Project EPIC

Work Package 7, Deliverable 1: Evaluation and Learning Report

Version 1.0

EPIC

Energy Planning Integrated with Councils

This report was produced for	**Project EPIC**
Issue date	28 August 2022
Version	1.0
Written by:	Christine Chapter, Johnny Gowdy, Bruce Bardsley, Regen Jenny Woodruff National Grid Shahab Khan PSC Esther Dudek, Ian Cooper – EA Technology
Approved by:	Johnny Gowdy, Regen

Regen, Bradninch Court. Exeter, EX4 3PL

T +44 (0)1392 494399 E admin@regen.co.uk www.regen.co.uk

Registered in England No: 04554636

All rights reserved. No part of this document may be reproduced or published in any way (including online) without the prior permission of Regen

Contents

Glossary of Terms

Abbreviation	Term
ASHP	Air Source Heat Pump
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CI / CML	Customer Interruptions / Customer Minutes Lost (key performance indicators for network reliability)
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
EE	Energy Efficiency
ENA	Energy Networks Association
EPIC	Energy Planning Integrated with Councils
ESA	Electricity Supply Area
EV	Electric Vehicle
FS	Flexibility Service
GDPR	General Data Protection Regulations (data protection)
GIS	Geographic Information System
HP	Heat Pump
HV	High Voltage
HV NAT	High Voltage Network Analysis Tool
INM	Integrated Network Model
LAEP	Local Area Energy Plans
LCT	Low Carbon Technology
LPZ	Linepack Zone
LV	Low Voltage
LV NIFT	Low Voltage Network Investment Forecasting Tool
MPAN	Meter Point Administration Number
NOP	Normally Open Point
NPC / NPV	Net Present Cost / Net Present Value
OPEX	Operational Expenditure
PC	Profile Class as used by Elexon to categorise customers that were originally Non Half-hourly metered.
SPA	Strategic Planning Area
TOTEX	Total Expenditure
ToU	Time of Use
UPRN	Unique Property Reference Number
WACC	Weighted Average Cost of Capital
WECA	West of England Combined Authority
WP	Work Package
WPD	Western Power Distribution (DNO prior to National Grid merger)
WS CBA	Whole System Cost Benefit Analysis
WWU	Wales and West Utilities

1. Project and document scope

1.1. Background to the EPIC project

The **Energy Planning Integrated with Councils (EPIC)** project has sought to test the hypothesis that creating a process and tools that would allow local authority development and energy plans to be better integrated with electricity and gas network planning will enable networks to better reflect local energy objectives and lead to better investment outcomes for both the networks and regional stakeholders.

As part of the current process to create **Distribution Future Energy Scenarios** (DFES), gas and electricity utilities reflect local and regional factors as well as information from local authority development and decarbonisation plans. Although local authorities are consulted and input into the annual DFES process, the DFES is based on national scenarios and is completed for entire licence areas within a short timeframe. It, therefore, cannot wholly adopt or incorporate local authorities' strategic plans for specific geographic areas. This can lead to different expectations of future energy requirements between local authorities and the utilities for specific areas.

At the other of the spectrum, the current **New Connections** process can involve a detailed application, design and costing for the development of a specific site or project. However, the New Connections process is not well suited to consider the wider integration of local authority plans across different parts of the network and between networks and it does not involve the sort of whole system costs benefit analysis that would be needed to underpin wider network investment.

EPIC has, therefore, attempted to create a new process whereby electricity and gas distribution networks are able to work more closely with local authorities to incorporate local energy plan requirements (which may come from a variety of planning processes) for a specific **strategic planning area** (SPA) into a set of network analysis tools and a whole Cost Benefit Analysis framework. If successful, the intention is that these costed network plans could then be used to create a joint investment plan for the SPA.

The **EPIC** process and supporting tool set was trialled in three selected SPA areas within the **West of England Combined Authority** (WECA) area, spanning four local authorities. The SPAs were selected on the basis that they would provide a good mix of urban and rural demographics, and because they were already the subject of local authority planning processes either as part of an Infrastructure Master Plan or the development of an Enterprise Zone.

This type of plan may result in lower overall cost to the consumer, improved risk management or enabling local partners to realise their own strategic outcomes including net zero decarbonisation, economic growth, industrial strategy and wider societal benefits.

Please note, the electricity DNO involved in the project is referenced here as Western Power Distribution (WPD) as this was the name during the project. It is now part of National Grid.

1.2. EPIC trial project outline

There are six core EPIC process stages as illustrated below and described in the rest of this report:

I. Opportunity identification and area selection
II. Data collection
III. Local Energy (requirements) Planning
IV. Network analysis
V. Investment and options appraisal
VI. Local Energy Planning (completion)

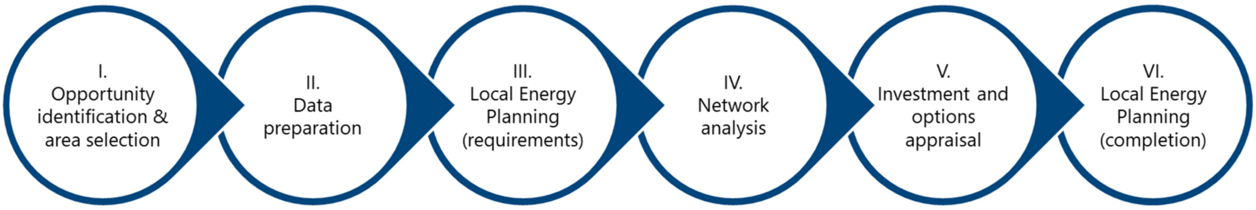


Figure 1-1 EPIC process key steps

Full details of the EPIC project methodology is described in the EPIC Project Work Package 2 deliverable 1 document "Epic Trial Process".

1.3. Document purpose and associated project deliverable

The EPIC project is made up of several work packages and deliverables, each of which has its own learning section.

This overarching learning and evaluation report:

a) brings together and summarises the learnings from each of the project work packages

b) provides an overall commentary on the learnings from the entire project including some of the cross-cutting learnings

c) provides an evaluation of the project methodology and outcome, potential for adoption as a business-as-usual process and makes recommendations for future development.

2. Learning from the EPIC project work packages

2.1. Work Package 1: trial area selection (and data gathering)

The objective of WP1 was to document the area selection process and also to define how SPAs will be mapped onto the electricity and gas networks in order to produce an integrated energy plan.

One of the early EPIC project challenges was to define geographic areas for trial that met the requirements of the local authorities and that could also be mapped onto gas and electricity network assets for the purpose of network planning.

We described the process and key considerations that were used to select the three trial areas as well as summarising the approach for area network mapping and the data requirements. The two reports also contain an interim learning review of the lessons, opportunities and challenges of the selection process.

The overall EPIC process worked in the sense that the project was able to define workable SPAs but the definition of the trial areas took considerably more time and the mapping back to both the electricity and gas network asset planning areas was problematic, especially for gas.

2.1.1. Deliverable references

- Project EPIC – WP1 Deliverable 1 Area Selection Document vFINAL
- Project EPIC – WP1 Deliverable 1 Area Selection Document Addendum vFINAL

2.1.2. Learning points

Trial Strategic Planning Area (SPA) selection process

The selection process for two of the three EPIC project SPAs was relatively straightforward in that key strategic areas had already been identified across the region from WECA's Spatial Development Strategy and Strategic Infrastructure Master Plan.

The third area described originally as the "North Fringe" of Bristol and later renamed the Filton SPA was less well defined and resulted in a significant project change request to shift the trial area boundaries.

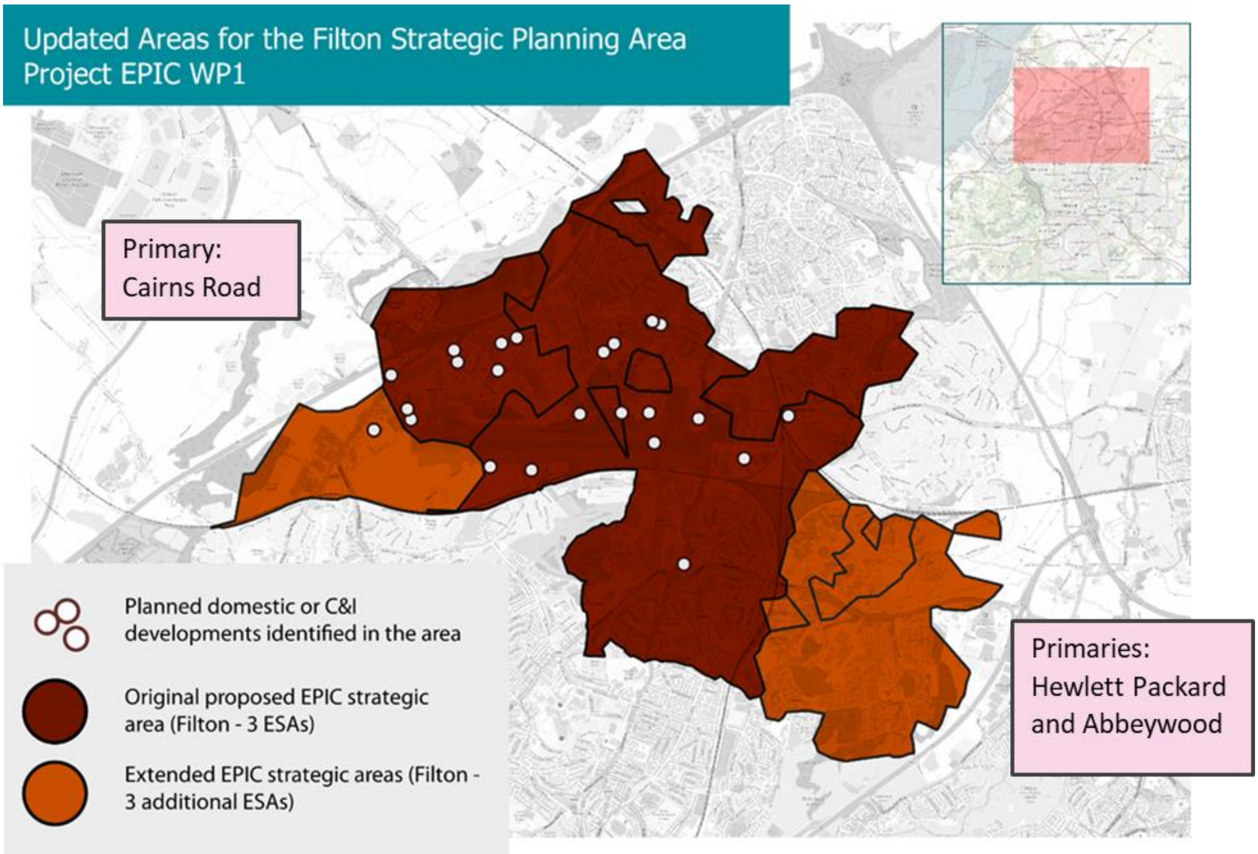


Figure 2-1 The Filton Trial Area boundary was re-drawn incorporating three additional electricity supply areas

The EPIC experience reflects the fact that local authority boundaries and areas of strategic interest do not map easily onto network assets, and may not be very clearly defined. A key learning of the project was the need to get areas identified and signed-off up front. It is hard to do that, however, when the process for local authority planning may itself be in a state of change. On a positive note, the EPIC project was able to accommodate the requested change in the Filton SPA and re-process the necessary data.

It is realistic to assume that SPA selection and definition will originate from a variety of methods, including areas that have already been defined as part of another process, e.g. an enterprise zone, regional development area, Freeport or master planning exercise. Connection requests and DFES data will also have a part to play in the area selection process.

Where planning areas are not already clearly defined, it would be necessary to adopt a more structured selection process that incorporates a weighting to each of the selection criteria. In future, the area selection process should be developed in partnership between councils and the networks and would likely start with engagement from electricity and gas network distribution and area managers.

The risk with the SPA selection is that an area does not produce the variety of investment options and strategies that would be expected by taking a strategic, whole systems approach. This may be especially true for the gas networks, since none of the areas that were selected for the EPIC project featured a strong strategy for green gas production. Green gas production sites are generally located in rural areas with current sources including farms, food production sites and waste water treatment works. Hydrogen production is also likely to be cited away from urban areas.

SPA boundary definition and mapping to network assets

A critical part of finalising the SPA was defining the boundaries in a common language that was useful and meaningful to all stakeholders and that could be digitally mapped to network assets for the purpose of network planning.

For project EPIC, it was very challenging to pictorially represent the SPAs on a map in a common language for the local authorities, National Grid) and Wales & West Utilities. For EPIC the project adopted four definitions of spatial area:

1. **Strategic Planning Area (SPA)** which represented the strategic area of interest to the local authority
2. **Electricity Supply Area (ESA)** which is the network planning areas based around a network asset(s) – which in the DFES process is normally a primary substation
3. **Gas Supply Area (GSA)** which is a network planning area used in the gas network and is normally defined around a higher pressure area of gas distribution or line pack zone (LPZ)
4. **EPIC trial area** – the complete area that the trial project needed to model and gather data for.

An immediate problem for EPIC was that the different geographic areas did not correspond to each other and it was quickly recognised that, in order to ensure that the EPIC trial area included complete ESA and GSA network planning areas, it would be necessary to significantly increase the trial area size.

As a compromise, the EPIC project defined the trial area based on the number of complete ESAs that overlapped with the SPA. This considerably increased the size of the trial areas. As an example, the South Bristol SPA and trial area is shown in Figure 2-2 Intersection of the South West Bristol SPA selected for EPIC and the primary-level ESAs.

The project was not, however, able to adequately map the trial areas back to a workable GSA. The gas network topology does not lend itself to creating spatial zones in quite the same way as the electricity network and local authority boundaries, as it is not as strictly hierarchical. For the gas network, customer-level nodes could be represented with a postcode list, but the higher pressure network planning zones covered a significantly larger geographical area than the local authority and Western Power Distribution (WPD) areas (i.e. more akin to regions).

A consequence of the area mapping methodology used in Project EPIC that should be considered for future users, is that the total area to be analysed is likely to be significantly larger than the agreed SPA boundary. Not only are the GSAs likely to be much larger than the SPA, but the ESAs will also cover a larger area and there is no way to match and map the data from an individual substation to a specific area within the ESA it serves to better match the SPA boundary.

