REF

RENEWABLE ENERGY FOUNDATION

# THERMO-ECONOMICS

## Energy, Entropy, and Wealth

*The dangers of current renewables policies and energy taxation*

Dr John Constable

Greenough Society, UCL

30 October 2014

# Renewable Energy Foundation

- Energy policy think tank, and UK registered charity
- No political affiliation, supported by private donations and research contracts
- REF publishes searchable databases:
  - Performance data for all renewable electricity generation for which there is public domain data in the UK (10,000 sites)
  - Feed-in Tariff lists: 500,000 sites
  - GB electricity fuel mix by half hour since 01.01.09
- Occasional analytic papers

# Summary

- Energy is not just another economic input: negative entropy *constitutes* wealth.
- Government should not be relaxed about the costs of current energy taxation or energy and climate policies, because:
  - Taxes and levies will result in long term economic poisoning, wealth destruction, and salient reductions in standard of living.
  - A mandated energy transition against the cost gradient will cause politically controversial of concentrations of power and wealth.
- Current energy and climate change policies premised on the deployment of existing technologies are not economically sustainable.

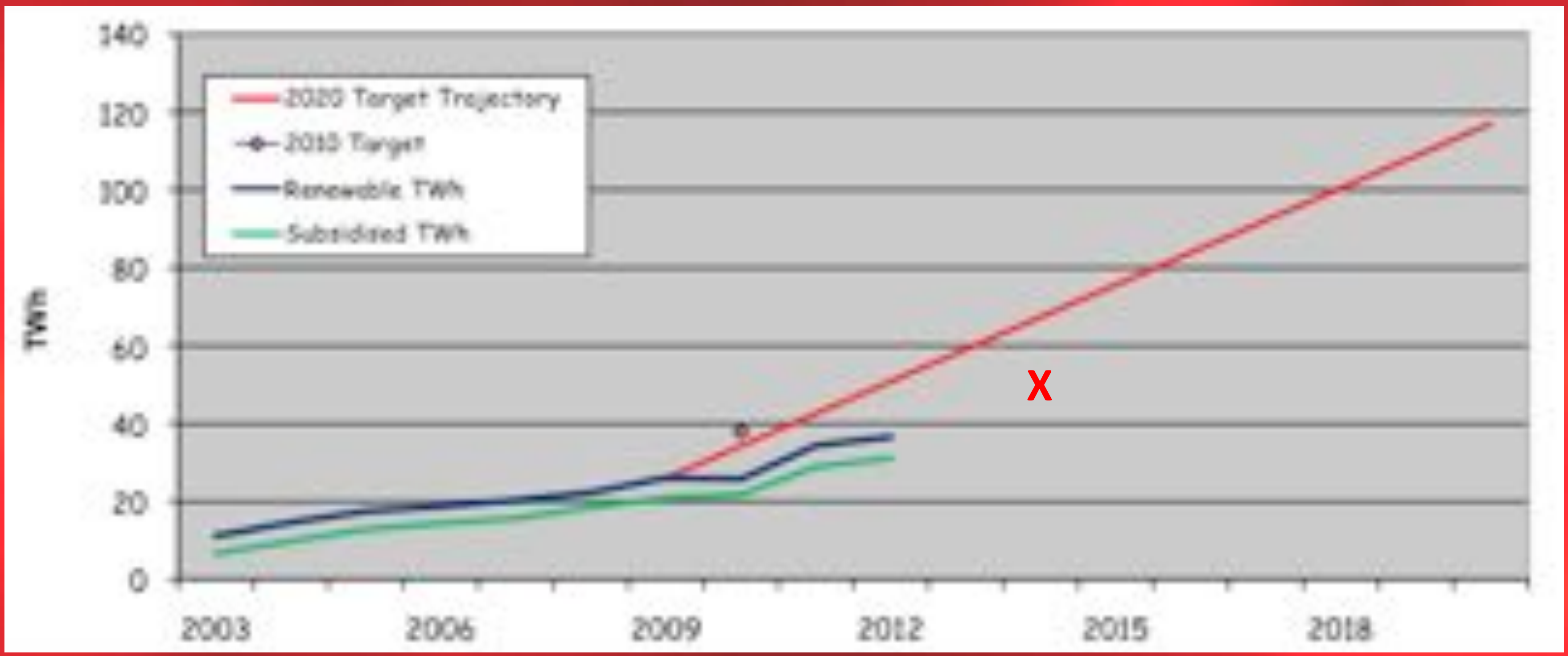
# Impositions on Energy in the UK

- Tax on transport fuels:
  - £27 billion a year (60% of the pump price)
    - Perhaps the most significant brake on economic development in the UK in the post-war period
- £3 billion a year to subsidise mandated transition to renewable electricity
    - Rising to ca. £8 billion a year in 2020, for 30% of electricity consumption
    - System costs of about £5bn a year, so total  additional cost = £13bn a year in 2020, for decades

# European Union Renewables Directive (2009)

- 20% of EU 27 Final Energy Consumption (FEC) in 2020 to be from renewable sources
- UK burden share: 15% of FEC
  - Largest increase of any major state
  - > 25% of EU-wide costs fall on the UK
    - Current renewable electricity subsidy cost > £3bn per year
- UK FEC = 150 mtoe x 0.15 = 22.5 mtoe = 260 TWh
- Electricity target 120 TWh (30% of UK electricity)
- 140 TWh from transport fuel (10%) and heat (12%)

# Meeting the EU 2020 Target…

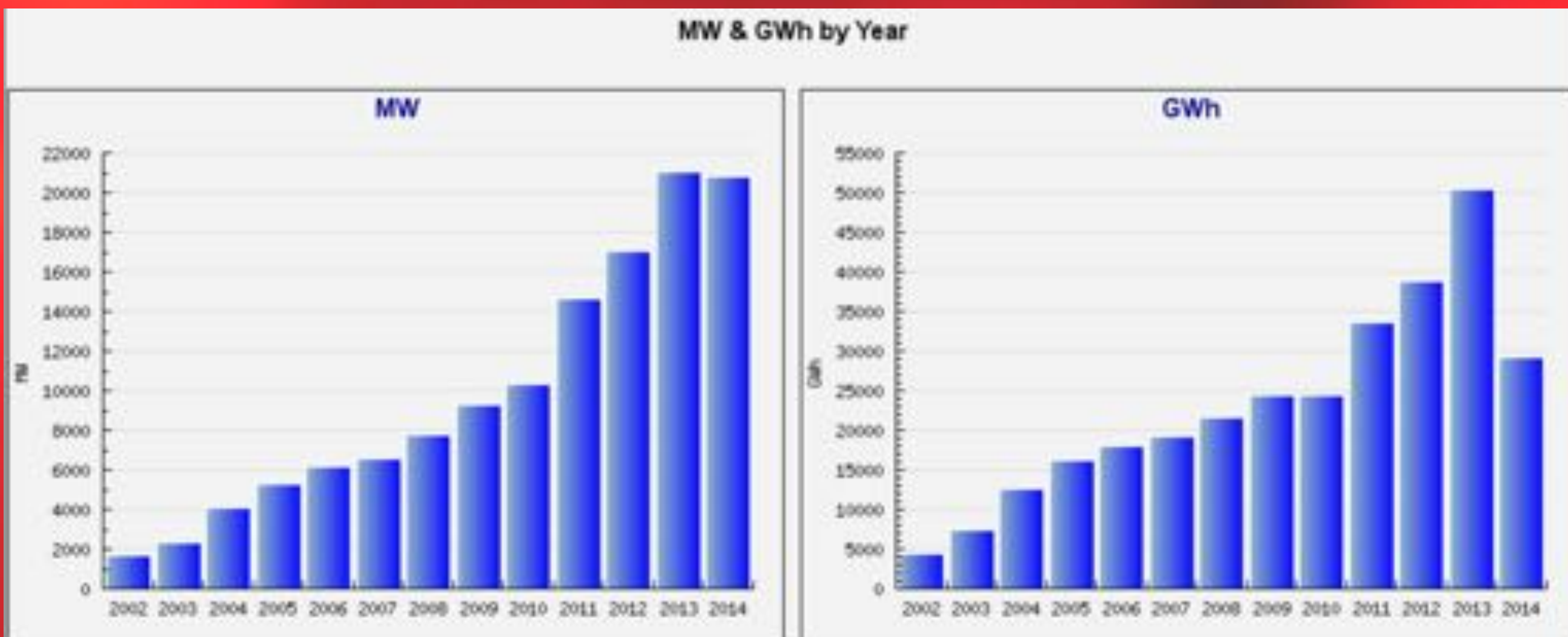



X = Current Renewable Electricity Output ca. 50 TWh, of which about 3 TWh is unsubsidised

Source: DECC, Ofgem data, REF estimates. Chart by REF.

