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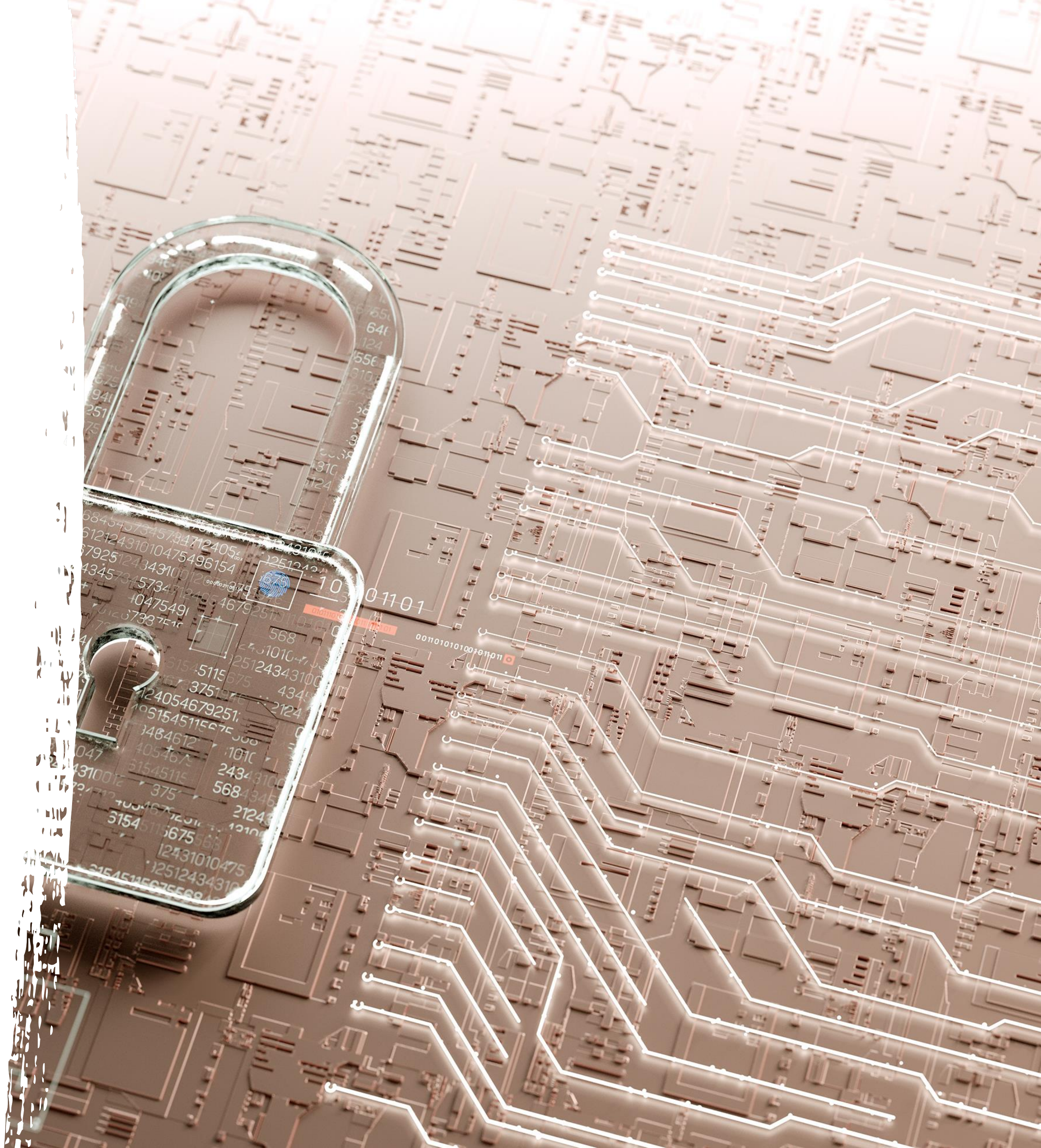
Emerging Technologies Quarterly Review

November 2023 - January 2024



Digital Platform for Leakage Analytics - Strategic Innovation Fund

Agenda

1. Introduction to DPLA
2. Executive summary
3. Data collection and modelling technologies
4. Data analysis technologies
5. Data storage and sharing technologies
6. Key takeaways for DPLA

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1.
Introduction to DPLA

Digital Platform for Leakage Analytics (DPLA) aims to significantly reduce gas network leaks and emissions in a cost-effective way

The background:

The **DPLA** project aims to develop and demonstrate a functional Minimum Viable Product (MVP) for how **data, analytics and models can be used to identify and locate gas leaks in the gas distribution network**.

The core functionality is **data-driven leakage modelling**, unlocking proactive leak detection capabilities, combined with testing the application of novel gas sensor technologies.

GHG

DPLA's mission is to reduce **carbon emissions**, realise **customer benefits** and **improve safety** in a **cost-effective way**

DPLA through the Strategic Innovation Fund (SIF) Phases:

SIF (Strategic Innovation Fund) is a **competitive funding mechanism** delivered in partnership with Innovate UK, part of UK Research and Innovation (UKRI), and aims to **find and fund ambitious, innovative projects with the potential to accelerate the transition to net zero**.

