AI in Energy

White paper: transforming Energy through AI

Contents

1. Executive summary

Artificial Intelligence (AI) is transforming the Energy Sector. In this white paper we highlight key areas of impact both now and those that need to be transformed in the next five years. At Energy Systems Catapult we take a whole systems approach to considering the future impact of energy sector changes. We work with a wide range of stakeholders to understand and communicate both approaches to innovation and best practice within Energy, Machine Learning, Data Science and AI.

- Within energy markets the pivotal question is how best to design markets which help motivate the market players to optimally establish the flexibility and ability to balance supply and demand. This is in a new world where there are more ways to consume electricity on the demand side and greater variability in the timing of the supply from renewable sources.

- Energy networks have challenges around ensuring the supply is managed in this new world of increased flexibility and greater numbers of market players. And there is a real opportunity to provide this through better use of data and AI, for example through improved fault detection, improved power flow, the use of new performance measures and increased stability.

- Across transport there are key themes for the areas of improving energy through AI: improving travel efficiency; and improving vehicle efficiency. The key contributions to these themes are the use of AI to improve route planning, EV battery design, congestion easing, and optimising charging across fleet vehicles.

- Within the area of domestic energy use, behind the meter, there will be a move from gas to electricity and an increase in the numbers of smart devices controlling the consumption (EVs, heat pumps etc) and local supply (solar panels). AI solutions or interoperable sets of solutions are needed to solve both the needs of hiding the complexity for the individual in the home controlling the myriad of energy devices and creating an optimal space for networks to smooth the increasing demand peaks from more devices.

In each of these areas there is increased complexity. AI can both hide this complexity from the end user and to optimise within these systems. A whole systems approach is required to consider the multiple stakeholders and system demands and constraints within these complex systems. AI, Machine Learning, Data Science and whole systems thinking are key areas in which Energy Systems Catapult already supports the transition of the energy system.

2. Industry wide challenges

AI has the potential to play a significant role in supporting energy system transition to Net Zero. However, the effective use of AI requires a number of generic challenges to be addressed. These challenges are driven by the nature of AI and the newness of some of the technologies and algorithms.

Machine Learning (ML) is the area of using data to infer algorithms and models which can make predictions about the future state of the world and learn about the historical picture through inferring groups. While AI is commonly used to refer to the area of application of algorithms that extend to replicating the decisions and understandings that humans make about the world. And Data Science is the space in which algorithms are developed with data and ML and statistical techniques, for the purposes of understanding data, visualising data and creating predictive models. Figure 1 summarises these categories.

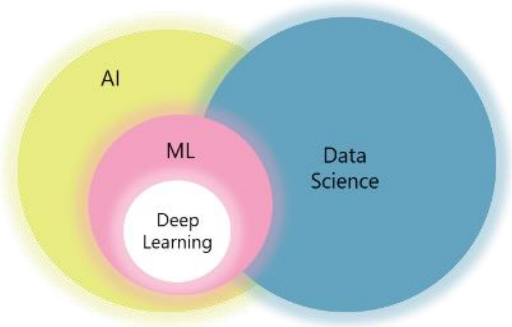

Figure 1: AI, ML and Data Science

AI and machine learning tools make predictions about the future and give real value to the solutions they are part of. Without data they cannot be built, therefore access to open data is necessary for high quality research and product development in all areas of the sector. This data access is being developed by initiatives such as Energy Data Taskforce[1], Energy Data Best Practice, and the Modernising Energy Data programme. Efforts to increase the use and understanding of behind the meter data include Smart Meter Data and the Smart Meter Public Interest Advisory Group (SM-PIAG).

Key themes across the examples of AI in energy are the need for greater interoperability between devices to facilitate data transfer and effective solutions; the problem of complexity and how AI can help solve this; and the route to optimisation through deployment of machine learning.

[1] https://es.catapult.org.uk/case-studies/energy-data-taskforce

2.1. Energy Markets

With the plan for the UK to decarbonise its grid by 2050, (and a recommendation from the Climate Change Committee for this to be by 2035) the strategy to date has been to increase the use of renewable energy generation and low carbon technologies (predominantly wind and solar in the UK), slowly replacing traditional gas and coal fuelled generation. These generation technologies rely on the weather to generate electricity, making their supply inherently uncertain. A sudden drop in wind speed or a large cloud passing can significantly reduce output and more importantly do so in a very short time frame. These sudden changes in the system can have dramatic negative effects. The converse can also happen, a large gust of wind for a short period of time on an offshore wind farm could increase the energy output, leading to a situation where supply is greater than demand. The grid must be protected against such events. Such occurrences can lead to periods of zero or negative prices in the wholesale markets, indicating oversupply which cannot be utilised. With an increase in renewables coming online, these events cannot be recurring as they will have negative impacts on owners and investors of assets, as well as longer-term investment implications.