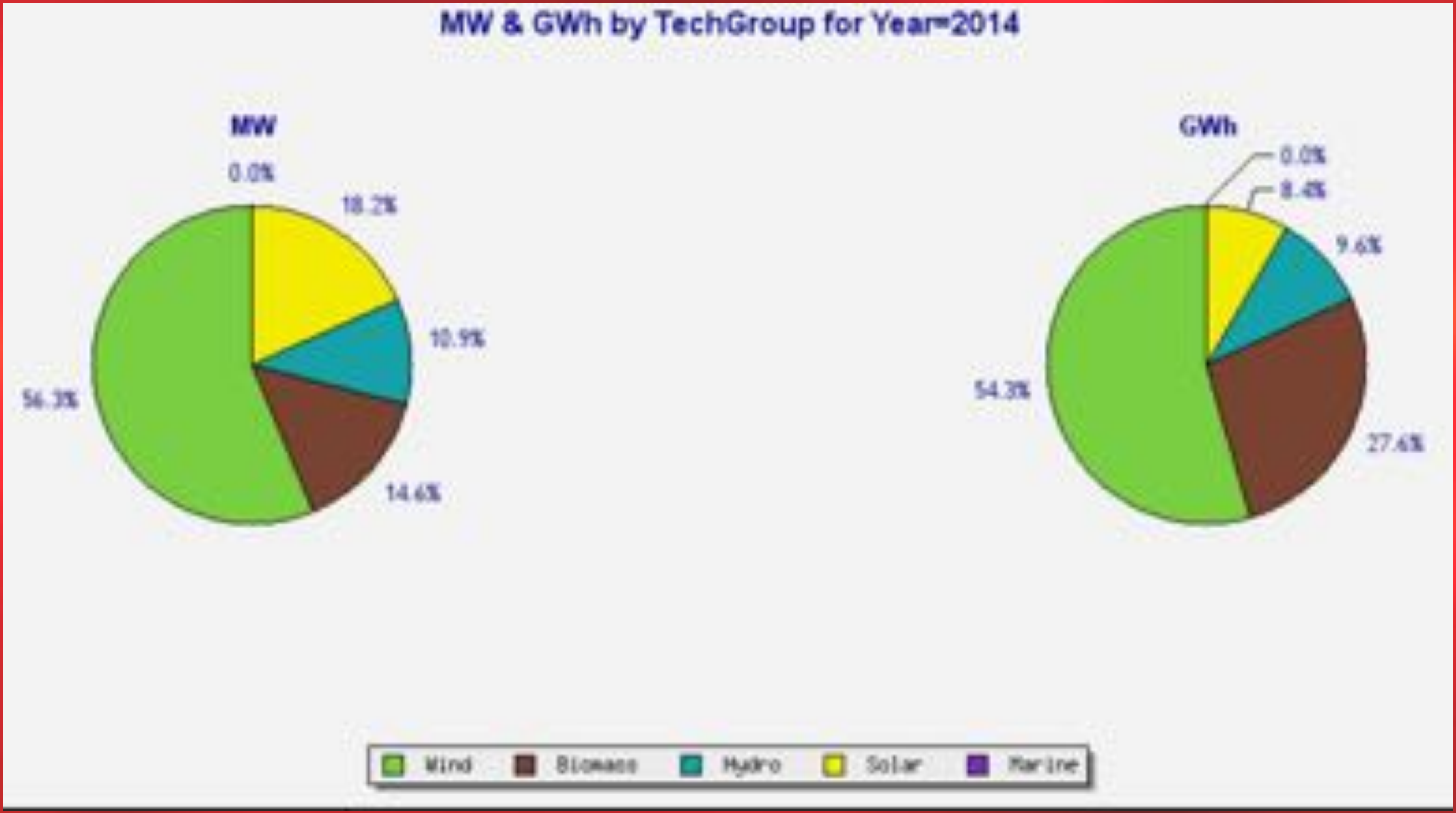
# United Kingdom Renewable Electricity: Capacity and GWh, 2002–

Annual Subsidy Cost: £3bn: Cumulative Cost so far > £12 billion
Output = 16% of UK electricity consumption



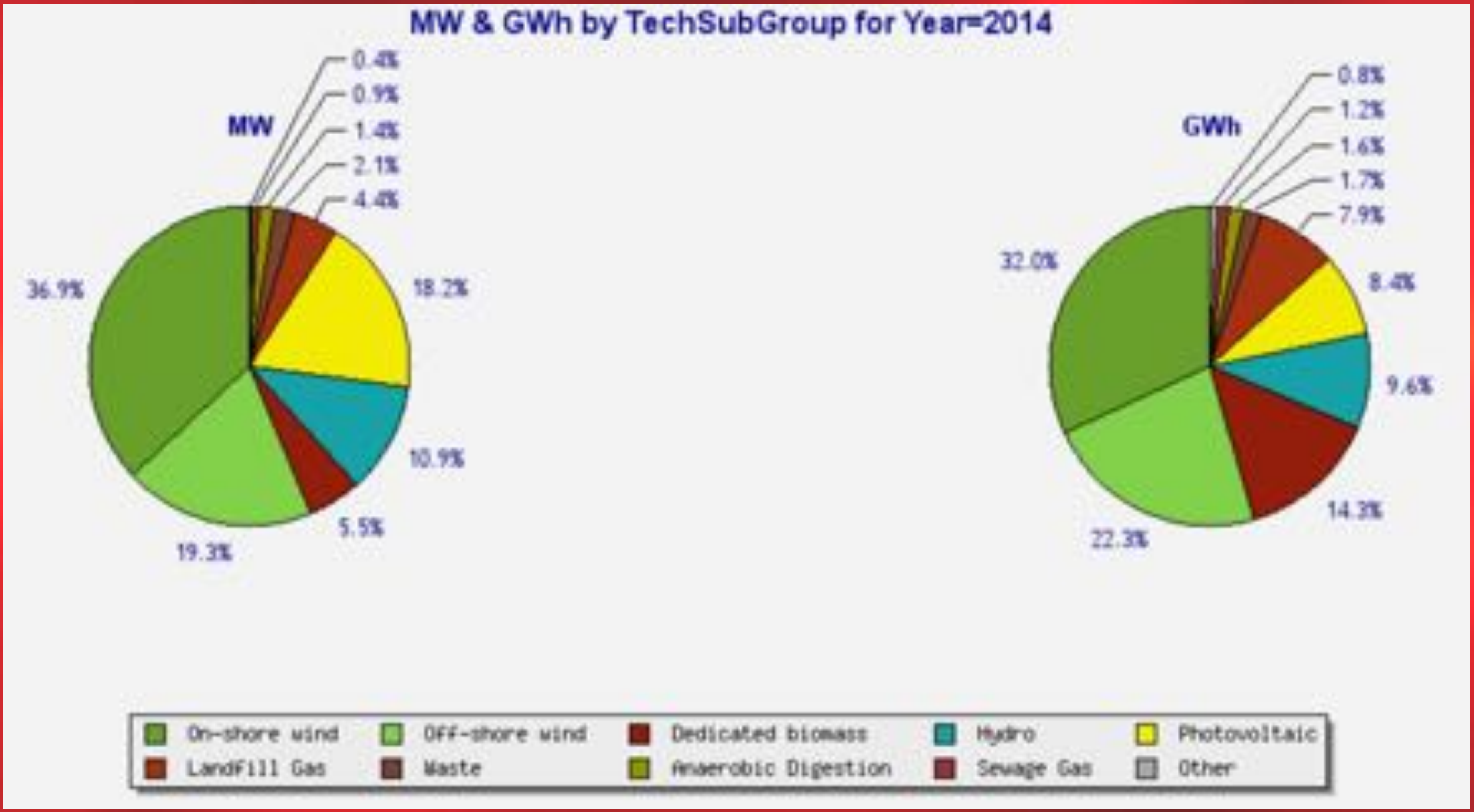

Source: www.ref.org.uk. Data from Ofgem.

# Capacity and GWh by Technology: 2014




Source: www.ref.org.uk. Data from Ofgem.

