# Some micro- and macro-economics of offshore wind*

*EPSRC SUPERGEN Wind Energy Hub*
*University of Strathclyde*
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* The research reported here by EPRSC SUPERGEN wind.

# 1. Introduction and background

- Provide a ***flavour*** of some of our micro- and macro-economic analyses of offshore wind.
- On the "micro" side, brief account of our attempt to provide a cost-benefit analysis of offshore wind (others: levelised costs; accuracy of forecasts; portfolio approaches)
- On the "macro" side:
  - consider the appropriate measurement of "green jobs", and provide some indicative estimates of employment effects of offshore wind development
  - explore the impact of projected levelised cost reductions on the penetration of offshore wind

# Policy framework

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- Key objectives of energy policy
  - Environment
  - Security of supply
  - Affordability (competitiveness)
- But also economic growth – so at least a ***quadri***lemma
- Indeed, distributional considerations (fuel poverty) and social acceptability
- Possibility of double or triple…. "dividends"
- Ideally, want energy-economy-environment models that can –in principle – capture trade-offs/ dividends

# 2. Illustrative cost benefit analysis

- Cost benefit analysis (CBA) standard Treasury method for assessing projects/ policies from the perspective of ***society as a whole***.
- Commercial concerns evaluate projects solely on the basis of the purely PRIVATE costs and benefits that they incur (undertaking them if e.g. Net Present Value – discounted sum of all net revenues – is greater than zero).
- However, Government's assess investments – at least in principle – in terms of the discounted sum of NET SOCIAL benefits.
- This seeks to quantify all social costs and benefits, which differ from private costs and benefits in the presence of ***externalities***.
- Example of an external cost is the impact of emissions – cost borne by society, not by the individual polluter (unless made to pay e.g. through carbon tax or emissions trading scheme)

# 2. Illustrative CBA (2)

- Number of challenges in CBA - conceptual and practical.
- Need to express in monetary values (e.g. value of a life; environment)
- Measure some things that may not be directly observable (e.g. prices for missing markets; visual disamenity; distributional effects)
- However, standard practice in Government - in attempt to ensure consistency and transparency.
- Are investments in offshore wind capacity socially desirable when compared to investments in other technologies? (For a given electrical output.)

| Counterfactual: Offshore wind replaces… PV (£millions) | Gas | Coal w/o CCS | Coal with CCS | Onshore Wind | Nuclear | Wave | Tidal |
|---|---|---|---|---|---|---|---|
| **COSTS** | | | | | | | |
| Capital costs | 195.49 | 163.62 | 44.23 | 46.04 | 43.84 | -129.51 | -86.75 |
| O&M costs | 72.05 | 43.46 | -27.88 | 5.09 | 32.85 | -48.55 | -76.52 |
| Extra balancing costs | 13.99 | 13.99 | 13.99 | 0.00 | 13.99 | 5.15 | 5.15 |
| Upstream and Downstream CO2 emissions | -8.16 | -3.17 | -3.17 | 0.00 | -0.10 | -1.34 | -0.38 |
| Economic costs of location | 0.27 | 0.27 | 0.27 | 0.27 | 0.27 | 0.25 | 0.25 |
| Other environmental costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **BENEFITS** | | | | | | | |
| Avoided fuel costs | 90.37 | 38.58 | 38.58 | 0.00 | 0.00 | 0.00 | 0.00 |
| Avoided GDP loss | 20.85 | 20.85 | 20.85 | 0.00 | 0.00 | 0.00 | 0.00 |
| Avoided CO2 emissions | 97.05 | 209.31 | 20.93 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total Costs | 273.64 | 218.17 | 27.44 | 51.40 | 90.86 | -174.00 | -158.26 |
| Total Benefits | 208.28 | 268.74 | 80.36 | 0.00 | 0.00 | 0.00 | 0.00 |
| | | | | | | | |
| **Net PV benefits of windfarm project (relative to counterfactual) without visual disamenity** | **-65.36** | **50.56** | **52.92** | **-51.40** | **-90.86** | **174.00** | **158.26** |
| Visual disamenity | 178.50 | 178.50 | 178.50 | -80.61 | 178.50 | 88.29 | 88.29 |
| **Net PV benefits including visual disamenity** | **-243.86** | **-127.94** | **-125.58** | **29.22** | **-269.36** | **85.71** | **69.97** |

