Do Renewables Reduce GHGs?

Marginal Greenhouse Gas Offset for Renewable Energy in the UK

Camilla R Thomson, GP Harrison and JP Chick

Institute for Energy Systems, School of Engineering, University of Edinburgh, UK

26th September 2012

Images from Harvey McDaniel and www.pelamiswave.com.

Introduction



- Identify the Greenhouse Gas (GHG) offset of intermittent renewable energy sources by examining the real marginal effects of wind power.
- Found marginal offset to be 0.75 kg CO_2e/kWh, significantly higher than the values typically used in carbon payback calculations.

IES

THE UNIVERSITY *of* EDINBURGH

Introduction

- Identify the Greenhouse Gas (GHG) offset of intermittent renewable energy sources by examining the real marginal effects of wind power.
- Found marginal offset to be 0.75 kg CO_2e/kWh, significantly higher than the values typically used in carbon payback calculations.

IES

THE UNIVERSITY *of* EDINBURGH

Carbon Payback

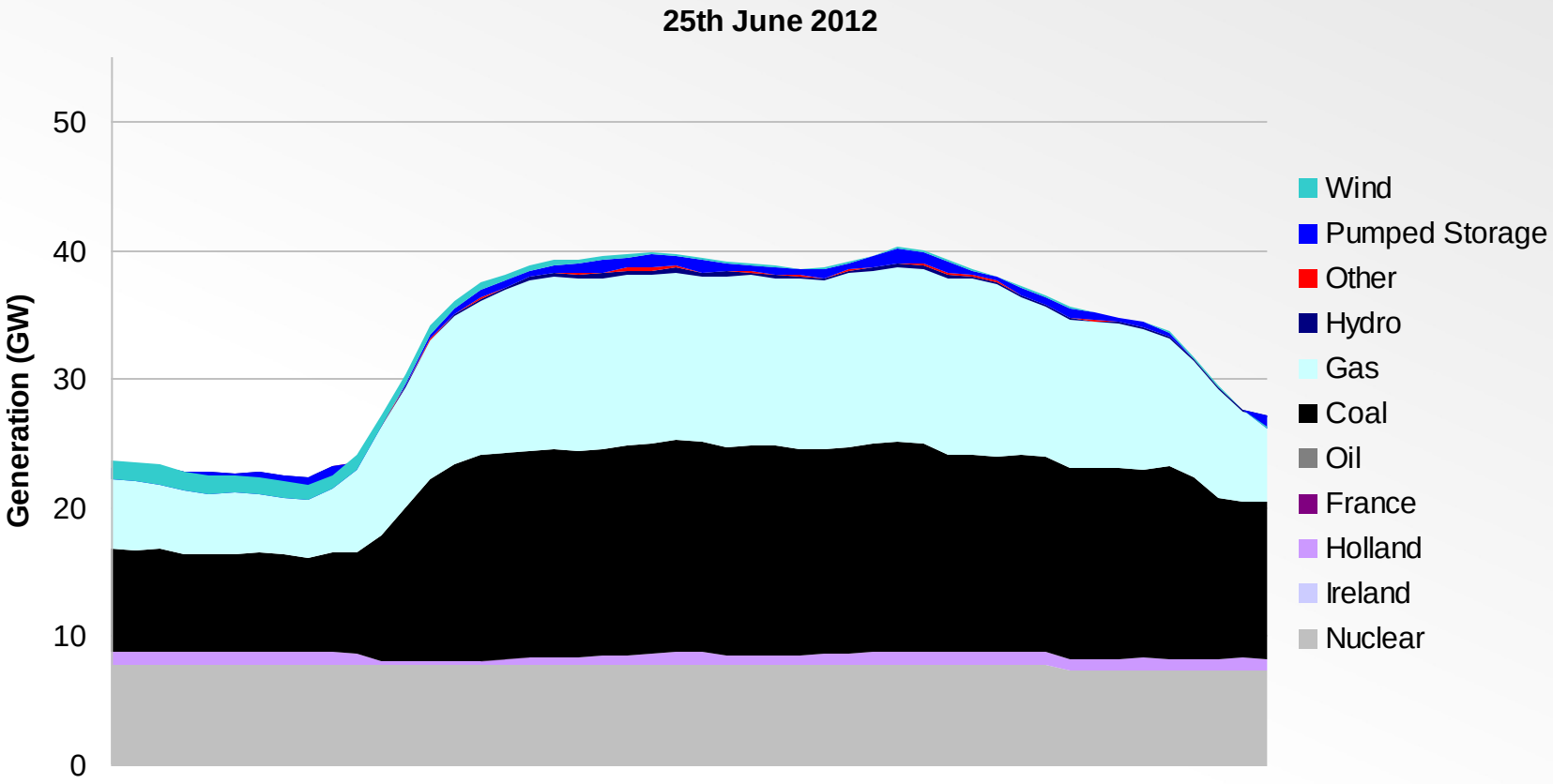
- LCA is used to calculate the Greenhouse Gas intensity of renewables, but carbon paybacks and carbon savings need to be estimated to assess whether they will achieve carbon reductions
- Carbon payback is typically calculated from mean network emissions, in accordance with UK government recommendations.
- Intermittent renewables may also have hidden carbon impacts associated with reserve capacity and reduced efficiency of other generators.