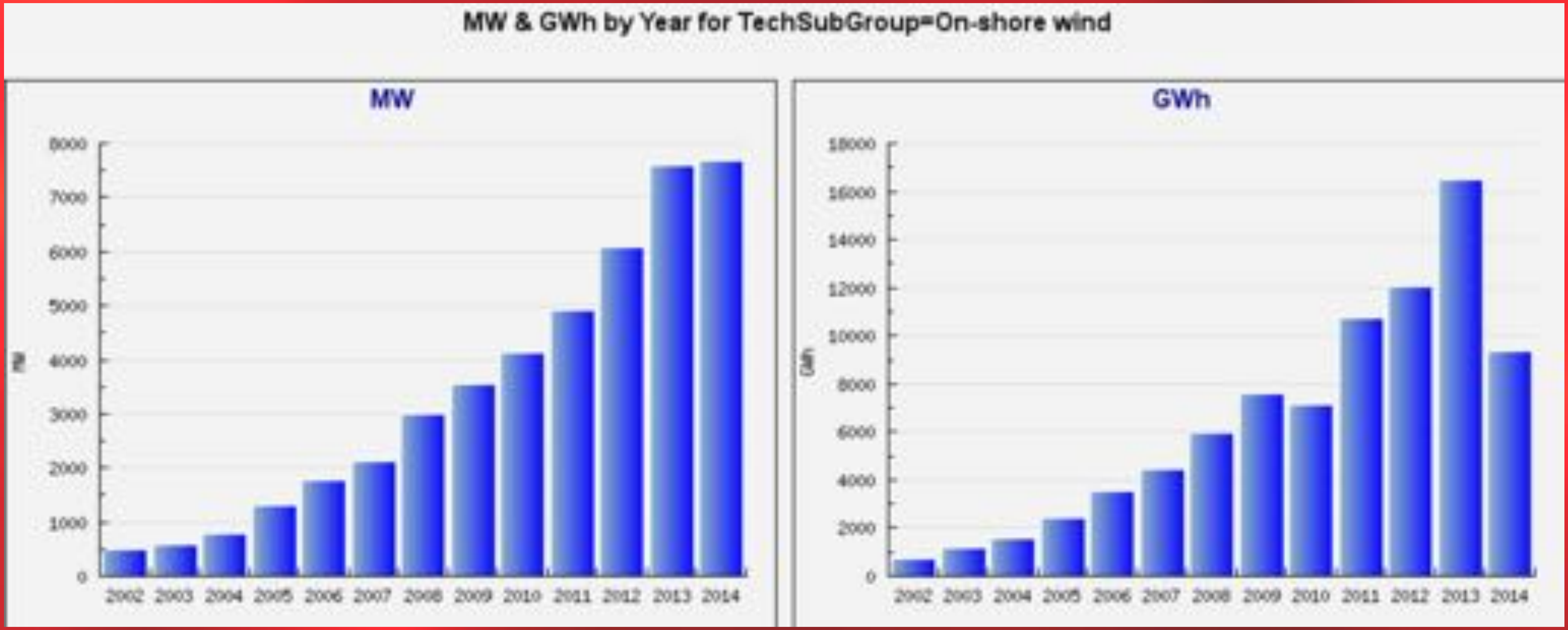
# Capacity and GWh by Technology: 2014




Source: www.ref.org.uk. Data from Ofgem.

# Onshore Wind

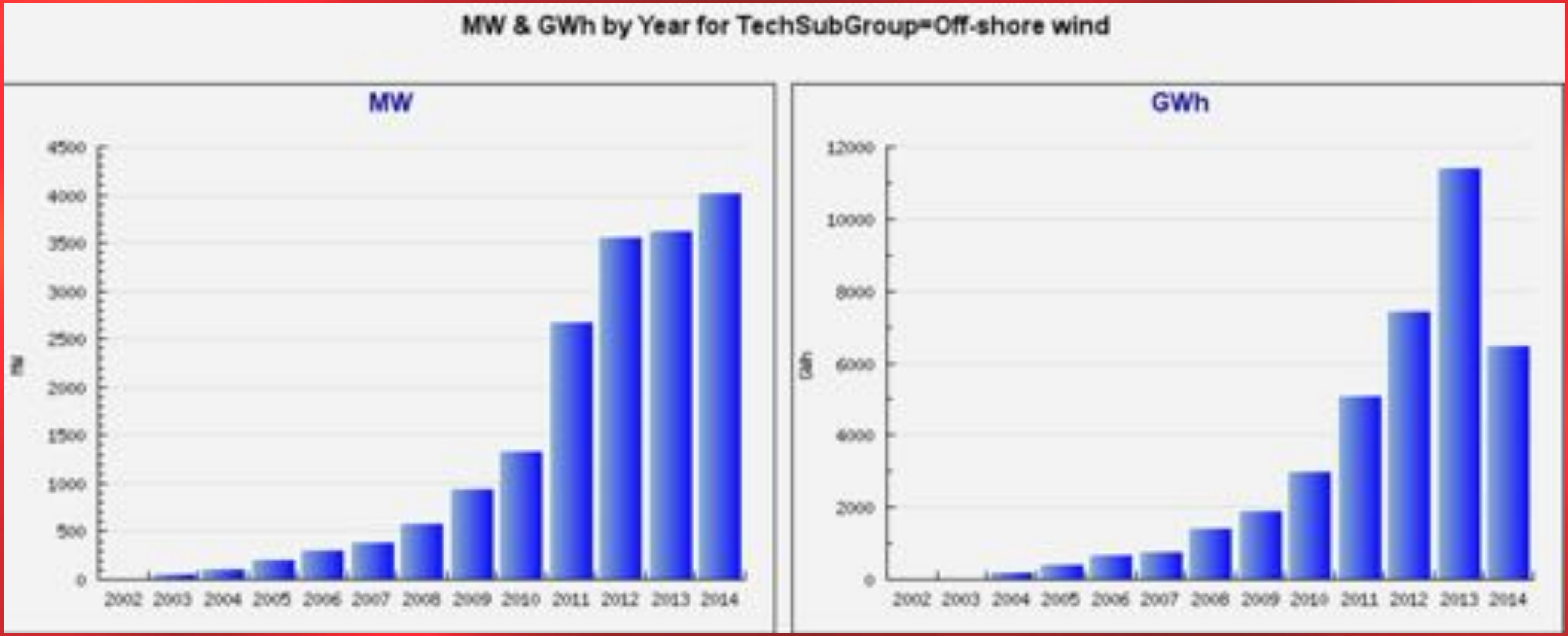
Capital Cost ca. £8bn: Annual Subsidy Cost: £700m
Output = 5.5% of UK annual electricity consumption




Source: www.ref.org.uk. Data from DECC, Ofgem.

# Offshore Wind

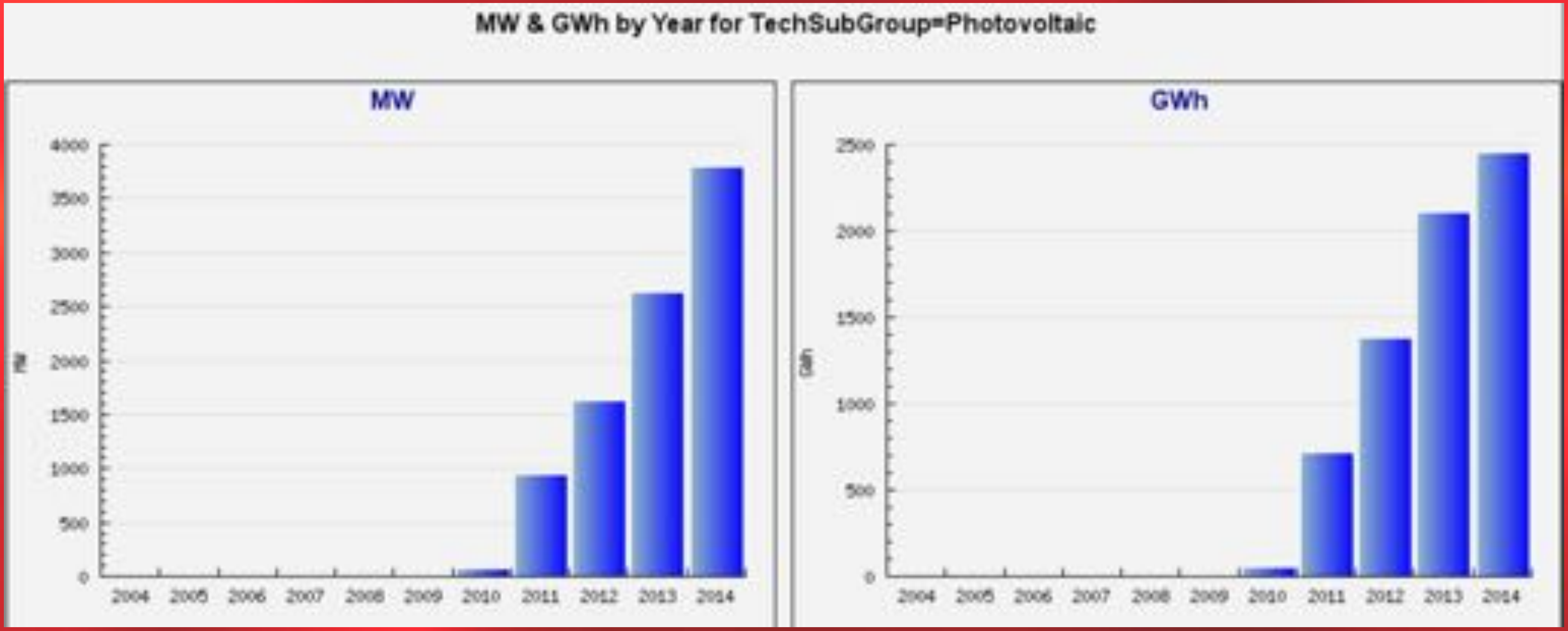
Capital Cost ca. £10bn: Annual Subsidy Cost: £1bn
Output = 4% of UK annual electricity consumption




Source: www.ref.org.uk. Data from Ofgem.