# 2. Illustrative CBA (3)

- Ignoring visual disamenity, offshore wind appears to dominate coal, wave and tidal, but not other technologies (including onshore wind).
- With the visual disamenity effect included offshore wind dominates wave, tidal and onshore wind.
- However, the results are sensitive to other assumptions too e.g.:
  - lower oil price favours non-renewables
  - higher carbon price favours renewables
- Policy not driven simply by such considerations (political; uncertainty; portfolio effects).
- BUT CBA does NOT typically take into account any macroeconomic benefits that offshore wind may bring to the UK in terms of a stimulus to employment and value added.
- What is the likely scale of such macroeconomic effects? Start with a discussion of "Green Jobs"

# 3. Measuring "green jobs": Low Carbon and Renewable Energy Economy Survey

- First survey run by ONS covering economic activity in the low carbon and renewable energy (LCRE) sector
- Results reported 18th May 2016, relating to 2014 (currently undertaking 2015 survey).
- Survey launched "in response to user demand for more detail on the low carbon and renewable energy economy".

# What does the survey cover?

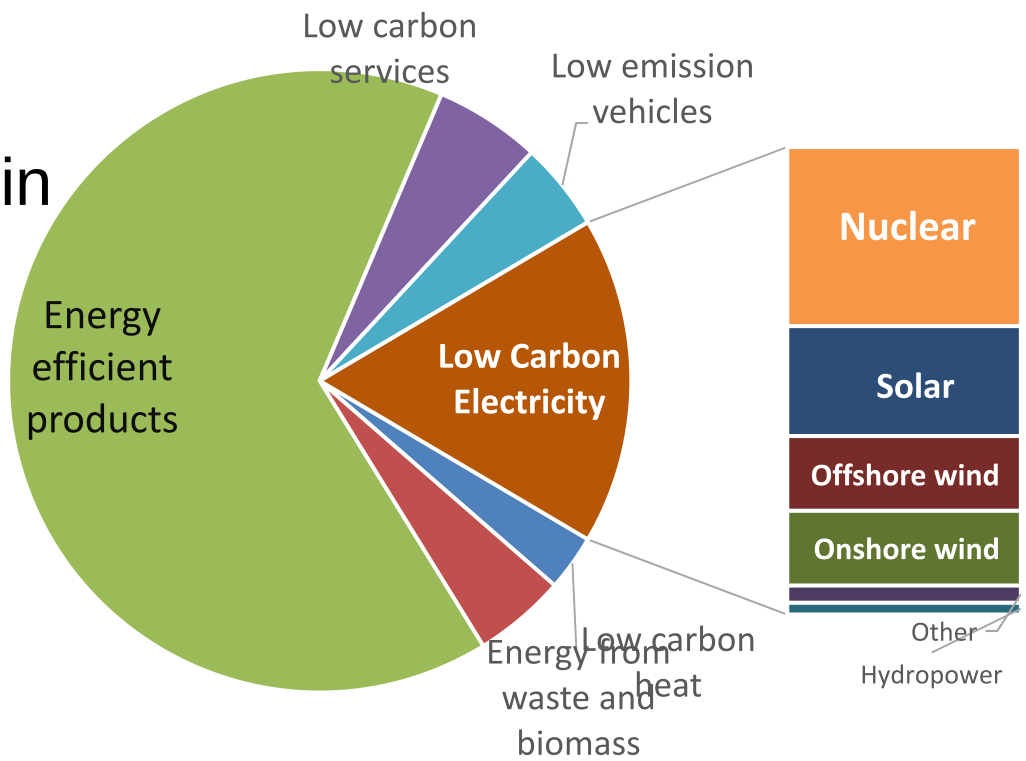
- Activities by UK businesses in any of 17 “Low carbon and renewable energy” *sectors*:
  - *e.g. Offshore wind: “The production of electricity from offshore wind renewable sources and the design, production and installation of infrastructure for this purpose. Including operations and maintenance”.*

