Open Networks Project

Whole System Cost-Benefit Analysis Methodology

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WS4 P1

DOCUMENT CONTROL

Authorities

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1.0	1/12/2020	Product team	Released to WS4 for sign-off

The whole system CBA is freely available on the ENA's website. In order to support users of the model and gather feedback for subsequent updates, we would kindly request those using the model to contact opennetworks@energynetworks.org.

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1 Introduction

1.1 About ENA

Energy Networks Association (ENA) represents the owners and operators of licenses for the transmission and/or distribution of energy in the UK and Ireland. Our members control and maintain the critical national infrastructure that delivers these vital services into customers' homes and businesses.

ENA's overriding goals are to promote UK and Ireland energy networks ensuring our networks are the safest, most reliable, most efficient and sustainable in the world. We influence decision-makers on issues that are important to our members. These include:

- Regulation and the wider representation in UK, Ireland and the rest of Europe
- Cost-efficient engineering services and related businesses for the benefit of members
- Safety, health and environment across the gas and electricity industries
- The development and deployment of smart technology
- Innovation strategy, reporting and collaboration in GB

As the voice of the energy networks sector, ENA acts as a strategic focus and channel of communication for the industry. We promote interests and good standing of the industry and provide a forum of discussion among company members.

1.2 Our members and associates

Membership of Energy Networks Association is open to all owners and operators of energy networks in the UK.

- Companies which operate smaller networks or are licence holders in the islands around the UK and Ireland can be associates of ENA too. This gives them access to the expertise and knowledge available through ENA.
- Companies and organisations with an interest in the UK transmission and distribution market are now able to directly benefit from the work of ENA through associate status.

1.2.1 ENA members

1.2.2 ENA associates

- Chubu
- EEA
- Guernsey Electricity Ltd
- Heathrow Airport
- Jersey Electricity
- Manx Electricity Authority
- Network Rail
- TEPCO

2 Scope

2.1 Definition of whole system

We use the following definition of "whole system", based on the definition given by WS4 in their 2019 Final Report[1]:

"Whole system" was interpreted as interactions between the gas and electricity networks and across transmission and distribution boundaries. Broader whole system interactions such as transport, water, waste were noted and it was agreed that these would be considered but not as core focus.

The definition of whole system is used as one of the three tests of when a whole system CBA should be used. This is discussed in a later section.

2.2 Aim of the whole system CBA

The whole system CBA has been developed to meet the following vision:

- A whole system CBA should **evaluate options to help achieve net-zero**. This includes assessing the wider societal impacts of different options, considering both current and future consumers and developing a consistent approach to appraise options.
- **Consumer impacts should be at the heart of decision making**. A whole system CBA should capture the varied ways benefits can be delivered. The whole system CBA process should be transparent and understood both inside and outside of regulated energy networks. Key stakeholders should support it, including BEIS, Ofgem, the energy networks, other industry participants and other statutory bodies.
- The whole system CBA should be used to **articulate the benefits the energy industry delivers**. With growing political and regulatory scrutiny of costs and activities, a whole system CBA can be a key tool to demonstrate that energy networks are acting in the best interests of consumers.
- **Help deliver a secure network at optimal value for money to consumers**. This includes considering the needs of both present and future consumers, and wider society.
- Support **objective, technology neutral and transparent decision making.** It will enable costs and value to be drawn out, explicit for all to see.
- The whole system CBA should be **one element of a decision-making toolkit.** In any investment decision, several factors need to be considered, some of which may not be suitable for a whole system CBA.
- Supporting regulatory frameworks that allow **sharing of the surplus value** generated from allowing another company to provide a more net beneficial solution.

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[1] https://www.energynetworks.org/assets/images/Resource%20library/ON19-WS4-Final%20Report%20(PUBLISHED).pdf

2.3 When the whole system CBA should be used

The three tests for a whole system CBA

Three conditions must be met to determine whether a whole system CBA is appropriate.

1. **Are there whole system interactions, or is there potential for it?** If the only realistic options are within an individual network an appropriate sector-specific CBA should be used.
2. **Could a whole system CBA drive you to make a different decision?** A whole-system CBA needs to be carried out in good-faith with the genuine aim of considering and accepting a range of options. As we discuss below, regulatory changes may be needed to encourage this behaviour. The whole system options considered need to be plausible, but there is also likely to be a de minimis value.
3. **Is a whole system CBA reasonable?** CBA is complex. It can be difficult to estimate costs and benefits. There are limits on the number of factors that can reasonable be considered. A whole system CBA needs to be proportionate, transparent and understandable. Especially at first, this may limit some of the use cases.

2.4 Use cases

Several use cases of a whole system CBA have been identified, all of which meet the three tests. These have been developed for two reasons. Firstly, to aid the development of the methodology and model, through enabling discussion about parameters they must incorporate. Secondly, to show a range of plausible situations the whole system CBA could be used in. It is important to note that these are by no means the only areas in which the whole system CBA can be used.

The use cases, and how they meet the three tests, are summarised in the table below. Further details are in Appendix 1.

Use Case	**Test 1: Are there whole system interactions, or is there potential for it?**	**Test 2: Could a whole system CBA drive you to make a different decision?**	**Test 3: Is a whole system CBA reasonable?**
Asset Intervention: Suppose a gas pipe feeding a small town is reaching the end of its asset life. Is it better to replace the pipe like-for-like, convert the town to electric heating or install a biomethane plant and upgrade the gas network?	Potential for interactions across gas and electricity.	The options appear feasible and potential benefits could be in tens to hundreds of millions	A number of factors should be considered, for example: Whether consumers are willing to switch to electric heating? Whether the local electricity network can manage increased demand?
Investment Planning: Suppose an electricity line is	There may be opportunities to	Assuming the right regulatory	Before proceeding with CBA confirmation

heavily constrained. From a whole system perspective, what is the best solution?	expand the range of options to include demand, service or looking to hydrogen in longer term.	mechanisms and incentives are there. Benefits could be in the billions .	of stakeholder buy in to secure necessary data will be required
Embedded Generation: farmer wants to build a biogas plant running on agricultural waste. Should it generate electricity or enter the heat network?	New connections have the option to connect and provide services to either the gas or electricity networks.	The options appear feasible and potential benefits could be in tens to hundreds of millions	This is a reasonably classic use case for a CBA.
Local Authority Planning: A local authority has been given £50 million funding from central government to support decarbonisation in their area. How should they spend it?	Any local area energy plan would interact heavily with gas and electricity networks, and would focus strongly on power, transport and heat.	Given the variety of potential options and the trade-offs between them, a whole system CBA would be a valuable tool.	Given the large number of potential options, so shortlisting based on commercial, technical and engineering judgement and stakeholder feedback would be necessary first.
Strategic Planning: What is the best way for the UK to meet its net-zero target?	By definition	Given the variety of potential options and the trade-offs between them, a whole system CBA would be a valuable tool.	Given the large number of potential options, so shortlisting based on commercial, technical and engineering judgement and stakeholder feedback would be necessary first.

Table 1 – Summary of use cases

2.5 Overlap with related work

There are a number of related pieces of work underway or recently completed. These are summarised in the table below. In conjunction with the three tests, this may guide the user to determine which tool is most appropriate. Some consideration should be given to whether these tools are appropriate. In addition, some models can be used as inputs to the whole system CBA.

