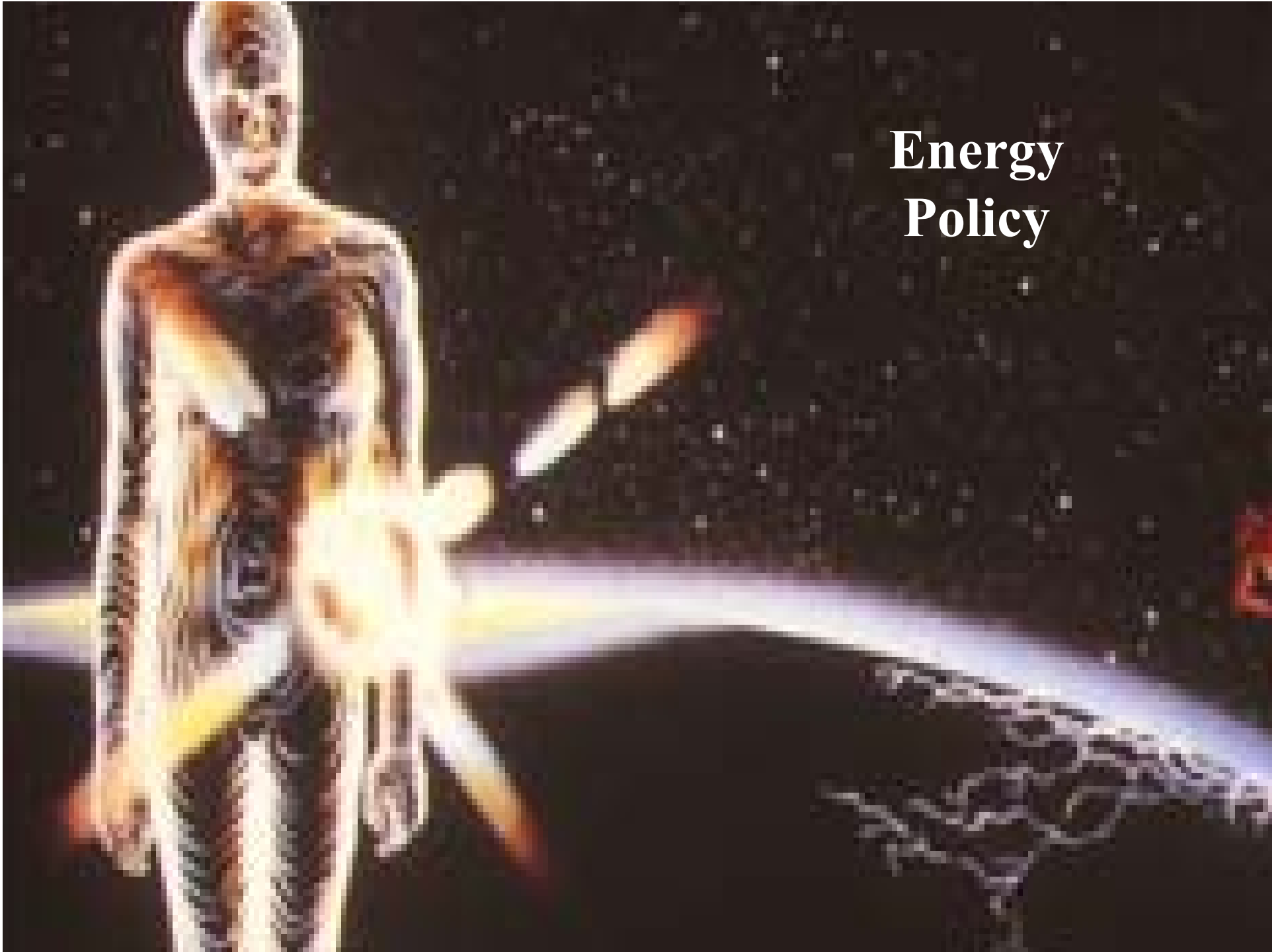


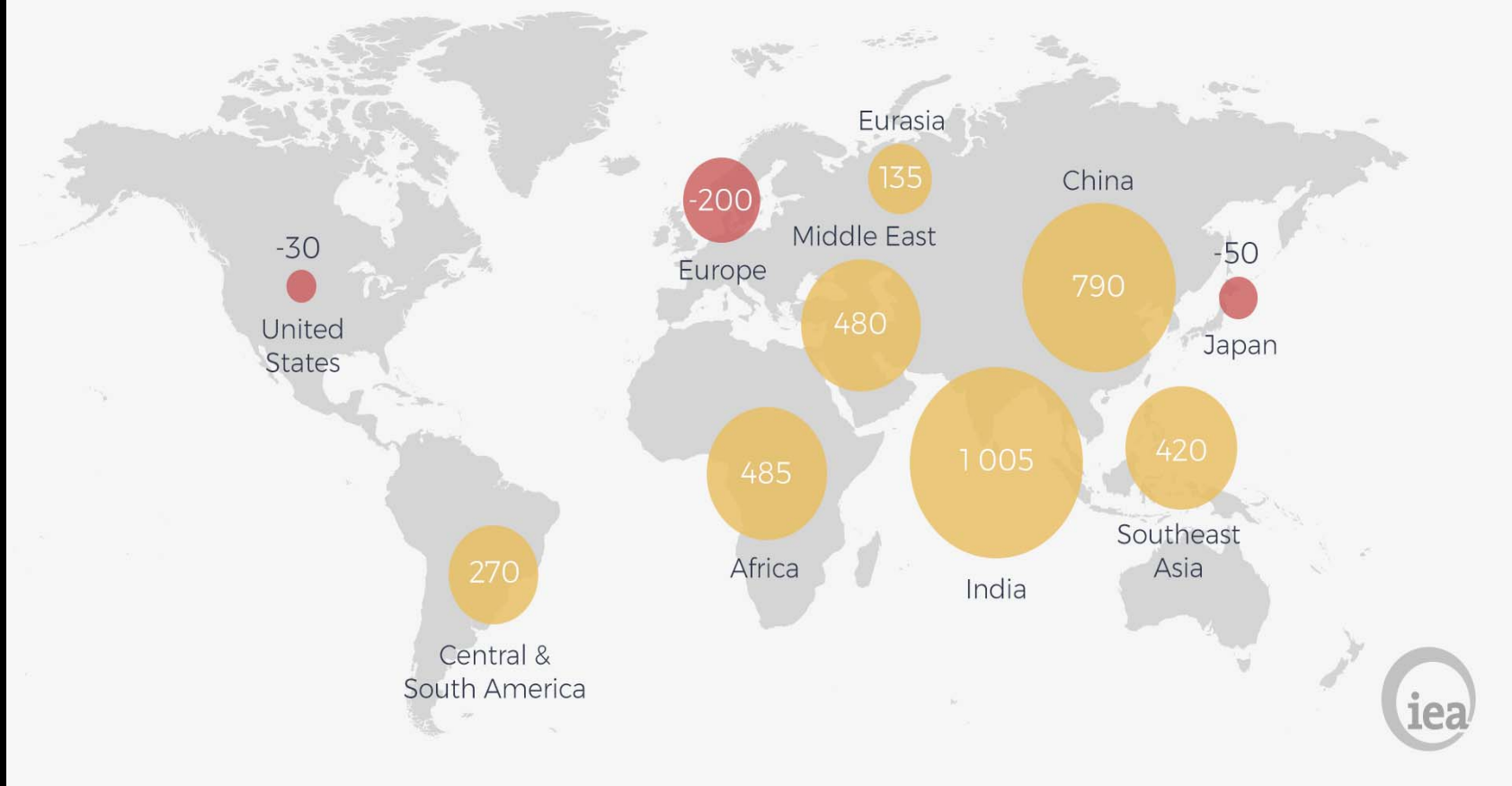
Energy Policy



World energy outlook

Change in primary energy demand, 2016-40 (Mtoe)

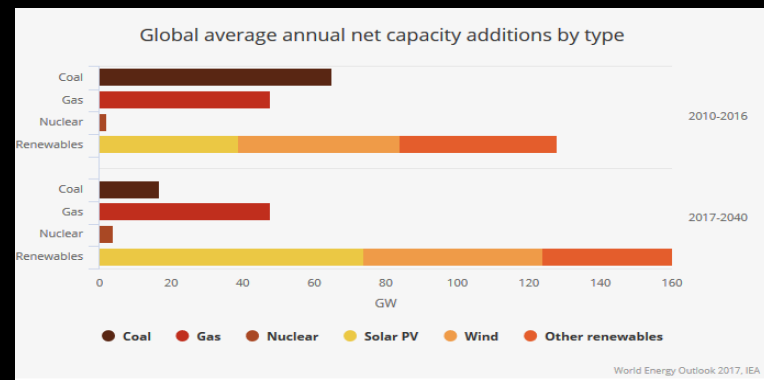
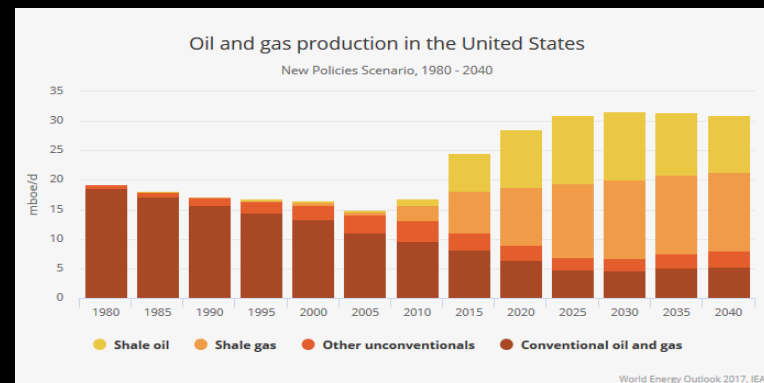
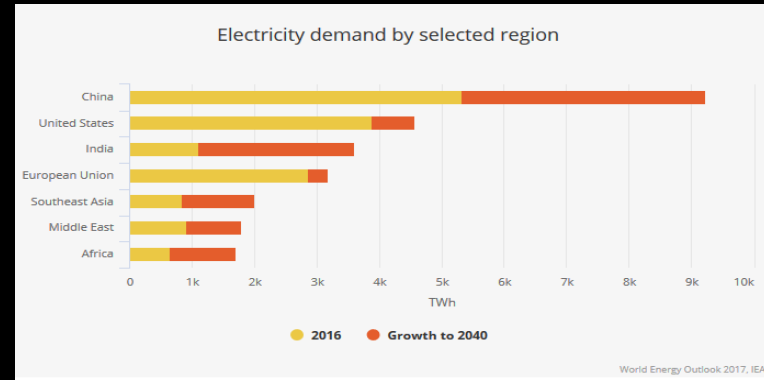
World Energy Outlook 2017



WEO 2017, IEA

World energy outlook

- ❑ Electricity accounts for 40% of the rise in final consumption to 2040 – the same share of growth taken by oil for the last 25 years.
- ❑ In the US, by 2025:
 - the oil output rise from 2010 matches the highest sustained period of growth by a single country in the history of oil markets;
 - increase in shale gas production exceeds the previous record for gas;
