NPL National Physical Laboratory | Centre for Carbon Measurement

Carbon emissions and savings in energy systems

Valerie Livina, National Physical Laboratory, UK

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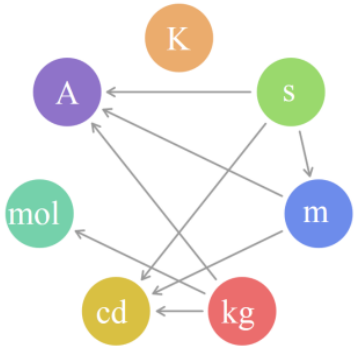
UK national metrological institute (governmental lab)

- Interface between business, academia and government
- Science with impact: ensure that measurements are comparable and traceable to the same standard units of the System International (SI)
- 700 staff



Magna Carta - 1215

"There is to be one measure of wine and ale and corn within the realm, namely the London quarter, and one breadth of cloth, and it is to be the same with weights."

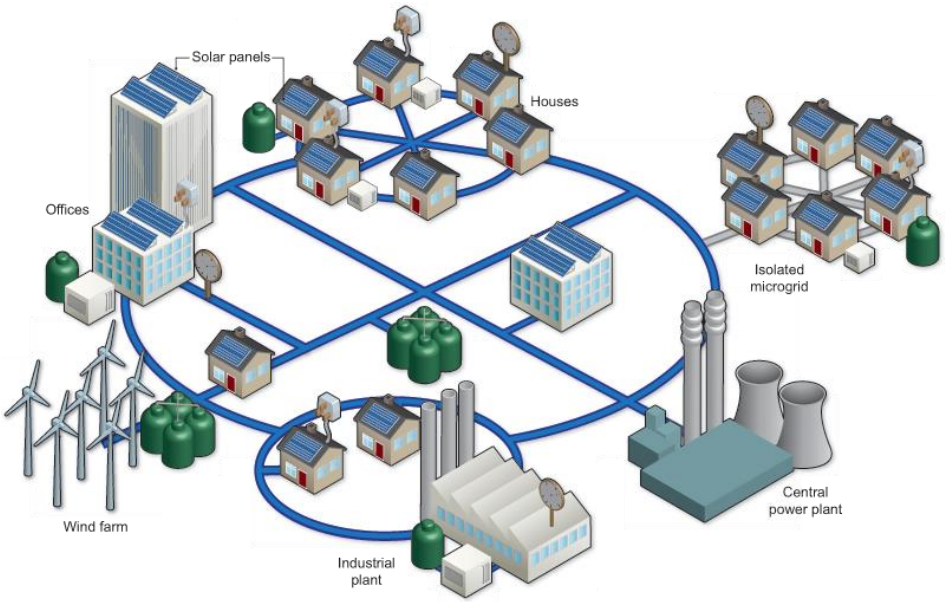
Europe 2020 strategy:
20/20/20 targets

- A 20% reduction in EU greenhouse gas emissions from 1990 levels
- Raising the share of EU energy consumption produced from renewable resources to 20%
- A 20% improvement in the EU's energy efficiency

Currently renewables produce 11% of energy in the EU

Carbon emissions in electric systems

(eqCO2 in grams per kWh)