DPLA is one of SIF projects for the Gas Transmission and Distribution sectors in the UK and so it has been developed according to the following phases:

Discovery

- March-April 2022
- Feasibility studies

Alpha

- August 2022-February 2023
- Experimental development

Beta

- September 2023 to February 2026
- Build, operation and/or demonstration

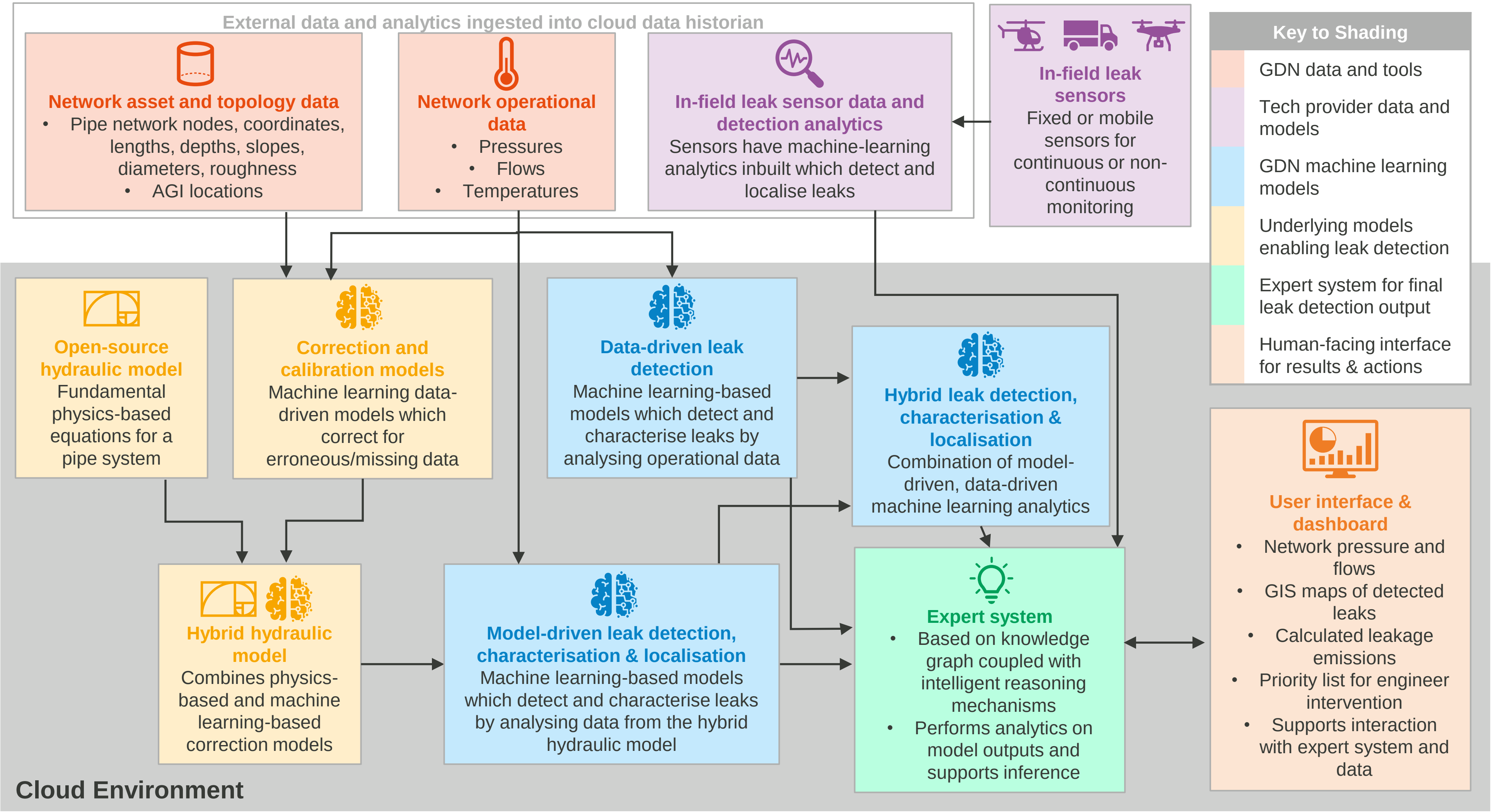
Project partners:

Cadent – Your Gas Network: **Lead Network**

Guidehouse – Outwit Complexity: **Delivery Partner**

national gas transmission; Northern Gas Networks; Wales&West Utilities; SGN – Your gas. Our network.: **Network Partners**

DPLA combines the innovation of novel sensing technologies, machine learning, and hydraulic modeling techniques



The DPLA project is reliant on advanced technologies for data collection, modelling, analysis, storage and sharing

DPLA is made up of 8 work packages:

These work packages focus on different areas of the project.

The technical components of the DPLA, including data analysis, model development and novel sensor trials are covered by work packages 2 and 3.

Work package 8 focuses on open data, interoperability and emerging trends and technologies.

