ANNEX A

Local Area Energy Planning: The Method

FINAL REVIEW DRAFT 30 July 2020

Centre for Sustainable Energy and Energy Systems Catapult

For Ofgem

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Title	**Local Area Energy Planning: The Method**
Purpose	Deliverable 1 of Local area energy planning discovery project for Ofgem
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Background	This report from the Centre for Sustainable Energy (CSE) and the Energy Systems Catapult describes the purpose and value of local area energy planning (LAEP). It identifies four critical elements of LAEP and sets out quality criteria for each element which together define what LAEP 'done well' involves. The report was commissioned by Ofgem and has benefitted from the input of a Steering Group including the Department for Business Energy and Industrial Strategy (BEIS), the Committee on Climate Change, the Scottish Government, the Welsh Government and Innovate UK. The report is part of a wider project for Ofgem commissioned in February 2020 which also reviewed (a) the different approaches currently available to model local energy systems and (b) how local area energy planning could support better proposals and decisions in the planning of energy networks across GB. This is a ***Final Review Draft***. The final version may be subject to revision as a result of further discussions with members of the project Steering Group and other contributions.
Comments	Comments on this report can be provided to Simon Roberts at Centre for Sustainable Energy on simon.roberts@cse.org.uk

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Executive Summary

Local area energy planning (LAEP) is a process which has the potential to inform, shape and enable key aspects of the transition to a net zero carbon energy system.

If done well, LAEP can provide sound foundations for effective and sustained local action to cut carbon emissions taken by well-informed local leaders and initiative-takers. They will have a shared purpose and a clear plan outlining the changes needed over time to achieve local commitments on net zero carbon emissions. And they will understand what others – such as national government, regulators and energy networks – need to do (and when) alongside them to establish the conditions for success.

This document outlines the four key elements that constitute LAEP and which in combination can ensure these positive outcomes are achieved.

- The use of robust technical evidence produced using analytical techniques which consider the whole energy system and make consistent use of available data, and whose strengths and weaknesses are well understood.
- A comprehensive assessment of wider non-technical factors which need to be understood and addressed to secure change.
- A well designed and involving social process which engages appropriate stakeholders effectively, uses the technical evidence appropriately, and manages vested interests effectively, thus ensuring the resulting plan can be seen as an informed and legitimate representation of local intent in relation to energy system decarbonisation.
- A credible and sustained approach to governance and delivery.

It is important to see all of these elements as equally critical. Without an effective social process, the buy-in of stakeholders, and an understanding of all the changes needed to succeed, any results from technical modelling will remain an interesting set of data, graphs and maps; it will not become a plan being put into action.

This document sets out how each of these critical elements of LAEP can be done well, including describing key issues to consider and techniques which could be applied.

It provides guidance for those looking to undertake, commission, fund, or simply participate in LAEP on how to approach the different aspects of the process.

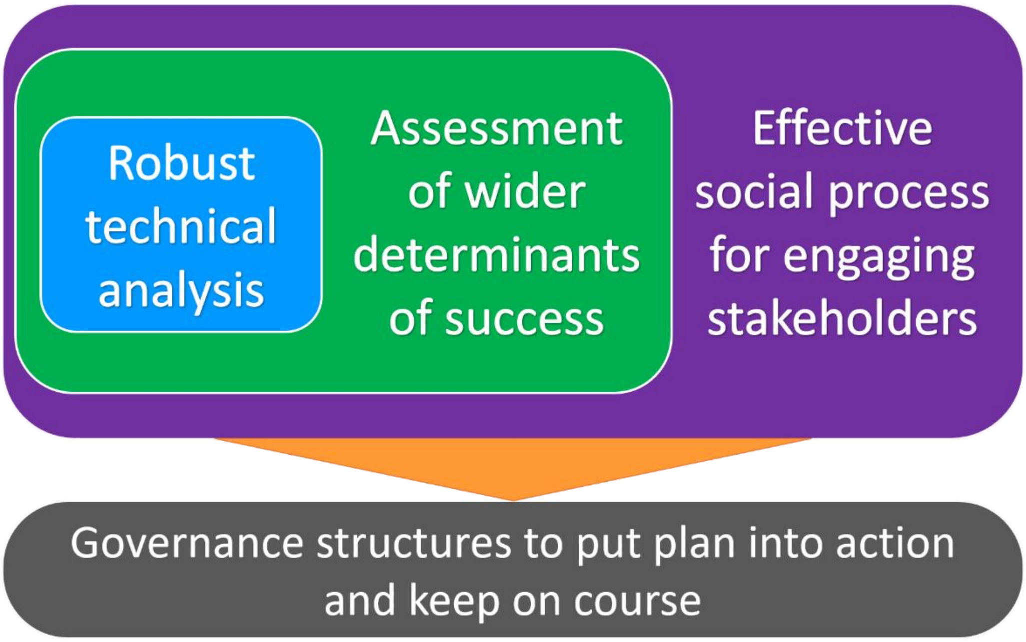
By outlining criteria for good quality LAEP – the 'done well' checklists for each of the four elements – the document also provides a quality assessment framework.

These 'done well' criteria can therefore not only help guide the design and delivery of the LAEP process. They can also enable a systematic assessment of the resulting plan's analytical quality, representative legitimacy and likelihood of delivery. This will assist those parties – from energy networks and national governments to innovators and developers – potentially looking to draw on the resulting local area energy plans to inform their own plans for a particular locality or to target their efforts, funding and investment within or between localities.

The LAEP Method outlined here will enable LAEP to be undertaken on a more consistent basis in different places across Great Britain. It should also ensure that the process produces more reliable and informative outputs which are therefore more useful and influential at the local, regional and national levels.

Each of the four elements of LAEP is addressed in a separate section in this document. The associated 'done well' checklists for each element are presented below.

The four key elements of local area energy planning



LAEP 'done well' checklist: robust and consistent technical analysis

If a local area energy plan has been done well, the technical analysis undertaken to produce the underpinning evidence of energy system changes needed to achieve agreed objectives will reflect the following considerations:

Overall approach

☑ Technical analysis should **combine decision and scenario modelling**, enabling stakeholders to understand the cost and carbon emissions implications of a range of alternative plans, relative to a known low/least cost solution.

☑ The **energy system scope** of the analysis must include: local generation opportunities for low/zero carbon heat and power; distribution networks for electricity, gas and heat; use of distributed hydrogen where regional/national contexts suggest it may be an option; heat demand in buildings, and the opportunities for managing and meeting it; expected demand for EV charging, and its impacts on electricity distribution systems.

☑ The analysis should represent the energy system components and their relationships in **sufficient detail to capture important interactions between vectors**. The level of detail must also be sufficient to avoid excluding potentially valid solutions. This means that supplies and demands (such as buildings) should represented independently at their spatial locations; the representation of demand in buildings should allow modelling of the effects of demand management measures; network representation should account for geographic routing, system sizing, and network connectivity (including the terminal connections to demands); and changes in demand should propagate up networks, to capture interactions between decisions regarding different demands connected to the same network. Where gas networks will be required to carry hydrogen, some estimate of the cost of repurposing should be included. Changes in energy cost should be quantified to enable analysis of fuel poverty impacts, and emissions of local air quality pollutants should be quantified and potentially constrained in decision modelling.

☑ **Representation of time** i.e. how the system will change over time, should include operational (annual and peak demands) and planning (multi-year) horizons. The rate of installations of different technological options over time should be characterised, taking account also of non-technical factors which will affect rates of installation, such as supply chain readiness, consumer appetite etc.

☑ The **geographical scale** selected for the LAEP technical analysis should be clearly defined and reflect a balanced appraisal of the issues described in discussion on 'scale' in Section 1.

☑ The sensitivity of modelling results to **key uncertainties** (e.g. fuel prices, plant costs and efficiencies, weather effects) should be presented to participants in the social process along with the results themselves.

☑ The **data inputs and their sources** should be detailed transparently. Where possible, standard inputs should be used to represent costs, efficiencies and availability of technologies, the attributes of fuels, the nature and location of potential and actual supplies, demands and distribution networks, and assumptions about future climatic conditions. (REFERENCE 'DATA AND ASSUMPTIONS REPORT' FOR 'STANDARD'). When non-standard inputs are used, this should be explained and justified.

Quality assurance

☑ **Validation of models**: The technical analysis should be accompanied by documentation explaining and justifying how the models used actually work. This must be in sufficient detail to enable readers to understand what is being calculated (as opposed to what it is supposed to represent). It should include a frank assessment of the weaknesses of the approaches taken so that outputs can be treated with appropriate care by stakeholders (rather than treated as 'truth').

☑ **Validation of numerical inputs:** Where non-standard values are being used as inputs to modelling, detailed sourcing and justification must be provided. This should include quantitative evidence that critical values (such annual and peak energy demands) are plausible – for example by comparison with external data.

☑ **Verification of implementation:**
At a minimum: detailed documentation explaining how the model implementation has been tested, the results of that testing, and why the approach taken to testing is appropriate. This should include quantitative evidence that the outputs of the model are plausible.

Better: development and application of a formal third-party verification process to ensure that the implementation is free of critical bugs. This would benefit from access to model source code, which would have to be structured to address any concerns about commercial sensitivity.

Ideally: independent expert review of the design, implementation and performance of the model based on review of the model source code.

LAEP 'done well' checklist: understanding the wider determinants of success

If local area energy planning has been done well, it will reflect a good understanding of the full range of conditions required for success in delivering decarbonisation locally and their current state of play. The LAEPlan should therefore include:

☑ An explanation of the different non-technical factors – from skills and supply chains to relative costs and consumer perceptions to national policy and funding decisions – which will need to be addressed if the technological options are to come forward at the rate and scale identified as required.

☑ A description of the conditions for success for each of these factors that need to be put in place over time to secure the required societal and energy system changes.

☑ A picture of the current state of play for these conditions in the locality so that the plan starts from where things are now. This should include those factors which relate to national policies, regulations, market conditions etc which may be similar everywhere but which still have a strong influence on what will happen locally.

☑ An account (also informed by the technical analysis) of how the rate of implementation of the different decarbonisation solutions (e.g. number of buildings insulated each year) is influenced by these non-technical factors and how this is reflected in the implementation trajectories identified in the plan to meet the adopted decarbonisation commitments.

☑ A set of timetabled actions to be undertaken as part of the plan to realise these conditions for success locally. This should include actions needed from non-local stakeholders such as government or regulators – and how the locality will influence such stakeholders to take these actions to support local efforts.

LAEP 'done well' checklist: evidence of an effective social process and engaged stakeholders

If local area energy planning has been done well, it will be able to demonstrate that it has both shaped and been shaped by the perspectives of a decent range of relevant local stakeholders. The LAEPlan should therefore include a description of the social process involved in its production, featuring:

☑ An outline of the design of the social process, including the range of stakeholder engagement techniques involved, the intention of each element at each stage of the process, and how they were conducted to manage the influence of vested interests and to ensure differences of opinion were heard and explored.

☑ A stakeholder map for the locality, detailing the role of each stakeholder and characterising their potential influence/agency on outcomes, and demonstrating that a sizeable proportion of them, including those with significant potential influence and/or agency, engaged with the development of the plan.

☑ Details of the stakeholders who were involved in the process, the seniority and/or authority of their attendees, and the nature and extent of their involvement in each element (e.g. attended workshops, commented on drafts, participated in steering group etc). This should also identify those stakeholders who did not get involved. To be credible as a process, stakeholders involved must include the relevant local authorities (both member and officer representation), energy network operators, local business representatives and community organisations.

☑ Evidence of how stakeholder views changed (or not) during the process, both about specific issues and also about level of commitment they were prepared to make to act and work together on the delivery of the LAEPlan.

☑ A description of how each of the different elements of the process contributed to the development of the plan and an acknowledgement of those areas which proved difficult to resolve.

☑ In all of the above, evidence which demonstrates that the process was suitably transparent and open and managed in a way which kept it free of the undue influence of vested interests.

LAEP 'done well' checklist: a realistic and deliverable plan

If local area energy planning has been done well, the LAEPlan will include:

☑ An articulation of a realistic sense of local agency which reflects:

(a) the objectives and priorities of the locality

(b) the powers and influence available to stakeholders across the locality

(c) an understanding of what commitments and changes are required from other stakeholders, including national governments, to enhance local agency and create the conditions for success and what local actors (potentially in alliance with others) can do to secure these commitments

(d) awareness of the dependence on wider conditions and future national decisions that could influence the availability of some technical options (e.g. hydrogen) in the locality, whatever the local technical evidence or local preferences had anticipated.

☑ A range of endorsements and commitments to act from key local stakeholders.

☑ An awareness of the further analysis and programme design which will need to be undertaken to finalise delivery plans for new infrastructure, network investment or building upgrades.

☑ A description of how the plan will be taken forward in terms of governance arrangements and how progress will be monitored and driven forward

☑ A timetable for monitoring and reviewing progress and for updating the plan to reflect that progress and changes in local and wider circumstances (e.g. technology cost reductions, policy changes, new funding opportunities, changes in social norms and public willingness to act as technologies and behaviours become more common etc).

1 Introduction: The value of local area energy planning and the purpose of this document

Local area energy planning (LAEP)[1] is a process which has the potential to inform, shape and enable key aspects of the transition to a net zero carbon energy system.

If done well, LAEP can provide sound foundations for effective and sustained local action to cut carbon emissions taken by well-informed local leaders and initiative-takers. It will enable these actors – from local authorities and other public sector bodies to businesses, charities and community groups – to establish an explicit shared purpose and to work with the consent and involvement of a range of stakeholders and the wider public. They will have a clear pathway setting out the changes needed over time to achieve local commitments on net zero carbon emissions. And they will understand what others – such as national government, regulators and energy networks – need to do (and when) alongside them to establish the conditions for success.

