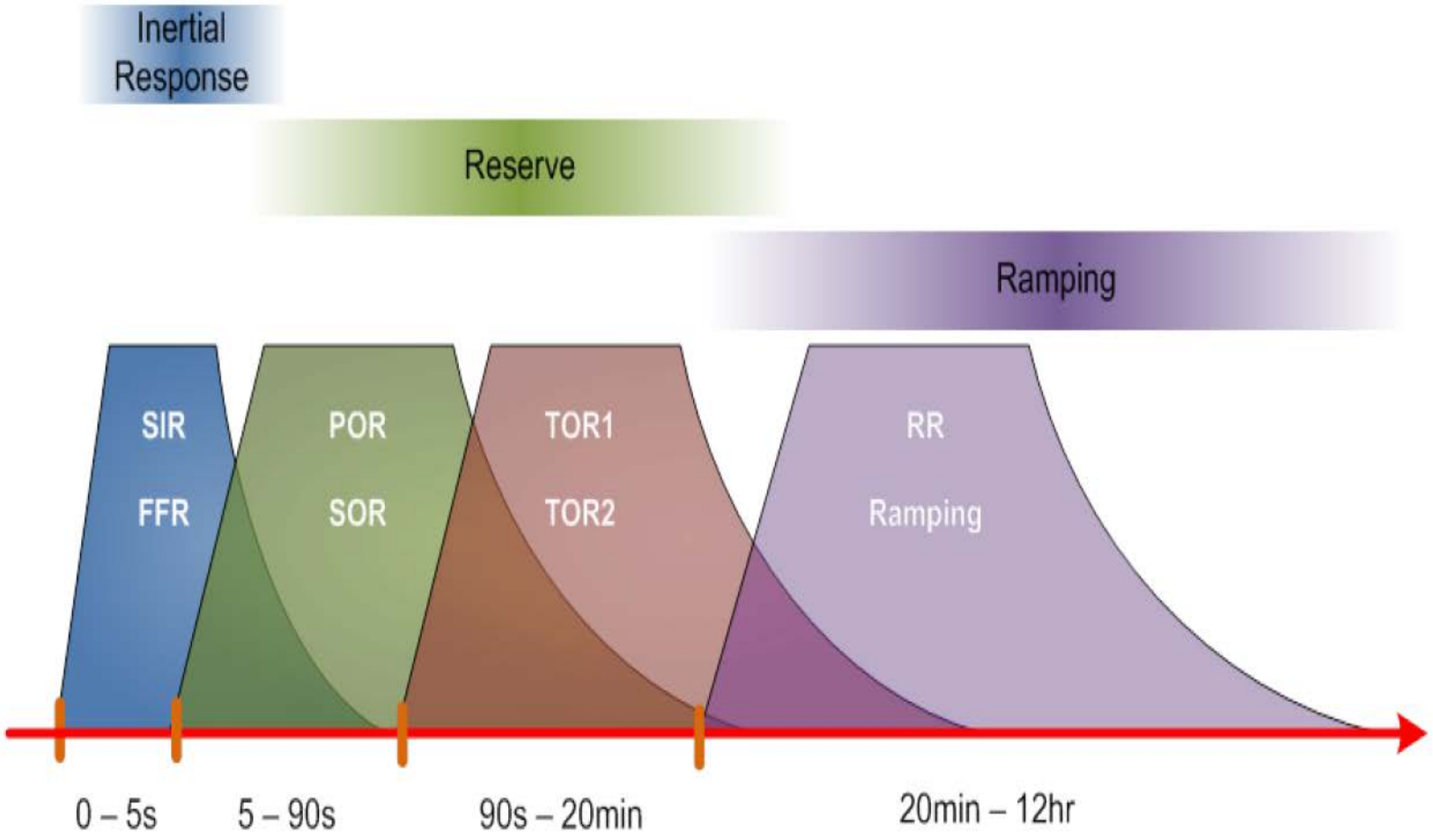


Figure 1: Frequency Control Services (Source: EirGrid)