 - becomes the world’s largest LNG exporter and a net exporter of oil.
- ❑ Policies continue to support renewable electricity worldwide, increasingly through competitive auction rather than feed-in tariffs.
- ❑ The transformation of the power sector is amplified by households, communities and businesses investing directly in solar PV.

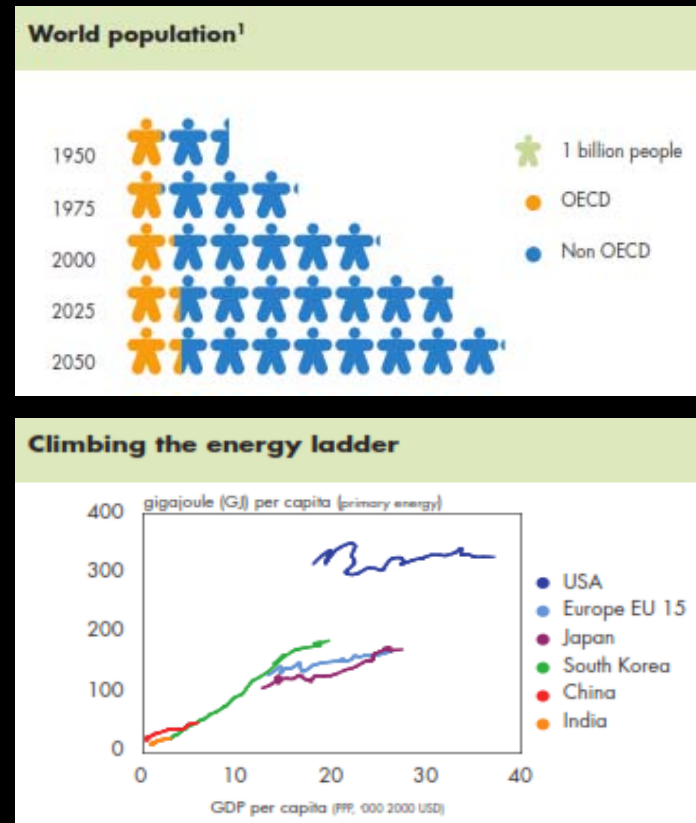


Background

- ❑ Growing world population
- ❑ Rapidly developing economies
- ❑ Rapidly increasing energy demand
- ❑ Shortages of food, water and other raw materials
- ❑ Concerns over security of energy supplies
- ❑ Climate change policies gathering pace

How best to assess proposals?