- 17 sectors allocated to one of six “groups”, including

- “Low Carbon Electricity” which includes Offshore- and onshore wind, nuclear, hydro, solar photovoltaic, “other renewables” (i.e. wave, tidal and geothermal), and Carbon Capture and Storage”

# Findings: employment, 2014

- 1.3% of UK non-financial business employees are in LCRE activities
- 238,500 FTE employees across the UK in total
- 40,500 FTE employees in Low Carbon Electricity
  - 0.22% of total UK employees

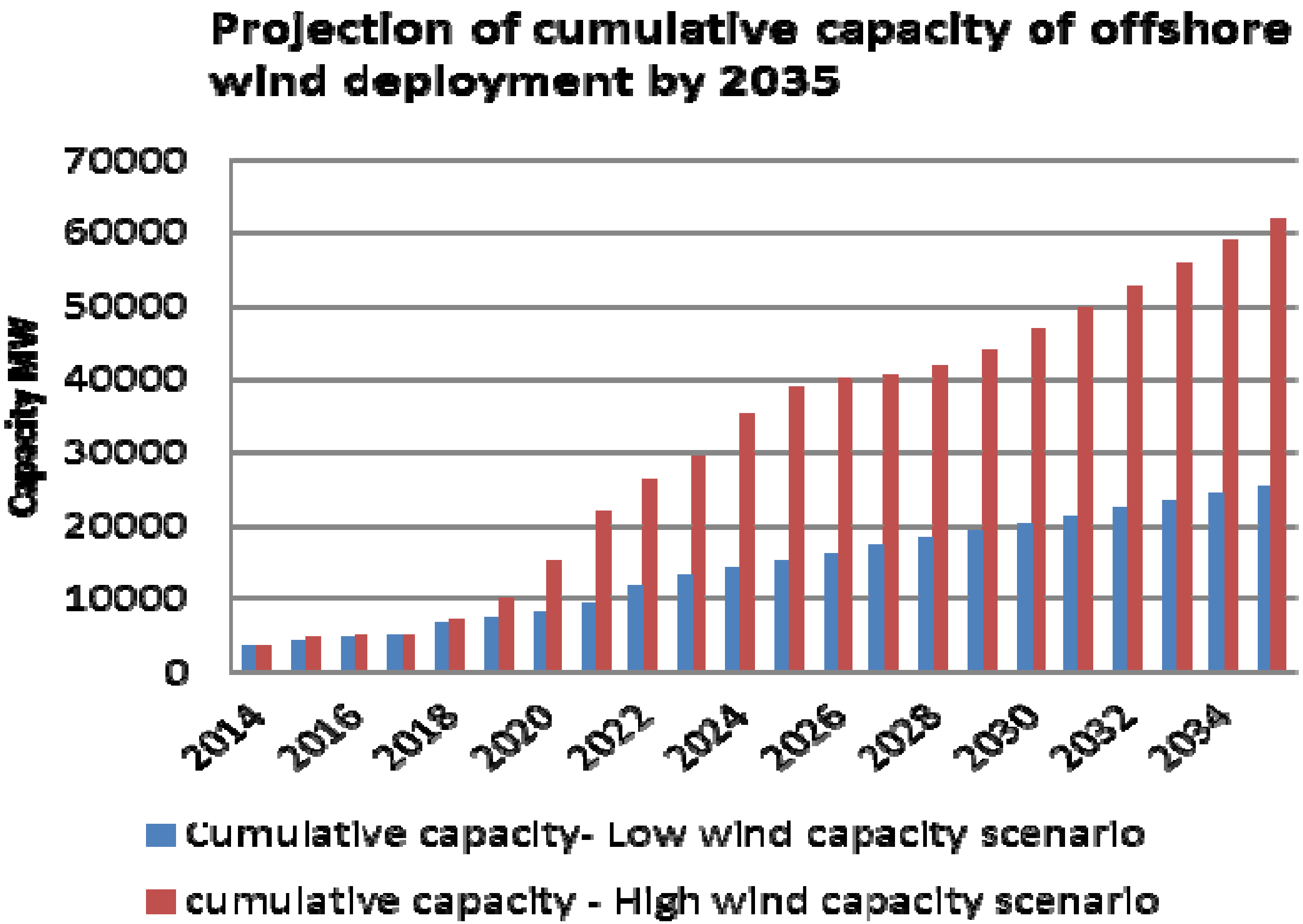


# Issues

- How “green” are LCRE activities?
- What is driving the economic activity in each of the 17 sectors? e.g. UK or international activities.
- Are drivers temporary (e.g. installation) or long-term (e.g. O&M) in nature?
- These are ***direct*** jobs – ONS will provide “estimates of indirect LCRE activity using published [input- output] multipliers” later in 2016
  - Beware of “*double counting*”; sensible to embed in input-output (IO) accounts (e.g. Allan et al 2015)
- IO accounts effectively embody the UK supply chain - crucial for: correct identification of the wider ***indirect*** and ***induced*** employment effects of offshore wind; identifying drivers.

# 4. Application of IO approach

- Developed a UK IO table and model to project the potential impact on UK economy of the continued development of offshore wind.
- Need to project:
  - Likely capacity changes through time (used DECC projections)
  - Associated capital expenditures
  - Operations and Maintenance expenditures
  - Extent of UK content of all spending
- These stimulate demand and economic activity
  - substantial increases in value-added and
  - Employment (but distributed across sectors)


Projection of cumulative capacity of offshore wind deployment by 2035
Capacity MW
70000
60000
50000
40000
30000
20000
10000
0
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
Cumulative capacity- Low wind capacity scenario
cumulative capacity - High wind capacity scenario

# The Economic Impact of Offshore Wind Development on the UK Economy: An Input-Output Analysis

## Simulation Scenarios

- Likely time path of offshore wind energy capacity deployment in the UK until 2035
  - ➢ Low and High alternatives based on DECC 's projections and projects in the pipeline

- Assumptions about UK content in the development of offshore wind
  - ➢ Gradual and Accelerated Growths