Ensuring supply meets demand will be made more difficult as we shift to the electrification of transport and heating, leading to an increase in demand for electricity and changing the profile of demand. With a push for residential generation and storage, community and local energy systems will eventually exist. To have a balanced system, these aspects will make forecasting even more important and much more difficult than before.

Historically, to balance the system, market mechanisms were put in place which would create the environment and incentivise actors, i.e., traditional markets were created for traditional power systems. Supply could easily be ramped up and down depending on demand requirements, and the market supported this approach with concepts such as capacity markets and marginal pricing. With the new low carbon energy system, marginal cost of electricity is flat, thus incentives are limited for any other types of market players. A new market needs to be created which can effectively support system balancing of uncertain generation and demand-side flexibility.

- This system balance will in part come from the Energy System Operator offering different types of contracts to players in the market. Frequency firm response contracts exist now to support the grid to balance by allowing owners of assets to either reduce demand or increase generation. This will help in curtailment of energy, ensuring that over supply does not exist which negatively impacts pricing, and wastes generated electricity.

- Markets will change to allow players to trade wholesale, capacity, and balancing electricity, but also carbon. As we move to a low carbon future, carbon markets, which would price carbon, will have a large impact on electricity market, particularly pricing and demand.

- As the system becomes more complex and its costs are tilted towards balancing rather than generation, AI will be a key enabler. As the system balancing becomes more complex, this will in turn with an increase in data availability, thus allowing and making AI a key component.

Market participants need to be able to effectively price electricity to ensure a stable system, as well as providing incentives for various assets to be installed. Using AI, prices can be set which include information from the whole system, thus allowing for optimal market response.

- We can consider when DNO's will try and balance renewable energy assets via auctioning contracts. If they can effectively price the commodity, these incentivise asset owners to trade and ensure the market is stable. AI cannot only provide novel approaches but can consider many more variables (including location), ensuring optimal prices are generated.

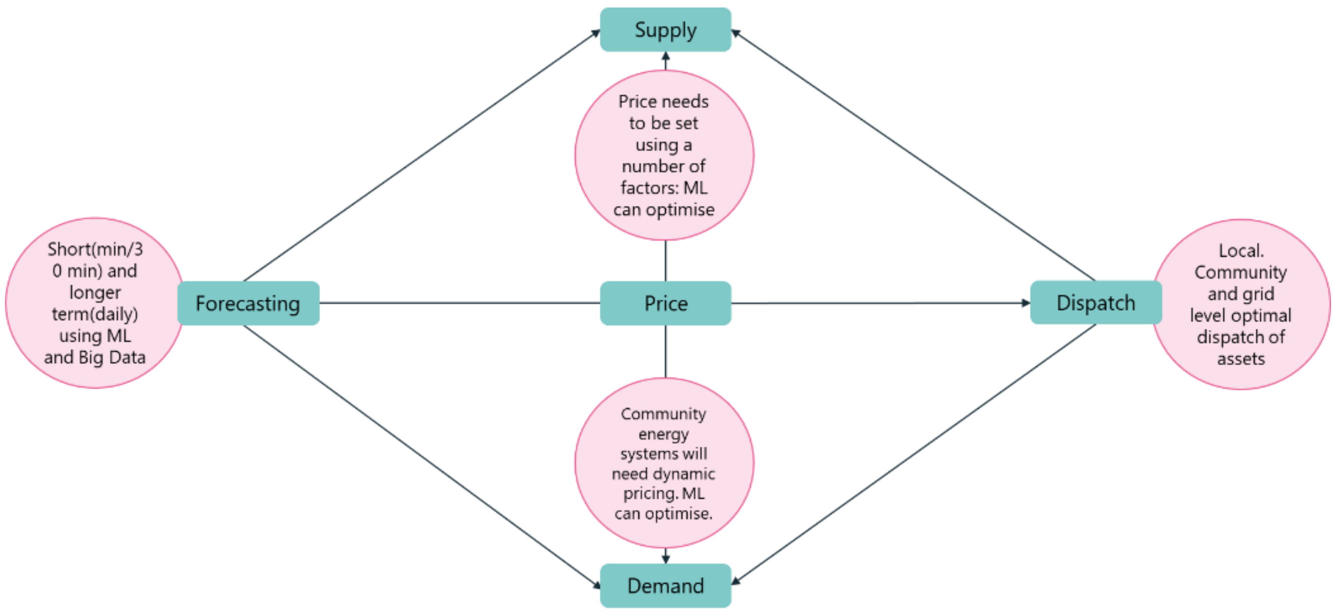

Figure 2: AI and ML solutions in the new multi-actor energy market space.