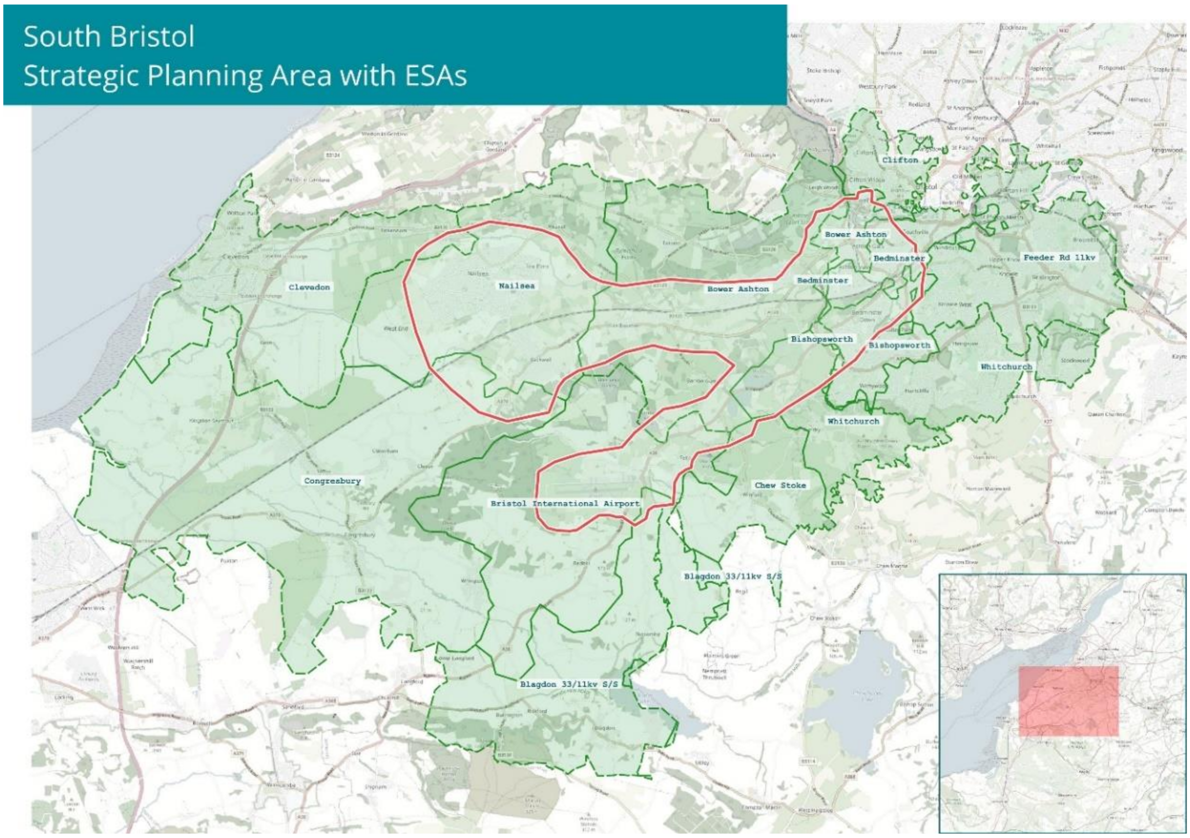


Figure 2-2 Intersection of the South West Bristol SPA selected for EPIC and the primary-level ESAs

If we were to use a larger SPA boundary to better align to the ESA boundaries, the process may be more manageable but we would lose a level of detail that the smaller SPAs give us.

There is no "one size fits all" approach that can be recommended to solve these issues and it's likely that this is something that should be considered and approached on a case-by-case basis in the future to find the optimum for the area under consideration.

This challenge of spatially mapping planning areas onto network assets is likely to be encountered by other energy planning projects, such as Local Area Energy Plans (LAEPs). This points to a fundamental point that network planning needs to consider the entire geography, and all loads, served by the network assets that are to be planned. Even then, this is an approximation given the meshed characteristics of many network topologies. For electricity networks this is possible, while more work is needed to bottom out how to incorporate gas network planning.

New housing and commercial and industrial development considerations

Future users of the EPIC process should consider the location of confirmed new developments that will have an impact on the energy networks when starting to define the boundary of the trial area. As was the case for the North Fringe SPA, stakeholders may want to include areas where there is likely to be significant potential future development. The project team will need to work closely with the relevant local authority to gather information about new developments, including:

- Location of each proposed development
- Total homes / non-domestic floorspace
- Type of development if non-domestic
- Build rate by year

- Levels of efficiency, types of heating, Electric Vehicle (EV) chargers and other low carbon technologies that will be part of the development.

It would be useful for future users of the EPIC process to run a slightly separate, more detailed study on new developments for both the gas and electricity networks which could allow for more targeted local authority engagement.

Learning from data gathering

As part of the work to define the SPAs, it was necessary to examine and analyse several datasets – many of which came from WPD and Wales & West Utilities. These included:

- High Voltage (HV) network topology
- Low Voltage (LV) network topology
- Customers by postcode at LV substation
- Location of LV feeders and upstream network topology
- ESAs from the WPD DFES
- Definition of gas supply areas from Wales & West Utilities
- WPD DFES data by local authority and primary for SPAs
- New build phasing, sites, and network connection voltage/location
- Typical energy consumption values by primary and profile class[1]

In common with a lot of projects, gathering this data took longer than anticipated and required a good deal of iteration between the project partners, networks and local authority stakeholders. Future users of the EPIC process may benefit from requesting this data from the relevant electricity and gas network upfront to streamline the process.

Significant efficiencies would be obtained for future use of the EPIC process if the main data elements were already prepared and available. A complete package of data requirements could be defined up front and provided digitally. Standard formats and processes for regional data exchanges are under investigation as part of the Open Networks project, Work Stream WS1b P4[2]

Data Quality

The quality of network data did cause problems during the network planning phase of the project. This is discussed further in Work Package 5 and Work Package 6. At present while it is known that there are general data quality issues, there are no metrics to indicate areas which might have better or worse data quality to help the process of area selection. As part of the process of improving data quality it would be helpful to;

- determine what metrics would help with area selection and/or network analysis
- provide metrics at a suitable level of resolution
- provide a plan for quality improvement so that this can be reflected in any scheduled analysis.

[1] Profile Classes are used by Elexon to categorise customers into eight groups for settlement purposes. More information is available here https://www.elexon.co.uk/knowledgebase/profile-classes/

[2] https://www.nationalgrideso.com/document/164061/download

Stakeholder engagement during site selection

Effective stakeholder engagement has been critical to the project, particularly with the unitary authorities, and will be for any future user of the EPIC process meaning that an effective stakeholder engagement plan would be beneficial.

With hindsight, it is clear that the stakeholder engagement in relation to the site selection process was not perfect. Sites were selected very early when the project was still in development, several months before the project kick-off, and were then written into the project scope definition. The sites were communicated to stakeholders, but not properly reviewed and signed off until the first round of stakeholder workshops, by which time quite a lot of work had already been undertaken. Hence the change to the Filton site area caused some rework.

A lesson for the project is that the site selection and boundary setting should have been (re)signed off with the key project stakeholders early in the project kick-off.

In part, this lesson reflects the inevitable delay and suboptimal "messiness" associated with the start-up of an innovation project.

Network modelling area limitations and future expansion

Although the EPIC project gathered energy requirements data for entire SPAs, a decision had been taken in the project scope and set-up phase to limit the scope of detailed network planning for the area covered by a single primary substation within each SPA. Most SPAs had between 4 and 6 primary substations.

While this was done for project budget and resource delivery reasons, in order to provide a proof of concept, the limitation of the network analysis to a single primary sub-station did reduce the value of the EPIC trial outputs for future energy and network planning. Similarly a larger sample size of networks may have made it easier to infer rules of thumb from the results of network analysis.

If the EPIC process is adopted then clearly it would be better to provide a network analysis and modelling for the entire SPA.

EPIC process timing

In the case of the EPIC project, WECA had already undertaken the Master Planning process for the areas surrounding (and including) the North Fringe and South West Bristol SPA. This can be advantageous as this activity can inform the EPIC process; but equally, the EPIC process can be useful to inform future Master Planning work so this is not a pre-requisite for future area selection. It is not known whether LAEP production will result in all local authorities having to update their plans concurrently. It would be preferable if updates were staggered on a rolling basis to even out the workload between years and an agreed schedule would allow for data quality improvement work to be focussed on upcoming areas.

2.1.3. Key recommendations

- Careful consideration of the SPA boundary is critical and will be influenced by a variety of factors including location of significant new developments and the boundaries of the ESA and GSA
- EPIC did not resolve the issue of gas network mapping and, if a whole system network analysis is to be undertaken, this will need to be addressed

- As part of the process to define the SPA boundary, several datasets will need to be examined and it will be useful for future users of the process to request these from the networks upfront
- Effective stakeholder engagement will be a cornerstone of the success of any project using the EPIC process and a stakeholder map and engagement plan is likely to be very useful
- The quality of network and demand profile data needs to be improved, this applies to both high voltage and low voltage network data but is especially true of the low voltage network , providing metrics for data quality would allow for progress to be tracked and work to focus initially on areas where data quality was better.
- Future EPIC deployment should cover all network assets within each strategic planning area.
- If possible, a schedule of upcoming local plan development should be used to direct data quality improvement work
- If possible, a rolling schedule of plan updates should be agreed so that DNOs do not need to support all Local Authorities at the same time

2.2. Work Package 2: EPIC trial planning process and Local Energy Requirements Plans

Work Package 2 delivered several key outputs:

- The first deliverable compared the existing planning processes for the gas and electricity networks, as well as the engaged local authorities. It also detailed the new EPIC process for generating a local energy plan with stakeholders and strategically assessing the investment options for both the gas and electricity networks. This included a summary of the investment strategies to be modelled for the EPIC trial, the variations within the network modelling and the necessary data sensitivities and exchanges.
- The second deliverable analysed and assessed the suitability of using the 'Whole System Cost Benefit Analysis' tool developed by Energy Networks Association (ENA) and the networks for use as part of the EPIC process
- The specifications of the HV and LV analysis tools were the third and fourth deliverables, respectively
- The fifth deliverable was the three local energy plan datasets, one for each of the trial areas used in project EPIC, with the agreed use cases and sensitivities. These were generated after two successful workshops with the local and unitary authorities for each of the SPAs where the quantitative updates to the baseline DFES data were agreed to ensure the data was an accurate reflection of local policies.

2.2.1. Deliverable references

- WP2 D1 FINAL clean
- WP2 D2 – EPIC Investment Options Appraisal Tool Specification Final Draft V3
- WP2 D3 – HV Analysis Tool Specification
- WP2 D4 – LV Analysis Tool Specification
- WP2 D5 – Local Energy Plan v2 clean

2.2.2. Learning points

Local authority engagement

Regular and ongoing engagement with local authority stakeholders was vital to the success of the workshops.

In the EPIC project, we worked extensively with all the local authorities prior to the workshops to provide the background, context and progress-to-date of the project to enable the workshops to focus on the modifications to the baseline DFES data in line with local policies. This early engagement identified a number of additional stakeholders within the local authorities whose input would be required for the workshops and who were then invited.

For the EPIC project, and likely for future users of the EPIC process, capacity conflicts and resource constraints did cause, and likely will cause, some scheduling issues. In the EPIC project, we tried to mitigate these by:

- Having the 'right people in the room', which was critical to the success of the workshops. Of course, this was not always possible and some additional stakeholder contacts were identified by the local authorities in the first workshops for further engagement on particular topics
- Although one of the objectives of the first workshops was to agree the quantitative updates to the baseline DFES data, this, again, was not always possible. Often local authorities needed to refer to published (or draft) policies after the workshops which took additional time and resource
- In addition to having the 'right people in the room', crucial to a good output is for stakeholders to have had to the capacity to think about and engage in the project.

Therefore, it may be useful for future iterations of the EPIC process to allow more time between workshops to allow for further stakeholder engagement and information gathering for all parties.

An issue that became apparent as the project progressed was that the key stakeholders within the local authorities changed. This had a bigger impact on the EPIC trial project, owing to the project's long duration, but would probably affect any local energy planning project. Having at least two representatives from each stakeholder organisation was found to help.

Workshop format and baseline data

EPIC used an extract of DFES data for each SPA to provide a baseline and a 'starter-for-ten' for constructive discussions with stakeholders. This allowed the project to ask targeted, specific questions which worked well. It also meant that, in the cases where there were no published policies or local authority plan data available, we were able to use this baseline as a data-driven and informed fall back option.

Local authority energy requirements plan input and data

A key premise behind the EPIC methodology was that local authorities would have a good, or at least fair, amount of published net zero and energy policies and future plan data in order to create the EPIC energy requirements plan, and a SPA dataset that could be used for network planning. This assumption was based on the selection of SPAs which were already the subject of master planning.

In reality the local authorities did not have a comprehensive, or readily available, set of policy objectives and plan data for the SPAs. This was fine, as far as the EPIC process was executed, since the DFES data could be used as a fall back and fill in. It did mean however that the energy requirements planning process became a case of making adjustments to the DFES data rather than integrating local authority plans. The lack of detailed energy plans then contributed to the issues later in the project around the assumed deliverable of an integrated investment plan. The integrated investment plan was conceived to be the output of a manual optimisation process where the planned investments from the local authority and network companies were brought together to find where benefits could be increased and synergies maximised. This would take place by selecting from a set of possible investments those that would result in the most complementary set and by adjusting the timings of investments where that would allow for better outcomes e.g. by upgrading the network in a particular location earlier than expected, it may enable a local authority driven roll-out of heat pumps in a particular area. In reality, none of the trial areas had planned investments to this level of detail as many were still at the stage of determining their policies.

The EPIC experience probably reflects the reality that some local authorities will have a wide range of input data available, some may have fully worked up plans while others will have limited data or resource to provide.

It was noted at a recent workshop that perhaps EPIC was "a year too early" and that if we had been starting the project again today, a lot more data would have been available.

It should also be noted that, if the local authorities had conducted a full Local Area Energy Planning process then there would have been a full set of energy plan data available. The integration between EPIC and LAEP processes is discussed further in Section 3.5.

