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Digital twins for energy

Opportunities for applying digital twins in the UK's energy sector

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Introduction

The UK's energy system is rapidly transitioning towards flexible, decentralised and renewables-dominated service models. As the system evolves, there are massive opportunities to leverage digital twins to drive this transition forward.

techUK defines a digital twin as 'a relevant, virtual representation of the state and behaviour of something physical or non-physical with a functional output in the real-world'. Digital twins are developed through the systemic integration of foundational capabilities- such as sensors, data, integrators, models, analytics, and actuators- and can be connected, talk to, and learn from one another.

This report demonstrates how digital twins are ***already*** supporting better **strategic planning** across the energy sector, **optimising the performance**, control, and adaptability of energy delivery, and **providing assurance** in the safety and resilience of energy infrastructure.

However, it also highlights that, while digital twins are already enabling the UK's energy system to transition to flexible, decentralised and renewables-dominated service models, adoption remains immature and disjointed relative to other sectors.

An sector-wide approach to accelerating the development, adoption and diffusion of connected digital twins will support enhanced strategic planning, drive performance optimisation of critical energy infrastructures, and enhance the UK's resilience in the face of unprecedented levels of uncertainty and complexity.

In light of current events, with energy prices rising, and energy providers folding, we need to acknowledge the urgency for an immediate step change. The impact of the international dependency on energy and gas, COVID-19, the France-UK interconnector outage and increasing demand for gas in Asia, has had a catastrophic impact on the UK energy system. The energy market, although drastically changing, is still underdeveloped technologically. Transitioning to a digital, data driven economy needs to be a top priority in order to achieve net-zero and utilise local energy sources. In this paper we hope to showcase the massive opportunities to leverage digital twins to drive this transition forward.

More detailed recommendations are outlined in the conclusion of the report.

Digital twins for strategic planning

i. Cross-sectoral energy system modelling

Digital twins are currently being leveraged to explore the effects of different policies, strategies and plans related to the optimal network structure (e.g. location, size, end users and infrastructures) of the UK's energy system.

Drawing on inputs and data from multiple sectors (e.g. water, electricity, heat and gas), digital twins are helping to expose gaps and relationships between plans, actions, and possible outcomes, supporting multi-criteria decision-making and enabling users to test and model options and important trade-offs.

If this category of digital twin can be developed further, then those leading the UK's energy transition will have enhanced exposure to a wide range of feasible interventions and decision pathways.

In turn, the UK will enjoy improved opportunities to realise cross-sector information sharing, to achieve net zero and resilience ambitions, and to develop dynamic, agile regulatory interventions.

Notable examples:

> The Connected Places Catapult (CPC) is working together with National Digital Twin Programme, Anglian Water, UK Power Networks and BT to develop a demonstrator Digital Twin of critical infrastructure across the water, energy and telecoms sectors. The Digital Twin will showcase how combining data and insights across sectoral and organisational boundaries will increase resilience to extreme weather events, through improved coordination of operational and investment decisions.

> The Integrated Development of Low-Carbon Energy Systems (IDLES) programme is a 5-year, EPSRC-funded programme that started in November 2018 and centres on whole-energy systems analysis; aiming to create a modelling tool that can better coordinate the complex interactions within the energy domain and indicate optimal forms of future, integrated, energy systems to policy makers.

ii. Disruptive energy technology deployment

Digital twins are currently being used to drive understanding and awareness of the value of energy generating, conversion, and storage technologies.

Digital twins of this kind can provide decision-makers with critical information that enables them to understand the untapped potential of existing technologies, and identify where emerging, disruptive solutions could be effectively deployed in the future.

In the years ahead, it will be essential to develop and connect this type of digital twin with high resolution, multi-carrier, cross-sector energy system models. Doing so will support the delivery of national innovation goals and provide key decision-makers with up-to-date capability projections.

Notable examples:

> Assessing energy infrastructure options: Buro Happold are working with partners and clients to use digital twins to assess different energy infrastructure solutions to provide clients with the right information and insights at the right time to make the right choices.

Digital twins for performance optimisation

iii. Whole energy system demand management

Another emerging tranche of digital twin use is concentrated on better understanding the increasing complexity of energy *demand* at a whole system level. This type of digital twin tends to incorporate activity-based approaches, energy-agent behaviour models, methods of behavioural data collection and analysis, as well as, machine learning and short-run demand prediction tools. Leveraging this kind of digital twin can reveal and predict underlying patterns of behaviour, demand elasticity, and support the development of new energy regimes.

Notable examples:

> Costain has a programme in the water sector with Open Energi and National Grid. This project involves hooking up water assets (such as large pumps, air compressors etc.) to the Open Energi platform. During peak times on the grid, Costain can turn down the connected assets to reduce the load on the grid and maintain 50Hz frequency. In this way, a digital twin approach is supporting demand side management and is proving key to the evolution of smart grids.