Markets will incentivise different types of players to invest and operate different asset types. Given a snapshot of the system at any given time, AI can be utilised to optimise planning for generation, i.e., what generation would be best given the current mix and economics, where this generation could/should be installed (this is particularly useful when looking at offshore generating assets), and planning for system reliability and reactive power planning.

Dispatch and scheduling means having the right amount of electricity at the right time. In the low carbon grid, this will be a central component in providing system flexibility.

- At the grid level, the ability to manage near real-time fluctuations will come from scheduling generation and storage assets. AI will play a key role in this service, as it will be able to utilise information from assets around the country and at different time frames to balance the grid. Not only will balancing be important but other ancillary services, such as frequency response and back-up. As an example, large scale batteries will need to dispatch according to what services they provide. Given there are many assets, and growing in number, scheduling their dispatch in an optimal way, e.g., ensuring life of asset is imperative. Given that some of these services require near real-time response, AI will have to be a component.

- At a community level, there will be organisations who aggregate assets such as batteries (EV, residential, VPP) and utilise them collectively to provide services to the grid. These are essentially pooling together assets, either by type, location or a mix, and allow asset owners to pass the risk of system stability to other entities. Aggregators will provide liquidity in the market and support system stability. These organisations will rely heavily on AI to ensure they are able to assign and dispatch assets as and when required all the time, ensuring that they are profitable when doing so.

- On an individual level community level energy systems will allow for peer-to-peer trading. Owners of batteries and EV's as well as other demand side assets will have the ability to procure services that match their needs. This means they will be able to first input their requirements, and then mechanisms which utilise AI will procure from the market to minimize cost to the consumer. These AI enabled processes will also playing an active role in grid stability and provide demand shift mechanisms.

- Whatever level we look at, power flow, frequency and voltage will be key variables which need to be controlled. Electricity markets will be taking in all this information, which is essentially a result of demand and supply.

- The ability to optimally dispatch and schedule assets, as well as effectively price the market is predicated on accurate information being provided to systems. Accurate forecasting of generation and demand at short-, medium- and long-term time scales will be key in ensuring that system operators are as close to certain as possible. Being able to forecast in shorter timeframes will be particularly key from the energy market perspective, as it will ensure balancing markets work efficiently, and are not penalised. Forecasting minutes and hours will be a key component in grid stability, but also allow optimal dispatch of assets to occur for balancing services.

AI will have impact on many aspects of the system, advancing some existing operations, while enabling new ones, however, it all comes down to providing a stable grid which can be utilised by consumers. While traditionally this was this done through control measures, the key for the future is flexibility, in generation and consumption.

At the Catapult, we have areas of expertise and can provide support to setting the direction needed to realise a new flexible grid, ranging from data analytics services to assessing operations of assets, local and system wide energy modelling to look at impact of various scenarios of technology and investment uptake, as well as required policies to set the scene.

2.2. Energy Networks

Traditionally, the gas and electricity network operators balanced the generated energy supply to meet the demands of end-consumers. The infrastructure to transport gas and electricity is through transmission and distribution networks. Electricity transmission network transfers the energy at high voltages, minimising losses, which is then stepped down at connecting distribution substations until it reaches 230V from where it is fed to individual homes and businesses. The gas network transmission operates at high pressures to transport the bulk over long distances then pressure is reduced at the distribution level before being supplied to consumers. Transmission network operators manage the assets and infrastructure, while it is distribution network operators who focus on the distribution network. They ensure the security of supply to consumers, upgrading infrastructure and managing what and how new devices or infrastructure can be connected safely to their network. The National Grid is responsible for matching supply and demand at a second-by-second granularity. This is achieved through a variety of energy markets mechanisms and ensuring there are sufficient reserve generators to match sudden losses of generation or by contacting large suppliers to reduce demand.

This arrangement has ensured a relatively reliable supply of energy for decades with very little disruption, although extreme events could still cause major outages[2]. This status quo is expected to change as we move towards a low carbon economy and AI and machine learning is expected to play a significant part in enabling the network of the future.

For the gas networks there is large amount of uncertainty. The goals of Net Zero are not compatible with the gas network in its current form. There are two main possible outcomes, either gas is largely decommissioned and/or the gas pipelines are repurposed to use green and blue hydrogen as a cleaner alternative. Machine learning can be particularly useful in the transition to heat decarbonisation by helping to more efficiently use the gas network.

For electricity networks, the increased uptake of low carbon technologies (LCTs) and distributed generation is also expected to have a significant effect. The decarbonisation of heating and transport is enacted through a rapid uptake of devices such as heat pumps and electric vehicles (EVs). Further, there is an increase in distributed generation, including photovoltaics of different power outputs (from individual roof-top residential to solar farms), wind farms, and combined heat and power. These LCTs have two core effects:

- Increased demand - heat pumps and EVs are not only high demand technologies but they also tend to be utilised at similar times. For example, many households will charge their EVs at the same time, and most homes will need heating (and hence use of their heat pumps) when it is cold.