A positive learning was that, as a pragmatic and cost effective approach, using the DFES data as a baseline and fall back did mean that the project was able to create the necessary datasets for network planning.

Availability and timing of published policies

The workshops brought to light the challenge in aligning local authority policy development timeframes with the EPIC process. The local energy requirements plans produced as part of project EPIC represent a snapshot of current published policy and ambition but our conversations with the local authorities highlighted that there is significant policy in the development pipeline that would impact and shape future local energy requirements plans. Local authority policy timeframes are often informed by other events, for example, government policy, as well as other local authority priorities rather than on a set, regular timetable.

Future users of the EPIC process may find it challenging to play out all the various decisions together and align in real time with policy development but this should not hinder the usage of the EPIC process. Even if draft policy is not yet available, local authority stakeholders will most likely know the 'direction of travel' which can be used (with appropriate caveats) to inform the local energy requirements plans.

Adoption of use cases and sensitivities

The initial EPIC methodology envisaged working towards an agreed energy requirements plan, with potentially a small number of sensitivities. In reality, for reasons already described, it was difficult to come to a single agreed plan. Instead the EPIC project worked with local authorities to identify potential scenarios or "use cases". These use cases were chosen because they would provide useful insight to support both network planning, cost benefit options appraisal and future local authority decision making.

The five main use cases are described in Figure and included, for example, whether an EV charger strategy based on low voltage on-street chargers entailed more network costs than one based on higher voltage charger hubs.

The decision to focus on different use cases did change the nature of the subsequent cost benefit analysis and options appraisal in the sense that, rather than working towards a single investment plan the final project output would be an assessment of different investment options.

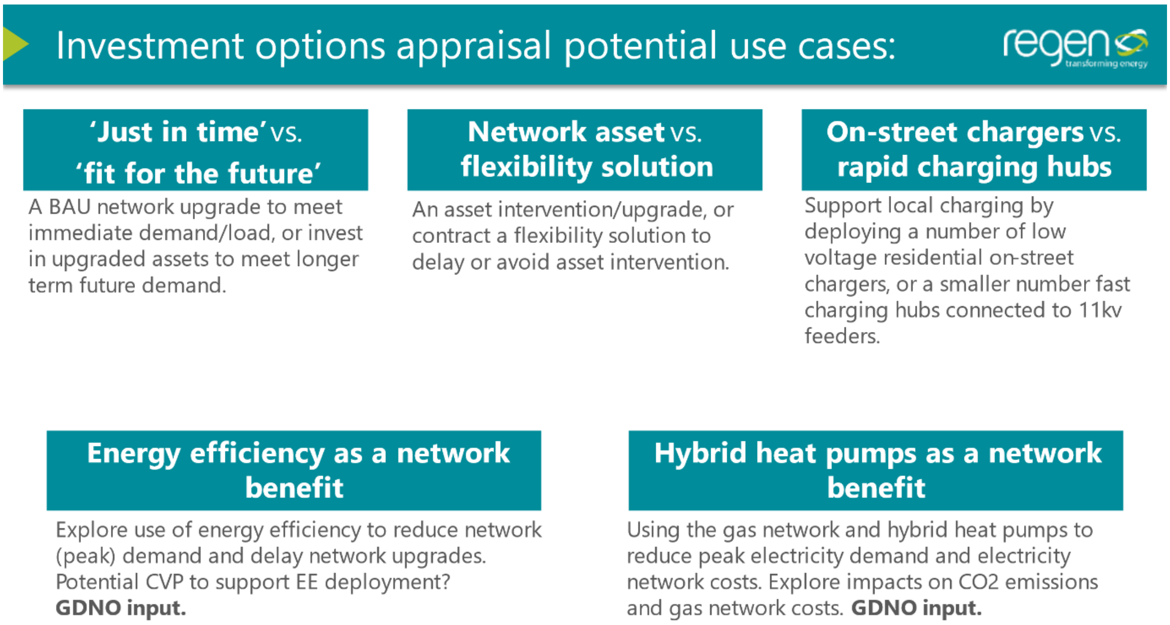


Figure 2-3 Overview of potential use-cases in Project EPIC

The local authorities we engaged as part of the EPIC project were all interested in including further use cases in the EPIC project analysis. Although it wasn't possible to include them all, it does highlight the potential for bespoke analysis depending on the particular policies and ambitions of the individual local authorities. For example, some may be focusing on developing EV policies rather than heat pump rollout. This could have the advantage of making the outputs even more relevant to particular local authorities.

The focus on use cases worked well in terms of providing a number of options that could be assessed using the whole system CBA tool, and it also provided useful insight to assist future local authority planning and network planning.

It did, however, greatly complicate the subsequent network analysis, not least because it expanded the number of analysis "runs" that needed to be completed. There is, therefore, a clear trade-off between the number of sensitivities analysed and the effort taken to complete multiply network analysis and CBA runs.

WPD customer behaviour demand profile assumptions

Energy consumption and profile data obtained drew heavily on WPD's recent work to define customer behaviour and demand profile assumptions[3]. This was extremely useful.

[3] https://www.westernpower.co.uk/downloads-view-reciteme/523762

This new document outlines the process used to create load and generation profiles for use in WPD's Shaping sub-transmission reports which contain the results of analysis on the Extra High Voltage (EHV) and 132 kV networks. This analysis is carried out annually and has much in common with the EPIC approach in that it uses DFES data for different scenarios and determines the impact on load profiles so that network modelling can be carried out. While the Shaping sub-transmission analysis does not extend below primary substations, EPIC extended this to HV feeders (the networks supplying multiple distribution substations at either 11kV or 6.6kV) and distribution substations, which supply the Low Voltage cables that customers are connected to. It was hoped that providing a view of the network upgrades for these networks which operate at a more local level would be more relevant and easier to interpret for the Local Authorities than the output of the Shaping sub-transmission reports, however this turned out not to be the case due to the sheer volume of network upgrades.

This customer behaviour demand profile assumptions document was useful in providing both data and consistency of approach to project EPIC. Future users of the EPIC process may find a similar document from the appropriate DNO useful to inform their datasets. Some of the use cases and sensitivities (in particularly the hybrid heat pump case) focused on the impact that adoption of different profiles would have. For example the same total number of heat pumps were deployed in each heat pump run, with the proportion which operated on two different profiles being the only difference. The results are therefore sensitive to assumptions in the demand profiles. This is an area which could be further improved by using results from network innovation projects to develop more robust profiles. Improved heat pump profiles, including the likely impact of flexible heat options will be investigated in the Equinox[4] innovation project. Similarly the projects funded under the Heat Pump Ready Programme[5] managed by BEIS should be encouraged to capture and share data which would help refine heat pump profiles. This in turn would give greater confidence in the results from the EPIC process.

HV Analysis Tool Specification

PSC have developed the HV Network Assessment Tool (HV NAT) associated with carrying out the power system analysis and network reinforcement requirements associated with the HV system as part of the EPIC project. HV NAT is basically a python powered tool interfaced with PSS SINCAL for Power System Analysis, and has a number of different stages and decision points throughout its analysis.

HV NAT carries out the analysis utilising both the Top Down (TD) and Bottom Up (BU) approach for different use-cases agreed amongst the project EPIC partners. HV NAT takes in different inputs such as **Error! Reference source not found.** shows a general overview of the different inputs and outputs a ssociated with HV NAT.

[4] https://www.westernpower.co.uk/projects/equinox-equitable-novel-flexibility-exchange

[5] https://www.gov.uk/government/publications/heat-pump-ready-programme/information-about-the-heat-pump-ready-programme

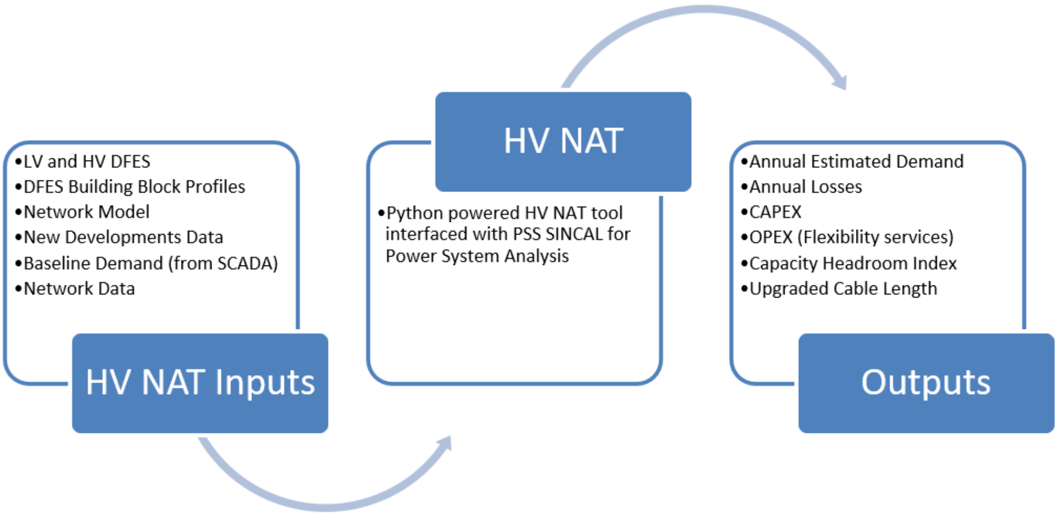


Figure 2-4: HV NAT Inputs and Outputs

HV NAT has a graphical user interface (GUI), as shown in Figure 2-5, which allows the user to select different runs, year, primary, equipment upgrade and flexibility threshold.

Figure 2-5: HV NAT Main User Interface Window

One of the learning points from the specification work was where to draw the line between the general operation of the tool and specifying the details. As the specification document often gave general direction but not every detail, this had to be revisited and updated subsequently. Some of this was necessary in order to work in step with the evolution of the LV NIFT. Similarly, it is only when you try to perform the functions that the issues with the underlying data become apparent and some of the changes to the specification were driven by problems that were only found once development work was underway.

- It was intended to work out the Flexibility Services (FS) cost on an annual basis by extrapolating the FS cost from five representative days to an annual estimated figure. However, considering the challenges and complexities in this approach an assumption has been made that we would only use flex services on HV networks to support the Restore service and, therefore, modelling a year's worth of data is not required, but modelling the peak days gives us indicative values of the service capacity requirements, including the worst case.
- It was intended to include Customer Interruption (CI) and Customer Minutes Lost (CML) figures as one of the HV Network Assessment Tool (HV NAT) outputs, however, as PSS SINCAL doesn't provide CI/CML figures from any of the standard functions in the software, therefore these figures have been dropped from the list of outputs from HV NAT.

LV Analysis Tool Specification

The Low Voltage (LV) modelling in the EPIC project used the Network Investment and Forecasting Tool (NIFT) developed by EA Technology for WPD in 2019. The NIFT was originally completed to help WPD generate investment profiles, following from work on the Electric Nation project. NIFT has been used in the intervening time to study the impact of different Low Carbon Technology (LCT) adoption rates on the loading of LV networks as part of WPD's business plan submission for RIIO-ED2.

NIFT is a software tool which combines a number of sophisticated algorithms to predict the impact of LCT uptake over time and across large geographical areas. It does this by:

1. Intelligently distributing LCTs across LV networks according to uptake scenarios.
2. Running DEBUT[6] assessments to measure thermal and voltage impact on LV networks, using network data and demand profiles for each technology.
3. Producing reports which present aggregated results to reveal insights and inform business decisions.

It can also optionally recommend "solutions" where networks become constrained, based on constraint type, magnitude and the expected impact and availability of traditional and smart solutions. This 'solutions module' was used to provide the majority of data for the CBA analysis.

The inputs and outputs to the NIFT are shown below:

[6] DEBUT is a load flow analysis engine used to model LV distribution networks. It uses information on the properties of LV networks (ratings, length of feeders etc.) combined with the loads fed from the network to determine the thermal utilisation of cables and transformers and voltage rise and drop along feeders. DEBUT is the load flow engine within WinDEBUT™, which has recently been upgraded to Connect/LV.

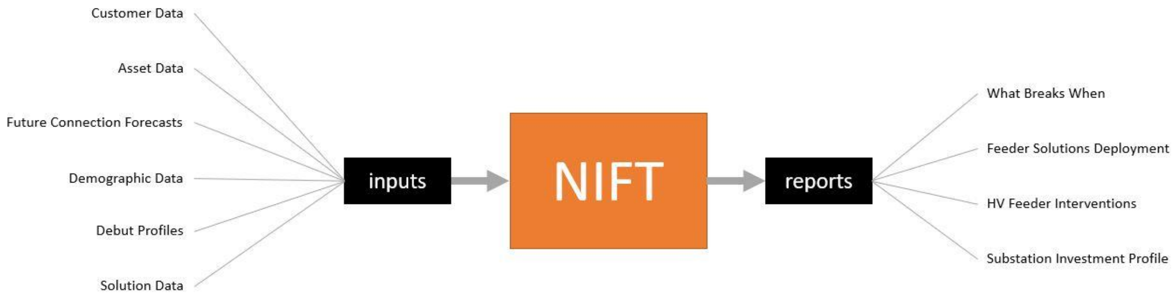


Figure 2-6: LV NIFT Inputs and Outputs

Project EPIC used the existing data held in NIFT for network assets and the number of customers in each of Elexon Profile Class 1 to 8. Forecasts of the uptake of LCTs against each distribution substation ID were provided by Regen, following engagement with the local authorities. The standard NIFT output reports were used with some post processing to produce the required CBA inputs as defined by Regen and PSC. The main outputs were:

- The total of each CBA metric for each primary substation in each year (capex and opex spend, total km of feeders requiring roadworks etc.) – used by Regen for the CBA analysis; and
- The half hourly load profile for each distribution substation for each of the five representative days – used by PSC to model the load on the HV network.

The format of the output reports were agreed during Work Package 2 and detailed in the specification document. This allowed the correct export/import processes to be built by all concerned.

