AI for Net Zero Electricity

Assessing the Electricity Sector's Readiness for AI

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Executive Summary

Enabling more variable renewable energy generation will be critical to delivering a low-cost transition to net zero, and diversifying in this way will require every electricity asset to be fully optimised to be competitive in the market. AI is well suited to optimisation and ensuring system flexibility. It offers the promise of radically improved forecasting of generation and demand, the optimisation of asset management and electricity trading, and efficient grid balancing through to optimised dispatch markets. It can also support increasing demands on electricity systems - from heat pumps, EVs, battery storage, distributed generation - and more efficient operation and maintenance of demand response assets.

AI is already enabling progress across a wide range of use-cases in the electricity system, and its importance will only grow as more applications emerge. However, a major roadblock is that many electricity companies are not yet ready to apply AI in their operations.

This booklet seeks to inform companies operating in the electricity sector on how they can prepare their organisations to apply AI to accelerate a low cost net zero transition.

To support companies in assessing their current level of AI readiness and to map out areas for further investment, we provide an AI for Electricity Readiness Self-Assessment tool. This highlights five key themes that electricity companies can advance to become AI ready: AI opportunity identification, human capacity, data for AI, digital infrastructure and responsible AI governance. These key aspects for AI readiness were identified by industry and AI experts. We summarise the key recommendations below; however, a full self assessment is recommended to identify all AI readiness requirements.

Opportunity identification

Organisations should develop the capacity to assess business challenges to determine whether AI can support delivery.

Human capacity

Effective management of AI requires a deep and broad understanding of the technology. Managers with business needs that AI can help address should receive training in understanding, procuring and managing AI solutions. For in house solutions, data scientists recruited to the sector should be given training to support a thorough understanding of the electricity sector. For external providers, companies should ensure their contracting and procurement processes allow ongoing iteration and learning.

Data

The quality of AI solutions is highly dependent on the *quantity and quality of the data used. To effectively apply AI, companies will need to invest in AI-grade data collection, management and sharing systems. For any specific AI project, companies will need to identify the data required for the project, review existing internal data, identify data capture needs, and invest in data cleaning and labelling to ensure data is AI-ready.*

Digital Infrastructure

Powerful AI algorithms require enhanced compute and data storage infrastructure. An important choice is between hosting infrastructure through on-premises hardware or in the cloud. Companies should assess and procure the best solution for compute and data storage for initial pilot projects and subsequently assess and procure the best solution for compute and data storage for wider organisational AI roll out.

AI Governance

AI is a powerful tool with many benefits but also some risks. We recommend electricity companies establish principles and processes to manage AI-specific risks.

Develop Projects

AI readiness can be developed concurrently with early AI projects. Effective use of AI requires problems to be clearly defined. AI project teams will need to determine what the objective or objectives are, define completely the possible actions the AI can take, and identify any system constraints that will need to be imposed to

1. Introduction

The objective of this booklet is to support companies in the power sector to understand the prerequisites needed to deploy AI in support of a low cost transition to net zero.

Electricity systems can make use of AI in the transition to net zero. *The transition to net zero electricity will involve countries building, connecting, and integrating increasing shares of renewable electricity generation, with a smaller number of countries seeking to rely primarily on nuclear generation. Increased integration of renewables will require better forecasts for renewable supply, better prediction and management of electricity demand, a more intensive role for balancing services, and rapid innovation in energy storage to support constant matching of electricity supply and demand. AI and ML tools will be needed to efficiently adapt to these new requirements. At the same time as more renewables come online, electricity systems will see rapidly increasing demand as heating, transport, and various industrial processes move away from fossil fuels and towards electrification. This will intensify the need to flexibly manage the grid, increasing the role for AI. The complexity of some potential configurations for net zero electricity grids, with many thousands of interconnected two-way assets, will require advanced digital tools. AI is well suited to optimise and manage these kinds of systems.*

AI can accelerate the transition to net zero electricity. *In this booklet, we refer to AI as a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. AI is becoming increasingly useful as it can help identify subtle patterns in very large amounts of data, allowing it to optimise and automate complex systems. However, it also has weaknesses: its outputs can be strongly influenced by poor or biassed data; it is not always clear how it arrives at its conclusions; and any answers it offers are only as good as the questions it is asked.*

AI offers opportunities for all aspects of electricity system planning and operation, *however there are some immediate opportunities where AI can be deployed. These include:*

Forecasting supply and demand: *To enable the integration of large amounts of renewables, and reduce the need for expensive gas backup generation, it is essential to improve forecasts of both* *electricity supply and demand. AI can increase the accuracy of renewable electricity supply and demand forecasting. These forecasts, in turn, will support improved forecasting of system inertia.[2] For example, Open Climate Fix has helped to double the accuracy of demand forecasting for the UK National Grid and increased the accuracy of solar forecasting.*

Asset optimisation: *AI can optimise the operations of renewable electricity-generating assets, such as wind turbines and solar panels, and battery storage assets. For example, Habitat Energy uses AI to optimise grid battery storage assets against the chemistry of the battery and the market in which they are operating. DeepMind also applied AI to optimise Google's wind assets and increased their value by 20%.*

Electricity trading: *AI-enabled trading algorithms will optimise traders performance on the electricity markets, and allow trading to take place closer to real time - which will become increasingly important to allow for more variable renewable capacity on electricity grids.*