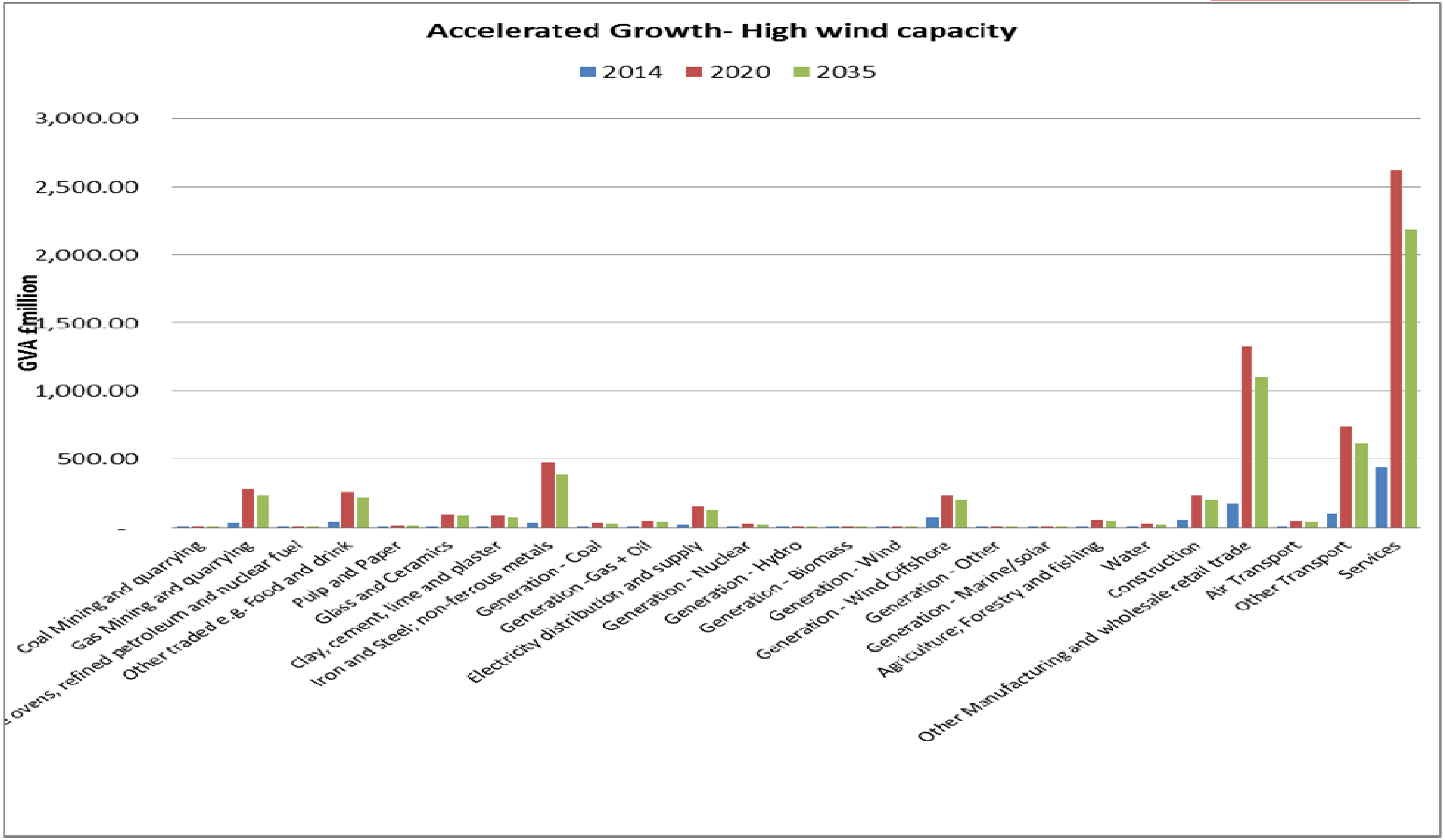
| **4 Scenarios** | | |
|---|---|---|
| | UK Supply Chain development | |
| UK offshore wind capacity deployment | Low wind capacity<br>Gradual growth | Low wind capacity<br>Accelerated growth |
| | High wind capacity<br>Gradual growth | High wind capacity<br>Accelerated growth |

# Input Output Modelling Results

- Expenditures in Offshore Wind Capacity modelled in an IO framework as an annual stimulus to demand in the UK economy
- Findings - continued expansion of the offshore wind sector has significant system-wide impacts on the UK economy: these reflect total impact – direct, indirect and induced effects.

**Annual Aggregate Results** “Gradual Growth, Low Capacity” scenario

| Type II impacts | Medium-term (2020) | Long-term (2035) |
|---|---|---|
| Cumulative Capacity (GW) | 8 | 25 |
| Employment (FTE) | 34,620 | 38,467 |
| GVA (£m) | 1,597 | 1,775 |



Accelerated Growth- High wind capacity
2014
2020
2035
3,000.00
2,500.00
2,000.00
1,500.00
1,000.00
500.00
-
GVA £million
Coal Mining and quarrying
Gas Mining and quarrying
ovens, refined petroleum and nuclear fuel
Other traded e.g. Food and drink
Pulp and Paper
Glass and Ceramics
Clay, cement, lime and plaster
Iron and Steel; non-ferrous metals
Generation - Coal
Generation -Gas + Oil
Electricity distribution and supply
Generation - Nuclear
Generation - Hydro
Generation - Biomass
Generation - Wind
Generation - Wind Offshore
Generation - Other
Generation - Marine/solar
Agriculture; Forestry and fishing
Water
Construction
Other Manufacturing and wholesale retail trade
Air Transport
Other Transport
Services

# 4. Application of IO approach

- Note all the jobs identified above are attributable to growth in offshore wind, but many not be "green".
- Input output:
  - Useful (and ONS use), but focuses on the demand side
  - Projections dependent on assumptions about changes in offshore wind capacity and UK shares of spending
  - Moderate longer term projections in light of Government's "reset" of energy policy
- Ideally want models which seek to ***explain*** the scale of capacity changes as a consequence of private sector investment decisions- and incorporate the supply side.
  - So is it likely that DECC's projected capacity would be met given their levelised cost assumptions?