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
  - ***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**

Revised RES Directive supports these principles

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 spill-overs driven by cumulative global capacity

					GWp cumulative		
Country	2010	2011	2012	2013	2014	2015	cum. value
China	0.8	3.3	6.8	19.7	28.2	43.5	$22,060
Germany	17.4	24.9	32.5	35.8	38.2	39.8	$25,185
Japan	3.6	4.9	6.6	13.6	23.3	34.2	$17,653
USA	2.5	4.4	7.3	12.1	18.3	25.6	$13,508
Italy	3.5	12.8	16.5	18.1	18.5	18.9	$11,863
UK	0.1	0.9	1.9	3.4	5.1	8.9	$4,492
France	1.2	3.0	4.1	4.7	5.7	6.6	$3,851
subtotal	29.1	54.1	75.6	107.3	137.2	177.5	$98,611
Global cumulative capacity	*47.0*	*78.0*	110.0	144.0	184.0	234.0	
spillover per kWp	$705	$644	$587	$535	$487	$443	

80% of total

Source: Newbery EPRG Working Paper 1706

Post 2020 RES-E support

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

⇒ Contract €***X***/MWh for ***N*** MWh/MW, Auctioneer sets ***N***

⇒ Auction determines ***X*** – not left to bureaucrats

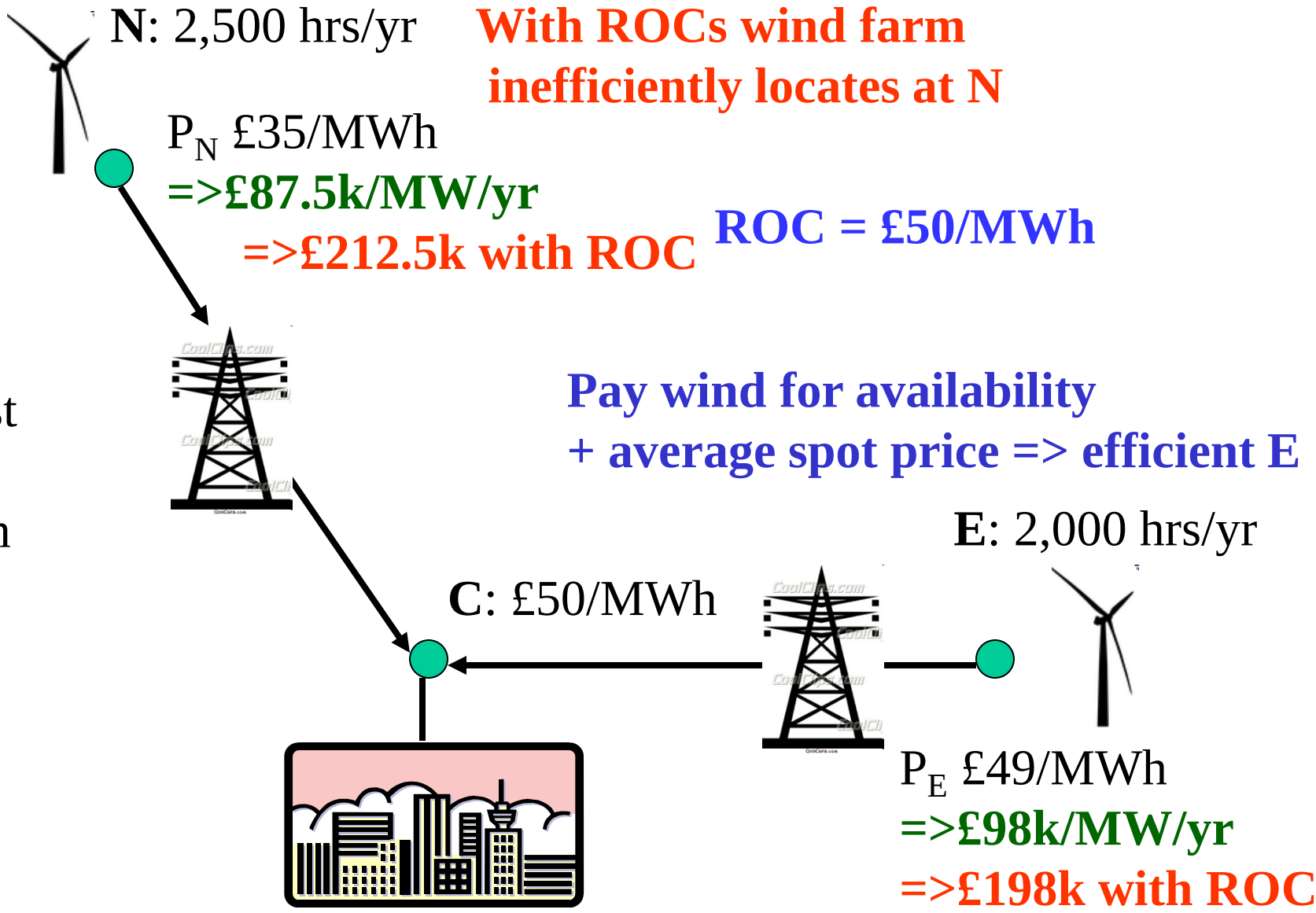
Reasons:

- 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
- Pay zero-C generation shortfall in social cost of carbon

If marginal displaced generation CCGT = €10/MWh?

Location choices under LMP and spot pricing for wind



RES CfD 2015 auction results

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)

withdrawn

Capacity auctions

- 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, …

Long-term contracts the solution?

⇒ Auctions for Reliability Options

Reliability Options: the I-SEM proposal

- 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***

Efficient 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 prices => cut demand ***equi-proportionally***
- Diamond-Mirrlees: **tax only final consumers**

⇒ T&D revenue shortfall on final consumption ***not*** net demand reduces embedded G benefit from £60 to < £10/kWyr

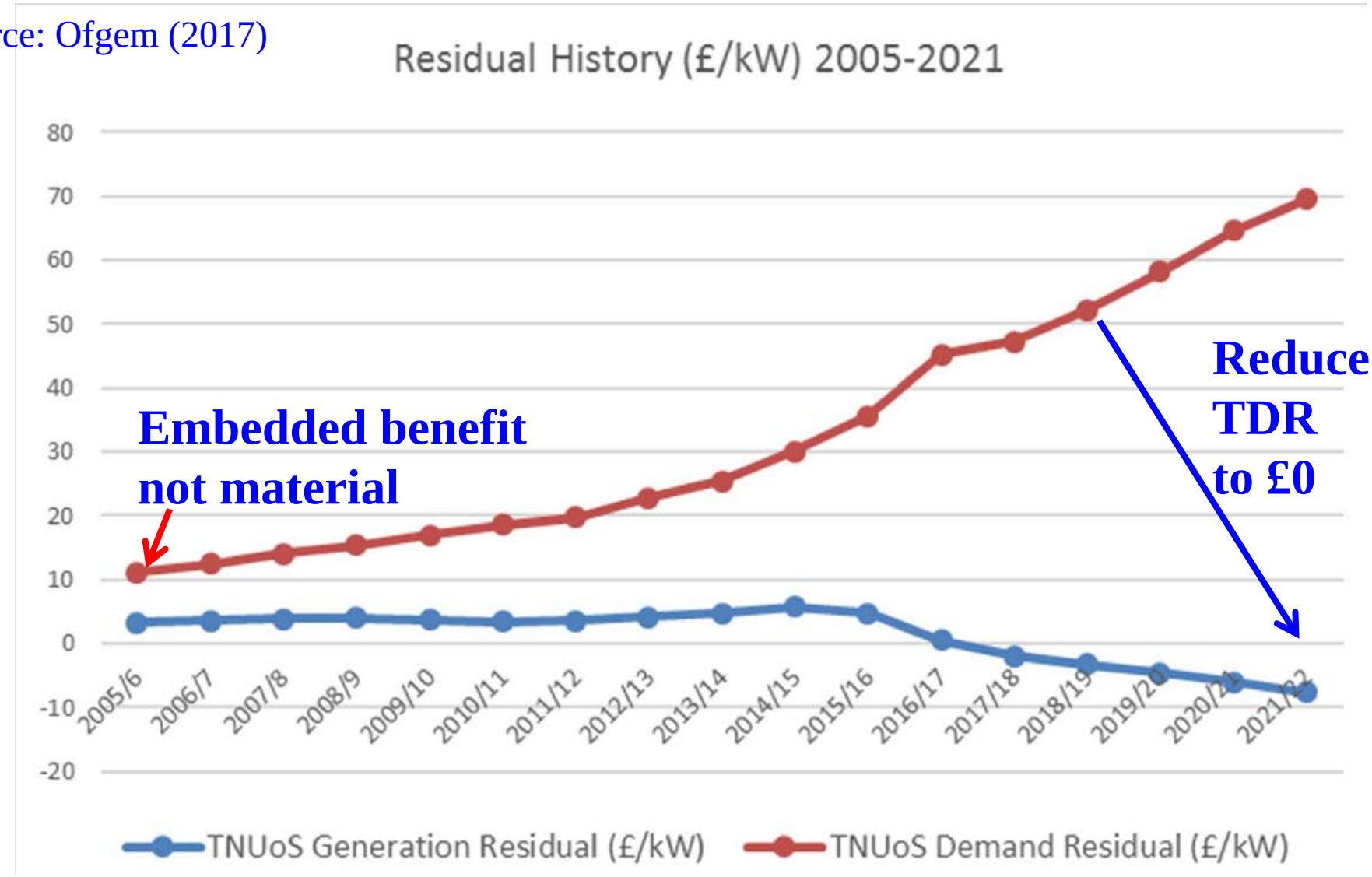
⇒ **Regulator**s need to compute efficient T&D tariffs

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

Ofgem alerted to adverse effects Dec 2014, decides June 2017 to reduce to zero by 2020/21

GB Transmission demand
residual – extra to DN connex

Source: Ofgem (2017)



Conclusions

- The priority is to decarbonise electricity
  - –To avoid long-term lock-in
  - – **EC Clean Energy Directive** identifies **good principles**
  - **=> clear guidance for good policy instruments**
- Low-Carbon electricity has high capital, low variable costs
  - –Distinguish prices for **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
  - – **network tariffs** need reform
  - – **reliability auctions and contracts** avoid trade distortions
- Countries can learn from experiences elsewhere

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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
EUA	EU Emissions Allowance Price (per tonne CO_2)
GHG	Greenhouse gas
G, L	Generation, Load
I-SEM	Integrated Single Electricity Market of island of Ireland
LMP`	Locational Marginal Pricing (Nodal pricing)
LoLP	Loss of Load probability
LoLE	Loss of load expectation in hrs/yr = reliability standard
MS	Member State
QoS	Quality of service
R&D	Research and Development
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

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- 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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Spare slides