# Solar Photovoltaic

Capital Cost ca. £5bn–10bn: Annual Subsidy Cost: > £300m
Output = 1% of UK electricity consumption

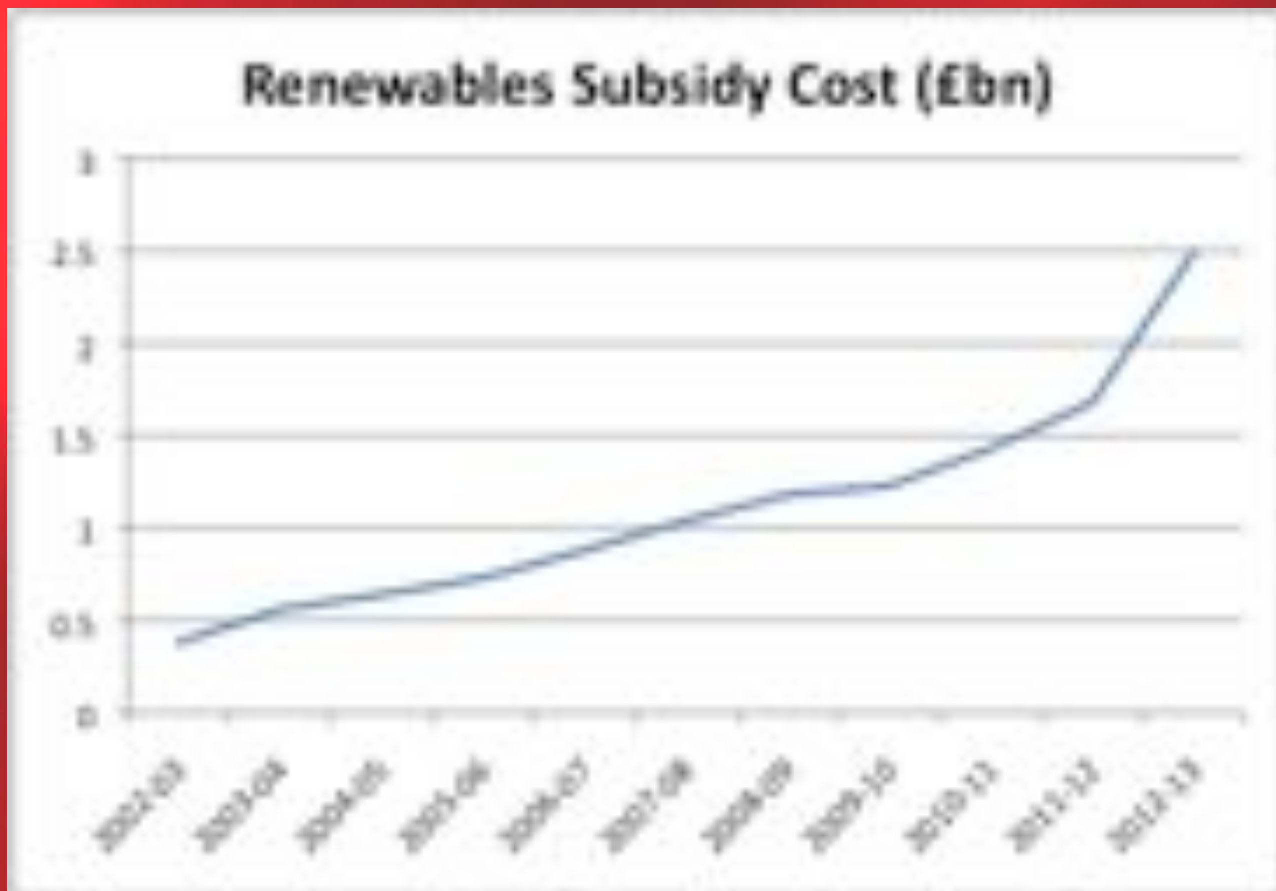



Source: www.ref.org.uk. Data from Ofgem.

# Renewables Obligation + Feed-in Tariff Subsidy Costs

## Cumulative Cost: 2002–2013: £12.2bn

## Annual Cost in 2013/14: > £3bn



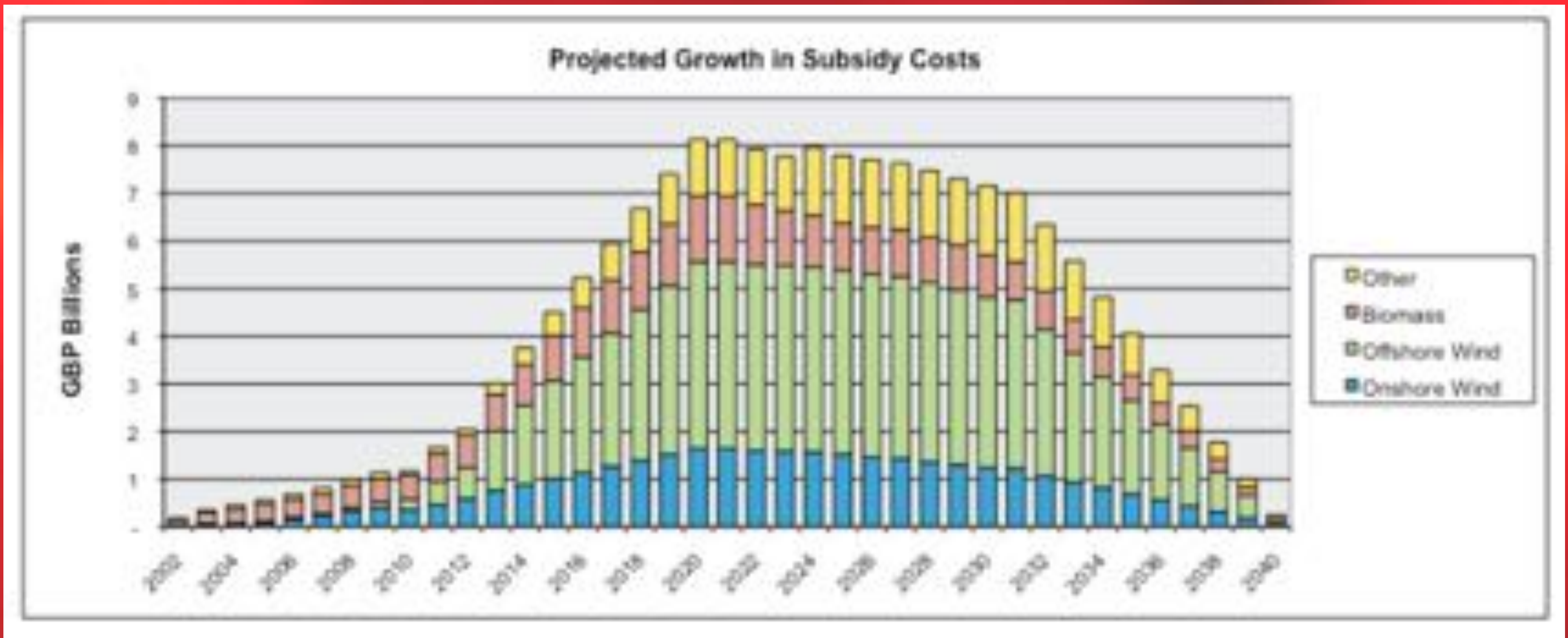

Source: Chart by REF. DECC Data (Real 2012/13 prices).

# Subsidy Costs per MWh (2012)

- Feed-in Tariff: £260 per MWh
  - £520/tCO2 abated
- Renewables Obligation: £58 per MWh
  - £116/tCO2 abated
- Cf: Wholesale price £50 per MWh so
  - Average income per MWh in the FiT = £310/MWh
  - Average income per MWh in the RO = £108/MWh

# Renewable Electricity Cumulative Subsidy 2002–2040

- Assumptions: Current subsidy levels; no new capacity after 2020; DECC technology pipeline projections
- Cumulative subsidy Cost 2002–2040: ca £162bn




Source: REF. Based on DECC's pipeline projections in *Renewable Energy Roadmap* 2013.

# DECC: 2020 Electricity Price Policy Impacts

- Domestic Households
  - Low fossil price scenario: + £54/MWh (+ 44%)
  - High fossil price scenario: + £45/MWh (+ 26%)
- Medium Sized Businesses
  - Low fossil price scenario: + £48/MWh (+74%)
  - High fossil price scenario: + £37/MWh (+33%)
- Even in DECC's High Fossil Price scenario prices rise by ca. 30% due to climate and other policies

Source: DECC, *Estimated Impacts of Energy & Climate Policies on Prices and Bills* (2013)