# 5. The computable general equilibrium (CGE) model

- CGEs attempt to specify the behaviour of all transactor groups and solve for simultaneous equilibrium in all markets.
- Multi-sectoral, like IO, but incorporate the supply side of the economy (and model investment).
- Widely used around the world for policy analysis.
- UKENVI is a purpose-built energy-economy-environment CGE model of the UK economy that incorporates offshore wind as a separate sector.
- Allows us to track: aggregate and sectoral economic activity; emissions; aspects of security of supply (generation portfolio); affordability/ competitiveness; distributional impacts (if households disaggregated)

# 5. The CGE Model (2)

- Seeks to capture full system-wide interdependence  among economy, environment and energy sub-sytems.
- Consumers and investors inter-temporally optimise under perfect foresight.
- 25 sectors, with multi-level structure and particular emphasis on energy (13 sectors)
- Labour market characterised by imperfect competition in wage bargaining (wage curve)
- Model calibrated on an energy-disaggregated Social Accounting Matrix for the UK.
- Can be used to analyse the impact of wide variety of disturbances, including policy changes.

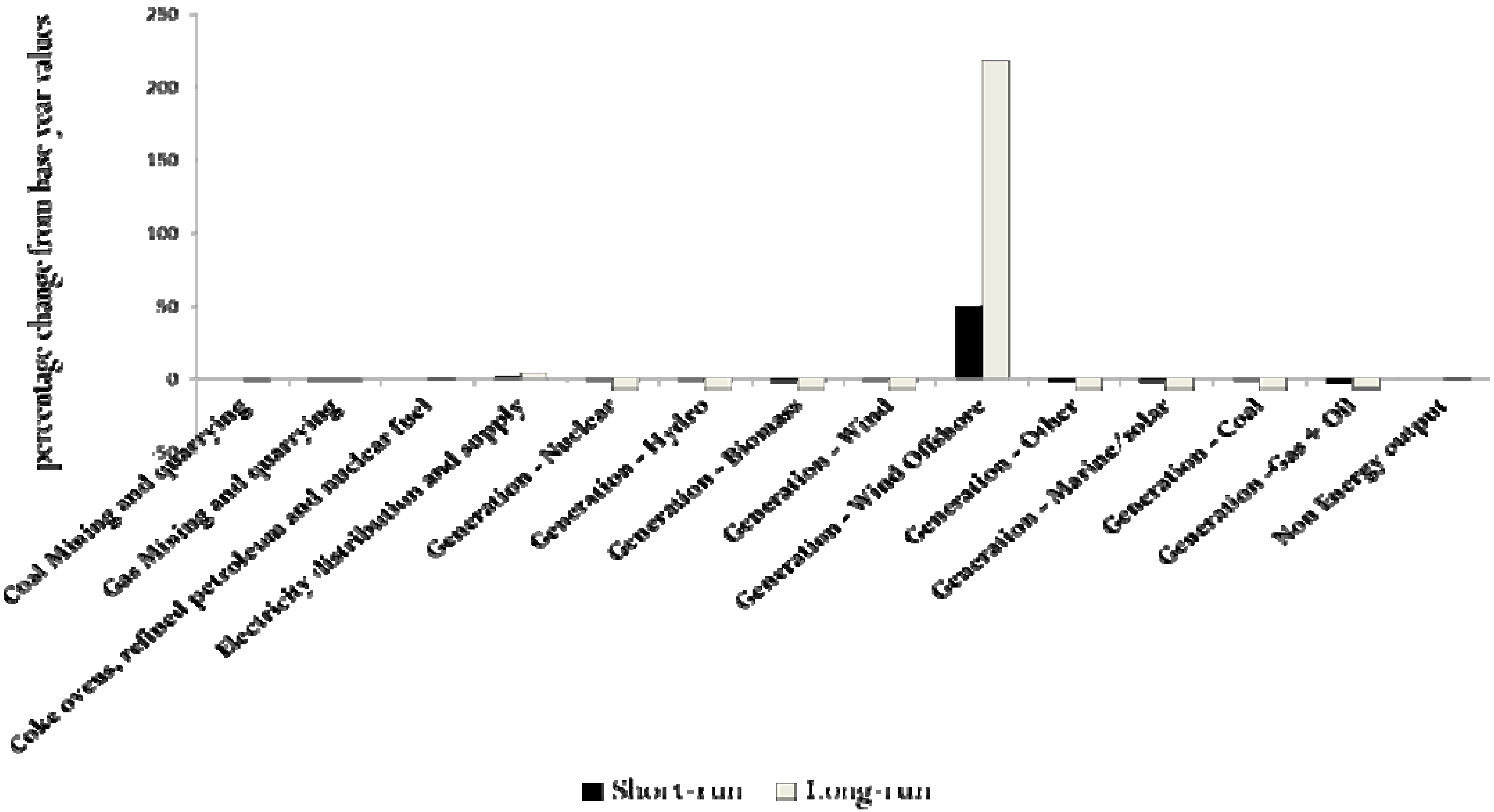
# 5. Application of UKENVI

- Recent rapid development of offshore wind in UK. DECC's projections for future deployment ambitious: 10GW by 2020 and up to 22GW by 2030
- A key element of this is the 30% reduction in levelised costs assumed by DECC using our energy-economy-environment CGE.
- We model this as a 30% stimulus to productivity in the offshore wind sector, and analyse the consequences for the sector itself and the wider economy.
- Here the change in levelised costs is imposed (but can model technological change endogenously generally)

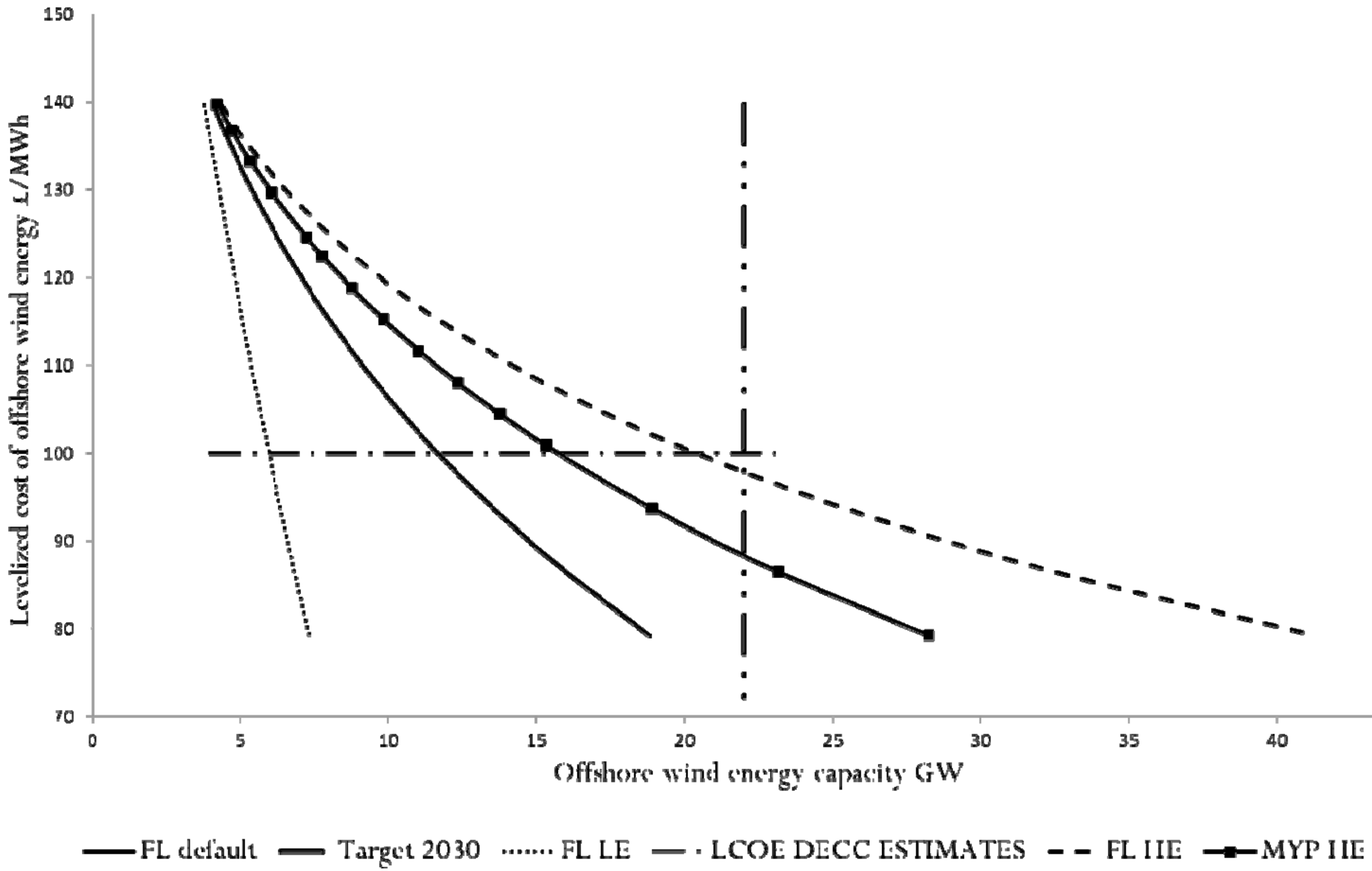
# Percentage changes in key macro variables