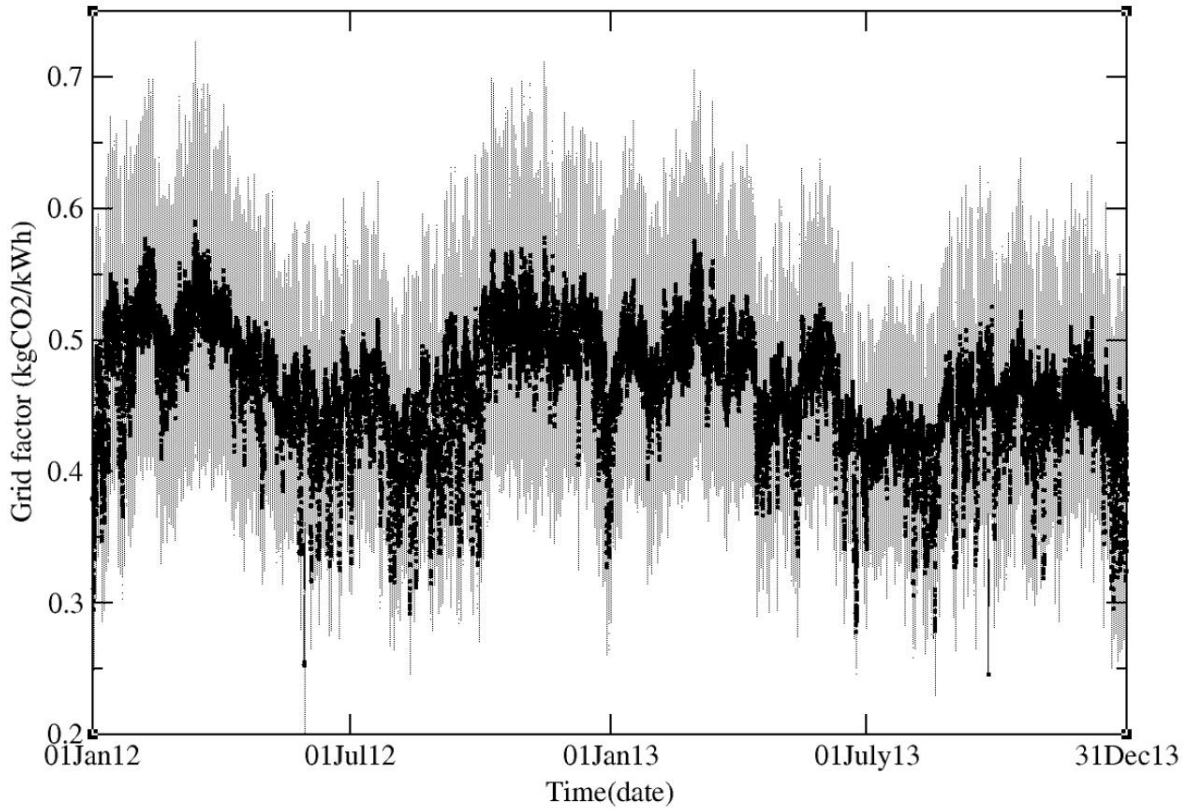


$$Emissions = Energy \times CarbonFactor$$

Energy consumption means
that somewhere there are carbon emissions

Two types of grid carbon factors: consumed energy factor in the UK energy grid (around 450 gCO2eq/kWh, annual or dynamically varying, based on the fuel mix) and single-fuel generation energy factors (depend on the fuel used)

