Programme Area: Smart Systems and Heat

Project: EnergyPath

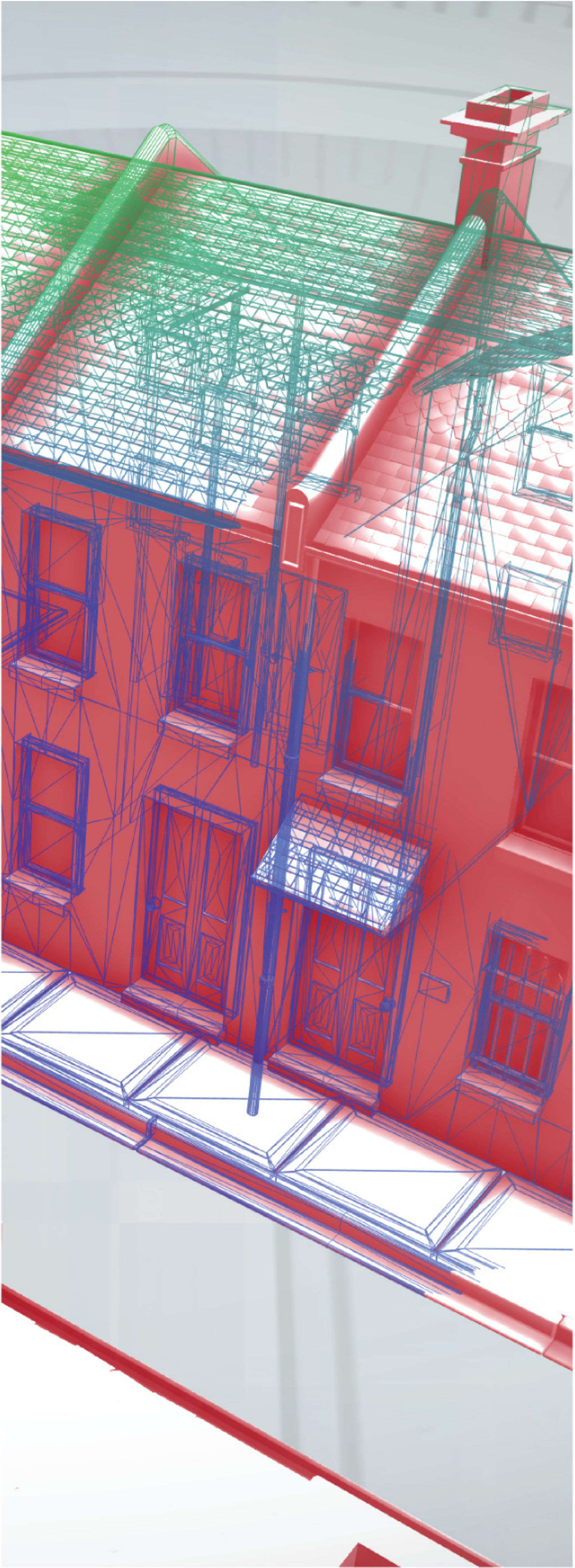
Title: EnergyPath Networks Use Cases

Abstract:

This report sets out five prioritised EPN use cases, comprising a summary of each use-case providing an accessible overview of the potential application of EPN and related capabilities. This builds on work carried out by Mark Bornhoft in Autumn 2017 to explore options for future exploitation of EPN.

Context:

Energy consultancy Baringa Partners were appointed to design and develop a software modelling tool to be used in the planning of cost-effective local energy systems. This software is called EnergyPath and will evolve to include a number of additional packages to inform planning, consumer insights and business metrics. Element Energy, Hitachi and University College London have worked with Baringa to develop the software with input from a range of local authorities, Western Power Distribution and Ramboll. EnergyPath will complement ETI's national strategic energy system tool ESME which links heat, power, transport and the infrastructure that connects them. EnergyPath is a registered trade mark of the Energy Technologies Institute LLP.



Smart Systems and Heat
Phase 1

EnergyPath™ Networks
Knowledge Transfer

Bidders Pack

D1 Use Cases for EnergyPath™ Networks

Final

Delivered by Catapult Energy Systems

Disclaimer

Contents

Acronyms

Table 1 Abbreviations and Acronyms

Acronym	Elaboration
BaU	Business as Usual
BCBC	Bridgend County Borough Council
CO_2	Carbon Dioxide
DHN	District Heat Networks
DNO	Distribution Network Operator
EHS	English Housing Survey
EHV	Extra-High Voltage (33kV and above)
EPN	EnergyPath™ Networks
ESC	Energy Systems Catapult
ESCo	Energy Service Company
ESME	Energy System Modelling Environment
ETI	Energy Technologies Institute
GIS	Geographical Information System
GOR	Government Office Region
HOM	Household Options Module
HV	High Voltage (11kV)
LA	Local Area
LV	Low Voltage (400V)
NAM	Network Analysis Module
NCC	Newcastle City Council
NPG	Northern Power Grid
Ofgem	Office of Gas and Electricity Markets
OS	Ordnance Survey
POM	Pathway Optimisation Module
RIIO	Revenue = Incentives + Innovation + Outputs
SAM	Spatial Analysis Module
SAP	Standard Assessment Procedure
SME	Subject Matter Expert
SQL	Structured Query Language
SSH	Smart Systems and Heat (programme)
TOTEX	Total Expenditures
UPRN	Unique Property Reference Number
VOA	Valuation Office Agency

Executive Summary

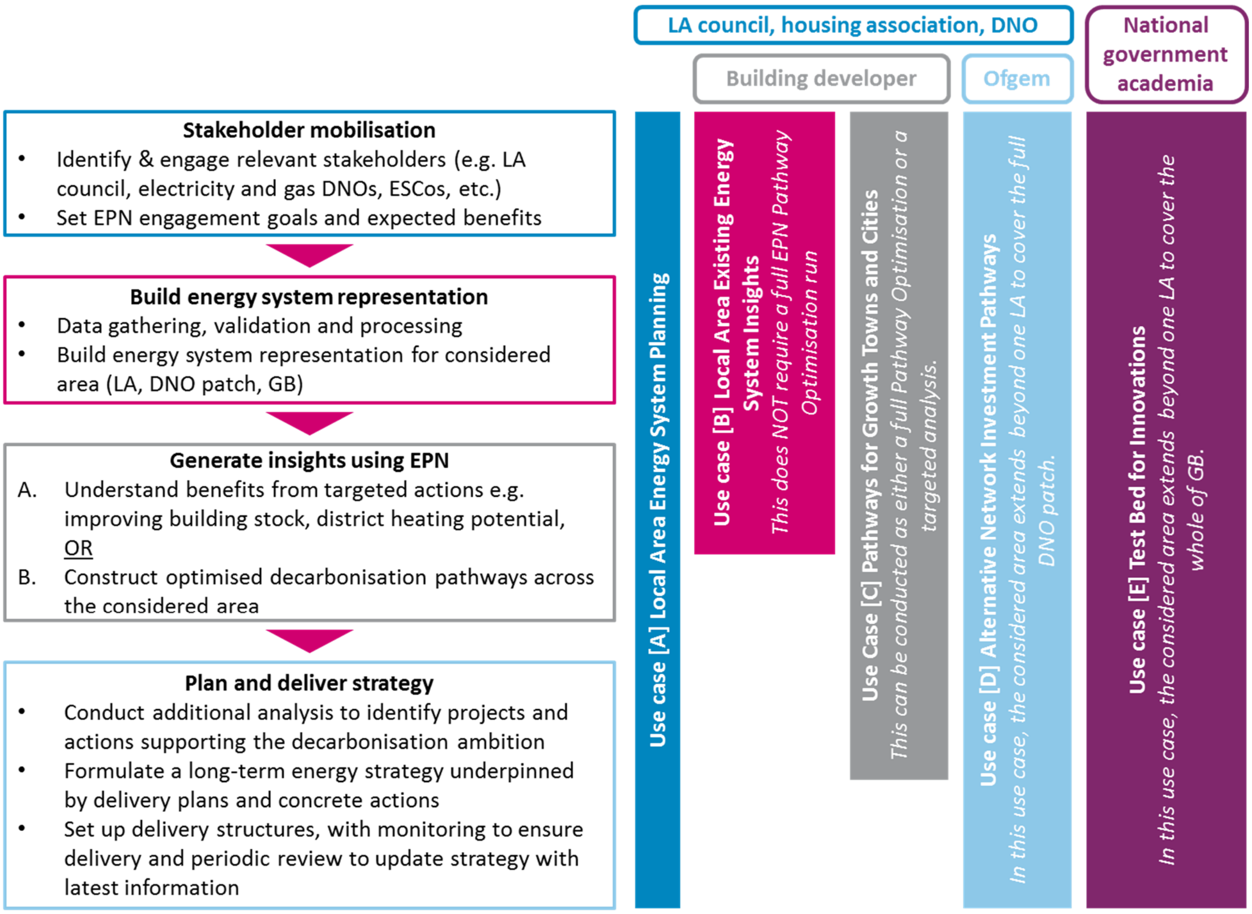
Over the next decade, the UK must prepare to meet national greenhouse gas emission targets by moving to low carbon technologies. This transition requires substantial upgrade, replacement or repurposing of our energy networks, and the considerable challenge of transitioning over 27 million homes to low carbon heating systems.

The EnergyPath™ Networks (EPN) analysis framework can provide robust evidence to help identify, prioritise and plan changes to decarbonise energy systems for specific Local Areas (LA). This use case has been piloted with three Local Areas as part of the Smart Systems and Heat Programme**.** Building on this capability, EPN can also be used in a variety of ways to provide guidance for the design of cost-effective local energy systems, simultaneously taking into account multi-vector interactions across the whole local energy system and long-term decarbonisation goals.

Five key use cases have been identified as particularly well-suited to EPN's capabilities. These range from near-term Local energy systems analysis to long-term, national level decarbonisation pathway studies.

These use cases are summarised in Figure 1 below.

Figure 1 EPN use cases workflow and main beneficiaries



- Use case **[A] Local Area Energy System Planning** provides an overview of the core process through which future Local Area Energy Strategies are developed using insights from the EPN modelling. This includes both the full end-to-end running of the EPN analysis framework itself

– i.e. to the end production of the optimised decarbonisation pathways – and the context of the wider local area energy planning process and stakeholder engagement within which the Local Area Energy Strategies are produced . This would be particularly useful for Local Area stakeholders (Councils, Distribution Network Operators, etc.) for defining a long term holistic local decarbonisation strategy informed by a range of future local energy scenarios, underpinned by a shorter-term delivery plan which identifies target areas for different solutions, deployment projects that can be delivered for near term quick wins within the current policy and market conditions, opportunities for innovation in the form of research and demonstration and policy support that could be instrumental to reach the decarbonisation objective as cost-effectively as possible.

- Use case **[B] Local Area Existing Energy System Insights** is focused on exploring the value that can be generated for different LA stakeholders from a simpler use of the EPN analysis framework (i.e. without the need to undertake the full decarbonisation pathway optimisation as in use case [A]). For instance, **a structured LA Energy Data Schema could help LA stakeholders add value and integrate decisions across a range of services and priorities** (e.g. electricity, gas and heat network development, social housing retrofitting), not just for long term planning.

- Use case **[C] Pathways for Growth Towns and Cities** can be undertaken as either a limited analysis of the existing local area as per use case [B] or as a full pathway exercise in use case [A] while focusing on the new developments to accommodate population growth in the LA. This **would help Local Authorities, network operators and developers evaluate the costs and benefits of various local energy design options** (e.g. oil boilers versus a heat network) taking into account network reinforcement costs arising from the proposed developments, **as well as provide LAs with the potential benefits of these developments for decarbonisation** pathways in the wider local area.

- Use case **[D] Alternative Network Investment Pathway Optimisation** broadens the geographical scope of the future pathway analysis undertaken within use case [A] from a single city or council area to the broader region that falls within the responsibility of a gas or electricity DNO. This analysis relies on using a pre-existing portfolio of decarbonisation pathway studies (as in use case [A]) in several LAs representative of the whole DNO region, to be able to extrapolate conclusions to the larger geographical area. In particular, this use case **focuses on exploring multi-vector network interactions** (e.g. potentially retaining use of the gas network to more cost-effectively manage peak heat demands, through use of gas boiler / heat pump hybrids). This use case could also be used as part of the analysis to **support price control submissions under RIIO-2**[1]**.**

- Use case **[E] Test Bed for Innovations** further expands the geographical scope of use case [D] by looking to generalise the insights from local decarbonisation pathways to the national level, to **help design new support regimes to spur adoption of low-carbon technologies** (for the UK government) **or provide evidence of performance and cost thresholds for innovative**

[1] For example, as outlined in the recent RIIO-2 consultation Ofgem flagged the need to support the delivery of "whole systems outcomes" and for more extensive stakeholder engagement with consumer, user groups and others, both of which align closely with the way EPN has been developed and how it has been applied in practice.https://www.ofgem.gov.uk/system/files/docs/2018/03/riio2_march_consultation_document_final_v1.pdf

technologies to provide potential system-wide value[2] (for technology developers). As per use case [D], this analysis relies on extrapolation of a subset of local results to generate conclusions for a larger geographical scale.

[2] Note that this EPN analysis would need to be complemented by significant work to define the customer value proposition as well as meet all technical and regulatory hurdles required for successful commercialisation.

1 Introduction

1.1. Context

The Energy Technology Institute's (ETI) *Smart Systems and Heat* (SSH) programme aims to create future-proof and economic local heating solutions for the UK. This will be achieved by connecting together the understanding of consumer needs and behaviour with the development and integration of technologies and new business models into enhanced knowledge to deliver industry and investor confidence to implement changes in heat provision in the UK.

Phase One of the SSH programme is being delivered by the ESC on behalf of the ETI working with three local areas Bridgend, Greater Manchester and Newcastle, to create the capability and pilot a process of local area energy planning with these local communities. The programme is undertaking a number of consumer behaviour, technology development, business modelling and supply-chain activities to create heat supply and demand products and services that meet consumer needs.

Phase One has included the creation and piloting of a process and structured framework for local area energy planning with an analytical platform, **EnergyPath™ Networks (EPN)** to enable a dialogue between local authorities and network operators to plan future local infrastructure needed to decarbonise. – *which is the focus of this document.*

The overarching objectives for the development of EnergyPath™ Networks and piloting of a whole systems approach to local area energy planning were agreed as follows:

- To support decision-making on future local area energy systems to 2050, principally to help support Local Authorities and their strategic stakeholders, such as Distribution Network Operators (DNOs)
- More specifically, for the analysis framework to help prioritise and plan interventions in the local area energy system, including generation, network, storage and buildings projects, aligned with a national 2050 decarbonisation pathway
- For the analysis framework to do this by focussing on the development and application of a cost-effective local plan, which is subject to 'real world' constraints and uncertainty. This helps to inform, more subjective, strategic decision making on a transition pathway as part of wider business planning processes;
- Be able to account, at least indirectly, for the potential impact of consumers on local area energy system pathway design; and
- To ensure that the analysis framework and associated databases are based around a scalable architecture, in order to set the ETI/ESC on the trajectory towards building the full level of functionality and capability.

As a result, the Local Area Energy Planning process and supporting EPN analysis aims to provide future credible pathways to decarbonise heat in a local area as well as informing long-term policy decisions on the impact of energy on the local community. For example, outputs can be used to assess the impact on fuel poverty, taking into account specific local energy infrastructure and plans, consistent with the national decarbonisation pathway.

The EPN analysis framework sits at the core of the wider energy planning framework and its use provides a number of important benefits, many of which are unique to the way the EPN has been developed, for example by:

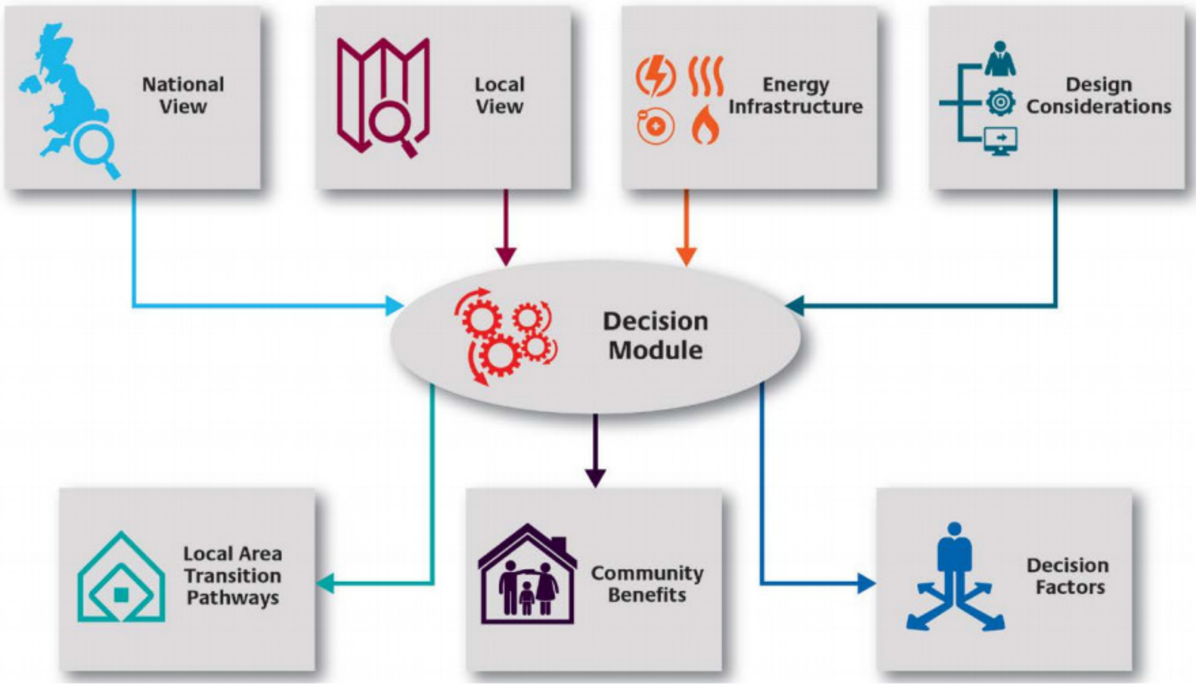
- **Taking a 'whole systems' view of the local energy system** it provides an independent and internally consistent framework for creating an evidence base to inform local area energy planning, whilst facilitating close collaboration with all of the key stakeholders (e.g. the Local Authority, electricity and gas Distribution Network Operators (DNOs) and heat network developers).
- **Analysis based on a detailed spatial representation of each local area**, which helps to reflect better the relationship between buildings and the networks that serve them and more accurately represent the associated costs and benefits. Capturing the nuances of each real world area also improves collaboration amongst stakeholders by giving them more confidence that their particular issues are well represented (e.g. the costs associated with network reinforcement in highly rural or urban areas).
- **Using a least cost optimisation process to develop future decarbonisation pathways**, which allows for much wider set of options and trade-offs for the local area to be explored, compared to manual scenario development. For example, the role of heat networks versus electrification of heat in different locations.
- **Ensuring the scope of the optimisation simultaneously covers buildings, distributed generation/storage and network options** across multiple energy vectors and timescales (i.e. 10-year steps to 2050) helps to drive a more complete picture of how decarbonisation can achieved whilst attempting to minimise costs to the end consumer, compared to analysis which only considers each vector in isolation.
- **Incorporating a Monte Carlo mode of operation whereby a wide range of uncertainty in the value of future inputs** (e.g. the costs of different heating systems or commodity prices) can be more easily explored, helping stakeholders to understand better which pathways and solutions are more robust to changing external conditions from now to 2050 and which costs are more significant in terms of making decisions.