This document sets out how LAEP can be done well. It provides guidance for those looking to undertake, commission, fund, or simply participate in LAEP on how to approach the different aspects of the process. It outlines criteria for good quality LAEP – the 'done well' checklists at the end of each section – and thus provides a quality standard for those, such as energy network companies, who may be looking to rely on LAEP as an input to their own plans.

This document can therefore:

a. assist with the specification of technical analysis and other activities being procured

b. guide the design and delivery of the process

c. help to ensure participants in LAEP are better equipped to determine whether the technical evidence provided and other elements of the process are of sufficient quality

d. provide a systematic framework for the quality control of the plans which result.

If done well on a widespread basis, LAEP and the resulting local area energy plans (LAEPlans)[2] can inform and enhance the design, development and targeting of regional and national policies, programmes and funding and shape energy network investment plans and their regulatory oversight.

This is because, done well, local area energy planning can lead to:

- **Improved understanding of what the transition to achieve net zero carbon emissions is likely to involve and cost in a particular locality over time**

This includes the nature, scale, rate and timing of changes to how we heat our buildings and the quality of their energy performance, how and when we generate, use or store electricity, how we fuel industrial processes, and how people and goods move about. Exploring these issues through robust technical analysis at a local level, informed by an understanding of the influence of national factors, will reveal the potential implications for investment in local infrastructure

1 In this document we have used the acronym 'LAEP' to refer to local area energy planning as the process, and 'LAEPlan' as the documented output of the process.

2 See Footnote 1

such as energy networks as energy demand levels and patterns of use change. In addition, it will enable the relevant local conditions to be reflected in far more detail than can be achieved in national-level analysis.

- **A clearer picture of the wider conditions, locally and nationally, required for these changes to take place in a locality to meet adopted commitments to achieve net zero carbon emissions**

This includes revealing what needs to change (and when) to support the energy system transition not just technologically but also in terms of skills and capacity, commercial and market factors, policy and regulatory design, and socio-cultural conditions. It will also reveal what powers and resources are needed to secure these and the associated dependencies between national and local decision-making and action. This will lead to:

- **Increased local stakeholder awareness of what needs to be done over time to achieve net zero decarbonisation targets and more widespread and meaningful consent for the changes required**

This results from an effective social process as part of local area energy planning which engages relevant stakeholders and provokes debate based on robust evidence, enables and builds shared understanding, and informs, shapes and reveals options, trade-offs, preferences and priorities. Such involvement can foster wider consent for the nature and scale of changes needed and the actions required both locally and nationally to deliver them.

- **More comprehensive and effective local, regional and national plans to create the conditions for success**

Good quality LAEPlans can inform not only what needs to happen by when in the locality in question but also, in combination and through co-operation with adjacent areas, what is needed from regional and national stakeholders in their own decarbonisation plans.

- **Credible commitments to action from local stakeholders to deliver the plan**

An effective LAEP process can help to secure commitments to action from the many stakeholders whose involvement is key to delivering the plan, including local government, energy network operators, key businesses and institutions, relevant supply chains, community organisations etc. This turns what would otherwise risk being a wish-list for local activity into a process which builds confidence that the LAEPlan represents what is likely to happen in a locality. This means others can rely on the LAEPlan to inform their own plans for the locality.

1.1 The key elements of LAEP

Securing these outcomes needs local area energy planning to be done well. This includes:

- The use of robust technical evidence produced using analytical techniques which consider the whole energy system and make consistent use of available data, and whose strengths and weaknesses are well understood.
- A comprehensive assessment of wider non-technical factors which need to be addressed to secure change.
- A well designed and involving social process which engages appropriate stakeholders effectively, uses the technical evidence appropriately, and manages vested interests

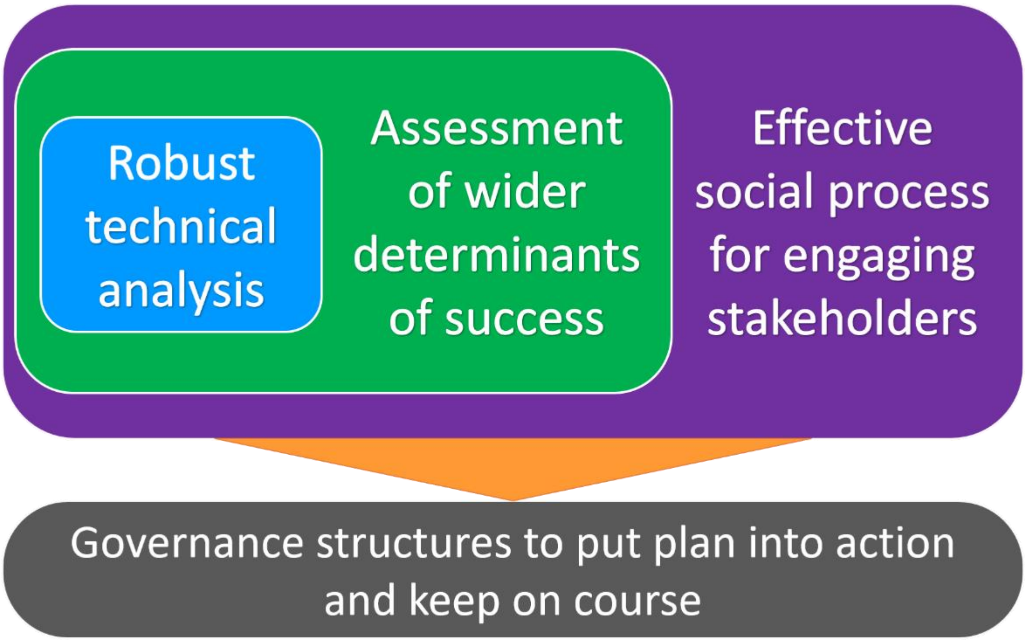
effectively, thus ensuring the LAEPlan can be seen as an informed and legitimate representation of local intent in relation to energy system decarbonisation.

- A credible and sustained approach to governance and delivery.

Each of these elements of LAEP is addressed in a separate section in this document.

While there can be a tendency for the technical analytical element of LAEP to be treated as the focus (and there is plenty of detail about it in this document), it is important to see all of these elements as equally critical. Without an effective social process, the buy-in of stakeholders and an understanding of all the changes needed to succeed, any results from modelling will remain an interesting set of data, graphs and maps; it will not become a plan being put into action.

Figure 1: The four key elements of local area energy planning



Please note that this document does not address the setting of local targets for achieving net zero greenhouse gas emissions earlier than the UK legally binding target of 2050 for this goal. This has scientific, moral and ethical dimensions which are beyond the document's scope. Scotland has set a statutory national target of 2045 for this goal. A large number of local authorities and other bodies across the UK have chosen to set targets to achieve net zero carbon emissions by 2030 or other dates between then and 2050. Others are, by default, committed to the 2050 target or, in Scotland, 2045.

That said, LAEP can be a very useful tool in testing and honing such local targets. LAEP done well as described here will help to reveal the technical and system challenges, the potential costs and benefits, and the rates of change and actions required to achieve an area's chosen target. The technical analysis could also help explore the potential implications of aiming for an earlier or later target date for net zero, particularly in localities where commitments have yet to be firmed up.

Furthermore, by exploring non-technical factors as part of LAEP, the required scale and rate of local and wider change to meet targets and the actions needed to underpin local success will become apparent. Through LAEP's social process of stakeholder engagement, understanding of these actions and commitment to taking them can be developed and enhanced. Establishing the delivery plan and governance mechanisms will test local resolve and capabilities to deliver on their commitments. All these elements of LAEP may therefore result in an iterative adjustment to local targets to reflect the findings of the process; they may also result in a greater sense of urgency and stronger commitments to action as the scale of the challenge to achieve a net zero energy system becomes more evident.

1.2 A guide to doing local area energy planning well

This document sets out how local area energy planning can be done well. By providing 'done well' checklists in relation to the key elements of local area energy planning, this document provides a quality assessment framework.

It seeks to provide sufficient guidance to those involved in the process and those (like national governments) funding or commissioning such activity so they know what needs to be done to achieve good quality outcomes.

The 'done well' criteria are also intended to assist those parties looking to rely on the LAEPlans for their own plans for a locality (or their judgement of others' plans). They enable a systematic assessment of a LAEPlan's analytical quality, representative legitimacy and likelihood of delivery. These parties include:

- BEIS and the Scottish and Welsh Governments in shaping their own policies[3] and potentially targeting pilot programmes, funding, the granting of improved powers and other measures to support local action.
- Energy distribution network operators (GDNs and DNOs) to inform their investment and operational business planning across their network in response to local plans.
- Ofgem, in assessing the validity of GDN or DNO business plan proposals that have relied on a LAEPlan as part of its justification for the scale and timing of investment in local network upgrades.
- Other infrastructure developers, including new housing providers and EV charging point providers, and other businesses looking to understand how the energy system in different localities might be changing.
- Innovators, including those developing data-driven smarter and net zero energy services, looking for localities likely to drive change first with well curated data and evidence bases which thus create earlier opportunities for new business.
- Regional bodies (e.g. Local Enterprise Partnership in England, Statutory Joint Committees in Wales, Regional Economic Partnerships in Scotland) and combined authorities looking to establish a coherent economic development strategy based on local opportunities created by decarbonisation.
- Fuel poverty agencies and community energy groups looking to target their activities and align them with wider activities planned in local energy systems.
- Building owners (including individual households) looking to upgrade the energy performance of their building and wanting to understand the likely heat decarbonisation options in their locality that would suit their property.

3 For example, the Scottish Government's work with local authorities to develop a methodology for delivering Local Heat and Energy Efficiency Strategies (LHEES)

1.3 Finding the right scale for local area energy planning

It is important to undertake LAEP at a scale which reflects both: (a) the technical realities of the energy system, renewable generation opportunities and heat and transport decarbonisation options, and; (b) the social realities of how stakeholders and decision-makers define their geographical allegiances and governance arrangements. This section outlines the factors that should be used to determine the scale at which local area energy planning takes place and how it might relate over time to activities taking place in neighbouring or affiliated localities (such as within combined authorities).[4]

There are technical factors which inform the selected scale of a LAEP 'unit':

- Too small an area may not allow some options to be considered because they can only be realised at a certain scale – from heat networks to the distribution of hydrogen for heating. It may also overlook investment or operational implications for gas or electricity networks which only become apparent when the combined effect of decarbonisation solutions across a wider area can be taken into account. Similarly, these implications and their financial consequences may themselves shape what constitutes the best solutions for any given area.
- Too large an area may challenge the capacity of analytical techniques to evaluate choices across so many buildings while retaining the fine grain detail required to reflect pertinent local circumstances.

The considerations in respect of local governance, decision-making, and social realities are perhaps more obvious and relate to accountability, agency and allegiance, such that the resulting plan has legitimacy as a genuine reflection of local intentions:

- The area needs to be of a scale which has a recognised governance structure that has representational and decision-making powers, leadership and convening functions. This is so that any plan emerging from the process is rooted in a structure with some degree of local accountability. This suggests local council areas as the minimum scale.
- The scale also needs to reflect a locality's ability – or agency – to influence and implement changes identified in the plan. This suggests unitary local authorities as a minimum scale because of their planning duties and range of powers and influences (with English district councils being combined at top tier county level).
- The scale should also reflect the nature of allegiances of the key stakeholders who need to be involved in the local area energy planning process and who are potentially key to its subsequent practical realisation. Some key stakeholder institutions (such as universities), and representative bodies (such as chambers of commerce or voluntary sector associations), and relevant business interests (such as building contractors and heating

4 Clearly there are some engineering aspects of the energy system which are much more national-level than local-level due to their scale (even though they end up happening 'somewhere'). These would include, for example: the siting of offshore wind farms or new nuclear power stations and associated infrastructure; the availability of CCS (carbon capture and storage) (and therefore for hydrogen derived from natural gas); the need for large pumped storage facilities. The national-level decisions on these larger scale matters will influence the choices available to local areas and, for some of them, the carbon emissions associated with the electricity consumed anywhere (see Section 2 for some discussion of how such influence can potentially be reflected in local analysis). However, the existence of these national-level matters does not alter the value of LAEP done well, or the considerations about the optimum scale for undertaking it as outlined in this section.

engineers) may operate and have allegiances at a larger scale than individual unitary authorities. That said, other stakeholders may have more locality-specific interests associated with particular initiatives or neighbourhoods. Given their potential importance for delivering change on the ground, the scale should not overwhelm these voices or reduce their potential for influence.

There may also be additional system-level considerations for the scale chosen. For example, the topology of different operational levels of gas and electricity networks are rarely perfectly aligned with administrative boundaries (or with each other). However, accountability, agency and allegiance considerations will almost always be more important to defining the 'right' scale than network topology (which will rarely offer these qualities).

The network topology needs to be understood for local area energy planning but resolving the local 'boundary' issues will need to rely on combining and aligning the different local area energy plans covering the area in question.

Indeed, one of the purposes of describing here the characteristics of good local area energy planning is to ensure that individual area energy plans are done on a reasonably consistent basis and can therefore be compared and combined to inform net zero energy system planning across a wider area and by regional interests such as energy networks. It will also make it more straightforward in the future to describe how any national and regional level net zero energy system planning should reflect – and be reflected in – local planning.

So, for example, developing a local area energy plan for the whole of Greater Manchester Combined Authority (GMCA) area may best be done as series of ten unitary authority based processes. This would ensure the technical evidence is sufficiently detailed and, in particular, that the stakeholder engagement is sufficiently local in focus to reflect perspectives and secure commitments to act from those with local agency and those less likely to engage at GMCA level. These energy plans can then be combined across the GMCA to assess, and where necessary address, differences and commonalities and potentially adjust local plans. This then establishes plans for both the GCMA and the ten unitary authorities which are aligned and mutually reinforcing, having been based on a consistent approach and understanding and on stakeholder engagement at sufficiently local level to reflect local interests and secure commitments to act.