Dynamical grid factor

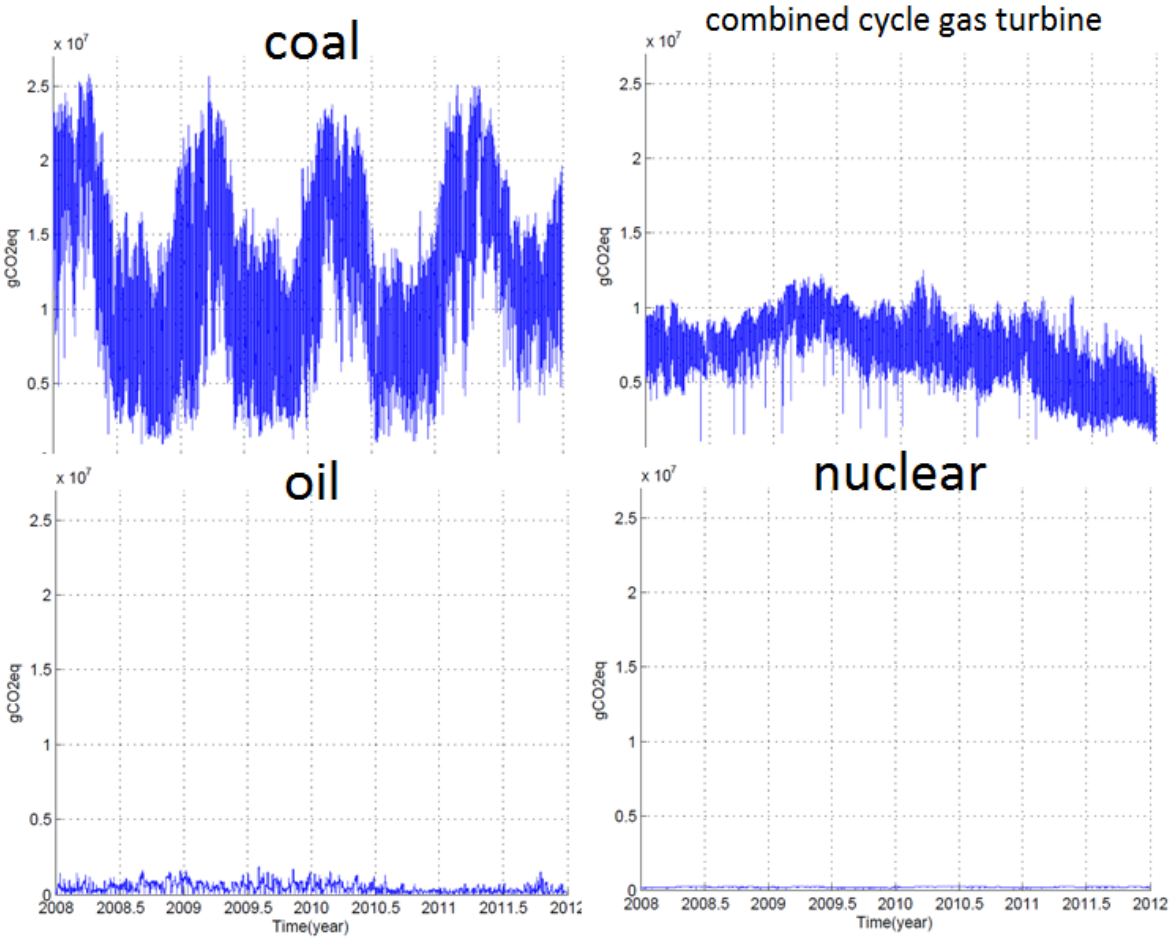


$$G_{UK} = \sum_{t=1}^{N_t} \sum_{m=1}^{N_m} \frac{(F_m \times E_m(t))}{\sum_{t=1} E_m(t)}$$

Fuel mix with
Monte Carlo simulations
for uncertainty quantification

Elexon national data

CO_2 emissions from electricity generation



Types of fuel	Percentage fuel mix (%)	
	Year 2013	Year 2014
Coal	35.80	39.66
CCGT	23.11	24.02
Nuclear	21.48	21.57
Wind	6.95	6.02
OCGT	0.02	0.01
Hydro	1.15	0.89
PS	0.08	0.08
Oil	0.00	0.01
Interconnector	6.64	5.84
Other	1.34	1.21

Carbon savings estimation

Carbon savings are estimated by comparing carbon emissions with Business-As-Usual scenarios:

$$Carbon\,Savings = Emissions_{usual} \quad - \quad Emissions_{improved}$$

The energy consumption/generation is estimated using energy records (30min smart meter records or 5min Elexon records, as well as modelled data)

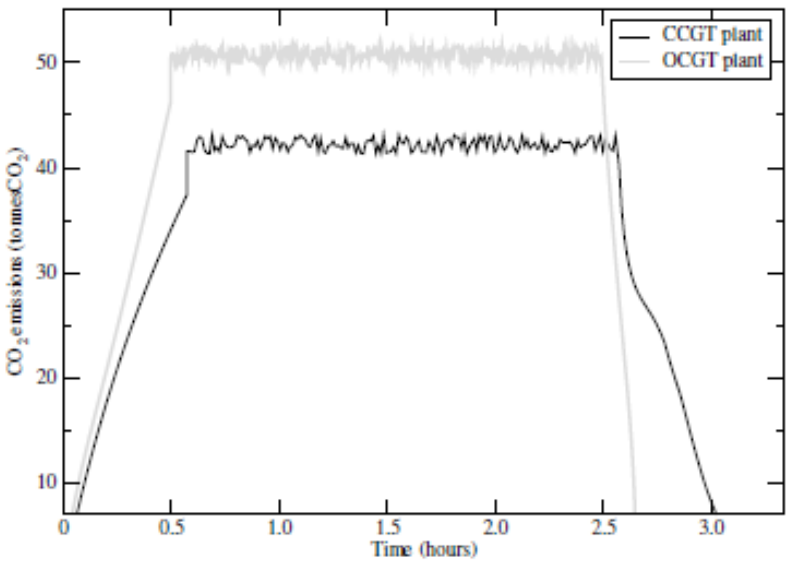
Carbon savings scenarios

- Smart interventions (Demand Side Response programs of large and small scales) – working examples and industrial collaborations, case studies reports