IES

Images from www.guardian.co.uk and cleantechnica.com

THE UNIVERSITY of EDINBURGH

Generation in the UK



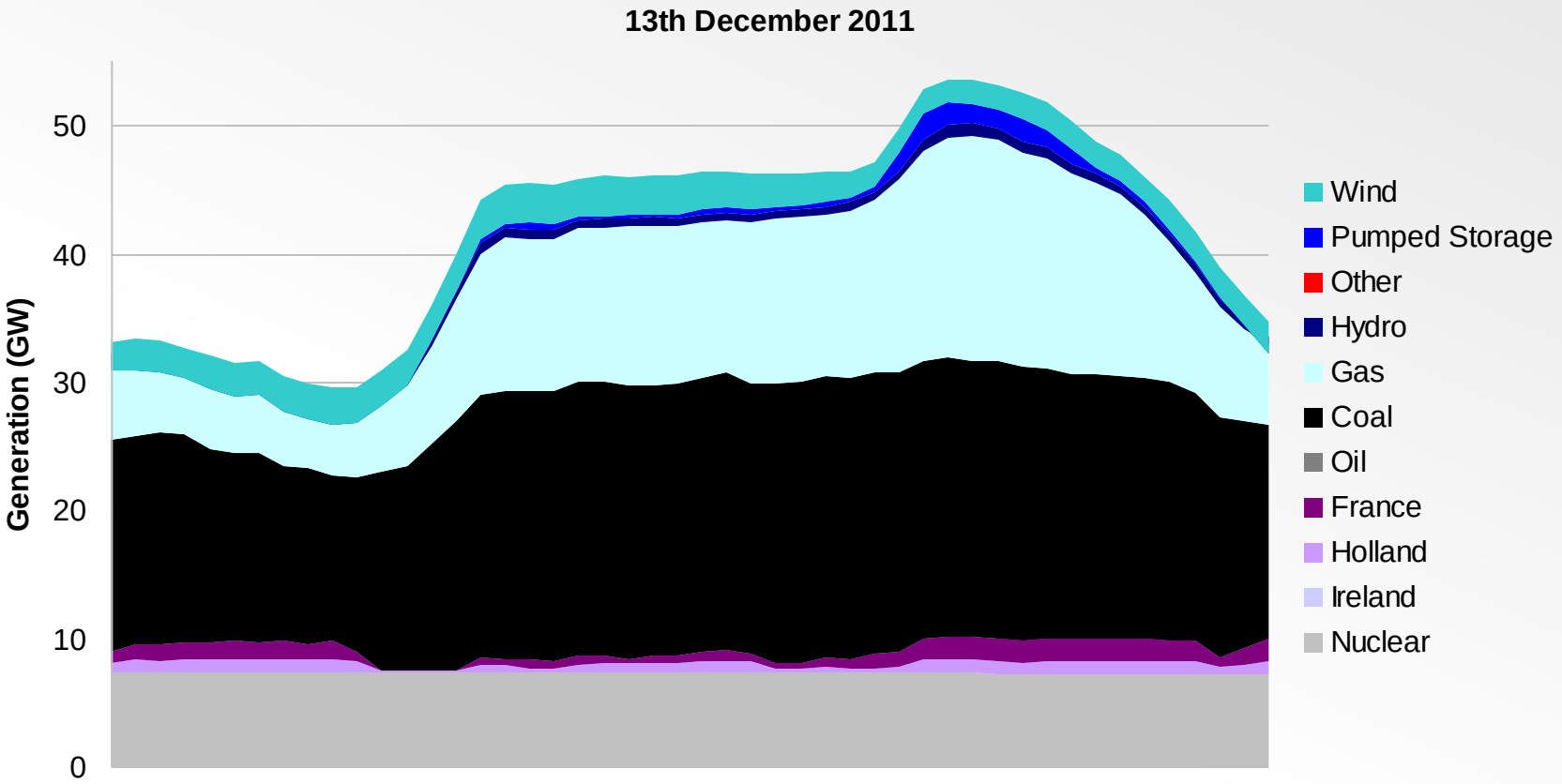
- Marginal emissions rate – the greenhouse gas emissions associated with a marginal change in wind output.

Data from Elexon, 2012, National Grid Data: Generation by Fuel Type, ELEXON Limited

IES

THE UNIVERSITY of EDINBURGH

Generation in the UK



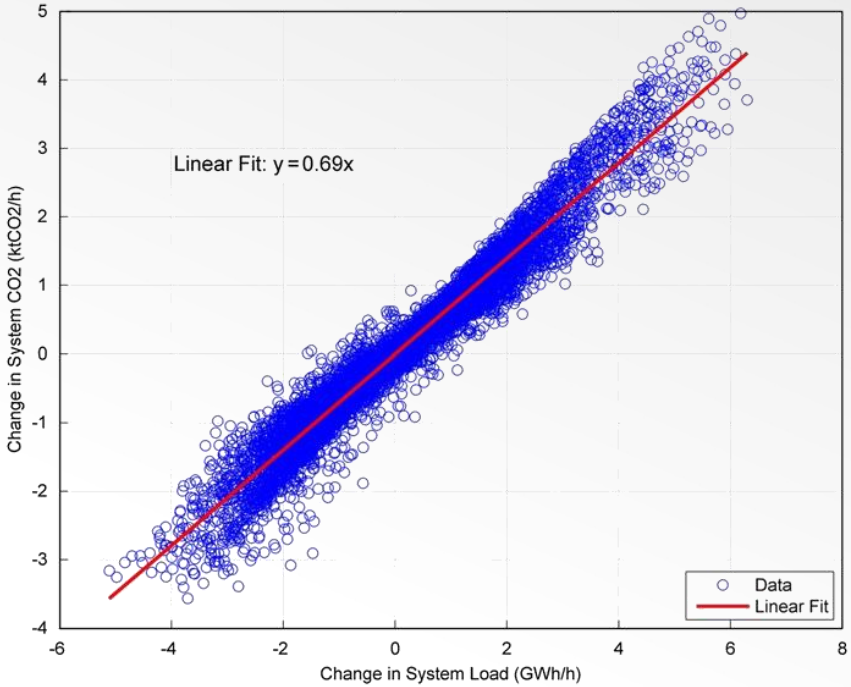
- Marginal emissions rate – the greenhouse gas emissions associated with a marginal change in wind output.