Work package 8 has three focuses:

1) Research emerging technologies that are adjacent to DPLA and how these could inform or impact the project.
2) Foster collaborations and data sharing with other related projects (such as the SIF-funded Intelligent Gas Grid).
3) Develop an interoperability framework for the DPLA platform to ensure that the outputs can be effectively shared with and used by all stakeholders.

Focus 1 ensures technological advances are considered

Reviews of the findings from research into emerging technologies in the field, alongside conclusions about their impact on DPLA, will be presented quarterly.

This is the first of these reviews which may vary in focus and scope, but are intended to inform the DPLA project, ensure key future technologies are considered in the pipeline, and foster future innovation within and outside the project.

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2.
Executive Summary

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Executive Summary

Advances in technology are occurring rapidly in every sector. New technologies have the potential to disrupt the energy industry at every step along the data pipeline, providing improved system monitoring, management and insights for future innovation.

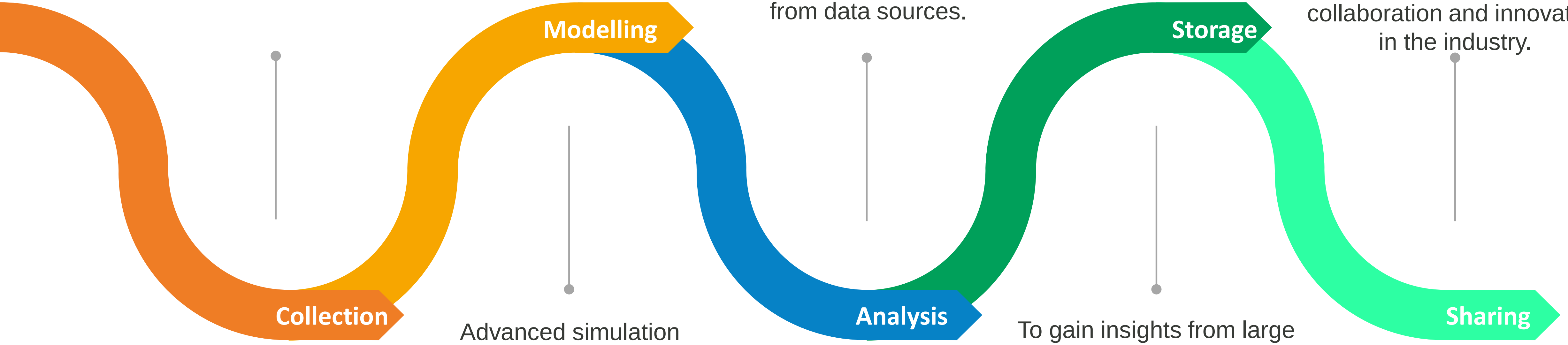
New sensor technologies (e.g., satellites and IoT) collect data at increasing scale.

Advanced simulation and data modelling methods can be used to model systems.

Data analysis techniques, such as machine learning, can provide new insights from data sources.

To gain insights from large quantities of data it must be effectively (through employing good data standards) and securely (aided by technologies such as blockchain) stored.

Improving the ability and motivation to securely share data will foster further collaboration and innovation in the industry.



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3.

Data collection and modelling technologies

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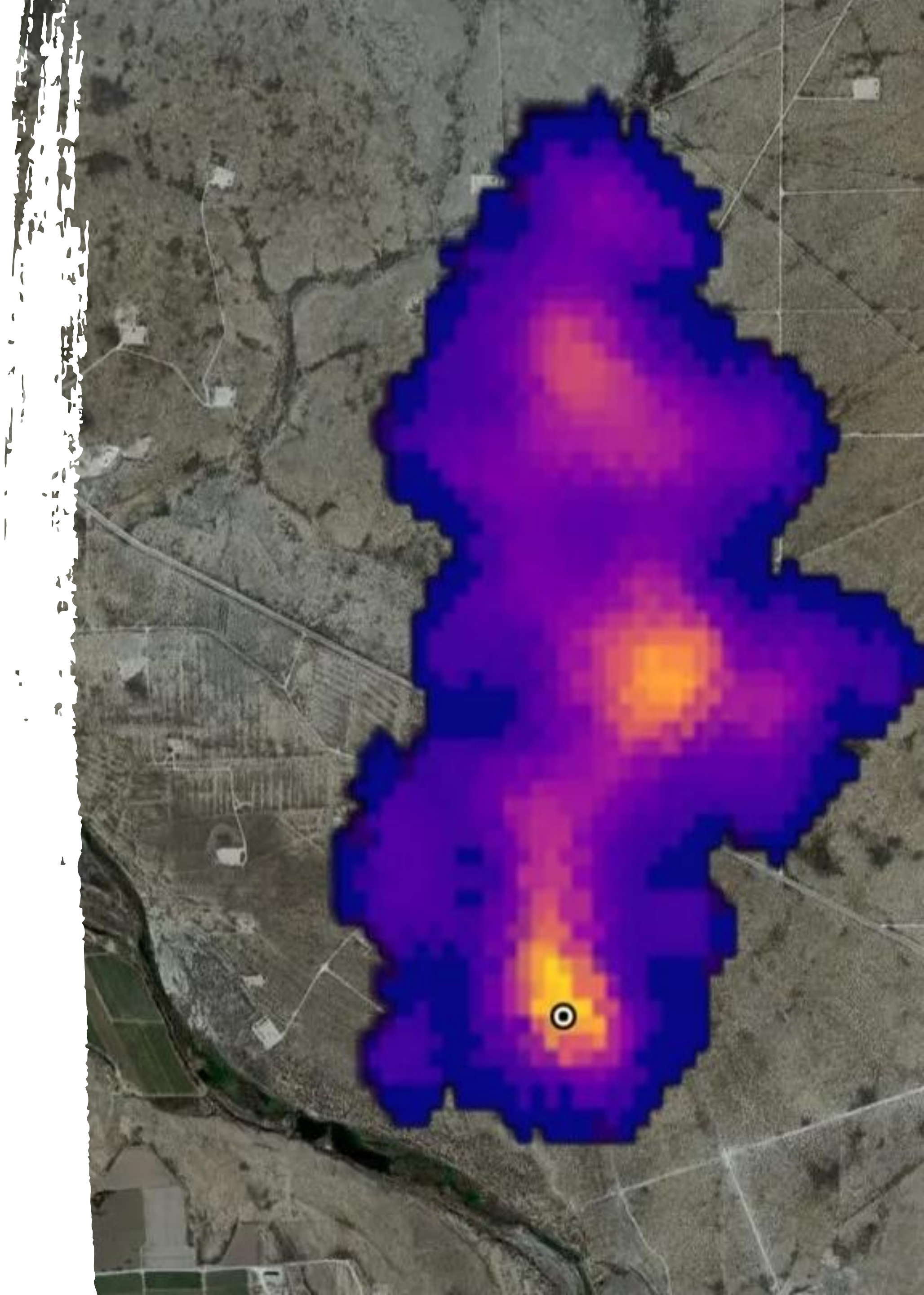
Increasing numbers of satellites in orbit provide new opportunities for methane monitoring