Flexibility markets: *AI can allow for the flexible management of millions of connected devices to offer flexibility services to electricity grids. The optimised management of domestic and commercial sources of electricity demand and supply can support system balancing.*

Accelerating energy innovation: *AI is also being used to accelerate discovery of new energy-relevant materials, such as those used in photovoltaic cells, batteries, and electrofuels. For example, Aionics uses AI to increase the pace of battery experiments.*

Dispatch and scheduling: *AI also has the potential to improve algorithms for electricity dispatch scheduling and storage by the system operator, as well as management of microgrids in areas with decentralised systems.*

To use AI to support the transition to net zero, companies in the power sector need to become AI-ready. *To deploy AI for net zero challenges, companies in the power sector need to put in place the capacity, skills, governance, data infrastructure, and digital systems that are prerequisites to enable the application of AI. This booklet defines these prerequisites and proposes activities to support electricity companies to develop their AI readiness in support of net zero challenges. We are seeking to appeal to a wide range of actors within the power sector, including electricity transmission and distribution companies, system operators, electricity suppliers, renewable asset developers and operators, researchers, and innovators, who are seeking to support the digitalisation of electricity networks. Within these organisations, we are looking to appeal to executives,* *innovation leaders, data and digital team leaders, HR leaders and product leaders. We hope this booklet can help initiate conversations between such leads that can support organisations to develop AI Readiness capacity in support of their net zero objectives.*

We are seeking to offer advice that is relevant across a wide range of countries, where electricity systems are at different stages in their digitalisation. As such, we recognise some of the proposed actions in this booklet will be new for some organisations.

AI is a powerful tool and it is important that it is applied in a responsible way. The OECD has set out a series of principles regarding the responsible application of AI. Organisations considering the implementation of AI solutions should familiarise themselves with these principles. AI governance can connect to existing IT governance structures, but the complexity and power of AI means it will often require additional organisational skills, guide-rails and policies, especially in the early stages of adoption.

Electricity systems are critical infrastructure, so ensuring good governance of AI solutions in this sector is of the highest importance. This booklet offers recommendations for how power sector companies can develop Responsible AI Governance structures and processes.

A company's progress on each of the 5 AI Readiness criteria established in this booklet can be given a quantitative score based on score sheets located at the end of each section. For example, a company's progress in developing human capacity can be assigned a score between one and five based on various sub-criteria. Based on the scores for each of the five major AI readiness criteria, the company will receive a qualitative level of AI readiness, ranging from 'AI Unaware' to 'AI Practitioner'. The company must reach a certain score in the five criteria to achieve a qualitative level like 'AI Aware'. This reflects the fact that AI readiness requires effort across all criteria – for example, strong progress to establish digital infrastructure but limited progress on opportunity identification will not be sufficient to build AI readiness. Companies must compute their score for each criterion at the bottom of its corresponding section and can then use those to

[3] OECD AI Principles (2019)

Table 1: Summary table for AI Electricity Readiness Assessment

AI Readiness Criteria	*AI Unaware*	*AI Aware*	*AI Planner*	*AI Ready*	*AI Practitioner*
Opportunity Identification	*1*	*2*	*3*	*4*	*5*
Responsible AI Governance	*1*	*2*	*3*	*4*	*5*
Human Capacity: Internal and External	*1*	*2*	*3*	*4*	*5*
Data	*1*	*2*	*3*	*4*	*5*
Infrastructure	*1*	*2*	*3*	*4*	*5*

2. Opportunity identification

There are a range of opportunities to apply AI to help address key challenges that the power sector will experience as part of the transition to net zero. Beyond these sectoral opportunities, each individual organisation could usefully consider how AI could support their business needs as they arise.

Some organisations will seek to assess which tools and technologies, including AI, are best placed to support individual business challenges as they arise. Some organisations may seek to actively identify where data science and AI can support their business objectives. Others may use a combination of these two approaches.

For organisations that seek to assess which tools and technologies, including AI, are best placed to support individual business challenges as they arise, business challenges can be assessed against common AI problem types to determine whether an AI system may be able to support the delivery of a particular business objective. A (non-exhaustive) list of common problem types include:

Classification: *Based on training data, AI can classify input data as belonging to one of a set of categories supporting greater insight. For example, an AI image processing algorithm might be able to identify and classify transmission lines on satellite images.*

Prediction and forecasting: *Based on training data, an AI algorithm can estimate the next value or values in a sequence. This type of use-case can go beyond forecasting future trends in time-series data and can be applied to a wide range of data types to support pattern recognition and sequence prediction.*

System optimisation: *AI can support the operational optimisation of well-monitored systems by recommending a set of actions that optimise outcomes for a specific objective based on feedback from system monitoring.*

Anomaly detection: *AI can help determine whether specific inputs are out of the ordinary when provided with historic training data.*

Data generation: *These problems require a system to generate appropriately novel data based on training data. For instance, historic power system data might be used to generate new scenarios for how the system could operate.*

In addition to considering whether a challenge fits one of these common problem types, there will be a need to assess whether a range of other prerequisites are in place to enable AI to be deployed as a potential *solution. These include an assessment of the quantity and quality of data available, the digital controls available, the clarity of the objectives of the challenge, how quickly and easily the AI system can receive digital feedback on its performance, how clearly bounded the problem is, and whether other, perhaps simpler tools would be better placed to address the challenge — if such tools exist in the market.*

For organisations actively seeking to identify where AI can support net zero challenges across the company, there are a range of additional criteria to consider. These include:

> *The* **emission reduction potential** *an AI solution could offer. This could be either a direct corporate emission reduction potential or a solution that enables a systemic reduction in emissions.*
>
> **Connection to the company's core business and KPIs:** *AI for net zero projects should be in alignment with key business objectives and should support specific company KPIs that they seek to deliver against.*
>
> **Risk:** *initial AI project should build organisational trust for the technology by initially avoiding business or safety critical projects and demonstrating usefulness through discrete projects. AI risks should be identified and addressed as part of project and programme risk management. There are various frameworks that have been developed to assess AI related risk, including by the OECD, NIST, and EU.*
>
> **Innovation priorities:** *Companies should consider how AI for net zero projects can support wider innovation priorities required to deliver business improvement and development.*
>
> **Deployment and scaling mechanism(s):** *Companies should ensure the deployment pathway for AI is feasible and clear. The solution should also be able to scale to achieve the estimated emissions reduction potential. Real-world AI projects can hit major obstacles during deployment and scaling, so it is necessary to assess both upfront to ensure impact is achievable.*
>
> **Availability of third-party solutions:** *to help prioritise AI for net zero projects, electricity companies should assess where there are existing AI solutions in the market that they can draw on.*

Regardless of whether organisations take a business-objective led approach or a technology led approach, there is a benefit to developing a systematic method for assessing business challenges to determine whether AI can support delivery.

Electricity AI Readiness Assessment: Opportunity identification

These numerical scores represent an organisation's stage of opportunity identification. An organisation's score corresponds to the box where they have satisfied all requirements for that score and the requirements for lower scores.

AI Unaware (1)	*AI is not assessed as a possible tool for addressing business needs*
AI Aware (2)	*The organisation has individuals who are aware of a few AI techniques but do not assess business objectives to see whether AI is a suitable tool to support delivery.*
AI Planner (3)	*The organisation has individuals who can assess a small number (25% or less) of business challenges against a limited number of AI techniques to determine its potential application*
AI Ready (4)	*The organisation has individuals who can assess at least 50% of business challenges against a wide range of potential AI techniques to determine its potential application, as well as deployment and scaling pathways*
AI Practitioner (5)	*The organisation has enough individuals to assess all business challenges as they arise against a full range of potential AI techniques to determine its potential for application, as well as deployment and scaling pathways*

3. Human capacity: internal and external

Building AI understanding of executives and managers

Different levels of knowledge and understanding exist across the power sector regarding the potential that AI offers to support the transition to net zero. As a result, there is a need to support up-skilling to help power sector executives and managers understand the potential AI offers to support the transition to net zero electricity, to identify the opportunities for where it can be deployed, and to understand the risk of doing so based on its strengths and weaknesses. Such up-skilling is essential to facilitate the integration of AI within power sector planning and operation.

Priorities:

- **Offer AI training for key managers.** *Executives and managers in electricity transmission and distribution networks, suppliers, system operators, asset developers and operators should be encouraged to enrol in AI and data training courses, and, where possible, courses focused on AI for energy, such as those provided by InnoEnergy or TUDelft.*[4]
- **Invite AI and electricity researchers and innovators to discuss opportunities to apply AI for net zero challenges** *through workshops, challenges or curated competitions.*

Developing internal data science and data engineering capacity

Many organisations in the power sector have been developing their own digital teams. Electricity companies can build the capacity of these teams to both deliver specific AI for net zero electricity projects themselves or to work with third party AI providers to integrate their solutions into the organisations' systems. There are many companies that offer software solutions for pre-existing power system infrastructure (see Annex A). Power sector organisations may choose to develop their own data science capacity where there is a strategic imperative to develop a specific AI project internally – for example, if it could become an important business opportunity, or if there is no existing third-party solution available and the skills required are not overly specialised in nature. When hiring data scientists, electricity companies would ideally seek data scientists who have an interdisciplinary skill set — in other words, a combination of deep

[3] Alternately, giving data engineers crash courses in the sector is valuable, like this on Future-Learn

technical expertise in AI, data and software engineering skills, and a f domain expertise in the power sector. However, there are currently few individuals with this interdisciplinary skillset. As a result, organisations in the power sector seeking to hire AI specialists to support their net zero objectives may need to hire specialists with limited power sector knowledge. Companies will then need to offer training in the operation of their specific digital systems and data processes, as well as the operation of the power sector more broadly. For example, a machine learning engineer hired by a wind farm to optimise their generation will need to understand how wind farms operate, the specifics of this wind farm, and the way the electricity generated is traded on electricity markets

When developing internal AI capacity, companies should:

- **Hire technical talent (data scientists, data engineers, ML engineers, DevOps etc) to develop strategically important projects.** *Assess project opportunities as to whether they are strategically important for the organisation and whether there are existing third-party providers to determine whether to build internal capacity or bring in third party solution providers.*
- **Encourage newly hired data scientists to enrol on training courses that cover the wider functioning of the electricity system,** *and of the digital and data environments used in the power sector. This may require the development of new training courses.*
- **Establish a recruitment sourcing pipeline** *that targets interdisciplinary skill sets, individuals who have both domain expertise and machine learning experience.*
- **Establish academic and research partnerships to focus university data science research** *on electricity data challenges. This may involve establishing or funding Master's, PhDs, and Professorships, to construct a talent pipeline and ensure new research is targeted and applicable.*

Working with third-party AI solution providers

Electricity companies may choose to work with third party AI service providers:

- *Where there is no strategic need to develop a data science capacity internally*
- *If they might struggle to hire sufficiently skilled data scientists*
- *Where there is an existing AI service that they can draw on*

Performance benchmarking and due diligence is always required when procuring an IT service, however there are some issues that require specific consideration when working with third-party AI providers:

When seeking external AI capacity, companies should:

- **Conduct assessment of third-party companies' AI talent. Internal digital teams should** *consider bringing in an external advisor to assess the AI technical quality of the team and solution offered.*

- **Assess how easily third-party AI software can be integrated into company ICT infrastructure.** *Companies should consider establishing ICT architecture standards that will allow third parties to connect their solutions quickly and easily.*

- **Conduct an AI governance and risk assessment of the third party provider.** *Organisations offering AI solutions should have best-practice AI governance structures and risk management processes in place. There are a range of AI-specific risks that may need to be assessed, including functional, security, privacy and compliance risks. This may require bringing in additional technical expertise to advise as to whether the solution offered is sufficiently effective, secure and data is managed safely and responsibly.*

- **Contract and procure the solution in such a way as to allow for ongoing iteration and learning.** *Successful AI projects can require frequent updates to optimise performance. Structuring procurement contracts to allow for this is important to maximise the potential that AI systems can offer.*

- **Assess risks and opportunities associated with the size of the company delivering the AI service.** *TThis will range from large multinationals to small startups. There are pros and cons of working with either end of this spectrum. Working with large companies may offer security of continuity but may be more expensive and / or increase the risk of reliance if working on a number of projects. Working with SMEs may allow for better terms and more nimble processes, but may come with continuity risks.*

For more detail on AI procurement the World Economic Forum have published a series of AI procurement guidelines.[5]

[5] *WEF: AI Procurement in a Box (2020)*

Electricity AI Readiness Assessment: Human Capacity

These numerical scores represent an organisation's stage of opportunity identification. An organisation's score corresponds to the box where they have satisfied all requirements for that score and the requirements for lower scores.

AI Unaware (1)	*No progress made towards developing internal or external human capacity for AI*
AI Aware (2)	*Organisation is aware of the need to develop AI capacity but has not determined the specific skills they require*
AI Planner (3)	• *Organisation has determined the specific AI / data science skills they require and initiated a hiring process; OR* • *Organisation has identified a range of third party solution providers that are relevant to their organisation*
AI Ready (4)	• *Organisation has identified the AI skillset required to meet their objectives and has hired the necessary technical talent; OR* • *Organisation has identified the AI skillset required to meet their objectives and has procured the expertise from an external company*
AI Practitioner (5)	• *Organisation has fully operational technical team tackling AI objectives in collaboration with requisite domain experts* • *Organisation has sought to upskill senior management about the potential for AI to support organisational objectives* • *Organisation has sought to upskill any machine learning engineers or data scientists with energy system training*

4. Data

AI depends on large volumes of data from which it can learn about its environment, the variables that might influence performance against the project objective, and their relationship to each other. Data inputs must be determined carefully. In some instances, this data might be historic data, such as time series on electricity market prices or renewable generation. In others, the data might be captured by sensors during the process of the AI making changes in the action space, which can help the AI to learn and improve on a rolling basis. There are many data capture hardware solutions that provide insight into electricity system processes and are important to implementing effective AI solutions. Companies should seek to balance primary and secondary objectives. For instance, using internal instead of external data on wind farm generation rates can improve AI training, but may not always be worth the extra cost of internal data capture.

Data for AI needs to be considered within a wider data governance framework that seeks to ensure that organisational data is managed safely and responsibly to manage risks, including those related to data quality, privacy, intellectual property, security, bias, diversity and traceability. The need for increasingly robust data governance measures increases with the potential impact an activity may have, including on society and economy at large.

Data sharing will be very important in developing high-quality effective AI solutions in the power sector, due to the interconnected nature of the electricity grid. Companies should work out data sharing arrangements or seek to join pre-existing ones to access data that can boost the development and operation of AI solutions. For example, generation asset owners may find it useful to share data with other owners of the same type of asset, to optimise forecasts and bids into balancing

Identify required data

The first step is to identify data that might be relevant for a particular project. In seeking to identify data that is relevant for a project, it is worth considering the following actions:

- *Measure key variables in the system or process AI will be applied to, such as demand for electricity at different times and in different locations.*
- *Measure variables that either impact or are impacted by that system or process, such as demand-shifting factors or peak-load performance of local power lines.*
- *Measure all variables that relate to ensuring that the system operates within safety and stability constraints, both for individual components and across the system. For instance, measuring maximum operating temperature of battery storage assets.*

- *Where relevant, identify and measure all controls within the process.*
- *Where relevant, measure conditions of equipment, such as the corrosion of power infrastructure.*
- *Measure all attributes that contribute to quality of process output.*
- *Determine benchmarks for performance so are baselines available for comparison before and after AI optimisation.*

Review existing internal data

After having assessed the data requirements for a particular project the team should then assess what data exists and its quality (e.g. resolution, robustness, fitness for purpose, specificity, representativeness, inclusiveness, diversity, traceability). Relevant data may be held within the company or may need to be sought externally with additional constraints in terms of quality control, compliance/liability, and desired traceability, among others.