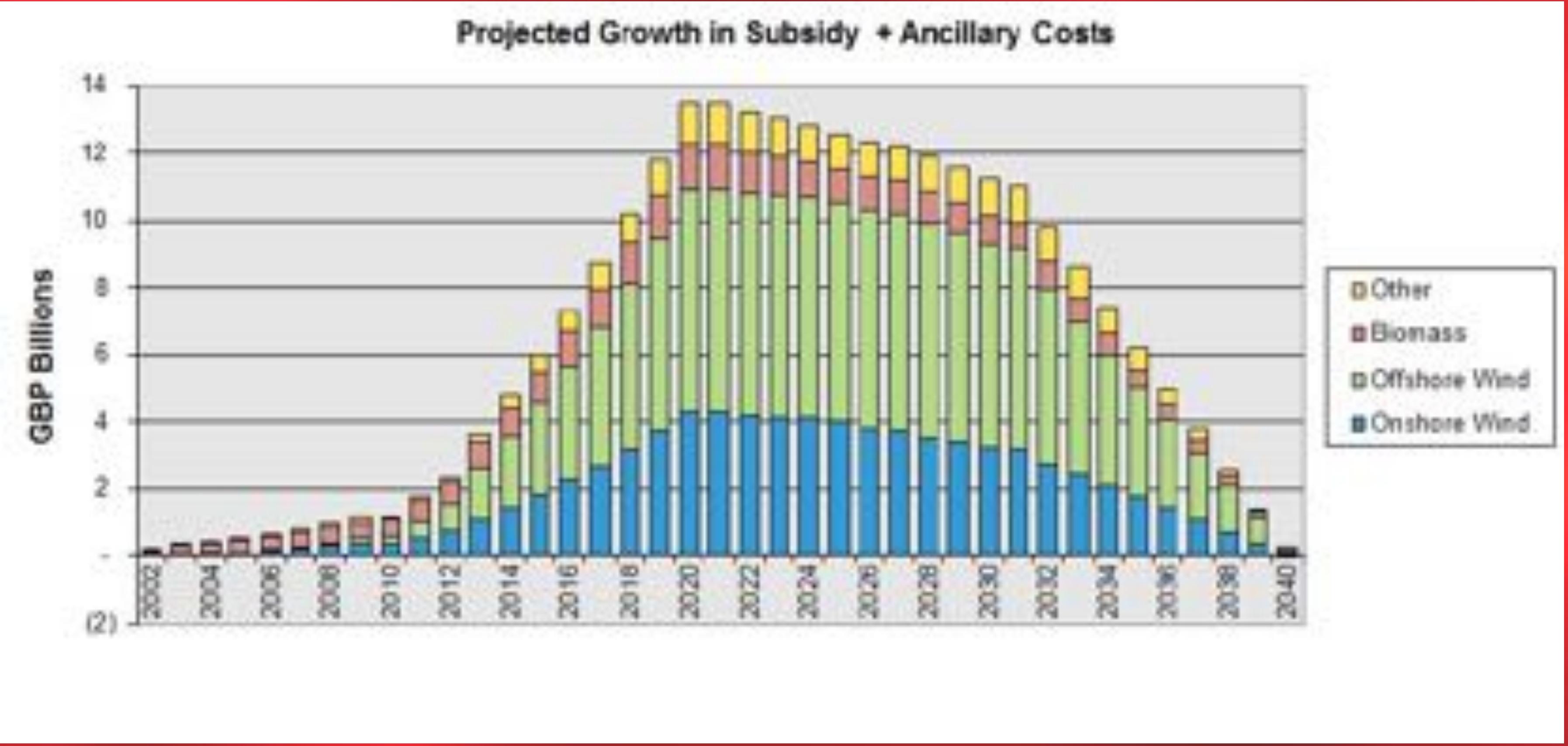
# Wind Power System Integration Costs: Grid, Balancing, Security of Supply

| Technology | Subsidy (£/MWh) | System Cost (£/MWh) *over and above* the system cost of conventional generation | Total (£/MWh) |
|---|---|---|---|
| Onshore Wind | £45 | £75 | £120 |
| Offshore Wind | £95 | £64 | £159 |
| Biomass (Conversion) | £50 | £0 | £50 |
| Biomass (Dedicated) | £75 | £0 | £75 |

Source: Colin Gibson, "Levelised costs estimates for electricity generation", (Institute of Engineers and Shipbuilders in Scotland: 2011): http://www.iesisenergy.org/lcost/

# Renewables Subsidy + Integration Costs

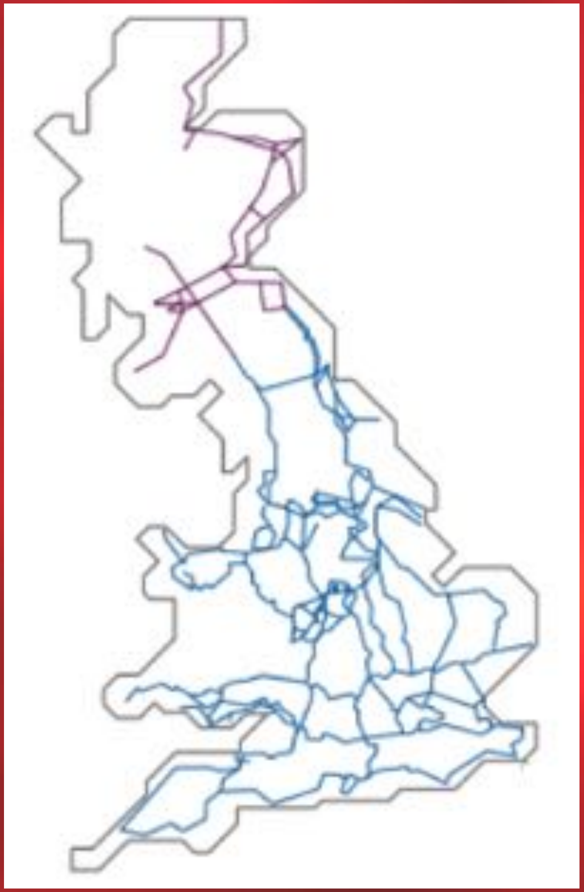
## Total Cost 2002–2040: ca. £256bn




Source: REF. Based on DECC Pipeline projections. Ancillary costs based on Colin Gibson for IESIS (2011).

# Integration Problems: Constraint Payments to Wind Power

- Total 2010 to 27.10.14: £93m
  - £32.7m in 2013
  - £41m so far in 2014
- **Almost all in Scotland**
  - **Behind the B6 Boundary**
- Average price in 2013 to reduce generation: **£86/MWh**
  - **1.7 times the lost income**
- **But "constraining wind off the system may be cheaper than building more network"**
  - Colin Gibson, Former National Grid Power Networks Director

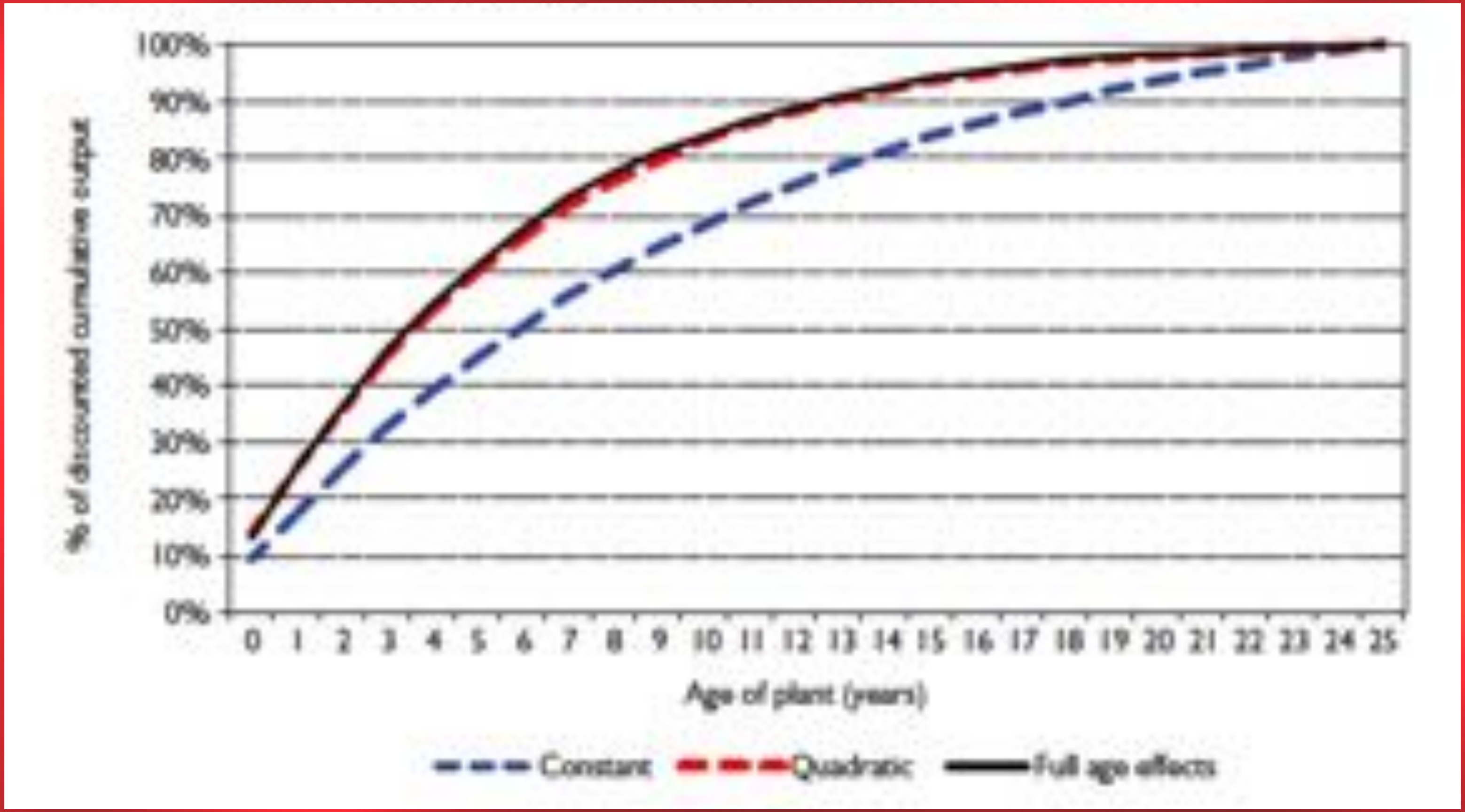


The UK HV Network
Source: National Grid

# Economic Lifetime of Wind Turbines

- Gordon Hughes, *The Performance of Wind Farms in the United Kingdom and Denmark* (REF: London, 2012).
- The normalised load factor for UK onshore wind farms declines from a peak of about 24% at age 1 year to 15% at age 10 years and 11% at age 15 years.