The specification document also set out some amendments/additions to the work to be completed in NIFT as follows:

- LCT projections to be provided at the distribution substation level (previously given per primary and distributed by NIFT);
- Energy consumption per profile class can vary by primary substation and year. This modification was required to model the benefit of energy efficiency (varying between SPAs depending on their ambitions) and increasing utilisation of on-street EV chargers through the study period;
- Inclusion of additional LCT types – hybrid heat pumps, flexible heat pump profile and domestic energy storage. These profiles were largely based on the WPD customer behaviours document;
- The processing was adapted so that the aggregated load profile at each distribution substation was included as an output, as this was required by PSC as an input to the HV model; and
- A spreadsheet tool was developed which calculated load profiles for new ‘dummy’ distribution substations supplying new developments, based on the number and type of properties built each year and the LCTs present for each development. These new developments typically had much lower annual energy consumption figures than existing properties to reflect higher standards of insulation, partly as a result of more stringent planning conditions. These aggregated load profiles were provided to PSC so that the impact of additional demand on the HV network as a result of new developments could be studied.

The learning points from WP2 in relation to the LV modelling tool were:
- Agreeing the format of the input and output files from the different modelling stages was beneficial as it allowed all parties to develop the correct templates in advance, reducing risks

at the analysis stage. It was possible to keep a degree in flexibility about some of the processes at the specification stage whilst still agreeing data formats – for example, the exact methodology to be used to calculate spare capacity in each year was not defined at the specification stage, merely that a column would be included on the data sent to Regen for the CBA; and

- An existing tool was used for project EPIC, rather than developing a bespoke solution. This reduced costs overall, and would mean that the same tool could be used for other areas of WPD's network relatively easily (although with the same issues as were present in project EPIC). There were some downsides to this, principally:
    - Poor data quality in relation to the existing network. This led to an unrealistically high proportion of the network appearing to have constraints in the baseline year (i.e. before significant LCT uptake). This effected most use cases equally but has the largest impact on the timing and total cost of network investment.
    - Some amendments to the existing system were required to meet the requirements of project EPIC.
    - Separate post-processing needed to be developed in order to convert the standard NIFT outputs into the necessary metrics for the CBA. Bespoke graphing was also created to compare scenarios and report on the results for the LV Learning and Evaluation Report. In the future it would reduce the time required if a standard set of output reports/views for each implementation of the EPIC process was agreed, rather than producing a bespoke set of reports.

2.2.3. Key recommendations

- Active local authority engagement is critical to the success of gathering the data required to generate accurate local energy plans. Continued, regular engagement is crucial and building sufficient time into the project plan to allow local authority stakeholders to refer to published (or draft) policies between the two workshops could be advantageous for future users of the EPIC process to ensure that the local energy requirements plans are as accurate as possible.
- To develop a fully integrated plan it is necessary to have local authority plan data and defined energy policies. This could come from a LAEP type process that would proceed EPIC.
- Where published (or draft) policies and local planning data are not available, using the existing DFES data as a baseline for discussion was incredibly useful
- Use cases provided a useful starting point for network analysis and options appraisal. The number of use cases and sensitivities needs to be balanced against the increased network planning resource that is required.
- Networks should continue to develop customer behaviour and demand profile data.
- Work needs to take place to improve the underlying LV electricity network data.
- It would be useful to consider future potential use cases so that further development could be considered for example modelling LV Flexibility, the use of battery storage etc. Local Authorities could be asked about potential future use cases as part of the routine DFES engagement.
- Existing stakeholder engagement with stakeholders, should be extended to capture potential future use cases that may require modelling so that the future tool development can take place with those option in mind. For example it may be that there is value in modelling the use of electrical battery storage, thermal batteries, LV connected flexibility etc. The future increase in loads from EVs and Heat pumps may require the analysis tools to not only recognise breaches of thermal and voltage limits as triggers for reinforcement, but to also recognise where parts of the network that previously supplied under 1MW of peak load are likely to exceed it, triggering

additional fault resilience requirements under Engineering recommendation P2/7. Work Package 3: investment and options appraisal tool testing

2.2.4. Deliverable references

- EPIC WP3 Deliverable 1 Investment and Options Tool Testing

2.2.5. Learning points

Complying with industry and government best practice

The EPIC project considered two options to provide an investment option appraisal tool, to build a proprietary tool or to adapt the Whole System (WS) Cost Benefit (CBA) tool[7] that had been developed by the ENA's Open Networks project.

The decision to use the ENA's Whole System CBA tool was beneficial, it made best use of the existing work in the sector, avoided duplication of efforts, and, in using the tool, the EPIC trial was able to validate it and pass feedback to its developers – which has been appreciated.

The Whole System CBA tool was released with a well referenced methodology and user guide which was very useful in signposting best practice. This provided confidence that the methodology was being applied in line with government and industry standards, and cut down on time which would have been spent in research.

The CBA tool allows the user to define financial metrics (Weighted Average Cost of Capital (WACC), Capitalisation Rate, and Depreciation Period) to apply to stakeholders, regulated by Ofgem or otherwise. For regulated stakeholders, WPD and Wales & West Utilities, reference to their business plans for the current or upcoming regulatory period and/or network-specific CBA tools was required. Where costs are allocated as wider societal costs/benefits (spare capacity, final demand, deployment of EV chargers) the approach taken has been to follow HM Treasury Green Book guidance on the valuation of societal impacts.

Reliance on good inputs to the tool

While the WS CBA tool does feature a number of built-in 'whole system valuations'. For example, the tool will convert annual carbon emissions into a monetised societal impact. One of the learnings from the EPIC trial is that the **work done before the CBA process to generate and value impacts is the key driver of a good CBA analysis.**

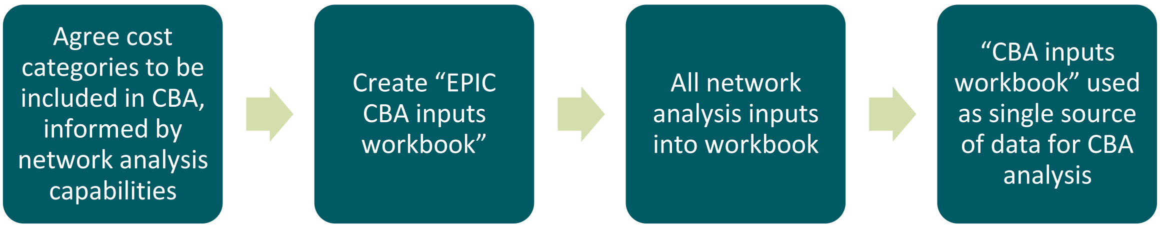
In the case of the EPIC trial, the list of impacts which could feasibly be modelled by network analysis tools and considered was reduced to capital expenditure (CAPEX), operational expenditure (OPEX), losses, spare capacity, roadworks and final demand. In any future project, and with the benefit of having pre-developed CBA tools, effort should be focused on the ability to accurately capture more network and whole system impacts.

Work process and data input integration

[7] https://www.energynetworks.org/creating-tomorrows-networks/open-networks/whole-energy-systems

The CBA method used in project EPIC relies on having impacts broken down into annual monetised figures. EA Technology and PSC undertook work to ensure their network analysis outputs were compatible with CBA analysis.

In the EPIC trial process, the development of the LV-NIFT, HV-NAT and testing of the CBA tool were separate processes happening concurrently. The agreement on outputs, units and formatting was, therefore, a late stage consideration for the developers of the network analysis tools. As a result, there are different data output templates being used by the HV and LV teams. The agreement of these templates was critical and has ensured that network analysis outputs can be successfully integrated into the Whole System CBA analysis. However, considering the benefits of simplifying the tasks of the future ‘EPIC energy planner’, subsequent EPIC studies could improve the process. With the capabilities of the network analysis tools known from the outset, the process below could be used:



A live “EPIC CBA inputs” workbook, with a locked format, and space to input all required data, would minimise the amount of data manipulation required from the ‘EPIC Energy Planner’. It would allow an efficient integration of the network analysis tools with the EPIC CBA tool. If a large number of areas or strategies are being considered, it could be linked by macros with the CBA tool to speed up data transfer. In order to ensure the standardised workbook can support a wide range of requirements from different local authorities it may be helpful to first survey them to determine which inputs are commonly required and to develop a means by which different metrics could be included or excluded in a standardised way such as through a defined set of menu options. This could allow a degree of flexibility and customisation between local authorities without requiring customised post-processing of outputs for every possible combination of metrics to be included in the tool.

Top down vs bottom up approach for HV results

Two methods of HV network analysis were used to produce results for impacts on the HV network; a “top-down” and a “bottom-up approach”. To compare the results of these two methods, both sets of HV results were input into the CBA tools. This increased the data transfer requirements, and complicated comparisons, but it was hoped that some learning could be gained on the application of these modelling methods. Given the number of difficulties encountered in the HV network analysis and the limited project time to resolve all issues, **future iterations of the EPIC process should consider focusing on just one method**.

Gas network decarbonisation assets

The gas network topology does not lend itself to creating localised spatial zones (such as ESAs) in the same way as the electricity network, as it is not as strictly hierarchical, and at the low pressure level is made up of large contiguous networks. In the case of project EPIC, the low pressure networks (Bath and Bristol) are more akin to regions, and dwarfed the SPAs. In addition, the assets with the potential to decarbonise gas supplies (e.g. biomethane plants, hydrogen electrolysers or reformation plants) are, or will be, relatively centralised so were unlikely to be planned within the chosen SPAs. These assets tend not to feature in local area energy planning either, and are instigated on a more ad hoc basis, meaning that anticipating locations in the context of EPIC wasn't feasible.

In hindsight, it may have been possible to just assume that green gas imports are available.

Using grid references to locate network demand

Project EPIC data produced for the LV networks and gas networks was produced as postcode data (postcode data was based on WPD's data for LV demand customers) which was then shared with Wales & West Utilities. Postcode level data was used to provide a small level of disaggregation that could be built up and aggregated by distribution substation, HV feeder or gas zone. The impacts of demand changes are likely to be more locationally specific on the gas networks than for electricity; for example, a demand increase or decrease would be far more material at network extremities than at the outlet of a governor, and aggregating demand changes to SPA level overlooks this.

However, it was found that the postcode data from WPD did not match the postcode data from Wales & West Utilities. This seems to be an issue with both networks' customer data. As a result, the team reverted back to aggregating demand changes to SPA level.

While the analysis tools used by WPD and Wales & West Utilities use different exact approaches, they both rely to some extent on grid references to locate demand on their networks. An alternative combined approach could make use of this common feature and use grid references as a way to define boundaries on both networks in any future EPIC processes. In the case of WPD's model, any missing grid references for Meter Point Administration Numbers (MPANs) could be populated using the postcode centroid data already provided.

A further solution to this would be a database which combines all demand customers (aggregated at postcode level) and is used by both gas and electricity networks for uses above and beyond project EPIC. This could be based on the unique property reference number (UPRN) or a combination of gas and electricity meter numbers and potentially combine EPC records as well. This would also improve confidence in records for on-gas and off-gas customers. However, there may be some GDPR issues to consider in how it is created and used.

Forecasting methodology

The project team believe it is important to have joint forecasting, where gas and electricity networks use the same forecast data. Although most technologies don't use both networks (hybrid heat pumps being an example exception) the change from gas boiler to air source heat pump (ASHP), for example, impacts both networks and it is important to use the same forecasting. Future projects assessing cross-network, whole system impacts must collaboratively decide on the forecasting approach, either arriving at an agreed scenario or exploring multiple pathways through multiple scenarios (whilst also considering the resource requirements of increasing the number of scenarios, as noted elsewhere).

Talks between Regen and Wales & West Utilities discussed how gas network costs could have been considered to align it with the level of detail seen in the HV and LV analysis. CAPEX costs would be based on the size of piping needed to deliver the required additional capacity. OPEX would be minimal if assuming plastic piping is used. Shrinkage, if viewed annually and against throughput, would be an insignificant direct cost to the gas network. However, its environmental impact could be considered using a societal cost per cubic meter leakage.

2.2.6. Key recommendations

- The use of the WS CBA tool saved time and gave confidence that best practice was being applied. For future CBA studies, use of pre-exiting tools should be considered before any tool development.

- For user-defined financial metrics (e.g. WACC, capitalisation rate etc.), it's important to ensure the most up-to-date and accurate values are used as these will change with time
- The functionality of the CBA tool should be understood – it relies on having good inputs from network analysis tools, the focus should be on generating these
- To ensure compatibility of network analysis tools with the Whole Systems CBA tool, it would be useful to pre-define a live "EPIC CBA inputs" workbook where the outputs of the network analysis tools can be stored for effective data integration with the CBA tool. This would minimise the data manipulation required by the 'EPIC energy planner' and would be the most efficient way to collect and input the required data into the CBA tool.
- To support potential future use of the CBA tool by a wide range of local authorities, that may have differing views on which metrics to include in the tool, stakeholder engagement should take place to determine if standardised sets can be determined and the tool adapted to select between these sets rather than requiring custom modification.
- Future users of the EPIC process may want to align an approach to reference and locate network demand in the gas and electricity network analysis models. Although a postcode approach was used in project EPIC, a database based on UPRNs or a combination of gas and electricity meter numbers could ensure more effective, common language that is relevant and meaningful for both the gas and electricity networks.
- For technologies that impact both the gas and electricity networks, it is essential that the same forecasting methodology is used for these technologies by both networks and early agreement on an appropriate forecasting approach will be useful.

2.3. Work Package 4: LV, HV and gas network analysis tool development

The objective of WP4 was to use the specifications developed in WP2 to develop, test and validate the three network analysis tools that would be used as part of project EPIC: the HV, LV and gas network analysis tools.

2.3.1. Deliverable references

- JK9398-3-1 EPIC HV NAT Evaluation and Learning Report
- Network Investment and Forecasting Tool (NIFT) Evaluation and Learning Report v1
- Synergi Gas report

2.3.2. Learning points

Gas network analysis tool

- The Gas network analysis tool is still under development and now has a focus on understanding the gas network impacts of a switch to hydrogen rather than whole system integration with electricity systems.
- Aligning the areas used for DFES disaggregation and gas networks was hampered by comparing postcodes with lat/long systems. This also flagged up the need to track postcode changes.
- The maximum reduction in peak gas demand across all scenarios and SPAs was 13% but information wasn't available for network analysis to determine whether this was because of e.g. local growth from new developments being outweighed by reductions in load via energy efficiency and / or switching to heat pumps. As a result it wasn't possible to identify the reinforcement that would be needed for new developments or any decommissioning if whole areas were moved to

other technologies. In order to provide an opportunity to follow a process for gas network analysis and costing, work was done to generate dummy reinforcement based on arbitrarily modelled demand increases, or a change in the properties of the gas being transported, even though this wouldn't influence the CBA or the integrated investment plans for this project.