In addition, the detailed representation of the local area could provide a range of benefits for different stakeholders as it:

- Helps to provide a consistent and structured focal point to manage and audit available data on the local area energy system from a range of different stakeholders.
- Allow for area specific economic and wellbeing indicators to be derived by combining outputs from EPN's decarbonisation pathways with other socioeconomic indicators to explore the impact on jobs, health, etc.

Figure 2 below summarises the main constituting elements of the EPN Local Area Planning Framework as well as its outputs for local stakeholders (LA council and community, DNOs, building and DHN developers, etc.).

Figure 2 Conceptual overview of the EnergyPath™ Networks analysis framework



1.2. Purpose and structure of this document

This documents aims to establish a series of 'use-cases' for EPN, defining potential applications of the modelling framework for prospective users and recipients of outputs outside of the ESC.

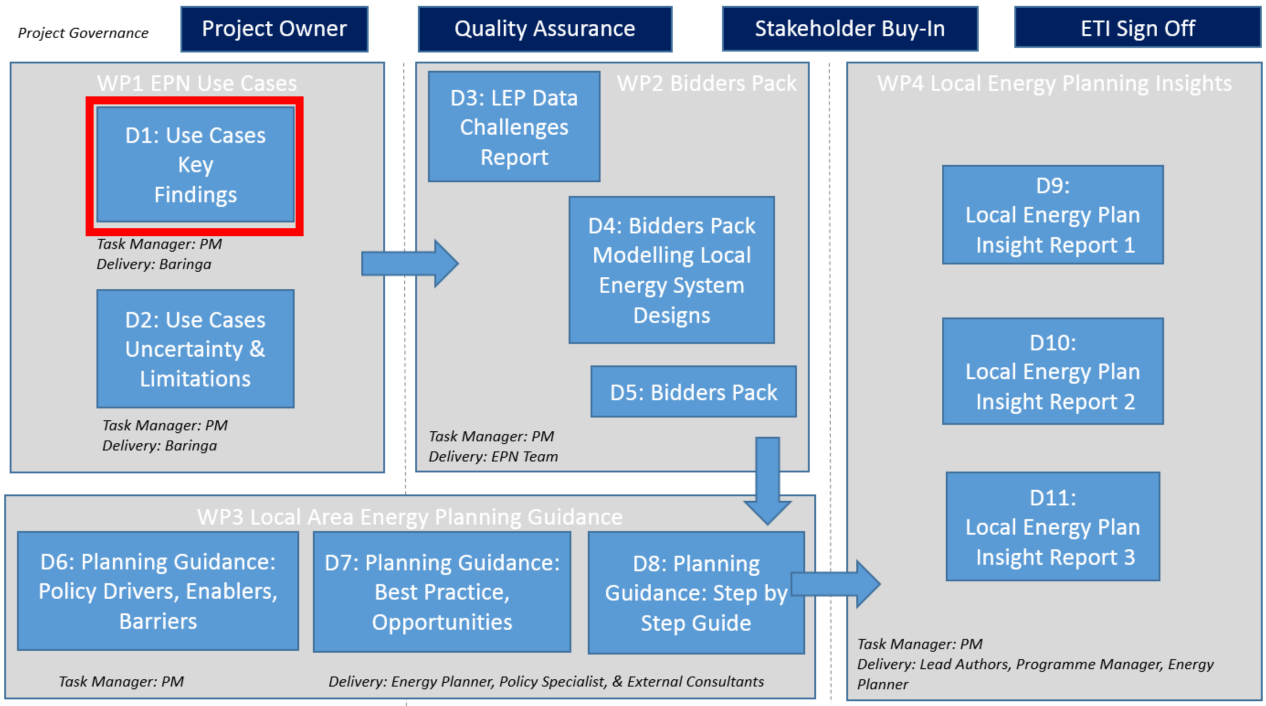
- Prospective users include academia along with private and public sector organisations.
- Recipients include local authorities, regional and national government, network operators and developers, energy service providers and the regulator Ofgem.

This is informed by experience using EPN planning in combination with stakeholder feedback, and aligns with the ESC's wider exploitation strategy of supporting local area energy planning.

1.2.1 EPN Bidders' Pack

As part of the Smart Systems and Heat Phase 1 Programme this document has been written with the objective of supporting the progression of Local Area Energy Planning in the UK. Local Area Energy Planning is seen by the ETI and the ESC as central to achieving national greenhouse gas emissions reduction targets. More effective local area planning supported by objective, technology agnostic evidence can support transition in a way that enables local communities to realise the benefits and understand the costs of decarbonisation. Figure 3 below presents how this documents fits within the totality of the Bidders' Pack work programme.

Figure 3 EPN Bidders' Pack documents



This document supports this objective through providing five example use cases for EPN complete with illustrations and proposed delivery plans.

1.2.2 Structure of this document

This document presents five overarching use cases of the EnergyPath™ Networks framework, as:

- **[A] Local Area Energy Planning** in section 2,
- **[B] Local Area Existing Energy System Insights** in section 3,
- **[C] Pathways for Growth Towns and Cities** in section 4,
- **[D] Alternative Network Investment Pathway Optimisation** in section 5, and
- **[E] Test Bed for Innovations** in section 6.

1.3. Overview of use cases

Use case [A] Local Area Energy Planning provides an overview of the core process through which future LA Local Area Energy Strategies are developed using insights from the EPN tool. This includes both the full end-to-end running of the EPN modelling toolkit itself – i.e. to the end production of the optimised decarbonisation pathways – and the context of the wider business processes and stakeholder engagement within which the master plans are produced. This **would be particularly useful for Local Area stakeholders** (LA council, Distribution Network Operators, etc.) **for defining a long term holistic LA-wide decarbonisation strategy**, **underpinned by a shorter-term delivery plan** which identifies target areas for different solutions, deployment projects that can be delivered for near term quick wins within the current policy and market conditions, research and demonstration opportunities and policy support that could be instrumental to reach the decarbonisation objective as cost-effectively as possible.

Use case [B] Local Area Existing Energy System Insights is focused on exploring the value that can be generated for different LA stakeholders from a simpler use of the EPN analysis framework (i.e. without the need to undertake the full decarbonisation pathway optimisation as in use case [A]). For instance, **a structured LA Energy Data Schema would help LA stakeholders add value and integrate decisions across a range of services and priorities** (e.g. electricity, gas and heat network development, social housing retrofitting), not just for long term planning.

Use case [C] Pathways for Growth Towns and Cities can be undertaken as either a limited analysis of the existing local area as per use case [B] or as a full pathway exercise in use case [A] while focusing on the new developments to accommodate population growth in the LA. This **would help network operators and developers evaluate the costs and benefits of various local energy design options** (e.g. oil boilers versus a heat network) taking into account network reinforcement costs arising from the proposed developments, **as well as provide LAs with the potential benefits of these developments for decarbonisation** pathways in the wider local area.

Use case [D] Alternative Network Investment Pathway Optimisation broadens the geographical scope of the future pathway analysis undertaken within use case [A] from a single city or council area to the broader region that falls within the responsibility of a gas or electricity DNO. This analysis relies on using a pre-existing portfolio of decarbonisation pathway studies (as in use case [A]) in several LAs representative of the whole DNO region, to be able to extrapolate conclusions to the larger geographical area. In particular, this use case **focuses on exploring multi-vector network interactions** (e.g. potentially retaining use of the gas network to more cost-effectively manage peak heat demands, through use of gas boiler / heat pump hybrids). This use case **could also be used as part of the analysis required for price control submission under RIIO-2[3].**

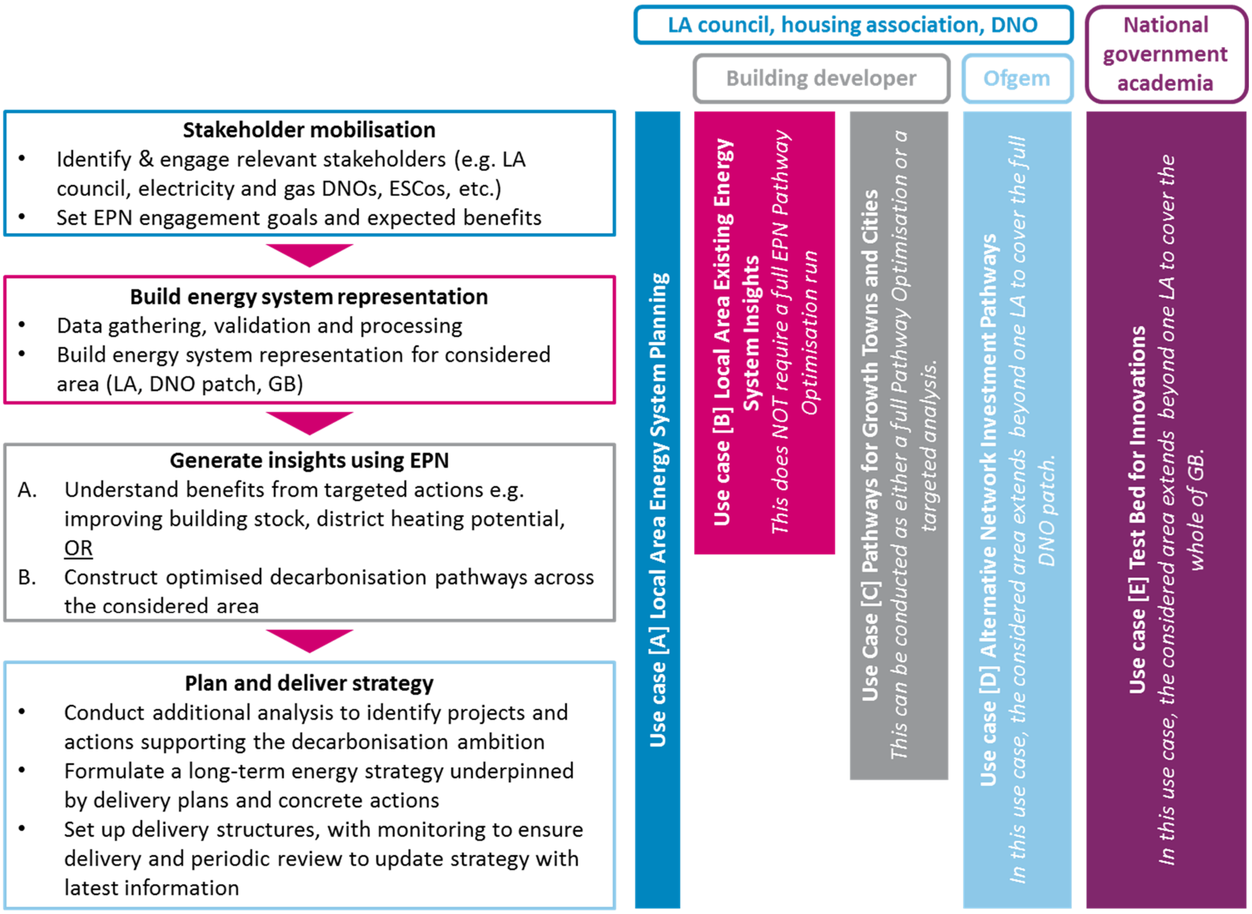
Use case [E] Test Bed for Innovations further expands the geographical scope of use case [D] by looking to generalise the insights from LA optimised decarbonisation pathways to the national level, to **help design new support regimes to spur adoption of low-carbon technologies** (for the UK government) **or provide evidence of performance and cost thresholds for innovative technologies to provide potential system-wide value**[4] (for technology developers). As per use case [D], this analysis relies on extrapolation of a subset of local results to generate conclusions for a larger geographical scale.

Figure 4 illustrates the workflow steps orchestrating these five EPN use cases and maps them to their main intended beneficiaries.

[3] For example, as outlined in the recent RIIO-2 consultation Ofgem emphasised the need for this to support the delivery of "whole systems outcomes" and for more extensive stakeholder engagement with consumer, user groups and others, both of which align closely with the way EPN has been developed and how it has been applied in practice.https://www.ofgem.gov.uk/system/files/docs/2018/03/riio2_march_consultation_document_final_v1.pdf

[4] Note that this EPN analysis would need to be complemented by significant work to define the customer value proposition as well as meet all technical and regulatory hurdles required for successful commercialisation.

Figure 4 EPN use cases workflow and main beneficiaries



2 [A] Local Area Energy Planning Use Case

2.1. Overview

Over the next decade, the UK must prepare to meet national greenhouse gas emission targets by moving to low carbon technologies. This transition requires substantial upgrades to the energy infrastructure, and the considerable challenge of fitting up to 27 million homes with low carbon energy systems.

At a local level, energy decarbonisation can take many forms e.g. insulating homes, deploying district heating schemes or installing low-carbon heating systems in each property, using electric or hybrid sources of energy depending on the special characteristics of the considered area. As part of the wider Energy Planning Framework the **EnergyPath™ Networks analysis framework, generates an evidence base and intelligence (outputs) to help explore a range of future local energy scenarios and identify near-term projects consistent with a long term local energy strategy to help decarbonise heat as cost effectively as possible.**

Figure 5 Dominant energy systems and networks (Bridgend 2050)

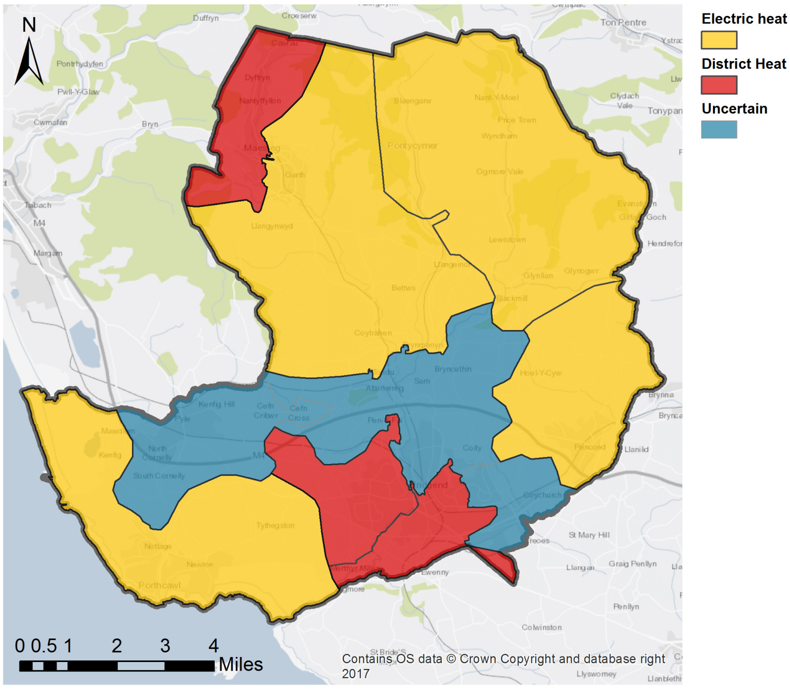
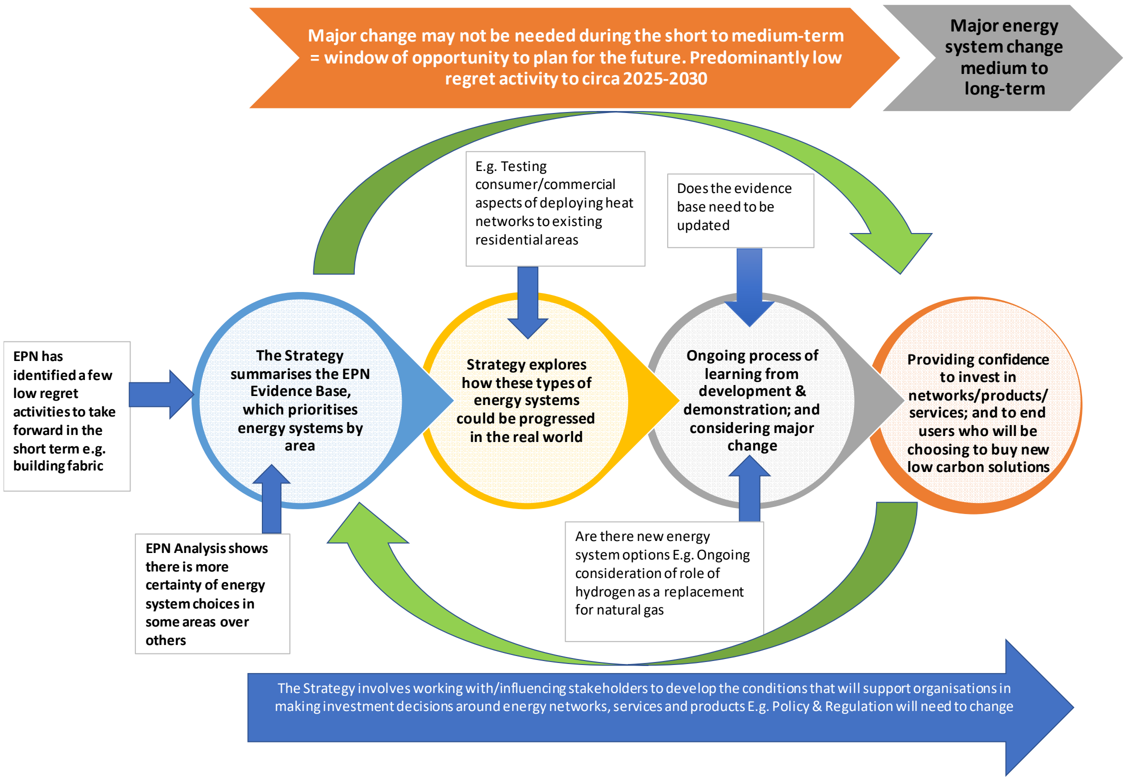


Figure 5 above illustrates a key element of the long-term energy strategy for Bridgend: the most cost effective deployment of heating systems and networks by analysis area by 2050 as derived using results from EPN's least-cost optimisation engine. The robustness of results comes from starting with a detailed baseline model and the comparing a very large number of options and sensitivities using the EPN model. It can be used to inform long-term trajectory as well as short-term trials and demonstration projects, focusing on 'low-regret' projects that are suited to their areas, noting that variations exist within a single analysis area.