> Adger Energi, a Norwegian electric utility, is using Microsoft Azure Digital Twins to identify ways to operate its electrical grid more efficiently through distributed energy resources, device controls, and predictive forecasting—thus avoiding costly and time-consuming network reinforcement and infrastructure upgrades. This innovation, by using distributed energy resources, has already garnered industry recognition, receiving the Innovative Star of Energy Efficiency Award: Power Generation and Supply.

> Siemens has developed an 'electrical digital twin' which enables utilities to optimise transmission grid performance with a single source of truth for data, allowing automated data exchange between internal and external systems.

> BT has developed a digital twin to understand its own network energy use and opportunities to save energy. BT is now exploring whether this twin can be used to track the impact of specific changes on the network, to recommend network compaction opportunities, to understand how to manage power infrastructure and to predict how energy use will change in the future in response to different architectural design choices.

iv. Microgrid management

At a local level, digital twins can be leveraged to understand energy demand associated with microgrids – ‘small-scale, low-voltage power systems with distributed energy sources, storage devices and controllable loads’.

Incorporating a digital twin at this level can allow microgrid designers and operators to simulate the impacts of cost-cutting measures (e.g. by evaluating the trade-offs of various CapEx strategies) and enable the servicing of multiple customers.

While financial analysis of a conventional (single-customer) microgrid is relatively simple, analysing the financial rewards of multi-customer community microgrids (which are becoming increasingly prevalent across the UK) is considerably more complex. In this regard, digital twins can be used to make sense of complexity, to provide vital information to decision-makers and to help define the potential benefits involved in community microgrid projects, helping to attract sustainable buy-in and investment.

Notable examples:

- Costain - Another water project is using a ‘system of systems’ digital twin to manage energy consumption across a water network, early trials have identified a 20-30% reduction in energy consumption using this approach and again, there are ties with National Grid to look at this through a carbon reduction lens.
- Microsoft recently published an open-source Energy Grid Ontology for digital twins, an open-source GitHub repository. This will help solution providers accelerate development of digital twin solutions for energy use cases (monitoring grid assets, outage and impact analysis, simulation, and predictive maintenance) and facilitate digital transformation and modernisation of the energy grid.

Digital twins for assurance

v. Resilience and risk management

In an energy system characterised by unprecedented levels of uncertainty and new emerging risks, it is vital to adequately quantify the risks associated with the adoption and diffusion of no-and-low carbon energy technologies and solutions.

In this space, digital twins are beginning to play an incredibly important role in supporting the prevention of errors and mistakes. Indeed, assurance digital twins are already being leveraged to certify levels of safety or resilience for new methods, services, and features and helping to extend the life of high value, critical assets.

Notable examples:

> The West Cambridge Digital Twin developed by the University of Cambridge is driving better asset management decision-making, improving safety and efficiency and optimising value. Algorithms are being employed to detect operational anomalies in key assets, while facility managers can be alerted to problems and access data to inform remedial action.

> MottMacdonald have developed a digital twin for Watercare, helping to drive 400% return on investment over two years by providing greater accuracy in determining water supply and wastewater network capacity. This resulted in less risk to the business in allowing development to proceed without the need for upgrade requirements.

Conclusion

The examples provided in this report represent just some of current areas of opportunity for applying digital twins in the energy sector. Additional opportunities will inevitably arise as the sophistication of relevant foundational technologies improves.

While digital twins are already enabling the UK's energy system to transition to flexible, decentralised and renewables-dominated service models, adoption remains immature and disjointed relative to other sectors.

An energy sector-wide approach to accelerating the development, adoption and diffusion of connected digital twins will support enhanced strategic planning, drive performance optimisation of critical energy infrastructures, and enhance the UK's resilience in the face of unprecedented levels of uncertainty and complexity.

Our core recommendation, therefore, remains aligned with our recent "unlocking value across the UK's digital twin ecosystem" report: the need to provide continued support for the development of a cross-cutting, interdisciplinary coordinating body dedicated to driving forward digital twin adoption and diffusion in the UK.

This type of support will enable the UK's energy sector to develop a coherent, future-focused strategy and support the development of a connected ecosystem of twins made up of many of the use cases cited in this report and incorporating new use cases as they emerge. It will also enable the UK's energy sector to learn from other sectors and markets where digital twins are emerging at higher levels of maturity.

Additionally, we recommend that the UK Government invests in a series of strategic demonstrators to better understand the value associated with the application of digital twins in the energy sector, as well as, to scope out possible risks and barriers to implementation and scale.

Lastly, we recognise the need to work with industry and academia to anticipate levels of future demand for skills across the UK's digital twin ecosystem and develop the talent pipeline required. Doing so will ensure that the energy sector has the necessary skills available to take full advantage of digital twin use cases economically and secure a just transition for all.

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About techUK

techUK is a membership organisation that brings together people, companies and organisations to realise the positive outcomes of what digital technology can achieve. We collaborate across business, Government and stakeholders to fulfil the potential of technology to deliver a stronger society and more sustainable future. By providing expertise and insight, we support our members, partners and stakeholders as they prepare the UK for what comes next in a constantly changing world.

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