Data from Elexon, 2012, National Grid Data: Generation by Fuel Type, ELEXON Limited

IES

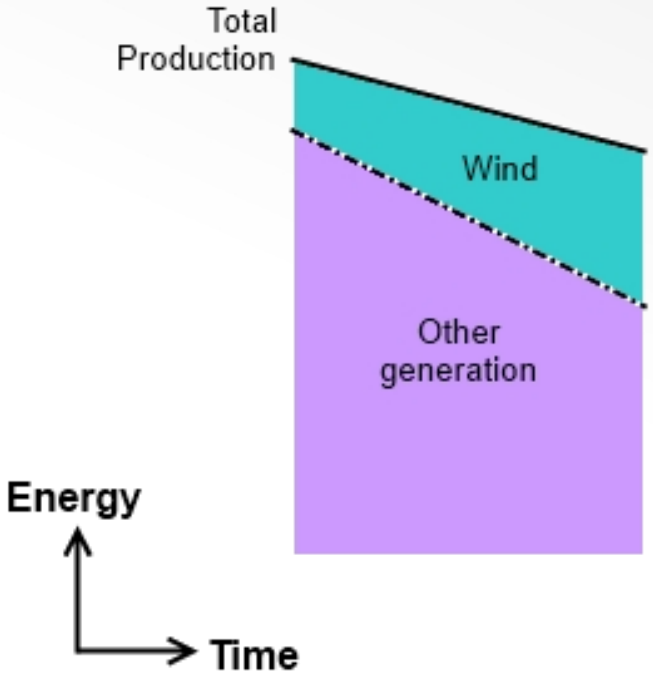
THE UNIVERSITY of EDINBURGH

Previous Work



- Data from Hawkes A. (2010) Estimating marginal CO_2 emissions rates for national electricity systems. Energy Policy, 38, pp 5977–5987
- Linear result inevitable due to constants being applied for the greenhouse gas intensities of generation