1.4 'All at once' vs 'emergent' LAEP: being pragmatic about how a LAEPlan might come into being

Some localities or nations may prioritise certain aspects of local energy system decarbonisation (e.g. heat, transport, power or new-build developments) ahead of others. This could be in response to timing or funding constraints, policy development needs, or the wish to address simultaneously other associated objectives (such as tackling fuel poverty) which only relate to some aspects of the energy system.

Clearly, this may result in 'bit-by-bit' or 'emergent' approach being taken to developing a LAEPlan. These more focused exercises have the potential to provide very valuable insights both in their own right and as a component of the future LAEPlan.

However, in such an approach, some important interactions between these aspects risk being lost (such as the combined effect on the electricity network of electrifying both heat and transport). Effort will therefore need to be made both to consider the other aspects of decarbonisation on a timely basis and, over time, to revisit each aspect to consider the wider interactions to establish a truly whole system perspective.

In addition, for any activity designed to establish a local strategy or plan for only a particular aspect of energy system decarbonisation, the method described here and the relevant 'done well' criteria should be applied. This would ensure it could be considered a credible component of full LAEP.

It is also possible that, for similar pragmatic reasons, the different elements of LAEP described in this document (i.e. technical analysis, social process, etc) are not all delivered (or procured) as 'one project'. This is not, in itself, a problem provided there is interaction between the different elements (so that, for example, the stakeholders can ask questions of the technical analysis and access additional analysis if needed to inform their deliberations).

In such an 'emergent' approach to the process, for the resulting LAEPlan to be considered credible, each element will need to be completed in line with the 'done well'. In addition, and given the rapid rate of change in the energy system and associated policy and regulation, the whole process should be completed within 12 months (and 18 months as a maximum) so that is sufficiently up to date to be relevant and actionable, and the input assumptions remain consistent.

1.5 Background to local area energy planning

Local area energy planning is not new. Aspects of it have been undertaken in some way for well over a decade, albeit typically in relation to individual aspects of local energy systems. For example, in assessing potential for renewable energy and informing and shaping associated planning policies *[e.g. REVision 2020 in South West, 2004-5; Welsh Government Planning for Renewables and Low Carbon Energy Toolkit 2010]* and in modelling local heat demand and thus revealing associated opportunities for district heating [*e.g. original London Heat Map, 2005*].

More recently better integrated and data-driven whole energy system approaches have emerged. These meet the need to consider the inter-relationships across different energy vectors (gas, electricity, heat) and covering some or all of the different aspects of energy system decarbonisation *[e.g. ESC LAEP pilots, and Scottish Local Heat and Energy Efficiency Strategies*].

As the challenge of energy system decarbonisation has come to the fore, it has become increasingly obvious that many aspects of decarbonisation have solutions which vary by geography or local building types to an extent which national analysis typically fails to reflect. In such circumstances, national policies risk being rather blunt and potentially limited in their effectiveness when applied anywhere.

In addition, the implementation of energy system decarbonisation will have to rely, at least in some part, on local leadership, engagement and initiative-taking. This is because of the nature and challenges of the systemic changes required (and how they vary between places), and the volume and distribution of people and organisations who will need to be involved in making them.

Such considerations are particularly relevant to decisions about:

- how to meet the demand for warmth and hot water in every building (including anticipated new buildings) and what can be done with each building's fabric to reduce that demand;
- how to decarbonise the heat used in industrial processes (and how to use waste heat from industrial processes effectively);
- how we manage and use energy, where we generate it and what local energy resources (from mine-water for heat to roofs for PV);
- how people and goods get around locally;
- how and when local energy networks ensure their investment plans and operational practices fully reflect the anticipated and planned local implementation of decarbonisation solutions.

This history and current situation creates a need for both (a) more extensive implementation of local area energy planning (to secure its benefits more widely) and (b) a closely defined methodology which describes the processes and analytical approaches to be deployed in effective LAEP (to secure decent quality LAEP more routinely).

A defined methodology, such as outlined in this document, will enable LAEP to be undertaken on a more consistent basis in different places across the UK. It should also ensure that the process produces more reliable and informative outputs which are therefore more useful and influential at the local, regional and national levels.

2 Technical Analysis

This section outlines the importance and the limitations of technical analysis as an essential underpinning element of local area energy planning.

The purpose of the technical analysis in LAEP is to provide a detailed understanding of the changes required in the local energy system to achieve agreed objectives (such as achievement of net zero by a particular time, along with other considerations such as fuel poverty and air quality) and the likely costs. The scope and detail of the potential changes are likely to vary between areas, reflecting the nature and complexity of local energy systems.

Nationally, the energy system comprises a set of interacting processes that exists to satisfy our demands for energy services such as warmth, light, motive power, computing, etc. It does this by distributing a range of processed primary energy inputs to end-use conversion devices, via distribution networks and ultimately via the wires and pipes within buildings. These devices are the appliances we use every day in our houses, offices, factories, and vehicles. This can be visualised in various ways – for example BEIS maintains a flow chart for the UK energy system, which is available online[5].

The system is inherently complex, even after narrowing the scope and geography from the whole of GB to that required for a single LAEP process. In fact much of the complexity of the national system is located at the local end because this is where the majority of 'action' takes place. For example 97% of the total length of all the wires in the GB electricity system is in the distribution tier[6], with almost 90% at 11kV or below.[7] And virtually all of the decisions about when and how to use energy actually take place in millions of individual buildings and vehicles.

Local energy systems are complex, so planning their development – in particular how they need to change to achieve net zero carbon emissions – requires analytical approaches which recognise and can handle this complexity. As described in Sections 3 and 4 below, this technical analysis must be embedded in (a) wider analysis of other factors which also influence the energy system and (b) social processes with local stakeholders to inform and reflect their perspectives on priorities and preferences.

Put another way, LAEP decision making needs to be well-informed about the technical, social, economic and environmental impacts of the options for changing the energy system. Stakeholders need good evidence to hold informed discussions and reach meaningful conclusions about the options available, considering the uncertainties, costs, interactions, trade-offs, and synergies.

5 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/818151/Energy_Flow_Chart_2018.pdf

6 The UK electricity system is separated into a national transmission network, and 16 'Grid Supply Point Groups', each of which contains distinct local distribution network(s) operating at a lower range of voltages.

7 Total length of transmission network cables: 27,970 km (Electricity Ten Year Statement, National Grid (2019)); total length of distribution network cables: 789,765 km. Total length of HV and LV cables: 716,402 km (personal communication, Marko Aunedi, Imperial College (2020)).

This is challenging partly because of the complexity of the energy system, but also because of the significant uncertainty about some important factors (see section on 'Uncertainty and regret' in Section 2.1 below).

The degree of complexity and uncertainty involved in planning technological and system changes to the local energy system needs to be reflected in the approach taken to, and the use made of, technical analysis and modelling.

The practical implication of this is that LAEP technical analysis will require sophisticated analytical tools, because:

- the number of technical choices that comprise an 'option' will often be too large (e.g. in a medium sized city there might be 200,000 decisions about heating systems for buildings, multiplied by a very large number of heat and other network permutations, with parallel choices about whether, how and where to insulate buildings to improve thermal efficiency)
- the interactions between different components of the system will often be too complicated and/or nonlinear (for example a change may have disproportionate cost impacts if it causes the capacity threshold for some existing infrastructure to be exceeded)
- the need to understand the impact of uncertainties on the range of possible outcomes means that sensitivity analysis will be required, compounding the above issues.

There is therefore an important role for computer modelling to play in providing technical analysis to underpin local area energy planning. It can support participants' thinking by helping them to explore potential outcomes, providing evidence, revealing options and their relative merits against various criteria, and informing decisions. Models have to reflect at least some of the complexity inherent in the real-world system they represent, and in the questions we are trying to answer. And their limitations must be very well understood, otherwise they risk misleading rather than informing our thinking.

LAEP participants will therefore need to be equipped to determine whether the modelling evidence offered is of sufficient quality to inform the process – this document sets out what sufficient quality might look like, and how it can be secured.

2.1 Scope of LAEP technical analysis

Questions

The overarching <u>technical</u> question for LAEP is: 'what is the preferred combination of technological and system changes we can make to the local energy system, to decarbonise heat and local transport and realise opportunities for local renewable energy production?'

Here 'preferred' is a loaded term importing some potentially conflicting objectives:

1 decarbonising heat
2 decarbonising local transport
3 minimising cost, or at least avoiding excessive cost
4 using locally acceptable solutions
5 enhancing, or at least not compromising other local objectives, such as on fuel poverty or air quality
6 maintaining consistency with evolving national policy and decisions.

Within this there is a large number of additional (and potentially interacting) questions, such as:

- What proportion of an area's heat demand should be met from district heating? In what areas should this be prioritised? Where should we start?
- Which existing buildings should be prioritised for retrofit insulation, and where should we prioritise heat pumps rather than heat networks?
- Should we use zero carbon gas rather than heat pumps? What about hybrids?
- What thermal standards and solutions should we impose on new development to ensure they will contribute appropriately to the area's net zero commitment?
- What local low/zero carbon heat and power sources can we exploit, and how does this affect decisions about heat and power supply to buildings?
- What solutions might there be to protect low income households from higher energy costs?
- How many electric vehicle charging points will be required in a given city? What types will be needed, where, and by when?
- At what rate should we be planning to phase out petrol and diesel vehicles? What's the right balance of replacement between new 'net zero' vehicles, other forms of mobility, and steps to reduce need to travel?

The following sections summarise the essential dimensions of a technical analysis designed to support LAEP.

- **Costs and revenues**

Cost is a fundamental component of the core LAEP question and any technical analysis must evaluate and compare the costs of various options. In trying to find a cost-effective solution, the focus should be on the overall lifetime societal cost[8], rather than the cost to a particular set of actors. .

However, the social and political assessment of a proposed solution will need to consider the distribution of costs and benefits across society and over time. And an assessment of the commercial attractiveness of proposed solutions will need to account for value flows between actors (in particular to investors).

Cost itself can be separated into three components:

- capital costs: the up-front investment required to make a given change – note that this can include future replacement and decommissioning costs incurred when equipment reaches the end of its life
- running costs: these are the recurring costs associated with operating the different parts of the system. They include fuel, maintenance and operating costs.
- carbon costs: the damage caused by greenhouse gas emissions must be accounted for when comparing the costs of alternative decarbonisation pathways. For example, an option which delays emissions reductions until 2050 may be cheaper in capital terms, but will incur greater climate damage than an option which meets decarbonisation targets by 2030. This

8 Lifetime societal cost is the appropriate measure here: optimising the design of the energy system for the benefit of a present or future sub-group would not be democratically acceptable. See page 23 of the Treasury Green Book for a definition of social costs and benefits: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

is particularly important given that the marginal damage cost associated with the emission of a tonne of CO_2e is rising, so that the later emissions are reduced, the more damage they will do *per tonne*. Government guidance on accounting for the value of carbon in policy appraisal[9] reflects this and includes figures to be used for the 'social cost of carbon' over time[10,11]. Like running costs, carbon costs recur over the lifetime of the analysis.
The appropriate annual values from the government guidance should be used when costing decarbonisation options in LAEP. However, these values are both inherently uncertain and likely to be influential. Therefore the effect on preferred options of changes in the social cost of carbon should be explored in sensitivity analysis (see section on 'Uncertainty and regrets below').

When evaluating a given set of changes (for example in how a building is heated), all three types of cost must be accounted for.

Revenues are similar to running costs in that they accrue over time. However they are only relevant if we are assessing the value of a set of changes from the point of view of a particular set of actors.

Since some of the costs and revenues accrue over time, we need to define an accounting period over which the cost of the changes will be calculated. This introduces the question of discounting, which is an accounting technique for representing our tendency to value money in the present more highly than money in the future. This reflects that fact that, for example, most people would agree that £1 available now is worth more than the promise of £1 ten years from now).

Discounting enables the conversion of a long time-series of financial costs and benefits into a single number (its 'net present value'), taking into account a preference for value in the present over value in the future.

It is standard practice to use the Treasury's Green Book discount rate (currently 3.5%) when comparing public sector investment options. For consistency, this rate should be used in the calculation of costs for LAEP.

However it is worth noting that there is some controversy about the idea of discounting the cost of future climate damage. Krogstrup and Oman (2019) touch on this in work for the International Monetary Fund (Working Paper 1WP/19/185): "Weighing the future benefits of climate action against the present costs requires valuing time and hence the present value of the welfare of future generations, but there are no objective criteria for making such an evaluation, which is inherently subjective and political… Based on similar climate damage assessments, Cline (1992) and Nordhaus (1994) arrived at substantially different carbon reduction recommendations, reflecting different time discounting. Cline argued that the pure rate of time preference should be zero, since it is not ethical to weight future generations less

9 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/245334/1_20090715105804_e____carbonvaluationinukpolicyappraisal.pdf
10 https://www.gov.uk/government/collections/carbon-valuation--2
11 https://www.gov.uk/government/publications/guidance-on-estimating-carbon-values-beyond-2050-an-interim-approach

than current generations. Nordhaus argued that the discount rate must be equal to the interest rate observed on financial markets, which at the time stood around 6 percent."

The effect of discounting on the preferred LAEP option should therefore be explored as part of the sensitivity analysis. This will allow participants to explore the question for themselves, in a transparent manner. The cost of the chosen plan should then be calculated using the Green Book rate for public investment, to ensure consistency with standard practice.

