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CENTRE FOR AI & CLIMATE

AI for energy

Opportunities for applying AI in the energy sector

May 2021

Introduction

Energy systems are transitioning from being centralised and fossil fuel dominated, to increasingly decentralised and renewables-dominated with new demands from transport and heat. As they do so there will be an increasing need to optimise and manage the many distributed and complex constituents of the energy system including variable renewable generation, electric vehicle charging, battery storage and demand-side response.

Artificial intelligence (AI) will not only be a useful tool in optimising and managing future electricity systems but will become essential in managing the increased complexity, whether it be in relation to solar and wind forecasting, dispatch optimisation, battery management or analysing smart meter data.

AI refers to a suite of computer science techniques and technologies that allow computer systems to demonstrate intelligence. A more elaborate definition characterises AI as "a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation".

A recent Microsoft/PwC report estimates that applying AI to the energy sector can help reduce global emissions by up to 4% against business as usual by 2030, while boosting GDP by up to 4.4%.

This paper outlines emerging and promising use cases and applications of AI in the energy sector.

Applications of AI in the energy sector

Grid management

AI can optimise the management of existing network operation processes, and support the networks' abilities to transition to net zero. One of the most important roles AI could play in energy systems is to optimise grid dispatch. Grid dispatch is the process where system operators determine how much power controllable generators should produce over a range of timescales.

The process is already challenging but will become even more complex as electricity systems include more variable generation, storage, and flexible demand, since operators will need to manage more system components while simultaneously optimising scheduling more rapidly to respond to second-by-second variations in electricity production.

Data science and AI can help improve the optimisation of current grid dispatch processes. In addition, AI will be needed to help develop and optimise control systems for further layers of grid balancing at the distribution network level, and at the individual substation level, which will be needed to allow for greater proportions of variable generation. This could enable DSO decision makers to manage constraints or balance local networks (ANM, use of flexibility, voltage charge, etc) and assess that economically in a whole systems context.

Companies/pilots/trials include:

- Autogrid helps utilities in the US automate distributed energy management. They use machine learning to process data from millions of energy assets and predict demand patterns.
- National Grid ESO is increasingly looking at the potential for data science and AI to improve grid management.
- IBM worked with Western Power to use machine learning and cognitive analysis to identify previously unknown EVs and other low carbon technologies to support network planning and investment strategies.
- In the UK, Utonomy is using both hardware and software solutions to provide active gas pressure management to the gas grid to reduce leakage, increase the use of biomethane and the transition to a hydrogen economy.

Renewable generation forecasting

A higher proportion of renewable energy generation can be enabled by improved long- and short-term forecasting of renewable energy generation, and improved electricity demand forecasting. Improved long-term forecasting can support investment and planning, whilst short-term forecasting can support immediate operational decision making.

The more uncertainty grid operators have in either electricity supply or demand forecasts, the more back-up power, known as spinning reserve, is needed. Spinning reserve is provided by fossil fuel generation (mostly gas) and comes with associated emissions and costs.

AI coupled with improved data collection has the potential to improve short-term renewable energy generation forecasts and demand forecasts allowing for reductions in spinning reserve, and reductions in the loss of expensive excess renewable energy power. Balancing the UK electricity grid currently costs end-users about £300 million per year. AI could help keep these costs under control as renewable penetration increases.

Improved forecasting of generation and demand will not only be useful for network operators but will be important for all players in the energy market. Generators will want better forecasts to allow them to improve the efficiency of their generation assets; aggregators will want better forecasts to optimise their deployment of their flexibility assets, and suppliers will want to use forecasts to optimise their energy trading.

Companies/pilots/trials include:

> Open Climate Fix research into use of machine learning to improve solar photovoltaic forecasting to grid balancing.

> Centrica is using AI to manage fluctuating supply and is investing in AI and automated trading systems to optimise balancing, market price exposure and forecasting.

> Digital Engineering, working with the Energy Systems Catapult, is a firm whose technology enables utility firms to understand the impact of weather on their networks.

Demand-side-response

Machine learning can enable dynamic pricing and trading, creating market incentives and price signals, smart meter signals, or learned user preferences to use energy when there is plentiful low carbon energy on the grid.

Edge computing can be used to process data from distributed sensors and other Internet of Things devices, and deep reinforcement learning can then use this data to efficiently schedule energy use.

Companies/pilots/trials include:

> Limejump's AI Virtual Power Platform is an aggregation of flexible energy generation and storage assets of different sizes and technology types.

> Octopus Energy's Kraken Technology uses advanced data and machine learning to support 17 million customer accounts. It is being used to roll out its Agile Tariff, demonstrating evidence of the successful functioning of flexible price signals.

> OVO's Kaluza platform using AI to help manage and aggregate electric storage heaters allowing the load to be bid into ESO markets.

Optimising existing technologies

Beyond grid optimisation, there is widespread potential for AI to be used to optimise the efficiency of individual assets within the energy system. This could come in the form of optimising renewable energy generation assets or battery assets.