Methane is detected through the shortwave infrared bands in satellite imagery.

Satellites can collect large amounts of data, repeatedly surveying the same location, and improve monitoring capabilities in remote areas.

Varying resolutions of detection are available with lower resolution generally allowing for higher spatial extent and temporal coverage.

This data is becoming increasingly available both through commercial providers (e.g. Satelytics or GHGSat) and open-source projects (e.g. CarbonMapper and MethaneSat).



Innovative sensor technologies attached to drones or robots provide new opportunities for remote and autonomous monitoring

Hardware developments in both sensors and robotics increase the ability for sites to be autonomously monitored by robots or drones. They can either follow preprogramed survey paths to repeatedly cover the same area or they can leverage software advances and algorithms which allow them to search actively for leaks. Multiple robots can also communicate and work together to cover larger survey areas.

A SeekOps sensor attached to a drone to survey a site following a preplanned flight path.

Boston Dynamics' Spot robot dog equipped with various sensors to autonomously detect leaks.

Sensors that wirelessly connect and communicate, Internet of Things, improve our ability to monitor full systems

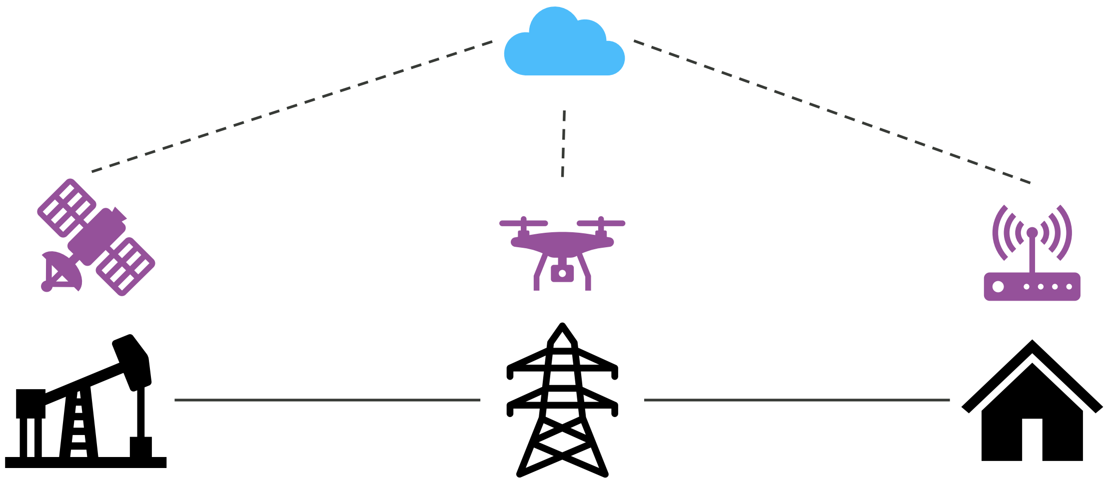
The IoT describes a network of devices equipped with sensors or analysis capabilities that wirelessly connect and share data.

Developments in sensor technologies enable IoT networks to instantaneously transmit data for real-time monitoring and analytics.

IoT networks enable the whole system to be monitored in detail and produce large amounts of useful data for analytics.