- **Geography**

To start addressing this question in a concrete way for a particular locality, we need to define the geographic scope of the LAEP process.

As explored in Section 1, while this question has significant implications for technical analysis, it is in practice likely to be imposed by socio-political realities, with analytical approaches needing to be adapted accordingly – though within certain constraints as noted in Section 3:

- if the area chosen is too small, the analysis risks missing options that only pertain above certain scales (for example for technical or financial reasons)
- too large an area may prove intractable to analyse properly in the required detail
- the analysis may need to be extended somewhat beyond the specified area, to capture certain relevant cross-boundary energy system assets and interactions, and to avoid cutting across the existing network topologies (e.g. grid supply point and associated primary substations).

There are also some potentially complex interactions between adjacent area LAEPlans which will need to be considered over time (for example the potential impact on costs – or availability - of hydrogen in one locality if it features significantly as a solution in a neighbouring area). However, these interactions are too complex to consider in the technical analysis for each individual LAEPlan and do not in themselves justify a significant influence on the choice of scale for a LAEP process and plan.

- **Time**

In addition the technical analysis must account for two important temporal scales.

The first is 'planning time'. As noted in Section 3, an effective plan must set out the nature, scale, rate and *timing* of changes to the local energy system. This is likely to be measured in years, and will show the planned evolution of the system from the present to a date in the future at which the decarbonisation commitments are to be met. This has important implications for the costing of options, because the expenditure and emissions profiles of a given pathway will interact with increasing carbon prices, and with the effect of discounting future values.

The second is 'operational time', which captures important sub-hourly, daily, and seasonal variations in energy demand. Without an understanding of these variations it is impossible to assess the costs and benefits of a range of technological options – for example the economics of all networks (and indeed supply plant) is driven by the fact that capital cost is determined principally by peak demand (which dictates the capacity of cables, pipes and other plant required), while revenue tends to be determined by throughput. The former is measured on a sub-hourly basis, while the latter can be considered annually.

- **Energy system complexity and scope**

While the core LAEP question set out above may sound reasonably simple, the devil is in the detail, which masks considerable complexity. For example, to decarbonise heat we will need to alter the heating system for nearly every building in an area, adapting our distribution systems to meet the resulting changes in annual and peak demand. And this has to be done in parallel with decisions about insulation, storage, demand flexibility, and the additional loads anticipated from the decarbonisation of transport (e.g. via electrification, or hydrogen).

Consider the questions that arise, and the interactions that are relevant, in thinking about how to meet the heat demand of a single building.

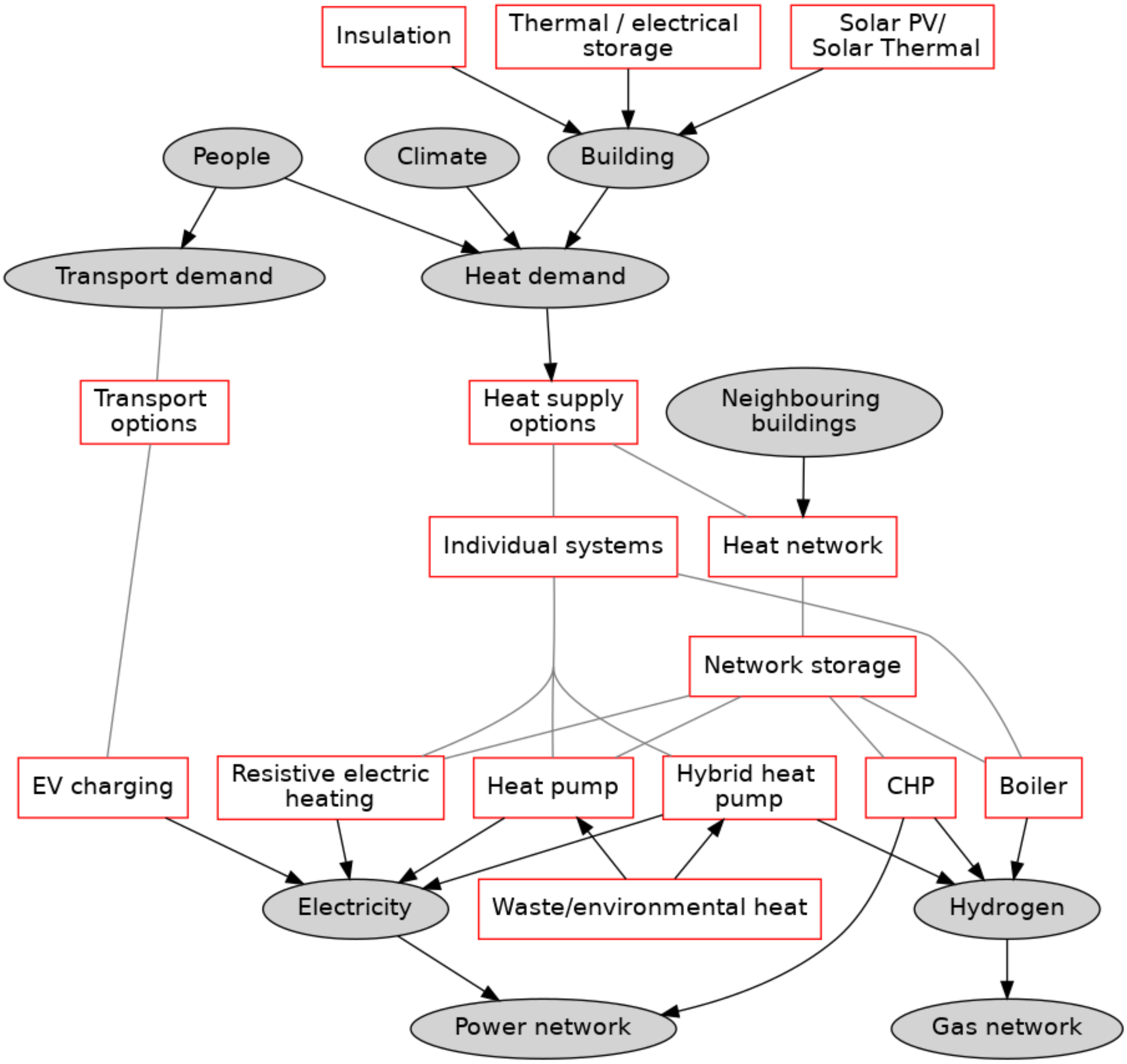


Figure 2: Highly simplified representation of the options and interactions associated with the choice of heating systems for a building

In Figure 2, red boxes are technological choices we can make about the system, grey arrows denote options for these choices, and black arrows show directions of influence.

Even from such a simplified representation we can see that modelling cause and effect in this system is going to be complicated, and finding acceptable, cost-effective sets of choices challenging. This is because:

- some important factors are very uncertain (people's behaviour, the climate, technology costs and efficiencies, availability of hydrogen at competitive prices, etc.)
- there are many options to consider, on two separate but interacting levels, including:

  1 building level:
    - tens of thousands of buildings
    - multiple kinds of insulation
    - energy storage
    - six different heat supply options (with various sub-options not shown here, as well a cooling options)

  2 network level:
    - heat network viability (and hence its availability as a solution for a particular building) depends heavily on very local context, including demands from surrounding buildings, and availability of supply options (which must be assessed)
    - for any set of buildings, there will be numerous potential heat network routing options
    - heat network supplies depend in turn on electricity or hydrogen distribution networks, and these must be sized to cope with resulting peaks (which can potentially be modified using storage)
    - individual building heat supply options may require reinforcement or existing electricity and gas networks, while hydrogen based options depend on area-wide upgrade of the gas network, which is unlikely to determined locally.
    - transport demand, while seemingly unrelated, will be coupled to heat demand at building and network level, via the power network, when electric vehicles are charged. In practice this means that it is impossible to know what capacity is needed in the power network without understanding how, when and where these demands co-vary.

- A description of the preferred, cost-effective decarbonisation solution for an area involves finding an acceptable set of choices over all buildings and networks that simultaneously avoids excessive overall lifetime societal cost for the resulting system
- In the case of heat networks this requires identifying networks that largely do not yet exist, in sufficient detail to enable accurate cost estimation.
- In the case of the gas and power networks it requires similar detail regarding which components of the existing networks will need upgrading, replacing, extending, or decommissioning.

The high degree of connectedness of the system means that technical analyses will need to integrate across energy sources, vectors and end-uses, and attempt to capture as many important interactions as possible. As discussed in Section 2.2, this presents technical challenges of a different kind: the number of decisions implied by the question is very large, since for every building in the problem there are several choices, and for each of those, there are several network-level choices. Worse, decisions on the network level constrain choices at the building level, and vice-versa.

This leads to a very large number of possible solutions for the system as a whole. In fact the number of potential solutions is literally astronomical, even for a simplified binary question like 'which of these 1,000 buildings should go on a heat network?'. Here the number of distinct solutions is 2^n for n buildings. In a problem with 1,000 buildings this means that there are 10^{300} possible solutions. For comparison, the number of atoms in the observable universe is 10^{80}.

Finally, given the core LAEP question set out above, all of the following local elements of the energy system need to be considered within any technical analysis contributing to LAEP:

- Location and nature of local low/zero carbon and transitional supply options: the scope here has two distinct components. The first is resources which are consumed locally, such as power generation connected to the distribution network, waste heat sources connected to district heating systems, or building-integrated solar PV. The second is resources which are exported from the local area, such as transmission-connected renewables, or hydrogen piped to locations outside the area.
- The former are very important inputs to the analysis of requirements for local distribution systems, which by definition exist to connect supplies with local demand.
- The latter are less important from a local energy system planning perspective, but critical at the national level - the UK needs to maximise its exploitation of renewable energy resources, all of which have to be located somewhere.
- The following summarises the types of resources that are in scope:[12]
    - waste heat from other activities
    - environmental heat (air, ground, water)
    - renewable heat and power (e.g. wind power, solar PV, solar thermal)
    - biofuels
    - hydrogen from steam reformation of methane, in combination with CCS (this is likely to be constrained to locations close to existing gas wells)
- Thermal energy used in buildings (space and water heat, cooling, industrial processes)
- Fuels and the networks that distribute them
    - electricity
    - gases
        - methane (including bio-methane)
        - hydrogen
        - blended
    - hot water (heat distribution networks, solar thermal)
- Thermal conversion devices
    - boilers
    - heat pumps
    - hybrid heat pumps
    - resistive electrical heating
    - heat exchangers

12 Detailed spatial data describing local low carbon and renewable energy resources are assumed to be available for use as inputs to LAEP, having been produced in separate resource assessments typically undertaken to support local planning policies. See for example Welsh Government Planning for Renewables and Low Carbon Energy Toolkit 2010.

- burners
- fuel cells

- Technologies that reduce or time-shift thermal demand, such as:
  - various types of insulation to improve thermal efficiency of building fabric
  - thermal and electrical storage
  - advanced heating controls
- Non-thermal uses of electricity, such as: lighting, electrical appliances, IT, and industrial processes. While the management of electricity demand from these activities is out of scope for LAEP, the demands must be accounted for, otherwise the technical analysis will not correctly size the infrastructure required to satisfy them (e.g. local renewables, electricity distribution networks)
- Local travel: there are two separate issues to consider here. LAEP needs to consider transport activity and associated changes which

  1. impact the wider local energy system, and/or
  2. are covered by the definition of local CO_2 emissions

  For (1) this will include among other things the location and impacts of electric vehicle charging on networks, and competition with other applications for limited hydrogen resources. For (2), the definition of local travel is as per the National Atmospheric Emissions Inventory.[13]

- In both cases LAEP should take account of existing statutory transport plans when considering future changes to transport demand, and the modes by which it is satisfied. The transport system scope for both sets of issues is:
  - Fuels and their networks
    - electricity
    - petrol & diesel
    - LNG
    - hydrogen
  - Vehicles and modes
    - Road
    - Rail
    - Cycling
    - Walking

This means the following emissions are in scope:

- CO_2 equivalent emissions of from non-electric heating fuels used in the area, regardless of where they are produced (Scope 1 emissions)
- CO_2 equivalent emissions from electricity use in the area, regardless of where it is generated (Scope 2 emissions)
- CO_2 equivalent emissions from in-scope transport energy use (see above). This will comprise a mixture of Scope 1 and Scope 2 emissions

13 See pages 39-42 of 'Local and Regional Carbon Dioxide Emissions Estimates for 2005–2018 for the UK Technical Report. Prepared by Ricardo Energy & Environment for BEIS', available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/894790/local-authority-co2-emissions-technical-report-2018.pdf

And the following emissions are out of scope:

- Scope 3 ('embodied') emissions of any kind
- Scope 1 and 2 emissions from out-of-scope transport occurring within the area (see above)

- **Uncertainty and regrets**

In addition to the technical dimensions of the local energy system, the analysis will need to assess the sensitivity of the results to various sources of uncertainty. Many of the inputs to the modelling – especially those concerning the future – are estimates of one kind or another, and prone to error. Sensitivity analysis enables us to identify which input assumptions are most influential on the results, and hence which kinds of uncertainty and error we should be most concerned with understanding.

This is also relevant to the need to minimise the risk of regret, which can be thought of as the probability and cost of making the wrong decisions. In the context of LAEP, decisions with a low risk of regret are those which tend to be part of a cost-effective solution under a wide range of values for influential but uncertain inputs – in other words, choices which are robust to our uncertainty about the future. **Local area energy plans should prioritise robustness across a wide range of such scenarios, rather than seeking least-cost solutions in a narrower range**.