- A limitation of the current gas analysis tool is that it does not export any cost outputs – reinforcement solutions (such as parallel pipes, links or new governors) are arrived at through an iterative process then manually exported. The costing of these solutions is currently undertaken as a distinct activity because unit costs can vary considerably depending on the location of the scheme. It may be beneficial to the EPIC process to explore whether the analysis tool's functionality can be broadened to address this.
- There was a lack of data on heat pumps and their evolution to hydrogen over longer timescales which limited the hydrogen modelling that could be carried out. There is a need for profiles for hydrogen variants and a longer term view of prices and carbon intensity of gas vs. electricity.

HV network analysis tool

- At Bower Ashton primary, renumbering of the circuit breakers has taken place following work a year ago, however while CROWN and EMU are consistent, there was no update to the datalogger information making it very hard to interpret which logger relates to what data. This resulted in what was really a transformer load being shown as if it were the load of an outgoing HV feeder and vice versa. This suggested incorrectly that the transformer was very lightly loaded and that the HV feeder was severely overloaded. There does not appear to be a way to make the datalogger labels time-sensitive and reflect the labels that were valid at the time.
- A number of HV connected sites do not have MPANs associated with them but appeared to be operational and this was confirmed using other systems such as PowerOn to determine whether the HV site was energised. In most cases it was not possible to identify the related MPAN and this was an activity that could not be automated.
- The SINCAL model generates dummy transformers of 100 kVA capacity at the locations of HV connected customers. These would have been likely to create investment upgrades on non-existent transformers. Similarly these will introduce an impedance which is not correct for network modelling. These were corrected for EPIC.
- The SINCAL model contains cables with no thermal rating information as this has been sourced from the Geographic Information System (GIS) data. Using a value of 99A allows us to prevent the tool over-reporting the required investment upgrades.
- The initial models for the primaries had a number of disconnected sections of network, only one of which was genuine. One was 33 kV network associated with the primary but without a source, another was reflecting a GIS error and the GIS also had the NOP in the wrong place. This is the kind of issue which INM will help with.
- The lack of HV feeder attribution in the underlying network model has resulted in the HV NAT needing to model an entire primary at a time rather than modelling each HV feeder separately. It is possible that this is slowing down the overall processing time for the tool but it can't be confirmed without having a comparable network model and changing how the HV NAT operates. This should be investigated as we are likely to make use of more automated network analysis in the future.
- The HV NAT running time was very slow, partially due to the number of nodes being processed in SINCAL. There were amendments that were made to speed up the process without compromising the results. One was to carry out analysis for 120HH timesteps rather than 240HH timesteps in the time series reflecting the representative days i.e. hourly rather than half hourly analysis. This had no major effect on the investment required. Similarly, calculating Capacity Health Index (CHI) in the same power flow analysis, in which NI and FS calculations were carried out, saved time rather than carrying out the same power flow multiple times.

- Originally it was planned to calculate the diversity factor between HV feeders and the primary transformer because the way in which the primary transformer replacement is calculated is to assume overload if the total profiles exceed 50% of rating but this is a bit pessimistic as not all HV feeders experience their most onerous conditions concurrently. This could be adjusted for by altering the point at which assets are considered overloaded.
- Very high increases in annual demand values due to the EV building blocks were found to be the result of a problem where the load added was incorrectly multiplied by the number of chargers, overestimating the demand as a result. The calculation of EV loads is currently complex and a simplified process with typical profiles for different chargers would be useful in the long term. This is an area which is likely to require further data gathering. Demand profiles for EV hubs have not been collected as part of DNO network innovation projects to date, and in any case, profiles are likely to change as increasing EV uptake increases the utilisation of chargers.
- In the distribution substation to primary mapping data there are certain distribution substations which appear twice in it but with different distribution transformer rating at the same site. This duplication was removed to ensure HV NAT reads the correct value of transformer rating at the concerned site. The cause of the duplicated results is not known.
- The HV connected sites had no transformer rating data with all of them reading zero. This is correct as unless we have details of customer equipment the site will not contain WPD owned transformers. However this resulted in issues with the disaggregation approach which was based on transformer ratings. Therefore, transformers for HV connected sites was assumed to be 2 MVA so that they get disaggregated load in the top down approach.
- The LV DFES data has got profile class (PC) information only for non-hybrid heat pumps i.e. a distribution substation had heat pumps allocated for PC1 and PC2 separately[8]. This profile class split information is used by EA Technology. As PC information is not needed in HV NAT this PC split was seen by HV NAT as duplication of HP volume allocation and only PC2 volume was getting picked up in the analysis thereby underestimating the demand due to HPs.
- The contribution to the demand by EVs reduces in year 2050 when compared to the contribution for year 2040. For the year 2050 there is a reduced volume of EVs in comparison to 2040 for both Dorchester St and Nailsea. This was initially considered to be a potential error, however Regen confirmed that this is on the basis of the assumption that there will be more utilisation of the public transport, car sharing schemes and autonomous vehicles, and hence less usage of EVs.
- OPEX costs associated with modelled reinforcement (other than flexibility services) are not considered as part of the HV NAT due to the challenges in correctly identifying these in an automated fashion to impact the overall investment decision.
- Upgrading of 6.6 kV cables to 11 kV cables was intended to be captured in HV NAT; however, it has been decided not to consider this upgrade programmatically but to consider it as a one off. Hence it is not considered in HV NAT.
- The number of representative days in this kind of long term analysis can be reduced from five to three. The “Int_Warm” and “Summer MinGeneration” representative day recorded the least level of investment. Dropping these representative days would lead to lesser computational effort as the number of HH time steps reduces by a one fourth of the processing time.
- Filton DC primary had issues in terms of quality of data. For a good part of the year, the incoming transformer data was missing as can be seen from the plot below – Figure 2-7.

[8] Hybrid heat pumps (i.e. where gas is used for heating in some periods) were assumed to only be allocated to Profile Class 1 customers. Profile Class 2 is used for homes with electric heating (night storage heaters). It would be unusual to replace a home with electric heating with a hybrid heat pump requiring a gas connection.

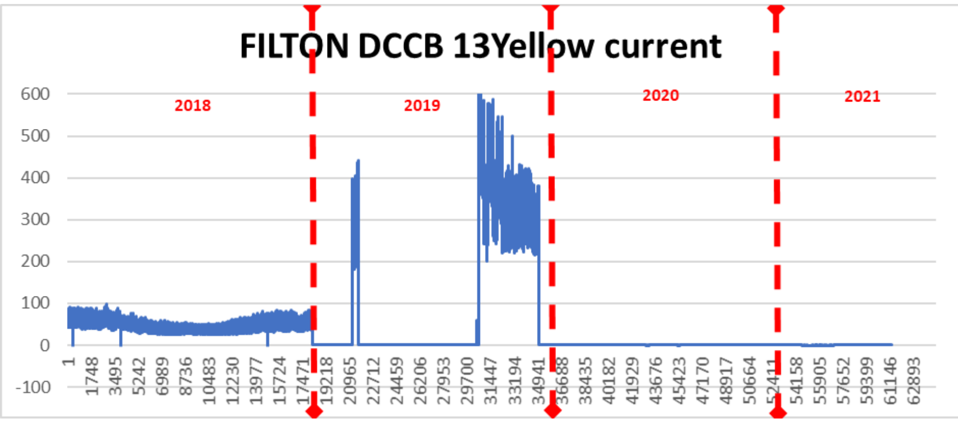


Figure 2-7: Filton DC Primary - Transformer T1 (CB 13) current in amps

LV network analysis tool

The NIFT was modified for EPIC but the majority of the functionality already existed therefore there was less learning generated during this tool development stage of the project compared to the HV NAT.

- The baseline run of the NIFT suggests that there are a large number of LV feeders that are affected by voltage and thermal issues. Analysis suggests this is due to data quality with unknown elements in the asset data and is unlikely to be the real situation. High levels of non-conformance were reported by the NIFT previously when modelling was carried out to support ED2. WPD is undertaking significant effort to improve its network data so it is anticipated if this is the cause it will be less of an issue in future runs. This is likely to be a learning point for other areas.
- During the project, a number of changes were made to both the input profiles required for the modelling and the output reports required. This resulted in redevelopment and rework during the project.

2.3.3. Key recommendations

Key recommendations from the WP4 tool development work:

- It would be beneficial for future work to agree inputs and outputs up front. If consistent information is valuable to stakeholders, then report visualisations can be created to present these to improve efficiency of future results delivery.
- There is a need for profiles for hydrogen variants and a longer term view of prices and carbon intensity of gas vs. electricity.
- The HV NAT development was affected by data quality issues that were not known at the time of specification. The improvement of data quality has already been flagged as a recommendation but it should be emphasised that this affects a wide variety of the project phases and not just the network analysis WP5.
- HV feeder attribution needs to be provided in the network model to improve the way in which the analysis tool can operate.

- Another method to capture upgrades from 6.6kV to 11kV needs to be devised as this cannot reasonably be included in the HV NAT.
- Reducing the number of days modelled and switching to hourly modelling from half-hourly modelling brings performance benefits without greatly affecting the quality of the results

2.4. Work Package 5: trial area analysis

The objective of WP5 was to generate the disaggregated local energy requirements datasets down to postcode-distribution substation level.

2.4.1. Deliverable references

- WP5 D1 – Project EPIC_Energy consumption statistics over time_v2
- WP5 D1 – Project EPIC_Gas network data disaggregated v1
- WP5 D1 – Project EPIC_HV input data disagg_v2
- WP5 D1_Project EPIC_LV input data disagg_v6
- WP5 D1 – Project EPIC_New developments_domestic and non-domestic v4

2.4.2. Electricity Network Analysis Learning points

Dataset timeframes

Within the disaggregated datasets, the data projections were provided annually until 2035 and thereafter in five year intervals until 2050. The main benefit of annual projections is that these are usually more relevant for local authority plans and these projection intervals match the corresponding DFES data. Limiting the data to 2050 does mean, however, that technologies likely to play a major part after this timeframe (for example, hydrogen) remain partially unaddressed. Adopting 5 yearly timeframes after 2035 required additional data manipulation for the LV analysis as the NIFT is designed to analyse individual years.

Data projections for heat pumps and other new heating technologies and fuels

To date there is little data to support the split of managed and unrestricted profiles for heat pumps, and the potential uptake of hybrid hydrogen heat pumps, in the same way as this is split in the DFES data for managed and unrestricted EV charging. As part of the disaggregation methodology, project EPIC used smart appliance uptake as a proxy, but future users of the process may want to examine this again if new data and insights (such as profiles for hydrogen hybrid variants) become available.

New development loads and modelling

It can be challenging to represent the loads for developments that are planned but do not yet exist. For project EPIC, the approach we used was to generate dummy substations and this turned out to be more complex than expected. This was due to the lack of spatial data in the plans, which leads to uncertainty around where new developments will connect to the network, especially where the new development is remote from existing infrastructure.

For project EPIC, the team agreed a simplification in terms of modelling energy efficiency for new properties which was that there are no expected changes in heating load as the building will be designed to a relatively high specification. However, changes in EV charging efficiency are modelled as these would reflect changes in cars rather than building structure. Similarly, there will be no new

LCTs deployed to new developments after they are introduced on the basis that they would be provided with suitable LCTs as standard.

Error trapping and Tool Performance improvement

After the majority of the HV results had already been calculated, an error was found in the treatment of EV charger allocation that affected the results. This error had not been identified in the User Acceptance Testing as it was occurring within the parts of the application that were not evident to the user and could not be easily seen in the results. This resulted in the HV analysis being carried out again once the error was corrected. This was only possible within the project timeframes because there had been time spent before the error was detected looking for opportunities to speed up the analysis by using better machines, multiple instances of the tool running at once and moving to hourly rather than half hourly calculations. This was found to reduce processing times while the results were affected very little by the change. The learning points here are to ensure some contingency in the time for analysis and to seek performance improvements early, even if they are not considered to be necessary.

Confidence in LCT profiles

Differences between the scenarios depend on both the LCT uptake and the differences between the demand profiles for each technology/operating profile. Greater confidence on the future operating profile for different technologies would increase confidence in the modelling results. This is particularly true in the case of heat pumps, on-street EV chargers as EV adoption increases and domestic energy storage where there is a lack of substantial trial data from which to generate a suitable profile.

Representative days modelled

Analysis of the LV modelling results shows that with the existing load/generation profiles it is sufficient to model a smaller number of representative days (winter and summer). The worst case network conditions across all constraint types occurs on either the winter or summer day in at least 89% of cases. Reducing the number of days to be modelled would reduce the time required to produce results and the post-processing needed to consolidate the results from multiple representative days.

Missing data for HV connected customers and IDNOs

It was expected that the only missing customer demand data would be HV connected customers. During the analysis it was found that IDNO and other private LV network customer data was not available to be analysed in the NIFT. The process to identify these customers was more difficult than expected and there are locations where there are clearly customers taking significant load but no associated MPANs. Failing to model these customers correctly will skew the bottom-up modelling.

Dataset version control

There was confusion over two similar datasets giving customer details for LV networks from CROWN extract and NIFT. Neither dataset contained a date stamp to determine which was more up to date. In this case the difference was small and it could be resolved simply but metadata provided with datasets is something to aim for in the future, and may be provided when the energy data hub is the established data provision point.

Scenario differences vs. overall change

The overall increase in electricity demand through to 2050 is revolutionary such that the variation between different uptake scenarios seems relatively small. This may be influenced by the lack of confidence in the future operating model of the different low carbon technologies.