Model	**Fuel**	**Purpose**	**Inputs**	**Notes**
Low carbon technology modelling tool	Electricity	Highlighting impact to network costs of low carbon technology (heat pumps and EVs) uptake, with some with some optimisation	• Flexibility costs • Component costs • Heat pumps • EVs • Network topology	Demand side only

[Common Evaluation Methodology]()	Electricity	Common evaluation framework (methodology and tool) for assessing active network management v flexibility v reinforcement	• Forecast network demands on an or group of assets under review for each DFES scenario • Expected overload per DFES scenario defines flexibility requirements (ie forecasted demand on an asset or group of assets) • Proposed network reinforcement solution and costs • Carbon impact (in £s) of difference in losses between options	Input into Innovation benefit framework realisation (see below) This model could serve as an input to the whole system CBA, for example by being used to short list or evaluate within sector solutions.
[Innovation benefits reporting framework]() (under development)	Electricity and gas (separate)	Common framework for assessing benefits from innovation projects	• Economic, environmental, social factors • Unit costs • Solution costs • Solution benefits • Technology readiness • Benefits (often qualitative)	Takes inputs from WS1A Flexibility Aligned parameter base with whole system CBA. As innovation project could become a network investment, it is important that these CBAs are aligned
Whole system CBA	Dual fuel	Economic evaluation of options to whole system problems. Use cases include: asset intervention, network investment, generation, local/strategic planning	• Economic, environmental, social factors • Unit costs • Solution costs • Solution benefits	Aligned parameter base with innovation benefits framework. Innovation project could become a network investment. Ofgem have signalled an intention for this to be used in the coordinated adjustment

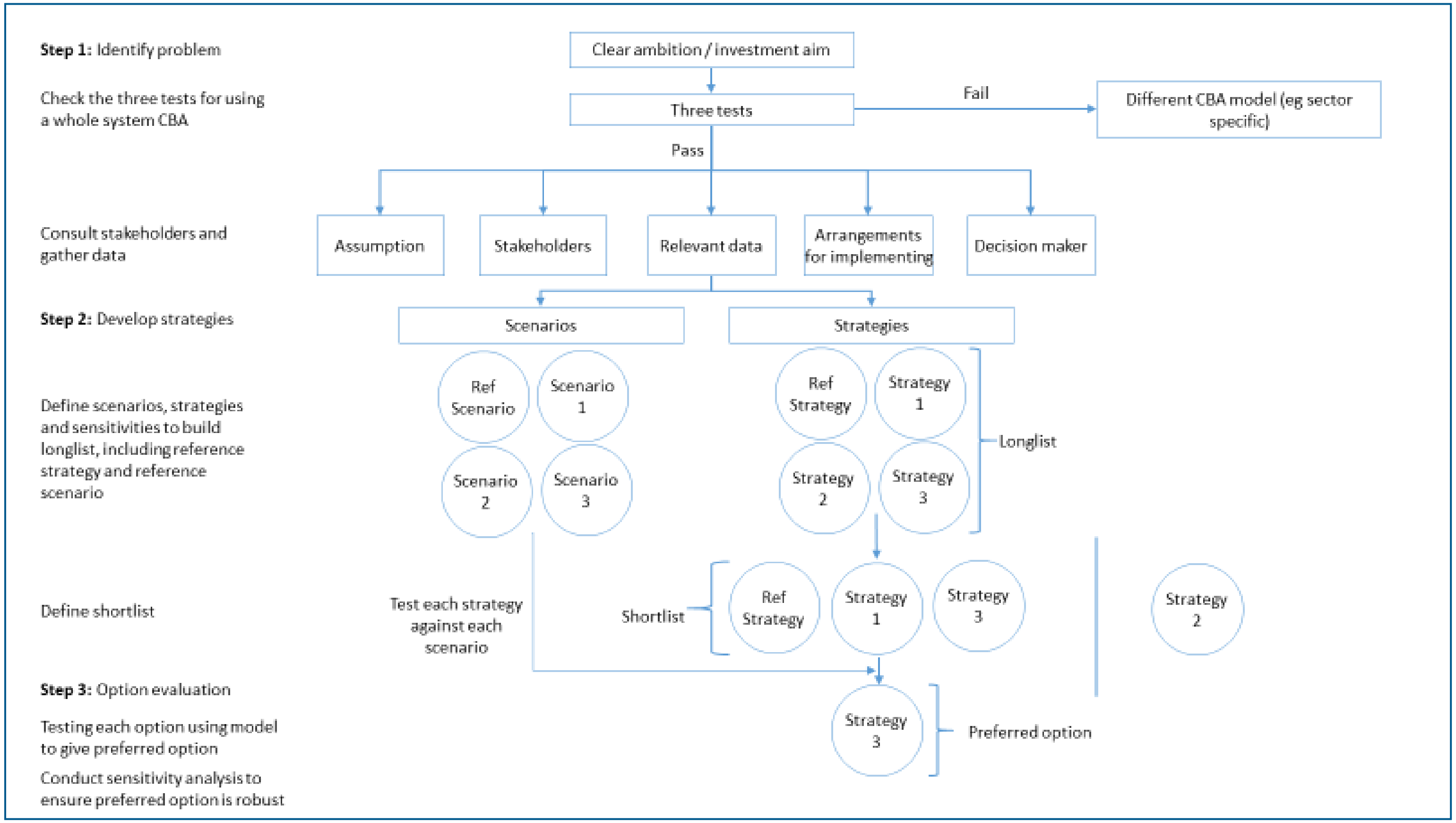
				mechanism (CAM)
Sector specific CBAs	Electricity and gas (separate)	Used to support regulatory submissions (eg RIIO-2)	• Network costs and benefits • Customer improvements • Carbon and other environmental impacts	The model and methodology of the whole system CBA has been based on these

Table 2 – Related workstreams

3 Methodology

3.1 Overall process

The overall methodology is summarised in the high-level flow diagram below. It broadly follows the HM Treasury Green Book.



3.2 Step 1 – Identify aims

3.2.1 Investment aims

It is necessary to set out clearly the purpose of the intervention. This should explain how the intended changes in outcomes will be produced by the analysed strategies. A clear investment aim is important in evaluating options, particularly in relation to apply commercial, technical and engineering judgement and seeking stakeholder feedback.

The aim of the investment may be to:

- Maintain service continuity arising from the need to replace some factor in the existing process
- To improve the efficiency of service provision
- To increase the quantity or improve the quality of a service
- To provide a new service
- To comply with regulatory changes
- Often a mix of all these.

The application of this to an energy context will vary between use cases. Details for each use case are provided in the appendices, but at a high-level these are likely to include:

- Assets reaching their end of life or requiring invention
- New generation or demand sources wishing to connect to the network
- The need to solve a network or system issue (for example constraints)
- Development of a local area energy plan
- Production of a local, regional or national decarbonisation strategy
- Identified opportunity for collaboration or whole system interactions
- Change in law or regulation
- Start of a new price control period

3.2.2 Key stakeholders

To enable effective decision making and ensure the relevant input data is collected, a range of stakeholders need to be consulted. This will vary on the use case, but it is likely to include some or all of the below. This should not be considered a complete list. In all cases, the ultimate decision maker should be defined.