The following gives some examples of the kinds of parameters that should be explored in this context:

- The future (and in some cases present) availability, cost and performance of fuels and technologies are not always well understood, and are in some cases contested. This includes for example the cost and availability of zero-carbon fuels such as hydrogen, and the cost and real-world efficiency and emissions intensity of the various types of heat pump (ASHP, GSHP, WSHP, gas-hybrid) across buildings with different thermal properties and occupant heating regimes[14].
- The capability and willingness of people and organisations to make different choices and change behaviours, and our understanding of the many interacting factors which influence these (see Section 3). Note that this is very difficult (some would say impossible) to model quantitatively.
- The choice of carbon pricing used in the calculation of costs can have a significant effect on the preferred solution, and this should be explored, with central assumptions based on government guidance (see section on 'Costs and revenues' above). The same is true for the choice of discount rate.
- The future climate, which will significantly affect the energy system, is itself unpredictable.
- Spatial plans for future development of buildings and associated energy system investments should also be considered.

This imposes a requirement that sensitivity analysis forms part of the technical method. The practical implications of this are discussed in Section 2.2. The principle is that we need to

14 Note that the analysis should take into account the potential for correlation between different variables. For example, when testing the sensitivity to assumptions about the future cost of electricity, it may make sense to vary the cost of electrolytically produced hydrogen at the same time (since electricity is an input – and therefore cost – to that process).

understand the effect on the results (the preferred combination of changes, and their associated cost) of varying some important parameters whose present and/or future values about which we are uncertain.

- **Other local objectives**

Although decarbonisation is the primary motivation behind LAEP, other important policy objectives are affected by the design and performance of the energy system; LAEP needs to account for these. These objectives may be in tension with the search for a low-cost solution to the decarbonisation problem, and this needs to be properly considered, and the impacts made explicit in the technical analysis and results.

Two obvious examples are air quality, and fuel poverty.

Air quality emissions can generally be modelled quite straightforwardly as a function of fuel consumption and plant type. However the effect of emissions on local concentrations of air quality pollutants is far more complex, and beyond the scope of LAEP modelling. In practice therefore, it will be necessary to import any required emissions limits from local or national air quality policy, potentially using these to constrain solutions to the decarbonisation question.

Fuel poverty is a function of the thermal efficiency of buildings, the efficiency of heating systems, fuel costs, and household incomes. Of these, the first three are clearly in scope for LAEP technical analyses, and the fourth can be considered as an exogenous variable. LAEP analysis should at therefore at a minimum quantify and attempt to minimise the negative impact on fuel poverty of decarbonisation approaches under consideration. It should also explore the options for reducing fuel poverty, for example by prioritising the rollout of appropriate technical solutions to fuel poor areas.

Other examples may include:
- Management of the social distribution of the costs of decarbonisation
- Local economic and industrial strategies and employment growth priorities.

2.2 Modelling approaches

To help us address these questions, there are four main kinds of quantitative model available:

1. 'What if?' – scenario modelling
2. 'What will happen?' – predictive modelling
3. 'What should I do?' – decision modelling, within which there are two categories:
   - 'What is the best possible solution?' – optimisation
   - 'What would be a good solution)?' – satisficing

The sections below introduce these different approaches, and explore the issues of scope, detail, sensitivity and quality assurance. The final section outlines suggestions about what sort of modelling is most appropriate for LAEPs.

- **Scenario modelling**

Scenario modelling involves the user describing a set of decisions about the system, with the model calculating the impacts of those decisions on some quantities of interest – e.g. carbon and air quality emissions, total cost, final demand, etc. The key point is that in this case the user must describe the system at whatever level of detail is required, before the model can produce an answer. If scenario modelling is the only approach used, then the choice of scenarios is critical. There is a risk of bias, and the analysis will be constrained to the set of scenarios that can be imagined by the participants. By the same token, scenario modelling enables participants to explore their own ideas and assumptions, which is an important part of the planning process.

- **Predictive modelling**

Predictive modelling is used to help identify what is likely to happen, given a set of assumptions provided by the user. For example we could use assumptions about the climate to predict changes in demand for heating or cooling from some group of buildings. Predictive models are often trained on the historical relationship between some predictors and a quantity of interest (e.g. heating degree days can be used to predict heat demand). They are then used to make predictions using assumptions about the future values of the predictors (if we have X heating degree days in the future, what will happen to heat demand?). While predictive modelling is a useful tool which is likely to have a role to play in LAEP, it is generally less effective at predicting the evolution of complex systems (which are by their nature inherently less predictable).

- **Decision modelling**

In contrast to scenario modelling, decision models are used to identify the solution to a problem under a set of constraints. Instead of taking the energy system state as an input for evaluation, decision models are used to *find* the system state that satisfies the specified objectives and constraints.

Decision models are therefore complementary to scenario models: they can find answers that participants may not have imagined, but their design makes them less useful for exploring scenarios imagined by participants.

Put more simply, while scenario models take the 'means' as an input and output the 'ends' that would be achieved, decision models take the 'ends' as an input and attempt to find the best means to achieve them.

  - ***Optimisation***

Optimisation models are used to find the set of choices which absolutely maximises or minimises a quantity of interest (referred to as the objective), subject to some rules about what sets of choices are allowable (referred to as constraints).

In the case of LAEP constraints might include things like 'emissions must be zero and there can only be 10MW of solar PV in the solution'. The model then tries to find a set of set of decisions which satisfies these constraints while minimising the objective - which for LAEP might be total lifetime societal cost.

There is a limit (because available computing power is finite) to the number of decisions that can be solved within a practical timescale, and this constrains the use of optimisation models for solving very complex questions (including about the energy system). A further limitation of optimisation models is that the problem has to be formulated in a special way, which can have two drawbacks: firstly it can make it difficult to explain to domain experts who are not modellers (and whose buy-in may be important) how the model is representing their domain of expertise; secondly it can force the omission of certain problem details, which may turn out to be important.

- ***Satisficing***

Satisficing models are used in a similar way to optimisation models, but can handle more complex questions (i.e. comprising larger numbers of computed decisions) and do not require special formulation. They combine a what-if type evaluation model with a strategy for generating candidate solutions for evaluation. Unlike with optimisation models, the 'problem space' is sampled, rather than 'conquered'. The resulting trade-off is that the guarantee of optimality is lost, but on the other hand, the system can be modelled in more detail, and perhaps more transparently. In addition, the what-if model can be used independently of the search algorithm, to answer user-generated questions.

In cases where the system being modelled requires significant simplification to fit into an optimisation formulation, optimality may already be lost, since the question being optimised no longer resembles the real-world system in some important way. In such cases, satisficing may be a better approach: instead of compromising on the representation of the problem, we can compromise on our search for optimality. So we trade a certainly-optimal solution to the wrong problem (the simplified representation), for a good-enough solution to the right problem (the detailed representation).

2.3 Model scope

Another very important set of choices in the approach to technical analysis to underpin LAEP concerns which aspects of the system to actually model. There are a few issues to consider here:

1. we want the simplest possible model commensurate with the question we are asking
2. but we want to capture as much relevant (to our question) detail and interaction as possible
3. the type of model we need may constrain the amount of detail we can afford to represent. For a what-if model, this is likely to be greater than for an optimisation model. So the number of points of supply and demand in the problem will also be a factor: the smaller the area, the more tractable the modelling is likely to be. On the other hand, if we split the problem into multiple smaller problems, then we may miss interactions that affect the answer.

Decisions about modelling scope fall into the following categories. For each category there are further decisions about the level of detail to include:

- human behaviours
- energy demands
- fuels and associated emissions (both climate and air quality)
- devices
- networks
- primary energy sources
- energy system interactions

- **Model detail**

The amount of detail to incorporate in a model is always an important design choice, and LAEP technical modelling is no exception. The units of analysis will determine the kinds of questions that can be asked, and the kinds of answers that can be provided. This is a trade-off: too high a level of detail, and the problem can become intractable to compute. Too low a level of the detail, and the answers become less useful. For example:

- If heat demands are modelled as a spatially continuous function[15] (e.g. heat density mapping), then it will never be possible to model heat networks in a direct way: we will be limited to density-related heuristics about places that might be suited to networks, and we will have to think about the detail of the networks later. This may allow larger areas to be analysed, and may be OK, assuming that we can trust the heuristics to reflect accurately the cost of those networks. In practice however it is likely to lead to the omission of important interactions with the power system.
- If buildings are represented in groups, a larger geographic area can be analysed, but it won't be possible to model different changes to buildings within the same group (such as some being fitted with an individual heat pump and others connected to a heat network): the result is that some valid solutions might be ignored, and these may include the best one.
- If heat or electricity networks are represented simply as power flows, then some details will be ignored, such as hydraulic pressure changes (in the case of heat networks), and the effects of resistance, active, and reactive power (in the case of power networks).
- If heat networks are represented in full hydraulic detail, it is unlikely to be possible to evaluate a large number of alternatives in an acceptable amount of time.

The choices of what detail to incorporate can be summarised as:

- how should the locations of supplies and demands be represented? As individual point locations, groups, or areas?
- building-level interventions: which technologies to cover, and how much detail to model them in?
- network-level interventions: represent in detail, simplify, summarise, ignore?
- operational timescales: average demand? Peak demand? Full demand time series?
- planning timescales: ignore, annual, price control periods, decades, etc.

- **Sensitivity analysis**

Given the uncertainty around many influential inputs to LAEP analysis, participants will need to understand the sensitivity of the results to changes in input assumptions. For example, assumptions about the future price of electricity can have huge effects on the extent to which heat pumps are preferred over heat networks, as can the presence or absence of major options such as hydrogen distribution

These sensitivities can be analysed in two different ways:

- analytically: if we can understand the detail of the relationship between the parameters of interest, we can use this to calculate the effect of changes in parameter A on outcome B.

15 A spatially continuous function is something that has a value at any point on a map, for example height above sea level. In contrast, a discrete function only has a value at certain locations, such as a map of the point-locations of some heat supply options.

This is generally preferable, since it does not require modelling, and may yield useful insights into the behaviour of the system. However it is unlikely to be possible for all parameters of interest in a model of a complex system.

- when an analytical approach is not possible, the alternative is an empirical one: this simply involves running the model repeatedly while varying a small number of parameters to study the effect on the results. This is a potentially resource-intensive and time consuming approach, but is often necessary.

- **Numerical assumptions**

Last but not least, given an approach based on some combination of the options above, we will probably need to provide a large number of data inputs before we can use the model to answer a question. These will represent things like the costs, efficiencies and availability of technologies, the attributes of fuels, and the nature and location of potential and actual supplies, demands and distribution networks. These inputs tend to be hugely influential on the answers obtained from a model. So much so that it is not really possible to interpret the results of a model without knowing these details. See accompanying report on data and assumptions for use in LAEP (currently in preparation), which gives some detail on current and potential future approaches to selecting appropriate inputs.

- **Quality assurance and transparency**

LAEP stakeholders need to have confidence in recommendations based on evidence produced by models. This means that transparent quality assurance (QA) of the models and their inputs is of primary importance.

The aim of QA is to ensure that models are fit for purpose. This requires the development and publication of the following kinds of evidence:

1 That the model design is appropriate to the purposes for which it is being used

The evidence here will comprise a detailed explanation of what purpose the model is designed for, how it actually works (what is being calculated, not just what it is meant to represent[16]), a description of what details have been omitted and why, and a justification of how the resulting design meets the intended purpose. The detail here should be sufficient for an independent domain expert to critique the approaches taken.

2 That the inputs and assumptions being used by the model are plausible and non-biased

The results from well-designed models will be sensitive to key inputs and assumptions. QA of these inputs and assumptions is therefore just as important as QA of model design. For LAEP this requires a comprehensive dictionary explaining and justifying the value and provenance of all inputs and assumptions, including but not limited to parameters like costs, efficiencies and availability of technologies, the attributes of fuels, and the nature and location of potential and actual supplies, demands and distribution networks. This dictionary should always be provided to users of the evidence produced

16 For example 'the demand reduction effect of solid-wall insulation (SWI) is estimated by assuming a linear relationship between the % of the external wall area treated, and a maximum % demand reduction for SWI defined for all buildings. See Section X to understand how buildings are defined, how their external wall area is estimated, and how the above linear relationship is derived'. Rather than: 'the demand reduction effect of SWI is based on the amount of insulation installed'.

by the model (as well as users of the model itself). See accompanying report on data and assumptions for use in LAEP (currently in preparation) for further discussion in the context of LAEP.

3 That the model design has been implemented as intended.

All models are in effect computer programs, most of which have bugs. While it is unrealistic to expect any software to be completely bug free, it is important to employ systematic procedures to check for important bugs. This requires the development and implementation of a testing strategy. This strategy, and a summary of the results of the tests, should form part of the QA documentation provided alongside the model and/or results.

These QA procedures can be undertaken either by the authors of a model, or, ideally by third parties. The important thing is that the process is fully documented and transparent, since the objective is to give end-users confidence in the outputs. Further confidence can be secured by independent peer review of models, and by publication of model source code, enabling any suitably qualified person to review the implementation directly.

2.4 Conclusions

- **Purpose of technical analysis in LAEP**

The question at the heart of LAEP is "what is the preferred combination of technological and system changes we can make to the local energy system, to decarbonise heat and local transport and realise opportunities for local renewable energy production?" This can be further qualified: we want to minimise or avoid excessive cost, perhaps rule out solutions that are unacceptable locally, eliminate, or at least avoid exacerbating, the problems of fuel poverty and air pollution, and remain consistent with national decision-making about the energy system.

The role of technical analysis and modelling in LAEP is to provide tools and evidence to support decision-making, rather than to make the decisions. In practice, stakeholders will need to understand what a range of cost-effective solutions look like, and be enabled to explore variations with a clear understanding of the impacts of those variations on cost. This implies two requirements:

1 Identifying cost-effective candidate solutions
2 Evaluating variations to those solutions, to reveal the effects of different stakeholder priorities and preferences

The approaches used in the two steps need to be as consistent as possible, to allow valid comparisons between the costs and benefits of the computer-generated solutions, and the stakeholder-developed variants.