Targeted analysis - building on the EPN outputs – of the broader technical, commercial, policy and consumer impacts is undertaken to identify projects (e.g. district heating deployment) and actions (e.g. research to identify sources of low carbon heat) that could **support delivery of the key elements required to achieve the longer-term energy strategy** as shown in Figure 6 below.

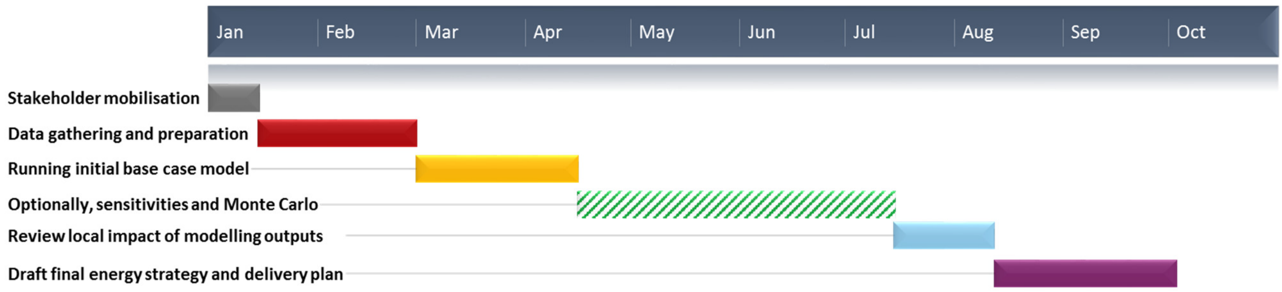
Figure 6 Illustrative local area energy strategy evolution over time



Use of the EPN modelling toolkit sits within a larger local energy system planning framework, where **low-level analysis can be iterated and refined**. **The full analysis can also be re-run periodically** to help validate past actions, update long-term strategy and form new delivery plans. Running the full EPN Pathway Optimisation requires setting up a powerful desktop machine with the relevant commercial and free software integrated within the modelling toolkit. This is followed by gathering commercial and free data sources as well as assembling a team of 3 to 4 people to run the analysis in circa 6 months, up to 9 months including optional sensitivities and Monte Carlo analysis. Underlying 3rd-party software and data licencing, as well as hardware **costs amount to around £100,000**. Figure 7 illustrates a suggested work plan for this use case[5].

[5] This assumes only local data needs gathering and preparation. Preparing non-location specific data can take significantly longer.

Figure 7 Proposed work plan for delivering a Local Area Energy Plan

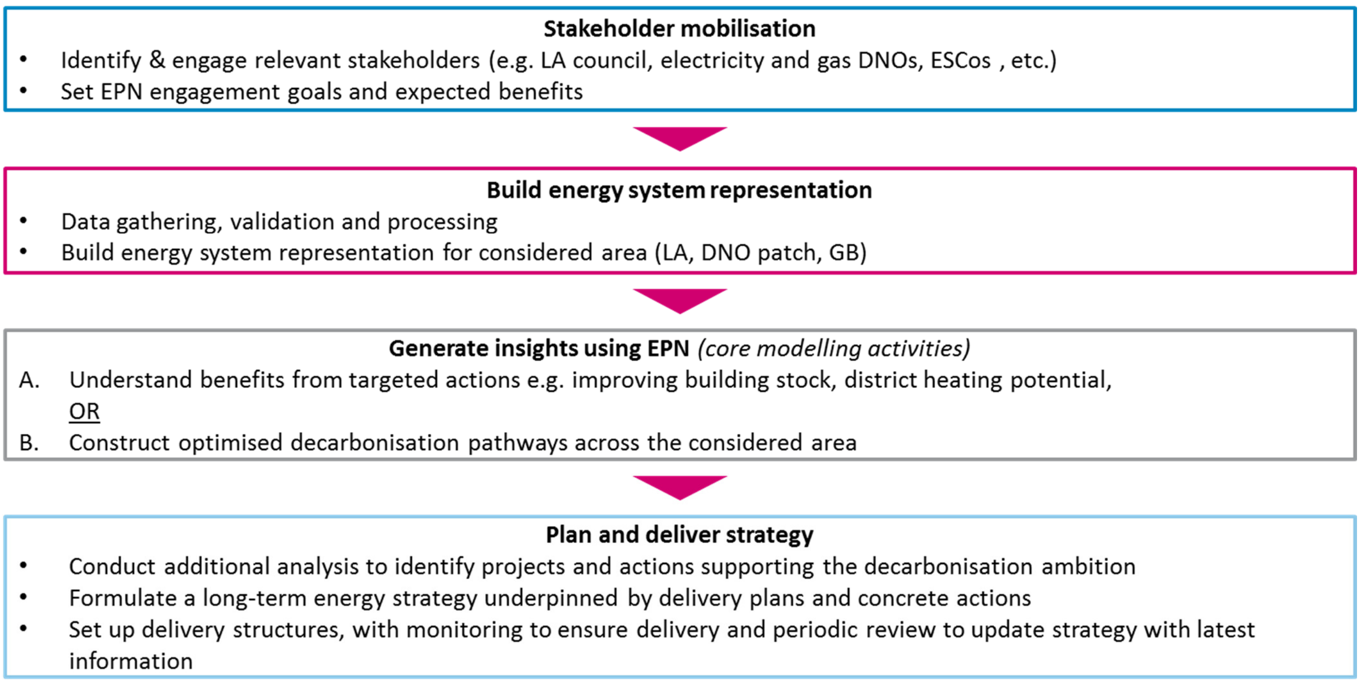


2.2. Processes for running the EPN framework

A flexible iterative framework, with local energy system modelling at its core

The Local Area Energy Planning Framework, will help LAs integrate energy-related data, analysis and energy-decision making across its services and planning functions.

Figure 8 Process for local area energy planning and strategy development



As illustrated in Figure 8 above, **EPN Pathway Analysis** (in grey) **sits within this broader process of Local Area** energy planning activities and decision making. The overarching end-to-end process to deliver the Local Area Energy Strategy also comprises other key activities such as area-specific data gathering and processing (in pink) and a broader set of business processes (in dark and light blue). The latter include activities such as managing engagement with the relevant local area stakeholders and defining the precise scope of the analysis[6] (in dark blue), as well as the required steps to define and deliver a decarbonisation strategy (in light blue).

[6] EPN business processes are presented in more details in the *EPN Functional Specifications document* (April 2014). The document is available here: http://www.eti.co.uk/programmes/smart-systems-heat/energypath

Many aspects of this process are iterative. For example, engaging with key external stakeholders at multiple points throughout the process to refine the analysis; or better targeting sensitivities so as to answer the key questions for the stakeholder group. These sensitivities could include shortlisting possible sites for a new energy centre, understanding the impact of retrofit projects, or evaluating the influence of setting different carbon targets.

Overview of Energy Planning activities

An initial phase of *stakeholder mobilisation* allows for framing the challenge and defining a shared vision for the Local Area Energy Strategy across the relevant stakeholders (e.g. LA council, electricity and gas DNOs, ESCos[7], etc.). This will define the goals of the energy planning engagement, the expected benefits for each stakeholder (e.g. inform policy or commercial decisions) and formalise an extended project team comprising the core EPN modelling team and the local area stakeholders.

Following this, the core modelling team can start building the input dataset and running the EPN modelling toolkit:

- First, a *data gathering, validation and processing* phase can begin to collate, curate, join and transform commercial, freely available and local area-sourced input data for input into the EPN[8] analysis framework. This can also be the occasion to set up more formalised schemas for organizing local area energy data or to quality assess it as needed.
- From here, the EPN analysis framework can be run *iteratively* to provide the evidence base to *refine the long-term vision* by, for example, identifying robust transitions such as low regret building efficiency improvements and understanding the implications of different decisions and their timing. It is anticipated that this would involve the various stakeholders to varying degrees, to help focus the analysis and gain buy-in to the results.

Beyond the modelling activities, *targeted additional analysis* – building on the direct EPN outputs – could be undertaken to help identify projects (e.g. district heating deployment) and actions (e.g. research to improve low-carbon technology economic viability, targeted policy support) that could support delivery of the key elements required to achieve the longer-term energy strategy. Examples could include:

- Broader technical analyses e.g. performance of large-scale heat pumps for supplying district heat networks,
- Commercial e.g. system value of building insulation,
- Policy (e.g. fuel poverty remedies), and
- Consumer (e.g. acceptance of transition to heat pumps)

The reference case energy strategy (including detailed long-term decarbonisation pathways) can be finalised through stakeholder feedback from interim results and a comparison of benefits for each stakeholder compared with expectations set at the mobilisation phase.

[7] Energy Service Companies
[8] We later assume in estimating workload that only local area data needs to be collected.

Finally, *periodic review and update* of the energy strategy can be undertaken to re-assess progress against past objectives as well as plan new near-term delivery goals.

2.3. How EPN outputs inform the Use Case

At a high-level, the results from the EnergyPath™ Networks analysis framework can be used to inform local area energy system planning in several ways:

- The first step involves review and interpretation of results from running the full EPN[9] Pathway Optimisation. This will help understand **what the EPN outputs suggest as the cost-optimal pathway** across buildings, networks and distributed energy **to reach the long-term local decarbonisation objectives**. For example, where and when specific interventions should be deployed and their associated costs. Interpretation is required to understand the inter-dependencies between various elements of the solution.
- Uncertainty in these results can be explored by either comparing a number of what-if scenarios, or, by looking at the distributions of results from a Monte Carlo analysis. This allows for a **systematic exploration of the impact of uncertainty,** due to factors such as the evolution of future technology costs on the robustness of the obtained energy pathway.
- Finally, and broadening the perspective **beyond the modelling activities**, the user can combine EPN outputs with other factors e.g. political and local policy, commercial, behaviours, technical capability to **draft a long-term energy strategy and a shorter-term delivery plan to enable the desired changes**.

Examples of the use of EPN outputs to inform the local area energy system pathway, based on the categories above, are provided in the following sections.

2.3.1 Modelling long term Future Local Energy Scenarios

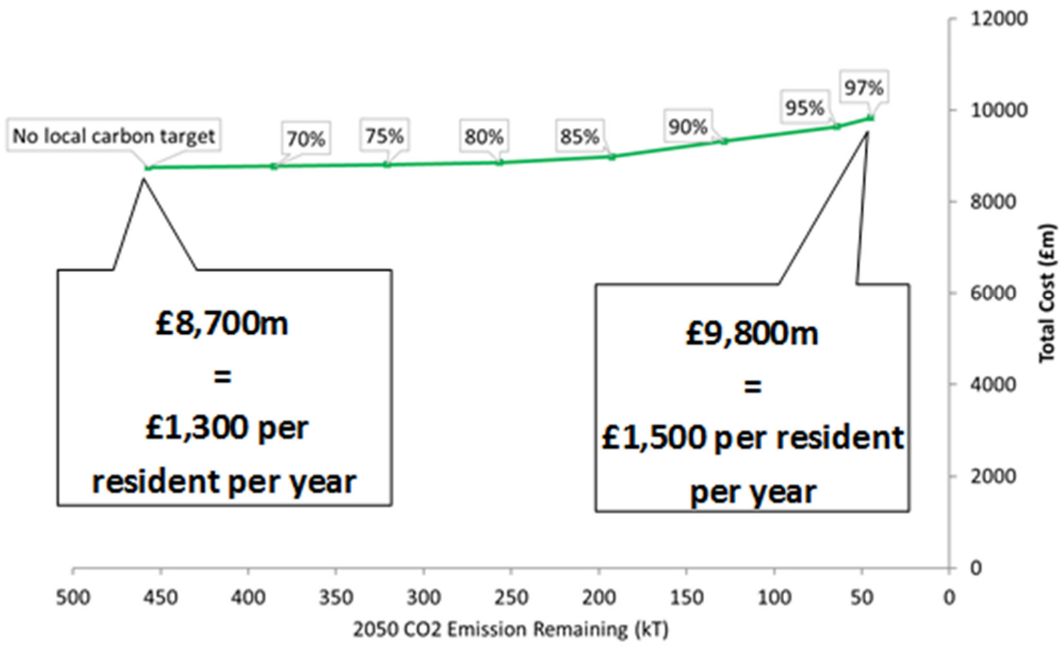
EPN provides **an analysis framework to investigate whole system decarbonisation pathways and develop future local energy scenarios for a given local area**. For instance, Figure 9 below represents how total system-wide costs increase as CO_2 emissions targets tighten from Business-as-Usual (BaU) to the maximum level of decarbonisation achievable in Bury District Council area within the EPN modelling i.e. a 96.5%[10] reduction for in-scope emissions as compared with 1990 levels. Up to an 85% reduction the curve is shallow, showing that carbon can be saved at a relatively low cost. Between 85% and 95% the curve steepens as the cost of reduction increases. Going from 95% to 97% is modelled to cost almost the same as going from 65% to 85%, as the last 2% of emissions are extremely expensive to cut. This suggests a cost increase of £90/year per person for the total cost of reaching 97% reduction over not setting a local target if shared equally across Bury residents[11]. Note that the Business-as-Usual case is when no local carbon

[10] The 100% decarbonisation objective cannot be reached here as some non-domestic buildings will continue using gas for process heat (not space heat) which do not have low-carbon retrofitting options in the EPN modelling framework.
[11] This assumes: Discounting of future spend to 2015 values; Paying over 35 years; An equal split between all residents of Bury regardless of age or ability to pay; and Bury businesses do not contribute to this decarbonisation effort. In practice, costs would be shared between residents and businesses so that residents would not pay the full £90/year contribution.

target is set. Under this target it is assumed that decarbonisation of nationally generated electricity still occurs as a result of national action to meet the requirements of the 2008 Climate Change Act[12].

Only low costs are incurred to reach the 85% target because this can be achieved by switching a small number of buildings from gas boilers to electric solutions (requiring minimal electricity network reinforcement) and building small, cost-effective heat networks such that 70% of buildings remain on gas boilers.

Figure 9 Evolution of system costs[13] as carbon targets tighten (Bury)



EPN can help stakeholders to understand the scale of the decarbonisation challenge as well as its ramifications across the local area energy system e.g. networks, energy centres and buildings. For example, a significant portion of emissions reduction comes from decarbonisation of the national electricity system by 2040. However, significant change is still needed within a local area including retrofitting domestic buildings and transitioning from gas boilers to low carbon alternatives.

[12] https://www.legislation.gov.uk/ukpga/2008/27/contents

[13] Whilst these costs are similar in magnitude to the average household (retail dual fuel) energy bill comparing the two is difficult as their scopes are different e.g. EPN does not take into account additional energy supplier operating costs (e.g. salary, etc.), margins or taxes on energy which are included in the final retail price seen by the consumer. Conversely, the current retail price does not account for the full social cost of CO_2 emissions.

Figure 10 Domestic heating systems in 2050 as carbon target tightens (Bury)

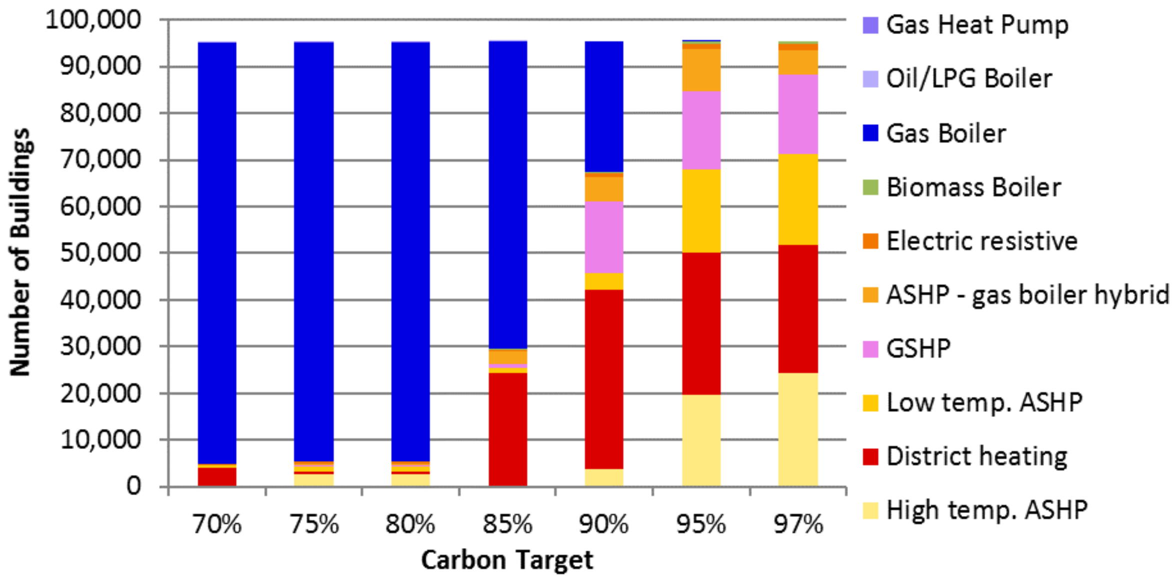


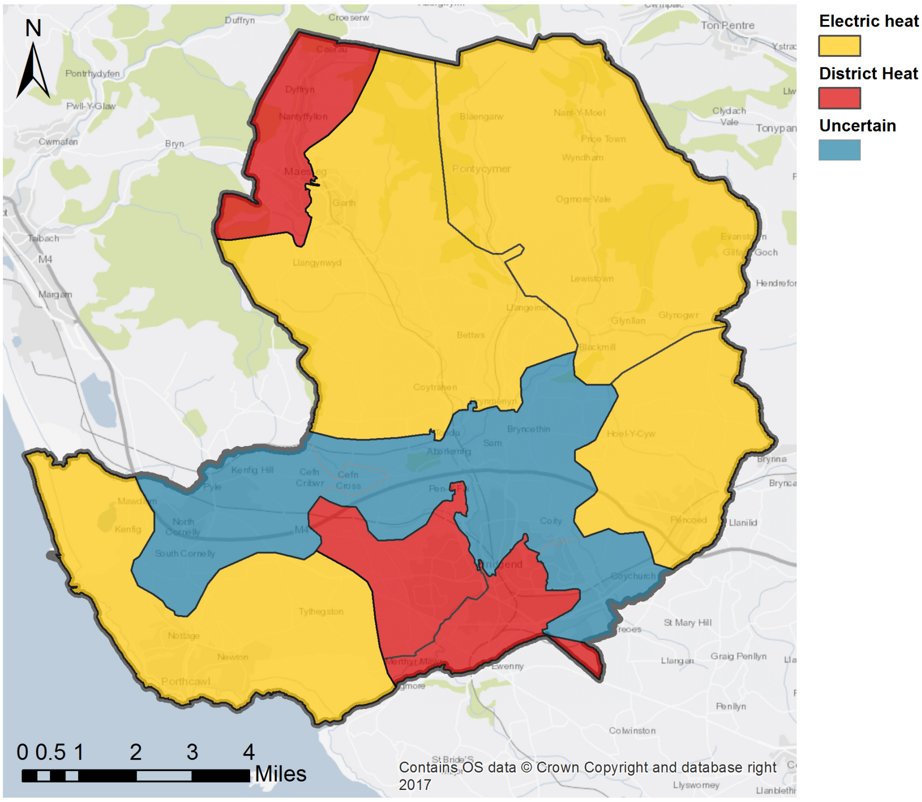
Figure 10 above shows the sensitivity of domestic heating systems transition to tightening the carbon target. While little change is observed below an 80% local CO_2 reduction target, as carbon emissions reduction targets increase there are much more significant changes needed to networks and buildings.

