Queen Mary
University of London
Science and Engineering

QMUL-BUPT Joint Programme
JP Student Innovation Centre
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Virtual Smart Assets (Phase 1)

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Outline

- Background
- Process
- Result
- Future work (next Phase)

Background

- Big changes in energy consumption and generators.
- Quantify the power consumed in UK.
- Translate calculation formula into code (python).
- Analyze carbon footprint, and the resultant and carbon emission per energy use in the electricity.
- Obtain trends, conclusions and future suggestions.
- Develop a website interface (next Phase).

Background-Dataset

- Source:

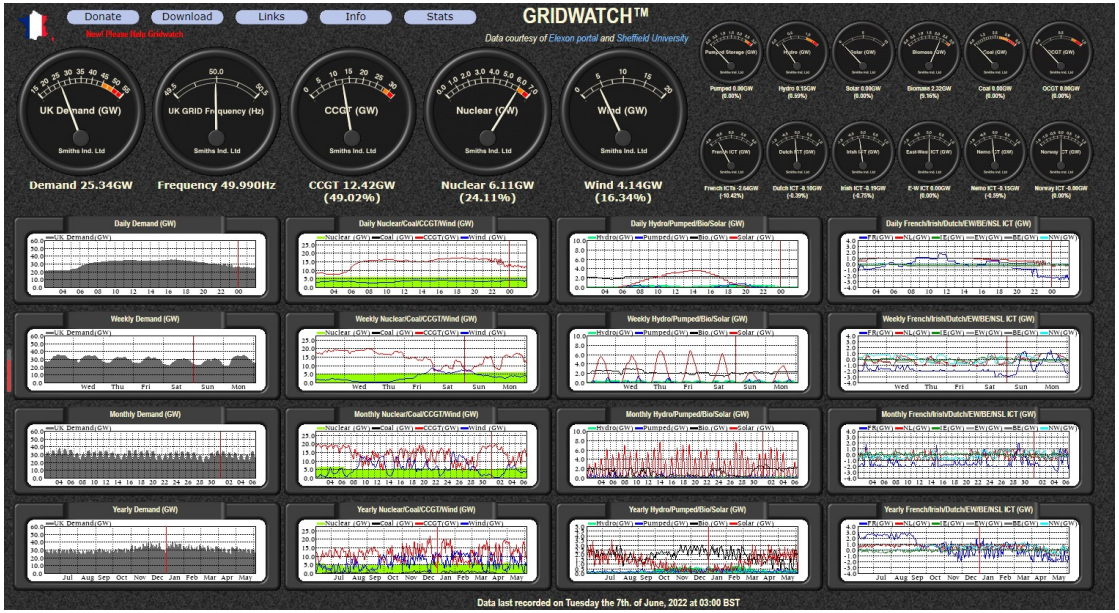
Elexon (subsidiary of

UK National Grid)

- 2011-2022

UK Power generation/demand

energy dataset



- Types of generation:

■ Common generator

Coal, solar, wind, hydro, pumped

■ Uncommon generator

Nuclear, CCGT, OCGT

Nuclear	These stations use a Uranium nuclear reaction to produce heat. This is used to heat water to produce steam which turns a steam turbine which drives a generator to produce electricity. The output from these is more constant than other power generation. Fluctations usually indicate maintenance, refuelling or problems. There are currently 8 Nuclear power stations in the UK.
CCGT	Combined Cycle Gas Turbine - These use Natural Gas to power a Turbine which turns a Generator. A second system uses the heat to produce steam which is used to turn a turbine which powers a generator. There are 39 CCGT power stations in the UK.
OCGT	Open Cycle Gas Turbine - These use Natural Gas, Diesel or Gas oil to power a Turbine which powers a Generator. These are expensive to run so are only used when necessary. There is currently approximately 30 of these in the UK.