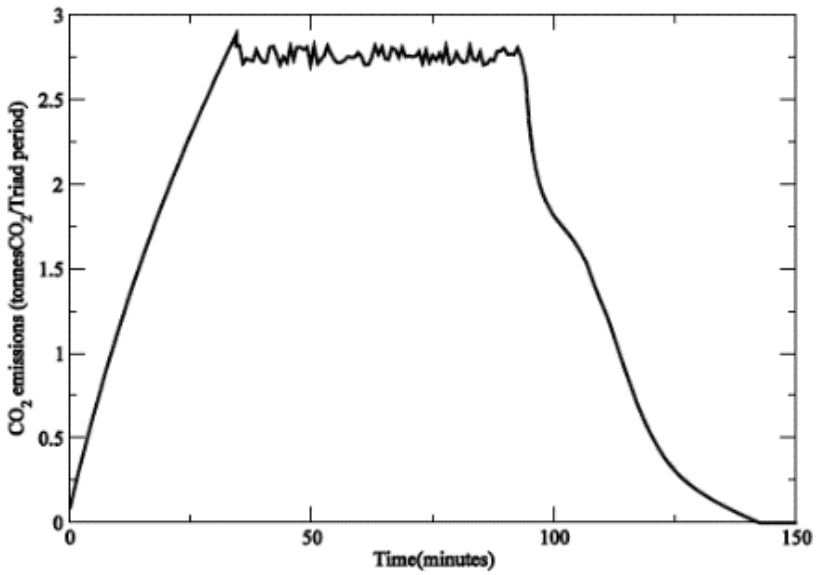
- Central control of energy generation with optimisation and forecast of carbon emissions – EnOpt modelling framework (Ensemble Kalman Filter + Optimisation)

National Grid DSR ("intelligent use") STOR & Triad programmes

(Short Term Operating Reserve and Triad Avoidance)



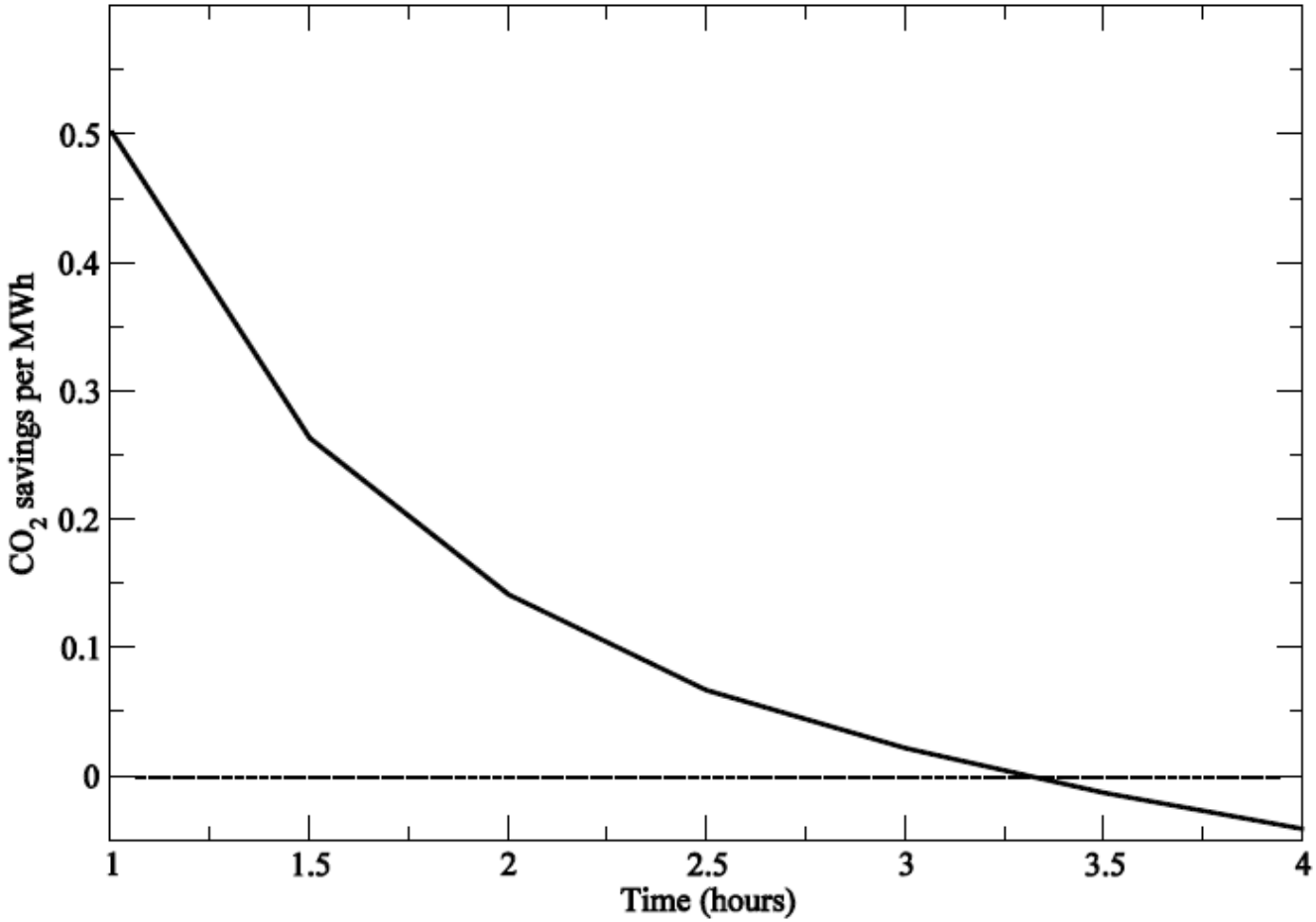
OCGT and CCGT plant emissions during one STOR run (500MW capacity)