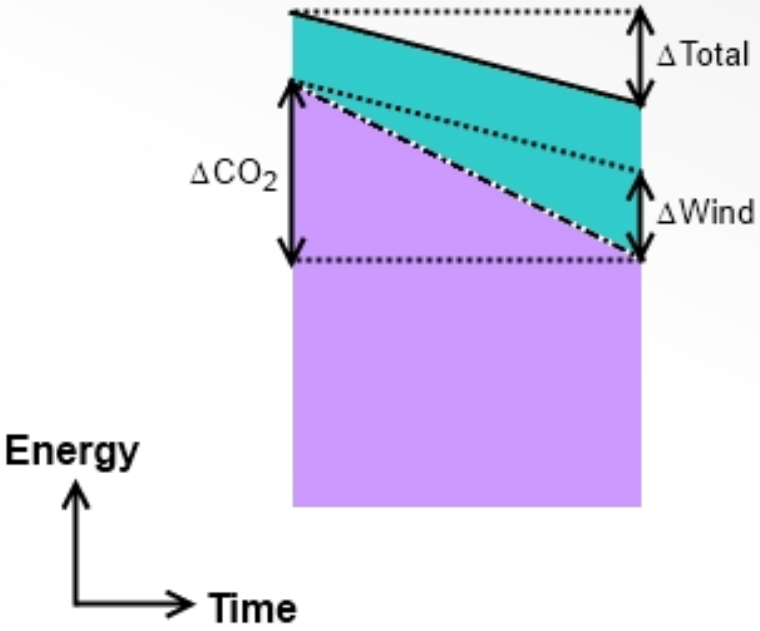
Method



IES

THE UNIVERSITY *of* EDINBURGH

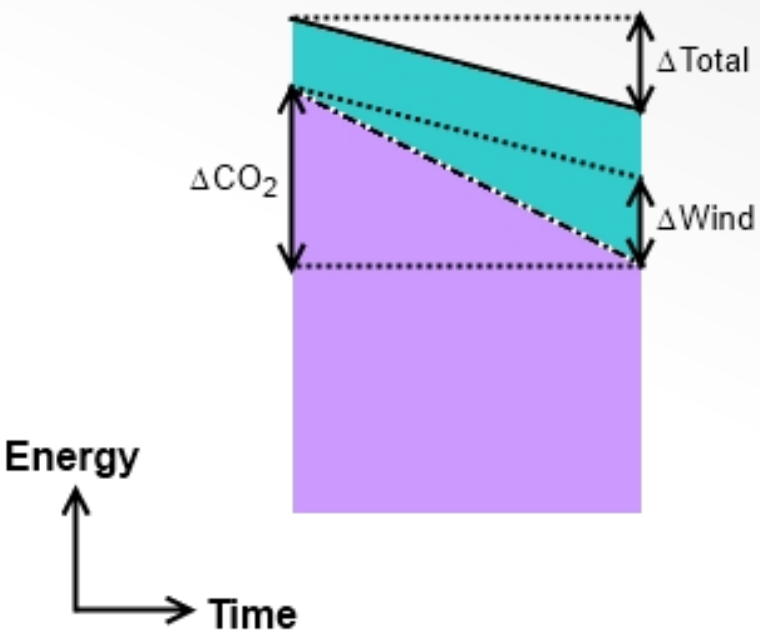
Method

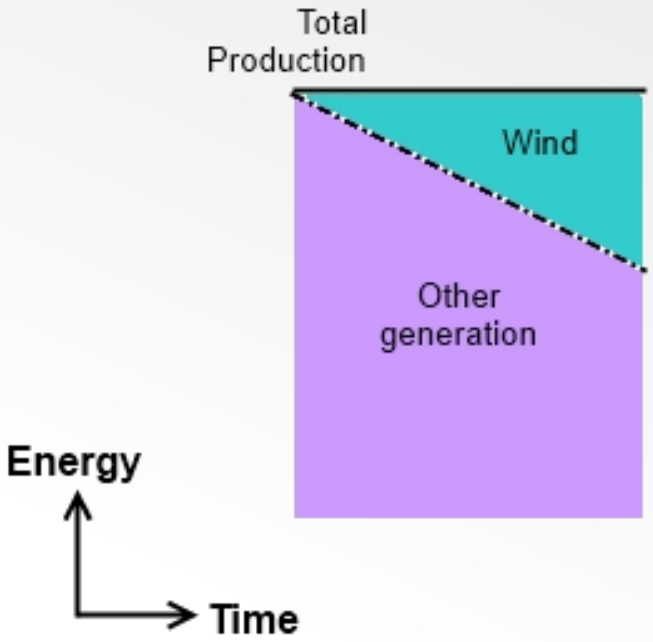


IES

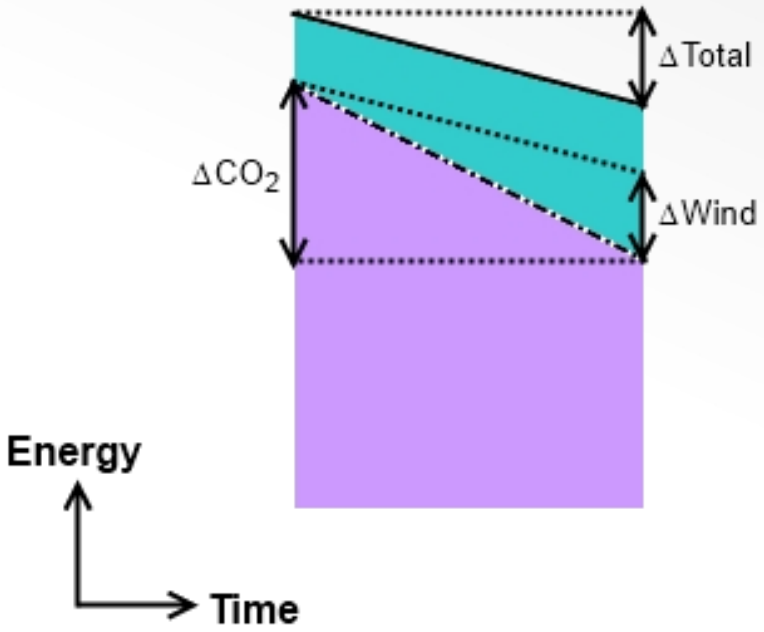
THE UNIVERSITY of EDINBURGH

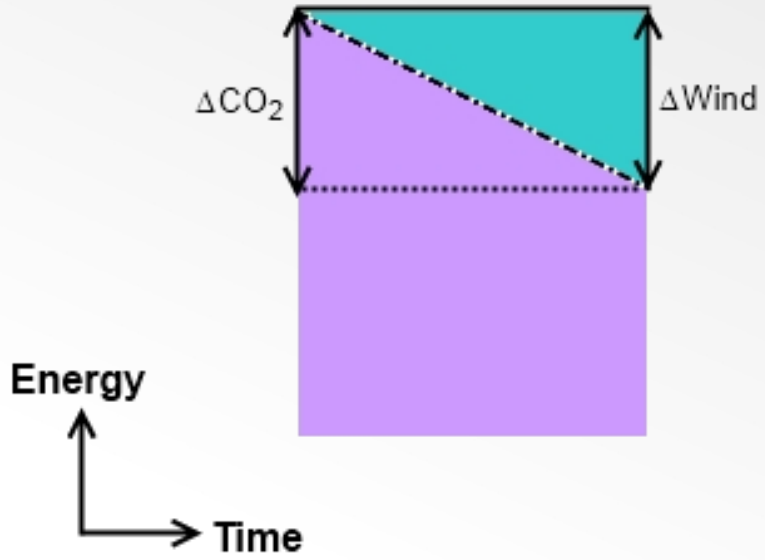
Method


ΔTotal
ΔCO2
ΔWind
Energy
Time


Total
Production
Wind
Other
generation
Energy
Time

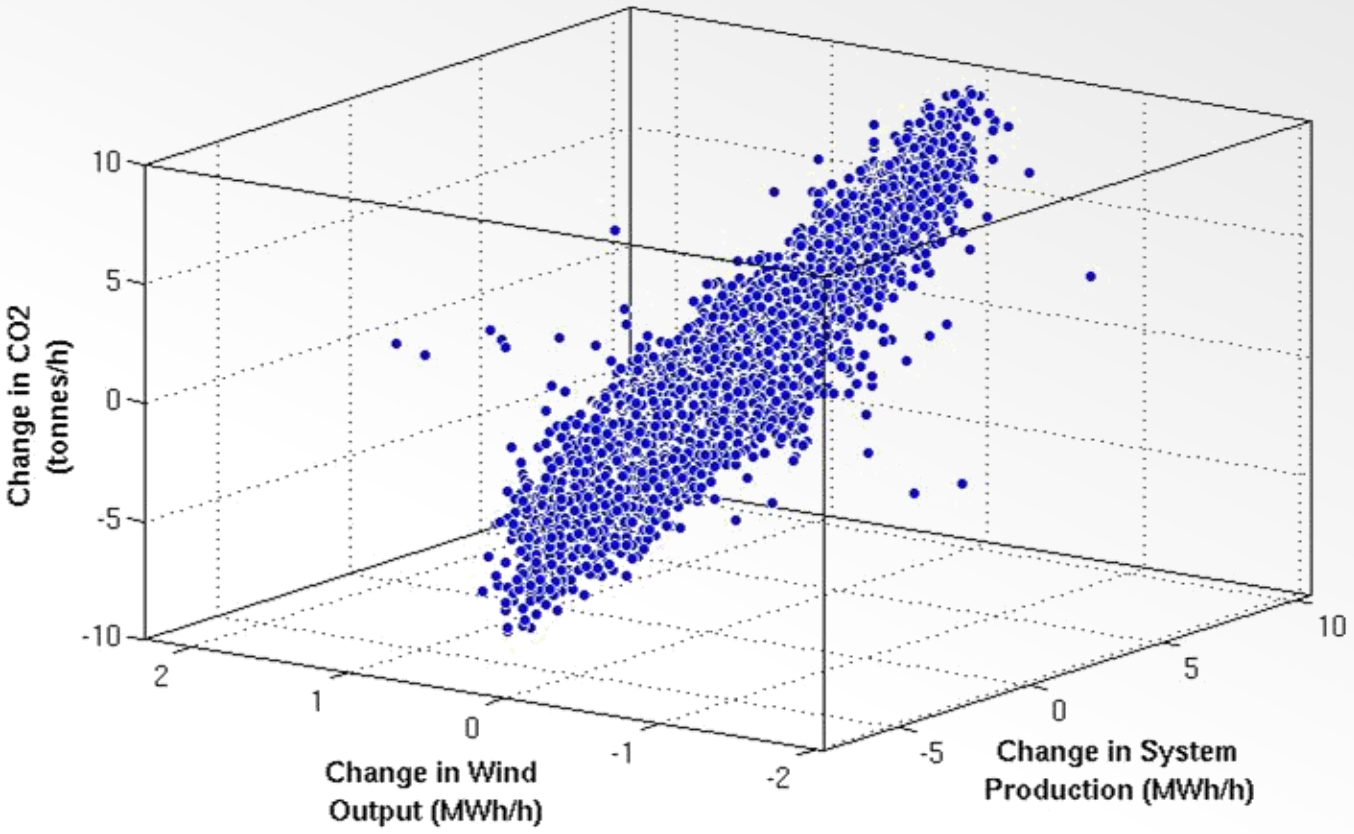
Method





- When the change in total load is zero ALL changes in GHG are due to the change in wind generation.