Background-Basic analysis

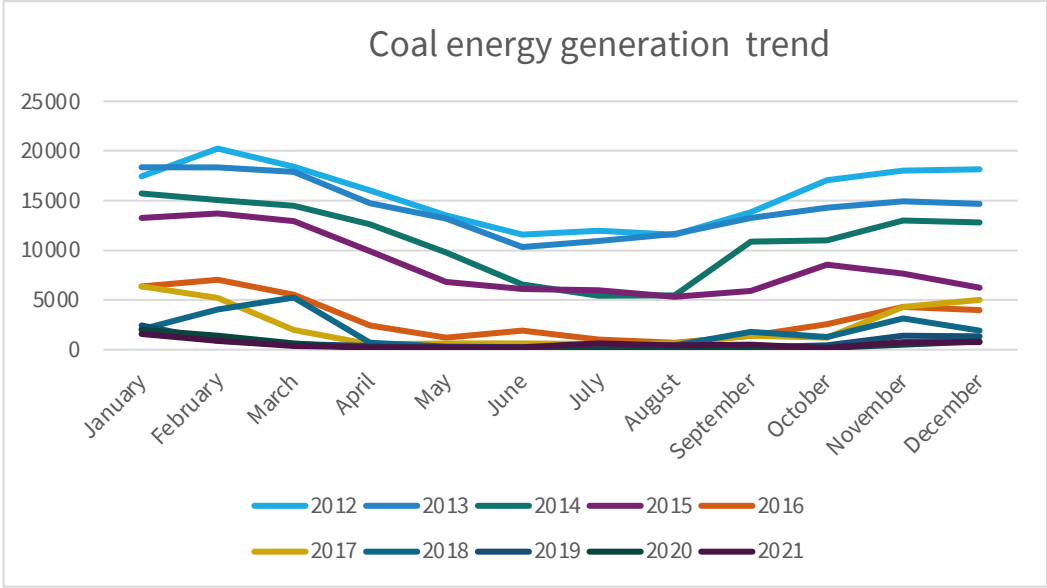
- For coal

Daily & Yearly diagrams

Figure out outliers

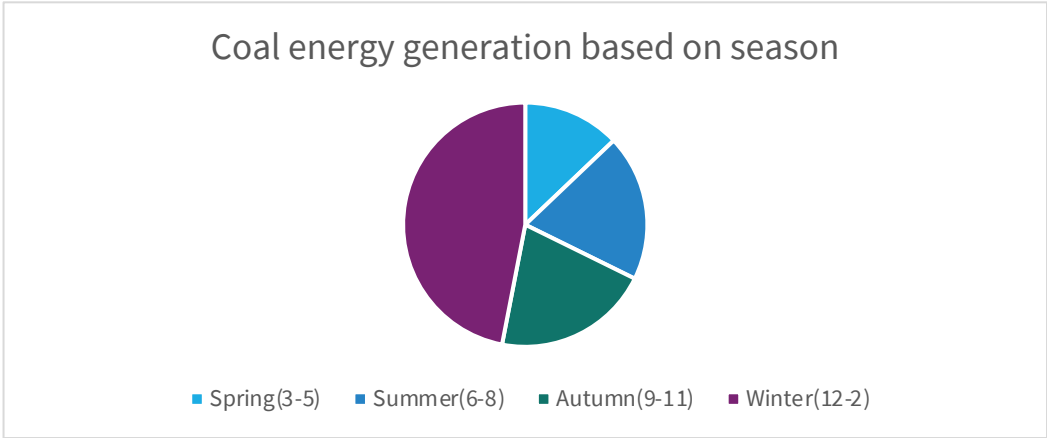
Analyse trend

Get conclusions



- For other generator

Clean generator



Process-carbon emission computation

- **CO_2 emission** ($\mathcal{E}$) is estimated using life-cycle assessments with units kilogramCO_2 (kgCO2),

$$\mathcal{E} = \sum_{t=1}^{N_t} E(t) \times C(t),$$

E = amount of energy generated/consumed (kWh),
$C(t)$ = **CO_2 intensity** based on the averaged fuel-mixed used for generation,
t =time step and N_t is the total number of time steps.

$C(t)$ is estimated as:

$$C(t) = \frac{\sum_{m=1}^{M}(C_m \times E_g(t))}{\sum_{m=1}^{M} E_g(t)},$$

E_g = amount of energy generated/consumed (kWh).
C_m = **CO_2 intensity** based on the m number of fuel-mixed used for generation,
t =time step.

Lau et. al (2015) Carbon savings in UK demand side response programmes, Applied Energy.