This can be supplemented by mapping the transitions to building types within sub areas of the study area to understand the spatial differences of different decarbonisation pathways for a local area.

2.3.2 Building the evidence base underpinning a Delivery Plan

Sensitivities (e.g. higher electricity costs or restrictions on the availability of bio-fuel or green gas) can be used to test the robustness of EPN outputs in various contexts, while a Monte Carlo mode can be run to explore if, and how much, pathways respond to variations (e.g. heating system and network costs, energy prices, insulation efficiency) around a central scenario. For example, Figure 11 synthesises the learnings from all the sensitivities run for Bridgend in the form of dominant energy systems by analysis area in 2050. This shows the areas where the dominant heating vector (electricity and district heat) is most robust and the intermediate areas where decarbonised pathways in EPN are more variable.

Figure 11 Dominant energy systems and networks (Bridgend 2050)



As well as showing **the most cost effective long-term network solutions for different areas** this EPN output also provides **the evidence base for identifying the areas where near term deployment and demonstration projects are lower risk**[14]. From this, targeted additional analysis would be conducted to understand the 'real-world' challenges to achieving deep decarbonisation. There are a wide range of other commercial, policy/regulatory, consumer and technical factors that need to be considered before a project can be delivered in practice. The ESC is developing a methodology to provide a holistic assessment of each project on these four dimensions. Table 2 below provides an example for district heating applied to existing LA-managed homes.

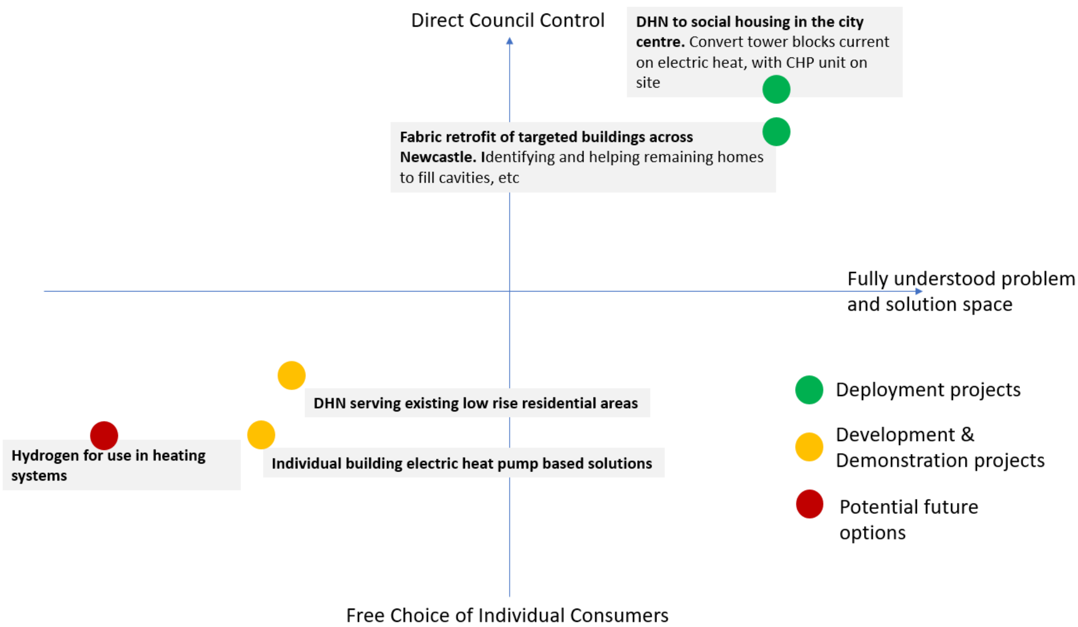
Table 2 Retrofit of Heat Networks to Existing Homes

Capability factor	Description
Commercial	Establishing routes to market for low carbon heat.
Policy/ Regulation	Technology-agnostic carbon policy to drive transformation. Heat network regulations to assure consumers and investors.
Consumer	Whilst consumers may regard the technology itself as acceptable, the change will still be disruptive so acceptance of the scheme requires engagement with residents.
Technical	Dependent on heat source, enabling gas and electricity network for future needs, including detailed network planning for near-term geographic zones.

[14] An energy service provider or energy technology manufacturer could also use EPN as a starting point to evaluate possible deployment in a targeted LA or nationally as in use case [D], noting that further analyses would be required to ensure commercial viability of the offering considered.

Ultimately, the long-term decarbonisation plan involves making decisions in the face of imperfect information about the future. Figure 12 below provides an example of how potential options are assessed in a comparative manner, to help define an actionable near-term delivery plan. This will be informed by a mix of EPN and other analyses, as well a range of stakeholder expert judgement. In many cases the plan will likely contain a mix of "low-regret" projects, but could also include some demonstration projects (i.e. higher-risk and higher reward) to prepare for delivering the next stage of the energy strategy.

Figure 12 Relationship between Solution Understanding, Control and Influence



This targeted analysis would **determine the current and future challenges to implementing a decarbonisation pathway in practice and suggest ways to address them** in the short-term either directly by commissioning relevant projects or indirectly by collecting a better understanding of the issues to be able to address them later on. This would be synthesised in a short-term delivery plan comprising:

- **Deployment Projects**: these are considered to be low regret short-term opportunities which appear resilient to uncertainty and where there is an existing plan to realise them in the current commercial and policy environment (e.g. fabric retrofit of social housing stock). They are usually on the least cost decarbonisation pathway.

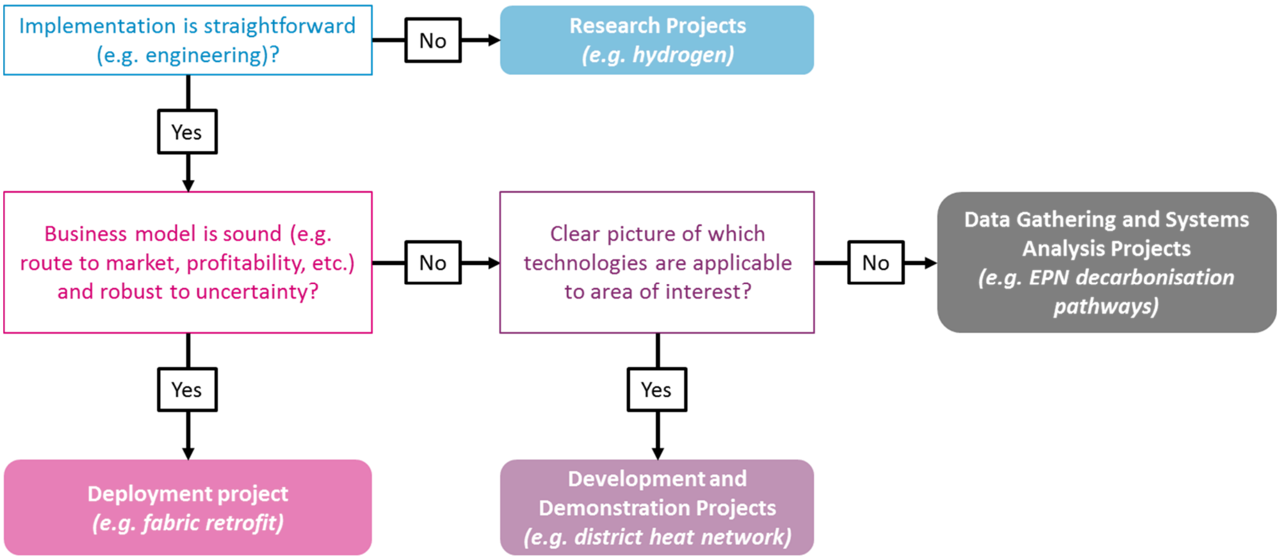
- **Development and Demonstration Projects**: these are prospective deployment projects that are expected to be needed in the medium-term but do not have a current 'Capability' to be realised at scale. They often arise as the least cost method of decarbonisation, but are subject to uncertainties (e.g. timing, location) or there is little clarity on how to realise them in the current consumer, commercial and policy/regulatory environment. Development and Demonstration projects are intended to improve knowledge to reduce this uncertainty and overcome barriers to mass market uptake.

- **Data Gathering and Systems Analysis Projects**: these are activities to improve knowledge of technology and energy system transition options in areas where improved information will help understanding and influence future decisions. These projects should be started early in order to provide the knowledge required to support future decision making. The supporting EPN based whole system analysis is in itself a Data Gathering and Systems Analysis activity.

- **Research Projects**: Some low carbon technologies might be attractive in the long term if certain specific performance and cost targets can be met and technical, commercial or policy barriers can be overcome; hydrogen being a good example. In addition, further information may also be needed to validate the applicability of a decarbonisation option. Research projects should also be progressed to identify new Development & Demonstration themes that could be evaluated through future Data Gathering & Systems Analysis.

Figure 13 illustrates the key questions used to decide which of these four categories of projects can be retained in the LA decarbonisation delivery plan.

Figure 13 Decision tree for determining what projects are right in the short-term delivery plan



2.3.3 Building a holistic Local Area Energy Strategy

Figure 14 Illustrative Local Area Energy Strategy Planning Process

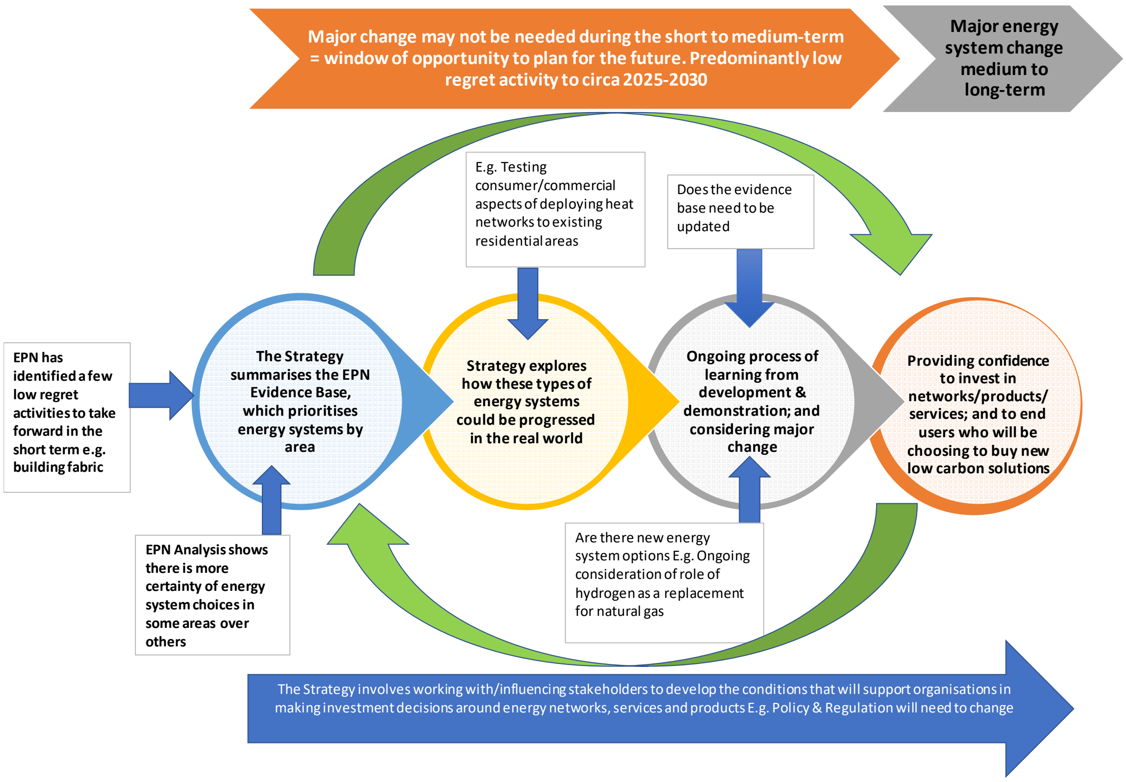


Figure 14 above illustrates the steps to move from defining an energy strategy vision to delivering it over time. This involves:

- **Defining a shared long-term vision across all relevant stakeholders** e.g. city council, network operators, building management organizations, energy service companies and project developers, residents and businesses;
- **Representing and refining whole-system local energy pathways** consistent with the long-term goals using EPN **to form the evidence base for future decisions**. This should involve assessment of the robustness of the output energy plans subject to uncertainty e.g. costs evolutions, policy and consumer preferences, etc.
- **Identifying pivotal projects** (e.g. deployment, demonstration, research[15]) **and their challenges** with additional analysis **to build a near-to-middle term delivery plan underpinning the long-term decarbonisation goals** and addressing identified challenges e.g. through funding research, energy policy schemes, communication, etc.
- **Repeating the analysis cycle periodically** to review progress on previous delivery plans, re-assessing the long-term energy decarbonisation pathway in light of updated information e.g. technology costs, national electricity decarbonisation, etc. and forming new near-to-middle terms delivery plans. This re-assessment can align with:

[15] To fill gaps in understanding or reduce areas of significant uncertainty.

- Regulatory Stakeholder Engagement exercises to support DNO investment planning, or
- Local Area Plan cycles and preparation of supplementary planning documents.

2.4. Undertaking Local Area Energy Planning with EPN

Running a **full EPN Pathway Optimisation** requires setting up a powerful desktop machine with the relevant commercial and free software on which EPN relies, as well as gathering commercial and free data sources. **Software and data licencing, as well hardware costs amount to approximately £100,000**. Due to the complexity of the data, modelling and extensive stakeholder engagement, a team providing a resource of 3-4 full time equivalents is needed to deliver the energy strategy over a circa 6-9-month period.

2.4.1 Data, hardware and software resources required

Hardware requirements

Table 3 below shows a typical machine specification allowing for acceptable EPN run times, typically 5 to 7 days end-to-end[16]. The analysis framework is designed to scale with more powerful machines, for example many sub-processes are parallelised and can take advantage of multiple cores. The typical cost for the specification below is approximately £10,000.

Table 3 Example specification for EPN dedicated model machine

Part	Specification
Processor	32 cores @ 3.1GHz
General machine memory	256 GB
Dedicated GPU memory (primarily to speed ArcGIS visualisation)	6GB
Required disk space (data from one model run excl. software)	40~70GB

Software requirements

EPN was built by integrating several specialised software components[17]:

- Python is used to orchestrate EPN operation,
- EnergyPlus, PSS®Sincal, ArcGIS and the ETI Optimising Thermal Efficiency Standard Assessment Procedure (SAP) model are hard-linked within EPN for representing buildings and networks,
- AIMMS supports the optimizer, and @Risk Monte Carlo simulations,
- The model is supported by Microsoft Windows 10, SQL Server Commercial 2014 and Excel.

With the exception of EnergyPlus and Python, all other software components are subject to commercial licence costs with **the total cost amounting to approximately £65,000 per machine**.

[16] Depending on the nature of a new scenario it is often possible to update and re-run the final pathway optimisation step only.
[17] The rationale for selecting each of these and for the overall design architecture is outlined in more detail as part of the documentation from the scoping phase of EPN: *Energy Path Networks – Deliverable (S1D2) Design Architecture – April 2014*. The document is available here: http://www.eti.co.uk/programmes/smart-systems-heat/energypath

Data requirements

Table 4 Key input data[18] items for the EPN toolkit

Source	Required	Data description
Ordnance Survey	Yes (commercial)[19]	Provides GIS-layers for a local area's road network and building location, footprint size and height. In addition, it provides some basic categorisation of building features for use in domestic and non-domestic building matching. This can require substantial manual effort for data cleansing and checking.
English Housing Survey	Yes (free)	Provides a high-level regional view of the split of building archetypes. This is used to inform the building matching where no other data is available. Similar datasets are available for Scotland (Scottish House Condition Survey) and soon for Wales[20].
Valuation Office Agency	Yes (commercial)	Contains further categorisation of non-domestic buildings at an individual building level, as well as an understanding of multiple occupancy within a single building footprint. Data on non-domestic buildings is expected to be very uncertain so that VOA data can be contradicted by other data sources. Resolving these conflicts can be very time consuming.
University of Exeter	Yes (free)	PROMETHEUS project UK location specific weather files for EnergyPlus, including simulated impact of climate change.
Geo-Information Group	No (commercial)	Provides further data on building characteristics at an individual building level to improve the building archetype matching process (i.e. trying to categorise the existing building stock as accurately as possible given incomplete knowledge about the state of each individual building).
ETI	Yes (licensed)	Domestic heating system performance and costs[21], network component performance and costs[22], non-domestic building heating demands and retrofitting costs, and ESME results for boundary conditions.
LA-specific	No (licensed)	Additional information about the local area e.g. social housing stock characteristics, new buildings and demolitions, existing heat networks, solar Photovoltaic and Electric Vehicle deployment, electricity network links, etc. This data can require large manual processing and cleansing effort to be ready for use in EPN.

The EPN analysis framwork requires several key input data items as outlined in Table 4 above, most of these are from commercial (i.e. paid for) sources. Excluding LA-specific and ETI-licenced data, **the total costs of data licences for a given LA study amount to approximately £25,000[23]**.