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[2] For example the major outage on 9th August 2019 caused by a lightening strike: https://www.bbc.co.uk/news/business-49402296

- Intermittent and uncertain generation - solar and wind are highly dependent on weather (primarily solar irradiance and wind speed respectively). Further, solar generation often occurs during the day, but the majority of energy is consumed in the evening.

The effects above produce complications for both the transmission and the distribution networks. Demand on the distribution networks aggregates further up through the high voltage and transmission network. Distributed generation is proving to be one of the most significant challenges for the network. This is primarily because not all connected renewable energy sources are known especially for solar generation. Despite requirements for PV installations to be registered many are not, and at the transmission level their effects accumulate. The number of renewables installed is also changing at a rapid rate. The result is that is very difficult to predict the net demand across the network and increases the difficulty in matching supply and demand. AI and machine learning are proving to be powerful tools in tackling this. They can be used to improve solar forecasts[3] and can also identify previously unknown locations of renewable energy generation.

Perhaps the biggest impact is on the distribution network. The increased uptake of LCTs are putting increased demand on a network which was originally not designed with such technologies in mind. Further the prevalence of distributed generation means that demand is much closer to where it will be used. Fortunately, the increased uptake of LCTs coincides with the transition to digitalisation and increased data collection (both with increased and more granular monitoring). Network operators are implementing digitalisation strategies, in alignment with the recommendations set out by Energy System Catapult through the Energy Data Taskforce. The increased availability and visibility through better data are opening-up opportunities for businesses and innovators to support the Net Zero agenda.

The move toward responsive and flexible electricity networks (so called smart grids) is one example of the potential for AI and machine learning. High concentrations of LCTs on distribution networks are expected to cause excessive strain on the network through: increased demands, causing violations of thermal constraints; and high levels of renewables, e.g. solar PV, potentially causing voltage constraint violations.

Furthermore networks will become more unbalanced as demand becomes unevenly divided across the phases of a network supply feeder. All these strains will lead to increasing power failures. The traditional solution would be simply to dig up the road and replace the cables, a very disruptive and expensive solution for consumers. However, it has been estimated that moving to a smart grid can help reduce the "cost of additional distribution reinforcement by between £2.5 Billion and £12 Billion" by 2050 [4]. One such smart grid solution is community storage devices. Using the monitoring and communications infrastructure now available to us, AI and machine learning can learn patterns in the local demand and generation to design the smart control of distribution

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[3] https://www.current-news.co.uk/news/ai-improves-accuracy-of-national-grid-esos-renewable-forecasting-by-33

[4] Department for Environment and Climate Change - Smart Grid Vision and Routemap, 2014

management devices such as batteries. For example, the battery will charge during times of low demand (or high local generation) and then discharge during periods of high demand, thus helping support the grid. These algorithms can be further extended to other applications including phase balancing, voltage control and arbitrage.

These are by no means the only solutions which can be supported or created through advanced algorithms. Below is listed of a fraction of the applications that ML can support:

- Fault detection and Condition monitoring analysis - condition monitoring performs analysis on assets monitoring data in order detect developing faults. Machine learning techniques have been used to apply condition monitoring across the network assets including wind turbines and distribution networks and smart grids. Image processing methods are also being employed, using images from drones and helicopters to detect and predict asset faults.

- Outlier and anomaly detection - due to the increased visibility of the distribution network through advanced metering infrastructure, machine learning models can detect unusual or potentially fraudulent behaviour on networks.

- Optimal Power Flow - the equations which calculate the power flow on networks and are required for understand network strain, losses and health, are complicated to solve. Machine learning techniques can help solve these equations more optimally and in less time.

- New performance measures - the National Grid’s new Carbon intensity[5] measure uses machine learning to forecast carbon intensity and generation mix. Machine learning and AI will be essential in the development of more informative measures for complex characteristics of the energy system.

Due to the increased control and complexity of the distribution network there is a transformation in the role of network operators from DNOs to DSOs (Distribution System operator) who will more actively manage the distribution networks. For DSOs machine learning and data science will become an increasingly important part of their skill set to manage and balance the high uncertainties and complex interdependencies between demand and generation at a local level.

Energy System Catapult can help support these challenges facing the innovators and players in the future network through expertise across forecasting, control, and advanced data analytics. Most recently the Catapult hosted the Presumed Open Data Challenge where we designed, organised and implemented a data science challenge around the area of smart storage control utilising solar photovoltaic generation for peak demand reduction[6].