| | Short-run | Long-run |
|---|---|---|
| GDP | 0.03 | 0.15 |
| CPI | 0.01 | -0.05 |
| Unemployment Rate | -0.25 | -1.20 |
| Total Employment | 0.03 | 0.13 |
| Nominal wage | 0.04 | 0.09 |
| Real wage | 0.03 | 0.14 |
| Replacement cost of capital | 0.10 | -0.07 |
| Households Consumption | 0.12 | 0.16 |
| Investment | 0.22 | 0.13 |
| Electricity use-domestic | 1.83 | 3.41 |
| Electricity use-total | 1.77 | 3.16 |
| Capital Stock | 0.00 | 0.13 |
| Export | -0.01 | 0.07 |

# Sectoral output changes



# Relationship between levelised costs and offshore wind capacities in UKENVI



# 4. Application of UKENVI

- We focus solely on the impact of the levelised cost reductions in DECC's projections, but they take into account a range of other factors.

- In our default model, the assumed cost reduction generates only 11.5 GW capacity by 2030.
  - However, the forward-looking model can achieve the target, if high elasticities
  - If myopia - the target would not be met even with high elasticities
  - Even with default elasticities emissions fall by 25 Mt CO2 equivalent in long run

- There is a beneficial stimulus to economic activity as a result of the assumed cost reductions, but even if achieved this would be unlikely in itself to achieve DECC's capacity targets for offshore wind.

- Wide array of possible future research possible using UKENVI – hypothetical as well as actual policies and policy packages (and supply as well as demand side stimuli)

# 5. Conclusions

- We have developed a number of micro- and macro-economic analyses of offshore wind.
- CBA illustrates practical problems that face attempts to apply Treasury methodology to assessment of offshore wind developments – though not at clear this approach is the basis of current policy.
- CBA in any case neglects the MACRO-economic impacts of offshore wind: its potential to stimulate UK economic activity. Seems to be important:
  - Stimulates "green jobs" (though number of practical and conceptual difficulties in measurement)
  - Conventional input-output analysis analyses the demand-side stimulus of offshore wind deployment and operations and maintenance activity (though strength of domestic supply chain critical) - all good news
  - CGE model reinforces message on economic activity – through supply side - though more subtle and implication is that may well be some "losers"
- Range of potential policy-relevant analyses and model developments (e.g. link to energy systems models)