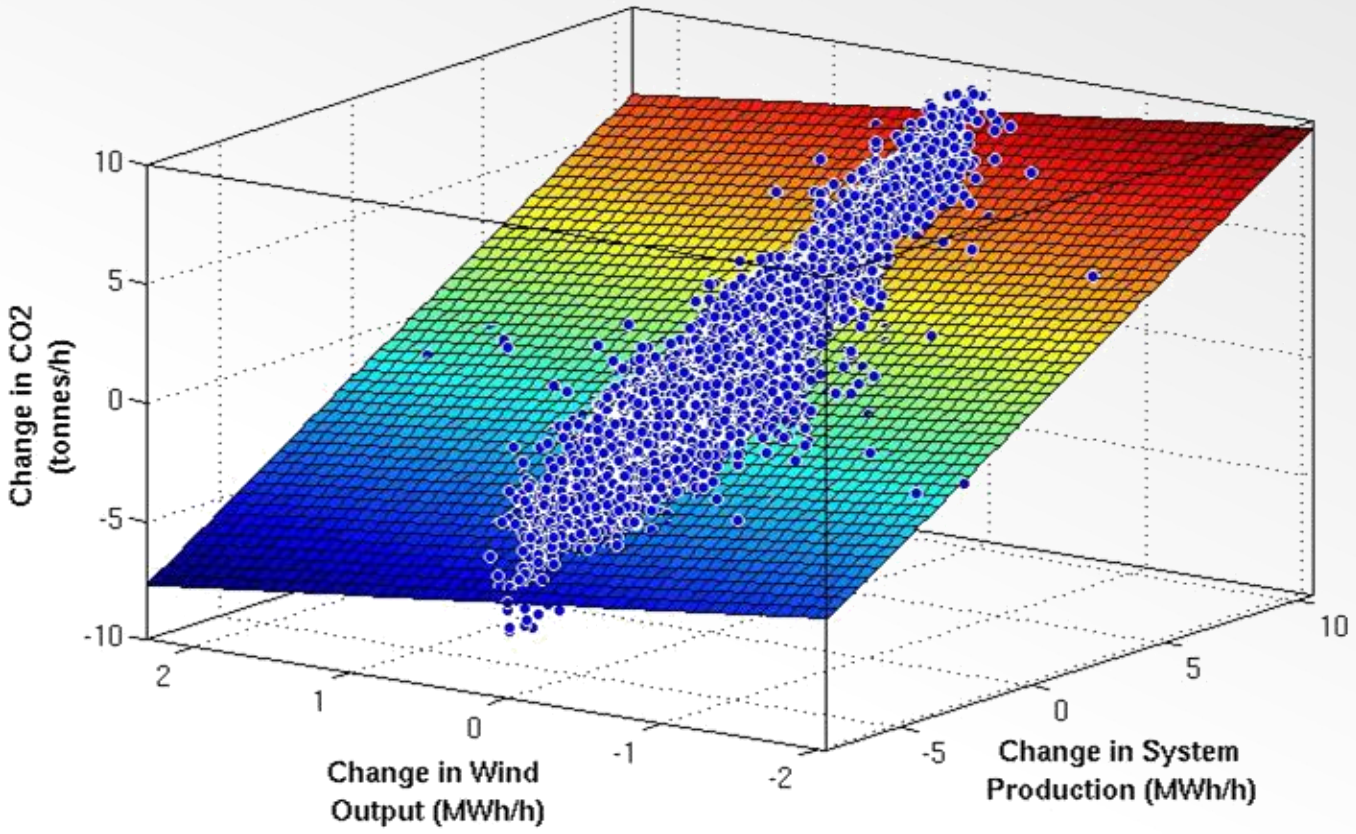
Results



IES

THE UNIVERSITY *of* EDINBURGH

Results

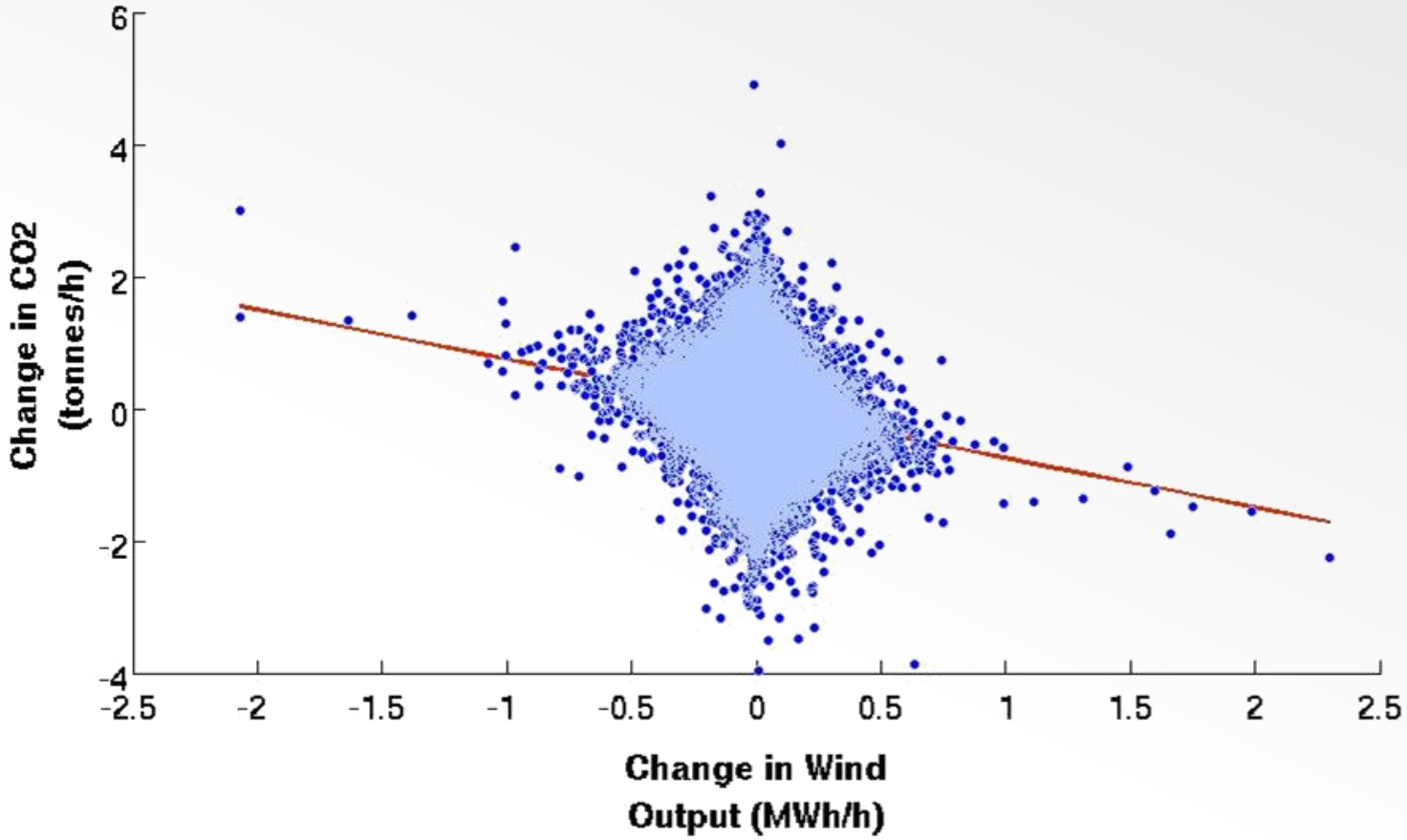


- Marginal offset of wind -0.747 kg CO_2e/kWh ± 0.027