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[5] https://carbonintensity.org.uk/
[6] https://www.westernpower.co.uk/innovation/projects/presumed-open-data-pod

2.3. Energy and Transport

Transport is a high contributor to CO_2 emissions. There is a strong need to both decarbonise transport and to also reduce the amount of energy used. The strategic energy challenge is to achieve a low carbon transport future that also has sufficient energy. Therefore, it is necessary to optimise travel efficiency, and improve vehicle efficiency. The impact on the network needs to be minimised and the optimisation of charging is central to this. Not only is the choice of where the charging is located to be determined but considerations need to be made of the frequency and where different numbers of vehicles charge.

A challenge for transport industry is energy suitability. Transport is the largest emitting sector (28%) of UK greenhouse gas emissions and the UK is seeking an 78% cut in emissions by 2035[7]. This has led to the battery electric vehicle (BEV) to become mainstream for cars and a good option as it only needs public charging points and electricity may be readily available in homes and workplaces (with potential costs associated with increased peak demand in the home charging context where other electricity powered devices are also used at the same time). Hence, incentives are being offered towards the purchase of EVs and investments are being made in electric public transportation including the installation of public charge points.

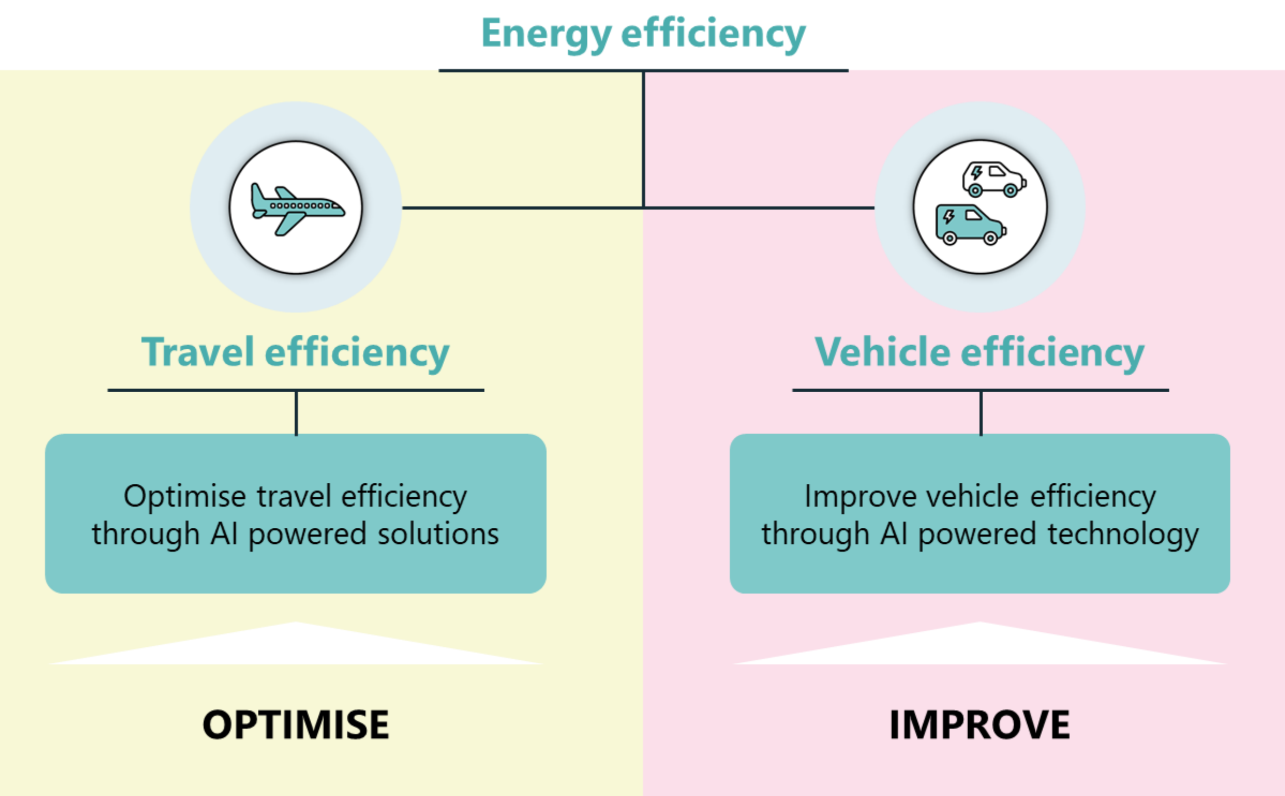

Figure 3:. Transport and energy efficiency
Source: https://energypedia.info/wiki/Urban_Transport_and_Energy_Efficiency

[7] https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035 UK Gov, 2021

The solution to transport energy challenge is to dramatically increase energy efficiency. AI and ML techniques will identify areas of inefficiency, develop energy efficient solutions, and make energy efficient decisions in real time. In recent years, AI has increased energy efficiency significantly in many sectors, including transport. This is achieved by using Machine Learning and AI to recommend solutions to complex business problems, for example real time route optimisation, scheduling, and automation. A key element of these techniques is analysing huge amount of data coming from many sources.

