Deep Reinforcement Learning in Electricity Generation Investment for the Minimization of Long-Term Carbon Emissions and Electricity Costs

Alexander J. M. Kell[1,2], Pablo Salas[3], Jean-Francois Mercure[4], Matthew Forshaw[1], A. Stephen McGough[1]

[1] School of Computing, Newcastle University, UK
[2] Chemical Engineering, Imperial College London, UK
[3] C-EENRG, University of Cambridge, UK
[4] Department of Geography, University of Exeter

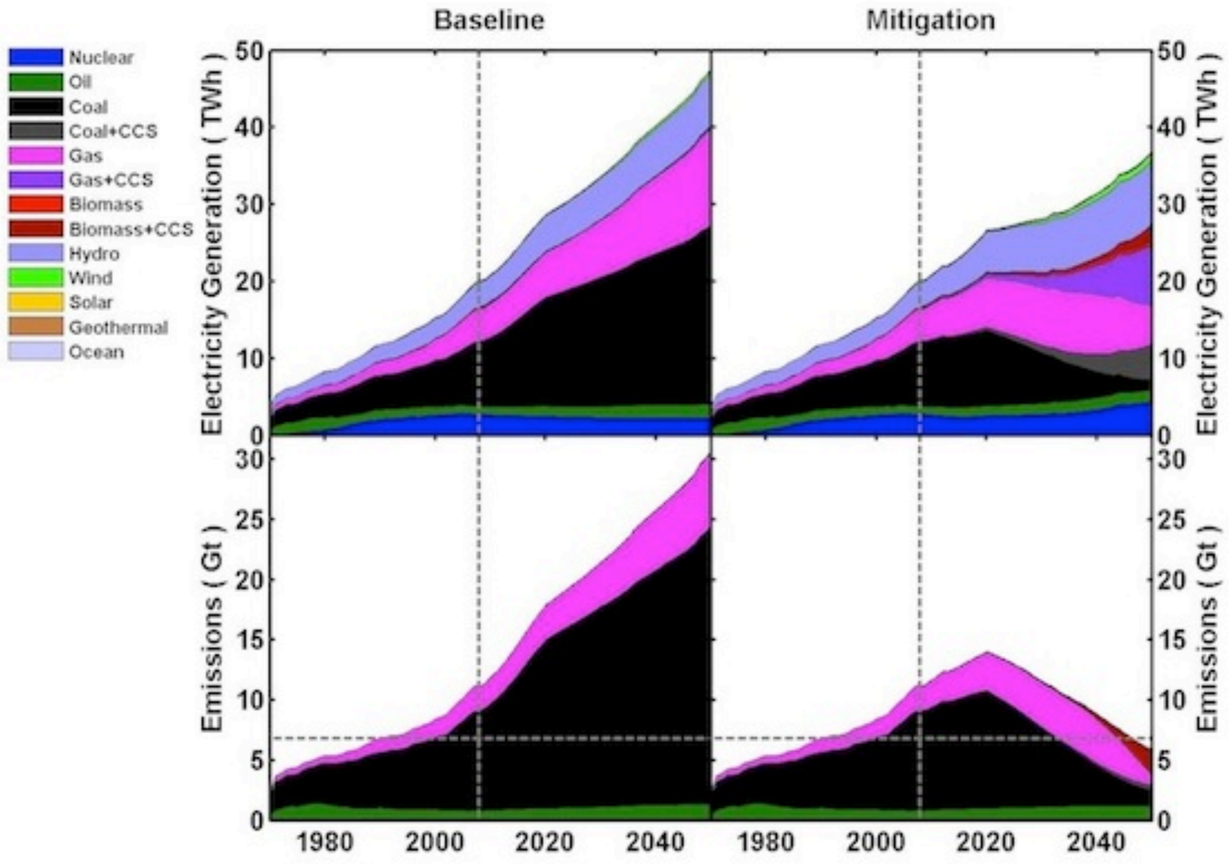
a.kell@imperial.ac.uk

Low-carbon electricity supply

- A movement from a high-carbon emitting electricity grid to low-carbon grid is required.
- Allow for wider decarbonisation of other sectors such as transport and steel industry.
- However, investors have to make decisions under uncertainty of the future:
  - Future costs
  - Future electricity demand
  - Carbon prices
- Can we use **reinforcement learning** to make investment decisions in a global power system?