- Marginal emissions rate of system 0.763 kg CO_2e/kWh ± 0.001

IES

THE UNIVERSITY *of* EDINBURGH

Results

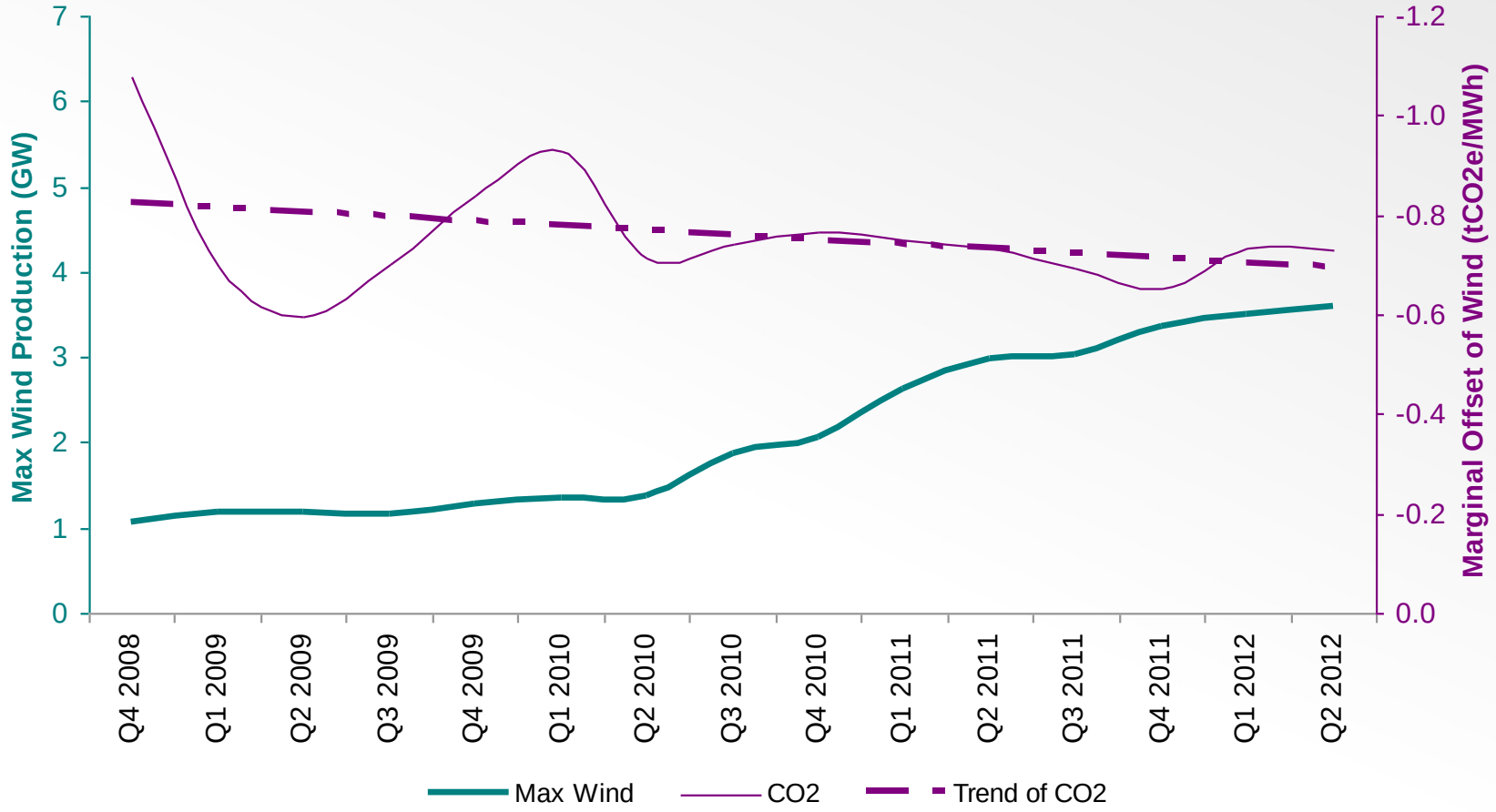


- Wind causes a reduction in greenhouse gas emissions so the gradient is negative.