AI can enable proactive forward planning and real time decision making allowing the transport sector to reduce the carbon intensity of its energy use. AI has almost brought the age of self-driving vehicles. By analysing the car sensors data, AI systems can assist with driving. While EVs can reach 95% energy efficiency, this is around 30% for traditional combustion engines[8].

Mobility is transitioning towards electrification. It is predicted that almost half of all cars sold in 2030 in Europe will be EVs. The most expensive part of the EV's total cost is battery, and half of the battery cost is materials. AI is speeding up of the exploration and the testing of battery material formulations by predicting lifetime performance after hours of data collection, and as result battery developments are happening at a very fast pace and short time spans, in some cases, in a matter of weeks. The main concerns about BEVs are that they have short travelling range and long charging times. Newer BEV models are addressing these concerns and deliver a range of 250 to 500 miles on full-charge and can charge rapidly in under an hour. However, designing ultra-fast-charging batteries can be a challenge because it is difficult to make them last long[9]. The intensity of faster charge puts greater strain on battery and causes it to fail early. Without testing exhaustive series of charging methods, AI can quickly determine the optimum EV battery recharging algorithms that create long-lasting EV batteries that charge faster and last longer.

There is a need for charging infrastructures to implement smart charging. There is also the complexity of charging multiple vehicles in fleets. EV fleets can be made up of multiple models and there will be business operations profiles to fit around the charging while also allocating charging between fleet vehicles. AI can help continuously prioritise between EVs by assigning charging resource in real time using scheduling data and battery data. AI can predict arbitrary charge profiles used in smart charging algorithms, which can increase infrastructure use significantly. The coordination of charging is a complex problem and requires machine learning to optimise both the choice of locations but also planning charging control algorithms for fleet vehicles.

Some examples where AI and ML can improve efficiency and reduce energy consumption within the areas of traffic management and route planning for individual vehicles and fleet are:

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[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/932122/decarbonising-transport-setting-the-challenge.pdf UK Gov, 2020
[9] https://www.sciencedirect.com/science/article/pii/S2590116819300116

- AI can help solve traffic congestion for example after a traffic incident, algorithms can accurately forecast the state of the road network and suggest effectiveness-based response strategies.

- ML integrated traffic management systems could deliver information about road conditions to autonomous vehicles and users. This way, AI can be used to reduce waste of energy by reducing unwanted traffic wait times.

- AI system can use data from connected vehicles to effectively predict traffic flow in real time and provide road traffic managers to plan to make traffic cost and fuel efficient. And AI can produce better results than conventional algorithms for route optimisation and travel planning.

In other transport areas, such as shipping and trains, AI can improve efficiency through increased optimisation and improve planning, for example:

- With AI systems, continuous monitoring of airplanes can be carried out, eliminating the unplanned downtime. Data Science and AI can also predict air freight transit time delays for proactive mitigation.

- AI can determine a ship's estimated time of arrival and departure, which can reduce waiting times for vessels in the port.

- Smart-freight locomotives can use AI to monitor brake performance, motor temperature, and other conditions to predict maintenance, and reduce locomotive failure rates and reduced energy waste.

AI can optimise routes and schedules for public transport and ridesharing. It can also predict new demands or detect changes in demands by analysing data from multiple sources, such as ticket sales and customer journeys. This can help improve scheduling and improve customer service levels.

Other applications of AI include logistics operations and the movement of goods, drones for fast deliveries of life-saving medical equipment, smart traffic systems that reduce congestion and emissions, and driverless vehicles that shuttle goods between those who make it and those who buy it. The services in support of the transport themselves are also areas where AI and ML can have an impact which will improve efficiency and reduce energy:

- AI can automate operations, such as using machine learning to streamline the international customs and taxing process and save great amount of energy waste by long queues at the customs and slow processing time.

- AI systems can recognize images and translate languages. This greatly helps transport companies to save fuel and deliver better service by reducing human error in administrative and business planning decisions.

Transport requires advanced planning, adapt to shifting demands and technological changes. AI and Machine Learning enables transport businesses to identify emerging patterns and shifting demand from ever complex transactions quickly and efficiently, and aid managers to craft increasingly creative, efficient solutions to present and future transport energy problems.