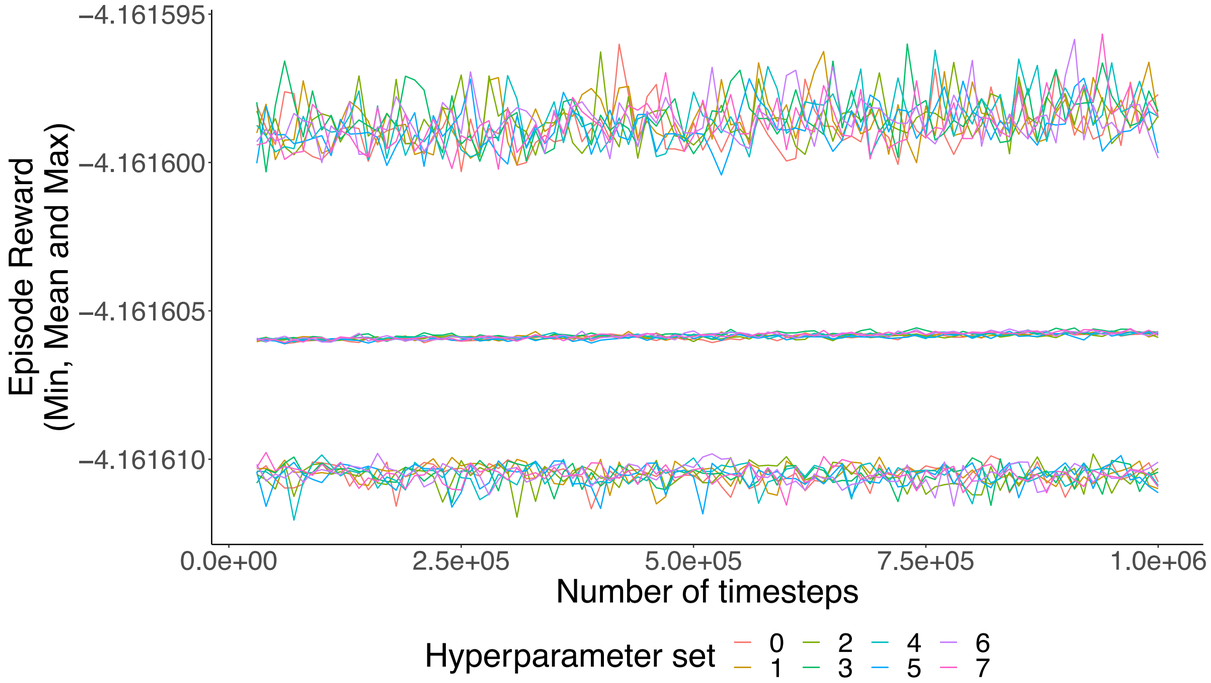
FTT:Power model

- Long-term global power systems model.
- Can simulate to 2050+
- Models induces technological change based on market competition.
- Natural resource use and depletion.
- Use of a dynamic set of differential equations for competition between technology options.