IES

THE UNIVERSITY *of* EDINBURGH

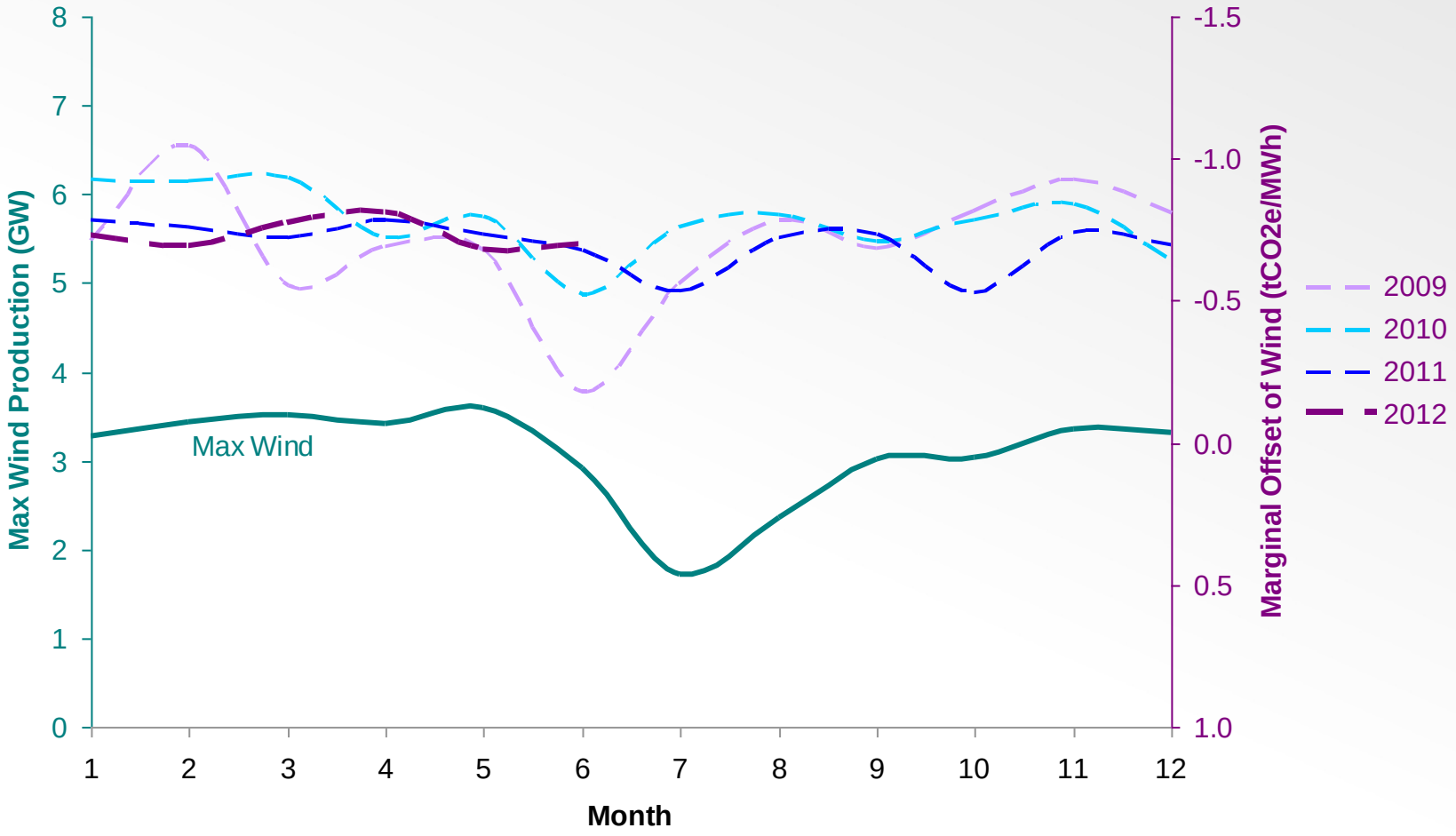
Quarterly Trends



IES

THE UNIVERSITY *of* EDINBURGH

Monthly Trends

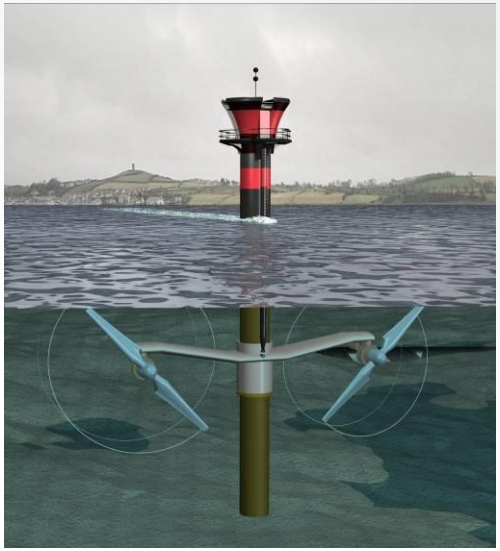


IES

THE UNIVERSITY *of* EDINBURGH

Carbon Paybacks

- Current DECC grid-average emissions are 0.457 kg CO_2e/kWh [3]
- Wind carbon payback [4-6]:
  - DECC: 5 to 8 months
  - Marginal: 3 to 5 months
- Wave carbon payback [7]:
  - DECC: 33 months
  - Marginal: 20 months
- Tidal stream carbon payback [8]:
  - DECC: 20 months
  - Marginal: 13 months



[Numbers in square brackets refer to references]

Images from www.pelamiswave.com and www.marineturbines.com

Payback of UK Wind

- Currently there is 6.9 GW of installed wind in the UK [9].
- Published LCAs provide an estimate for the embodied GHG per MW of rated output of 0.5 - 2 Mt CO_2e/MW [4-6].
- Worst case life cycle emissions of current installed capacity are 14 Gt CO_2e.
- If the marginal offset of wind is 0.747 t CO_2e/MWh, 17 Gt CO_2e has been offset since November 2008, a carbon saving of at least 3 Gt CO_2e.