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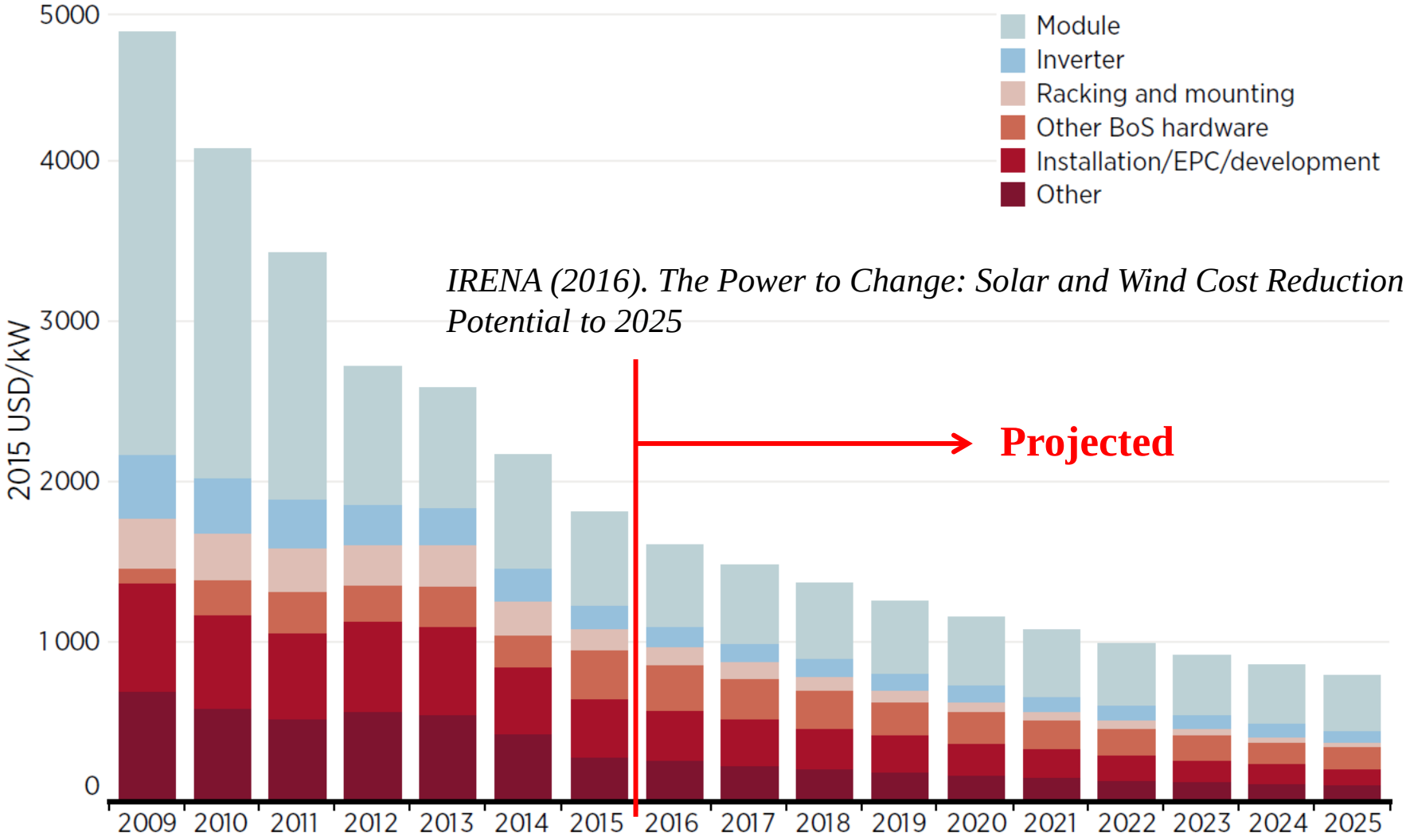
Dramatic fall in solar PV prices