For step 1, the energy system scope and detail required for LAEP (see 'Energy system complexity and scope' below) means that for any area comprising more than a few buildings, there will be a large enough number of potential answers to require an automated approach to finding good solutions. Therefore this step will require decision modelling (see Section 2.2).

For step 2, users will need to be able to make changes to the results of the decision modelling, and evaluate the impact on costs and other objectives such as those related fuel poverty and air quality. This is what-if modelling, with the initial scenarios being the solutions produced in step 1.

The two approaches to decision modelling are optimisation and satisficing (see Section 2.2). They have different benefits and disadvantages.

Optimisation guarantees a least-cost answer to the question being modelled, but limits to maximum problem size and constraints on formulation can cause issues: model detail may have to be compromised, so that we are no longer optimising quite the right problem. Model formulation can be opaque to non-experts, and makes it difficult to extend or improve the implementation over time: often it is necessary to start again. Lastly, optimisation models are not well suited to the scenario modelling needed in step 2, because they are inherently designed to *find* a solution, rather than to evaluate a solution presented to them.

Satisficing has the important disadvantage of not guaranteeing a least-cost answer. On the other hand, larger problems can be modelled without compromising the representation because there is no inherent limit to problem size. The modelling can be done with more flexibility and transparency because no special formalism is required. Extension and improvement are more straightforward than is the case with optimisation, and because we are already using a what-if type model, the same energy system model can be used for both steps.

Optimisation and satisficing are both acceptable approaches to decision modelling for LAEP – the important thing is to understand the impacts of the inevitable trade-offs that either approach brings.

However as discussed above, there are several good reasons to explore satisficing as an alternative to optimisation in which a more detailed energy system model can be used in a heuristic search process to identify low (but not guaranteed least) cost solutions. The same model can subsequently be used in a scenario context to allow users to explore variations.

- **Detail required of technical analysis in LAEP**

Addressing the core LAEP question requires an analysis that represents the relevant energy system components and their relationships in sufficient detail to enable accurate estimation of the costs and benefits of alternative solutions, and their impacts on related concerns such as fuel poverty and air quality.

This requires representation of important interactions between supplies, demands and vectors, and representation of at least two operational time periods – average and peak load.

The level of detail must be sufficient to avoid excluding potentially valid solutions, meaning that supplies and demands need to be represented independently at their individual spatial locations.

The models used to estimate energy demand in buildings must allow for the effects of demand management measures such as thermal insulation and storage.

Accurate assessment of the costs of network-level options requires the representation of networks to include routing, sizing and connectivity. Modelled changes in demand must be propagated up networks to capture potential interactions between decisions about demands on the same network.

Energy cost changes should be used to estimate potential fuel poverty impacts, and emissions of air quality pollutants from local combustion of fuels should be quantified.

- **Current practice: how is modelling being used now?**

There is currently no formal process for the technical analysis required for a robust evidence-based LAEP. However a range of activities is underway which corresponds, at least partially, to the definition and purposes proposed here.

The separate Modelling Evaluation Report undertaken as part of the commission from Ofgem (in press) summarises a large number of existing models, some of which have been used to support local energy planning in one way or another. The majority of these tools do not incorporate decision modelling, and many of them operate at lower level of detail than that required for LAEP.

The current analytical approaches closest to the idea of LAEP proposed here are EnergyPath Networks (EPN) and THERMOS. These both use optimisation decision models to generate least-cost solutions with considerable detail. Each meets some of the criteria outlined in 2.1 and 2.2. Each has some limitations which require further investigation. These models were explored in detail with the Modelling Sub-group of the project Steering Group.

The outputs of both of these models have been used to inform subsequent stakeholder-driven local energy planning, itself comprising further optimisation and what-if modelling, using a range of tools.

- For example in Bristol, CSE used THERMOS to quantify the relative contributions of solid wall insulation, heat pumps, and heat networks to the challenge of decarbonising heat in buildings by the city's adopted net zero target date of 2030. The results of this analysis informed stakeholder engagement and the development of high-level policy objectives and are now being used to target detailed subsequent feasibility analysis commissioned by BEIS to support Bristol City Council to assess initial locations for investment in heat decarbonisation.
- As part of the ETI's Smart Systems and Heat Programme the ESC used Energy Path Networks in three local areas – Bury, Bridgend and Newcastle - to trial approaches to LAEP. These projects worked with each of the three local authorities and local stakeholders including network operators. EPN was used to help produce whole system evidence bases and strategies to help the areas understand their local challenges and opportunities for decarbonising heat and meet their carbon targets. Future uncertainty was considered to give an assessment of low regret pathways. As a pilot process the approach to LAEP with EPN developed over time, with each study informing the next and ultimately helping to inform the thinking of this project.

These and other approaches are responding in ad-hoc ways to local requirements. Some of these have explored options for the LAEP process, but need further development to be fully consistent with the criteria developed here. However it is important to recognise the value of ongoing and emergent activity; the purposes of this document are to define some standards for current practice – in particular for situations where the results could ultimately lead to significant investments (see Section 5 bit on where LAEP stops and project specific analysis starts); and to point the way to improvements, enabling better identification of cost effective decarbonisation solutions. But action that cuts emissions is better than no action at all, and it would be perverse to allow a search for optimality to get in the way of immediate steps to decarbonise our energy system. This is another sense in which satisficing may be more appropriate than optimising: perfect must not be the enemy of good enough, particularly in an emergency.

2.5 LAEP 'done well' checklist: robust and consistent technical analysis

LAEP 'done well' checklist: robust and consistent technical analysis

If a local area energy plan has been done well, the technical analysis undertaken to produce the underpinning evidence of energy system changes needed to achieve agreed objectives will reflect the following considerations:

Overall approach

- ☑ Technical analysis should **combine decision and scenario modelling**, enabling stakeholders to understand the cost and carbon emissions implications of a range of alternative plans, relative to a known low/least cost solution.
- ☑ The **energy system scope** of the analysis must include: local generation opportunities for low/zero carbon heat and power; distribution networks for electricity, gas and heat; use of distributed hydrogen where regional/national contexts suggest it may be an option; heat demand in buildings, and the opportunities for managing and meeting it; expected demand for EV charging, and its impacts on electricity distribution systems.
- ☑ The analysis should represent the energy system components and their relationships in **sufficient detail to capture important interactions between vectors**. The level of detail must also be sufficient to avoid excluding potentially valid solutions. This means that supplies and demands (such as buildings) should represented independently at their spatial locations; the representation of demand in buildings should allow modelling of the effects of demand management measures; network representation should account for geographic routing, system sizing, and network connectivity (including the terminal connections to demands); and changes in demand should propagate up networks, to capture interactions between decisions regarding different demands connected to the same network. Where gas networks will be required to carry hydrogen, some estimate of the cost of repurposing should be included. Changes in energy cost should be quantified to enable analysis of fuel poverty impacts, and emissions of local air quality pollutants should be quantified and potentially constrained in decision modelling.
- ☑ **Representation of time** i.e. how the system will change over time, should include operational (annual and peak demands) and planning (multi-year) horizons. The rate of installations of different technological options over time should be characterised, taking account also of non-technical factors which will affect rates of installation, such as supply chain readiness, consumer appetite etc – see Section 3.
- ☑ The **geographical scale** selected for the LAEP technical analysis should be clearly defined and reflect a balanced appraisal of the issues described in discussion on 'scale' in Section 1 above.
- ☑ The sensitivity of modelling results to **key uncertainties** (e.g. fuel prices, plant costs and efficiencies, weather effects) should be presented to participants in the social process along with the results themselves.

- ☑ The **data inputs and their sources** should be detailed transparently. Where possible, standard inputs[17] should be used to represent costs, efficiencies and availability of technologies, the attributes of fuels, the nature and location of potential and actual supplies, demands and distribution networks, and assumptions about future climatic conditions. When non-standard inputs are used, this should be explained and justified.

Quality assurance

- ☑ **Validation of models**: The technical analysis should be accompanied by documentation explaining and justifying how the models used actually work. This must be in sufficient detail to enable readers to understand what is being calculated (as opposed to what it is supposed to represent). It should include a frank assessment of the weaknesses of the approaches taken so that outputs can be treated with appropriate care by stakeholders (rather than treated as 'truth').
- ☑ **Validation of numerical inputs:** Where non-standard values are being used as inputs to modelling, detailed sourcing and justification must be provided. This should include quantitative evidence that critical values (such annual and peak energy demands) are plausible – for example by comparison with external data.
- ☑ **Verification of implementation:**
  At a minimum: detailed documentation explaining how the model implementation has been tested, the results of that testing, and why the approach taken to testing is appropriate. This should include quantitative evidence that the outputs of the model are plausible.

  *Better***:** development and application of a formal third-party verification process to ensure that the implementation is free of critical bugs. This would benefit from access to model source code, which would have to be structured to address any concerns about commercial sensitivity.

  Ideally: independent expert review of the design, implementation and performance of the model based on review of the model source code.

2.6 Areas for further development

- **New tools**

To support consistency, transparency and comparability of studies, we recommend the development, publication and ongoing maintenance of a standard set of assumptions and inputs representing costs, efficiencies and availability of technologies, the attributes of fuels, and the nature and location of potential and actual supplies, demands and distribution networks. This should also include a standard[17] set of assumptions about the long-term evolution of the climate, perhaps based on Met Office UKCIP projections).

We recommend the development of a set of energy system models specifically for use in verifying third-party modelling tools. This could include detailed verification using a set of relatively small-scale test problems for which optimal solutions are known, as well as checking against known bounds for larger scale problems.

17 The accompanying report on data and assumptions for use in LAEP (currently in preparation) should be a useful starting point for the development of a standard set of inputs and assumptions.

- **Quality assurance and standards**

Quality assurance standards should be updated as best-practice evolves. In particular QA should be extended to require model behaviour to be checked against test problems when these are available.

- **Combining approaches to support planning**

As discussed at the start of Section 2.4, a new approach to modelling for LAEP may yield a more useful set of tools to support the process. This would involve the same what-if energy system model being used in two different ways:

1 heuristic search methods would drive the what-if model to search for a satisfactorily (as opposed to optimally) low-cost solution
2 the same what-if model could then be used as a scenario tool, supporting participants to explore changes to the computer-generated solution from the first step. This would enable participants to understand the additional costs imposed by variations which move away from the automated solution.

This approach would allow the use of a simultaneously more detailed and transparent energy system model than is the case with current optimisation-based methods – something which could have the additional benefit of making it easier to build stakeholder confidence in the results. And it should in principle be possible to use the same what-if model as required by the approach to verification proposed under ‘New Tools’ above.

3 Beyond the technical analysis: Understanding the wider aspects of system change that will determine success

Evidence derived from robust technical analysis is the underpinning for local area energy planning.

However, while the assessment of different technology options and the energy system changes they require is vital, any successful plan will also need to consider and address the wide range of non-technical factors that shape whether these options are realised in practice.

For example, the technical analysis might indicate how many heat pumps, heat networks and/or hydrogen boilers would need to be installed in an area to decarbonise heat over a particular time. And it could reveal how much the energy performance of local buildings would improve and heat demand reduce through the installation of different sorts of retrofit measures.

This is useful because it suggests the nature and scale of technological changes required.

But even the best technical analysis will not reveal what actually needs to be done in practice to ensure those installations happen at the scale and rate required. Such analysis will suggest what needs to be installed, but not how those installations might be brought about or what factors will determine the potential rate of growth of installations or how potential equity issues are addressed (e.g. who gets installations first and how any network upgrade costs are recovered).

This is because there is a range of non-technical factors which strongly influence and, in some cases, ultimately determine what can happen in practice.

For example, the transformation of how we heat buildings requires a different pattern of capabilities and supply chains than those which have been dedicated to delivering gas central heating for the last 50 years. The shift from gas boilers to heat pumps (for example) is likely to require a shift in public understanding and preferences which has only recently started to be explored.[18] In many cases, it will require a different regulatory approach and the balance of costs and incentives for different options will need to be changed. These changes can only take place over time and some are likely to require national level interventions, and how quickly they are introduced will affect how (in this example) the rate of installation of heat pumps could grow.

In addition, some technology options in any given locality, such as the availability of hydrogen for heating, are likely to depend heavily on regional conditions (such as the availability of locations for carbon capture and storage) and on national decisions on funding. Any locality's assessment of such options therefore needs to be tempered by an appreciation of these potential constraints and the wider influences shaping their local availability.

Many of these non-technical factors have local dimensions. But most are common across all areas. They are the product of national policies, regulatory and commercial practices, patterns

18 See for example: https://www.eti.co.uk/insights/the-journey-to-smarter-heat and https://www.gov.uk/guidance/electrification-of-heat-demonstration-project

of investment, supply and consumer choices that have developed over decades, often without taking account of the need to achieve net zero carbon emissions. These are the factors which currently sustain the status quo (e.g. gas for heating, petrol and diesel for mobility) and/or which create barriers and challenges for the ready implementation of decarbonisation options.

Creating the conditions for success locally (and nationally) therefore involves understanding and addressing these factors.

Indeed, if these wider non-technical factors and dependencies are not reflected in the development of a local area energy plan, the plan will not be rooted in an understanding of what actually needs to be done to realise change in practice. And, the plan will be incomplete if it does not include actions to address these factors and a recognition that this will require both local and national action by a wide range of stakeholders. As a result, even with extensive stakeholder engagement, the plan will not prove effective and will not be realised in practice.

How should this be addressed in local area energy planning? What would constitute it being 'done well'?