Identify data capture needs

After having assessed a projects' data needs and the relevant existing data it is probable that gaps in data availability will be identified. This may involve either procuring data externally, transferring existing data to a machine-readable format, or installing sensors to capture new data streams. When assessing existing and new data capture it is important to consider the following points:

- *Is your data being trended and archived? Where and how is it trended and archived?*
- *Do you have the quantity and quality of data required to compute the objective function?*
- *Do you have the quantity and quality of data required to verify that the actions determined by the control system are implemented?*
- *Do you have the quantity and quality of data required to measure the impact of your actions upon the process in question?*
- *Do you have the quantity and quality of data required to measure any external elements that influence the system?*
- *What is the quality of the data?*
    - *Is your data accurate? For example, sensors can drift over time or even be incorrectly labelled (in other words, what the sensor measures does not match the description).*
    - *How much of the data is missing? Do you track what is missing? If not, decide how you will.*

- *What is the cadence that you will capture data and monitor its quality? You should have a timestamp for each data point.*
    - *The more often you capture the state of the system or process, the easier it will be to identify the effects of changes made. Systems are dynamic, so changes to one area may have unexpected ripple effects elsewhere in the system.*
- *What is the latency of the data?*
    - *This the delay between when something occurs in the actual system and when the data about that occurrence is actually available.*
    - *You don't want to make decisions based on old data!*
- *How much data do you have?*
    - *It is important to know not only how far back the data goes, but also any changes that happened to the data collection process / sensor space / action space / control policy that happened since data started being archived. For instance, if you only started calibrating your sensors at a given point in time, it is important to note that.*
- *Do you know what the sensors are measuring?*
    - *It is often necessary to understand what the data represents to troubleshoot your system.*
    - *Sometimes a large percentage of the total data is unused due to bad quality or because the data does not add additional value for AI training. You need to be able to decide what data to include and what data to omit.*

Seek to maximise data variability

One of the issues for an optimization algorithm that learns from past experiences is lack of variability in the data and key variables. A process may have a few years of good quality data, but having data without much variability in setpoints could still be an issue as it can result in an algorithm that learns a good approach only for a limited set of scenarios. Ensuring data variability is thus key to developing generalised solutions.

It can also be useful to establish data sharing partnerships with similar companies whose data is on similar processes but adds to the variability of the AI input data. For example, solar generators will benefit from access to generation data from different areas of the country and world, as this will increase their AI's predictive power.

- *Make exploring the action space ("exploration") a priority.*
    - *It can be problematic if the value for the actions is mostly constant in the historical data in many systems.*

- *If working on critical infrastructure, identify a Controls Engineer to lead minimal* safe exploration *(once the setpoints and constraints are identified) with the objective to*
    - *Increase variance with respect to individual setpoints within the allowed range*
    - *Increase variance with respect to hard system level constraints*

Conduct data cleaning and labelling

AI may depend on data, but success depends on good data that is accurate, consistent, and has had any biases addressed. The process of cleaning data involves identifying and fixing bad data. It tends to require strong domain expertise and so is another area where partnership between AI experts and domain experts is vital. The process of data cleaning can involve:

- *Performing sensor calibrations where relevant*
- *Ensuring consistency within and across historical datasets*
- *Identifying anomalous data (e.g. outlier data that is clearly outside of the normal range), missing data, and stale/stuck data — and labeling it appropriately.*
- *Note that sometimes sensor data goes stale for long periods of time.*

Perform data maintenance

As the success of AI projects depends on good data, it is important to set-up routine, periodic checks to ensure ongoing data cleanliness. These require domain expertise. Data maintenance should ensure that:

- *Trend names matches the sensor which it is associated with;*
- *Values of the trend follow the same units;*
- *Trend is not stuck at a static value while the sensor is properly functioning;*
- *Processes collecting data do not change the time range within which they capture data.*
    - *For example, totalisation trend does not change its periodicity from being week totalizer to daily/monthly totaliser.*
- *There is spot checking (and re-calibration of any anomalous sensor)*

Throughout the process of identifying and collating data required for a project, it is critical that data governance is considered to ensure data risks are responsibly managed to address data quality, privacy, intellectual property, security, bias, diversity and traceability concerns.

Data assessment process that companies should consider alongside existing data management practices:

- *Identify required data*
- *Review existing internal data*
- *Identify data capture needs*
- *Seek to maximise data variability*
- *Conduct data cleaning and labelling:*
- *Perform data maintenance*

Electricity AI Readiness Assessment: Data

These numerical scores represent an organisation's stage of opportunity identification. An organisation's score corresponds to the box where they have satisfied all requirements for that score and the requirements for lower scores.

AI Unaware (1)	*No progress made towards meeting data needs for AI use cases.*
AI Aware (2)	*Organisation has an ad-hoc approach to meeting project-specific data requirements*
AI Planner (3)	*Organisation has conducted an initial assessment of its existing data resources*
AI Ready (4)	*Organisation has a structured approach to identifying relevant internal and external data for AI-specific projects that allows them to input data for all key variabless*
AI Practitioner (5)	*Organisation has a plan for increasing its internal data collection and external data access to enable greater digital optimisation*


MB 116A
B16
6000
3
MB 110A
B10
6000
3

5. Infrastructure

To be trained and deployed, AI algorithms require a range of infrastructure. This includes specialised hardware such as compute, data storage and networking to enable training and deployment of advanced AI models. Electricity companies often struggle with decisions about whether and when to develop their own hardware solutions or source them externally..