Such optimisation is possible both in terms of the operation of existing hardware, but also has the potential to optimise the design of new hardware solutions. One promising application is the use of machine learning coupled with time series, telemetry data, weather data and maintenance data to uncover the drivers behind wind farm production-decreasing events and allow wind farms to increase productivity by reacting to these negative events before they occur.

Machine learning, coupled with Open Street Maps, can be used to determine optimum locations for grid-scale electricity storage and electric vehicle charging stations to ensure high asset utilisation.

Companies/pilots/trials include:

> Deepmind and Google: Deepmind, Alphabet's AI Lab, applied their machine learning algorithms to Google's wind farms, and in doing so boosted the value of our wind energy by roughly 20%, compared to the baseline scenario of no time-based commitments to the grid.

> Habitat Energy uses AI to optimise grid-scale battery storage, to improve their performance in the wholesale and balancing markets in the UK.

> Smart Power Network's Smart Energy Controller is an all-in-a-box solution for unlocking a flexible electricity grid whilst ensuring it remains secure. The SNC supervises, optimises and controls energy assets of any kind in a coordinated manner. This enables advanced system monitoring, real-time control, fault detection and protection of energy assets. It is working with the Energy Systems Catapult to work towards commercialisation.

> SparkBeyond is working with an energy supermajor and large European utility to increase production at select wind sites, in one instance increasing wind farm production by 2% in under 2 days. They are also working with electric utilities to increase asset utilisation and EV/battery storage adoption.

Electric vehicle integration

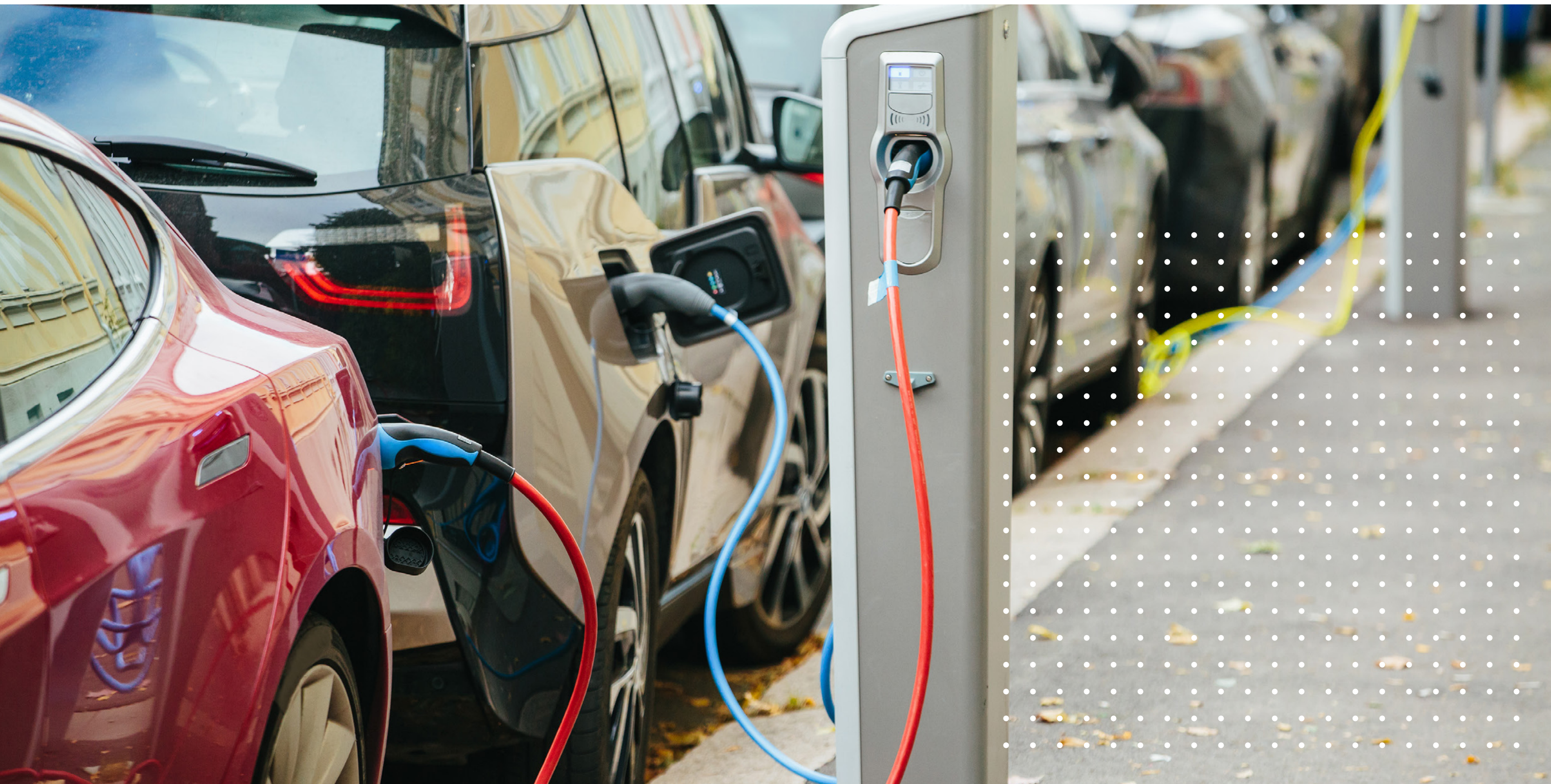
An increasing number of EVs on the roads will create challenges associated with integrating them into existing systems. AI can help address some of these challenges. Accurately modelling charging behaviours with AI will be increasingly important for grid operators looking to predict electricity demand.