- ❑ Feasibility (technical, social acceptability)
- ❑ Economics (in the conventional sense)
- ❑ Energy / carbon economics
 - energy efficiency of processes
 - net CO₂ per unit of useful energy produced
 - embodied energy in life cycle of products
- ❑ Environmental aspects
 - consumption of valuable resources (actual and potential)
- ❑ Is this an exhaustive check-list?



Source: www.shell.com/scenarios

Economic growth

❑ Necessary or not?

- Growth is tolerated; reduction causes panic.
- Growth is ‘good’; 6 months of even slight reduction in activity equals recession.

❑ Are there limits to our aspirations for improvement in living standards?

“The common enemy of humanity is man. In searching for a new enemy to unite us, we came up with the idea that pollution, the threat of global warming, water shortages, famine and the like would fit the bill. All these dangers are caused by human intervention, and it is only through changed attitudes and behavior that they can be overcome. The real enemy then, is humanity itself.”

Club of Rome

“You need in the long run for stability, for economic growth, for jobs, as well as for financial stability, global economic institutions that make sure that growth to be sustained has to be shared, and are built on the principle that the prosperity of this world is indivisible.”

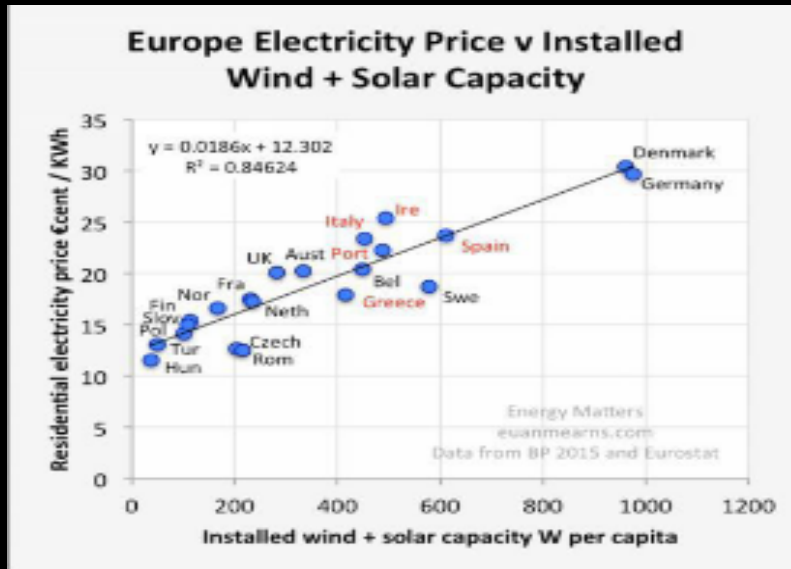
Gordon Brown MP

Evaluation matrix: fuels for road transport

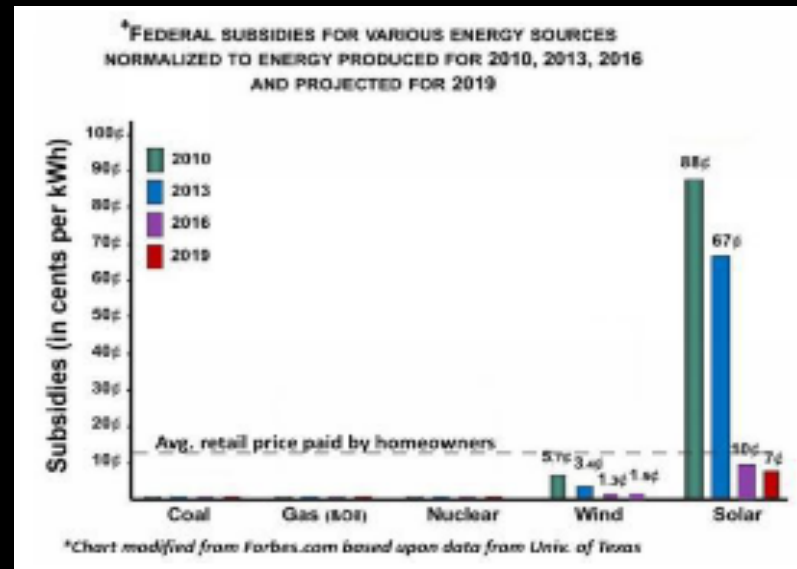
	Fossil fuels	Bio-fuels	H ₂ direct	H ₂ fuel cell	Battery/ electric
Technical feasibility	Yes	Partial only	Yes	Yes	Range issues
Economics	+++	+	-	--	+
Energy	$\eta = 35\%$	$\eta = 35\%$	$\eta = 10\%$	$\eta = 15\%$	$\eta = 40\%$
Carbon	High	Variable	High	Moderate	Low
Environment	<ul style="list-style-type: none"> ▪ Climate change 	<ul style="list-style-type: none"> ▪ Land use ▪ Food supply 	<ul style="list-style-type: none"> ▪ Needs infra. 	<ul style="list-style-type: none"> ▪ Needs infra. ▪ Uses scarce resources 	<ul style="list-style-type: none"> ▪ Needs power plant ▪ Uses scarce resources

Issue: who decides the weighting factors?