2.4. Behind the meter

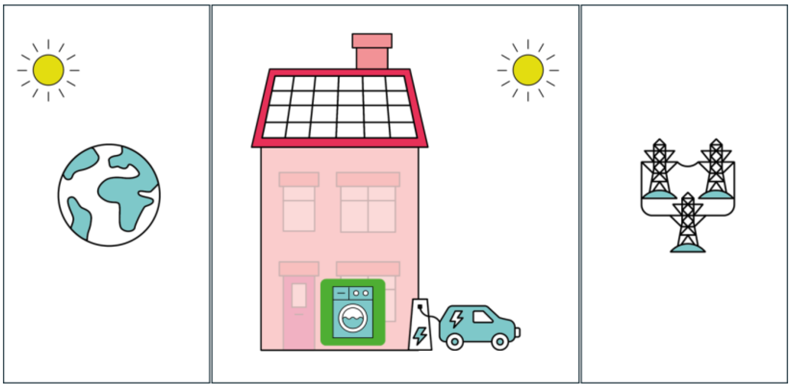
There is a real challenge in the path to decarbonisation within the context of domestic homes and energy use. The first major challenge is to get people off gas and onto electricity. Homes with heating systems that run on gas will need to be moved across to heat pumps or other low carbon energy sources such as hydrogen. This is because of the high proportion of greenhouse gases that are generated by heating with gas. The second large transition that needs to happen is from petrol and diesel cars to EVs. Removing the combustion engine from the home devices is central to decarbonisation. While the process of removing devices that add GHGs are key there is the need to simultaneously protect the energy network. While more heat pumps and EVs are added to the network there will be greater energy demand peaks on the electricity network.

Alongside the challenge described there is an opportunity to facilitate this transition in a way that is of benefit to both the resident and energy user and the energy networks themselves. Not only are heat pumps and EVs going to be part of peoples' lives but other home energy devices that can provide more choice around the timing of the use of devices. Smart heating systems linked to Home Energy Management systems will be linked to energy supply systems including solar panels. These devices can either consume or provide energy or both as in the case of EV batteries. The increase in number of devices that need control means that there is complexity beyond the daily easy choice for when to turn on/off devices.

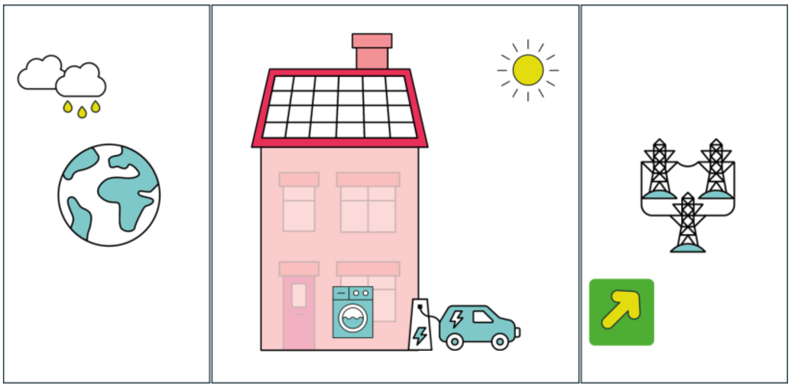
We hypothesise that AI and ML provides the solution to the problem of complexity that is present in homes with many devices that need control for consuming and providing energy. AI can hide the complexity by helping make decisions based upon multiple inputs. These inputs will be preferences the householder has, the price of energy, weather data, etc. A specific example of the choices that can be incorporated are in the situation where a householder has an EV, a set of solar panels, thermal storage and linked electricity devices including dishwashers and washing machines.

The other impact of the new high number of electricity using and generating devices are the electricity networks (DSOs, ESOs). These devices when drawing energy at similar times will provide a greater load on the electricity network with peaks that may exceed capacity. If there are no alternative solutions then the networks will need to expand and boost the existing network, at high cost, to increase capacity to solve this.

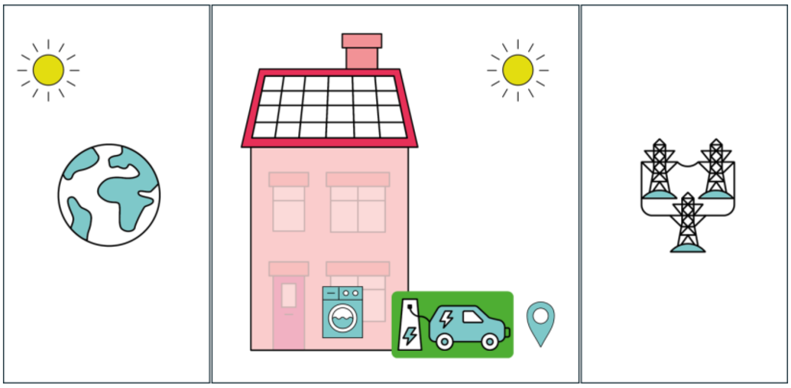
In addition, the devices that have the capacity to store energy provide an opportunity to co-ordinate local additional supply to the grid - for example from EV batteries or solar panels. The co-ordination of the supply of energy from these local storage devices will be part of the complex problem. Pricing signals from the network will need to be set and co-ordinated so the energy supplied is optimised for the network's requirements that capacity is not exceeded and supply is managed across all the homes.