3.1 Considering non-technical factors and influences

There is a variety of techniques that could be applied within local area energy planning to identify and consider the range of non-technical factors – locally, regionally and nationally – which will influence the adoption (or not) of different net zero options in a particular locality. For example:

- **PESTLE analysis** (Political, Economic, Social, Technological, Legal, Environmental)[19]

PESTLE analysis is a generic technique widely used in strategy development to capture systematically the conditions currently shaping the adoption of particular services or technologies.

For LAEP purposes, this technique is likely to need to be applied to specific areas of action (such as building retrofit, heat decarbonisation, transport decarbonisation, renewable generation, smart demand response etc) rather than decarbonisation generally. To reveal what needs to change across each of the PESTLE dimensions, the technique can also be used to consider what conditions would need to have been put in place to stimulate and sustain technology or service adoption at the rate and scale identified in the technical analysis.

Combining the standard 'here and now' picture from a PESTLE with such a forward-looking analysis should:

a. capture a sense of the full range of changes required to achieve decarbonisation locally

b. provide a rounded sense of the starting point for action to initiate any changes and the nature and scale of change required over time to underpin success.

19 For more details on this technique, see, for example (without endorsement), https://www.groupmap.com/map-templates/pestle-analysis/

- **'Walking right round the issues'**

As a framework for thinking about the non-technical conditions required for technical success, CSE's 'walking right round the issues' technique is more future-oriented than PESTLE analysis; it was developed with achieving energy system transition specifically in mind.[20] The technique combines consideration of the technical analysis for a particular energy system outcome (the red 'energy system' box in Figure 3) with consideration of the 'capability', commercial, policy and regulatory, and socio-cultural dimensions involved in shaping what is possible. This approach is captured in Figure 3.

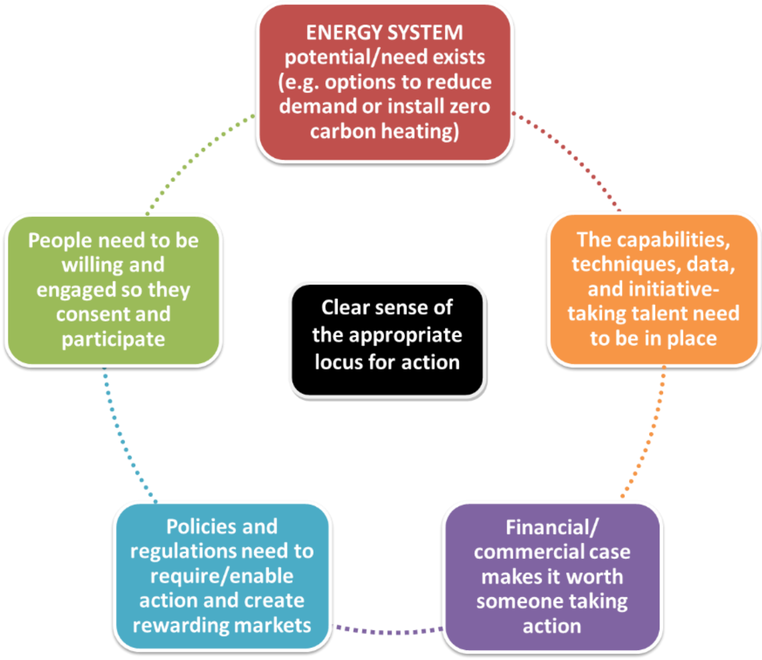


Figure 3: 'Walking right round the issues' systems model: the range of conditions for success

The technical analysis effectively provides valuable whole energy system evidence as one input to the LAEP process (the top, red box in the diagram). Adding in consideration of the four other dimensions should result in a more comprehensive and realistic understanding amongst local stakeholders of what is involved in delivering change and the full range conditions required for success. The same approach can also be applied to assessing the current state of play in relation to each required change in the locality (using a SWOT analysis or similar), thus establishing a clearer picture of the starting point for the local area energy plan.

The central consideration of the appropriate locus for action helps to draw out where powers, agency and influence currently lie and where they might need to lie for successful system transition to be achieved.

20 For how this model has been applied in projects which feature elements of local area energy planning, see, for example, www.cse.org.uk/Bristol_net_zero_by_2030_study_CSE_26_Feb_2020.pdf, www.cse.org.uk/west-of-england-energy-study-report-and-recommendations.pdf & https://www.cse.org.uk/downloads/reports-and-publications/policy/community-energy/insulation-and-heating/planning/renewables/towards-a-smart-energy-city-maping-path-for-bristol.pdf. These references (particularly the latter two) also include more detailed description of how this 'systems' model is applied.

As with PESTLE analysis, this approach brings that the wider factors – such as national policies and regulations, market conditions and the distribution of powers to act – into consideration. This avoids the risk that a local area energy plan is conceived in isolation and ignores how these factors shape and influence what is possible – or indeed desirable – in any given locality.

- **Participatory Systems Mapping**

Participatory Systems Mapping[21], developed by CECAN (the Centre for the Evaluation of Complexity Across the Nexus), is a more complex technique. It can be used to identify, map and assess the range of factors which influence a system and lead to different types of outcome, including the strength of their influence and their interactions. The technique has been designed to be used by groups of stakeholders for the discussion and exploration of complex societal problems and how they can be addressed.

Following its in-depth eleven step process (see reference in footnote 21 for details) will enable a group to:

(a) produce a clear picture of the different factors currently shaping the outcomes experienced
(b) examine how changes to those factors might result in different outcomes.

3.2 No local area energy plan needs to start from scratch on this analysis

Whichever analytical technique is applied in local area energy planning to review these non-technical factors, much of the knowledge and insight required to populate it already exists in government-commissioned and academic research.

For example, the Committee on Climate Change, BEIS, the devolved governments and various academic programmes have produced research reports identifying a wide range of barriers to the implementation of different heat decarbonisation options[22]. A number of local energy studies describe the typical influence of local conditions alongside these more general factors. To these will need to be added a consideration of the situation in the specific locality in question.

Drawing on such analysis and on the insights of local stakeholders captured in the LAEP social process (including, for example, installers and housing providers), the resulting 'conditions for success' analysis for installing heat pumps at scale might include the following factors:[23]

- Electricity network reinforcement and associated flexibility and smart constraint management systems to deal with the additional demand and peaks of heat pumps for

21 See https://www.cecan.ac.uk/sites/default/files/2019-03/PSM%20Workshop%20method.pdf for a description of the method being applied to an energy system issue in a stakeholder workshop and how to apply each of the 11 steps in the process.

22 See for example, the CCC (2018) https://www.theccc.org.uk/2018/09/10/cleaning-up-the-uks-heating-systems-new-insights-on-low-carbon-heat/, BEIS (2018) at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf and Energy Systems Catapult at https://es.catapult.org.uk/brochures/decarbonisation-heat/

23 For a more detailed assessment of these issues as part of a local area energy plan, see pp.37-44 at https://www.cse.org.uk/downloads/reports-and-publications/policy/insulation-and-heating/energy-justice/renewables/behaviour-change/building-performance/Bristol_net_zero_by_2030_study_CSE_26_Feb_2020.pdf

those areas where they are likely to be the dominant option and the network would become constrained.

- A skills upgrade for local heating engineers to fit heat pumps (instead of gas boilers) and to ensure local supply chains are geared up to supply the kit at the rates required.
- Some sort of funding package to address the capital and operational cost-differential between heat pumps and the current 'default' heating installation, a gas boiler.
- A series of new powers and regulations to drive out gas boiler replacements over time.
- A significant programme of public and business engagement to develop their understanding of the future of heating ('beyond natural gas') and the steps they will need to take (and by when and how they will be supported to do so), including local exemplars which show-case the new solutions and build confidence in their performance.

3.3 LAEP 'done well' checklist: understanding the wider determinants of success

LAEP 'done well' checklist: understanding the wider determinants of success

If local area energy planning has been done well, it will reflect a good understanding of the full range of conditions required for success in delivering decarbonisation locally and their current state of play. The LAEPlan should therefore include:

☑ An explanation of the different non-technical factors – from skills and supply chains to relative costs and consumer perceptions to national policy and funding decisions – which will need to be addressed if the technological options are to come forward at the rate and scale identified as required.

☑ A description of the conditions for success for each of these factors that need to be put in place over time to secure the required societal and energy system changes.

☑ A picture of the current state of play for these conditions in the locality so that the plan starts from where things are now. This should include those factors which relate to national policies, regulations, market conditions etc which may be similar everywhere but which still have a strong influence on what will happen locally.

☑ An account (also informed by the technical analysis) of how the rate of implementation of the different decarbonisation solutions (e.g. number of buildings insulated each year) is influenced by these non-technical factors and how this is reflected in the implementation trajectories identified in the plan to meet the adopted decarbonisation commitments.

☑ A set of timetabled actions to be undertaken as part of the plan to realise these conditions for success locally. This should include actions needed from non-local stakeholders such as government or regulators – and how the locality will influence such stakeholders to take these actions to support local efforts.

4 The Social Process: Engaging stakeholders to improve understanding, shape outcomes and build commitment to act

Effective local area energy planning needs to involve a wide range of local stakeholders to ensure its output – a local area energy plan – has been shaped by and reflects informed local perspectives and their shared priorities.

This requires an effectively designed and delivered social process which:

- engages relevant stakeholders and provoke evidence-based debate;
- enables and build shared understanding;
- informs, shapes and reveals options, trade-offs, preferences, and priorities;
- fosters consent for the nature and scale of changes needed and the actions required (and from whom) to deliver them;
- works within the democratically accountable processes within the area.

Its ultimate goal should be the adoption of the plan by the local council(s) for the area and endorsement by other stakeholders likely to be key to its subsequent implementation (see Section 5 on Governance and Delivery below).

Without a process to secure such involvement, the local area energy plan will not be credible as a representation of the informed will and intent of the locality. It is unlikely to be realised in practice, however good the technical analysis of options on which it is based.

4.1 The objectives of the social process

To be done well, the LAEP social process will need time and it will need to include a number of different events and facilitated exercises to enable stakeholders to:

i. determine the governance arrangements for the process (e.g. steering group and associated terms of reference and mechanisms of accountability)
ii. reveal existing or emerging local priorities and preferences and other key local considerations the plan must take into account
iii. examine and challenge analytical outputs (and request further iterations and sensitivity analysis) to understand trade-offs and cost implications of different approaches
iv. consider wider influences on what's possible and the conditions required for success (and how they might be created locally) (see Section 3 above).

In particular, the process must enable stakeholders to:

v. define how the emerging plan and the associated conditions for success will be delivered locally (and what further assistance and support might be needed and from whom)
vi. build consensus around the emerging plan and establish commitments to follow through on its implementation.

Depending on the timing of the commissioning of the local area energy planning process, it would be ideal if stakeholders could also help to:

- shape the design of the stakeholder engagement process itself

- set the priorities and parameters for the technical analysis, detailing the evidence they feel they need and the sensitivities it would be useful to understand.

4.2 Knowing and mapping the stakeholders

The social process needs to start with an exercise to map stakeholders and identify organisations and, within them, individual stakeholders who are central to the process.

It is very unlikely that this process will be starting from scratch. There will already be stakeholders who have been or are actively involved in at least some aspects of local area energy planning. The mapping exercise should therefore also include documenting and understanding what activity has already been undertaken in the area and its origins, purposes, participants, outputs and impacts.[24]

That said, stakeholders are likely to include:

- Members and officers of the local council(s) and of town and parish councils (officers to include sustainability, economic development, planning policy and development control, energy, housing and other relevant departments/disciplines)
- Representatives of regional bodies such as combined authorities and local enterprise partnerships in England, Regional Economic Partnerships in Scotland ,and Statutory Joint Committees and various regional economic and skills partnerships in Wales
- Electricity and gas distribution network operators
- Local MPs/MSPs/AMs
- Key institutions such as universities and hospital trusts (who also tend to have large heat loads) and FE and technical colleges
- Other locally-based organisations active in energy generation, supply, management and/or advisory services, including businesses, consultants, community organisations and charities
- Developers of new local building developments, heat networks, and local energy projects
- Transport providers and electric vehicle charge-point operators
- Building and heating trades and associated supply chains (such as heat pump manufacturers)
- Local businesses (or their representative local bodies such as chambers of commerce and federation of small businesses)
- Consumer representatives (such as local citizens advice and other advice and advocacy groups)
- Local Energy Hubs (in England)

The stakeholder mapping process should seek to characterise each stakeholder with reference to: their level of knowledge and experience of the issues at hand; their existing or potential influence and agency (in the context of achieving local decarbonisation objectives), and; their level of interest in and commitment to doing so. This last characteristic will help to inform what might need to be done to secure organisational commitments to deliver on the resulting plan.

24 Indeed, it may be that the previous work would meet the criteria in the 'done well' checklists outlined here and would therefore 'qualify' as good quality LAEP already, even if it was not called that or informed by this document at the time.

4.3 Facilitated engagement

The type, number and scale of stakeholder engagement activities will depend on available time and budgets but at a minimum the process should enable:

- Engagement on a timely basis with the outputs of the technical analysis to 'ground truth' them with knowledge of local stakeholders and consider their potential implications for the area (ideally with an opportunity for a more technically expert group of stakeholders – if available – to assess the analysis in detail).
- Exploration of the range of 'non-technical' conditions for success which need to be created to realise the decarbonisation options anticipated by the technical analysis (as described in Section 3).
- Identification and exploration of potential trade-offs between different options and the implications of linking decarbonisation plans with other associated objectives (such as tackling fuel poverty) and broader local political priorities (such as reducing inequality or sustainable economic growth).
- An assessment by stakeholders of the current state of play for each of these conditions and identification of (a) early actions which will start to shift the current situation towards the conditions for success and (b) more sustained initiatives required to further that progress.
- The description of commitments to act required from different stakeholders and a process to encourage such commitments and accepting associated responsibilities.

