Optimizing carbon tax for decentralized electricity markets with an agent-based model

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ABSTRACT

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KEYWORDS

Energy markets, policy, carbon tax, genetic algorithm, optimization, digital twin, agent-based models, electricity market model

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1 INTRODUCTION

Computer simulation allows practitioners to model real-world systems using software. These simulations allow for '*what-if*' analyses which can provide an indication as to how a system may behave under certain policies, environments and assumptions. These simulations become important in systems which have high costs, impacts or risks associated with them.

Electricity markets are an example of such a system. Disruptions to electricity supply, a substantial increase in the cost of electricity or unrestrained carbon emissions have the potential to destabilise economies. It is for reasons such as these that electricity market models are used to test hypotheses, develop strategies and gain an understanding of underlying dynamics to prevent undesirable consequences [2].

In this paper we use the electricity market agent-based model ElecSim to find an optimum carbon tax strategy [3]. Specifically, we use a genetic algorithm to find a carbon tax policy to reduce both average electricity price and the relative carbon density by 2035 for the UK electricity market.

For this, we use the reference scenario projected by the UK Government's Department for Business & Industrial Strategy (BEIS) and used model parameters calibrated by Kell *et al.* [1, 4]. This reference scenario projects energy and emissions until 2035.

In contrast to grid or random search, genetic algorithms have the ability to converge on an optimal solution by trialling a fewer number of parameters. This is of particular importance in cases with a large number of parameters or long compute time of the function to optimise.

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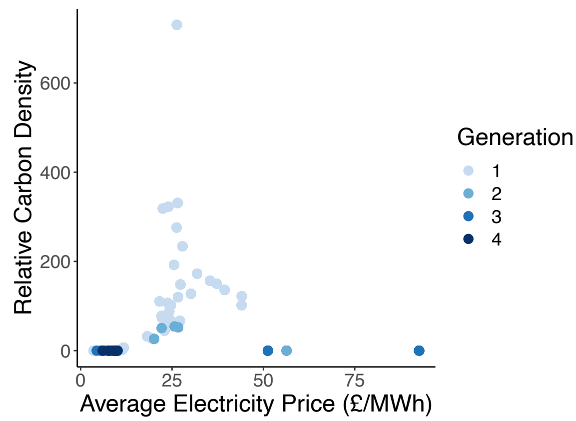

Figure 1: Development of genetic algorithm rewards of average electricity price and relative carbon density in 2035 over time for highest degrees of freedom per year.

2 LITERATURE REVIEW

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3 OPTIMIZATION METHODS

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4 SIMULATION ENVIRONMENT

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5 RESULTS

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6 CONCLUSION

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ACKNOWLEDGMENTS

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[2] S. Jebaraj and S. Iniyan. 2006. A review of energy models. *Renewable and Sustainable Energy Reviews* 10, 4 (2006), 281–311. https://doi.org/10.1016/j.rser.2004.09.004

[3] Alexander Kell, Matthew Forshaw, and A Stephen Mcgough. 2019. ElecSim : Monte-Carlo Open-Source Agent-Based Model to Inform Policy for Long-Term Electricity Planning. *The Tenth ACM International Conference on Future Energy Systems (ACM e-Energy)* (2019), 556–565.

[4] Alexander J. M. Kell, Matthew Forshaw, and A. Stephen McGough. 2020. Long-Term Electricity Market Agent Based Model Validation using Genetic Algorithm based Optimization (Under Submission). (2020).