Electricity price vs. installed renewables

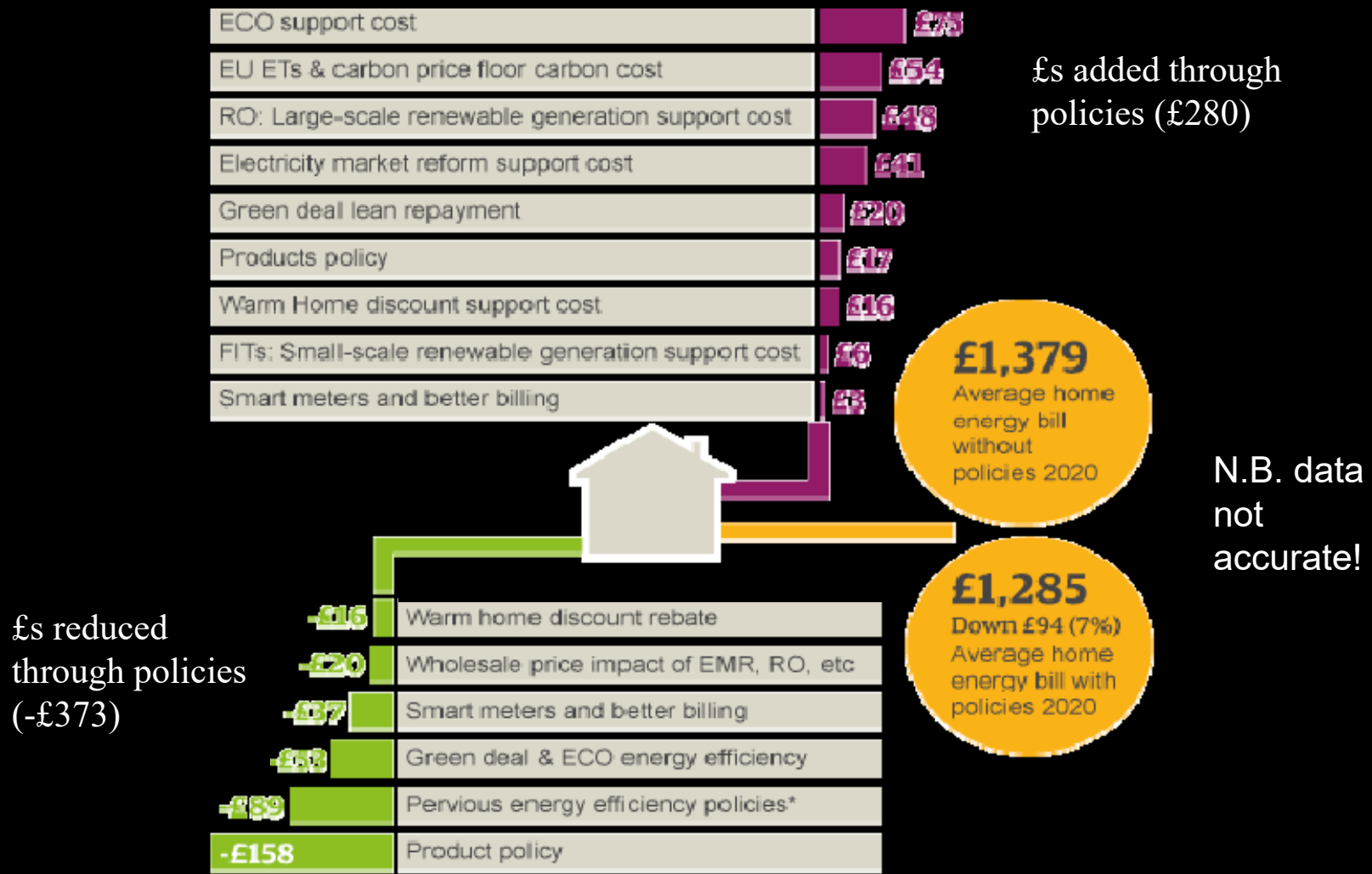


Subsidies distort markets



From Spencer 2017

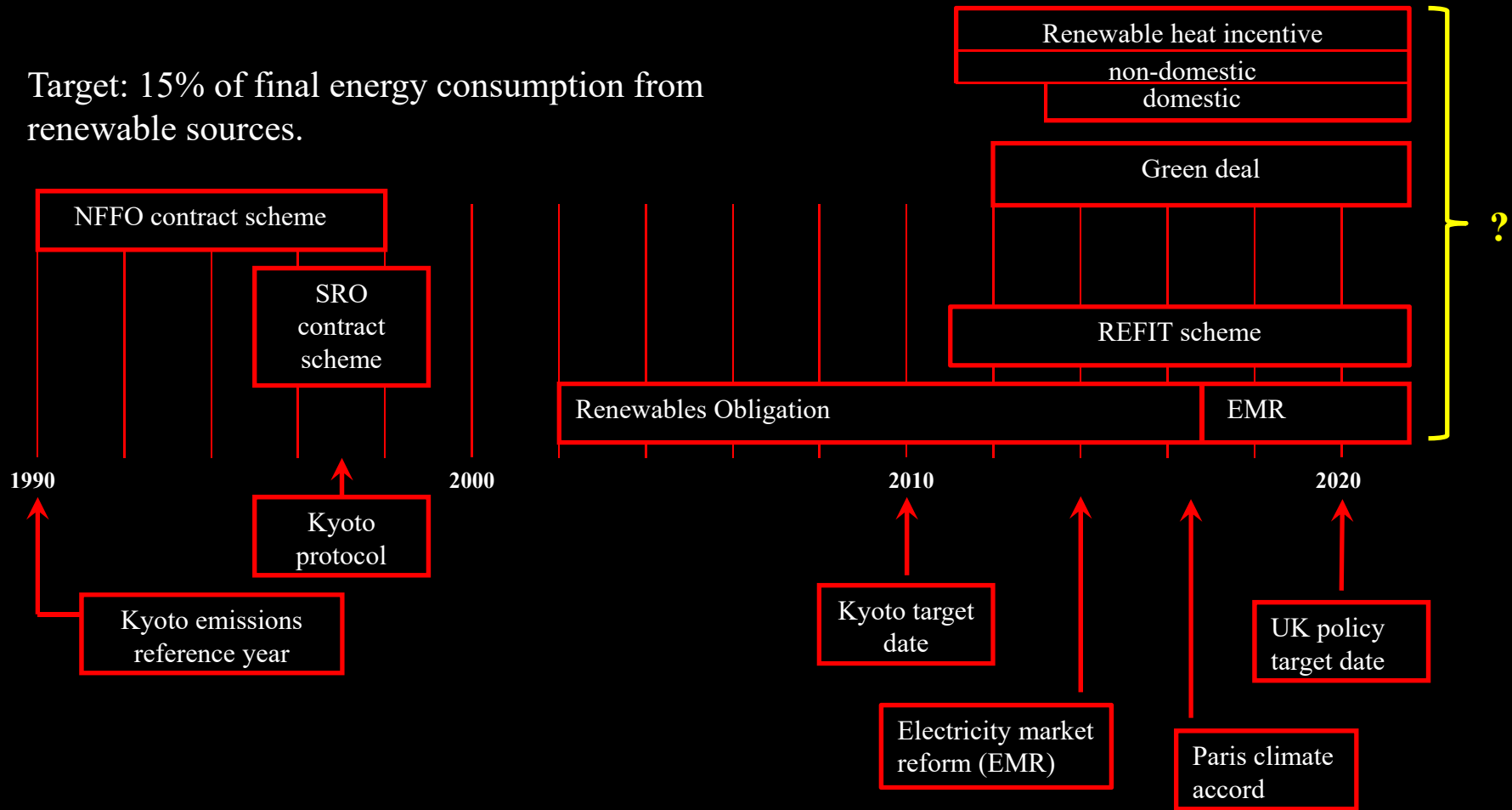
Impact of policies on average household bills in 2020



Source: <http://www.guardian.co.uk/environment/2011/nov/23/green-deal-insulate-homes>, 23/11/2011

UK renewable energy policy framework

Target: 15% of final energy consumption from renewable sources.



Issue: target backed by fiscal measures; what about technical feasibility and myriad impacts?