# Load Factor Decline and Discounted Cumulative Output: UK Onshore




Source: Hughes, *The Performance of Wind Farms in the UK and Denmark* (2012)

# Implications of Short Wind Turbine Lifetime

- Higher lifetime policy cost (shorter capital refreshment cycle)
- Higher levelised cost per MWh (current subsidies may not be sufficient to make all projects profitable)
- Wind is a dubious asset class and long term ownership of wind turbines less attractive
  - Most profits are in development stage, and dependent on early exit

# Renewables Policy Costs
# Conclusions and Questions

- Annual subsidy costs and system costs are very high
  - Very high cost per tonne of $CO_2$ abated: not economically compelling to developing world
- Cumulative costs are macro-economically significant
- Why does government remain relaxed?
  - "Efficiency measures will reduce demand"
  - "Direct energy costs are a small % of business costs"
  - "Factor substitution"
- Is government right?

# DECC 2020 Electricity Price Policy Impacts

- Domestic Households
  - – Low fossil price scenario: + £54/MWh (+ 44%)
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Source: DECC, *Estimated Impacts of Energy & Climate Policies on Prices and Bills* (2013)

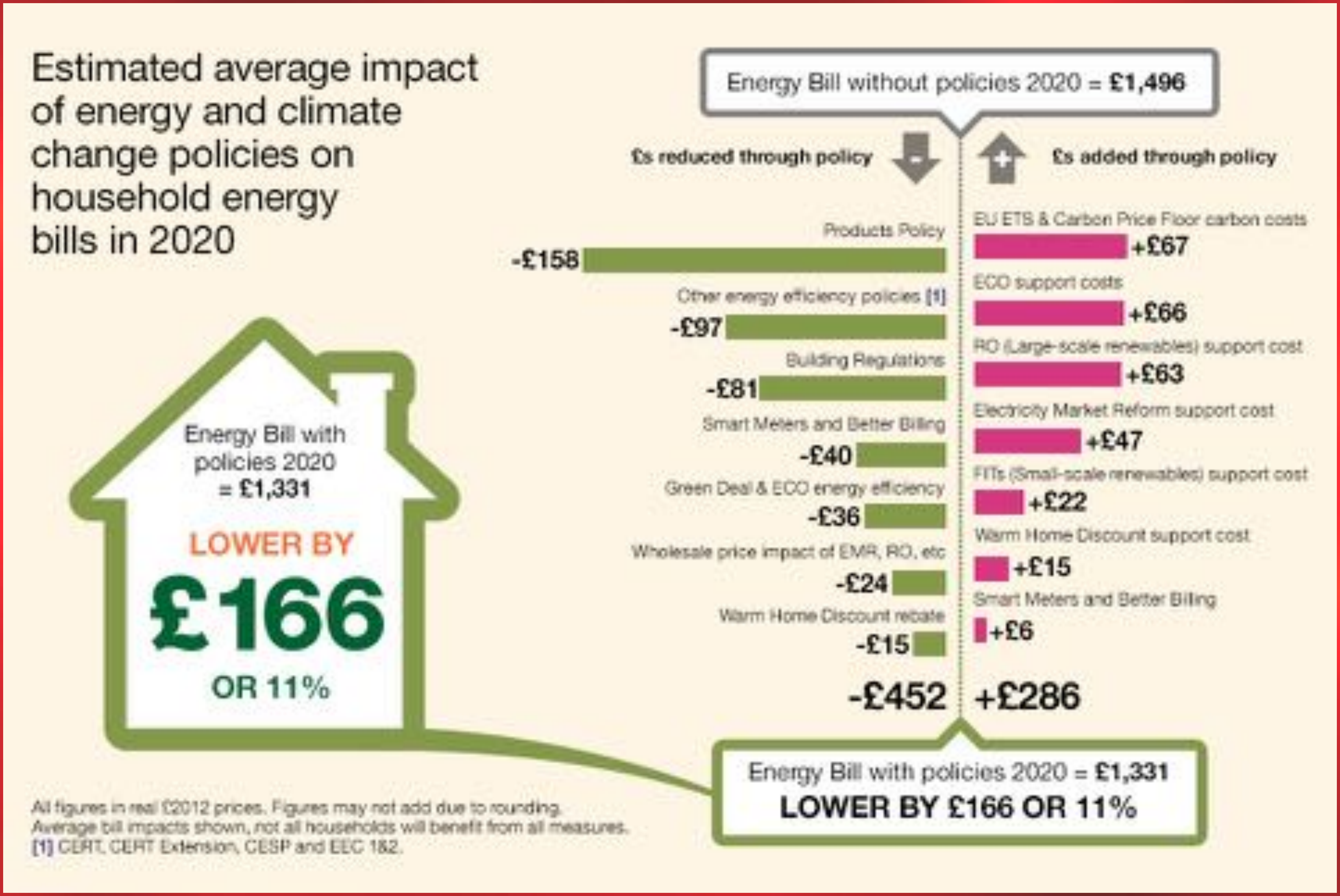
# DECC on Policy Costs

- Domestic Impacts
  - "[…] taken together [i.e. subsidies plus efficiency drives], the Government's policies mean that household bills will be on average 11%, or £166, lower in 2020"
- Commercial Impacts
  - "For most businesses, direct energy costs are a relatively small proportion of total costs. […] around 2.5% of total costs for UK manufacturing as a whole."

Source: DECC, *Estimated Impacts* (2013)

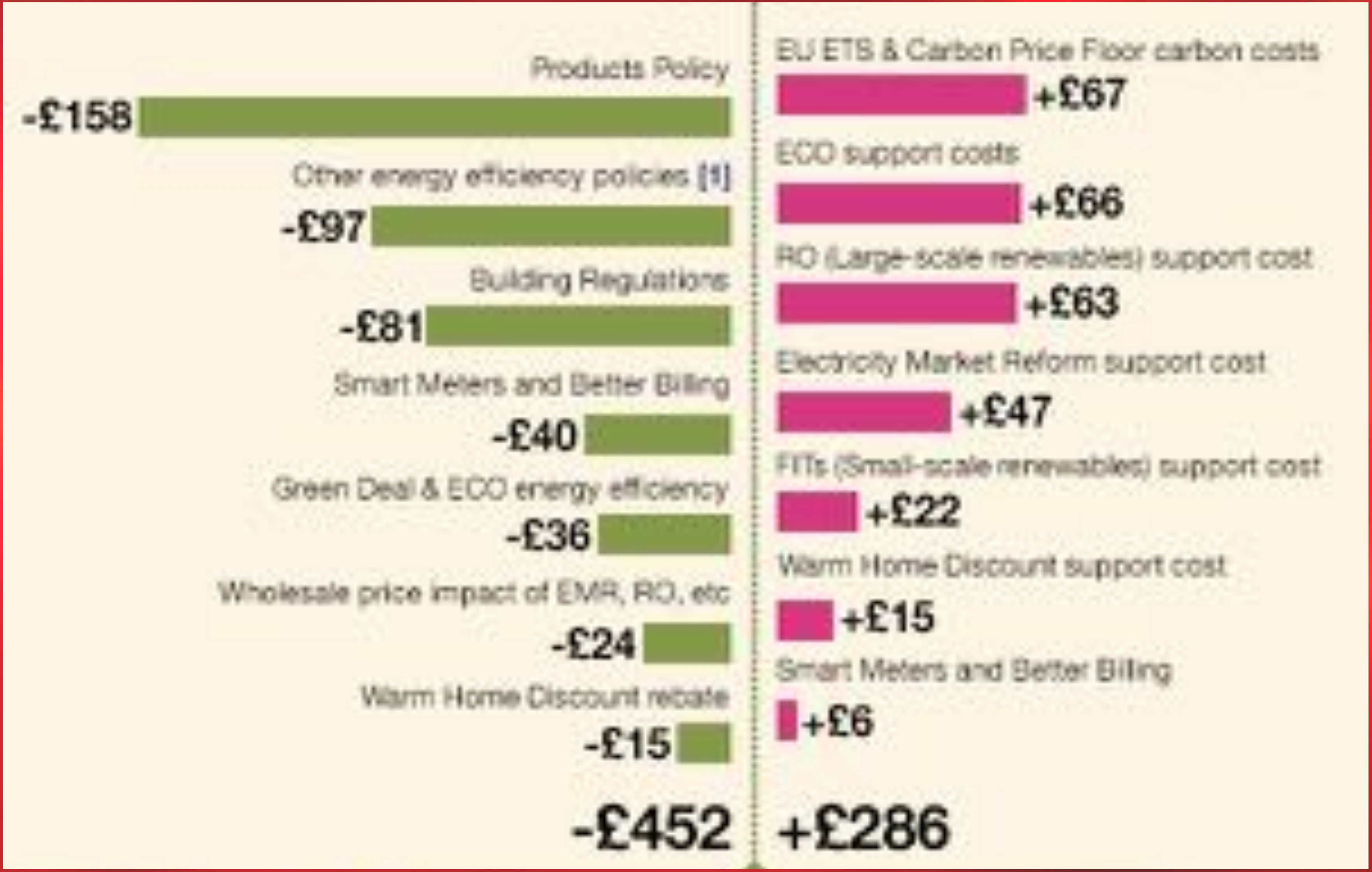
Rt Hon Ed Davey MP
Secretary of State for Energy & Climate Change

# DECC is optimistic about household impacts




Source: DECC (2013)

# Policy Savings & Costs




Source: DECC (2013)

# Efficiency Measures?

- Capital cost of energy efficiency measures is high
- Efficiency measures may not work at all (shortfall)
- Rebound Effect
  - *"[…] it is wholly a confusion of ideas to suppose that the economical use of fuels is equivalent to a diminished consumption. The very contrary is the truth."*
- Distributional effects mean that benefits are not spread evenly over all households
    - See REF, *Shortfall, Rebound, Backfire*

W. S. Jevons (1835–1882)

# Commercial Impacts

- "For most businesses, direct energy costs are a relatively small proportion of total costs. […] around 2.5% of total costs for UK manufacturing as a whole."