To prevent data overload, technologies like edge computing can be employed to do more of the data processing locally on the device and only transmit useful data.

An IoT network can be made up of different types of sensors all contributing to full systems knowledge e.g. across a network or grid.



More accurate simulations of dynamics across gas networks can be obtained through advances in hydraulic modelling

Current Models

Hydraulic models are sets of mathematical equations that can be used to simulate the flow of gas through pipes and networks. Performing these simulations using traditional numerical equation solvers is very computationally intensive.

Machine Learning

Deep learning methods can be used to supplement or replace these traditional methods, while keeping the same level of accuracy, increasing speed and decreasing computational intensity. Machine learning can also aid in making the models more accurate through parameter correction.

Motivation

This provides opportunities to perform more complex simulations of the network which is important for assessing the current state of the network but also looking into the future to predict how the dynamics will be impacted e.g., by different quantities of hydrogen injection.

The impact of data production technologies on DPLA

Included in the current pipeline

Assessing and trialling of technology providers currently offering advanced methane leak detection and quantification.

Building a hybrid hydraulic model of the network which uses machine learning to correct parameters and speed up simulations.

Considerations for the future pipeline

The aim of DPLA is to be technology agnostic. How this is implemented practically to account for future developments in technology (IoT, autonomous systems, different data types etc.) needs to be assessed.

Watch this space

Technologies, both solutions for leak detection specifically and IoT for real-time full system monitoring, are rapidly developing. These technologies have the potential to integrate with the DPLA and lead to autonomous monitoring and control.

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Data Analysis Technologies

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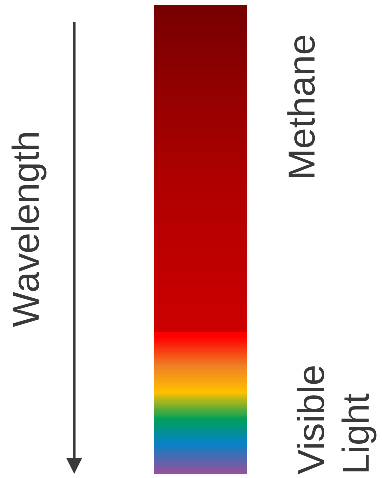
Deep learning can be used to quantify methane leak rates from imagery data

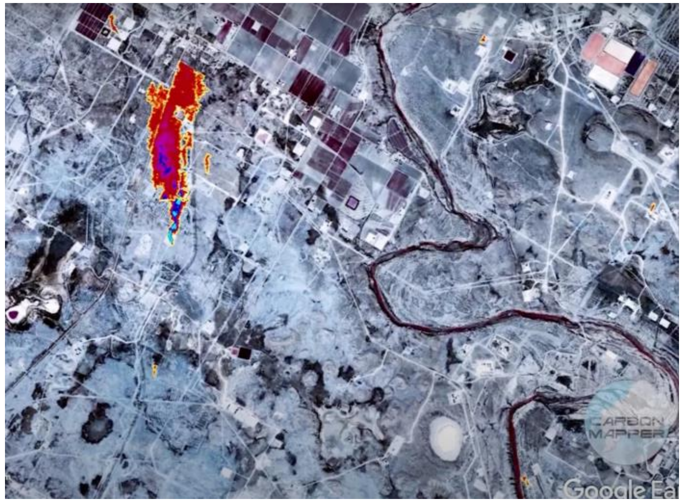
Introduction of novel methane sensors is providing large imagery datasets on methane emissions (from satellites or drones) that are difficult to analyse manually.

There is a whole field of deep learning devoted to analysing imagery data.

Training data for quantification can be provided by simulating methane plumes and embedding them in imagery data. Convolutional neural networks can then be trained to estimate methane presence and quantification on unseen imagery.



Imagery data is not limited to what we can see (red, green, blue) and methane appears in imagery at the short-wave infrared wavelength.



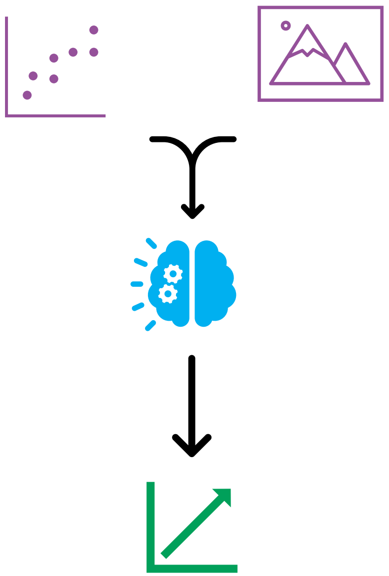
A methane emission detected by the CarbonMapper satellite.