As organisations seek to expand their use of AI beyond initial pilot projects, there is a need to consider the organisational infrastructure required to roll out AI more widely across the organisation.

Compute: *Compute is a generic term used to reference data processing capacity required for the computational success of any program. Most AI applications are compute-intensive and thus require specific processing hardware to operate effectively and efficiently. There are a range of compute hardware options to consider for AI including CPUs, GPUs, TPUs, and ASICs. The most appropriate hardware will depend on the specific use-case.*

Sensors and networking: *A sensor network is a group of small, powered devices, and a wireless or wired networked infrastructure. The sensor network connects to the internet or computer networks to transfer data for analysis and use. Examples of sensors include temperature sensors, infrared detectors, proximity sensors, and motion detectors. These can be applied across the electricity sector to produce wide-ranging data to track operations or to enable data sharing. It is crucial to provide a stable network to ensure that wireless communication is possible. Many assets and infrastructure elements in the electricity industry are fundamentally similar, so collaboratively developing sensors or sourcing generalised equipment may be a reliable and cost-effective method of meeting this need.*

Data storage: *Not only do AI applications require large volumes of data to operate effectively, but access to that data must be rapid, reliable, and scalable. As a result, not only do organisations planning on deploying AI often require substantially more data storage capacity, they often find there is a need for data storage that is tailored for AI requirements. Over time companies should consider combining a range of data storage options including data lakes - designed to store large amounts of raw data, to more purpose-specific data warehouses for cleaned, labelled data for easier querying. Organisations at an early stage in their digitalisation journey should consider initially building small data stores for each project. Over time, these can be connected together to allow for easier linking of data across organisations, whilst ensuring that provisions are in place to address data security risks.*

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[6] Databases, Data Warehouses and Data lakes: A database is a storage location that houses structured data. The next step up from a database is a data warehouse. Data warehouses are large storage locations for data that you accumulate from a wide range of sources. A data lake is a large storage repository that holds a huge amount of raw data in its original format until you need it. Data lakes are more flexible than data warehouses but due to the quantity of data there are greater risks if security is breached.

Cloud or on-premises?

Cloud computing refers to technology services and infrastructure that are provided over the internet. Data is stored and processed off-site. The traditional alternative is on-premises ('on-prem') infrastructure, involving hardware in company offices. Cloud facilities and services can include servers, storage, databases, networking, software, analytics and intelligence. Cloud infrastructure allows users to access reliable and optimised technology, only pay for the services they need, flex their requirements of these services up or down, stay up to date with the latest technology, forecast their costs, access services from anywhere and rely on security experts to prevent security breaches.

However, many electricity companies have yet to move their infrastructure to the cloud. This is due to a combination of real and perceived risks related to security and control. As the electricity sector involves the use of critical infrastructure, security is a non-negotiable requirement; however, cloud infrastructure is increasingly able to offer higher levels of security, and not every application of AI within the power sector will have direct impacts on critical infrastructure. As a result, electricity companies should consider a more nuanced approach to the use of cloud-based infrastructure.

For organisations piloting AI projects, there is often a strong case for initially using cloud-based services so as to avoid high upfront hardware costs and allow for a faster project development during the piloting stage. The piloting phase will allow companies to better identify what the opportunities are for them to apply AI and, as a result, what hardware is best suited to these applications. They can then make an informed decision as to whether it makes economic sense to continue to use cloud services or switch to "on-prem" infrastructure.

Priorities for companies to consider include

- *Assess and procure best solution for compute and data storage for initial pilot projects*
- *Assess and procure best solution for compute and data storage for wider organisational roll out*

Electricity AI Readiness Assessment: Infrastructure

These numerical scores represent an organisation's stage of opportunity identification. An organisation's score corresponds to the box where they have satisfied all requirements for that score and the requirements for lower scores.

AI Unaware (1)	*No consideration of AI infrastructure needs*
AI Aware (2)	*Conducted an initial assessment of the suitability of the company's existing hardware infrastructure resources for AI projects.*
AI Planner (3)	*Infrastructure requirements identified for initial AI projects.*
AI Ready (4)	*Procured any additional digital infrastructure required for initial pilot projects.*
AI Practitioner (5)	*Assessed and procured the optimal solution for compute and data storage to enable the application of AI to a wide range of business challenges.*

6. Establish Project and Organisational Governance for Responsible AI

AI is a powerful tool, and as such may require additional organisational risk management to ensure it is used safely, responsibly and effectively. The complexity and power of AI means it may require additional organisational guide-rails and policies. Given that electricity grids are critical infrastructure, the use of AI systems in informing decision making needs to be carefully considered.

The responsible application of AI requires the consideration of the following criteria:

Ensure AI-specific risks are identified and mitigated. *For companies that seek to work on small-scale or pilot AI projects initially, the assessment of AI related risk should be proportionate. For organisations seeking to deploy AI more widely, organisational governance processes should actively assess and mitigate AI-related organisational risks*

Organisations seeking to deploy AI widely across their operations should consider organisation-wide AI principles and processes. *This should include consideration of:*

- *How to build and test for safety*
- *The level of human involvement required at different stages of AI development and deployment*
- *How to communicate with stakeholders about the use of AI*
- *Avoidance of creation or reinforcement of data biases*
- *The level of explainability required for AI models in different contexts*

Engage legal teams to ensure AI compliance where necessary. *Those overseeing the development of AI should ensure it is legally compliant. Legislation governing the use of AI is nascent but growing: for example the EU is leading the way with its AI regulation, which takes a risk-based approach to regulating AI. High-risk AI systems, including those used in critical infrastructure like the electricity grid may be subject to obligations before they can be put on the market.*

Electricity AI Readiness Index: Governance for Responsible AI

These numerical scores represent an organisation's stage of opportunity identification. An organisation's score corresponds to the box where they have satisfied all requirements for that score and the requirements for lower scores.