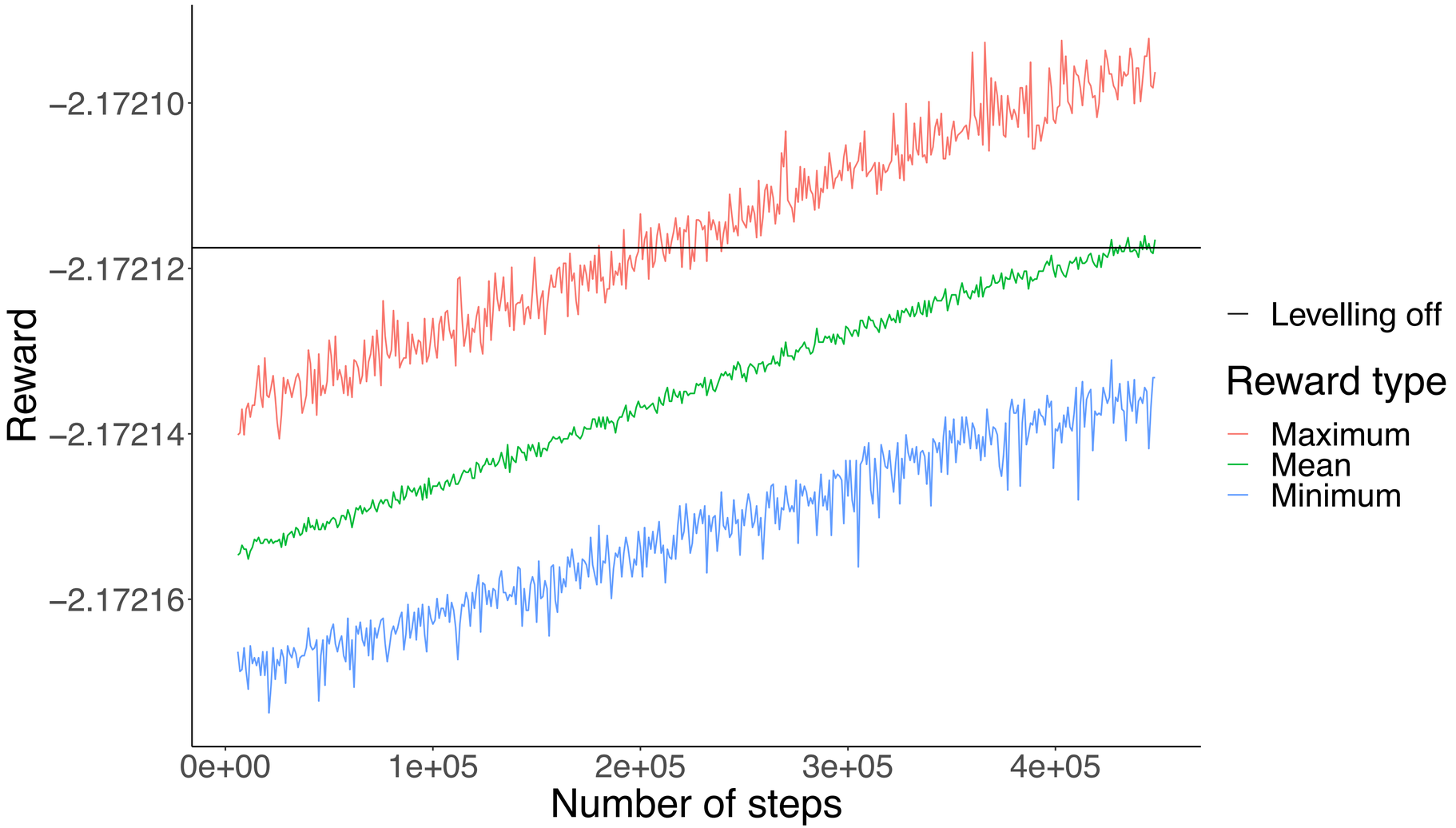


Deep Deterministic Policy Gradient Reinforcement Learning Algorithm

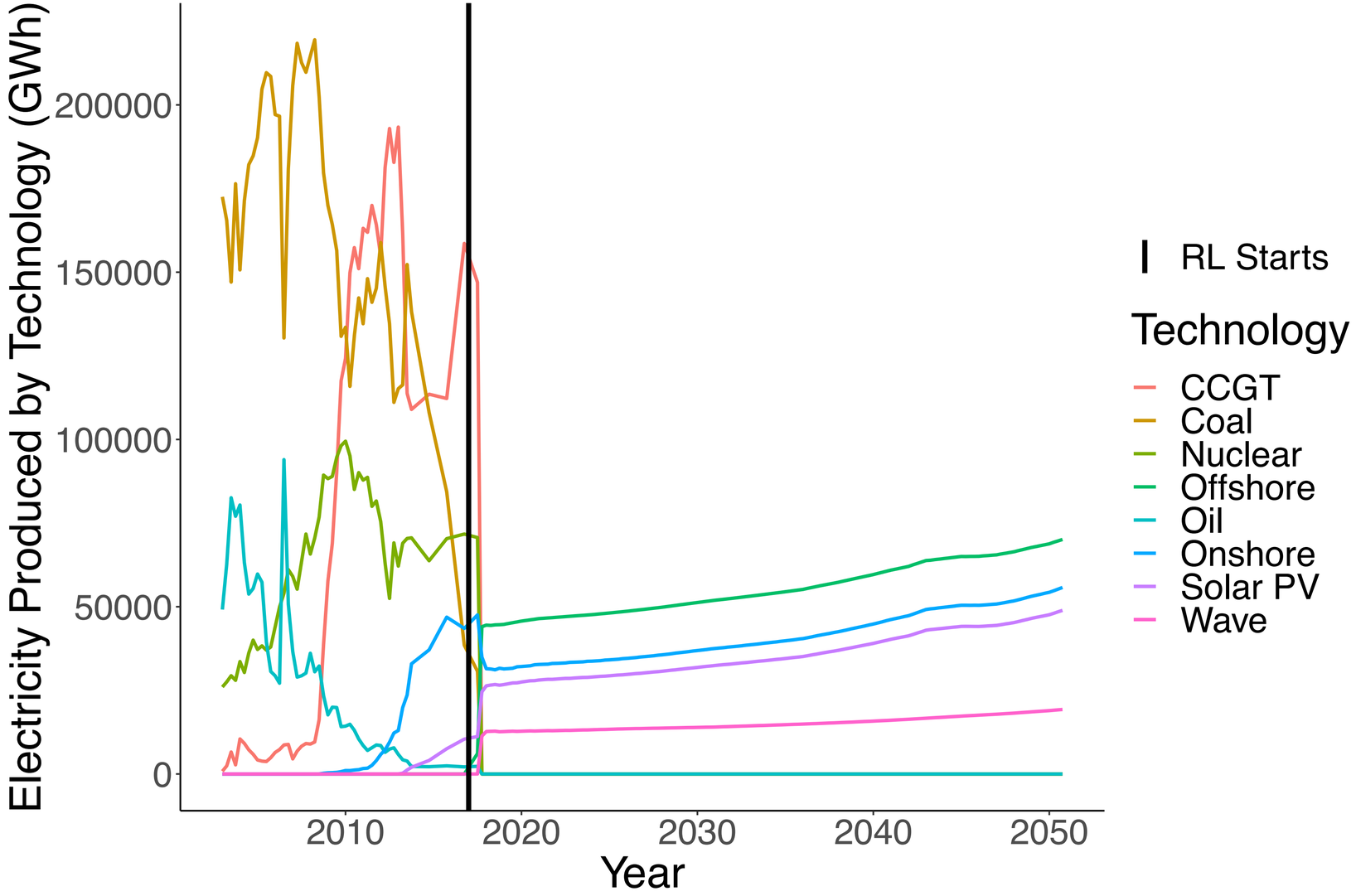
- Replace dynamic set of differential equations with reinforcement learning.
- Deep Deterministic Policy Gradient (DDPG) algorithm to make investment decisions.
- Reward minimises carbon emissions and levelized cost of electricity (LCOE):
  - $r = -(1000CO_{2_e} + \frac{LCOE}{1000})$
- Action: flow of share of technology from one to the other from 2017 until 2050.
- We model the UK and Ireland for compute tractability