2.4.2 Modelling capability and expertise

Table 5 below describes the team expertise required to deliver local energy strategy pathways with EPN. In particular, we will cover the individual skills and capabilities required to be able to operate and critically review results.

---

[18] This data can sometimes not represent reality accurately (e.g. missing data or out of date) or can be difficult to process (e.g. requires uniform re-labelling). Other data sources (e.g. BEIS postcode-level demand data set) can be used to validate EPN model outputs.
[19] OS data can be provided for free under a Public Sector Mapping Agreement if working with central or local government as described here: https://www.ordnancesurvey.co.uk/business-and-government/public-sector/mapping-agreements/public-sector-mapping-agreement.html
[20] The Welsh House Condition Survey is due to be published in Autumn 2018: http://gov.wales/statistics-and-research/welsh-housing-conditions-survey/?lang=en. In its absence the deployment of EPN to Bridgend used the UNO dataset: http://www.unoenergy.co.uk/.
[21] For the three pilot studies, this is based on data underpinning the Renewable Heat Incentive, originally analysed by Ricardo-AEA, although other sources could be used as desired.
[22] Based on local DNO data for electricity and gas. DHN data comes from an Arup study.
[23] These licensing costs could be reduced as OS data would be available under the Public Sector Mapping Agreement in the case of an EPN deployment to a LA. The ESC is also exploring options for alternatives to the GeoInformation data e.g. based on freely available EPC data.

Table 5 Roles of EPN modelling team

Title	Role description
Project Manager	Prepare project plan, manage relationship with key stakeholders, ensure commitments are met with respect to project deliverables, and that delivery is to time and available budget.
Senior Engineer	Subject Matter Expert (SME) on energy technology characteristics e.g. to parametrize energy centres, heat, electricity and hydrogen networks as well as building heating systems. Senior Engineer will also validate energy pathways from EPN from an engineering perspective.
Modelling Analysts	Analyst to run the EPN toolkit (requires some knowledge of python, VBA, SQL, AIMMS and ArcGIS) and Quality Assure model results, lead stakeholder technical engagements and act as SME on EPN inner working for the rest of the team. Experience in visualisation is beneficial to produce charts, maps.
Data Analyst	Gather data from stakeholders, quality check gathered data and prepare data for use in EPN run, process outputs and produce visuals for stakeholder meetings. Experience with python, SQL and visualisation (in particular for GIS) is required.

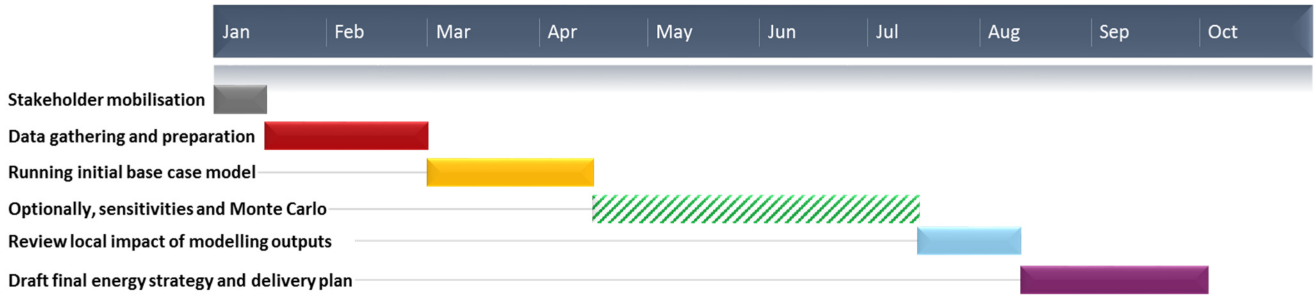
2.4.3 Work plan for delivering the Use Case

Assuming all data, software, hardware and team requirements are in place, delivering the local area energy plan, key steps in the process for delivering the use case would be articulated as follows:

1. Mobilising the relevant stakeholders (e.g. LA council, electricity and gas DNOs, ESCos, etc.) to assemble the extended EPN energy plan project team;
2. Local area data should be gathered (e.g. electricity network topology from the DNO) as well as commercial sources (e.g. OS), pre-processed and quality-reviewed before being inserted into EPN. This phase could take approximately 1-3 months, towards the lower end if LAs are able to provide data within a standard schema;
3. An initial base case model is run with the input data gathered at the previous step. These initial results are illustrative at this point and used to gather feedback from stakeholders and define a set of relevant sensitivities to refine and test the robustness of the shared strategic energy decarbonisation vision. This phase could take approximately 1-2 months;
4. Optional sensitivities can be performed to stress-test decarbonisation pathways under a different world view. These will typically to take 1 to 2 weeks each although some can take as long as 1 month
    - In addition, EPN can be run in Monte Carlo mode for further exploration of uncertainty in the Base Case scenario. This can take approximately 1 month;
5. Analysis and review of all the runs undertaken to understand common themes and to identify the factors which have the greatest influence on the results. This can take approximately 2 weeks and will involve collaborative discussions with the extended project team to identify items that are of particular local interest and to understand how the EPN analysis results can be used to inform decisions related to these key themes. This phase will require around 5 meetings of the project team;
6. The energy strategy documents are drafted for the external stakeholder panel to review. This could take approximately 1-2 months.

Figure 15 below recaps the overarching process of delivering the local area energy plan with EPN.

Figure 15 Illustrative work plan for local area energy planning with EPN



3 [B] Local Energy System Insights Use Case

3.1. Overview

Understanding the current local area energy system is the first step in understanding how it could transition to a low-carbon system. However, representing an existing local energy system accurately is often difficult as the relevant data is either not readily usable or sometimes does not exist at all.

The energy planning framework first creates a detailed picture of the local area, collating the best available data in a structured format, and applying techniques to fill data gaps[24]. However, even without running the full end-to-end EPN pathway optimisation (as in core use case [A]), significant value can be obtained by undertaking simpler intermediate analysis early in the planning process (which is the focus of this use case [B]), potentially by combining this with other non-EPN specific data. A selected, but non-exhaustive list, of the benefits of such a simplified analysis to Local Area stakeholders are summarised in Table 6 below.

Table 6 Examples of benefits of simplified EPN analysis

Beneficiary	Benefit of simplified EPN analysis
Buildings developers, managers, Local Authority	Combining existing building data with socio-economic data such as income levels to help identify areas of potential fuel poverty.
	Identifying high carbon local-authority-owned buildings to prioritise retrofitting opportunities
	Gain a better understanding of the local building stock and its improvement potential
	Better representation of the carbon footprint of buildings in the Local Area.
District heat network developers, Local Authority	EPN can calculate a heat density map to identify potential heat network opportunities across the Local Area.
	EPN can provide a planning front-end for retrofit programmes in public/private building stock to help identify potential projects and also highlight synergies with future energy infrastructure choices e.g. potential heat network locations.
	EPN can help build the evidence base for assessing community infrastructure contributions such as new energy centres or distributed generation.
Electricity and gas distribution network operators	EPN can be used as a framework and model for consistent LA stakeholder engagement and structured information sharing for energy network investment planning (for RIIO2 and beyond). EPN can serve as a common template across Local Areas in a DNO licence area for reporting demand growth projections or identifying potential resources for demand management and local balancing. Equally, EPN can help visualise current network assets e.g. capacity, location and relationship to connected buildings.
	EPN can help identify potential upstream energy network constraints arising from new housing developments, or heavy deployment of renewables like solar PV. EPN could also provide information to help plan Electric Vehicles charge point locations.

Data gathered for this EPN use case can be ported to a comprehensive **Local Area Energy Data Schema** with the goal of helping LAs most efficiently build energy data assets and analysis capabilities that can support a range of council strategic objectives and services. This structured energy data schema **could benefit development planning and refurbishment projects, spatial energy planning exercises, EPN**

[24] For example synthesising an electricity network topology in the absence of detailed connection information or statistically matching each building in the area to its 'closest' archetypal example, where its full characteristics are not known

decarbonisation pathway analysis, and potentially Stakeholder Engagement exercises for DNO regulated price control submissions.

Delivering this analysis in practice requires running a subset of the early steps in the full EPN pathway optimisation process i.e. focusing on current buildings and networks without simulating possible transitions and reinforcements or optimising a pathway to 2050. The majority of the early resource intensive activities around data gathering and pre-processing tasks are still necessary, such that this type of study can be carried out by a team of circa 3 people over a period of approximately 3 months.

3.2. Use Case description

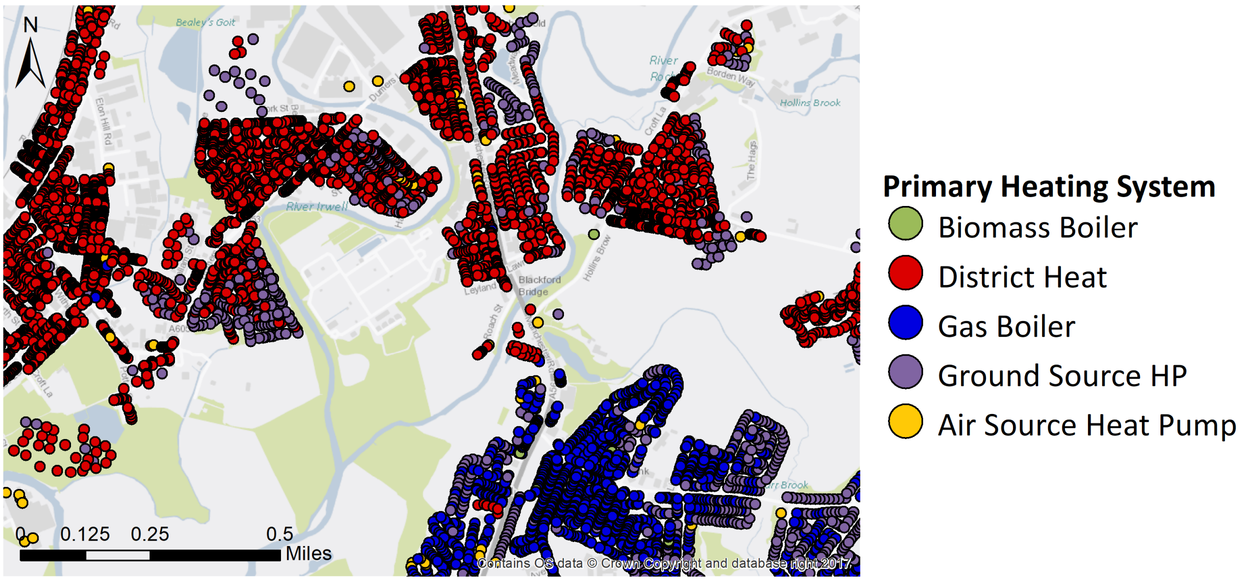
The core use case **[A]** uses information about the existing area to help inform the final pathway. However, even without running the full end-to-end EPN pathway optimisation, significant value can be obtained by undertaking simpler intermediate analysis earlier on in the EPN process, potentially by combining this with other non-EPN specific data. This data can also be used to populate a comprehensive **Local Area Energy Data Schema**. This integrated energy data model within a Local Area **can help councils** (in particular after the EPN engagement) **create intelligence needed to support a range of council strategic objectives and services** including:

- **Deploying local energy infrastructure**: encouraging renewables deployment, mapping potential district heat network locations (see 3.2.1) in relation to new build developments (see 4.2.2);
- **Achieving policy objectives**: tackling fuel poverty through social housing refurbishment (see 3.2.2), climate change risk management ownership;
- **Providing data to support the evaluation of possible new revenue streams** for councils and housing associations: becoming an energy supplier or intermediary/enabler, exploring local interest in community energy scheme ownership.

3.2.1 Identifying heat network deployment opportunities

One of the first steps in the EnergyPath™ Networks analysis framework is to characterise building attributes such as window or wall types, primary and secondary heating systems, etc. for domestic buildings. Non-domestic buildings are associated with their activity class and heating system. EPN is configured to associate each building identified to its Unique Property Reference Number (UPRN) and then to its known or imputed characteristics. Figure 16 below shows the mapping of different heating types (e.g. biomass or gas boiler, heat pumps, etc.) in the Bury town centre.

Figure 16 Primary building heating systems in Bury town centre



These building characteristics can be either:

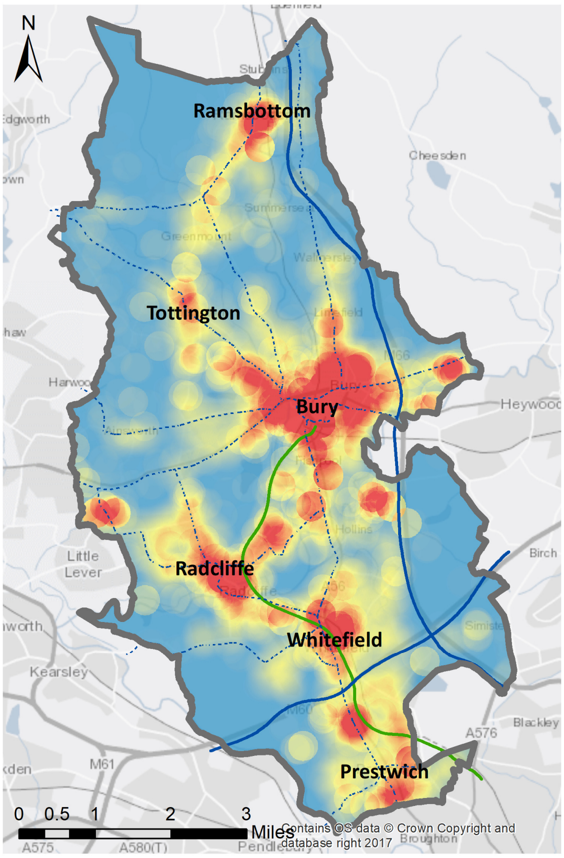
- **User-defined**, where detailed building-level data exists for example, from social housing records or imputed using buildings' Energy Performance Certificate (EPC) records, or
- **Statistically imputed** from aggregated data sets, for example, the English Housing Survey (EHS) provides heating system frequency of occurrence by Government Office Region (GOR).

Once building characteristics are defined, their energy demand profiles can be simulated on a half-hourly basis within the EPN analysis framework, either:

- Using their existing characteristics directly, or
- Simulating heating system change (e.g. conversion to district heating) or an insulation retrofitting.

This detailed energy simulation provides annual energy demands for all buildings in the Local Area in a variety of heating systems and insulation configurations. Heat maps can then be drawn, simulating all buildings transition to District Heat Network (DHN). This will provide the evidence base for an initial assessment of heat network deployment potential in a Local Area. Figure 17 presents heat density areas in Bury, Greater Manchester.

Figure 17 Heat density map for Bury, Greater Manchester



As described in section 2.3.2, insight from the EnergyPath™ Networks analysis framework will need to be complemented with targeted analysis to identify 'real-world' challenges to deploying heat networks and ways to address them.

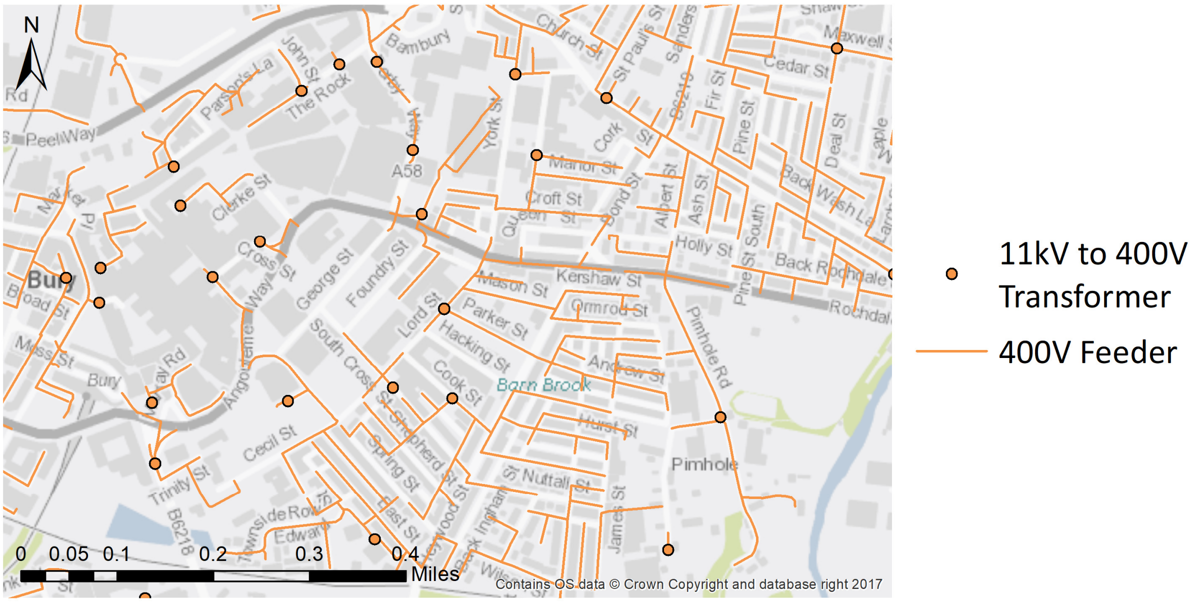
3.2.2 Identifying high-value building retrofit opportunities

EnergyPath™ Networks also offers a facility to simulate the layout of existing electricity distribution networks, using:

- **Actual data from existing assets** e.g. substations locations and rating, connections between High and Low Voltage substations, and
- **A robust methodology to simulate network topology** where data is either not available or cannot be shared for legal reasons[25].

Figure 18 illustrates the result of electricity network synthesis in EPN for Bury town centre.

Figure 18 Synthesised LV network topology in Bury town centre



By combining several Local Area maps with building energy demand simulations, we can assess where retrofitting interventions would bring the most benefits by:

- Evaluating cost savings and increased comfort levels for occupiers and staff of publicly owned buildings, as energy demand reduces and with associated decarbonisation benefits.
- Evaluating network headroom gained as retrofit reduces demand for current and future years and translates to cost savings for the electricity DNO as network reinforcement investment is deferred.
- Targeting buildings in heat-dense areas or where a district heat network proposed scheme exists so as to leverage the benefits of this deployment.

[25] Customer connections to the distribution network are protected by privacy laws so it is difficult for DNOs to share this information for the purposes of using it in EPN.

- Targeting buildings with a higher risk of fuel-poverty (combining energy demand with socio-economic data) so as to meet local policy objectives in the most cost-effective way taking into account whole energy system costs[26].

This way, EPN can provide data for evidence-based policy decisions, making it easier to prioritise interventions and get buy-in from local stakeholders.