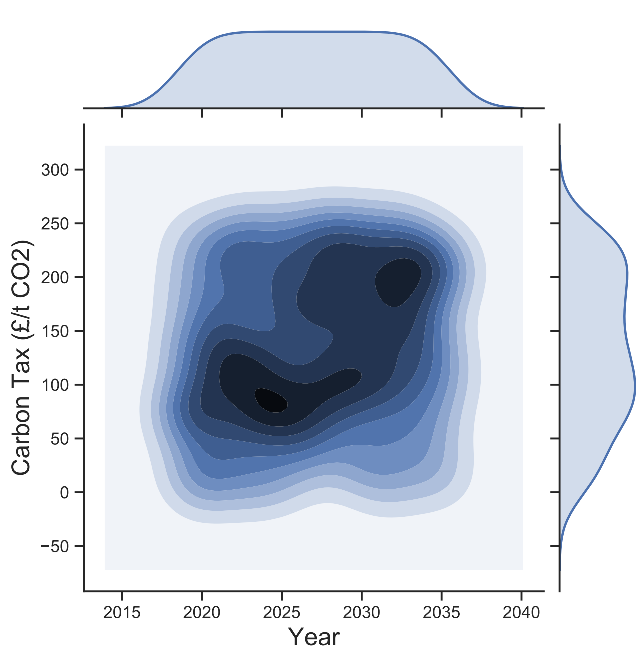

Figure 2: 2D density plot of carbon tax strategies that led to an average electricity price of below £5/MWh by 2035.

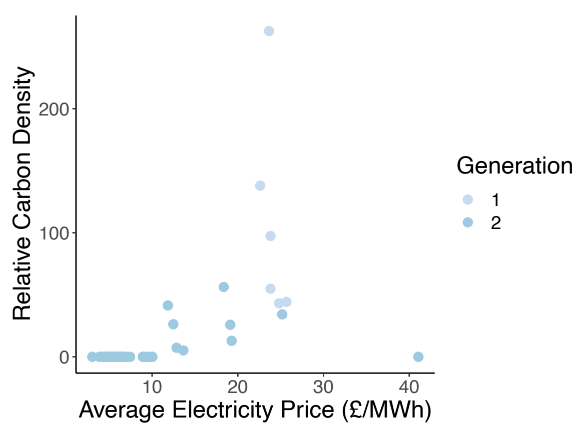

Figure 3: Development of genetic algorithm rewards of average electricity price and relative carbon density in 2035 over time for linear carbon strategy.

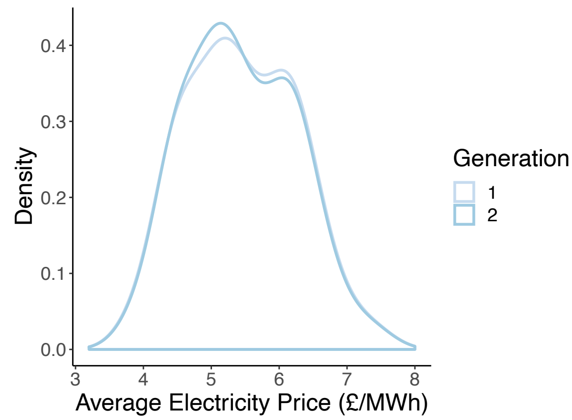

Figure 4: Density plot of average electricity price smaller than £8/MWh in 2035 over generation number of genetic algorithm.

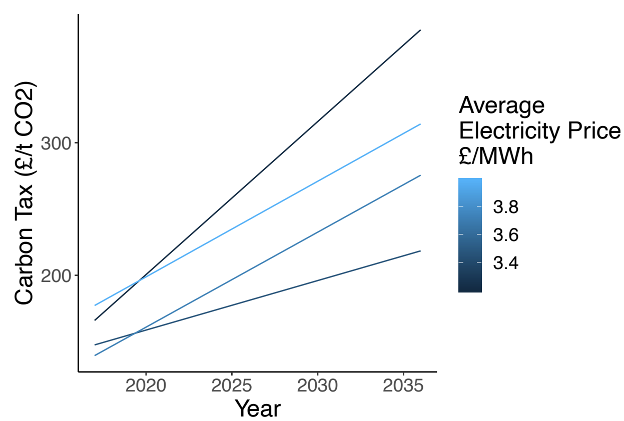

Figure 5: Linear carbon tax strategies visualised with average electricity price smaller than £5/MWh.