Stakeholder	Potential role(s) (will vary on use case)	Data
Energy networks – relevant transmission owners, distribution network owners and system operators (for both gas and electricity)	• Information input • Project proposer / investment maker • Decision maker	• Generation and demand forecasts • Peak and annual data on network usage, ideally at a nodal or grid supply point level • Standards that need to be followed (such as 1-in-20 security standard) • Current and future local, regional or national (as appropriate) network issues and operability challenges • Capacity and connection information • Equipment information • Capex and opex unit costs • Asset lifetime and depreciation periods • Rule of thumb estimates for demand
Project developers – this could include parties wishing to connect to the network, and housing or transport developers	• Project proposer / investment maker	• Project plans and timelines • Specific costs relevant to project (eg recruitment, training)
Local authority officials	• Project proposer / investment maker • Consult and inform • Decision maker	• Budget • Project plans and timelines • Current and future property types – domestic, commercial, industrial, with estimates for typical demand • Current and future transport types – type of vehicle, number of charging points etc, with estimates for typical consumption and usage • Current and future generation types, including cost, usage and carbon estimates • Local restrictions and factors (eg planning)

Government and regulatory bodies	• Approval • Obligations, codes and frameworks • Regulatory matters • Decision maker	• Macro-level forecasts and data (eg economics, population, GDP growth) • Approval for regulatory matters, such as transferring allowances and changing licence obligations

Table 3 – Key stakeholders

Checklist before proceeding

Before moving to Step 2, the user should check

- The investment aim is clear
- Key stakeholders have been identified
- Relevant data sources have been identified and collected
- The arrangements for implementing the whole system CBA, and the recommended approach, are clear
- The decision maker is identified

3.3 Step 2 – Develop strategies

At this stage, the purpose of the investment should be clear and the relevant data should have been identified. Consistent with the HM Treasury Green Book, an initial longlist of strategies should be considered that have the potential to meet the stated aim.

The strategies are the range of possible ways to meet the stated investment aim. For example, if the investment aim were to solve a network constraint, the strategies might include 1) developing a flexibility solution, 2) network reinforcement or 3) do nothing. The model allows seven strategies to be assessed. Additional spreadsheets can be used to assess more strategies.

3.3.1 Reference strategy

The longlist of strategies considered should include an option that requires minimal initial investment. This is often called the “do nothing” or “do minimum” strategy and is the strategy that all other strategies should be considered against. This is known as the reference strategy. The reference strategy will depend on the specific investment, but could include:

- The project not going ahead
- The minimum level of investment needed for a body (for example a network company or local authority) to remain compliant with obligations
- The current approach or ways of working
- An already approved solution (in the case of a regulatory re-opener, for example)

3.3.2 Longlist and shortlisting

The longlist of strategies should be tested to decide which to move to full cost-benefit analysis and which to reject. To make this decision a range of factors should be considered, and the rationale documented. Reasons for ruling out options at this stage are summarised in the table below.

Whether, or how well, the option meets the stated investment aim	**Stakeholder feedback**	**Commercial, technical or engineering judgement**
• An option that does not meet the stated investment aim • An option that is unreasonably expensive	• Clear and unambiguous stakeholder feedback against an option	• An option that is not feasible, according to reasonable judgement (for example installing tidal power in Birmingham) • An option that cannot be implemented (for example the technology does not or will not exist) • An option that is highly unlikely to be approved by a regulatory body • An option which breaks the law • An option that means non-compliance with codes, licences and frameworks (unless the cost and benefits of remedying this can be analysed)

Table 4 – Reasons for discounting longlist options

The options remaining should go forward for full cost benefit analysis and are known as the shortlist. A clear rationale for including/excluding options should be summarised – there is space to do this in the model.

Checklist before proceeding

Before moving to Step 3, the user should check

- Appropriate strategies have been defined, including the reference strategy
- Rationale for discarding any longlist strategies has been documented

3.4 Step 3 – Option evaluation

3.4.1 Scenarios

The nature of whole system decisions is that they are subject to future uncertainty. Scenarios allow the CBA to account for this uncertainty by providing a range of future energy landscapes.

A selection of relevant future energy scenarios should be considered to perform the CBA against. This allows the CBA to account for significant future uncertainties. The scenarios used may depend on the exact investment and could be GB-wide scenarios or those of a network company or local/regional area. Commonly used scenarios include:

- National Grid ESO's Future Energy Scenarios[2]
- Energy Network Association's Pathways to Net-Zero
- Distribution Future Energy Scenarios (DFES)

The model allows for five scenarios to be identified. The tool will present the outputs for each of the strategies under each of the specified scenarios. One scenario should be deemed the reference scenario. It is under this scenario only that NPV outputs are reported separately. The reference scenario is typically the "best view".

3.4.2 Exogenous and endogenous variables

This section deals with the question of whether a parameter (for example the number of electric vehicles on the road) should be fixed by a particular scenario and not vary within a strategy or whether it is influenced by an individual strategy.

An exogenous variable is one whose value is determined outside the investment and is imposed on the model. By contrast, an endogenous variable is one whose valued is influenced by the investment and is determined by the model. To aid transparency, the user should determine whether parameters are exogenous or endogenous.

[2] https://www.nationalgrideso.com/future-energy/future-energy-scenarios

This will vary depending on the particularly use case. In the example of the number of electric vehicles on the road:

- If the proposed investment was how best to install rapid charging solutions throughout GB by 2030, then the number of electric vehicles is exogenous, because all strategies reach the same aim, so they could be assumed not to influence consumer behaviour.
- If the proposed investment was decarbonisation of transport, with strategies including electrification and hydrogen, then the number of electric vehicles is endogenous, because it is clearly influenced by the particular strategy.

3.4.3 Input data

The user should consider a wide range of capex costs, opex costs and societal costs and benefits. Where possible, these should be monetised. The model and this document provide further guidance and structure to monetising inputs.

To aid transparency, standardisation and effective comparison of strategies, several rules should be followed:

- All monetised inputs and outputs must be in the same price base and ignore inflation / real price effects. The start of the depreciation period should also be set to that year. The user guide indicates how to set this in the model and can also output costs in a different year to that inputted, if necessary.
- All data should be entered either in absolute (gross) terms or in marginal terms against the reference strategy across the entire tool. Use one throughout – do not mix and match. In general, it is preferable to use absolute values and allow the model to "net-off" against the reference strategy.

3.4.4 Costs

3.4.4.1 Capex

Capital expenditure (capex) is spending on investment in long-lived network assets, such as overhead lines, underground pipes and cables, ground equipment such as substation and compressor stations and IT systems. It can include the cost of designing, purchasing, building, installing and dismantling equipment. Capex is expressed in Pounds and should be determined, quantified and monetised for each year over the asset lifetime for each strategy under each scenario.

Capex costs can include, but are not limited to:

- Network reinforcement and replacement costs
- Installations costs of alternative heat and power generation – e.g. wind, solar, gas peaking plants, tidal
- Installation costs of alternative heat and power networks – e.g. heat networks
- Installation costs of new appliances in people's homes – e.g. hybrid heating systems
- WACC – this will vary across Network companies and non-regulated companies. The model will provide a default where this is not known
- Avoided costs, although if data is being entered in absolute terms these should not be entered separately.

3.4.4.2 Opex

Operational expenditure (opex) is spending on operating and maintaining the network. This can include fault repair, tree cutting, inspection and maintenance and engineering and business support costs. Opex is expressed in Pounds and should be determined, quantified and monetised for each year of the project for each strategy under each scenario.