IES

THE UNIVERSITY *of* EDINBURGH

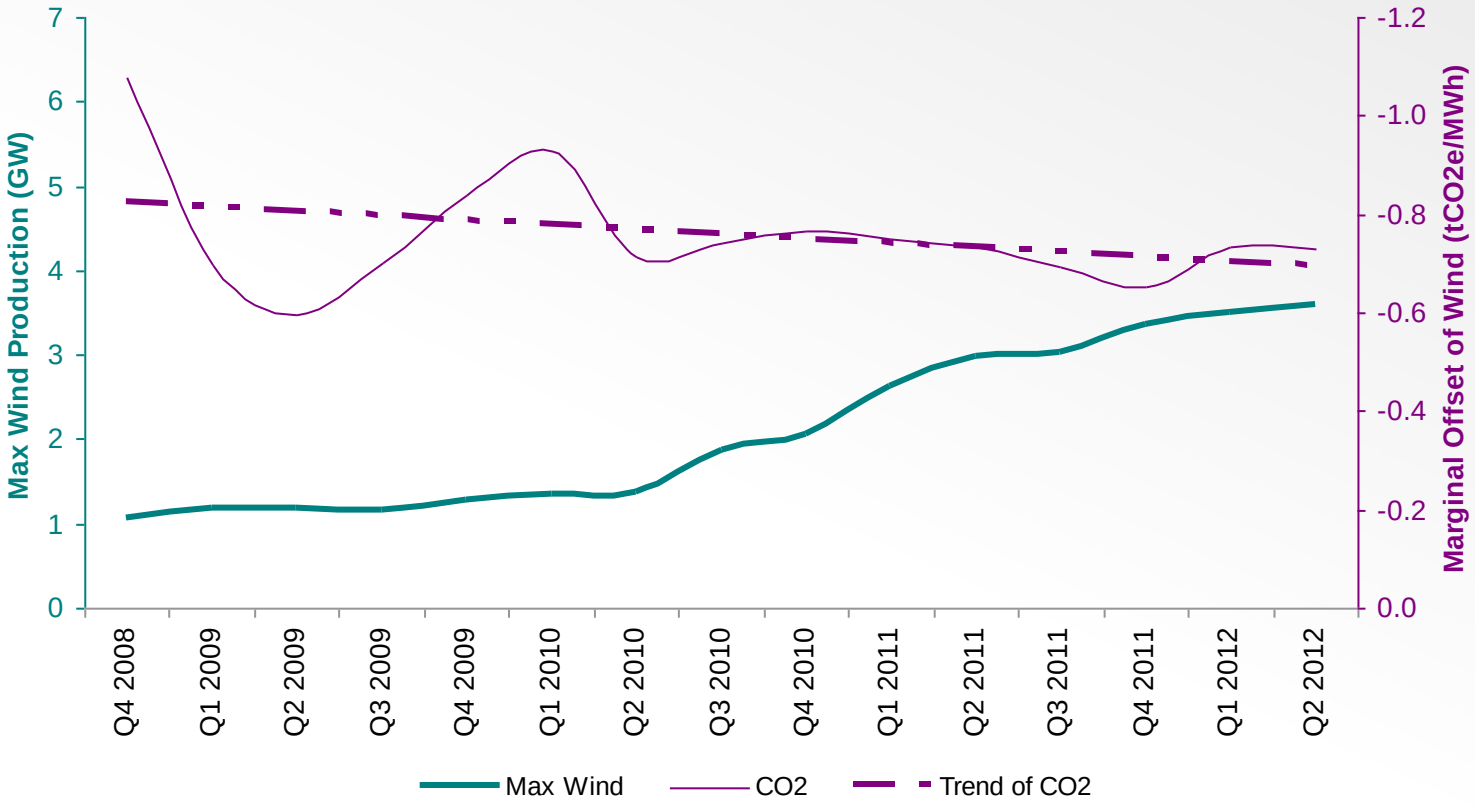
Conclusions

- The marginal offset of wind has been calculated to be 0.747 kg CO_2e/kWh, significantly higher than the average grid emissions.
- This suggests wind is offsetting some coal generation, in addition to gas and hydro.
- If wind is taken as typical of large-scale intermittent renewables, this finding can significantly reduce estimated carbon paybacks.
- The entire wind capacity currently installed in the UK is estimated to have already paid back its embodied carbon.
- Much of the installed capacity in the UK is less than 4 years old, with a design life of around 20 years.
- However, this model needs to be developed to include the carbon impacts of reserve capacity and efficiency penalties.

References

1. Elexon, 2012, National Grid Data: Generation by Fuel Type, ELEXON Limited
2. Hawkes A.D. (2010): Estimating marginal CO2 emissions rates for national electricity systems. Energy Policy, 38(10), pp. 5977-5987.
3. AEA (2012): 2012 Guidelines to Defra/DECC's GHG Conversion Factors for Company Reporting. Defra and DECC, UK.
4. Ardente F., Beccali M., Cellura M. , Lo Brano V. (2008): Energy performances and life cycle assessment of an Italian wind farm. Renewable and Sustainable Energy Reviews, 12(1), pp. 200-217.
5. Crawford R.H. (2009): Life cycle energy and greenhouse emissions analysis of wind turbines and the effect of size on energy yield. Renewable and Sustainable Energy Reviews, 13(9), pp. 2653-2660.
6. Tremeac B. , Meunier F. (2009): Life cycle analysis of 4.5 MW and 250 W wind turbines. Renewable and Sustainable Energy Reviews, 13(8), pp. 2104-2110.
7. Thomson C., Harrison G. , Chick J. (2011): Life Cycle Assessment in the Marine Renewable Energy Sector. LCA XI, Chicago, USA, 5th October 2011.
8. Douglas C.A., Harrison G.P. , Chick J.P. (2008): Life cycle assessment of the Seagen marine current turbine. Proc IMechE Part M: J. Maritime Environment, 222(M1), pp. 1-12.
9. RenewableUK, (2012). UK Wind Energy Database. Retrieved 20th August 2012, from http://www.bwea.com/ukwed/index.asp.

Thank You!



IES

THE UNIVERSITY *of* EDINBURGH