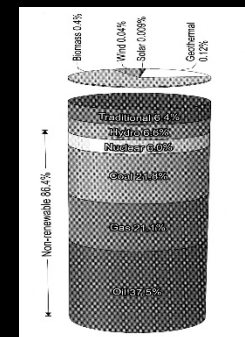
NFFO (1990 -1998) and SRO (1995 -1999)

- ❑ Fixed-term, fixed-price contracts to developers for the purchase of electricity.
- ❑ Support given to certain technologies, installed capacity limited.
- ❑ Planning permission not guaranteed; obtained by developer in a separate process.

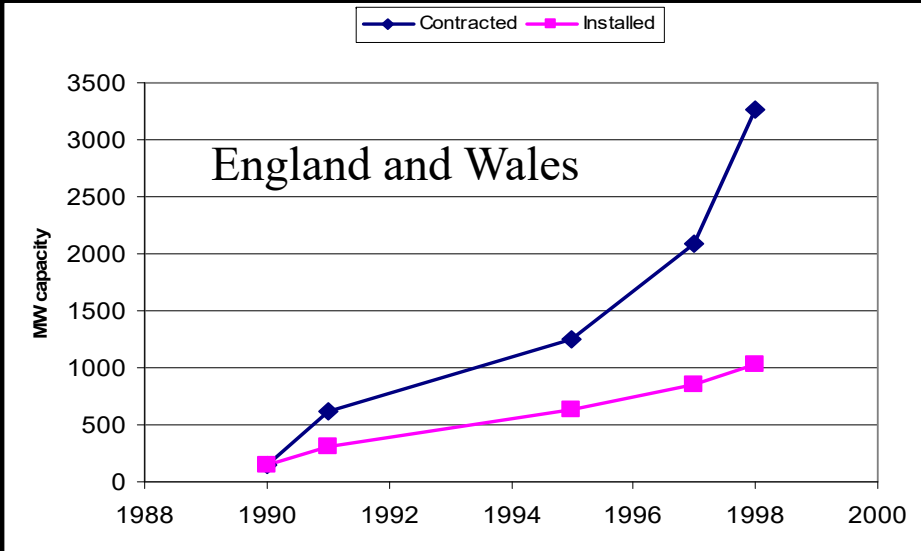


RO (2002 - 2017)

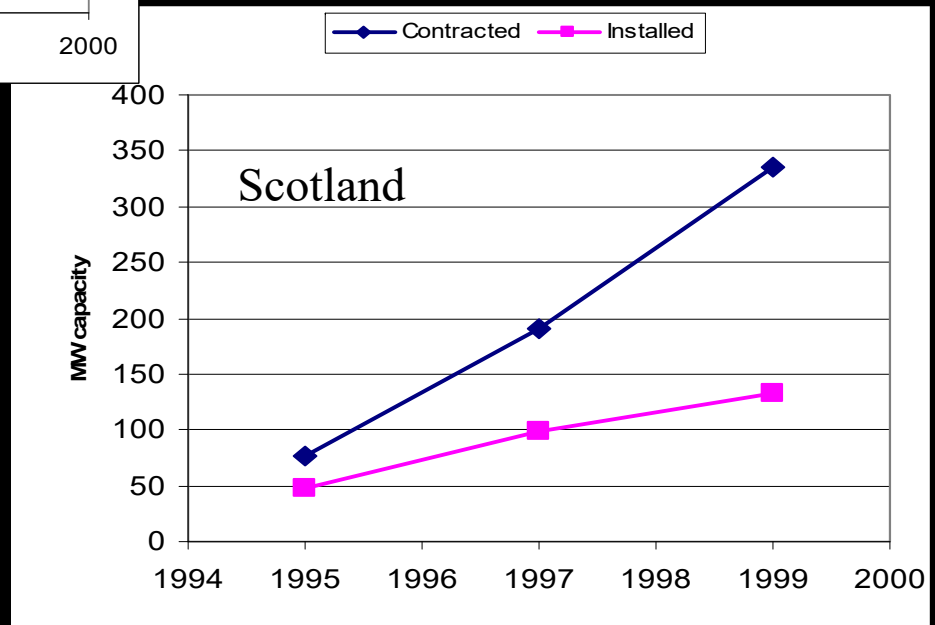
- ❑ Requires electricity suppliers to obtain a specified percentage of their output from renewable sources (rising: 10% in 2010).
- ❑ Additional costs incurred may be passed on to customers: no subsidies.
- ❑ Arrangements for the trading of Renewables Obligation Certificates (ROCs) or purchasing exemption: ROC auction price ~£50 per MWh.
- ❑ Modified (April 2009) to assist the development of relatively immature technologies (to avoid electricity producers going for the cheapest renewable sources, e.g. on-shore wind energy, land-fill gas or waste incineration):
 - 1.5 ROCs for offshore wind;
 - 2 ROCs for offshore wind and biomass with CHP;
 - 3 ROCs for tidal energy; and
 - 5 ROCs for wave energy.
- ❑ Current market reform will replace ROCS with a strike price as a means to reduce risk for generators.