3.3. Delivering Local Energy System Insights with EPN

This use case is comparatively simpler than [A] as it requires only running selected parts of the EnergyPath™ Networks analysis framework. As a result, the amount of effort required to deliver it would be more modest:

- 3 full-time people:
  - A (part-time) Project Manager to manage time and project deliverables,
  - A (part-time) Senior Engineer to provide guidance on parametrising solutions in EPN,
  - A (full-time) Modelling Analyst to run the EPN analysis framework, and
  - A (full-time) Data Analyst to prepare data for EPN and presentation to stakeholders.
- Working for around 2 months to identify potential DHN deployment zones, or 3 months for identifying high value building retrofit opportunities.

This assumes that only local data needs to be collected (national data being already in place), results are provided in standardised templates, and only a limited number of sensitivities is undertaken (e.g. 2 or 3).

Note that alternatively, some of the data gathering, validation and processing could be performed by a team of GIS analysts working either for a specific Local Area or for a shared planning service covering several Local Areas. This would help reduce the cost to the Local Area of such an analysis and ensure that benefits (e.g. validated data sets, methodology) are refreshed internally after the EPN engagement is over.

[26] Tools have already been developed for this purpose, for instance the Energy Data Integration System (EDIS) by Ricardo Energy & Environment, described here: http://edis-ricardo.com/what-edis

4 [C] Pathways for Growth Towns and Cities Use Case

4.1. Overview

The UK population is projected to grow from over 65 million at present to around 70 million by 2030, with England growing more quickly than the other UK nations[27] and large cities growing at an even faster pace. For instance, London's population is forecast to increase by almost 30% by 2040.

This population growth will be supported by the creation of many new developments, likely close to or within the boundaries of existing town and cities. **The EnergyPath™ Networks analysis framework can provide the evidence base to help understand the impact of new developments on Local Area energy systems across energy vectors.** As such, it can help Local authorities, developers and local DNOs by:

- **Informing the energy design** for heating systems or insulation for the new developments and provide guidance on solutions to reduce whole-system costs. This initial engagement could be completed in around 2 months by a team of 3 people;
- **Understanding how new developments can be beneficial to the immediate neighbouring areas** within the Local Area, with respect to near term decarbonisation pathways. For instance, by seeding a district heat network which could be extended to existing areas at a later stage. This could lead to listing the development as part of the near-term delivery plan of the Local Area Energy Strategy described in section 2. This simplified analysis could take around 2 to 3 months for a team of 3 people depending on the amount of effort required to prepare local data[28];
- **Understanding the influence of the new development on future long-term decarbonisation pathways across the entire Local Area.** For example, early deployment of district heating could serve as an anchor load for later extension. This would require a full pathway analysis as described in section 2 and therefore could take from 6 to 9 months to a team of 3 people depending on the number of sensitivities run.

This use case could be delivered:

- In an ad-hoc fashion, when a major new development is proposed, so that substantial analysis is required to model its impact on the energy system and help developers find solutions to minimise their contributions to funding the required infrastructure upgrades.
- As part of the regular LA processes where the Local Area already has the required energy data model (e.g. from a previous Local Energy Planning engagement) and the analysis team (e.g. as part of services shared across LAs) in place.

[27] Source: Office for National Statistics
[28] National data is assumed to be already in place.

4.2. Use Case description

4.2.1 Context and purpose

The EnergyPath™ Networks analysis framework can provide the evidence base to help understand the impact of new developments on Local Area energy systems across energy vectors. For example, several design options can be considered comparatively against one another for their immediate and long-term benefits for the entire LA:

- Fitting new buildings with oil boilers limits gas and electricity network reinforcement but is expensive in terms of capital and fuel costs. Large associated carbon emissions would also limit their long-term value in a LA decarbonisation pathway.
- On the other hand, developing a bespoke district heat network for new developments can be more expensive at first in terms investment costs but would have a high long-term value to the community for decarbonising new as well as neighbouring buildings.

This analysis could review:

- **Immediate effects** such as additional load requiring electricity and possibly gas network reinforcements, which could inform the heating infrastructure and building heating system design of the new developments. The impact of several heating system deployments on network reinforcement should be compared as it could help developers/network operators understand the heating system solution which would be cost-effective in terms of providing good quality living space while limiting the contributions to energy infrastructure reinforcement.
- **Impact on immediate neighbouring buildings** by providing seeds for enabling decarbonisation actions across a larger area. For example, a new build heat network could be extended to neighbouring buildings more cheaply than if the scheme had been introduced after the new buildings were already in place. This would also support the LA's development of an integrated energy planning capability.
- **The influence of the new development on the wider Local Area Energy Strategy Plan** e.g. by resolving uncertainties in the long-term decarbonisation picture or changing it at least locally. For instance, enforcing different heating systems could lead to different cost-effective decarbonisation pathways at the local area level (i.e. assuming initial heating investment costs as sunk). New developments would be a good occasion to review the existing LA Energy Planning Strategy (Use Case [A] in section 2) and alternative network investment options (Use Case [D] in section 5). This would also strengthen the need for developing consistent LA energy data templates to support effective communication between LA and DNOs for as part of the network investment planning process (Use Case [B] in section 3).

4.2.2 Inform design of heating solutions in new development

To meet the UK's carbon targets new developments must consider solutions to reduce the buildings' energy consumption as well as its carbon footprint. This needs to cover more novel building design, construction and operation as well as use of key technologies such as advanced controls, ground source heat pumps, integration of renewable energy such as solar PV to buildings, etc.

In the medium to longer term these technologies should lead to lower costs for consumers, assuming the underlying cost of carbon is passed through appropriately, but in many cases, could also lead to savings in the nearer term, for example if the new development is unlikely to be connected to the gas grid and the alternative is expensive oil-fuelled boilers. Stakeholders from the three EPN LA pilot studies have expressed interest in building a better understanding of:

- **How new buildings could be future-proofed** by aligning with the decarbonisation vision for the Local Area, for example, by making buildings "heat-pump ready", and the implications in terms of building blueprints and planning for potential near-term network reinforcements.
- **How energy-efficiency of proposed new buildings impacts the Local Area energy system** from electricity network reinforcement requirements, to current and future levels of emissions and the cost of developing and operating these buildings.

This analysis would benefit:

- **Local Area stakeholders** as it would help refine the options for decarbonising the local area and update the energy planning strategy;
- **DNOs** as this would feed into multi-vector network planning studies; and
- **Building developers** as this would provide the underpinning evidence for assessing contributions to the infrastructure development of various building design options.

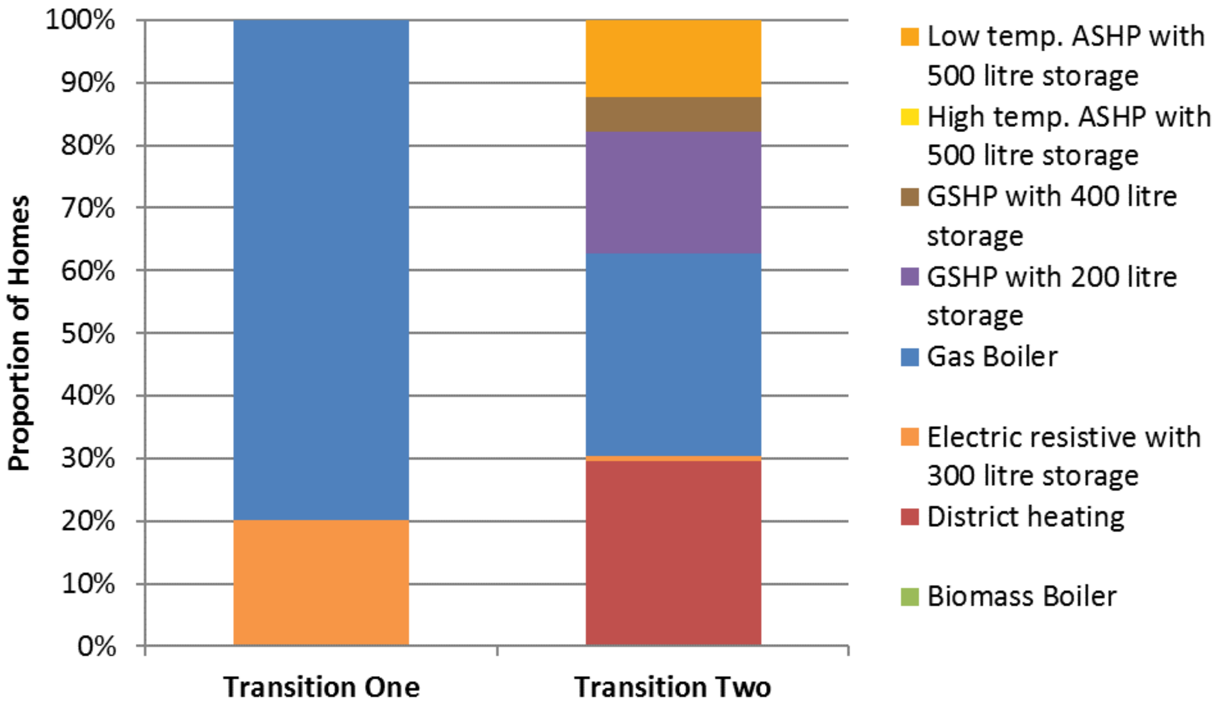
EPN can help to evaluate the total lifetime costs of providing energy to a building including energy sourcing, reinforcing distribution networks for gas, electricity and heat (if it exists), heating system and insulation retrofitting, etc. The EPN analysis framework embeds the capability to compare the costs of several building as well as network design options simultaneously. In particular, the following characteristics can be explored:

- **Insulation measures**: cavity wall insulation, triple glazing, loft insulation, etc.
- **Heating system components**: solar hot water heating, air source heat pumps, advanced heat controls, fuel cells, district heating, etc.
- **Energy production**: biomass district heat boilers, solar photovoltaics, etc.
- **Energy use**: electric vehicles, appliances and lighting demand, comfort level, temperature rise scenarios, etc.
- **Surrounding network design,** comparing several possible electricity distribution reinforcement options, for example building a bespoke HV substation versus connecting to an existing one.

Total whole-system energy costs of different design options over the modelled time horizon would be reviewed to understand the design solution with the most benefits in the context of the wider LA's decarbonisation plan. Figure 19 shows how new build developments in Bury have been 'built' in a model run with a mixture of gas boilers and air source heat pumps but many of these buildings have been transitioned to alternative heating systems as part of meeting the area carbon target at least cost. This information could be used to:

- Help decide which heating systems should be fitted at build time to avoid the need for future change, and to
- Help to ensure that new builds are designed and built so that they are ready for any future transition. For example, by making them suitable for transition to an air source heat pump.

Figure 19 Heating System Pathways for New Builds in Bury



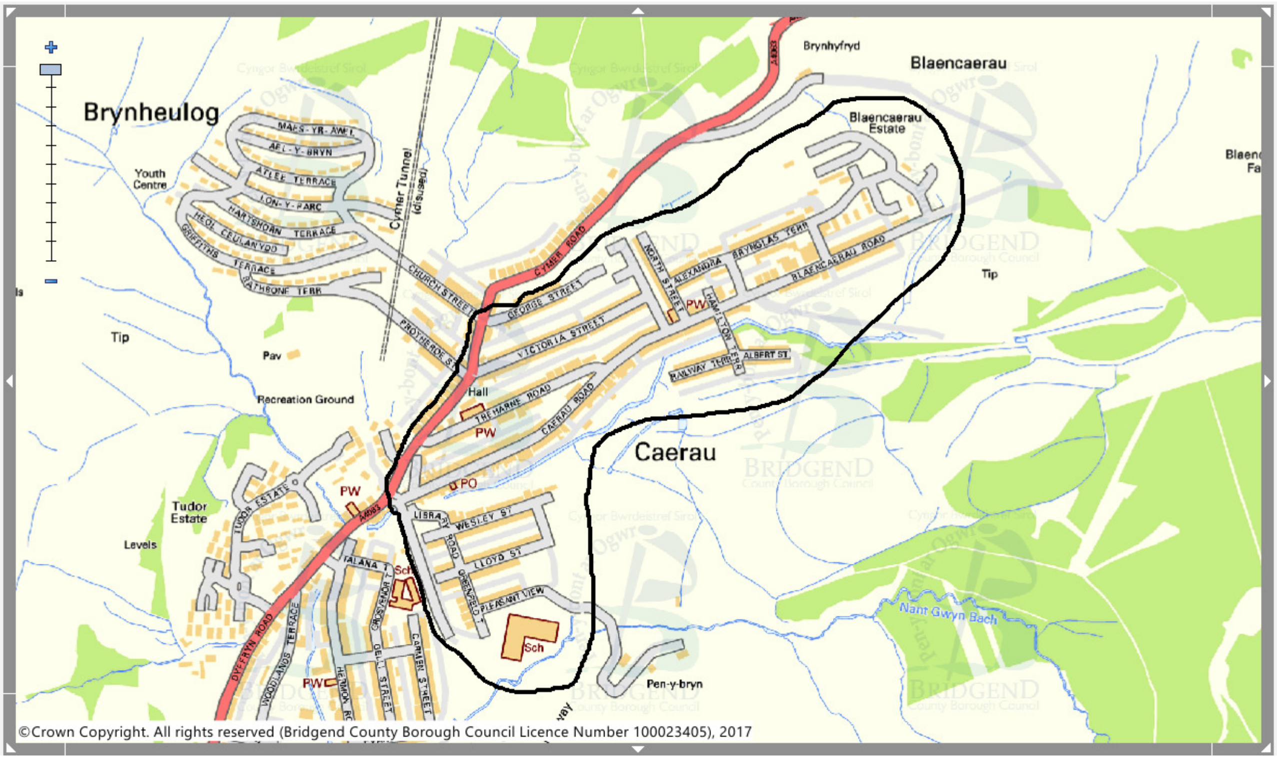
4.2.3 Assess benefits to neighbouring areas

New developments can be designed to be cost-effective in a decarbonised world, but also to provide benefits to their neighbouring buildings. For instance, a heat network scheme can be developed to provide low-carbon heating for new buildings, as it is generally more cost-effective to develop this as part of a new development compared to retrofitting existing buildings. However, this district heating network and its core anchor load could make the progressive extension of a heat network to surrounding – existing – buildings more feasible than it would otherwise have been, thereby providing a transition option to a more efficient and low-carbon heating solution.

EPN can provide an initial assessment of the long-term whole system benefits of such an extension, as compared with other alternatives for decarbonising the surrounding buildings. For example, electrification with heat pumps, re-purposing of the natural gas network to hydrogen, further insulation retrofitting and their benefits with respect to carbon reduction.

Local Areas can incentivise building designs that benefit the wider community and participate in decarbonisation goals, even if they are not the cost-optimal local energy system design identified through EPN modelling. For instance, deploying a district heating demonstration scheme can be considered in the scope of the delivery plan for a Local Area Energy Strategy, as explained in section 2. In practice, whilst an innovative large-scale mine water heat network scheme in Caerau, Bridgend (illustrated in Figure 20) might not be modelled as cost optimal, the area was identified to have high potential for existing homes to transition from gas boilers to heat networks, and has subsequently been awarded funding[29] as an innovative demonstration project which could also have wider benefits for the Local Area in creating jobs, and reducing fuel poverty.

Figure 20 Geothermal mine water district heating scheme in Caerau



4.2.4 Impacts of new development on Local Area Energy Strategy

The impact of new buildings will, in many cases, need to be considered as part of the decarbonisation strategy of the wider Local Area. Using the EnergyPath™ Networks framework as described in section 2, local stakeholders can build the evidence base for how designing new developments can influence the decarbonisation pathways generated for the Local Area. Effects of these new buildings on EPN-generated pathways could range from small to very large:

- **Self-contained**: the new buildings have no influence on the wider Local Area Energy Strategy beyond the analysis area where they sit.
- **Local impact**: in this case, the new buildings' energy design can be used to facilitate decarbonisation of neighbouring buildings, similar to the example in section 4.2.3. This could be particularly significant for analysis areas where the EPN framework's decarbonisation pathways have larger variability i.e. where it is difficult to decide which of the competing whole-system solutions is the clear 'winner' in 2050 as represented by blue areas in Figure 11. The initial design of new buildings could tip the cost-benefit balance in favour of specific pathways: as described earlier, DHN deployment could be seeded with new buildings design.

[29] See the announcement on Bridgend County Borough Council's website here: http://www.bridgend.gov.uk/media-centre/2018/january-2018/19-01-2018-65m-awarded-for-uk-s-first-large-scale-mine-water-energy-project.aspx

- **Wide-ranging impact**: Local Area decarbonisation pathways are significantly changed by the addition of new buildings i.e. with the new development, a significant number of analysis areas in the Local Area switch from their original low-carbon solution to another one influenced by the new buildings. This can be akin to a cascading effect where the solution propagates from one analysis area to the next. This effect may be driven by improved economies of scale for larger networks or due to the need to meet increased overall energy demands within the same absolute carbon target for the Local Area, driving a need for more aggressive abatement.

4.3. Delivering Pathways for Growth Towns and Cities with EPN

In terms of effort required for delivery, this use case can be considered as:

- Similar to use case **[B]** for informing the design of heating for new developments i.e. approximately 3 people for 2 months[30].
- Similar to use case **[B]** for assessing benefits to the neighbouring areas i.e. approximately 3 people for 3 months[31].
- Similar to use case **[A]** for assessing impacts of new developments to the long term LA energy strategy i.e. approximately 3 to 4 people for 6 to 9 months.