Area included in the modelling

Additional primary substation areas were modelled at LV (six in total, across the three SPAs). This allowed the variability of results between primary substations to be studied. Broad conclusions about which scenario/use case leads to lower levels of constraints are consistent across multiple primary substation areas. This is particularly true for the EV use cases studied, where the level of difference between scenarios was small across all scenarios and primary substations. The overall conclusion that the level of constraints is relatively insensitive to the EV use cases is valid for all the modelled primary substation areas. The results are more variable for heat pump scenarios. This is perhaps to be expected as the differences in the underlying profiles (e.g. for hybrid vs. non-hybrid heat pumps in winter) is greater than in the EV scenarios. Modelling a subset of primary substation areas is likely to be sufficient to draw conclusions about which scenarios give lower/higher level of constraints. However, to predict the absolute level of constraints for a given network then detailed modelling of that specific is required due to high variability in the results. This high level of variability is also true when considering the level of expenditure required over the modelling period.

2.4.3. Key recommendations

- Future users of the EPIC process may want to discuss the most appropriate timeframes for the data projections in the disaggregated datasets including modelling individual years for the later periods rather than intervals including a number of years.
- Using a 'dummy substation' approach for modelling the connections of planned new developments without an agreed connection location can be a useful proxy.
- There is limited data from which to generate profiles for heat pumps and energy storage, as well as on-street EV charging. This may be further influenced by a greater prevalence of smart assets responding to signals driven by energy market pricing or network services.
- Feedback gained from the local authorities which participated in the EPIC project could be used to standardise the analysis – using a common set of data inputs and reporting. This would reduce the time required to generate input data, run multiple simulations and manually analyse and comment on the outputs.
- The time taken to prepare, complete and analyse the results is much more dependent on the number of use cases/scenarios modelled, rather than the total number of substations. Where possible the number of scenarios should be minimised in order to reduce the costs involved.
- The availability of accurate, high quality network data for the area to be studied is key. In this project timescales did not allow for an existing model to be updated, resulting in older, less accurate data being used. As digitalisation of network data increases the availability of accurate models of the network should improve, and this should be a pre-requisite for future modelling.
- As knowledge about the operation of new technologies increases then this may provide the opportunity to improve the underlying demand profiles used in this type of network modelling, given greater confidence in the results. It is therefore recommended that in future innovation projects the opportunity is taken to collect and analyse the data to improve the profiles available for LV network analysis. This would benefit macro level modelling such as that undertaken in EPIC or for business planning purposes, and LV network design on a more local level.

- Some means of versioning of the datasets provided needs to be implemented so that it is always clear which dataset is the most up to date.

2.5. Work Package 6: integrated investment plan development

Building on the definition of the use cases from WP2, and the development of the CBA process from WP4, in WP6 the CBA results were generated for each use case. In the process, the outputs from the network analysis tools were interrogated; this led to key learnings on the current modelling ability and data needs of the networks. This work package had originally been envisaged as a collective process between the LA and network companies to select the best combination of investments to maximise wider benefits. However during the course of the project it became clear that the Local Authority plans were not sufficiently detailed to draw out particular investment options and that the gas network did not require reinforcement upgrades, thus the investment plan would include only electricity network upgrades and the process to determine interactions with other planned investments could not be tested in a meaningful way. However the development of the use cases has generated different investment sets from the network analysis with different benefits being determined in the CBA tool which is in line with the original intentions as the information can still be used to determine policy decisions and therefore influence future investments to maximise benefits.

With results presented graphically for analysis, conclusions and learning could be formed on the impacts of each strategy tested. In a number of cases, the small number of primary substations being tested (three) and inconsistency in results across these, highlighted the need for additional analysis on a larger range of primaries. However, in the case of the 'Energy Efficiency' and 'Fit for the Future' use cases – some consistency in the results leads to a rule of thumb being suggested.

Attempting a 'whole system' CBA, with impacts on the network and society combined into a single quantitative sum, also drew out learnings on the practicalities of such analysis, and the precautions which should be taken with their results.

2.5.1. Deliverable references

Work Package 6 Deliverables
- Use Case 1 - 'EV Charging' report
- Use Case 2 - 'Energy Efficiency' report
- Use Case 3 - 'Hybrid Heat pumps' report
- Use Case 4 - 'Just in Time vs. Fit for the Future' report
- Use Case 5 - 'Flexibility' report
- Use Case 6 - 'Solar in Nailsea' report
- Work Package 6 Key Learnings report

2.5.2. Learning points

Unresolved network modelling challenges

Challenges faced in the development of the electricity network analysis tools meant that results processing in the CBA tool and graphing workbooks became iterative. Graphing the results helped identify issues with the network models which, in some cases, could be resolved in subsequent results iterations. One example of this is the approach to modelling HV rapid charging hubs, which was changed after the first results iteration.

There is a trade-off between adopting an iterative and agile development approach versus trying to get the tools and data fully tested and in a good state of readiness before commencing the full trial.

With project time limited, a final iteration of the results was produced by the network analysis tools while issues were still being identified. **A learning from this is that more time and resource is needed on network modelling than was available in the EPIC trial**. It may have been beneficial to focus on fewer use cases, in order to have better confidence in the results.

More time could also have been spent to fully test the tools and data before going into full trial runs.

Integrating network analysis results with the Whole System CBA tool

Macros were able to automate the large amount of copy/pasting that was required from the many results files into the various versions of the CBA tool. However, the macros used in the trial have limited use outside of this specific CBA study, with their parameters not easily adaptable to consider different formats of results (e.g. additional cost categories being included). **For any future EPIC projects, a key output could be a more refined set of macros, easily adaptable to different CBA parameters, and with an accompanying user guide.**

The use of pre-defined data templates, agreed between project partners, allowed the use of macros. In the EPIC trial, the data templates were largely followed, allowing development of the macros before the delivery of results, and efficient re-processing of results when new iterations became available. In any future EPIC process, or similar 'multi-analysis tool' project, **data templates must be considered carefully and stuck to – appropriate time should be committed to deciding on these templates before analysis begins.**

Using the CBA tool

The ENA's Whole System CBA tool was stable and effective in processing the results. The methodology it employs follows government and industry best practice and guidelines in cost benefit analysis. A learning from project EPIC is that, **if any UK energy sector cost benefit analysis is to be undertaken, in line with accepted methods and practice, new tool development is not required**. There are a number of other CBA tools which could have been used had the Whole System CBA tool not been available, including the DNO's individual tools, all following an Ofgem template. The relatively simple nature of the CBA method (summing annual cost/benefits, depreciating and discounting), means it is likely that any one of these tools could easily be adapted for use in the EPIC trial.

The ENA's Whole System CBA tool does offer the benefit of being able to consider the costs/benefits to multiple parties simultaneously. This is its key feature and it was very useful in separating out HV, LV and societal costs and being able to easily extract them for graphing. **It is a good tool to use for Whole System CBA studies.** The 'outputs' section of the tool, which features 'tipping point' and 'least worst regret' analysis was not used in the EPIC trial, so its performance cannot be commented on.

The process of learning how the tool works was aided by the **User Guide and Methodology documents. These types of document are important if new users are to relatively quickly pick up and use the tool – it should be best practice to provide them.**

CBA methodology – discounting and the societal value of carbon

There is an argument that the use of future discounting, which emphasises the importance of short term cost/benefits over longer term cost/benefits, is not appropriate given the cross-generational timescales considered in network planning - or wise given the urgency needed to decarbonise by 2050. In its calculation of Net Present Value (NPV), this methodology will favour any strategy which delays spending in the short term. So, if the NPV produced by this tool was the determining factor in energy transition decision making, it would tend to offload the costs of decarbonisation onto future generations.

Having a similar effect, the BEIS societal value of carbon used in the trial rises linearly from £250/tC02e in 2020 to £380/tC02e in 2050. This means that if a strategy were to deliver reductions in emissions in the short term, it would have a lower NPV than a strategy that delivered the same emissions saving later on. Again, if the NPV determined a decision, this method would tend to shift necessary emissions cuts onto future generations.

For these reasons, **it is best practice that CBA methodologies are not to be used in isolation in decision making, and qualitative considerations are given appropriate weight.**

CBA methodology – the relative impact of cost categories

The approach taken in the EPIC trial was to use existing best practice and empirical data to monetise each impact considered. This resulted in some impacts being orders of magnitude more 'valuable' than others. While this was valid, given the evidence used to come to these values, the effect was to marginalise lower value impacts in the TOTEX and whole systems NPV sums.

In the EPIC trial CBA, the value of emissions was dominant in societal TOTEX and in whole systems NPV. Spare capacity and roadworks were, in comparison, of marginal value. As a result, societal TOTEX was not impacted by large roadworks variations, and similarly, whole systems NPV was not significantly impacted by large network cost variations.

With the results tending to show zero or very small emissions impacts, societal TOTEX and whole systems NPV were highly stationary. In many use cases, these metrics failed to communicate the significant impacts seen on the networks and from roadworks. Instead, these cost categories were discussed in isolation.

The range in the valuations of different impacts would likely increase with the more 'systems' included in any whole systems CBA. For instance, if any gas network impacts were able to be included in the EPIC trial, it is likely that emissions from the gas network would further dominate the societal TOTEX and whole systems NPV sum. This issue could be solved by moderating the value of any impact which was dominating TOTEX sums; however, if that value had been arrived at through evidence and a belief that it was reflective of the 'true' value - this would be departing from that.

As with above, the solution is not to blindly use a TOTEX or NPV value from a CBA tool to make a decision – consider independently all the costs included within the CBA, and outside qualitative factors as well.

Valuation of spare capacity

Spare capacity is created when network investments are made which exceed the immediate load requirements of the network. There is normally an element of spare capacity associated with any network investment.

It is common practice for networks to assign an economic value to spare capacity, since this will provide future benefits to network users and will, for example, reduce the time and cost of future connections.

The value of spare capacity can however produce counter-intuitive results. For example, when comparing two use cases, if energy efficiency reduces the need for network investment there is an obvious CAPEX and OPEX cost saving, but there is also a reduction in the amount of spare capacity created. In other words, a lost opportunity to create spare capacity.

In the initial analysis the value attributed to spare capacity was so high that it tended to outweigh the direct costs savings from the use case. After a review with the networks, the approach to valuing spare capacity was changed to reduce its weighting. **There is a specific learning here about spare capacity and also a more general point that applying "whole system" benefit analysis is complex and needs a degree of common-sense to be applied.**

LV network data quality

When analysing the results produced by the LV NIFT tool, it was noticed that for all primaries tested, NIFT suggested that a large number of feeders currently face voltage and thermal issues and, as a result, significant CAPEX investment was needed just to meet current loads.

More work is need to fully understand this, but it is likely that, while parts of the LV network are in need of immediate upgrade, the modelling results more generally reflect poor data quality on the state of the LV network; there is a disconnect between how the LV network is modelled and its actual condition. **One key learning from the EPIC trial is that improved data and planning methods for the LV network are needed.**

The fact that the LV NIFT tool has been used to support network planning, also suggests that more needs to be understood around how the networks are currently using the data they have, and how much they rely on it to make reinforcement planning decisions.

As a more general learning, increasing demand from the electrification of heat and transport will require a significant improvement in the ability of the networks to monitor the condition of the LV network. The strategy to maintain the LV network in a "responsive mode", based on the experience and ability of engineers to react quickly to network faults, may need to evolve into a more forward looking upgrade strategy. If this is the case then the quality of data and the use of tools like NIFT will become far more important.

CBA results depended heavily on the specifics of the network

A key learning from the CBA analysis was that the results for many of the use cases depended heavily on the specific condition of the network being planned.

The case for "fit for the future" versus "just in time" investment strategies was demonstrated across all three SPA. However, the case for "on-street chargers" versus "rapid charging hubs" varied across the network areas.

This is an important point and confirms that a bottom-up, area-specific approach does have value.

It would be interesting to see, however, whether there are particular network characteristics, combined with locational factors and demographics, that could be used to form more general guidelines and benchmarks as to the best energy strategy. Deriving these general guidelines would require modelling of a greater number of areas than was possible within project EPIC.

The modelling of heat pumps and EV chargers exploiting flexible, Time of Use (ToU) tariffs needs to be more detailed

The sensitivities examining the impact of a high uptake of flexible charging and heat pump operating profiles were not conclusive and produced some unexpected results. In some cases, a high uptake of flexible heat pump operating profiles led to increased peak demand on the LV network – while demand was shifted away from the traditional peak, this created a secondary peak earlier or later in the day.

This is not how flexible operating profiles would act if widely adopted, a degree of randomness or considered variation across multiple customers would be used to ensure an alternative peak was not an outcome. This should be factored into future modelling, as well as any potential interaction between flexible heat pump use with flexible EV charging.

Energy efficiency improvements can deliver network and societal savings

One of the more consistent results seen across all primaries was the network and societal savings delivered by investment in energy efficiency improvements. Savings to electricity network TOTEX in in the order of 2-10% by 2050 were seen on all primaries. A reduction in electricity network related roadworks was also captured, with up to 30% reduction in the societal cost of roadworks for the high energy efficiency strategy.

These savings reflect the inclusion or omission of large investments in the modelling, i.e. highly expensive primary transformers being replaced or not being replaced. This shows that the electricity network benefits of energy efficiency will vary according to the degree of spare capacity at a primary substation and the ability of energy efficiency to negate the impact of other LCTs being deployed. This in turn suggests that while there will always be some benefit to the electricity network, the scale of the benefit will vary between primary substations.

Future work into the application of energy efficiency, such as the ongoing DEFENDER[9] project, should attempt to cost the policies of delivering improved efficiency. At a certain point, the additional investment in efficiency will not deliver an equivalent whole systems saving; this relationship of diminishing returns would need to be better modelled by networks in order to refine any future energy efficiency investment strategies.

'Fit for Future' investment strategies can deliver long term savings

Testing a 'Fit for Future' approach to investment, whereby increased initial investment in higher rated assets to meet longer term demand growth is offset by savings from less frequent upgrades, demonstrated its potential to deliver significant long term savings.

Over the three primaries, a 13% average saving in HV TOTEX by 2050 was a significant result, marked by its scale and consistency relative to the other results generated in the EPIC trial. This was alongside a 28% average reduction in the cost of roadworks to society by 2050.

---

[9] Demand Forecasting Encapsulating Domestic Efficiency Retrofits (DEFENDER) https://www.westernpower.co.uk/projects/demand-forecasting-encapsulating-domestic-efficiency-retrofits-defender#:~:text=The%20DEFENDER%20project%20will%20develop,as%20an%20alternative%20to%20reinforcement.