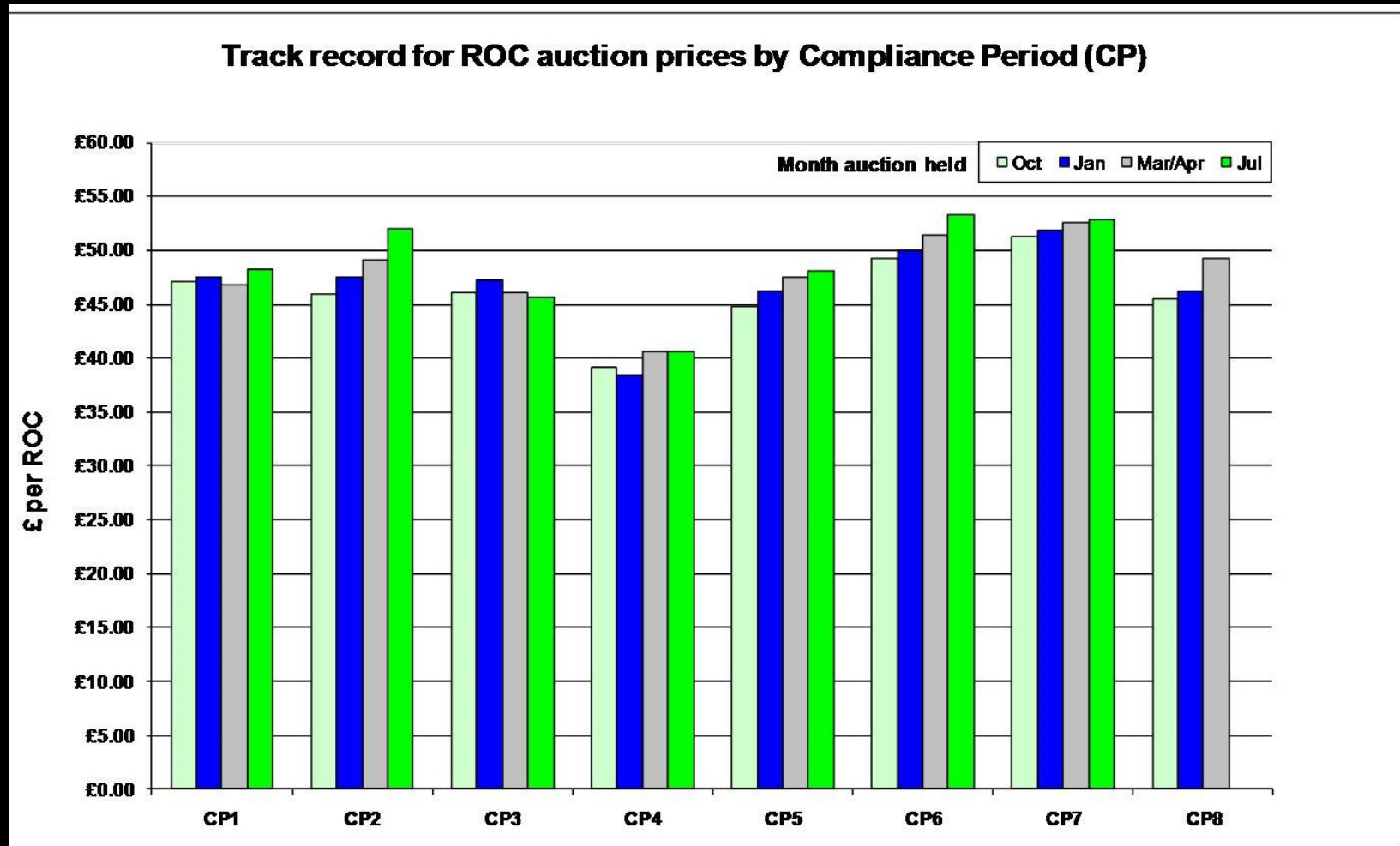
NFFO and SRO



- ❑ Projects completion rates initially high.
- ❑ Difficulties Then arose in the planning process, particularly for wind farms and waste incineration plant.
- ❑ Completion rates fell well below 50%.



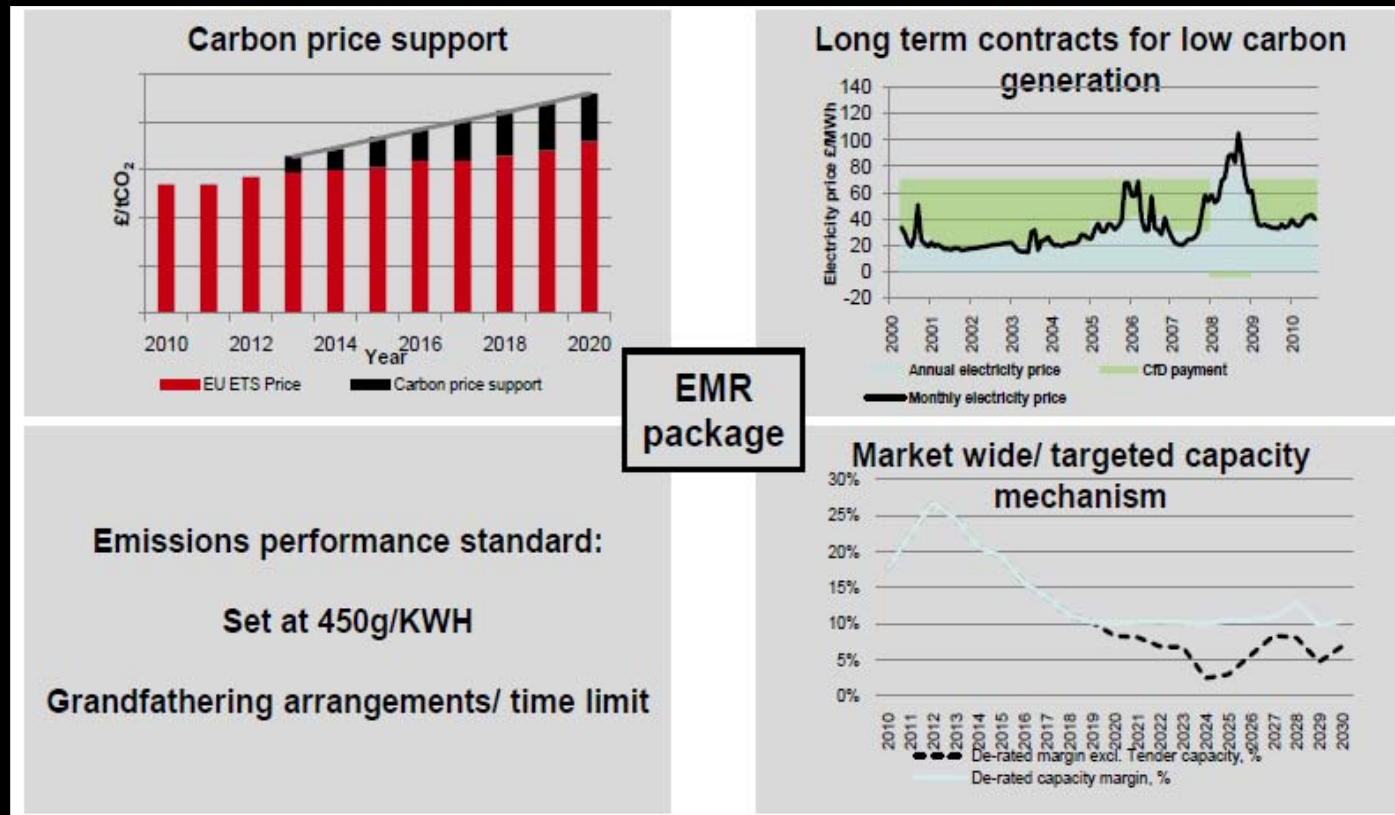
ROCs: trading price



Data up to April 2010. Each ROC equates to 1 MWh of electricity.

Electricity market reform

<https://www.gov.uk/government/collections/electricity-market-reform-contracts-for-difference>



- ❑ Addresses the energy trilemma: decarbonisation, security and cost.
- ❑ Contracts for Difference (CFD) to provide price stabilisation to low carbon plant, allowing investment at a lower cost of capital and at a lower cost to consumers.
- ❑ Capacity Market to provide a retainer payment to reliable forms of capacity (both demand and supply side), in return for such capacity being available when the system is tight.