Process-carbon emission computation

Example: CO_2 intensity across different generation fuels

Types of energy	Carbon factors (gCO_2/kWh)
Oil	700
Coal	990
Gas	488
Nuclear	26
Wind	96
Hydro	13

Lau et. al (2013) Modelling carbon emissions in electrical systems, Energy Conversion and Management

Result

For example:

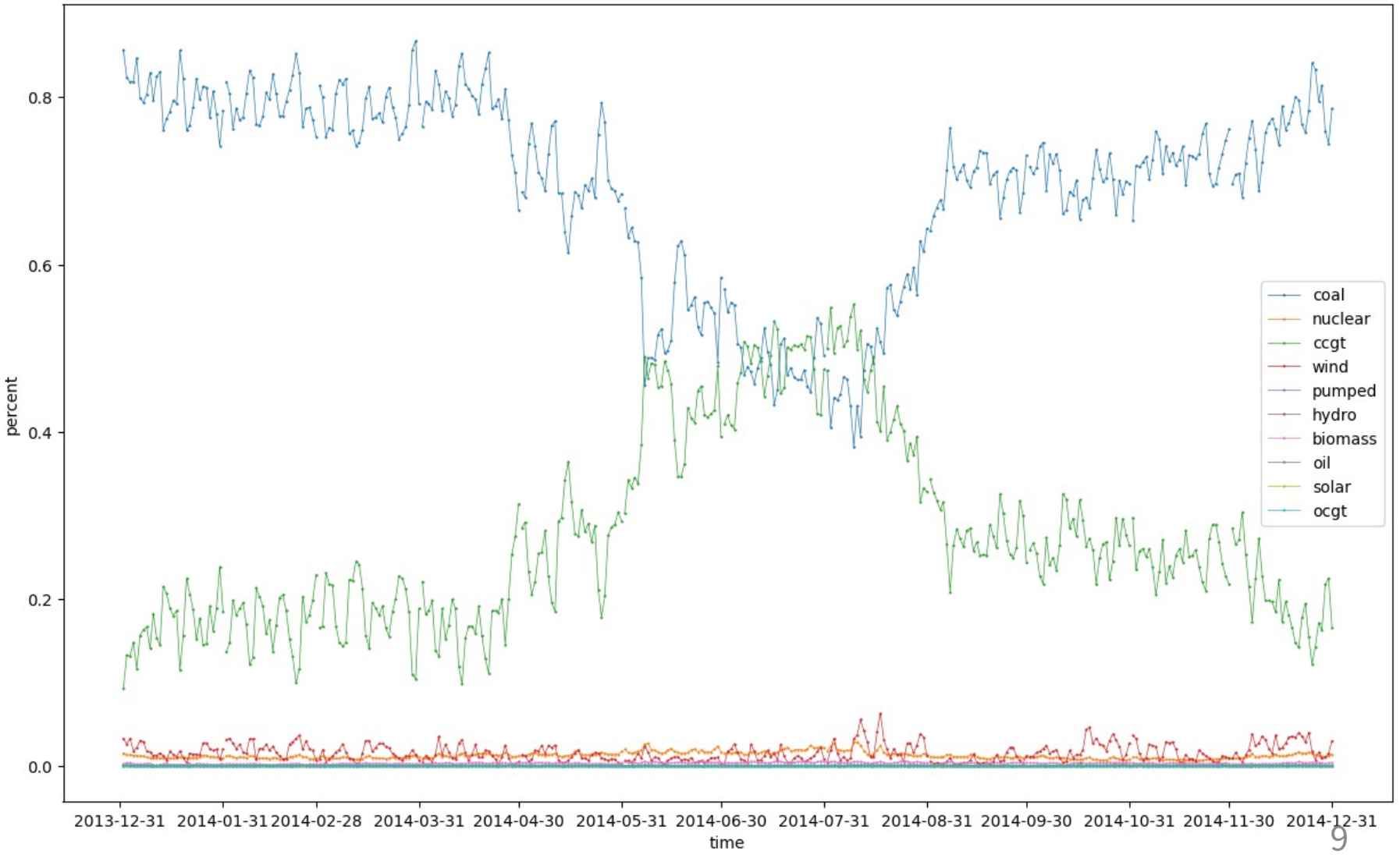
- Assuming that the power consumption of a Macbook is 61W, and a user is using the Macbook continuously (unplugged) for 8 hours.
- The CO_2 emission from the Macbook is therefore (assuming the averaged CO_2 intensity is 0.35kgCO_2/kWh):

$$61 \div 1000 \times 0.35 \times 8 \approx 0.17 \text{ kgCO}_2$$

- User can clearly see how much carbon is consumed when using an electrical product