Opex costs can include, but are not limited to:

- Network operation costs – gas, electricity and heat – to include maintenance and emergency response
- Customer appliance maintenance costs
- Training and recruitment – e.g. recruitment for hybrid heating system installers, house insulators
- Procurement costs
- Avoided costs, although if data is being entered in absolute terms these should not be entered separately.

3.4.5 Societal impacts

Societal impacts should be considered for each strategy under each scenario. They will vary depending on the use case but may include some or all of the below. The parameters inbuilt in the model and pointed to in the input depository provide a range of societal impacts that can be considered; the user can also input ones outside of this.

Benefit category	Examples
Safety	• Fatalities • Non-fatal injuries • Site safety • Public safety
Environmental	• Losses • Carbon emissions • Leakage • SF6 emissions • Shrinkage • Biodiversity and natural capital • Air quality
Transport	• Number and type of vehicle • Disruption
Electricity consumer	• Complaints • Customer interruptions

	• Energy not supplied • Guaranteed standards of performance
Gas consumer	• Complaints • Customer interruptions • Energy not supplied • Guaranteed standards of performance
Other	• Social factors (eg visual amenity) • Economic factors (eg jobs) • Health factors (eg air pollution or impact of an interruption to heating) • Vulnerability – impact on those most vulnerable in our community

Table 5 – Societal impacts

To aid effective comparison between different strategies and scenarios, benefits should be monetised in pounds for each year of the project for each strategy under each scenario. Where this is not possible, qualitative benefits can be considered, and can be compared in, for example, a RAG status. The user should make it clear how these are weighted in the overall decision-making process.

Some benefits will have common values (eg carbon price), others may be user inputted. The parameters library can be used to help quantify benefits and ensure standardisation.

3.4.6 Risks

For each option, risks should be captured and quantified in a proportionate way. Where relevant this should include the costs of mitigation and the expected costs if risks materialise. At a minimum. these risks should capture any material risk which may impact the cost and/or timing of the chosen investment. Risks should be quantified against a consistent framework, with the risk impact quantified and the likelihood of occurrence estimated.

A suggested approach would be to score likelihood and impact on a 1-5 with impacts considered as per the table below. Note the figures below are indicative only and will vary greatly between the use case.

Impact Rating	Score	Description
Insignificant	1	An adverse financial impact of less than £50k; *and/or*
		No potential adverse impact on human health or the environment; *and/or*
		No adverse reputational damage; *and/or*
		No regulatory impact or regulatory action taken.

Minor	2	An adverse financial impact of between £50k to £500k; *and/or*
		Minimal potential adverse impact on human health or the environment; *and/or*
		Minimal adverse reputational damage; *and/or*
		Minimal regulatory impact or regulatory action taken.
Significant	3	An adverse financial impact of between £500k to £1m; *and/or*
		Limited potential adverse impact on human health or the environment; *and/or*
		Significant adverse reputational damage; *and/or*
		Significant regulatory impact or regulatory action taken.
Major	4	An adverse financial impact of between £1m to £5m; *and/or*
		Medium – High potential adverse impact on human health or the environment; *and/or*
		Major adverse reputational damage; *and/or*
		Major regulatory impact or regulatory action taken.
Critical	5	An adverse financial impact of more than £10m; *and/or*
		High potential adverse impact on human health or the environment; *and/or*
		Critical adverse reputational damage; *and/or*
		Critical regulatory impact or regulatory action taken.

Table 6 – Risk framework

Combining with probability a risk score can be derived. This helps to drive the appropriate level of risk mitigation

Probability						
Highly Likely	5	10	15	20	25	
Probable	4	8	12	16	20	
Moderate	3	6	9	12	15	
Unlikely	2	4	6	8	10	
Remote	1	2	3	4	5	
	Insignificant	Minor	Significant	Major	Critical	*Impact*

3.4.7 Regulatory treatment of costs and benefits

3.4.7.1 Spackman approach

In line with best practice from the HMT Green Book, costs and benefits should be discounted using the Spackman approach. This is the standard approach for private investment leading to societal benefit[3]. The Spackman approach considers the value society places on benefits today rather than later, typically through the social time preference rate, and the costs associated with raising funds, typically though the weighted average cost of capital.

The Spackman approach has two-steps:

1. Capex costs should be converted into annual costs using the company's weighted average cost of capital (WACC)
2. All costs and benefits should be discounted over the life of the project. The model assumes the social time preference rate of 3.5% for up to and including the first 30 years of investment and 3% thereafter, expect for safety where the health discount rate of 1.5% for up to and including the first 30 years and 1.2857% thereafter should be used.

The model will automatically discount all costs that are flagged as requiring it. This is typically determined by when the costs are recovered.

[3] https://www.ofcom.org.uk/__data/assets/pdf_file/0029/37856/jrg_statement.pdf

3.4.7.2 Depreciation

Depreciation refers to two linked concepts:

- The decrease in the value of an asset over time. (Some assets may appreciate, that is gain value over time, but this is unusual in this context)
- The general principle that expenses should be reported in the same period that they provide benefits (even if the cost is entirely upfront).

The user can set the depreciation period. This will vary between stakeholders and can be entered individually for different stakeholders.

Checklist before proceeding

Before moving to Step 3, the user should check

- Relevant scenarios have been defined, including a reference scenario
- Stakeholder impacts for each strategy under each scenario have been monetised
- Societal impacts for each strategy under each scenario have been monetised
- Qualitative impacts have been identified and assessed

3.5 Step 4 – Decision-making

3.5.1 Role of the whole system CBA in decision making

The whole system CBA can only ever act as a guide to inform decisions. It is not necessarily the case that the highest NPV option should always be chosen, or that a negative NPV option can never be selected. The guide decision making, the model will output:

- Net-present value of different options, both in comparison to the reference strategy and gross
- Least worst regrets
- Sensitivity analysis and tipping points
- The cost impact on different parties, and how these might be recovered/socialised

Overall, the decision should be made through an evaluation of:

- Economic appraisal (ie the above)
- Stakeholder feedback
- Commercial, technical and engineering judgement, including:
  - Risks and mitigations
  - How the economic outputs vary across scenarios
  - Credibility of options and solutions

3.5.2 Reporting metrics

To aid comparison of options and aid decision making, the model will output a number of charts and tables. These include:

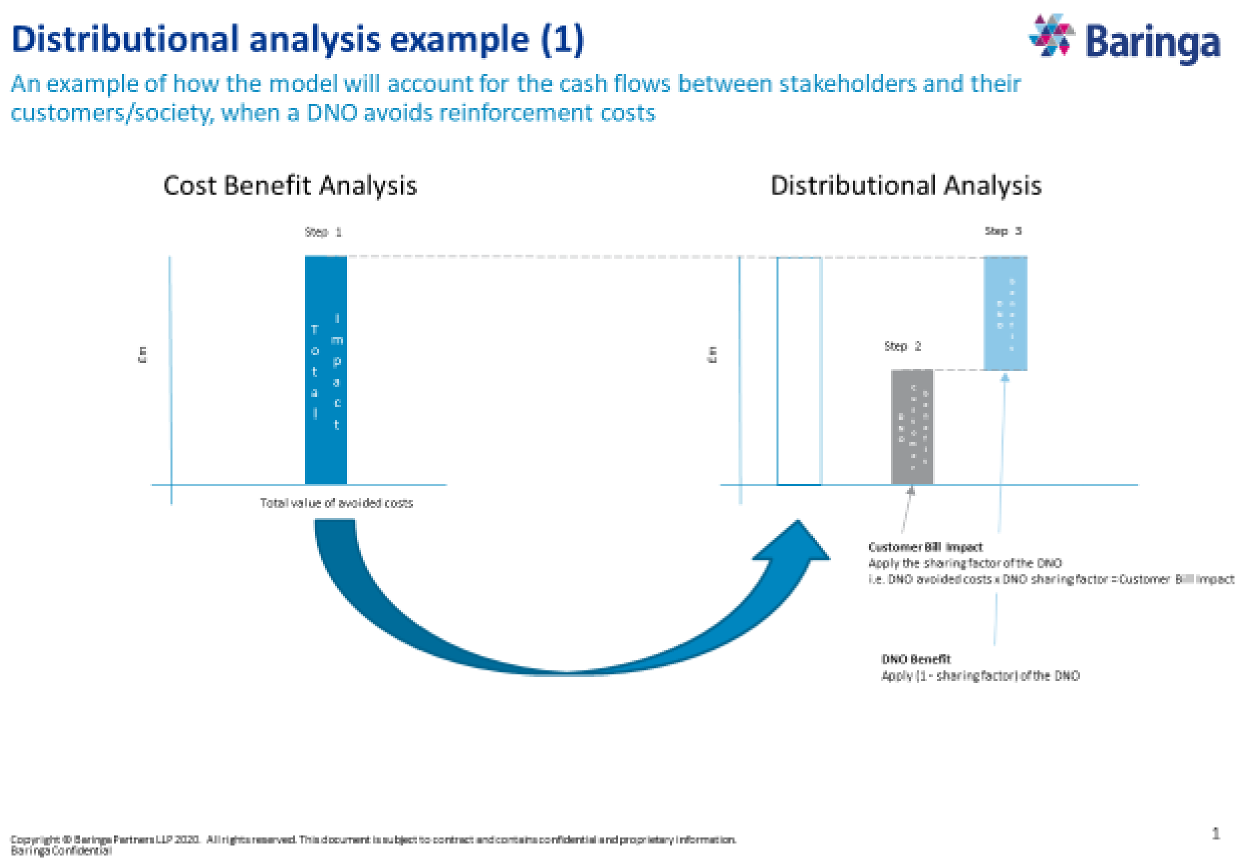
- Outputs for all strategies under the reference scenario, in absolute terms
- Outputs for all strategies relative to the reference strategy under the reference scenario
- A summary outputs table

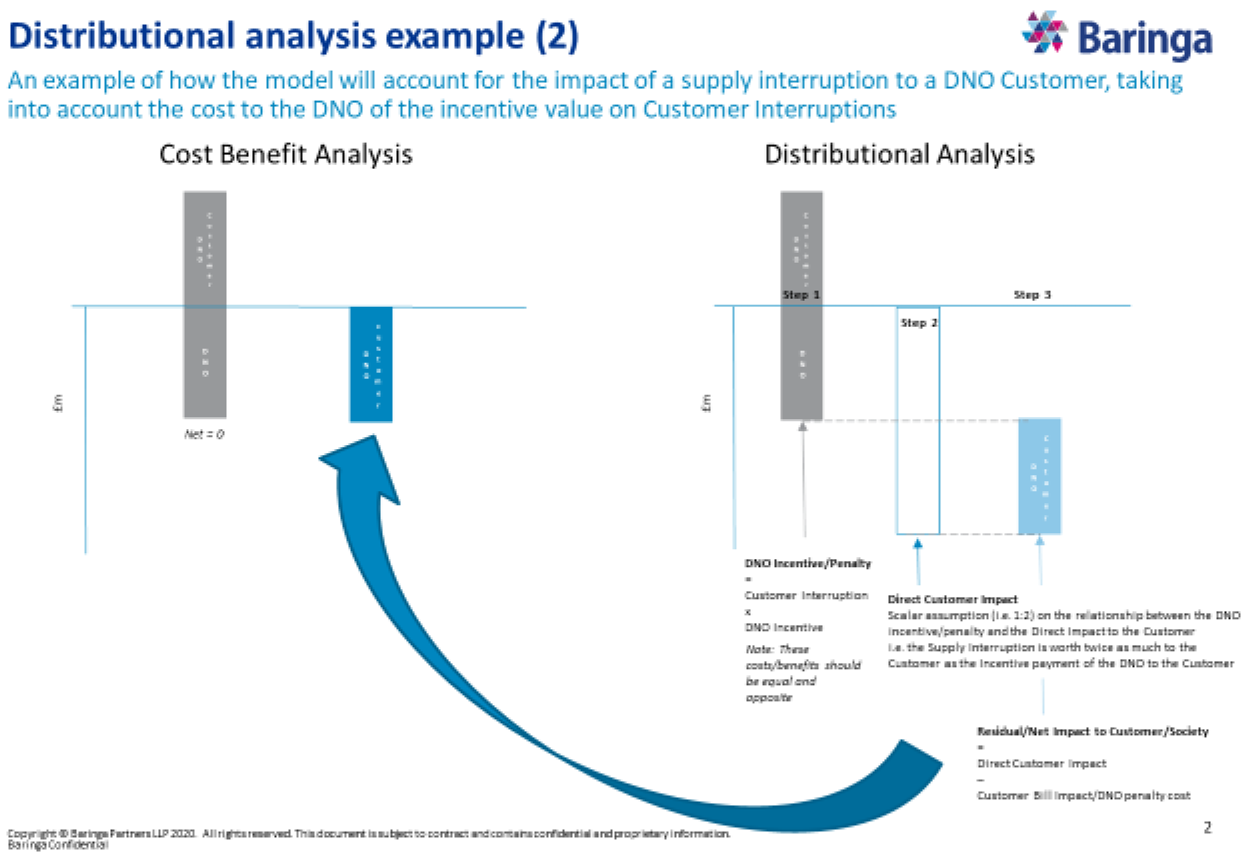
Outputs are presented on an overall basis and on a per stakeholder basis, including the customer monetised impact. The customer monetised impact is accounted for by distributional analysis.

3.5.3 Distributional analysis

Distributional analysis refers to cash flows between stakeholders and their customers and/or society. This can account for regulatory concepts such as sharing factors or incentive rewards or penalties that transfer costs and benefits between stakeholders. To enable this, the user can select the sharing factor and incentive reward/penalty rates in the model.

To show how the model accounts for this, two examples are provided below.





3.5.4 Sensitivity analysis

Sensitivity analysis explores how outputs change based on changes to the inputs. It is good practice to identify and test sensitivities on the preferred option, especially if it is highly sensitive to certain values or if the decision is marginal.

Tipping point analysis refers to the value a key input variable would need to take for a proposed intervention to switch from a recommended option to another option or for a proposal not to receive funding approval. It can be used to help identify sensitivities.

The tool will not automatically conduct sensitivity analysis due to the wide range of parameters considered. It can be done by adding additional strategies (with the relevant parameters changed) and re-running the model.

As a minimum, sensitivity analysis and the identification of switching values should be carried out on the options from the short-list appraisal. These results must form part of the presentation of results. If the costs and benefits of the preferred option are highly sensitive to certain values or input variables, sensitivity analysis will probably be required for other options in the short-list.

4 Parameters

4.1 Introduction

This section provides a description of the library of common parameters and models that can be used in the whole system CBA. Some of these are built into the model; others are referenced and need to be user inputted as necessary.