Contracts for difference



CfD strike prices 2014/15-2018/19

	Strike Prices £/MWh (2012 prices)				
	2014/15	2015/16	2016/17	2017/18	2018/19
Advanced Conversion Technologies (with or without CHP)	155	155	150	140	140
Anaerobic Digestion (with or without CHP)	150	150	150	140	140
Dedicated Biomass (with CHP)	125	125	125	125	125
Energy from Waste (with CHP)	80	80	80	80	80
Geothermal (with or without CHP)	145	145	145	140	140
Hydro	100	100	100	100	100
Landfill Gas	55	55	55	55	55
Sewage Gas	75	75	75	75	75
Onshore Wind	95	95	95	90	90
Offshore Wind	155	155	150	140	140
Biomass Conversion	105	105	105	105	105
Wave	305	305	305	305	305
Tidal Stream	305	305	305	305	305
Large Solar Photo-Voltaic	120	120	115	110	100
Scottish Islands Onshore				115	115

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263937/Final_Document_-_Investing_in_renewable_technologies_-_CfD_contract_terms_and_strike_prices_UPDATE_D_6_DEC.pdf

CfD 2nd allocation round results (September 2017)

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

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/643560/CFD_allocation_round_2_outcome_FINAL.pdf

REFIT (2011 »)



Description	Installed Capacity (kW)	Tariff 2017 (p/kWh)
Solar PV receiving the higher rate	0-10	4.00
	10-50	4.22
	50-250	1.89
Solar PV receiving the middle rate	0-10	3.60
	10-50	3.80
	50-250	1.70
Solar PV receiving the lower rate	0-10	0.38
	10-50	0.38
	50-250	0.38
Large solar PV	250-1000	1.54
	1000-5000	0.38
Stand-alone solar PV	0-5000	0.23
	0-250	4.99
Anaerobic digestion	250-500	4.72
	500-5000	1.76
CHP	0-2	13.95
	0-100	7.78
Hydro	100-500	6.24
	500-2000	6.24
	2000-5000	4.54
Wind	0-50	8.26
	50-100	4.88
	100-1500	2.58
	1500-5000	0.80

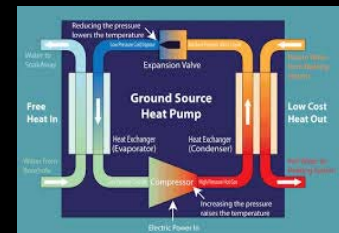
Energy source	Tariff (p/kWh)	Duration (years)	
Anaerobic digestion	11.5 to 9	20	
Hydro (below 2 MW)	19.9 to 11	20	
	2 to 5 MW	4.5	20
Micro CHP	10	10	
Solar PV	41.3 to 29.3	25	
Wind (below 500 kW)	34.5 to 18.8	20	
	500 to 1500 kW	9.4	20
	1.5 to 5 MW	4.5	20

Tariffs 2010

- ❑ Payments to property owners for small scale renewable electricity generation.
- ❑ Guaranteed price per unit of energy generated depending on system type and size + 1.5p/kWh for surplus exported to the grid.
- ❑ Tariffs guaranteed for fixed period, RPI linked.
- ❑ Payments tax exempt if most of the energy is used by producer.

RHI (2011 »)

- ❑ Applicable to households, landlords, businesses, farmers, schools, hospitals, care homes, communities *etc.*
- ❑ Fixed payment for heat generated for local use via heat pumps, biomass boilers and solar thermal panels.
- ❑ Paid by the Treasury not energy users.
- ❑ Steps:
 1. renewable heat systems installed in property;
 2. heat production measured;
 3. fixed amount paid based on output, technology type and system size.
- ❑ There is a separate non-domestic scheme.
- ❑ Changes made in May 2018



Domestic tariffs

Applications submitted	Biomass boilers and stoves (p/kWh)	Air source heat pumps (p/kWh)	Ground source heat pumps (p/kWh)	Solar thermal (p/kWh)
01/04/2017-30/06/2017	4.28p	7.63p	19.64p	20.06
01/07/2017 - 19/09/2017	3.85p	7.63p	19.64p	20.06p
20/09/2017-31/12/2017	6.54p	10.18p	19.86p	20.06p

Green Deal (2012 - 2015)

- ❑ Homes and businesses carry out energy refurbishments (insulation, boiler and glazing replacement, advanced control *etc.*) funded by a loan (<£10,000).
- ❑ Loan repaid through energy bill (<25 years) with the additions expected to be outweighed by the cost savings from the energy measures.
- ❑ Loan lodged against the property (not owner/occupier) and passed on if sold.
- ❑ Green Deal Assessors produce Green Deal Reports prior to the appointments of Green Deal Providers (source quotes, overseeing installation, provide loan).
- ❑ Includes an Energy Company Obligation to pursue affordable warmth and energy efficiency for hard to treat homes.
- ❑ Golden rule: loan repayment must not exceed the expected monetary savings as evaluated by a prescribed modelling package (savings not guaranteed – occupancy change, product failure).
- ❑ Will result in end of subsidies under the carbon saving obligation of the ECO and subsidies for low carbon electricity supply technologies.
- ❑ Market penetration level low because scheme is optional.
- ❑ Proposed that from 2018 it be illegal to own a property that does not achieve at least an E rating.



www.alamy.com/showcase/architecture.asp

Kyoto Protocol (2005 – 2012)

❑ Commitment to limit or reduce emissions of 4 greenhouse gases:

- carbon dioxide;
- methane;
- nitrous oxide;
- sulphur hexafluoride.



https://upload.wikimedia.org/wikipedia/commons/thumb/6/6e/Kyoto_Protocol_parties.svg/350px-Kyoto_Protocol_parties.svg.png

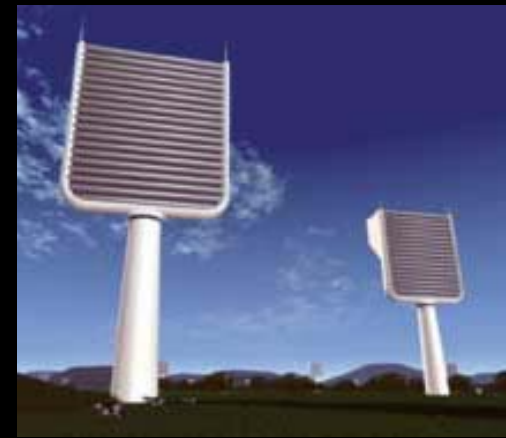
About Kyoto

Included:

- the effects of international carbon trading? Yes
- our share of emissions from international air travel? No
- our share of emissions from international shipping? No
- the effects of importing and exporting manufactured goods? No

What does this tell us about the validity of the results from the Kyoto exercise?

- EU has announced a commitment to obtain 20% of total energy and 10% of transport fuel from renewable sources by 2020:
 - seems ambitious since it would require ~35% of electricity to come from renewables;
 - how much environmental damage is presently caused by bio-fuel production?