  Source: DECC, *Estimated Impacts* (2013)

- Curiously stable since 1911 when direct energy was 3% of the cost of raw cotton (wages = 62%, cost of capital 22%, depreciation and supplies 12%).

  Source: Gregory Clark, *A Farewell to Alms* (2007)

# Efficiency and Factor Substitution

- "If we use less energy we will need to increase other inputs, e.g. more and better capital investment, or improved technique, if labour productivity is to be maintained."
  - Adair Turner, *Just Capital* (Pan Books: London: 2001), 286.

Adair Turner (Lord Turner)

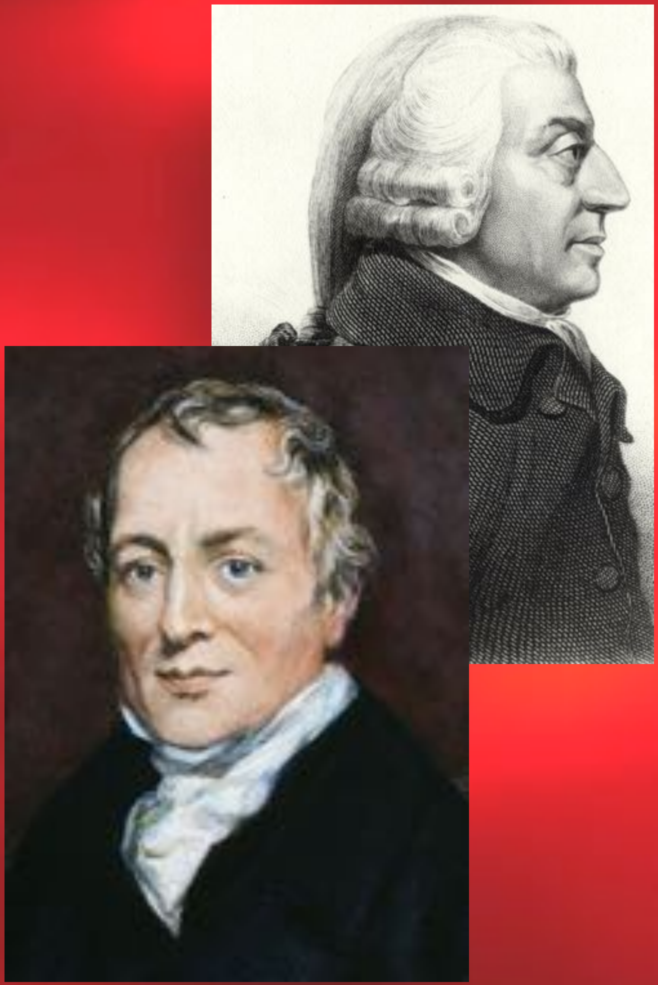
# The Ontology of Wealth

- "[Wealth] is a form or product of energy"
- "The flow of energy should be the primary concern of economics"
  - Frederick Soddy, *Wealth, Virtual Wealth, Debt* (1926)
- Economic growth is a reduction in entropy as a result of energy conversion.

Frederick Soddy FRS
Nobel Prize for Chemistry, 1921

# Smith and Ricardo: The Labour Theory of Value

- "Labour theory" recognises that a prime mover is needed to shape the world in accordance with human purposes and explain the emergence of value.
- "Labour is the real measure of the exchangeable value of all commodities"
  - – Wealth of Nations, V,1



Adam Smith (1723–1790): David Ricardo (1772–1823)

# The Labour Theory: What's Wrong?

- Labour theory not accepted, even by contemporaries:
  - Could not account for all observed growth in value in the pre-industrial period, let alone the mid-nineteenth century
  - Labour theory is central to Marx's ethical polemic, and the association is discrediting
- Labour is only *one* and even in Smith's time not necessarily the most important energy conversion amongst many such conversions performing the work that delivers wealth.

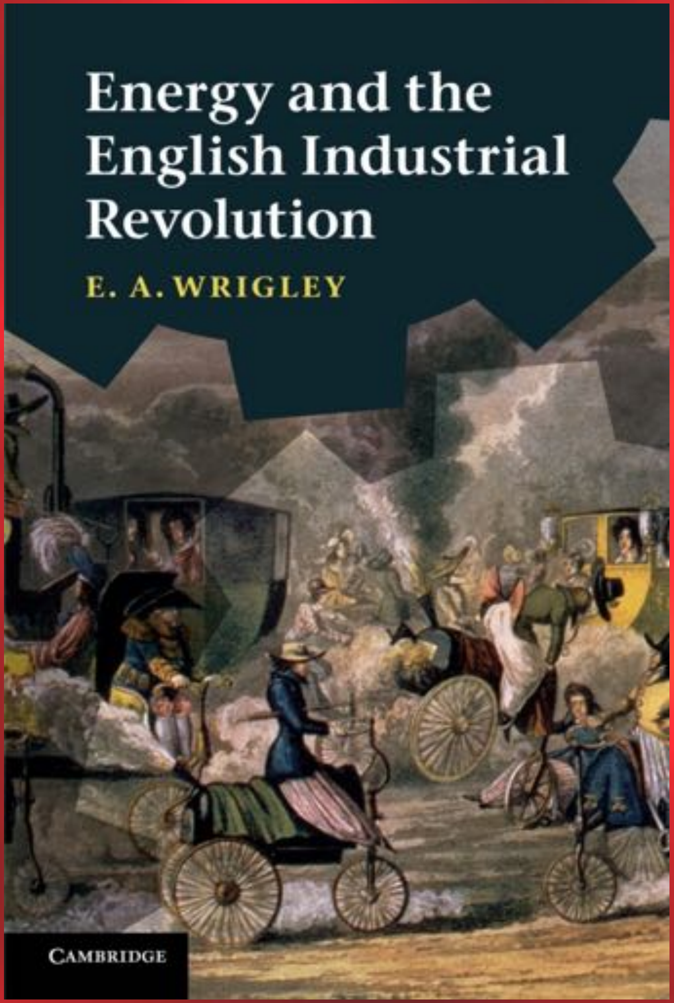
# Energy is No Ordinary Input

- "Coal in truth stands not beside but entirely above all other commodities. It is the material energy of the country—the universal aid […] With coal almost any feat is possible or easy; without it we are thrown back into the laborious poverty of early times."
  – *The Coal Question* (1865)

W. S. Jevons (1835–1882)

# Escaping the Organic Economy…

- "The 'laborious poverty'[…] to which most men and women were condemned did not arise from lack of personal freedom, from discrimination, or from the nature of the political or legal system"
- "It sprang from the nature of all organic economies. […] the plant growth in question represented the bulk of the sum total of energy which could be made available for any human purpose."
  - *Energy and The English Industrial Revolution* (Cambridge 2011), 239.



