Electricity carbon intensity of the UK grid for the years 2009-2015

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Motivation

The electricity sector is one of the largest sources of greenhouse gas emissions and the study of electricity grid carbon intensity has a key role in meeting the targets of limiting greenhouse emissions. The UK government (DEFRA) provides guidelines and annual carbon factors for companies to report their emissions. This study aims to examine the level of uncertainty when using a single annual value for grid intensity calculations. Here, grid carbon intensity refers to the amount of carbon released in generating each unit of electricity, typically measured in gCO_{2eq}/kWh (grams of carbon dioxide and other well mixed greenhouse gases per kilowatt-hour of electricity.)

Methodology

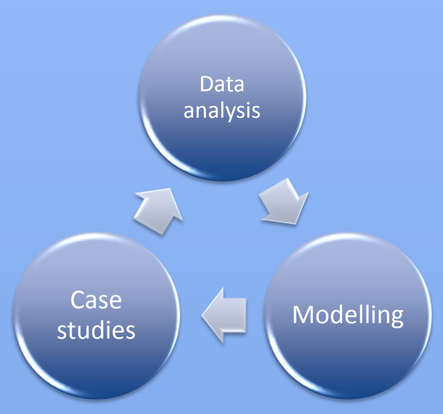

Figure 1: Flow chart of approach to investigate uncertainty of carbon intensity.

The project aims to investigate the uncertainty in carbon intensity calculations following this three-stage methodology:

- Data analysis: calculation of grid carbon intensity with half-hourly, National Grid & Elexon generation data;
- Modelling: simulation of time-varying UK grid carbon-intensity;
- Case studies: investigation of how government guidelines and policies affect the carbon management plan and carbon intensity measurement of large-scale organisations (i.e. University of Reading)

Data analysis

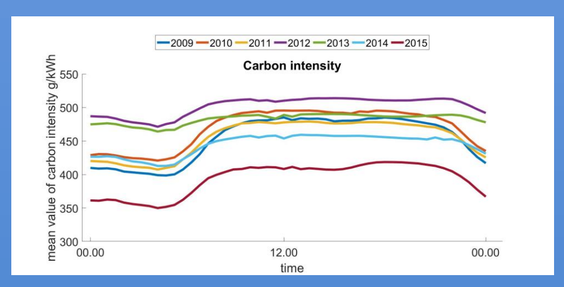

Figure 1: Daily mean grid carbon for years 2009-2015.

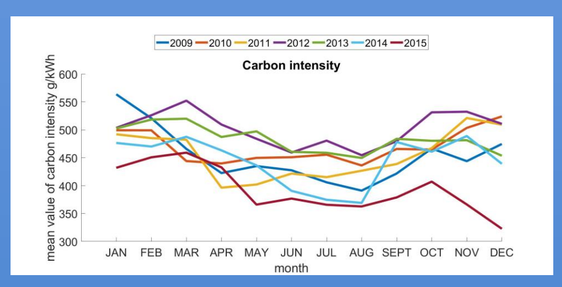

Figure 2: Monthly mean grid carbon intensity for years 2009-2015.

- Monthly, mean carbon intensity in 2015 was notably lower than the rest of the years while in 2012 it had the highest range, meteorological data and changes in generation type (closure of coal plants, increased renewable energy generation) should be taken into consideration;
- A pattern of intra-day seasonality is visible in Fig. 1 where carbon intensity follows the human energy use pattern;
- A pattern of seasonality is visible in Fig. 2 where carbon intensity is high during the winter months;

Modelling

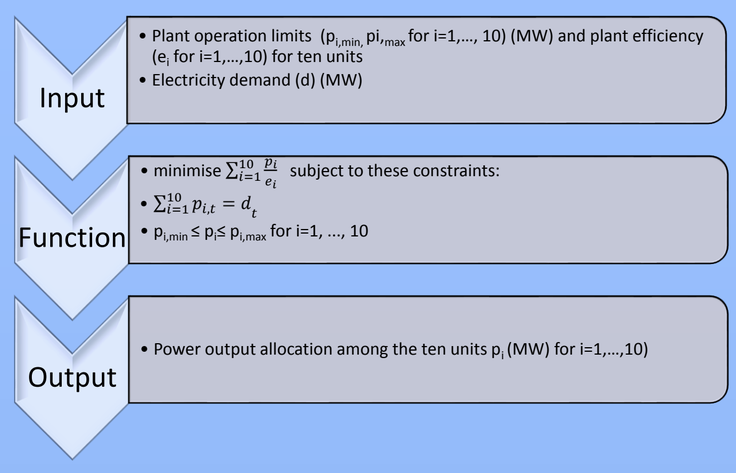

Figure 4: Flowchart of economic dispatch model .

A 10-unit model has been built to represent UK electricity grid. Coal, oil, gas (OCGT, CCGT), nuclear and interconnectors are included in the first modelling stage while renewable energy units will be added in the future. The units are assumed to have linearly increasing efficiency instead of real-life quadratic. The economic dispatch problem (optimisation problem where the power outputs are allocated among the units achieving minimum cost) has been coded for the 10-unit model.

Type of unit	Min power (MW)	Max power (MW)	Efficiency
NUCLEAR	5000	9000	33-36%
OCGT	1000	3000	35-39%
OCGT	2000	5000	35-39%
OCGT	2000	7000	35-39%
CCGT	3000	4000	47-58%
CCGT	1000	5000	47-58%
COAL	3000	9000	39-47%
OIL	1000	5000	38-44%
INTERCONNECTOR	1000	5000	75-76%
INTERCONNECTOR	1000	6000	75-76%

Figure 3: Operating limits and efficiency for the ten model units.

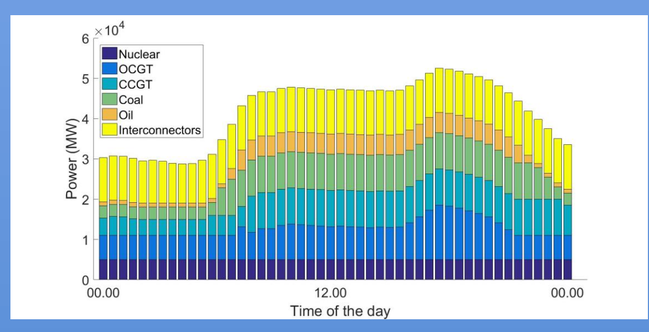

Figure 4: First results of optimisation simulation, power output by fuel type during a day.

Early findings

Data analysis' results indicate that as grid intensity widely varies not only during the year but also during the day, the use of a single carbon electricity factor for annual calculations might not be adequate. This will be investigated further with model simulations.

Future directions

- Include unit commitment problem in the model (determine the start-up and shut-down schedules of the generating units at minimum cost)- work in progress;
- Include wind and solar energy in the model;
- Replicate carbon intensity results;
- Case study: University of Reading carbon management plan.

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