Machine learning can combine data from multiple sources to improve insights

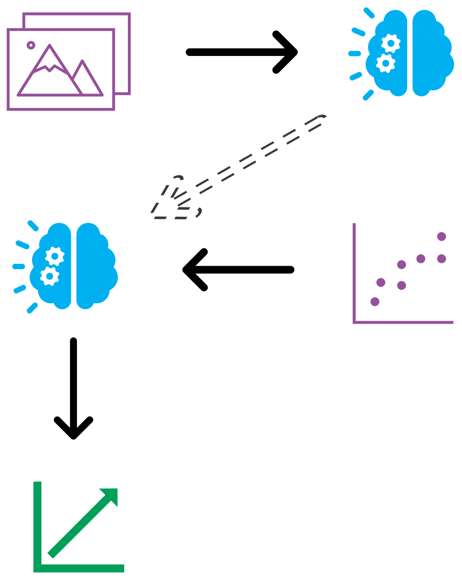
Data related to the same systems or problems is often provided in very different formats (e.g. for leakage, you may have pressure data time series and emission rates from sensors). Different machine learning algorithms can be leveraged to combine information from different datasets to enable key information to be extracted.

Example: Energy performance certificates can be combined with imagery from Google Streetview to improve prediction of emissions from individual buildings.

Data sources can be combined via data fusion algorithms or by extracting the key features from each data set.



A network can be pretrained on a more general dataset then fine-tuned using a specific data set via transfer learning.

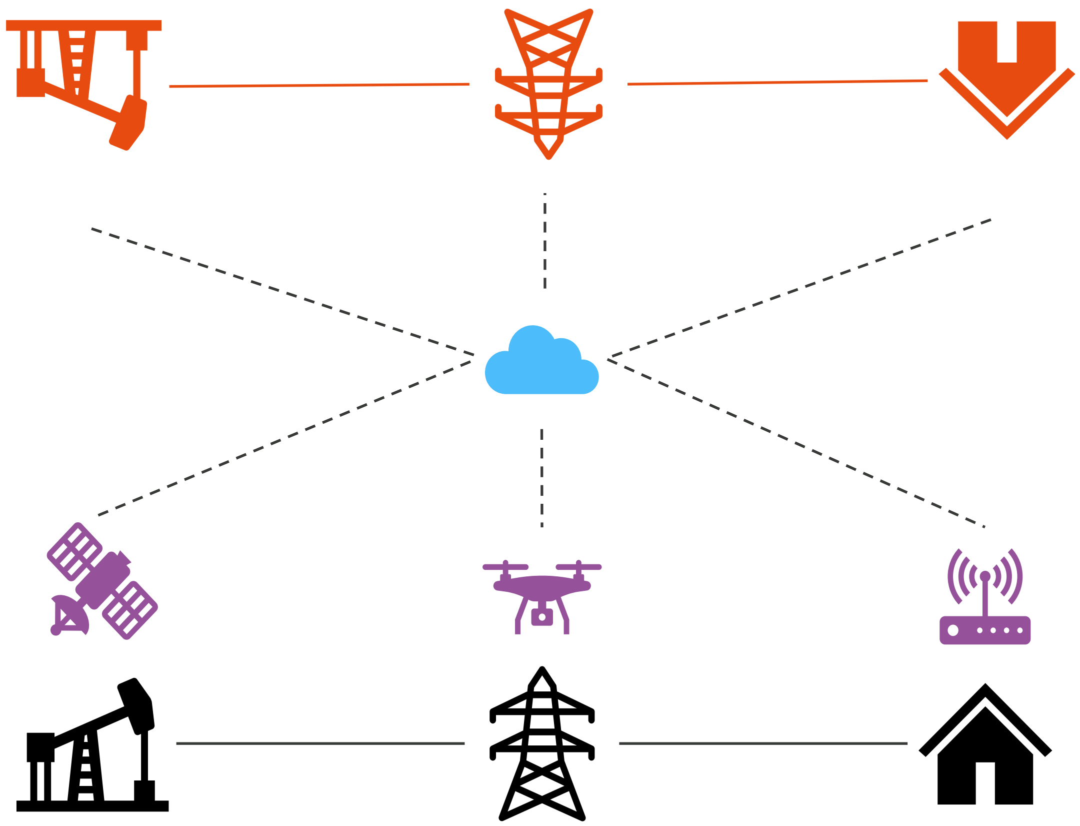


Digital twins provide virtual environments that mirror real world systems

Digital twins combine data collected from real systems with machine learning analysis and modelling to create a virtual replica of the given system.

These can provide real-time monitoring of systems as well as an environment to test and predict future scenarios.

The scale of digital twins can vary in scale from individual assets, to control rooms, to distribution networks, to full electricity or gas grids.



Case Study: Duke energy, Accenture and Microsoft have developed an advanced methane emissions monitoring platform with AI

Project goal

The aim of the project was to develop a platform that provides an end-to-end solution to detect and monitor methane emissions from gas distribution assets. The platform provides automated detection and improves the accuracy of emissions reporting.

Data sources

Multiple data sources inform the emissions monitoring: operational data, asset data, meters at houses, satellite, aircraft-based LiDAR, drones, audio/video and internet of things.

Internet of Things

IoT sensors are strategically placed to ensure maximum coverage. Microsoft provide a solution for optimal sensor placement from historical data combined with simulated methane plumes.

Analysis platform

Microsoft Azure hosts the cloud-based platform and provides the algorithms employed to ingest data and train ML models. Anomaly detection models are used to detect methane leaks and inverse modelling is employed to pinpoint and quantify the source.