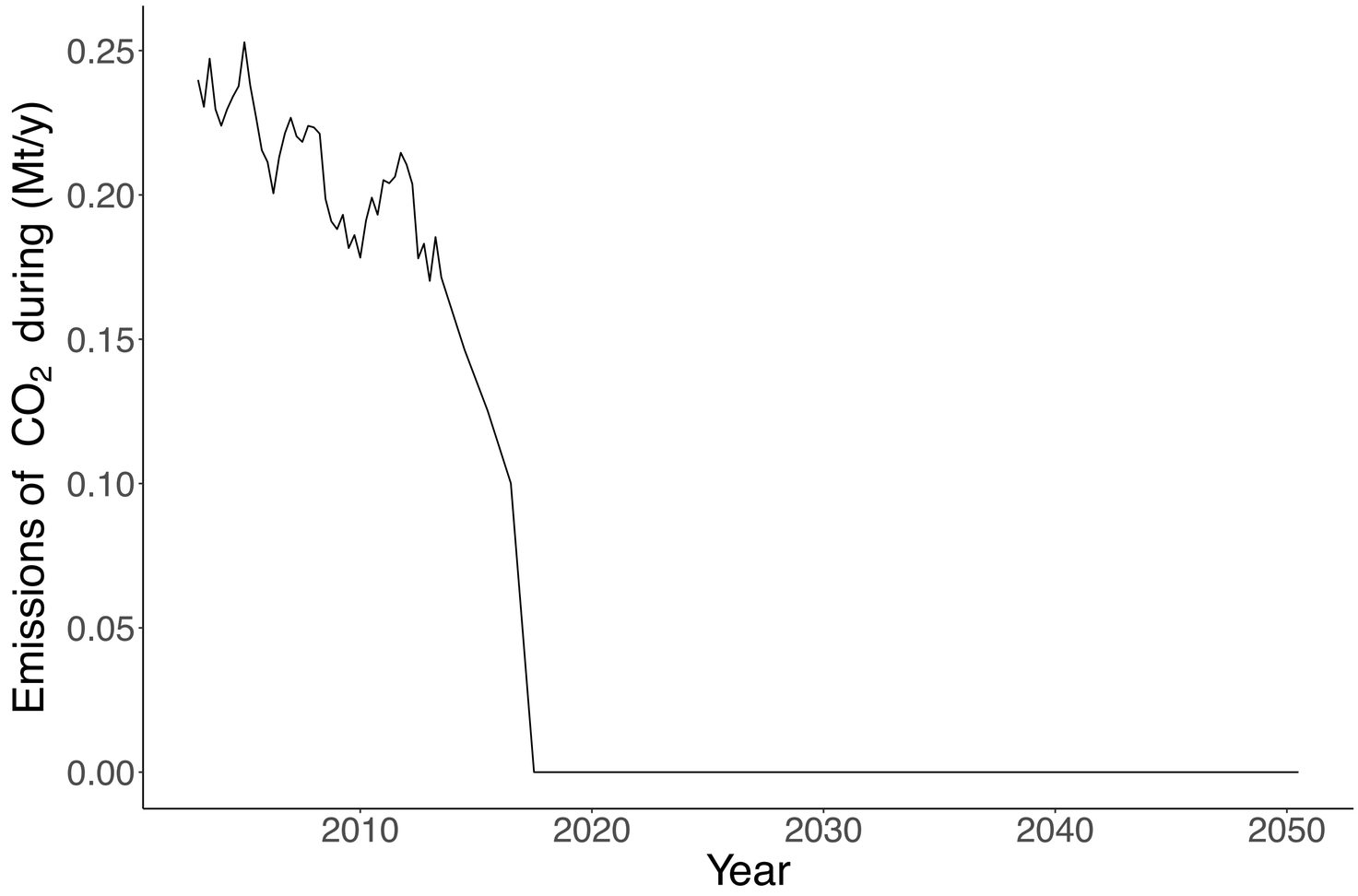
Sensitivity analysis of RL algorithm with varying hyperparameter sets



Reward of investment algorithm over time



Investments made by reinforcement learning algorithm within the UK and Ireland



Emissions after reinforcement learning algorithm begins.

Summary

- Move towards a low-carbon future requires a low-carbon electricity grid.
- We model investment decisions using the deep deterministic policy gradient reinforcement learning (RL) algorithm.
- Minimize levelized cost of electricity and carbon emissions.
- Use of the FTT:Power model to simulate investment decisions until 2050.
- A shift is observed from gas turbines, coal and nuclear to wind, solar and wave technologies.