Large savings were made by avoiding duplicated upgrades to electrical assets however, assets are also replaced for other reasons that increased load. There may be savings potential if when assets are replaced due to their age or condition there is also a facility to generate the long term expected loadings for the network so that capacity upgrades can be brought forward where this would avoid subsequent repeated asset replacement.

Additional work into 'Fit for the Future' approaches to network planning should be carried out by the network, and considered by local authorities as they consider implementing LEAPs or similar long term investment strategies.

One factor which would enable more 'Fit for the Future' investment is improved forecasting. Local authorities and networks should work together to enable the good forecasting that can give confidence in investment ahead of need. Engagement with the annual Distribution Future Energy Scenarios (DFES) process is one way to do this currently.

Another factor is the regulatory approach taken by Ofgem, which should attempt to recognise the long term benefit to future customers which can result from higher initial CAPEX investments. The current regulatory approach focuses on investment within 5-7 year business plan periods, and therefore offers limited opportunity to plan further ahead.

The need for an improved modelling of 'Fit for the Future'

In the EPIC trial, the HV NAT runs for the 'Fit for Future' strategy used a different form of analysis which worked backwards from 2050. 'Fit for Future' CAPEX results were presented as cumulative annual figures, as the timings of investments prior to the year being investigated were unknown and it was not valid to break this down into non-cumulative annual CAPEX.

This meant that, in order to compare 'Just in Time' with 'Fit for Future', the 'Just in Time' results had to be made cumulative. The inability to present a timeline of annual non-cumulative costs was a significant drawback of this use case. In a comparison between these two strategies, where the timing of different investments could be the determining factor, having no visibility on that timing is a major limitation.

A key learning is that an improved method of modelling 'Just in Time' vs. 'Fit for Future' investment strategies, which compares non-cumulative annual costs, should be developed.

Flexibility use case suggests lower costs flexibility services and wider coverage would be needed

The Flexibility use case suggests that while Flexibility services can enable networks to defer costs, and provide optionality, in a straight cost benefit analysis, the value for money of their application for HV feeders and distribution transformers is not there yet.

At lower voltages the costs of flexibility services would need to be further reduced. There would also need to be a much wider source of service providers to ensure sufficient coverage.

EV charging use case produced mixed results indicating that choice of charger strategy may vary

The comparison of EV charger deployment strategies which focused on a choice between low voltage on-street charges versus higher voltage charging hubs, delivered some mixed results across the different SPAs. The outcome showed that the outcome would be very much dependent on the state of the existing network and the specifics of the level of network investment required. This is in itself a valuable learning.

The difference in the outcomes was not however very significant and, if this was found to be more generally true, would suggest that local authorities can focus more on their own transport strategy and the needs of their community. For example it may be appropriate to start by installing on-street and move to inclusion of rapid hubs later when the costs come down and reinforcement share changes.

Flexible heat pumps and hybrid heat pumps

The use of both flexible load heat pumps and Hybrid heat pumps could deliver electricity network cost savings, although the EPIC project did not model the full system and consumer cost of either technology.

The limitations of the EPIC modelling, which time shifted peak time heat pump load, meant that the case for flexible heat pumps was unproven and, in fact, resulted in a slight increase in low voltage network costs. This was because the new demand load profile merely resulted in the creation of a new higher peak demand. This is not how a "smart" heat pump would be expected to work but it does highlight one of the key risks of a price signal based demand shift for the low voltage network. The level of flexibility (i.e. how long a heat pump could be turned off for over the peak period) available is not yet proven. There is likely to be less flexibility in heat pump load than EV charging as periods where the heat pump was not running could relatively quickly cause the temperature in the home to drop. This depends on the insulation standard of the home amongst other factors. The modelling of the impact of flexible heat pump operation could be improved if new profiles were available based on the results of consumer trials.

The use hybrid heat pumps did have a more direct positive impact on network costs, since it was assumed that demand was met during peak times by a gas back-up without shifting electricity demand to create another peak. Whether hybrid heat pumps are ever used in large volumes will reflect the incentives to install them and their relative desirability to customers. Hybrid heat pumps are specifically excluded from the current Boiler Upgrade Scheme[10] providing financial assistance to those installing air or ground source heat pumps or biomass boilers. The additional space required, and potential additional maintenance costs to maintain both heat pump and gas boiler may also put some customers off adopting this type of arrangement which suggests the need for financial support for customers to overcome the downsides is even stronger than for normal heat pumps.

Top Down vs Bottom Up analysis

The duplication of analysis to include both Top Down and Bottom Up versions of the analysis was intended to show the scale of the difference in the results from the two different methods.

Use case	Impact of TD vs BU load set.
Energy Efficiency	Greater capex seen for BU at Dorchester St and Nailsea, Greater Capex seen for TD at Cribbs Causeway
EV charging	Similar investments seen for both options in all areas
Flexibility	No comparison, analysis only applied for TD
Hybrid Heat Pumps	Very different results by area – similar results for Dorchester St, higher Capex for TD for Cribbs Causeway but higher Capex for BU for Nailsea.

[10] https://www.gov.uk/guidance/check-if-you-may-be-eligible-for-the-boiler-upgrade-scheme-from-april-2022

Use case	Impact of TD vs BU load set.
JIT vs FFF	Capex values comparable for Dorchester St and Nailsea with greater capex seen for BU for Cribbs Causeway.

Table 2-1 Comparison of Top Down and Bottom Up analysis results.

For many of the results these were of a similar order but where they were different this varied by location and was not consistent between use cases. Therefore it appears that the differences in the load sets are not so great as to cause differences in the results that are consistently skewed one way across use cases or locations. The impact of LCTs being unevenly distributed between distribution substations will act to enhance the differences in profiles between them. This suggests that Bottom Up modelling will be a better way to reflect the real loads on the network rather than simply using scaled versions of the same profile which occurs for Top Down modelling. The work under the SMITN project[11] to provide better planning profiles for distribution substations that reflect the loads being recorded by smart meters will improve the accuracy of the profiles used for Bottom Up planning and therefore it is likely that this will be adopted to ensure consistency between LV and HV planning. There may still be a need to find a method to scale up profiles where the total of the bottom up profiles falls significantly short of the measured loads for the HV feeders.

2.5.3. Key recommendations

- Despite the time taken to set-up and gain familiarity, the Open Network Whole System CBA tool proved itself very useful and could be more widely adopted
- There is a general need to improve the quality of (low voltage) network data and the assumptions underpinning LV network planning
- Care needs to be taken when applying "whole system" cost benefits to understand the relationship between different cost/benefit drivers, some of which may counteract each other
- While the CBA results were heavily dependent on area specific network conditions, more work to extend the EPIC analysis may enable planners to identify key characteristics and drivers to provide benchmarks and guidelines for energy planners
- Improved modelling of flexible ToU tariffs is needed to better reflect how they would act to reduce peak demand.
- The energy efficiency and 'Fit for the Future' results suggest that further work should be completed to articulate the benefits of either approach.
- Flexibility services may become cost effective for managing HV and LV constraints when there is a larger pool of LV connected flexibility service providers, therefore features to support future flexibility services should be built into domestic EV chargers and batteries.
- Given the similar costs of both EV charging scenarios, a policy that initially emphasises installing on-street charging points then moves to installing rapid charging hubs at a later stage is likely to be cost effective.
- While hybrid heat pumps can reduce network costs, the exclusion from incentive schemes may result in this opportunity being difficult to realise.
- DNOs should focus on improving the planning profiles used for distribution substations and use these for HV modelling with scaling factors applied as required.

[11] https://www.westernpower.co.uk/innovation/projects/smart-meter-innovations-and-test-network-smitn

2.6. Summary of whole system learning points

The terminology "whole system" can mean a number of different things including for example looking across transmission and distribution networks, working across gas and electricity sectors, considering wider societal outcomes, assessing full system impacts and consumer costs.

The EPIC project analysis focused on a number of "whole" system dimensions, including:

1. Consideration of both the gas and electricity distribution networks
2. Cost benefit analysis that included a number of societal and "non-energy" cost benefit drivers
3. Analysis of different energy vectors including transport, heat and power
4. Integration between energy and non-energy planning processes
5. Data and knowledge sharing between energy networks and wider energy stakeholders
6. Increasing the granularity of typical network analysis to focus in on a specific geographic area.

The extent to which EPIC was able to bring these different whole system dimensions together varied, and one of the key lessons learnt is that planning for whole systems outcomes is both complex and difficult.

Working across multiple stakeholders

Effective stakeholder engagement will be a cornerstone of the success of any project using the EPIC process and a stakeholder map and engagement plan is likely to be very useful. Continued, regular engagement is crucial and building sufficient time into the project plan to allow local authority stakeholders to refer to published (or draft) policies between the two workshops could be advantageous for future users of the EPIC process to ensure that the local energy requirements plans are as accurate as possible.

Accessing local energy plans, policies and data

In hindsight, project EPIC overestimated the extent to which local energy plans would be in place, or could be quickly collated from available policy documents and data.

The fallback methodology to use the available DFES data as a back-up and baseline source of data worked, but clearly it would be better to conduct an EPIC style network analysis on the basis of properly worked up local energy plans. The EPIC process would work well with, for example, a Local Area Energy Plan process.

Integration of local authority plan data across gas and electricity networks

EPIC was able to integrate plan data between local authority, SPAs and the electricity network, albeit with some compromises over the trial area that was covered. It proved, however, to be very difficult to integrate planning data with the gas network. As result the final EPIC analysis was much more focused on outcomes for the electricity network.

This area requires more work to bring both gas and electricity networks together. Future users of the EPIC process may want to align an approach to reference and locate network demand in the gas and electricity network analysis models. Although a postcode approach was used in project EPIC, a database based on UPRN or a combination of gas and electricity meter numbers could ensure more effective, common language that is relevant and meaningful for both the gas and electricity networks.

Consistency of planning data across networks

For technologies that impact both the gas and electricity networks, it is essential that the same forecasting methodology is used for these technologies by both networks and early agreement on an appropriate forecasting approach will be useful.

Whole system cost benefit analysis

Within the limitations of the project scope, the application of whole system principles to the cost benefit analysis worked well. The key limitation was that the EPIC project scope was focused on the network impacts of different use cases and not, for example, the overall impact on consumer bills or the business case for the deployment of EV charging infrastructure. Future projects could take a more holistic approach.

3. Summary evaluation of EPIC methodology

3.1. EPIC integrated local energy requirements planning

The EPIC methodology worked to the extent that it was possible to develop a local energy plan for each of the SPAs. The approach, however, relied heavily on the use of DFES data to provide a baseline and "fill-in" the gaps where local plan data was not available.

The project was able to increase the granularity of energy plan data down to the LV network and effectively down to postcode level.

With hindsight, however, the EPIC process would have worked better if local authority energy plan data and policies had been more advanced. This suggests that the EPIC process should be applied in areas which have already undergone a more complete energy plan development, for example, using a Local Area Energy Plan methodology or equivalent.

The EPIC energy requirements plan produced in WP2 did not, however, constitute a final agreed energy plan, but instead a number of options and sensitivities which became use cases. The EPIC project did well to formulate these use cases and they provided a useful basis for analysis and options appraisal, but not to develop a joint investment plan as first intended.

3.2. Network modelling

The EPIC project successfully developed and trialled two new or updated modelling tools for the electricity network, one for the HV network and a second for the LV network.

Both tools performed well and provided an appropriate level of network cost analysis to provide input into the subsequent cost benefit analysis.

The use of both tools was resource intensive and hindered by the quality of input data. The analysis was however limited to a single primary sub-station within each SPA.

There is a question regarding whether it would be viable to roll out this type of in-depth network analysis as a general service offering. To do this the network planning process would have to be further automated and streamlined, the number of potential sensitivities would need to be reduced and the quality of input data would have to be significantly improved.

3.3. EPIC investment options appraisal comparison

Compared to the existing planning and options appraisal processes, the EPIC project has achieved a number of key objectives, including:

- Increasing the granularity of planning and network analysis down to the level of primary substation (HV) and low voltage network
- Incorporating, to a greater extent than the current process, the development plans and net zero ambitions of local authorities for a specific planning area
- Providing a basis to compare and evaluate different energy and investment options, for example the choice of an EV charger strategy

- Applying a whole system costs benefit appraisal approach with the inclusion of societal costs, e.g. the disruption caused by road works.

The trial analysis was, however, limited by a number of factors, such as:

- The ability to incorporate the full gas network impacts within the core analysis which was in part due to the focus of the local authority energy plan requirements on the electrification of heat rather than a switch to hydrogen. The project did however include a hybrid heat-pump use case.
- The scope limitation that restricted electricity network analysis to one primary sub-station within each plan area
- Issues encountered with data, especially on the LV network
- Limitations on the extent of the CBA analysis which focused on network costs and impacts rather than the costs to, for example, the consumer.

Despite these limitations, the overall EPIC project outcome produced positive results especially as a proof of concept of a more integrated planning process, the use case analysis and also as a trial of the industry standard whole system cost benefit analysis tool.

3.4. EPIC investment options appraisal analysis comparison with LAEP

The EPIC project delivered many of the "best practice" methods that have since been documented as part of the development of a methodology for Local Area Energy Planning (LAEP).

Key features of EPIC that are consistent with a LAEP methodology include the:

- Scope of analysis across energy vectors
- Degree of granularity of analysis down to low voltage and postcode level data
- Continuous stakeholder engagement with local authority partners
- Cost benefit based approach to options appraisal.

It is important to highlight, however, that EPIC is not a full LAEP process. In particular, the objective of EPIC was not to develop a new local energy plan, but was instead to integrate energy plans for a specific geographic area into a network planning and options appraisal tools. The EPIC process did not, therefore, include the extensive engagement, energy system modelling and plan development activities that would be associated with a full LAEP.

A second major difference is that EPIC did not seek to develop, or model, an optimal energy system design. The scope of EPIC was to take a local energy plan and to model the network costs impacts of those plans.