There are two aims of the library. Firstly, it encourages the user to think widely, including out-of-sector, when considering the costs and benefits of different strategies, by suggesting parameters that they may not have otherwise considered. This helps ensure the robustness of the output. Secondly, it is desirable for a certain amount of standardisation to ensure effective and transparent comparison of options across networks and sectors. Other parameters and models can, of course, be used, and this library is not expected or intended to be exhaustive.

The parameters included in this section have a variety of statuses.

- Official parameters, such as the BEIS carbon price or HMT Green Book discounting, should be used unless there is clear and documented reasons for not doing so. These parameters are considered best practice in cost-benefit analysis.
- Widely accepted parameters, for example leakage or shrinkage, are taken from the RIIO-2 CBA models or are commonly used across network companies. Given their acceptance across the energy industry, they should be used unless there is a clear and documented reason for going so. It should be noted that these may vary between network companies.
- Other accepted parameters, for example biodiversity and natural carbon, as derived from authoritative sources.

The parameters provided in the library are subject to change. The user should check they are using the latest version – where possible, links are provided to the source.

The model divides the parameters into three sections:

- Fixed inputs – parameters where the unit cost is fixed across time periods (but may be updated in the future)
- Time series inputs – parameters where the unit cost varies over time
- Input depository – parameters that are not built into the model but comprise a list of accepted models that can be consulted. In general, the user would need to use the source material to derive the appropriate cost and benefit and input the workings and final figures into the model

The section below gives a brief commentary on each item in the library. This includes:

- What is built into the model (eg price or unit cost)
- What the user would need to input (eg volume to multiply the above price against)
- Commentary on the parameter

4.2 Fixed inputs

This section contains parameters where the unit cost is fixed across time periods (but may be updated in the future)

4.2.1 RIIO Regulatory Treatment

Parameter	What is built into the model	What the user needs to input	Commentary
RIIO Regulatory Treatment	For each network company: • Weighted average cost of capital (WACC) • Capitalisation rate • Depreciation period The WACC can also be used for non-regulated stakeholders if necessary The model will automatically apply these to any costs and benefits marked as "regulatory treatment applies"	User to check and adjust each as appropriate	The model allows two-types of cost to be inputted: • Where regulatory treatment is appropriate, the toggle "regularly treatment applies" should be selected • In other cases, the toggle "pass through cost" should be selected

Table 7 – RIIO regulatory treatment parameters

4.2.2 Societal benefits

Parameter	What is built into the model	What the user needs to input	Commentary
Safety	Fatality and non-fatal injury unit costs	Volume	The unit costs in the RIIO-2 CBA templates are higher for gas than electricity, reflecting presumed reduced liability. We have used the (higher) gas figure.
Environmental	Unit costs for losses, nitrous oxide emissions, oil leakage and, greenhouse gas emissions, methane leakage and shrinkage	Volume	These figures are taken from the relevant RIIO CBA templates or external sources that determine the best practice for use in RIIO submissions

Transport	Unit costs for transport fuels (petrol / diesel / electric / hydrogen / CNG), carbon emissions and air quality impacts of fuels	Calculated figures using parameter library	Taken from best available external sources and HMT Green Book where possible.
Electricity consumer	Unit costs for avoided complaints and guaranteed standards of performance	Volume	These are the figures for Electricity North West. To aid simplicity and transparency and to aid comparison, they can be used for all network companies.
Gas consumer	Unit costs for guaranteed standards of performance	Volume	Standard figures used by all gas networks and published on the ENA website
Demand turn-down	DNO average unit costs of demand turn-down	Volume	Figures are from the FNA-led Future Worlds Impact Assessment

Table 8 – Societal benefits table

4.3 Time series inputs

This section contains parameters where the unit cost varies over time

Parameter	What is built into the model	What the user needs to input	Commentary
Carbon prices	BEIS traded and non-traded carbon prices, for regulatory (April-March) and calendar year/ the base case and high case are provided	Volume	Use of BEIS carbon price is best practice following HMT Green Book
Inflation	Financial year inflation index. This is a composite index of RPI and CPIH. RPI is used until 2020/21. Thereafter, CPIH is used.	Cost conversation to same price base	Standard practice for CBAs is that all prices should be in the same price base, usually the first year of the investment
Technical assumptions	• Assumed global warming potential of methane • Assumed proportion of methane CO2 in natural gas • Methane uplift factor • CO2 emissions from losses • NOx uplift factor • Electricity GHG conversation factor	Volume	Use of BEIS / Defra conversion factors and following HMT Geen Book best practice

Customer interruptions term incentive rate	Unit cost per customer interruption for each electricity DNO	Volume	These are taken from RIIO-ED1
Revenue exposure to customer interruptions and minutes lost term	Unit cost for each electricity DNO	Volume	These are taken from RIIO-ED1

Table 9 – Time series input parameters

4.4 Input depository

This section contains parameters that are not built into the model but comprise a list of accepted models that can be consulted. In general, the user would need to use the source material to derive the appropriate cost and benefit and input the workings and final figures into the model/

4.4.1 Transport

Parameter	What is built into the model	What the user needs to input	Commentary
DfT Transport Analysis Guidance (TAG)	Link to source material	User defined calculations and input	TAG data book contains parameters for transport modelling and appraisal purposes, including: • Operating costs • Environment impacts • Social and distributional impacts • Rail appraisal • Marginal external congestion costs • Demand modelling • Accident and casualty It should be used in conjunction with the associated guidance document
Regional air quality damage costs for the transport sector	Link to source material	User defined calculations and input	Link to HMT Green Book parameters

Table 10 – Transport parameters

4.4.2 Economic

Parameter	What is built into the model	What the user needs to input	Commentary
NHS Savings from house efficiency improvements	Link to source material	User defined calculations and input	Chief Medical Officer report from 2009 stating that every £1 spent on keeping homes warm saves 42p in NHS costs
Local economic inputs	Link to source material	User defined calculations and input	Potential use of economic multipliers using LM3 methodology, which can vary if local or national suppliers are used.

Table 11 – Economic parameters

4.4.3 Environmental

Parameter	What is built into the model	What the user needs to input	Commentary
Various unit costs, including: • Electricity emissions factors • Fuel conversion to CO2 and CO2e • Carbon price and sensitivities • Retail fuel prices • Long-run variable costs of energy supply • Air quality damage costs from primary fuel use • Fossil fuel price assumptions	Link to source material from HMT Green Book	User defined calculations and input	Parameters are from HMT Green Book supplementary guidance on valuation of energy use and greenhouse gas emission for appraisal
Embodied carbon (the carbon footprint of a material)	Link to source material	User defined calculations and input	Link to Circular Ecology Database on embodied carbon, which is being used in RIIO-2 by the electricity transmission owners
Biodiversity	Link to source material	User defined calculations and input	Link to Natural England The Biodiversity Metric 2.0. Note this is currently in beta form with a final version due in 2020.

			Calculation tool and user guide can be used to assess biodiversity costs and benefits which can then be inputted into the model and displayed qualitatively
Noise emissions reduction	Link to source material	User defined calculations and input	Link to Defra study from November 2014 on environmental noise. Valuing impacts on a range of factors, including: sleep disturbance, annoyance, hypertension, productivity and quiet.

Table 12 – Environmental parameters

4.4.4 Social factors

Parameter	**What is built into the model**	**What the user needs to input**	**Commentary**
Social factors unit costs, including: • Crime • Education and skills • Employment and economy • Fire • Health • Housing • Social services • Energy	Link to source material from HMT Green Book	User defined calculations and input	Link to Greater Manchester Combined Authority CBA data book. This source can be used to quantify a wide range of social benefits.