CCGT plant emissions during one Triad run

E.T.Lau et al, Applied Energy 2015

Dependence of carbon savings on duration of Triad run



Eng Tseng et al, Applied Energy 2015

Nesta DSR competition, 2014

- Five finalists projects (demand shift, reserve storage, alternative heating with phase-change material, communal response, UPS-based DSR ideas)
- Assessed pilot installations, modelled business-as-usual and DSR carbon emissions
- Ranked the projects and provided reports for information to judges (assessment was based on many other factors as well: business case, development of prototype, etc.)
- The winner was the project with best developed prototype and biggest carbon savings (DemandShaper)

Very diverse technologies, needed rescaling for comparison and quantification of carbon savings

ENGIE IoT international competition (Brussels, May 2017)

- 14 finalists with IoT innovations (fuse optimisers, energy and water savings, air quality analysers, transport optimisation, etc)
- Assessment of carbon savings – run a workshop
- Estimation of emissions and savings for energy markets in the UK, Germany, Switzerland, Israel, Malaysia, Poland, the Netherlands
- Winner was the Israeli project with an innovative water tap that saves water and lots of energy in Israel, as water is obtained there by desalinisation

Key results

- Dynamical grid carbon factor with uncertainty quantification
- Studied carbon emissions in real data (Elexon, Irish SmartMeter pilot, Brunel PV, industrial case studies)
- Modelled carbon emissions for customers demand profiles (daily, seasonal)
- Estimated carbon savings in smart trials, innovation scenarios and DSR programmes
- Developed optimisation framework combined with assimilation, EnOpt (Ensemble Kalman Filter + optimisation)
- Eng Tseng Lau obtained PhD in February 2015

Publications

1. Optimisation of costs and carbon savings in relation to the economic dispatch problem as associated with power system operation, *Electric Power Systems Research* , 2016
2. Carbon savings in the UK demand side response programmes, *Applied Energy*, 2015
3. Ensemble Kalman filter forecasting grid carbon factor, *International Journal of Energy Systems*, 2015
4. The UK electricity Demand Side Response: carbon savings analysis, *12th International Conference on the European Energy Market*, Lisbon, 2015
5. Optimisation of carbon emissions in smart grids, *Proceedings of the UPEC 2014 conference*, Romania, 2014
6. Modelling Carbon Emissions in Electric Systems, *Energy Conversion and Management*, 2014

5 internal reports on the Nesta competition

3 commercial reports on carbon assessments of companies

Further work

- Industrial enquiries for carbon assessment of energy subsystems with various smart interventions
- PhD student (Reading), analysis of carbon intensity of energy grid, with meteorological input
- Recruiting a new student with Brunel, to work on energy systems in building environment, with an industrial partner and Brunel university
- Dissemination & engagement with government and energy industry stakeholders

Acknowledgements

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Thank you