Phase 1 Result

Yearly Carbon Emission Fuel Mix Percentage in **2014**



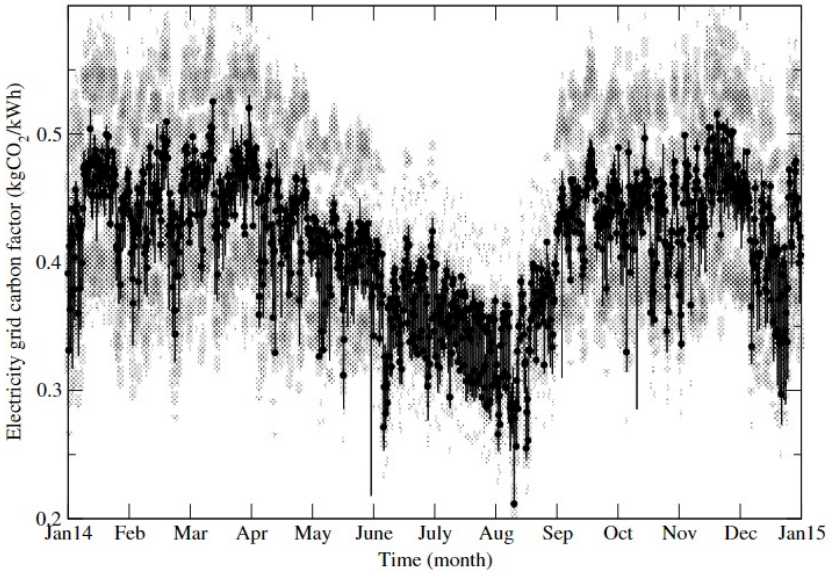
Phase 1 Result

Yearly Carbon Emission Fuel Mix Percentage in **2020** (COVID)

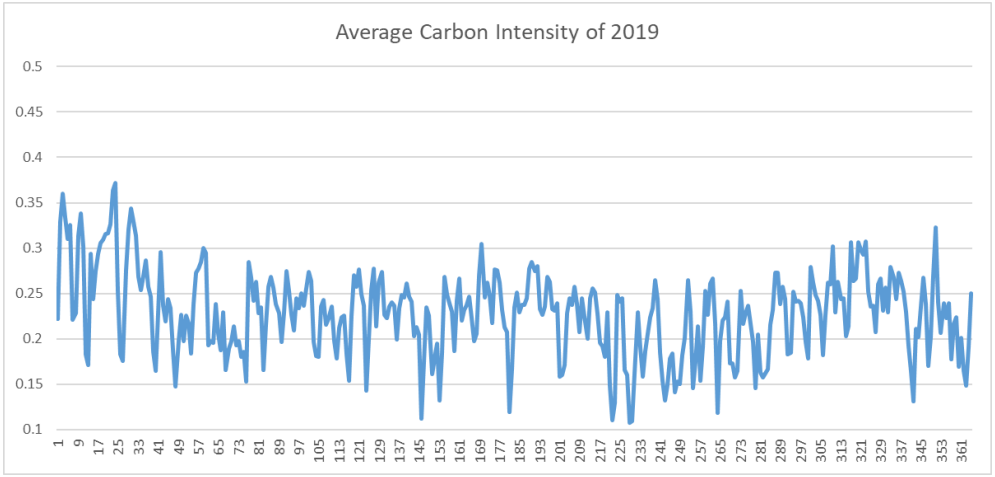
Phase 1 Result

Average UK Electricity Carbon Intensity

2014



2019



Result-Yearly Carbon Percentage(analysis)

- In 2014, **COALS** take a highest percentage of yearly carbon fuel mixes.
- The UK government urged for a gradual halt to coal power generation.
- CCGT gradually replaced coal power generation and became the main energy source.
- So, CCGT take a high percentage of yearly carbon after 2019.

Result-Difference between 2014 & 2019

- The overall level of carbon intensity is lower:
- The differences between seasons are smaller

Future work (next Phase)

Interface

- User-friendly
- Easy to understand
- Integrated
- Automatic
- Climate change awareness