Table 13 – Social factors parameters

4.4.5 Electricity consumers

Parameter	**What is built into the model**	**What the user needs to input**	**Commentary**
Value of Lost Load (VoLL)	Link to source material from HMT Green Book	User defined calculations and input	Link to Ofgem-commissioned report on VoLL. It should be noted that there is not one widely accepted figure, so this has not been built into the mode directly, although it is indirectly included through the CI/CMLs.

Table 14 – Electricity consumers parameters

5 Governance

The development of the model is being led by a product team with representation from most network companies. This is under the guidance of Open Networks and more specifically, Workstream 4. Sign off of the model and this methodology has included Open Networks, Gas Futures Group (GFG), the Network Regulation Managers and Ofgem.

The product team will remain in place following delivery of the model to measure the success of the tool, review initial feedback and provide the first model update in response to feedback. This team will not exist as an enduring entity over time.

Enduring model governance

It is not sustainable to maintain a product group of volunteers to manage the ongoing governance of the model. Following discussion between product team, Open Networks and Ofgem, the proposal is for Open Networks to eventually take ownership of the model and provide the ongoing governance and model updates.

The model will be made available for any interested party with suitable use cases. Requests for the model should be sent to opennetworks@energynetworks.org.

Any users who have requested the model will be added to a register. This will be used to track usage and to ensure that model and methodology updates can be issued to model users. This will prevent versioning issues and will ensure the most up to date version is in use.

Updates to the model will be considered annually to ensure the model remains relevant. Updates will fall into 2 categories: 1) those which will be made annually with no consultation and 2) more significant updates that will require a consultation process. These updates and management of any consultations will sit with Ofgem with support from the Network companies.

1. **Updates to the model with no consultation**

These will be limited to updates to parameters, for example carbon price. It will include factors changed through the regulatory process that have undergone the associated consultation process, such as regulatory treatment of costs. Parameters should be reviewed and updating during key regulatory publications, for example RIIO-ED2.

2. **Significant updates requiring a consultation process**

These will predominantly be updates to model structure.

Governing model usage is more difficult. Risk to incorrect usage will be mitigated in a number of ways

- The issuing of the model will include the methodology document and the model user guide
- The model itself is designed to be intuitive, helping the user through the process. Many parameters will exist in the model minimising the data and information required from the user
- Support will be available through Open Networks to users of the model.

6 Appendix 1 – Use case specific information

6.1 Use case 1 – Asset intervention

Use Case 1	Asset intervention
Exam question	Suppose a gas pipe feeding a small town is reaching the end of its asset life. Is it better to replace the pipe like-for-like, convert the town to electric heating or install a biomethane plant and upgrade the gas network?
Commentary	There is a need to ensure existing assets are well maintained. However, non-load related spend can form a significant element of consumer bills. As assets reach their end-of-life, there is opportunity to consider whether it is best to replace them like-for-like or consider a different option. In this example, factors to consider would include: • Whether consumers are willing to switch to electric heating? • Whether the local electricity network can manage increased demand? • Precedent from the 2025 ban of gas heating in new homes • The incentives on a gas network to consider a whole system CBA Potential benefits of bringing forward versus deferring investment
Inputs considered	• Asset costs • Cost of disruption • Carbon footprint of delivering solution • Ongoing maintenance costs • Current CBA process for asset replacement (this would provide options)
Benefits considered	• Lower bills • Reduced emissions • Minimisation of risks • Reliability of different solutions
Counterfactual	The counterfactual is the minimum investment needed to maintain compliance with licence obligations. In this case, it is likely to be a maintain and fix on failure by the asset owner, who is the current decision maker.
Stakeholders	• Network owners and operators • Generation / commercial solution providers • Local community
Order of magnitude of benefits	Tens to hundreds of millions, given past and expected levels of asset replacement spend

Table 15 – Use Case 1: Asset intervention

6.2 Use case 2 – Investment planning

Use Case 2	Investment planning
Exam question	Suppose an electricity line is heavily constrained. From a whole system perspective, what is the best solution?
Commentary	This can be considered as an extension of the current *NOA* process[4]. The *NOA process* will be expanded to consider commercial solutions. However, these will only value the commercial solutions on their ability to manage the constraint (and the implementation cost). rather than any other whole system consideration. A whole system CBA could be used to expand the assessment to consider whether the best solution is: • Installing a battery • Encourage demand-side response or load-shifting • Building a hydrogen plant and a new pipeline to transport clean heat to a nearby town • Network reinforcement or new build
Inputs considered	• Cost of asset and commercial solutions • Cost of disruption • Carbon footprint of delivering solution
Benefits considered	• Lower bills (optimal balance between network investment and constraint spend) • Reduced emissions • Wider societal and environmental benefits
Counterfactual	Viewed as an extension of the current NOA process, the counterfactual would be the output of the existing NOA process. Otherwise, a more generic counterfactual of managing the constraint in the balancing mechanism. Decision maker is the network company/commercial solution developer (who may be acting on the NOA recommendations).
Stakeholders	• Network owners and operators • Commercial solution providers • Local community (in the example of the third bullet point in the commentary)
Order of magnitude of benefits	Billions, given the current spend in investment planning considered over asset lifetimes.

Table 16 – Use Case 2: Investment planning

[4] For the sake of the example we consider this from an electricity constraint perspective. There are equally applicable examples that could be used in the gas of a gas constraint

6.3 Use case 3 – Embedded generation

Use Case 3	Embedded generation
Exam question	A farmer wants to build a biogas plant running on agricultural waste. Should it generate electricity or enter the heat network?[5]
Commentary	As noted by the CCC[6], a regulatory and support framework for low-carbon heating (heat pumps, biomethane and networked low-carbon heat) is needed to enable the transition to low-carbon heating by 2050. As the UK electricity system decentralises, there is also expected growth in embedded generation, including from biofuels. Installed capacity of biogas could triple by 2030[7]. Factors to consider include: • Costs of gas and electricity assets • Needs of local area (eg the area has a lot of embedded wind generation so gas is needed but that would require a more expensive pipe) • Gas quality challenges from biogas (calorific value, odourisation)
Inputs considered	• Cost of assets • Cost of disruption • Carbon footprint of delivering solution
Benefits considered	• Reduced emissions • Lower bills (eg potential local constraint or operability savings)
Counterfactual	Do nothing. Decision maker is the developer of the proposed asset.
Stakeholders	• Embedded generators (eg farmers, waste water companies) • Local authorities – they may have local net-zero targets that this can help with • Local community
Order of magnitude of benefits	Given the small-scale nature, we estimate this to be in the millions. However, if the carbon price is high in future years, this could move into the tens of millions.

Table 17 – Use Case 3: Embedded generation

[5] Other examples could include a small wind farm deciding whether to install a battery or electrolysis plant
[6] Committee on Climate Change: Net-zero – the UK's contribution to stopping global warming (page 200) https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf
[7] FES data workbook – Electricity supply data table ES1. Capacity filtered by Anaerobic digestion, Anaerobic digestion CHP, Biogas CHP, Biofuel and Biofuel CHP.