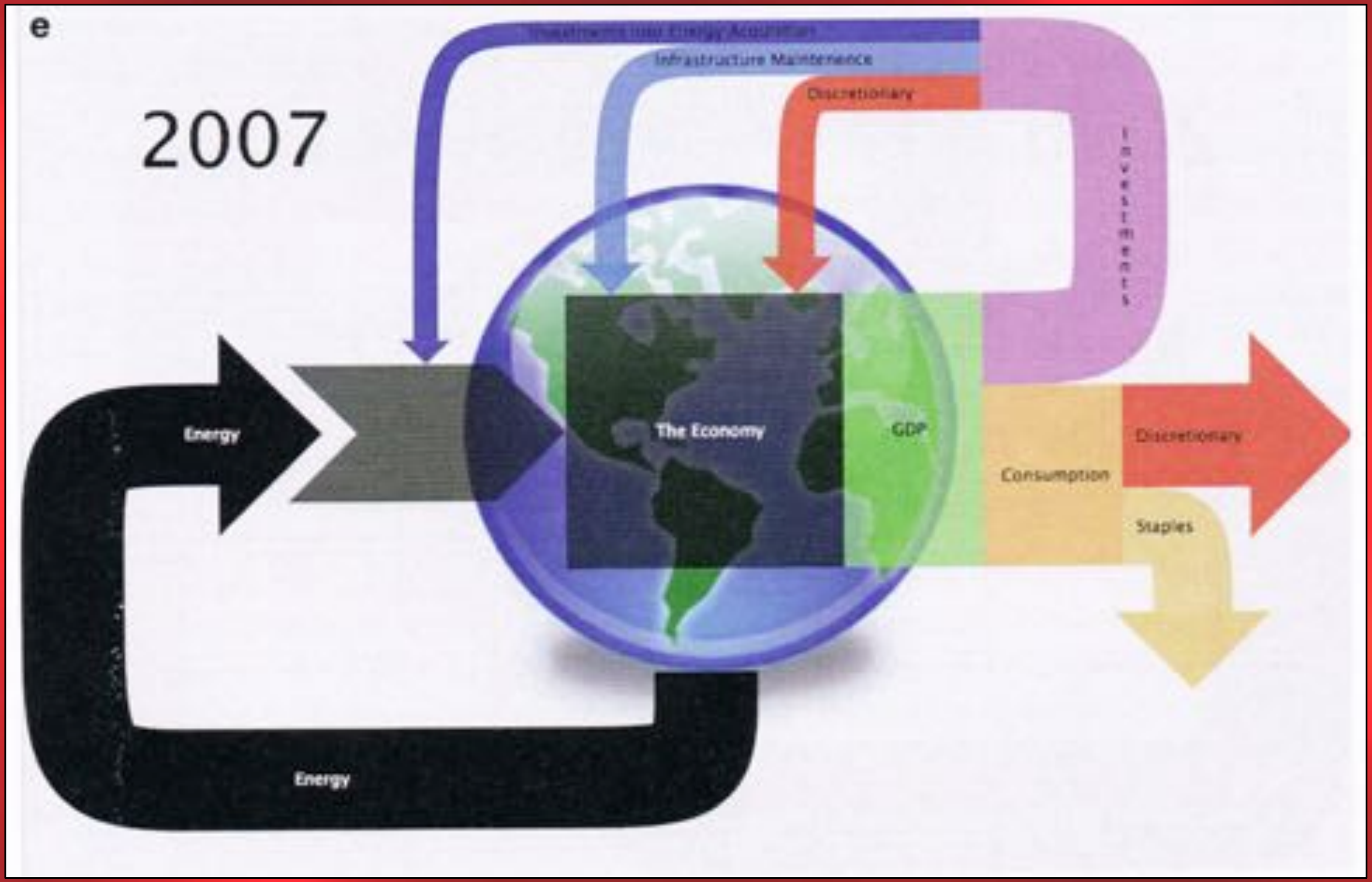
# The Thermodynamic Ontology of Wealth

- Wealth is created by using energy to order the world in accordance with human desires
- This valuable order can be analysed as *improbability*:
  - *Complex structure*: A refrigerator for example, or improved land, but also ideas and institutions
  - *Timeliness*: The glass of cool water in the desert is valuable because it is improbable in that location at our hour of need, and only the use of energy can make its delivery certain
    - Constable, "Thermo-economics" 2014.
- Energy is unsubstitutable, it is rendered as complexity in <u>all</u> inputs

# The Contemporary Human Sphere

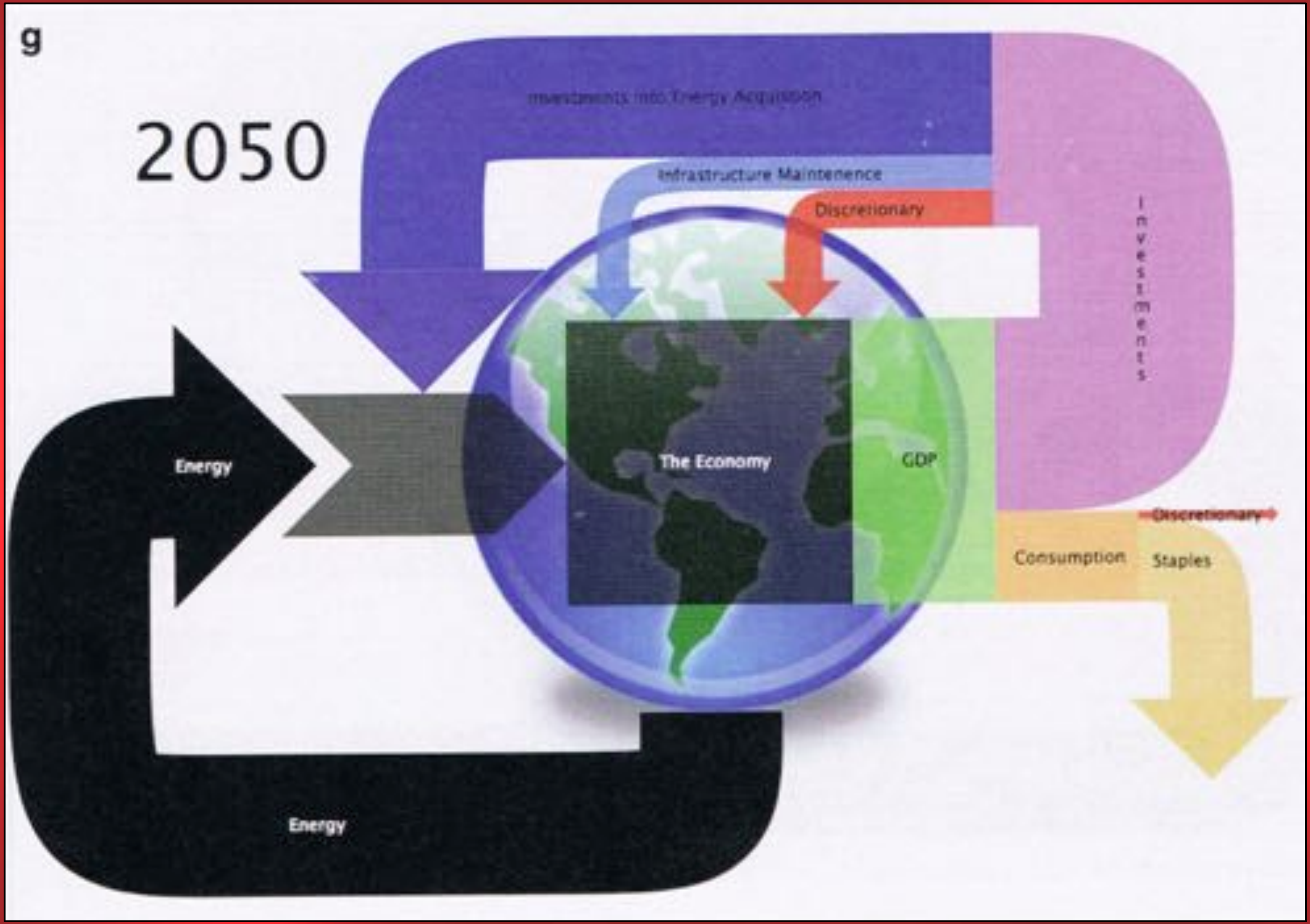
- The human sphere is far from thermodynamic equilibrium
- Current state results from slow accumulation of low entropy stock (capital)
  - Buildings, bridges, improved land, ideas, symbol systems, institutions…
- Previous energy consumption is <u>rendered</u> in the improbable complexity:
  - Cost of energy affects cost of use of capital
- Energy is needed to activate and repair capital
  - **<u>NB: Capital Erosion more important than resource erosion</u>**
- Expanding energy supply needed for economic growth
  - No limit to the convenient modifications to be made to the world

# High EROEI Economy




Source: Charles Hall et al, *Energy and the Wealth of Nations* (Springer 2012)

# Low EROEI Economy




Source: Charles Hall et al, *Energy and the Wealth of Nations* (Springer 2012)

# The Long Term Dangers of Expensive Energy

- A forced energy transition against the cost gradient drives energy resources into the energy generation sector itself, reducing their availability for other purposes.
- The smaller surplus of energy (Energy Return on Energy Invested, EROEI) is now more expensive, and as this surplus is used to repair and refresh capital, so the use of that capital itself becomes more expensive, an effect that will gradually but inevitably reduce general prosperity over time.
  - Constable, “Thermo-Economics” (2014)

# Capital Resources

- Energy costs are rendered in capital stocks, accounting for part of the cost of using those stocks
- Taxes and levies on energy therefore increase the cost of using capital stocks.
  - Germany is already a poisoned economy; the UK is heading in the same direction
- Policy-mandated shift to renewable energy against the cost gradient will concentrate capital resources in the energy sector with a consequent imbalance of wealth and socio-political power.
  - 18th Century landowners employed three quarters of the working population on very low wages

# Conclusion

- The current energy and climate policies are extremely unstable
  - Only low cost emissions reductions have any political future
  - Invention and innovation policies required
- Taxes on energy should be avoided
- OECD economies are all to some degree poisoned with high cost capital stocks resulting from decades of taxation and levies
  - Flushing with cheap energy is the only answer

# Resource or Capital Crisis?

- There is no shortage of 'free energy'
- With free energy we will never lack for resources
- But capital erosion (wealth destruction) may impair employment of the available free energy
- Alexander the Great conquered petroleum producing lands in the Caspian region ca. 330 BC, and saw oil seeps and burning gases but could not profit from this possession.