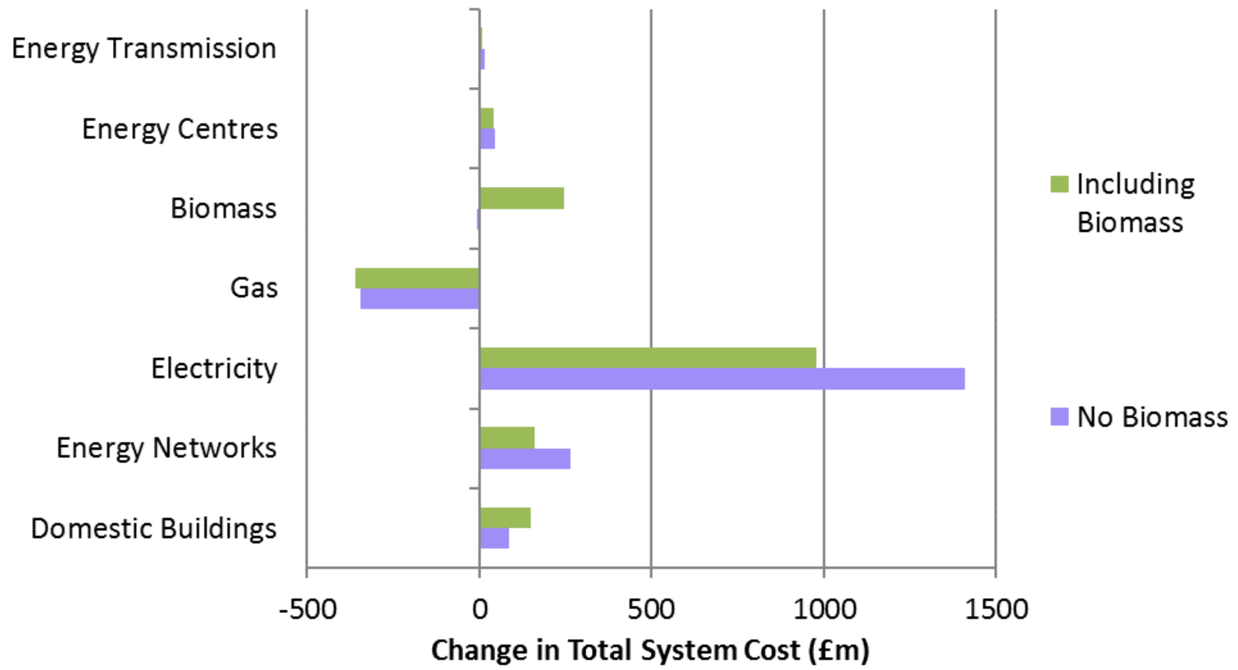
[30] More than 3 sensitivities would require additional effort.
[31] More than 3 sensitivities would require additional effort.

5 [D] Alternative Network Investment Pathway Optimisation Use Case

5.1. Overview

As the first RIIO[32] price control scheme progresses, distribution network operators (DNO) face increasing pressure to find solutions (both investment and operational under RIIO's TOTEX regime) which will ensure secure operation of the system and minimise costs for consumers over the long run. In particular, multi-vector interactions that bring significant whole system benefits should be increasingly considered in DNO's price control submissions. For example, potentially retaining use of the gas network to more cost-effectively manage peak heat demands, through use of gas boiler / heat pump hybrids. Ofgem's recent consultation on RIIO-2[33] has emphasised the need for the next price control regime to better support the delivery of "whole systems outcomes" and for more extensive stakeholder engagement with consumer and other user groups to be undertaken.

Figure 21 Total system costs to meet a given emissions target in NCC with and without biomass, compared to a BaU scenario with no target



EPN has been designed explicitly to take a whole systems approach for assessing long-term cost-optimal multi-vector investments across a local area taking into account buildings, networks and distributed energy; and to use this to facilitate engagement with the various key stakeholders in the local area.

[32] Revenue = Incentives + Innovation + Outputs. The current price controls for gas and electricity transmission (RIIO-T1) and gas distribution (RIIO-D1) networks will end on March 31 2021, and electricity distribution (RIIO-ED1) will end two years later. A new price control scheme (RIIO-2) will be designed to apply to regulated networks after this.
[33] https://www.ofgem.gov.uk/system/files/docs/2018/03/riio2_march_consultation_document_final_v1.pdf

The key difference within this use case compared to the core use case [A] is the need to broaden the coverage of the analysis beyond a single LA to cover the key (or ideally all) elements of the local energy system within the specific DNO's area of responsibility.

Figure 21 above shows the difference in total system cost for two scenarios with the same carbon target. The first (in green) included the option to use biomass locally while the other (in purple) did not. The solution without biomass is estimated to have a total system cost that is £0.3b more expensive between now and 2050. This demonstrates how EPN can adjust the decarbonisation solution (in particular energy network investments) to reflect the options available to help understand the interactions between different energy vectors in the whole system.

This demonstrates how EPN can adjust the decarbonisation solution (in particular energy network investments) to reflect the options available to help understand the interactions between different energy vectors in the whole system. In addition, as stated in Use Case [B] (section 3), DNOs could derive significant benefits from using the EPN Local Area Energy Data Schema without running the full pathway optimisation. In particular, this structured data template would facilitate LA stakeholder engagement and information sharing for price control submissions.

Delivering this use case with EPN could be undertaken via two main routes:

- Heavily simplify the spatial representation of the wider DNO area (e.g. where each analysis area comprises several HV substations) to undertake the core EPN analysis across the entire area of interest.
- Use an existing portfolio of local area studies (or undertake further ones based on representativeness within the DNO area) and compile the aggregate results to the DNO licence area level. Each individual study would be undertaken in a more rapid manner, for example, by limiting stakeholder engagement, given the focus on the broader DNO area as opposed to individual Local Authorities.

Insights from this initial analysis would help to inform, but is not expected to replace, the DNO's own more detailed analysis of the options available (e.g. to increase network flexibility) and constraints applicable (e.g. local carbon targets) in its region. This exercise would be undertaken by a team of 3 to 4 people in around 9-15 months – depending on the starting point used for the local area archetypal studies – and would feed in to the analysis required to prepare the DNO's price control submission.

5.2. Use Case description

EnergyPath™ Networks can help with the analysis of DNO investments, providing evidence base for their value over the long-term taking into account both long-term decarbonisation objectives, and multi-vector interactions[34].

[34] The RIIO-2 scheme is not fully defined at the time of writing this document, so that EPN could be evolved to fit particular regulatory requirements as they arise. Having said that, EPN is built to consider the general issues driving the price control reform.

5.2.1 Building a representation of DNO region

GB is divided into 8 DNO licence areas[35] for electricity and 8 for gas, each containing several LAs. EPN is currently designed to represent a single Local Area (e.g. a city of up to 300,000 people) in detail. To undertake this use case **EPN's geographical scope would need to be expanded** to represent the full DNO region.

This could be done to a limited extent now by **using the existing portfolio of three pilot Local Areas** already modelled. From these, insights around the scale of reinforcement and use of different building and heating system solutions would be extrapolated to the DNO area as a whole, for example, by considering the different solutions deployed across a diverse and representative set of local areas. Using the existing pilot areas – as well as potential future areas for which studies are currently being explored - would minimise the effort required, but may have more limited accuracy if these do not generalise well to a specific DNO region;

Beyond this, there are two main options to expand the geographical scope to better represent the broader DNO region.

- **Running additional EPN studies on carefully selected Local Areas, which act as archetypes that better generalise a broader area.** This would require effort to first assess which Local Areas are most representative of the DNO area (e.g. in terms of population size and expected growth rate, housing stock, network infrastructure, etc. as illustrated in Table 7), to be followed by detailed EPN Local Area Energy Strategy Planning engagements in the selected LAs as described in Use Case [A] in section 2. **This approach would provide the most insights** as the portfolio of LA pathways would be constructed to allow for reasonably accurate extrapolation at the DNO level.
    - Another variant of this approach could involve selecting the top X highest population or growth areas, which contain the majority of the potential for alternative investments, and undertaking detailed EPN studies on each. I.e. to better inform the most material sub-set of changes in the DNO area as opposed to trying to generalise results for the area as whole.
- **Simplifying the EPN model spatial granularity** so that the whole DNO region can be represented in a single EPN model. This option **will require coarse spatial granularity** in the EPN model, therefore potentially **limiting the usefulness of its insights**. For example, it will be difficult to estimate which LV substations require reinforcement if transitions are simulated in areas containing several HV substations (e.g. city-wide). Similarly, experience from three pilot projects shows that district heat network deployment decisions require a fine level of spatial granularity, so that analysis at coarse spatial granularity would need to be revisited locally (e.g. re-running the full EPN Pathway Optimisation focussing on the areas with largest heat density) to correctly account for DHN deployment. For this reason, this option seems to offer the least benefits;

[35] On top of these a number of independent DNOs develop, operate and maintain smaller scale local electricity distribution networks. IDNO networks are mainly extensions to the DNO networks serving new housing and commercial developments, so they will not be considered in this use case, but could be considered as part of use case [C].

Table 7 Mapping pilot LAs to their representative characteristics

Criterion	Newcastle	Bridgend	Bury
Area	113 km2	255 km2	99 km2
Population	292,000	134,000	187,000
Domestic Buildings	127,000	62,000	83,000
Non-Domestic Buildings	18,800	5,600	9,500
Domestic Buildings Off Gas	10,470 (8%)	2,060 (3%)	2,420 (3%)
Electricity Network Length	1,840km	3,340km	2,610m
Number of HV Substations	17	10	9
Number of LV Substations	769	759	570
Annual Gas Demand 2016 GWh	2,698	1,259	1,474
Annual Electricity Demand 2016 GWh	1,196	616	627
Annual Greenhouse Gas emissions kt CO2 2015	1,385	705	747

The last two approaches would provide a representation of Local Areas in the DNO region. These would need to be complemented by an analysis of overarching infrastructure[36], for example, EHV and parts of the gas network at higher pressure levels, which are not considered explicitly within EPN at present given its local area focus.

5.2.2 Exploring scenarios of network and alternative investments

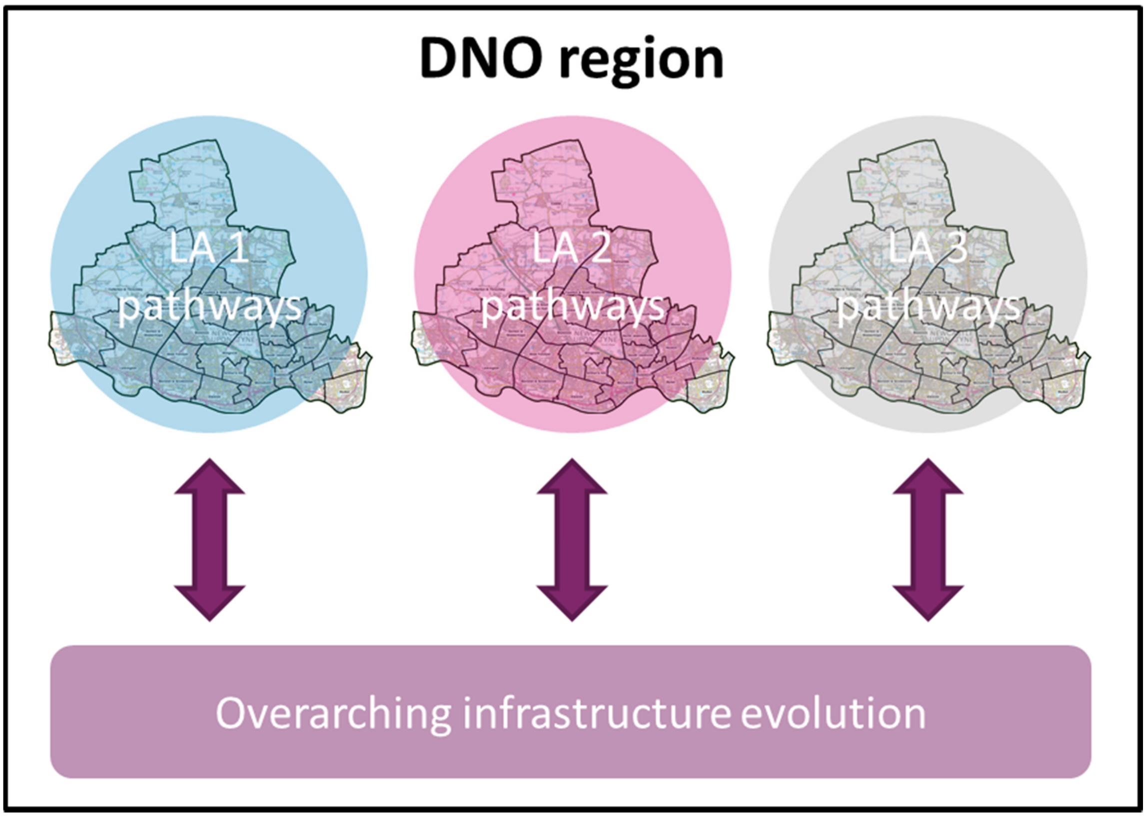
Once the number and location of the individual areas are selected (which serve as the archetypes for the DNO licence region as a whole), the insights from their decarbonisation pathways will need to be updated and extracted. This will likely involve re-running of EPN for each individual area archetype to ensure the scenarios for each pathway are created on the same basis (e.g. using a consistent set of commodity price and technology cost assumptions).

The results of the individual EPN archetype runs will then be extrapolated and aggregated (with appropriate weightings depending on how representative each is within the wider region) to understand how they affect the DNO region as a whole in terms of its overarching decarbonisation pathway. For instance, whether the DNO region could see substantial transition to district heating thereby limiting required reinforcements on the electricity network. This process of distributed analysis (for all relevant LAs in the DNO region) and collation of results (at the DNO region level including the off-model infrastructure) is illustrated using NCC[37] as an archetypal LA in Figure 22 below.

Clearly the number and selection of the area archetypes is critical to how well they can represent the DNO region in aggregate and the overall level of resources required to undertake the analysis; whilst bearing in mind that the purpose of EPN in this use is to provide additional planning information from a whole systems, multi-energy vector perspective, and not to replace the DNO's detailed planning tools. This would need to be explored in close collaboration with the relevant DNOs, but for the purposes of this use case it is assumed that 5 to 10 is sufficient.

[36] To be developed in a future version of EPN or simply performed off-model.
[37] In an actual Alternative Investment Pathway case study, the DNO region would be represented with several different archetypal LAs.

Figure 22 Constructing EPN Alternative Investment Pathways by assembling several LA pathway optimisation studies



The insights from the archetypes should then be combined with existing expertise from the DNO to:

- **Parametrise and refine investment options** for the EPN analysis framework using analysis of previously identified conventional and alternative solutions such as storage, DSR, smart networks, etc. This could be done by pre-processing the network reinforcement options passed to the optimiser e.g. embedding the cost of smart technologies and increasing the available headroom. This would allow the optimiser to trade-off a simplified representation of smart network technologies against conventional options but would need to be informed by the local DNO's expertise to test the right smart devices in the right locations. I.e. by helping the DNO to understand better the conditions under which specific investments are more effective and then feeding this into their detailed planning tools to identify specific locations within their licence area.

- **Represent the knock-on impact of non-modelled infrastructure** in EPN for example EHV as well as regional gas network reinforcements triggered by electrification and hydrogen repurposing respectively. This could also include the impact of additional local electricity generation. These additional infrastructure costs could be modelled in a future version of EPN or simply estimated using DNO's expertise and added to the costs of the appropriate HV substations.

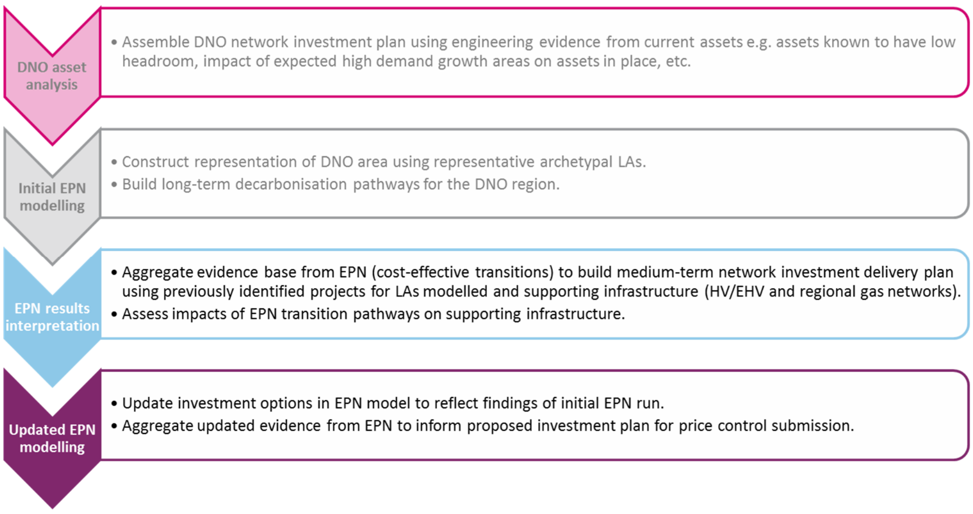
- **Represent regional decarbonisation ambition** in EPN at the DNO level.

This exercise would lead to the preparation of a series of EPN models representative of the **DNO's best view of its region's evolution**. Compared with use case [A], this could potentially involve collaboration with a larger group of stakeholders e.g. the largest LAs, the electricity and gas DNO, local DHN scheme operators, devolved governments, etc. to develop these studies and regularly update them over time. However, it is expected that this engagement is lighter touch outside of the core electricity and gas DNO scope given the focus of this particular use case. In particular it would call for less detail in representing buildings e.g. secondary insulation measures, advanced heat controls, gas heat pumps etc. could be omitted from this study.

Results from these regional models could be analysed to inform the electricity or gas DNO's price control submission. For instance, they would provide evidence as to the cost-effectiveness of the identified investment program in the context of the gas and electricity network operators along with competing alternative investments such as heat networks or building retrofitting. Figure 23 below recaps how EnergyPath™ Networks can complement the analysis of network investment planning already carried out by DNOs to provide Ofgem with a price control submission that more explicitly considers options across the whole energy system:

- The first two preliminary analysis steps, shown in grey text below, relate to gathering data to represent the DNO region. This requires careful selection of a subset of local areas which when analysed in EPN can serve as archetypes to scale and aggregate to represent the DNO region as a whole.
- The third step in this process consists in assembling initial pathway optimisation results for DNO region from archetypal LAs gathered at the previous steps. Note that it is described in more detail in Figure 22 above.
- Finally, the last step calls for refining the study using the DNO's expertise combined with feedback from the initial pathway optimisation runs in the previous step. Outputs from this final decarbonisation pathway at the DNO region level could be used in preparing the price control submission, by provide whole systems, multi-vector view of decarbonisation to complement the other detailed planning tools that are also used as part of the submission.

Figure 23 Using EPN to contribute to the analysis for a price control submission



5.3. Delivering Alternative Investment Pathway Optimisation with EPN

5.3.1 Preliminary creation of representative LAs

This use case differ significantly from [A], [B] and [C] in that it **requires preliminary work to** either:

- Design a heavily simplified mode for running EPN, or the more likely and preferable route
- **Assemble a portfolio of representative local area archetypes**, where the results can be extrapolated to a broader geographic region.

The first option would likely require significant effort (6 to 12 months) to update and test the EPN analysis framework, shared between modelling analysts and the EPN development team, whereas the creation of archetypal local areas would call for the selection of real-world local area for EPN deployment according to their key characteristics (e.g. degree of urbanity or rurality) and how representative they are of the broader geographic area when they are combined. Assembling such a portfolio of representative Local Area studies could require a team of 3 people for approximately 2 to 4 months for methodology development (i.e. which LAs can be used as templates), data gathering and analysis for an assumed 5-10 archetypal Local Areas. Running simple pathway optimisation studies for each of these selected archetypal LAs would take an additional 5 to 10 months (1 month per archetypal LA) for a team of 3 people.