6.4 Use case 4 – Local authority planning

Use Case 4	Local authority planning
Exam question	A local authority has been given £50 million funding from central government to support decarbonisation in their area. How should they spend it?
Commentary	Local and regional authorities are increasing investing for net-zero. Bristol City Council has recently declared a “climate emergency” and has identified £875 million of investment opportunities over the next 10 years[8]. Cornwall is trialling a local energy market approach (Cornwall Energy Island) due heavy constraints in the area[9]. A whole system CBA could be help to help them target investment to maximise consumer and societal benefits
Inputs considered	• Investment costs • Cost of disruption • Carbon footprint of delivering solution • Current and future supply and demand scenarios
Benefits considered	• Reduced emissions • Lower bills (eg potential local constraint or operability savings) • Societal benefits (eg benefits to local businesses and communities through job creation, future economic growth)
Counterfactual	Do nothing. Decision maker is the local authority.
Stakeholders	• Local authorities • Local communities and business (eg transport providers, housing developers) • Local energy networks and providers
Order of magnitude of benefits	Benefits potentially in the tens of millions at first, to hundreds of millions later.

Table 18 – Use Case 4: Local authority planning

[8] Bristol City Council and Energy Service Bristol: City Leap Prospectus https://www.energyservicebristol.co.uk/wp-content/pdf/City_Leap_Prospectus%204-5-18.pdf
[9] https://www.cornwallislesofscillygrowthprogramme.org.uk/projects/local-energy-market/

Introduction

Local and regional authorities are increasingly investing for net-zero. Bristol City Council recently declared a "climate emergency" and has identified £875 million of investment opportunities over the next 10 years[10]. Cornwall is trialling a local energy market approach (Cornwall Energy Island) due to heavy constraints in the area[11]. Other local authorities are creating Local Area Energy Plans to support clean growth and the low carbon transition[12]. A whole system CBA can be used to help them target investment to maximise consumer and societal benefit.

Trigger point

These could include:

- Development of a Local Area Energy Plan
- Creation of a local authority environment and decarbonisation plan
- Major new development within a local area that is likely to impact the gas and electricity networks
- Local authority making a financial investment in its assets
- Change in regulation or law

Key stakeholders and input data

Stakeholder	Role	Data
Local authority officials	Depending on use case: • Project proposer / investment maker • Consult and inform • Decision maker	• Budget • Project plans and timelines • Current and future property types – domestic, commercial, industrial, with estimates for typical demand • Current and future transport types – type of vehicle, number of charging points etc, with estimates for typical consumption and usage • Current and future generation types, including cost, usage and carbon estimates • Local restrictions and factors (eg planning)

[10] Bristol City Council and Energy Service Bristol: City Leap Prospectus https://www.energyservicebristol.co.uk/wp-content/pdf/City_Leap_Prospectus%204-5-18.pdf
[11] https://www.cornwallislesofscillygrowthprogramme.org.uk/projects/local-energy-market/
[12] https://es.catapult.org.uk/reports/local-area-energy-planning/

Energy networks – relevant transmission owners, distribution network owners and system operators (for both gas and electricity)	• Information input • Project proposer / investment maker	• Generation and demand forecasts • Peak and annual data on network usage, ideally at a nodal or grid supply point level • Standards that need to be followed (such as 1-in-20 security standard) • Current and future local network issues and operability challenges • Capacity and connection information • Equipment information • Capex and opex unit costs • Asset lifetime and depreciation periods • Rule of thumb estimates for demand
Local developers / customer, as relevant to the project, for example: • Housing developers • Potential demand or generation customers	• Project proposer / investment maker	• Project plans and timelines • Specific costs relevant to project (eg recruitment, training)
Local transport providers	• Project proposer / investment maker • Consult / inform	• Current and future demand profiles • Current and future energy needs (eg fuel, charging)

6.5 Use case 5 – Strategic planning

Use Case 5	Strategic planning
Exam question	What is the best way for the UK to meet its net-zero target?
Commentary	Significant investment is required if the UK is to meet the legal requirements to achieve net-zero. The cost of meeting net-zero is enormous. The CCC estimates it is likely to cost over £50 billion per year[13]. Important decisions around who funds this need to be made. The CCC also states that the economic impact of hitting net-zero could also be positive. A whole system CBA could be used to maximise the chance of this. A whole system CBA could look at certain sectors (eg should EVs or hydrogen be used for transport, do we use gas or electricity for heating) or more overarching (what is the cost of the different FES scenarios)
Inputs considered	• Investment costs • Technology costs • Market conditions • Consumer behaviour • Government policy
Benefits considered	• Lower bills • Reduced emissions • Societal benefits (eg health, inequality, fuel poverty, vulnerability)
Counterfactual	Do nothing. Decision maker is UK government
Stakeholders	• Governments (all levels) • Regulators • Business • Consumer groups • Network and non-network energy companies • Committee on Climate Change
Order of magnitude of benefits	Billions to trillions

Table 19 – Use Case 5: Strategic planning

[13] Committee on Climate Change: Net-zero – the UK's contribution to stopping global warming (page 229)
https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

7 Appendix 2 – Development of the whole system CBA

7.1 Network representation

The Whole System CBA has been developed by a Product team under Workstream 4 of the ENA Open Networks Project.

The following companies are represented on the Product:

Sector	**Company**
Electricity Transmission	• National Grid Electricity Transmission • Scottish & Southern Electricity Networks Transmission
Electricity Distribution	• Electricity North West • Northern Ireland Energy Networks • Northern Powergrid • Scottish & Southern Electricity Networks Distribution • UK Power Networks • Western Power Distribution
Electricity System Operation	• National Grid Electricity System Operator
Gas Transmission	• National Grid Gas
Gas Distribution	• Cadent • SGN • Northern Gas Networks • Wales & West Utilities

Table 20 – Company representation on the Product team

7.2 Governance

Governance of the Whole System CBA is through WS4, the Open Networks Steering Group (SG) and Gas Futures Group (GFG). These have representation from all GB gas and electricity networks and operators.

Date	Meeting	Purpose
12 February 2020	WS4	Update
11 March 2020	WS4	Update
8 April 2020	WS4	Approval of Phase 1 report
16 April 2020	SG	Approval of Phase 1 report
23 April 2020	GFG	Approval of Phase 1 report
13 May 2020	WS4	Update
10 June 2020	WS4	Update
8 July 2020	WS4	Update
12 August 2020	WS4	Update
9 September 2020	WS4	Update
14 October 2020	WS4	Update
11 November 2020	WS4	Update
26 November 2020	GFG	Update
7 December 2020	WS4	Approval of model and methodology Version 1
16 December 2020	SG	Approval of model and methodology Version 1
16 December 2020	GFG	Approval of model and methodology Version 1

Table 21 – List of governance meetings

7.3 Stakeholder engagement

The product team has engaged widely on the development of the methodology and model.

Meeting	Dates
ENA Regulation Committee	18 March 2020 29 September 2020 2 November 2020
ENA Gas and Electricity Environment Committee	13 November 2020
ENA Community Energy Forum	2 September 2020
ENA Open Networks Advisory Group	3 September 2020 28 October 2020
Model and methodology review sessions (all interested stakeholders)	17 November 2020 18 November 2020 2 December 2020 4 December 2020

Table 22 – ENA-led stakeholder engagement events

The product team has also had a number of bilateral conversations with stakeholders including:

- BEIS
- Community Energy England
- Citizens Advice
- Energy Systems Catapult
- Imperial College London
- Individual network companies
- Local authorities
- Ofgem

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