Programme Area: Smart Systems and Heat

Project: EnergyPath

Title: EnergyPath Networks Tool Gap Analysis Report

Abstract:

This Deliverable comprises a presentation which sets out an analysis of the potential enhancements to the Energy Path Networks Toolkit which could be progressed in the Toolkit Development Project.

Context:

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

Gap Analysis Report for EnergyPath Networks Post Release 2.1 – Interim Report

11/07/2017

Contents

Objective

The objective of this report is to define the priority software limitations of the EnergyPath Networks tool R2.1 with a particular focus on the requirements of local area stakeholders, i.e. the Local Authorities and Network Operators. Some of the prioritised items are low-regret and easy to implement, others are more major development items. Our proposal is to scope these items further before implementation.

The full list of limitations, as set out in Appendix A, have been collated from views expressed by local stakeholders, the tool developers and the internal Energy Systems Catapult EnergyPath team. These items were prioritised subjectively as high, medium or low priority by the EnergyPath Networks team based on the following criteria:

1) How often studies requiring these functionality enhancements /data improvements have been requested by stakeholders.
2) How much the credibility of the model is affected by not having these improvements.

High priority items have been discussed in detail in the body of the report and shared with members of the wider SSH1 team to build consensus.

As mentioned, the recommendations discussed in this report are based on feedback from local area stakeholders but there has not been a formal consultation project, since the three pilot projects (Newcastle City Council, Bridgend County Borough Council and Bury County Council) are not yet complete. This gap analysis will be revisited in the future through a formal consultation process with the three Local Authorities upon completion of the three local area strategies. A final report will be issued at this time (potentially as part of the bidders pack).

Please note that this report is not intended to be a comprehensive review of the functionality improvements necessary to turn EnergyPath Networks into a commercial product.

1) Repurposing of gas network to transport hydrogen

The repurposing of the gas network to transport hydrogen is very much a “hot topic” that is understandably of interest to Gas Network Operators (GNOs), as it gives them a business plan in a decarbonised future. However, interest has also been expressed by Local Authorities (LAs) and government during the three EnergyPath pilot projects, since these stakeholders are keen that EnergyPath Networks should consider as many credible options as possible. Inclusion of hydrogen in the EnergyPath Networks modelling would give stakeholders further confidence that EnergyPath networks is an unbiased tool that considers a wide range of transition options. Furthermore, inclusion of hydrogen would create an opportunity for the ESME and EnergyPath Networks teams to work more closely together, in order to improve the national versus local planning interface.

Currently EnergyPath Networks has the functionality to consider the repurposing of the gas network to transport hydrogen. However, until recently, there has been a lack of data on the real-world costs. The H21 project, (Dan Sadler et al., 2016), provides a technical and economic feasibility study for the repurposing of gas networks to transport hydrogen. However, the EnergyPath Networks modelling team has not yet had capacity to assess the credibility of the underlying data and process it into a form that can be used in EnergyPath Networks.

The Modelling team has learnt that Element Energy and Baringa are involved in a “Hydrogen supply chain technical evidence and modelling tool” project for BEIS, inspired by the H21 project, to further assess the repurposing costs. This project is due to end Summer 2017 and the intention is that all underlying data will be made publicly available. At present, initial evidence on cost and technical specifications for hydrogen production, transmission, hydrogen storage, carbon dioxide storage, distribution network repurposing and end use technologies is with BEIS for peer review. The same individuals from Element Energy and Baringa have also been heavily involved in the development of EnergyPath Networks throughout and know the data structure required for inclusion of hydrogen.

Recommended action

It is recommended that the steps necessary to represent hydrogen repurposing are scoped. This will involve reviewing the modelling framework for gas and hydrogen, alongside the outputs of the H21 and the “Hydrogen supply chain technical evidence and modelling tool” project. An initial proposed implementation methodology will be developed with cost estimates.

The estimated cost of scoping this work is £5000.