AI Unaware (1)	*No awareness of AI related risks or the need for AI governance*
AI Aware (2)	*Organisation is aware of risks associated with deploying AI*
AI Planner (3)	*Teams involved in developing digital projects have considered how to develop appropriate risk mitigation for AI*
AI Ready (4)	*Organisation has digital and data governance processes that have AI-specific considerations*
AI Practitioner (5)	*Organisation has fully developed AI risk mitigation framework capturing the principles and processes for addressing AI-specific risks and a plan to communicate their use of AI with external stakeholders*

7. Develop Projects

For each individual AI project that electricity companies plan to deploy to accelerate their transition to net zero, they will need to go through a process to determine what the objective or objectives are, define the possible actions the AI can take and identify any system constraints that will need to be imposed to guarantee safety and security.

Define the Objective Function: *Whereas with some organisational projects it may be possible to have slightly fuzzy project objectives, when applying AI, it is critical that the objective is clearly defined in computational language. For example, the objective for owners of grid-scale storage assets may be to maximise profit by storing electricity when it is cheapest and selling it when it is more expensive. It is worth noting that some projects may have multiple objectives that need to be balanced, and how these are weighted and prioritised will be important in defining project success. Some companies may have to trade-off economic objectives with social values and regulation. For example, owners of gas generators may have to balance making profits with pursuing decarbonisation. The most important objectives should be set in the project's 'objective function'. Additional objectives can be addressed when setting model parameters.*[7]

Define the parameters of the project: *For each AI project, there is a need to clearly and carefully delineate the parameters of the project and to understand what can, and indeed cannot, be controlled by an AI system. In reinforcement learning, the actions that AI can take or the "levers AI can pull" are called the action space. For example, in an HVAC optimisation system, the action space would include controlling the setpoints for temperature, pressure, equipment on/off switches, etc.*

Define System Constraints. *Within the action space it might be possible for the AI to make decisions that operators know in advance could have negative consequences, from a safety, security, ethical, social, or legal perspective. It is vital to ensure that AI software has clear boundaries that it must operate within. These constraints may need to be implemented at different levels – e.g. for a particular component or subset of the system and for the system as a whole. For example, in the grid-scale battery example, it may be important to ensure that a certain battery temperature is not exceeded to ensure the safety of the system. In the HVAC optimisation example, certain hardware components may have ramp-up or ramp-down times that cannot be exceeded. It is worth noting that defining too many system constraints will limit the AI's options, and potentially reduce the scope for system improvement*

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[7] *CIOs: Here's how Google is approaching AI*

Key questions to consider include:

- *What are the operating boundaries necessary to ensure the safety of the system?*
- *What are the multiple types of constraints?*
  - *Component-level constraints (for example: a constraint affecting a single piece of equipment)*
  - *System-level constraints (for example: constraints defined by the allowed combinations of equipment)*
- *What are process-level hard constraints? Hard constraints are constraints that can never be violated, including for safety and ethical reasons. It is important to determine for all constraints whether they are hard or not.*
- *What is the permissible operating range of each system component?*
- *What are the constraints on how quickly each component can ramp over time?*
- *When certain components are operating within a given range, what limitations should be imposed on how other components operate?*
- *Ensure data privacy controls are in place. Who has access to what data, trained models and inference? Are the access levels appropriate? Define who can see and who can use each type of data.*

Priorities companies should consider:

- *Define the Objective Function and list everything you want to optimise*
- *Define the Action Space*
- *Define the System Constraints*

Scoring summary

Organisations can add their scores from each section in the table below to determine an overall score:

Table 2: Summary table for AI Electricity Readiness

AI Readiness Criteria	AI Unaware	AI Aware	AI Planner	AI Ready	AI Practitioner	SCORE
Opportunity Identification	1	2	3	4	5	
Responsible AI Governance	1	2	3	4	5	
Human Capacity: Internal and External	1	2	3	4	5	
Data	1	2	3	4	5	
Infrastructure	1	2	3	4	5	
TOTAL SCORE						

Annex A: Summary of AI suppliers in the relevant sector

There are an increasing number of companies seeking to offer AI services to help reduce emissions in the electricity sector. The list below is not exhaustive and inclusion in it is not an endorsement of the product of service offered, however it can act as a starting point for companies seeking to identify relevant AI service providers.