Involving stakeholders in these activities will tap into their local and domain knowledge and insights while also improving their collective understanding of what needs to happen. This should result in a more refined set of actions in the plan and more ready commitments to lead or undertake or support them beyond the process of developing the plan.

Each stakeholder event (and any other engagement technique used) should be designed to achieve specific objectives and defined outcomes. Events should be facilitated to be involving, informative, accessible and inclusive. The management of vested interests should be a central feature of the facilitation process, to avoid undue influence from those with an interest either in maintaining the status quo or promoting particular solutions above others. The range of perspectives revealed and how differences were explored and resolved (or not) at these events should be documented.

The consistency of stakeholder representation through the process is important to its integrity. This means consistent attendance by the same person (or effective briefing of any alternates needed) so that the knowledge and insights build through the process.

The status of the stakeholder representative is also important. They need to have appropriate authority to represent their organisation's views in the process and to be able to anticipate (and potentially then shape) the organisation's future views in the face of new information and analysis. Without this, there's a risk that those involved in the process are not actually able to establish the subsequent buy-in, endorsement and commitments to act from their organisations that are key determinants in the LAEPlan's future success.

4.4 Wider public engagement

Wider public engagement may also prove useful, though may not be feasible within the available budgets beyond allowing interested members of the public to participate in the stakeholder events. If funding is available, public surveys, focus groups, citizen panels and engagement via digital platforms and forums, allied with appropriate information and evidence (such as maps and 'what if' tools), can reveal local attitudes to the changes being considered. The resulting insights can help to inform the nature and scale of the opportunities and challenges for public engagement and the action they would be expected to undertake. It should also be noted that the involvement of the public in such processes can often lead to greater interest and willingness to act and consent for others to make appropriate decisions which drive change. Equally usefully, it may also reveal the likely sources of concern and discontent that will need to be addressed or overcome.

4.5 LAEP 'done well' checklist: evidence of an effective social process and engaged stakeholders

LAEP 'done well' checklist: evidence of an effective social process and engaged stakeholders

If local area energy planning has been done well, it will be able to demonstrate that it has both shaped and been shaped by the perspectives of a decent range of relevant local stakeholders. The LAEPlan should therefore include a description of the social process involved in its production, featuring:

☑ An outline of the design of the social process, including the range of stakeholder engagement techniques involved, the intention of each element at each stage of the process, and how they were conducted to manage the influence of vested interests and to ensure differences of opinion were heard and explored.

☑ A stakeholder map for the locality, detailing the role of each stakeholder and characterising their potential influence/agency on outcomes, and demonstrating that a sizeable proportion of them, including those with significant potential influence and/or agency, engaged with the development of the plan.

☑ Details of the stakeholders who were involved in the process, the seniority and/or authority of their attendees, and the nature and extent of their involvement in each element (e.g. attended workshops, commented on drafts, participated in steering group etc). This should also identify those stakeholders who did not get involved. To be credible as a process, stakeholders involved <u>must</u> include the relevant local authorities (both member and officer representation), energy network operators, local business representatives and community organisations.

☑ Evidence of how stakeholder views changed (or not) during the process, both about specific issues and also about level of commitment they were prepared to make to act and work together on the delivery of the LAEPlan.

- ☑ A description of how each of the different elements of the process contributed to the development of the plan and an acknowledgement of those areas which proved difficult to resolve.
- ☑ In all of the above, evidence which demonstrates that the process was suitably transparent and open and managed in a way which kept it free of the undue influence of vested interests.

5 LAEPlan deliverability and ongoing governance: Arrangements and commitments that put a local area energy plan on course to be realised

Even the most soundly evidenced and involving local area energy planning process can prove ineffective if it does not result in a plan that local leaders and other key stakeholders are committed to deliver. Without some ongoing governance arrangements and realistic delivery commitments from those able to deliver, it becomes little more than a wish list.

Aside from the potential for frustrating local stakeholders, this matters if a local area energy plan is to be used to underpin the development and targeting of regional and national policies, programmes and funding.

And it particularly matters if a LAEPlan is providing the basis for energy network investment plans, for example to upgrade over time the electricity network in an area to accommodate the growth in different forms of EV charging and a significant take up of heat pumps. Both the network companies and the regulator will need to be confident that plan as set out will be delivered – that the EV charging points and the heat pumps will be installed at broadly the rate anticipated in the plan so that the investment is both timely and cost-efficient for consumers.

There are five (?) elements to consider here:

- a realistic sense of local agency (including an understanding of what action is needed from others)
- meaningful endorsements and commitments to act by those who matter
- an awareness of what else still needs to be done (i.e. where a LAEPlan stops and even more detailed planning begins)
- ongoing involvement and processes to monitor and drive progress and develop the plan in response to a changing context.

5.1 A realistic sense of local agency (with an eye to the potential for change)

A LAEPlan needs to be grounded in a realistic assessment of the current and potential future agency of the locality (i.e. its stakeholders) to deliver on the approach to decarbonisation it is embracing at the pace intended.

The exercise in assessing non-technical factors (described in Section 3 above) will help to reveal opportunities to shape and influence local conditions to enable decarbonisation. It will also reveal the importance of regional and national policies and programmes, regulatory and consumer protection practices, and the role of different market actors and socio-cultural conditions (e.g. norms of behaviour and consumer preferences). By doing so, it will reveal that sub-national levels of government currently have very few specific legal powers which have influence on the energy system and the changes which are involved in decarbonisation.

In this context, it might be tempting to conclude that the realisation of a LAEPlan is largely in the hands of bodies outside the locality and that any LAEP with more ambitious targets for achieving decarbonisation is bound to fail.

But local agency is not confined to specific legal powers (such as planning policy) available to local authorities or mayors or combined authorities. Agency extends beyond just the local authority and into opportunities to shape outcomes beyond those represented by legal powers.

For example, public bodies (including local authorities, health trusts and universities) and larger businesses have significant agency over their own emissions and the investments they make to upgrade their buildings, heating systems and transport fleets. They may also control significant procurement budgets which could be used to drive decarbonisation efforts by others. In addition, the powers to convene and influence others can be significant as can the opportunity to pilot and showcase better practice.

And many local stakeholders have mechanisms to engage their employees, the wider public, community organisations and the business and voluntary sectors. These mechanisms could be used to improve local understanding and promote the take up of particular actions or behaviours. Some local stakeholders may also have the ability to secure funding from national government or other agencies outside the area.

Moreover, these structure and powers – and the energy system itself – are not as they currently are because they were designed to achieve net zero. They are the result of many decades of practice across many different domains, some of which are now habitual rather than purposefully chosen for the challenges we now face. Indeed, they are not optimised to solve the 'net zero' challenge. And they have not be optimised to reflect the potential of local area energy planning to contribute to solving it.

The current arrangements between local and national powers and actions cannot therefore be considered inevitable or fixed. Other countries organise things differently (both technically within the design of the energy system and politically in how decisions about it are taken). And in the UK, national decision-making about policy design and funding priorities is often highly influenced by local 'bottom up' examples of initiative-taking and/or willingness to act.

In addition, national carbon budgets and national carbon reduction delivery plans have yet to be described in terms of how progress towards net zero by 2050 distributes geographically. Many localities[25] have, through democratically accountable processes, adopted targets to achieve net zero emissions sooner (in some cases 20 years sooner) than the UK legally binding target of 2050.

At first sight, that disparity might make these more ambitious local plans look unachievable – how could an area go faster than the national pace of change? And yet it is highly unlikely that everywhere will transition to net zero at the same rate. Some areas are likely to go quicker. And the achievement of the national 2050 target will probably be more achievable everywhere if there are such 'fore-runners' because of what they will demonstrate and learn and what they will stimulate in terms of supply chains. The question then becomes one of how national

25 And Scotland with its adoption of a statutory target date of 2045 for achieving net zero greenhouse gas emissions.

decision-making might support these fore-runners to go early and quicker, such that their plans are more achievable.[26]

It should also be noted that there are some engineering or technical factors which may constrain the options for heat decarbonisation in different localities. In this category would be the availability of sufficient carbon capture and storage facilities nationally to support extensive production of near-zero carbon hydrogen for use in heating buildings (or fuelling industrial processes or freight transport). For example, if CCS and therefore hydrogen production facilities are limited to certain geographical areas, it may well limit hydrogen use to areas near such facilities. It would likely severely restrict hydrogen as a cost-competitive option in locations which have no direct link to those the production areas via other 'hydrogen using' areas (and thus no continuous 'in use' pipelines to the supply). These are factors which may be genuinely outside a locality's control, irrespective of local preferences.[27] A LAEPlan should therefore reflect an awareness of which of the options being considered import such dependencies; it should also suggest alternative approaches should these options become 'out of reach' for the locality.

5.2 Meaningful endorsements and commitments to act

For a LAEPlan to be credible, it needs to be backed by local stakeholders who make meaningful commitments to take actions in the plan which are in their reach. These should emerge readily from an effectively designed and managed process. The nature and timing of endorsements offered by different types of stakeholder will vary. Some ultimately matter more than others. For example, a lack of endorsement and commitment from a local authority is likely to render the LAEPlan ineffectual. On the other hand, some organisations, such as energy network operators, may not wish to provide a blanket endorsement of the whole plan but will commit to undertake actions suited to their role which enable the plan to progress.

5.3 An awareness of what else still needs to be done

A LAEPlan done well will be far more detailed in its description of what needs to happen across a locality than would typically be available from regional or national assessments. It can thereby accelerate the implementation of decarbonisation options by revealing their local potential and their likely locations.

However, LAEPlans' limitations should also be recognised. The detail they can provide only goes so far. For example, they may indicate the likely number of EV charging points that will be required in an area to meet growing demand from the take-up of EVs which the plan anticipates will contribute in part to the decarbonisation of local transport. But the LAEPlan is unlikely to be able at this stage to specify the precise locations of the chargers, nor the type, nor how much

26 And, as a counterpoint, how to support those localities with more limited ambition and/or capabilities who are at risk of lagging behind and failing to contribute adequately to national efforts

27 Zero carbon hydrogen may become available in other areas from electrolysis of water using renewable energy. However, the questions of relative cost, where such opportunities genuinely arise, and also what applications the hydrogen will fuel all tend to involve factors which are also outside a single locality's control.

each will be used. Moreover, the way in which people charge their EVs is evolving as the charging networks evolve and as incentives to avoid demand peaks emerge.

Similarly, cost-effective opportunities for developing zero carbon heat networks may be identified in some detail in the technical analysis. But there will subsequently need to be a more detailed study of each opportunity to establish the engineering and operational design and underpin its financing and construction.

At the level of individual buildings, technical analysis might suggest retrofit measures to reduce demand by a certain level. But the works themselves will require more tailored assessment and design work. And building owners and the installation supply chain will need to be engaged to take this more detailed work forward.

At the level of the local electricity network, the Distribution Network Operator looking to support and enable the delivery of a LAEPlan will need to undertake its own technical appraisal of: (a) the potential impact of the LAEPlan's proposals on its network over time (compared with its existing plans); (b) the impact on existing or anticipated capacity constraints in the area, and; (c) the optimum combination of network upgrades and smarter management across the local network (and potentially beyond) to accommodate the LAEPlan as it progresses in practice.

A LAEPlan should acknowledge these limitations (even though they are somewhat inevitable at this relatively early stage of local energy system decarbonisation). It should therefore include in its plans a recognition of the need for this more tailored design work and proposals for how these might be realised as the plan progresses and is updated.

5.4 Ongoing involvement and processes to monitor and drive progress

A LAEPlan needs to become a 'living plan'; one which is actually being delivered and which has

- an enduring process of engagement and involvement by the key stakeholders and initiative-takers
- a process and assigned responsibility for monitoring, reporting and chasing progress
- a timetable for updating the plan to reflect progress and changes in local and wider circumstances (e.g. technology cost reductions, new funding opportunities, national policy developments – or lack of them, changes in social norms and public willingness to act as technologies and behaviours become more common, the findings of LAEPlans in adjacent areas etc)
- continuing alignment with national guidance on LAEP from Ofgem, BEIS, and devolved nation governments as it develops to reflect practice and experience and the availability of improved analytical techniques.

This might be done through the continuation of a steering group set up to develop the plan. However, over time, more robust governance and institutional arrangements between key stakeholders might be expected to be put in place.

5.5 LAEP 'done well' checklist: a realistic and deliverable plan

LAEP 'done well' checklist: a realistic and deliverable plan

If local area energy planning has been done well, the LAEPlan will include:

☑ An articulation of a realistic sense of local agency which reflects:

(e) the objectives and priorities of the locality

(f) the powers and influence available to stakeholders across the locality

(g) an understanding of what commitments and changes are required from other stakeholders, including national governments, to enhance local agency and create the conditions for success and what local actors (potentially in alliance with others) can do to secure these commitments

(h) awareness of the dependence on wider conditions and future national decisions that could influence the availability of some technical options (e.g. hydrogen) in the locality, whatever the local technical evidence or local preferences had anticipated.

☑ A range of endorsements and commitments to act from key local stakeholders.

☑ An awareness of the further analysis and programme design which will need to be undertaken to finalise delivery plans for new infrastructure, network investment or building upgrades.

☑ A description of how the plan will be taken forward in terms of governance arrangements and how progress will be monitored and driven forward

☑ A timetable for monitoring and reviewing progress and for updating the plan to reflect that progress and changes in local and wider circumstances (e.g. technology cost reductions, policy changes, new funding opportunities, changes in social norms and public willingness to act as technologies and behaviours become more common etc).

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