Next steps

The partners intend to further develop the platform to include prediction and prevention as well as detection and remediation. They also intend to integrate industry standards to enable the publishing of emissions data and incorporate generative AI.

Source: Duke Energy powers AI platform for methane reduction (accenture.com); Microsoft and Accenture partner to tackle methane emissions with AI technology | Microsoft Azure Blog

The impact of data analysis technologies on DPLA

Included in the current pipeline

Different machine learning models will be applied to operational network data and algorithms trained to detect leaks.

Many of the advanced methane leak detection technologies being considered use machine learning algorithms to quantify leak rates from their sensor data.

Considerations for the future pipeline

When the hydraulic model and leak detection components of DPLA are operational the expert system will be developed. This system will take multiple forms of inputs from the various model and sensor technologies. The optimal techniques and methodologies for combining these data types will need to be considered.

Watch this space

The introduction of more smart sensors as part of the IoT will produce more data requiring complex algorithms to process and analyse. This will improve the accuracy of system models and digital twins, enable more scenario prediction and capabilities such as predictive maintenance.

Algorithms for leak rate quantification will continue to increase in accuracy allowing for more reliable and automated leakage monitoring and prediction.

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Data Storage and Sharing Technologies

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Ofgem's Good Data Practice (GDP) guide highlights the importance of open and interoperable data

Formulation

The GDP guide provides guidance for working with 'Energy System Data'. It is formulated based on FAIR data principles (which state that data should be Findable, Accessible, Interoperable and Reproduceable) as well as Government Digital Services advice.

Presumed open

The GDP guide states that data assets should be made interoperable with other data and digital services as a minimum standard. It also states that all data assets, associated metadata and software scripts used for processing should be treated as 'presumed open' i.e. openly shared subject to privacy and security concerns.

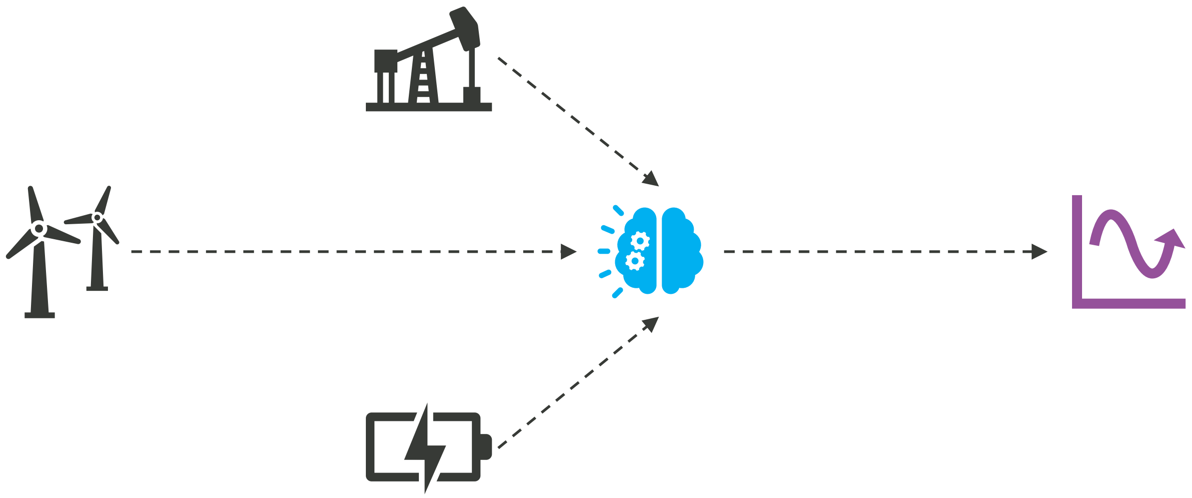
Open data triage

The open data triage is the process by which data is assessed for sensitivities (e.g. consumer privacy, negative consumer impact, security, commercial) to be made open as well as to determine how to mitigate risks while making assets, metadata and software scripts as open to stakeholders as possible.

Interoperability between digital twins unlocks further opportunities

Since individual digital twins can vary in scale, from representing individual assets to full systems, their combination can lead to further insights. Therefore, interoperability is important to consider when designing and implementing a digital twin to ensure it is useful beyond a single asset or system and into the future.

For example, separate digital twins of different energy sources could be combined for more informed demand forecasting and supply management.



Case Study: The Virtual Energy System is an innovation project with nationalgridESO developing a framework for interoperable digital twins

Discovery

The overarching goal of the project is to eventually develop a digital twin of the entire GB energy system. The discovery phase (SIF funded) focused on developing a common framework to set standards for collaboration and interoperability.

Demonstration

This stage of the project (funded by the Network Innovation Allowance) is ongoing and aims to implement a small-scale demonstration of the developed framework on a use case.

Benefits

The project benefits include the technical advantages of combining digital twins to integrate systems and model more complex scenarios. Providing a common framework will improve understanding, innovation and collaboration across stakeholders.

Learnings

Data sharing frameworks need to be agreed, including security requirements. Data standards should be followed, and ownership should remain decentralised. Collaboration between regulators and government is key to success.