Using machine learning combined with price signals, customers can also be encouraged to charge vehicles throughout the night and avoid excessive demands on the grid by "crowding" behaviours whilst ensuring it is affordable. Machine learning can open up the use of electric vehicle batteries, allowing them to act as energy storage for the grid, where charging and discharging is controlled by price signals.

Companies/pilots/trials include:

> Optimise Prime with UK Power Networks, Hitachi, Uber, SSE, Centrica, Royal Mail, and funding from Ofgem's Network Innovation Competition. It seeks to understand and minimise the impact the electrification of commercial vehicles will have on distribution networks using machine learning.

> Octopus Energy offers tariffs to EV drivers via its data analytics and machine learning platform Kraken. They can benefit from cheaper fees by smart charging at night, helping also to balance the grid. Homeowners can also get support in optimising home energy storage.



Domestic building and home management

Machine learning coupled with smart meters, home controls and sensors can support efficiencies in home energy, heat and cooling demand by dynamically adapting to changes in occupancy patterns. Electricity usage data can be combined with AI to deliver elderly care services in the home.

Companies/pilots/trials include:

> Nest Labs is a home automation company manufacturing sensor-driven, Wi-Fi-enabled, self-learning thermostats and smoke detectors.

> BuildingIQ provides an AI system which offers an advanced form of building energy management. Its software creates a thermal model of the building to account for the building fabric, external temperature forecasts, solar gains and the activities of occupants. The system is enabled by IoT sensors throughout the building, wireless controlled pumps and motors, and algorithms that can understand responses to internal and external changes. This has enabled energy savings across a number of building types of up to 17%, with payback in under a year.

> Informetis, applies AI and machine learning techniques to normal electricity data in an elderly person's home to provide "alerts" to their carer (e.g. their children) about "unusual activity patterns" (e.g. the kettle has not been used for an unusually long time today). This service requires no user input or additional sensors, and is completely unobtrusive and self-learning.

Increasing the energy efficiency of commercial and industrial facilities

AI can help optimise the energy efficiency of industrial processes, for example by optimising the use of energy inputs, increasing the efficiency of heating and cooling systems, predicting machine breakdowns, and improving production quality.

However, due to the rebound effect, where increased efficiency can lead to increased production, such improvements do not necessarily lead to emission reductions on their own and need to go hand-in-hand with policies designed to limit emissions.

Companies/pilots/trials include:

- Deepmind and datacentres: Deepmind applied its AI algorithms to optimise the energy systems within its data centres and was able to increase the efficiency of the cooling systems by 40%.

Microgrid management

AI and data analytics can be used to help operate microgrids, by supporting more accurate forecasts of demand and energy production. This is particularly important as microgrids can be difficult and harder to balance. Combined with blockchain, AI can also enable peer-to-peer trading.

Companies/pilots/trials include:

> Hitachi's Smart Islands Project on the Isles of Scilly is deploying AI with a range of other cutting-edge technologies to optimise locally produced renewable energy.

> Electron has created a blockchain enabled local distribution market allowing micro assets to be recorded to an asset register and then be traded in local distribution flexibity markets.

> Piclo has created a platform that allows DSR assets to register and creates peer-to-peer trading trials.

Conclusion

These examples represent some of the current areas of opportunity for applying AI within the energy sector that are being explored, however it is certain that additional opportunities will emerge over time. Whilst there are AI for energy projects already being developed, some of which are already in commercial operation, adoption is often slow and disjointed. A sector-wide approach to accelerating and scaling the adoption of AI in the UK energy system can rapidly improve system efficiency and reliability, help accelerate the transition to net zero and reduce energy bills for consumers.

Our recommendation is that a new institution is needed to fulfil this role, in the form of a fully funded Centre for AI & Climate with a government mandate to accelerate the adoption of data science and machine learning in the UK energy sector. A detailed case for the rationale for such a body can be found on the ICAIEC website (Rationale pdf).

Pillars of the Centre for AI & Climate

1. Policy design	Advise governments on how to upgrade climate-related policy to be AI-friendly and support its adoption
2. Data and tools	Develop processes and tools that make it easier for the wider AI community to engage in the sector
3. Accelerator	Provide bespoke innovation funding for initiatives that would not otherwise attract investment
4. Research	Support cooperation around academic research on AI for climate
5. Market facilitation	Support knowledge sharing on the opportunities for AI to support decarbonisation

Sources:

Rolnick et al. (2019) Tackling Climate Change with Machine Learning

Microsoft & PwC (2019) How AI can enable a sustainable future

Clutton-Brock et al. (2020) The rationale for an International Centre for AI, Energy and Climate

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CENTRE FOR AI & CLIMATE

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