Gridbeyond	*GridBeyond's focus is to build a shared energy economy that delivers sustainability, resilience, affordability and adaptability through collaboration and innovation. Their technology bridges the gap between distributed energy resources and electricity markets, allowing all connected asset tp be utilised to help balance the grid. By intelligently dispatching flexibility into the right market, at the right time, asset owners and energy consumers unlock new revenues & savings, resilience, manage price volatility, while supporting the transition to a Net Zero future.*
farad.ai	*AI-powered Digital Twin for the Energy System. Peak load prediction, Data and analytics, Local-level flexibility ; Suitable for EV Charging Point Developers, Renewable Energy Developers, Distribution Network Operators*
AutoGrid Systems	*Supply and demand management solutions: AutoGrid Flex™ mines the Energy Internet's rich data load to extract the highest value from all distributed energy resources.*
Open Energi	*Flexibility Optimisation: Dynamic Demand 2.0's core functionality is to optimise assets in response to dynamic power market signals. Uniquely, DD2.0 works with all parts of the power market. Through algorithmic analysis of that flexibility, mapped against market trends, we can optimise transactions for any given asset to maximise revenue. Tailored or fully managed approach for grid services are available, including prequalification, contract management, bidding, dispatch and settlement.*
clir	*Market intelligence platform for wind and solar. Clir Portfolio empowers owners to maximize financial returns by leveraging 200 GW of wind and solar data, advanced AI, and decades of technical expertise.*
BluWave ai	*BluWave-ai promises to orchestrate DERs to enable virtual power plants (VPPs) for distribution utilities to manage demand, smooth PV generation and shave peaks, optimizing for multiple objectives. They include energy trading and economic dispatch of controllable units to minimize net energy cost, reduce emissions and maximize battery energy storage life.*

naturailly	*LV Cloud is a software solution that collects, processes and aggregates data from different types of devices, including Reclosers, TDRs, GUARDs and VisnetHubs. Based on the collected data, it is possible to trace malfunctioning or physically damaged grids and immediately decide whether it needs to be fixed by a team of engineers or if it will fix itself. LVCloud is an (IoT) application that monitors and takes care of the grid. The project combines various technologies such as machine learning and transforms them into an app that can detect and solve power network malfunctions before they escalate into major problems.*
sees.ai	*Uses AI enabled drones to provide several major improvements to inspection of the electricity grid. Firstly, it enables the remote capture of high-quality, close-quarter data (component by component, if required), in a way that is more efficient (multiple towers per flight) and perfectly repeatable. Secondly, it simultaneously captures 2D data (e.g. photos, video) and 3D data (digital twin) in a way that allows the 2D data to be navigated from the 3D model or vice-versa. This significantly reduces the cost of analysis by human or machine. The system also almost eliminates risk to workers and carbon emissions.*
keen AI	*KAI digitalises the visual assessment processes. Generating more value from expensively collected data and can help manage assets more effectively. Keen AI is using deep learning and image processing to detect corroded steelwork on National Grid towers in high resolution imagery. KAI, is being used at National Grid to support analysts to rapidly identify the objects of interest in recorded footage. Using deep learning, KAI is able to identify the key components automatically and present these to the operator for review.*
Invenia	*Grid optimisation via machine learning: We interact directly with the grids, helping to plan for generation, flow and use of electricity in advance of real time operations. We help the system operators to optimize the power grid to ensure reliability, efficiency, transparency, while reducing harmful emissions.*
Stem	*Project developers and asset owners use Athena to optimize power generation and market participation revenues of both standalone energy storage and hybrid solar plus storage power plants. Services include market revenue optimization, incentive management, solar clipping, and solar self-consumption.*
Kaluza (Ovo)	*Demand response product. Intelligently charges millions of smart home devices to function as energy storage at times of high load.*

FLuence	*Tech Stack makes it simpler for customers to deploy storage faster and more cost effectively without sacrificing quality and configurability. The Tech Stack lays the foundation for better energy storage products with fully-integrated digital intelligence, an enhanced operating system, and factory-built, highly modular building blocks. Our digital intelligence platform, Fluence IQ, enables the optimization of storage and renewables to help customers maximize the value of their assets.*
Innowatts	*AI data analytics for energy grid supply & demand: use AI and learnings from more than 45 million global meters to help energy retailers, utilities and grid operators unlock meter-level data, understand their customers and make businesses processes automated and smarter. For a more reliable grid, a more profitable position, better customer experiences and a sustainable energy future.*
Open Climate Fix	*Project in progress: "Our main interest is in trying to build machine learning models to forecast solar PV (which basically boils down to trying to predict the movement and evolution of clouds). We will spend the majority of the next year or two writing code to experiment with new ways to predict sunlight for the next few hours. As quickly as possible, we'd like to get early-stage prototype PV forecasts used displayed in the National Grid control room, to validate our model's effectiveness and so we can start measuring the impact on emissions and cost. Beyond that we will release a nowcasting product for general market consumption."*
Kraken (Octopus)	*Kraken uses machine learning to optimise utility customer management processes including billing, payments, meter data management, CRM, customer communications, digital self-service, contact centre telephony, industry and market connections.*
Solytic	*Software helps stakeholders to make smart, data-driven decisions in real time. Today, monitoring, analytics and managing assets is done manually by humans. Solytic uses AI to automate processes to optimize production and cut costs throughout the entire life cycle of assets. Automating solar PV is key for a faster and more profitable energy transition.*
Sensewaves	*Dynamic optimization of the electricity grid. It provides the necessary analytics and analysis tools to integrate the legacy with the new infrastructure, ensuring agility and flexibility of operations and short and long term grid sustainability. Through machine learning, Adaptix.Grid correlates existing, sparse grid information to provide Distribution System Operators (DSOs) with accurate, high resolution, end-to-end visibility into the energy flows and congestion levels at any point/asset in the grid.*

Habitat	*Battery optimisation and trading, using AI to identify and participate in the most profitable markets for battery assets. Also offer a 'managed AI' service managing when to sell or store energy produced from DERs.*
DeepMind	*DeepMind engineers worked with a range of organisations across the power sector to explore the potential for the application of AI to support system management.*