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

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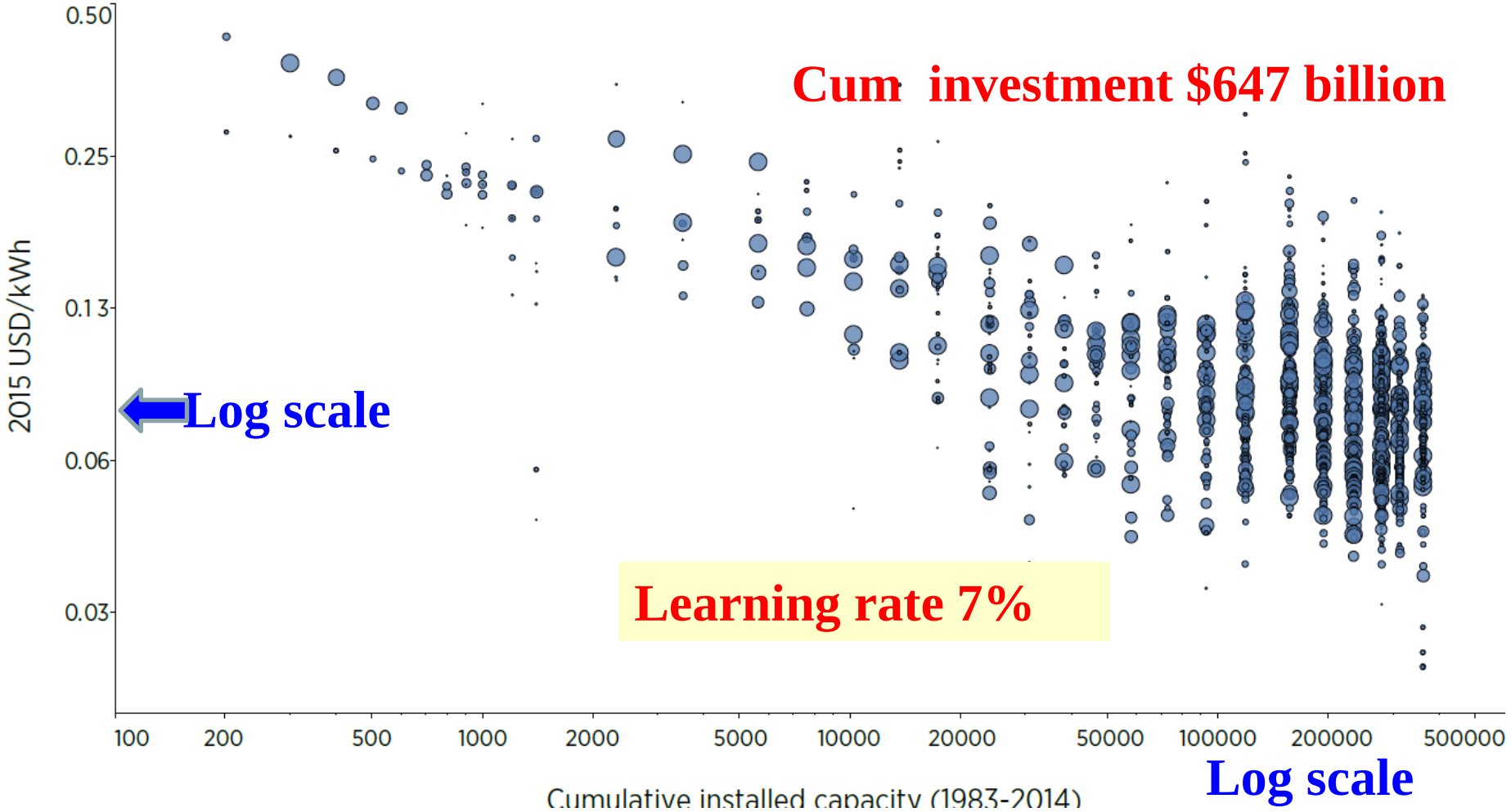
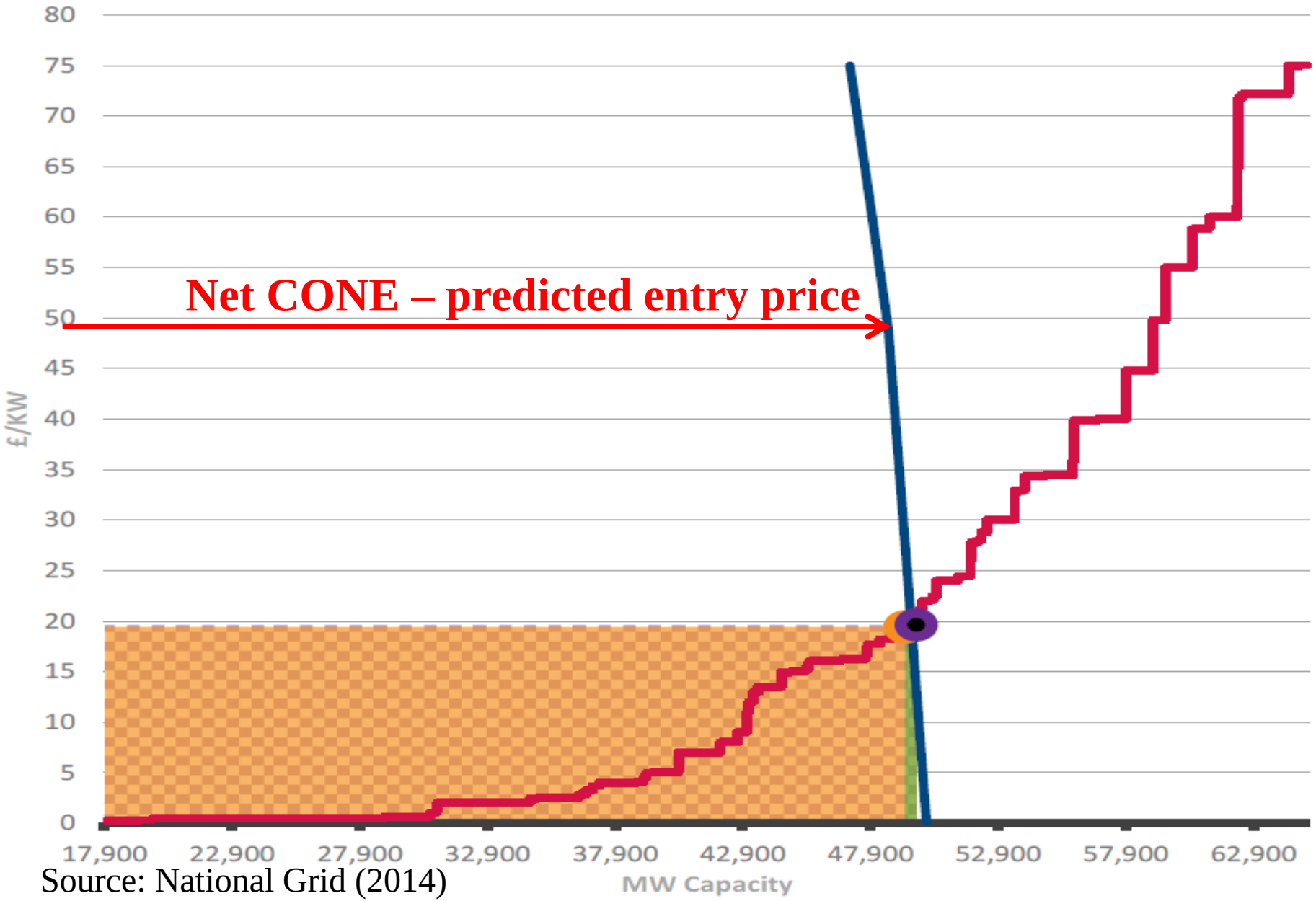
On-shore wind: taller towers give higher capacity factors

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



Source: *IRENA (2016*

GB 2014 Capacity Auction



Source: National Grid (2014)

Flaws in GB Capacity Procurement

- Transmission-connected generation TG ***pays*** G TNUoS
  - And 50% of BSUoS
- Distribution-connected generation DG ***receives*** L TNUoS
  - And avoids BSUoS
- TNUoS G + L charge roughly constant across zones
  - Rapidly rising from £20/kWyr to £66/kWyr

=> represents ***extra*** £53/kWyr embedded benefit in 2018/19

=> DG gets £73/kWyr and TG gets £20/kWyr

=> efficient locational charge = <10% total charge?

- Rest is revenue levy to pay for grid

=> should be levied on gross not net final consumption

Massive distortion

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**: Auctions + new technology => rapid 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