Example 1. There is high sunshine all over UK, with a lower price for electricity with the decision being do not sell to grid, but use dishwasher instead.



Example 2. There is strong sunshine on my house, but not elsewhere. Now a high price for electricity means the decision is to sell to grid.



Example 3. High sunshine all over UK and a low price for electricity and the decision is to charge up the EV because I will typically go on a long journey tomorrow.

Figure 4: Behind the meter multi-device scenarios.

There are two examples that draw out the details of the key actors: the householder with multiple devices; and the networks themselves. In the case of the householder they are likely to have devices that have a range of uses. This includes the existing functionality but also the capacity of storing energy and/or choosing when to time the device such it will turn on and off at a desired time. One may have a home with an EV parked on the drive.

One may have a heat pump and a water tank and a set of solar panels. How do you choose what to turn on when? It is not easy.

There are numerous decisions about the selection of timing of use of the connected devices. This is not a simple on/off decision for a single device for example only the EV charging, and the factors which effect the different decisions are multiple. These factors include the price that the grid may pay to receive energy back onto the grid; the need for charging the EV both in terms of the level of charge currently and how likely a long journey is coming up soon; the preference that the homeowner has for green energy and receiving income for the energy produced in the home from the solar panels. There is a level of complexity in the decision making between these factors and preferences is high. This level of complexity is too much for an individual to address in a day-today scenario. Therefore there is space for a solution which hides the complexity and gives the home-owner an optimised solution which addresses these multiple factors and therefore myriad of options on any given day.

The complex decision will depend on whether you want to sell energy back to the grid - will it be the right price for you? Do you need to charge your EV now or soon? If the price is not right for you to sell the energy back what do you want to prioritise in your home to use that extra energy? This is where a smart App with algorithm embedded technology will strike a solution. This technology would incorporate the smart control of heating (like some of the leading heating control tech now) and EVs. AI technology can learn your preferences - for example when you prefer to charge your EV - and you can also add your thresholds for cost-based decisions around selling energy back to the grid.

Maybe you will choose to use you own energy whenever you can - the App can set this as a preference. But when there is more sunshine in your neighbourhood, but it is cloudy elsewhere in the UK then your price of energy for the solar panel derived amounts will be a little higher and if this is above your set threshold for selling to the grid then this will be actioned and you will benefit financially. But if it is sunny everywhere then the price you can make in selling that solar panel electricity will be lower and here the decision is more complicated. What has the AI learned that you would like to do with the additional energy which is not being sold back to the grid. Your preference may be for running the dishwasher or storing more energy as heat in the hot water storage tank. The App and the AI algorithm will take care of this decision for you and allocate the decision to one it has learned you will desire.

The other player in this situation is the energy network. What do they want? They need to maintain the supply to households in this context of increasing numbers of electricity powered devices. This requires peak smoothing so that the capacity of the network is not threatened. To do this the devices need to be delayed in turning on or turned off to reduce the demand. In order to action these demand side responses a signal needs to be presented to the local home energy management tools. These signals can be pricing signals that indicate the use of energy at specific times is more expensive to the end user and can help regulate demand. But how does the network know what pricing to set. Once again AI comes to the rescue by providing a way to learn from the local energy market data given the weather and supply and demand data patterns. This is key because the network is not in direct communication with individual EV batteries to know what exact levels of battery remaining they have. The decision of which signals to send the market need to be made using learned information and trends from both past historical and simulated market data. This will be the predicted peaks in demand and supply and the predicted effects of specific price signals. AI provides the methods the answer these complex questions in real time and in advance of needing to make those decisions.

Here at Energy Systems Catapult with the Living Lab we have a great opportunity to explore these complex conditions. The trials the companies with different household appliances take part in real world experimentation. We can simulate price signals and network circumstances that one might have to wait seasons upon seasons to see on real data. We can do this through setting preferences for the appliance set-up and explore the data to see the effects.

3. Summary

AI, Machine Learning and Data Science are going to transform the energy sector in the next 5-10 years. This change is essential to the route to Net Zero and will bring about reduced waste in the sourcing of energy, more efficient energy markets with customers who are able to get the heat and energy that they want. AI is the key to solving the problem of complexity at the heart of the multi-actor new energy markets the need optimisation and require the complexity to be simplified for the end user. It is also the method by which the gnarly technical problems and big data questions can be most efficiently answered in real-time and with the required accuracy.

Central to these challenges are the ability to reduce complexity through applied AI, and the need for whole systems thinking to build solutions across domains. There are a range of business focussed solutions which are driven by AI that are transforming the sector both today and over the next few years. These range from improvements to energy in transport and within the networks and markets. We see a bright future with challenges that the sector should continue to address and ramp up the successful development of AI tech to transform the UK energy sector.

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Energy Systems Catapult supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system.

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