Useful outputs for DPLA

The project reports their findings on data needs and gaps, demonstrator technologies, a gas network use case, interoperability and data sharing.

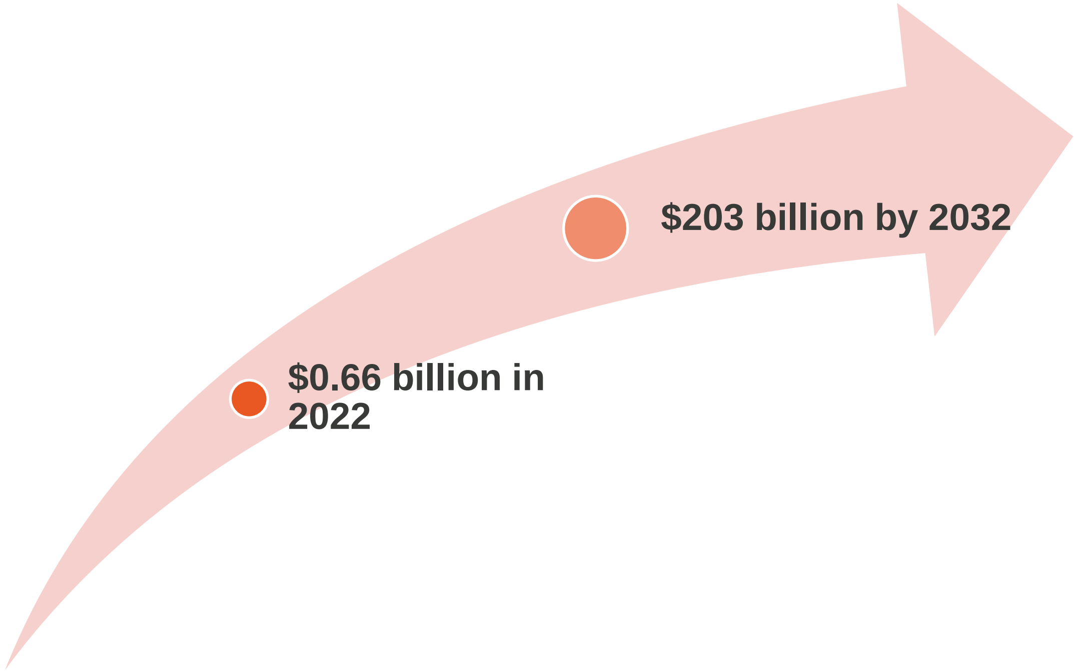
Blockchain is having a growing impact on the energy industry and how data is managed

Blockchain is a form of distributed ledger technology (DLT) that allows data to be stored securely and accessed by multiple participants at the same time. A full record is kept of any transactions made regarding the data.

This technology offers opportunities for reduced costs, improved transparency and traceability while not compromising on security.

Currently, the technology is predominantly used in energy trading but there is potential for blockchain-based management of smart grids and supply chains as well as reporting and regulatory compliance.

Projected increase in the global blockchain in energy market over the next decade.



Source: Blockchain In Energy Market Size To Hit USD 203.27 Bn By 2032 (precedenceresearch.com)

The impact of data storage and sharing technologies on DPLA

Included in the current pipeline

DPLA is funded by the Strategic Innovation Fund and therefore is subject to Ofgem's Good Data Practices. The data used throughout the project will undergo an open data triage and be shared as openly as possible with stakeholders.

Considerations for the future pipeline

DPLA provides a model of the gas distribution system for detecting, preventing and eventually predicting leaks. Ensuring that the outputs of DPLA are available to and interoperable with models of other systems and digital twins will be an important consideration for future-proofing the project.

Watch this space

Although currently used predominantly in energy trading, blockchain has the potential to majorly disrupt other parts of the energy sector through making data and supply chains more secure and transparent.

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6.
Key Takeaways for DPLA

November 2023 - January 2024

Recommendations for the DPLA from each of the areas researched

Production

As well as trialling a selection of sensor technologies and quantifying their impact on the resulting accuracy of leak detection, ensuring that the platform is truly technology agnostic will be essential. The sensor technology market is rapidly developing and as technologies progress, costs will fall and IoT sensor networks will grow. Therefore, the DPLA platform must be capable of taking in data from these IoT sensor networks and new sensor technologies (for hydrogen as well as natural gas).

Analysis

A complex data analysis pipeline has already been developed for DPLA including trialling different machine learning methodologies to obtain the most accurate results. Through this process, developers must ensure that state of the art methodologies, in areas such as multimodal data analysis, are assessed and implemented where necessary. Having the ability to easily adapt certain components to implement more advanced architectures would also be an optimal goal.

Storage and Sharing

The data and modelling employed in DPLA will be triaged according to Ofgem's Good Data Practices and shared accordingly. Knowledge and findings will also be widely disseminated and shared with other gas networks. Through the development of DPLA, the interoperability of the outputs should be considered so that they can integrate seamlessly with other models to build full-system digital twins.

Thank you

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Future review ideas:

- Time series analysis
- Reinforcement learning
- Water leak detection vs. methane leak detection

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