Other options: CO₂ capture using liquid sodium hydroxide as absorbent?

Paris Climate Accord 2016

- ❑ To keep global temperatures "well below" 2 C above pre-industrial times and "endeavour to limit" them even more, to 1.5 C
- ❑ To limit the amount of greenhouse gases emitted by human activity to the same levels that trees, soil and oceans can absorb naturally, beginning at some point between 2050 and 2100.
- ❑ To review each country's contribution to cutting emissions every five years so they scale up to the challenge.
- ❑ For rich countries to help poorer nations by providing "climate finance" to adapt to climate change and switch to renewable energy. The agreement requires rich nations to maintain a \$100 bn a year funding pledge beyond 2020, and to use that figure as a "floor" for further support agreed by 2025.
- ❑ The national pledges by countries to cut emissions are voluntary, and arguments over when to revisit the pledges - with the aim of taking tougher action - have been a stumbling block in the talks.

IPCC Special Report 15, *Global Warming of 1.5°C*, September 2018

<http://www.ipcc.ch/report/sr15/>

- ❑ 91 authors and review editors from 40 countries prepared the report.
- ❑ “We are already seeing the consequences of 1°C of global warming through more extreme weather, rising sea levels and diminishing Arctic sea ice, among other changes.”
- ❑ By 2100, global sea level rise would be 10 cm lower with global warming of 1.5°C compared with 2°C.
- ❑ The likelihood of an Arctic Ocean free of sea ice in summer would be once per century with global warming of 1.5°C, compared with at least once per decade with 2°C.
- ❑ Coral reefs would decline by 70-90 percent with global warming of 1.5°C, whereas virtually all (> 99 percent) would be lost with 2°C.
- ❑ “The good news is that some of the kinds of actions that would be needed to limit global warming to 1.5°C are already underway around the world, but they would need to accelerate.”
- ❑ Containment will require rapid, far-reaching and unprecedented changes in all aspects of society.

W/m² – the key to the problem?

Supply

<i>Renewable source</i>	<i>Potential yield (W/m²)</i>
rainfall for hydro power	up to 0.3
energy crops	up to 0.5
wind	2 to 3
solar PV	5 to 20
solar concentrators	about 15

On this basis, direct use of solar energy is by far the most promising idea

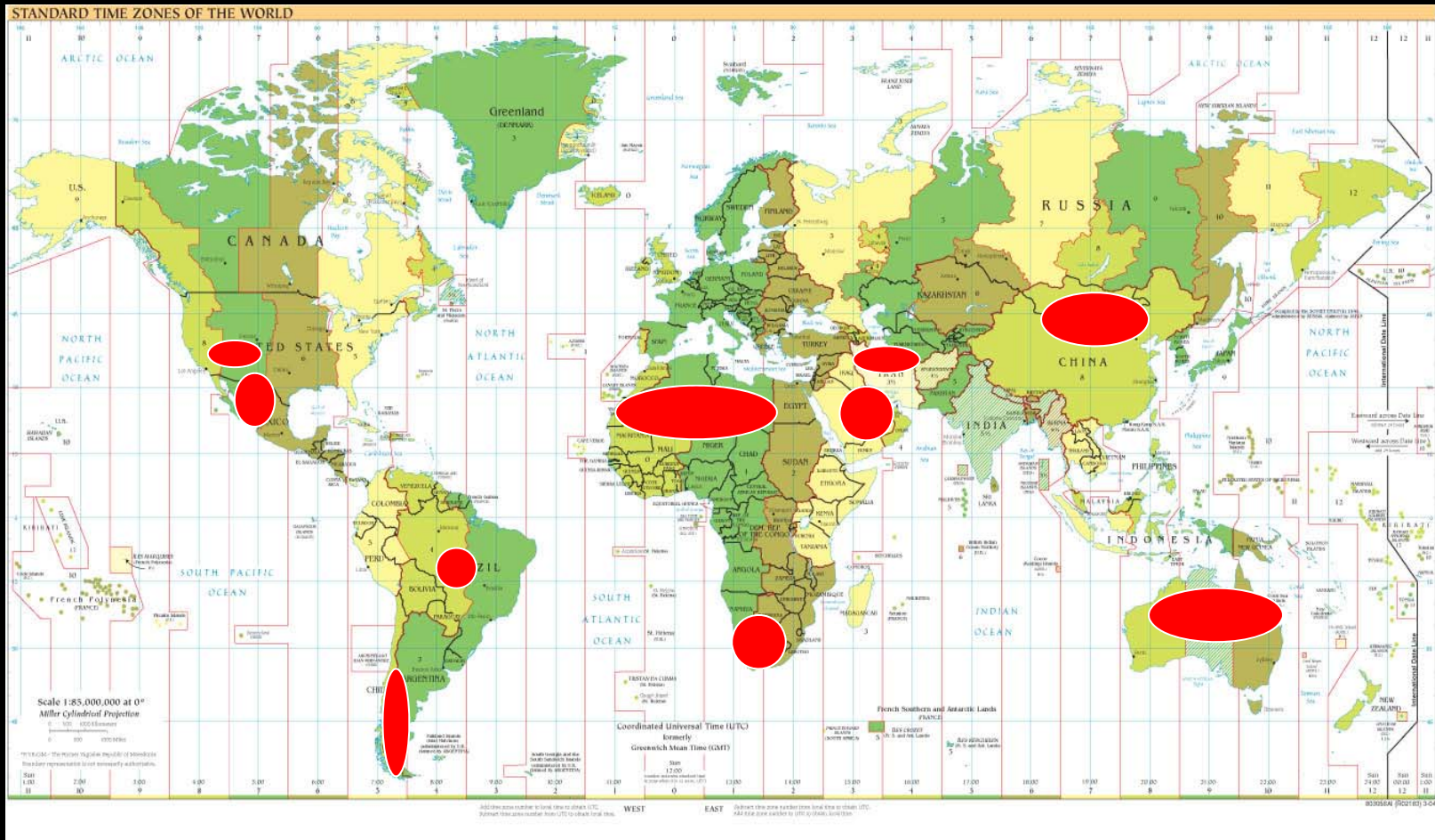
Demand

	<i>Population (M)</i>	<i>Persons/km²</i>	<i>Power (W/m²)</i>
Scotland	5.1	64	0.3
UK	60	243	1.3
Europe	496	115	0.3
World	6440	43	0.1

Regions with a demand in excess of 0.1 W/m² will struggle to survive on the use of renewables alone without heavy industrialisation of the landscape. When demand approaches 1 W/m², self-sufficiency is impossible.

Source: MacKay, Energy without the hot air

Firm power from direct conversion of solar energy



World desert regions.