EPIC could, therefore, be described as an allied process that could run alongside and inform a LAEP process, but is not a LAEP in itself. In many respects however the EPIC process does follow the same ethos and principles as a LAEP. In particular, the representation of a local area using data and graphical information, the emphasis on stakeholder engagement to understand local energy requirements, detailed and granular modelling and the application of socio-economic analysis to appraise results

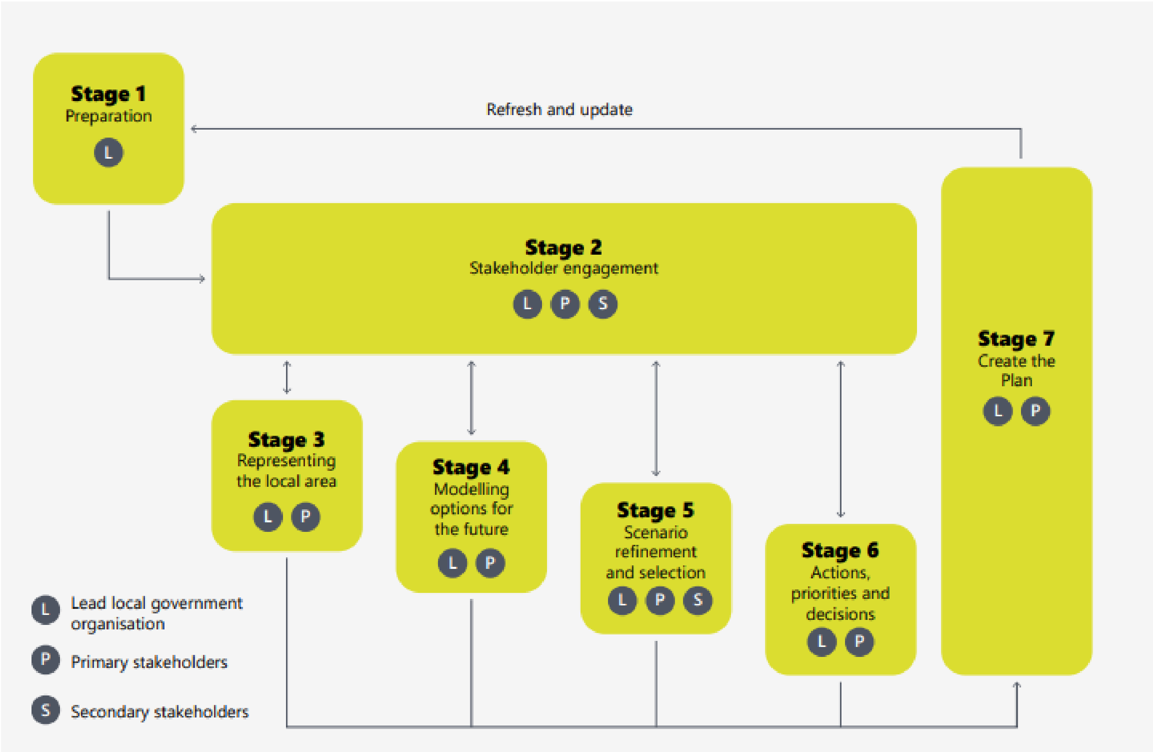


Figure 3-1 Key stages in the LAEP process

LAEP Key Stage	EPIC equivalent stage	EPIC approach
1) Preparation	2) Data preparation	Use of DFES as a baseline augmented by master planning, net zero and neighbourhood planning data
3) Stakeholder Engagement	Stakeholder engagement	Stakeholder engagement was conducted thought via workshops and bilateral meeting, albeit not to the extent of a full LAEP
4) Representing the local area	1) Opportunity identification and area selection 3) Local energy requirements planning	EPIC produced a very detailed and granular energy dataset for each SPA incorporating local authority data and using DFES as a baseline Energy requirements were identified and refined with LA stakeholders
5) Modelling Options for future	4 Network Analysis	EPIC was fundamentally about network analysis and modelling, although not a full energy system model
6) Scenario refinement	5 Investment and options appraisal	Use cases and sensitivities where identified to test different energy outcomes and network investment options Socio economic analysis drove the appraisal process albeit focused on a network CBA, rather than whole system or full societal CBA

LAEP Key Stage	EPIC equivalent stage	EPIC approach
7) Actions priorities and decisions	6 Local energy network investment plan completion	The intention was that EPIC would result in a network investment plan although, for reasons documented in this report, the end result was limited to a set of appraised options

Table 3-1 Comparison of LAEP and EPIC stages

3.5. Future use of the EPIC investment approach

The intention of EPIC was to trial a process that would enable energy networks to better integrate local authority energy (and wider economic development) plans into the network planning process for a specific geographic area.

Therefore, if successful, EPIC would potentially provide a new point of engagement and collaboration between networks and local authority partners. It could also result in a joint investment plan for strategic areas and provide a compelling evidence base to support investment proposals within the RIIO ED2 regulatory framework.

The results of the EPIC trial confirm that these objectives and outcomes could be met; however, there are a number of important pre-conditions that would need to be put in place before EPIC could be rolled-out as a business-as-usual process and offered more widely as a new network service.

1. Local energy plans and associated data would need to be made available. DFES data could continue to act as a useful baseline and input, but to properly add value a local energy plan would need to be developed.
2. The quality and robustness of network asset data and load assumptions needs to improve and it is recommended that data quality metrics are devised to assess the requirement for improvement and to confirm progress against targets.
3. The resources taken to run network analysis tools would need to be reduced.
4. The EPIC process would have to be scaled-up cover several primary substations, their HV feeders and LV networks

Practical roll-out of the EPIC process

For reasons described in points 1-4 above it would not be practical to roll-out EPIC as a new service and as a standalone process.

While it may be possible to reduce the resource requirement by reducing the number of use cases that are assessed, it seems inevitable that some degree of scenario analysis and sensitivity would be required. Indeed, there is an obligation within the LAEP process to carry out sensitivity analysis and consider other scenarios in order for the analysis to be considered robust. Even if the number of use cases is streamlined, this may be offset by modelling a much larger area of network as it is likely that the analysis should support all the local authority territory included in their local plan rather than a very small proportion.

Estimated future resource requirements

An estimate of the effort required to replicate the EPIC process for an entire Local Authority Area is given below in Table 3-2.

In this table it is assumed that the work previously undertaken by Regen is carried out by the Electricity and Gas DNOs LV network analysis may still require external support so the tasks are given separately.

Step	Step name	Comment	Estimated Workload for Electricity & Gas DNOs as a whole	Estimated Workload for LA	Expected LV Modelling Tasks
1	Opportunity identification and area selection	Largely scale independent but allow at least a week per event for preparation, meeting, after meeting queries.	1 week per DNO team member per LA	3 days per team member	Tasks to complete: Use database query to extract RAG for areas of interest in the baseline year. Summarise results. Outputs: Summary of RAG status for LV networks fed by candidate primaries to allow WPD to judge whether results are plausible. In the future where LV monitoring allows it may be possible for WPD to cross-check those results. Time: 2 days total for each LA area
2	Data Collection	Data extraction from key systems likely to take a similar time regardless of scale, however fixing data issues is very scale dependent.	At least 1/2 week per primary of data cleansing. So for average LA 4 weeks	1 week per team	If regular updates of the common data store for Connect/LV, ConnectLite (under development) and NIFT 2.0 are already in place and operational then this task would occur on a regular cycle, pulling updated data as it's improved by WPD. If regular updates are not up and running and new data needs to be imported on a 'one off' manual basis (into NIFT 2.0) then estimate 5 days to update full network.
3	Local Energy (requirements) Planning	Setting up meetings, explaining data for various sites, capturing LA plans, updating plan, recirculating, review & sign off	2 weeks per DNO team member	2 weeks per team member	No dev time has been assumed for this task. Approx. 2 days consultant/engineer time per LA to ensure correct data is provided etc. If this became a truly standardized process, then that would reduce further to maybe 0.5 days.
4	Network analysis	Run time reflects the scale of the network analysed so this would be expected to scale directly i.e. double the number	Even with the performance improvements to the HV analysis this is estimated		Setup/data input: 2 days. Could be reduced depending on the level of automation and data checking which was included in the scope of developing NIFT 2.0.

Step	Step name	Comment	Estimated Workload for Electricity & Gas DNOs as a whole	Estimated Workload for LA	Expected LV Modelling Tasks
		of primaries, double the analysis time. Plus data cleansing the network model would also be proportionate to scale.	at 2 weeks per primary. 1 week resolving data quality issues plus 1 week running tool) So for average LA - 16 weeks elapsed time but much of that does not require supervision. Estimate approx. 4 weeks of time supervising automated analysis and checking results.		Run time: 1 day run time for 8 primaries. Data outputs/reports: 1 dev day for 8 primaries (1 LA area). 2 days consultant time processing and checking outputs.
5	Investment and options appraisal	I.e. loading the CBA tool, comparing and interpreting the results.	At least 3 weeks per LA		N/A – outside of LV modelling scope. Assume task 4 would produce outputs for CBA.
6	Local Energy Planning (completion)	Determining where plans can be optimised etc.	At least 2 weeks per LA	2 weeks per team	N/A – outside of LV modelling scope
Total			17 weeks		

Table 3-2 Estimated effort to replicate EPIC process for an entire LA area.

WPD's 4 licences areas include 1086 Electricity Supply Areas and 135 local planning authorities. This suggests an overall average of 8 primaries per Local Authority

While some processes can run in parallel it appears that the likely duration of the analysis for a typical Local Authority would be 17 weeks.

WPD's plans for ED2 include four engineers to support local authority energy planning. Allowing for holidays and sickness each engineer is only likely to have the time to process plans for 2.5 Local Authorities a year. Even if Local Authority plans were only updated once every three years this would result in a requirement to update 135/3 = 45 plans in total and 45/4 = 11.25 plans per engineer.

Therefore the proposed electricity network engineers would only be able to complete approximately 1/5th (11.25/2.5) of the required workload. Therefore significant improvements would be required to reduce the time requirements, much of which would be expected to result from data quality improvements, standardisation and automation of data exchanges etc.

Resourcing gas analysis may be even more difficult as it is this resource was not included in the ED2 gas settlement.

The question of Local Authority resourcing for LAEP development is also a difficult one to answer given that resources are not currently ring-fenced to support this work and that immediate high-priority issues are likely to take precedence.

It may also be that in the short term, there will be less value in carrying out a detailed analysis of the gas network impacts of local authority plans if the pattern seen in EPIC, of small local increases in demand being offset by reductions within the same general area, is expected to continue.

Gas network companies are currently working on a joint project undertaking network analysis to determine the feasibility of transporting hydrogen across a range of locations, however, until the UK hydrogen network development strategy has been developed and a decision taken on the use of hydrogen for heating, it is likely that the gas network analysis within projects like EPIC can only be produced in a simplified form.

Potential value from EPIC process

While resource constraints are a concern, a resource heavy process can still be justified if this delivers net benefits. An assessment of the benefit in terms of reduced network costs by selecting the best option vs the worst option for each use case suggests that the NPV of benefits per primary up to 2050 could be in the region of £0.5m. It should be noted that this value does not include the cost of applying additional energy efficiency measures or the additional costs of installing hybrid heat pumps over regular heat pumps. However, it suggests that there may be value in supporting policy decisions that benefits all areas while modelling only a subset of the network or that if data quality and automation improvements significantly reduce the costs of performing the analysis the benefits could outweigh the costs.

It may take some time for the prerequisites listed above to be met, however there are elements of the EPIC process that can be adopted and re-used relatively quickly.

a) **Bespoke EPIC process to inform specific policy choices**
The use case learning was of value to the network companies and local authorities in terms of informing policy. This suggests that a bespoke EPIC type process could be used to inform certain policy decisions. It may be useful to repeat this type of analysis to determine the

impact of other potential policy choices by either the local authorities or the network company e.g.

- What would be the impact of providing domestic battery storage to a cohort of customers?
- What would be the impact of deploying phase balancing equipment on LV networks?

b) Using network analysis tools – Strategic planning

The network analysis tools, HV Network Assessment Tool and the LV NIFT will be of value to the networks and could be applied across a number of different applications. The LV NIFT, for example, has already been used for WPD's RIIO ED2 planning and could be a key tool to inform future use of Uncertainty Mechanisms.

Future development of these tools, for example to visualise and logically group a series of network upgrades, will help networks move from a reactive, piecemeal, reinforcement strategy to begin to make proactive investment plans. For example, upgrading logical groups of assets in a batch process and also implementing a more general "fit for the future" investment strategy.

c) Using network analysis tools – Opportunity identification

The automation of the network analysis means that batch processing to identify relatively rare opportunities can become feasible. For example, the LV NIFT tool has also been earmarked for use within the Defender project and be part of the toolset that can identify areas where energy efficiency is a legitimate investment. Similarly the HV NAT tool could be adapted to provide upgrade timelines for each asset in the study area over the study period to support decision making when assets are replaced due to their condition or age.

d) Using network analysis tools – Standard reports

1. Other routinely produced reports which may be of use to network planners include; Yearly investment over the study period horizon for each primary
2. Demand projection at the primary level over the study period
3. Which transformers replaced more than once over the study period (currently this requires manually reviewing non CBA output files from HV NAT to pickup which transformers get replaced more than once)
4. Which representative day triggers the upgrade of each asset
5. Which asset require Flexibility services and which asset require upgrading in each year
6. New rating of the assets which require upgrading for each year
7. Value of the flexibility service in (MW and MWh) required for each asset for each year
8. Feeder which requires splitting and its corresponding year
9. Load profile (i.e. representative days) in MW and MVAR for each distribution substation for each year for the Top down approach

These can be used by several different business areas within WPD.

e) Exploring investment ahead of need

A process similar to EPIC could be used to demonstrate localised cases where there is significant investment required and there would be savings from adopting a planned programme for an area rather than repeated separate upgrades. This could support trialling alternative regulatory approaches that encourage longer term savings by encouraging early investment and share risk, reward and costs in a different way to the current framework.

f) Using EPIC processes alongside a LAEP process

As discussed in section 3.4 EPIC could be used as an allied process to a full LAEP. In this approach LAEP would provide the overall energy plan and energy requirements scenarios, while EPIC would be used to conduct network modelling and options cost appraisal, to inform and confirm final LAEP actions, priorities and decisions. In order for this to work successfully the two process would need some alignment on the treatment of spatial data, mapping to network assets, and the use of common data building blocks.

Ultimately however EPIC could enable networks to play a more proactive and supportive role to enable LAEP studies to incorporate network impacts and costs into their whole system analysis.