Note that the selection and creation of the archetypal areas would ideally be undertaken once and these could be re-used, subject to their representativeness, for multiple DNO regions or nationally as in use case [E]. Once a comprehensive portfolio of LA decarbonisation pathway studies has been assembled, the effort and timescales mentioned above would be considerably reduced – additional investment would only be required to add new LAs to the portfolio or update the analysis.

5.3.2 Delivery of DNO investment pathway optimisation

Once the representative LAs have been created, delivering the DNO investment pathway use case would follow these steps[38]:

1. Parametrisation of the EPN LA archetype models to model DNO region could require around 3-6 months of work, assuming around 5-10 LA new archetypes are needed (this would be lower if existing areas can be re-used) and an appropriate level of engagement with other network and Local Authority stakeholders
2. Running underpinning LA EPN models would take a further 4 to 6 months depending on the number of LA archetypes to run (versus ones where pre-existing results can be re-purposed) and sensitivities (e.g. testing how smart technologies impact the network investment plan) required.

---

[38] Estimates are based on a team of 3 to 5 people.

3. Building a representation of DNO region using a weighted portfolio of archetypal areas. This could take a further 2 to 3 months, depending on the complexity of the DNO area and additional engagement with stakeholders on results.

6 [E] Test Bed for Innovations Use Case

6.1. Overview

The EPN analysis framework supports the creation of energy pathways specific to a local area, taking into account its unique characteristics and issues. However, being able to **generalise the resulting insights at the national level** (e.g. around the most cost-effective types of low carbon heating system or how extensively to deploy heat networks), **would provide significant value to** additional stakeholders:

- For **UK Government, Ofgem and other national institutions**[39] in terms of helping to formulate and assess the impact of new decarbonisation policies. EPN would give an estimate of the system-wide value of technologies which could be used to define the level of subsidy required to spur adoption. EPN analysis would then provide the evidence that policymakers can use to design new support regimes (for example overcoming cost barriers or tackling misaligned incentives).
- For **new technology developers and innovators** as it provides an indication of the cost and performance thresholds for innovative technologies to gain a potential system-wide value for a particular LA or the UK market as a whole. EPN can help inform the focus of research and development, but would need to be complemented by significant other work to define the customer value proposition and business case, as well as to meet all technical and regulatory hurdles required for successful commercialisation. It is important to note that:
    - This techno-economic analysis represents an indication of the whole-system value of innovative technologies and should be supplemented with a commercial evaluation to address other possible hurdles such as consumer acceptance, commercial risks (e.g. crafting a value proposition for individual customers as opposed to system-wide value in EPN) and suitable routes-to-market to recognise the value of the these technologies (as current market structures may mean that the additional benefit to the system of the technology does not necessarily flow back to the investor), etc.
    - Beyond research and development (technology innovation), re-structuring the supply chain (to reduce installation, maintenance, and financing costs) could be necessary to deliver the performance and cost levels required for large scale UK-wide deployment, as well as ensuring technology production at scale.

This use case differs substantially from [A], [B] and [C] in that the analysis is undertaken for a number of defined 'archetypal' local areas, underpinned by the ESC's portfolio of EPN analyses on representative real-world LAs. The definition of these archetypes would ideally align with existing definitions[40], in part to

[39] Note that this use case can also apply at the local level, as covered in Use Case [A] in section 2.3.2.
[40] For example, DEFRA's rural-urban classification methodology https://www.gov.uk/government/collections/rural-urban-classification

support data gathering, but noting that there exists a wide variety of spatial classifications used for different purposes by Government and other organisations. The results from these archetypal areas would be combined and weighted accordingly to represent the UK as a whole.

Delivering this study in practice depends on the approach to creating the archetypal LAs:

- The first is to select and analyse a series of new local areas which are good archetypal representations of the different types of areas across GB (in a similar manner to use case [D]) and undertake end-to-end analysis comparable with that in use case [A] on these LA archetypes. This could require a team of approximately 3-4 people over a circa 7-14-month period[41]. Note that part of this time is associated with the development of the new archetypal areas themselves and assumes a more limited degree of stakeholder engagement.
- The second is using a previously completed set of EPN projects across multiple UK cities as the starting point for the archetypes of local areas, potentially with some degree of tailoring or further analysis. This could require a team of 3 people for around 6-12 months given much of the detail around the underpinning archetypal areas is assumed to be in place already.

In both cases, results of the new or updated archetypal analysis would then be aggregated to the national level, with some weighting across the areas to reflect their relative importance.

6.2. Use Case description

The EPN analysis framework supports the creation of energy pathways specific to a local area, taking into account its unique characteristics and issues. However, being able to **generalise the resulting insights at the national level** (e.g. around the most cost-effective types of low carbon heating system or how extensively to deploy heat networks), **can provide significant value**.

6.2.1 Analysis of policy option for GB decarbonisation

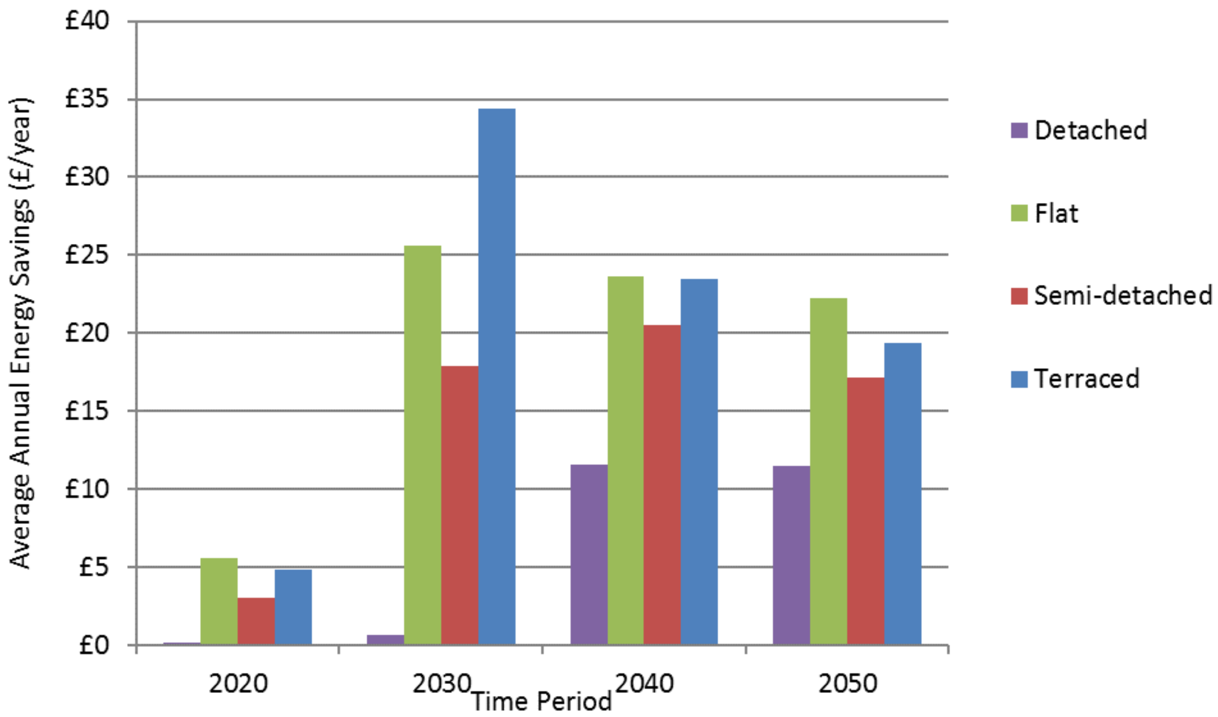
Since the 1990s, several policies[42] have been enacted into law by the UK government to reduce CO_2 emissions and increase energy efficiency of buildings through window, roof insulation, boiler retrofitting and more efficient lighting. Despite this effort, the majority of the UK building stock would still benefit from further energy efficiency improvements to help the UK achieve its emission reduction targets as cost-effectively as possible.

EnergyPath™ Networks would help provide a more robust evidence base to help target energy efficiency and other local-area specific improvement measures in a cost-effective manner nationwide, by evaluating their full system benefits in the context of deep decarbonisation. Figure 24 below shows average annual savings on energy bills as a result of advanced retrofitting by property type in Newcastle.

[41] This assumes analysis is carried out for 5 to 10 additional LAs.

[42] The Energy Efficiency Standards of Performance (1994-2002), the Energy Efficiency Commitment (2002-2008), the Community Energy Savings Programme (2009-2012), the Green Deal (2012-2015) and finally the Energy Companies Obligation (2013-present) are some of the schemes implemented specifically to reduce energy demand through efficiency measures.

Figure 24 Average annual energy bill saving due to advanced efficiency retrofits



Extending these findings at a national level would require:

- Developing a portfolio of EPN decarbonisation pathway analyses across several representative LAs. This would require selecting new archetypal LAs from first principles as explained in section 5.2.1;
- Building a representation of GB using these archetypal Local Areas in the appropriate proportions; and
- Analysing the resulting aggregated decarbonisation pathways to understand the full system-value of several insulation measures (including avoided network reinforcements), critical price-performance points for enabling large-scale deployment and whether specific patterns can be revealed (as per the example above across different building types or by rural versus urban area, etc.) to better target policy support.

6.2.2 Analysing technology tipping points

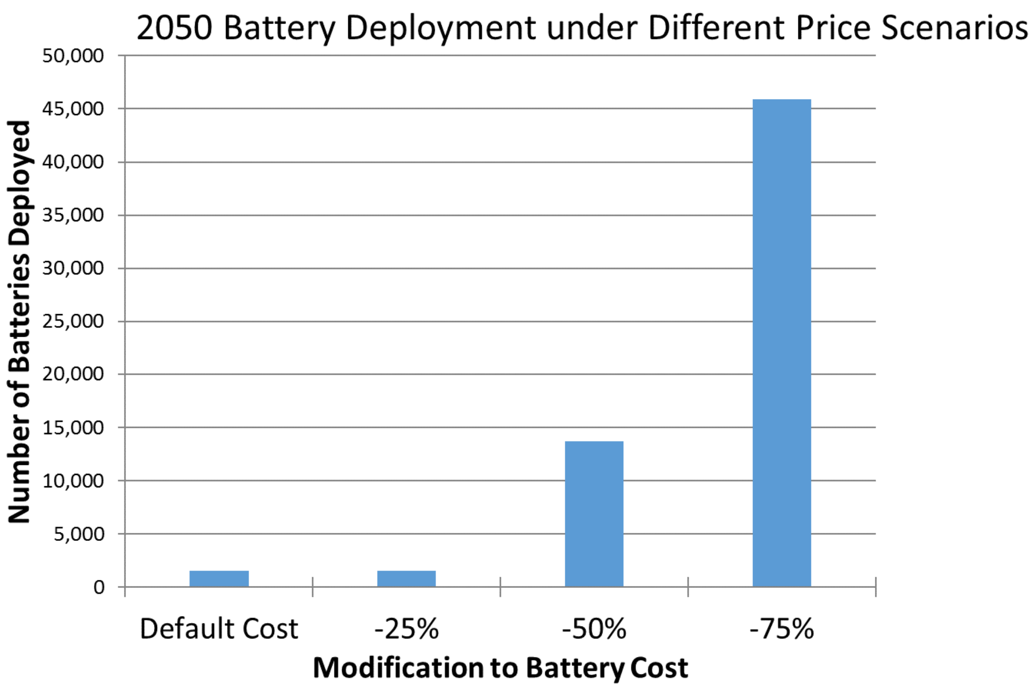
Analysis conducted during the three pilot EPN deployments showed a sizeable potential for new district heating schemes underpinned by low-carbon heat supply such as large-scale heat pumps. However, it is important to understand how robust these conclusions are to a variety of input assumptions to understand the tipping points that drive step changes in deployment of the technology. **Technology adoption tipping points can be driven by**:

- **Assumptions for the specific technology of interest**: for instance testing the impact of capital cost reductions due to mass adoption, or evaluating the benefits of a more efficient supply chain on deployment as installation costs reduce; as well as by

- **Wider system conditions** that may be less or more favourable e.g. tighter emissions targets and expensive fossil fuel prices would encourage energy efficiency and shift to low-carbon sources of heating.

Figure 25 shows an example of the sensitivity of final deployment of domestic batteries to their total cost in Bury by 2050. This analysis would need to be repeated using each of the representative Local Areas to evaluate cost targets required for potential deployment at the national scale. Note again that these cost thresholds are calculated based on system-wide value of the technology and do not necessarily represent the consumer-facing issues required to enable similar levels of commercial uptake (e.g. a faster payback period than is implicitly assumed in the EPN analysis).

Figure 25 Deployment of domestic battery storage in Bury



Building on these use case results, separate follow-on analysis would then be undertaken by the technology developer using this information to:

- Understand how these cost reductions could be achieved in practice e.g. further technology innovation, supply chain efficiency improvement, etc.
- Determine how other commercial challenges (e.g. consumer acceptance, safety requirements, business plans) could be addressed.

6.3. Delivering Test Bed for Innovations with EPN

As per use case [D], this requires a portfolio of archetypal LAs to construct a view for a larger geographic area, in this case to represent the national-level. The following tasks would need to be completed to perform this analysis:

- Developing a set of new archetypal local areas could require a team of 3 to 4 people for approximately 7 to 14 months for methodology development, data gathering and analysis for an assumed 5-10 archetypal areas: this breaks down between 2 to 4 months for determining the right LAs to add to the portfolio (based on their GB representativeness as explained in section 5.2.1) and then 1 month of analysis per selected LA. Using pre-existing LA archetypes could reduce this to circa 1 month.

- Performing the technology or policy analysis itself on the archetypal areas and aggregating the insights to the local level could take around 6-12 months, depending on the number of LAs to aggregate and the number of sensitivities to be run.

Document Control

This document has been prepared by the Energy Systems Catapult Ltd on behalf of the Energy Technologies Institute LLP

Programme	Smart Systems and Heat Phase 1
Project	WP2 Bidders Pack
Title:	EPN Knowledge Transfer Bidders Pack D1 Use Cases for EnergyPath™ Networks
ETI Project Number:	ESC00066
ETI Project Number:	SS9016
Version:	Version 2.2
Status*:	Draft
Restrictions**:	Confidential
Completion Date:	18/03/2018
Author	Baringa
Reviewer	Mark Bornhoft, Grant Tuff, Richard Leach
Approver	Richard Halsey

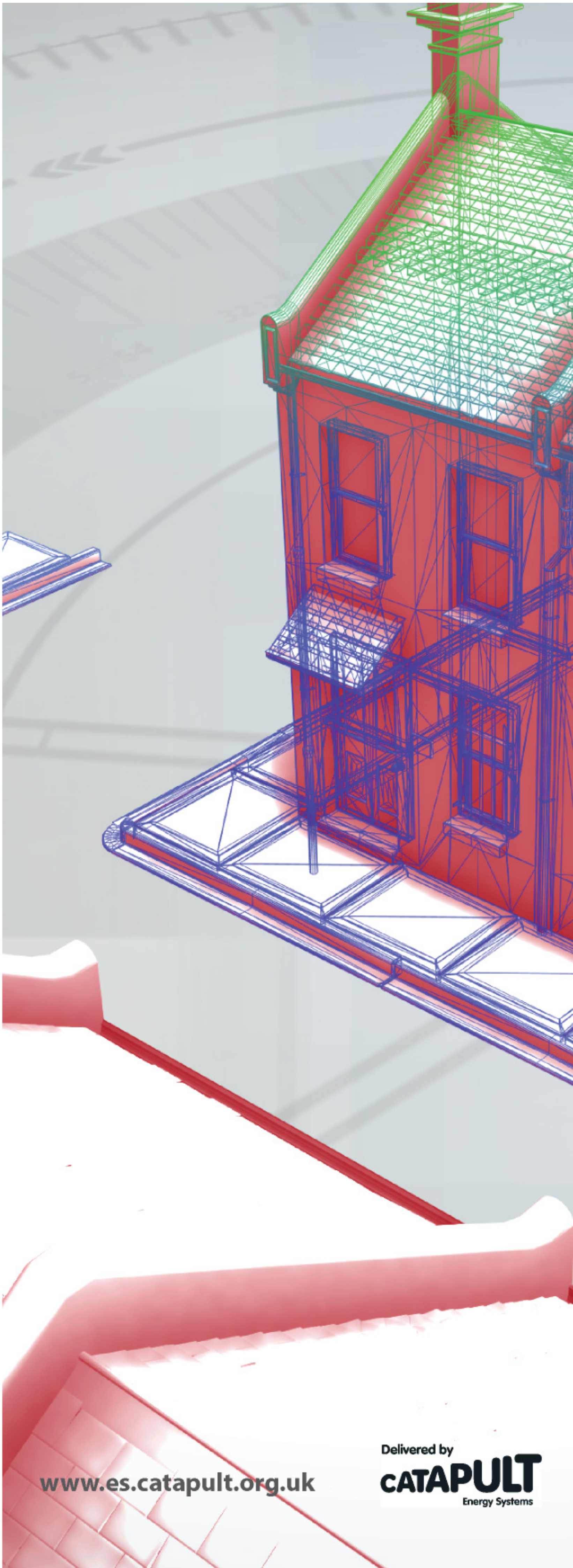
* Status defined as follows – Draft: Contains preliminary information only. Released: Contains reviewed and approved content.

** Restrictions defined as follows:
Public: Regarded as "within the public domain".
Confidential: Contains confidential information of the ETI and comprises intellectual property rights, including copyright, belonging to or licensed to the ETI.
Confidential (R): As Confidential, however certain information or data has been removed due to confidentiality, commercial, or license requirements. To request access to the full (Restricted) version, please refer to the document provider Energy Systems Catapult Ltd and / or contact the ETI (www.eti.co.uk).
Restricted: As Confidential, however additional restrictions apply (as detailed in this chapter) due to confidentiality, commercial, or license requirements.

Note that for all documents, copyright, trademark, license, and disclaimer restrictions apply.

Revision History

Date	Version	Comments
September 2017	V0.1	Draft skeleton
November 2017	V0.2	Initial draft
January 2018	V1.0	Revised draft
March 2018	V2.0	Final review



www.es.catapult.org.uk

Delivered by CATAPULT Energy Systems