2) The effects of climate change and representation of cooling demand

It is reasonable to expect that, as temperatures rise due to climate change, there will be more demand for cooling in dwellings, particularly in cities (T. Kershaw et al., 2010). Non-domestic demand for cooling was estimated to be around 11% of total UK electricity demand in 2005 (The Carbon Trust, 2009), with significant variation between locations. For example (BRE, 2016) found that monitored cooling demands had a variation of 25% (London having the highest demand, Edinburgh, Glasgow and Belfast having the lowest). There is also anecdotal evidence that cooling demand is becoming more important with increased insulation in new builds (A. R. Day et al., 2009).

Even at present, non-domestic cooling is a significant load that is currently omitted from EnergyPath Networks, which could affect the credibility of the resulting analysis with stakeholders.

There are two separate, but related, issues with the current functionality:

1. **EnergyPath has a constant view of the weather out to 2050.** The weather in a local area is represented in EnergyPath using the University of Exeter's weather file for the nearest location. This information is fed into EnergyPlus so that the impact of outdoor temperature on internal heating demand can be understood. In release 2.1 only one weather file can be considered for a given local area from 2014 out to 2050. The University of Exeter have produced future climate change weather files (for 2030 and 2050) that reflects the rise in temperature due to climate change (http://emps.exeter.ac.uk/engineering/research/cee/research/prometheus/downloads/). Representing scenarios for changes in average temperature over time in the EnergyPath analysis could cause a decrease in demand for heating, as well as an increase in demand for cooling.

   The EnergyPath Networks modelling team could run the tool with a University of Exeter future weather file. This would overestimate outside temperatures up until 2050 but could give an indication of the effects of rising temperature on heating demand. This is something that can be done using the existing R2.1 functionality. However, the impact of increased temperatures on cooling demand cannot be determined currently.

   The resulting variations in demand could be quite insignificant. However, this item is considered important mainly because of how it could affect stakeholder perceptions of EnergyPath Networks and the credibility of results.

2. **EnergyPath does not include cooling demand.** There are several ways that cooling could be represented in EnergyPath with varying complexity. As a minimum, the cooling demand could be represented as an exogenous input to EnergyPath Networks. This would require a review of available data on current and future cooling demand in domestic and non-domestic buildings. An alternative, more accurate but more complex approach is the consideration of cooling demand in EnergyPlus by defining target temperatures for cooling as well as heating. There are also different

methods of meeting cooling demand in buildings. EnergyPath could consider only individual cooling units in a building or it could also consider a cooling network – in a similar way to the current modelling of heating via individual heating systems versus heat networks. These extra options will undoubtedly impact of the run time of the tool.

Recommended action

It is recommended that the various options for utilising multiple weather files and representing cooling demand in the EnergyPath analysis are scoped, as well as the positive and negative implications of each approach and cost estimates for implementation.

The estimated cost of scoping this work is £7250 (£750 for scoping the management of multiple weather files, £6500 for scoping options for representation of cooling).

3) Single glazing replacement costing

UK building regulations specify that all replacement windows must be at least double glazed. This is reflected in EnergyPath Networks by prohibiting the replacement of single glazed windows with new single glazed windows. However, this causes the costs of replacement of single glazing to be excluded from the analysis. That is, any existing building with single glazed windows will not incur window replacement costs. This is something that could lead stakeholders to question the credibility of EnergyPath Networks since English Housing Survey data suggests that single glazed windows account for around 10% of domestic windows in England.

It is important to note that heritage buildings may be prohibited from transiting to double glazing. However, this can be reflected within EnergyPath Networks by utilising the new R2.1 building constraints methodology to restrict listed buildings from transitioning.

Recommended action

It is recommended that the additional functionality for the inclusion of replacement of single glazing with double glazing is scoped. This will involve a targeted update of the domestic costing to reflect the cost of replacing single glazed windows. An initial proposed implementation methodology will be developed with cost estimates.

The estimated cost of scoping this work is £1500.

4) Enabling heat networks for a subset of buildings in an area

In EnergyPath Networks the decision of whether to build heat networks is an all or nothing decision at a cluster level (where a cluster can be defined as HV substation and downstream connections, HV feeder and downstream connections, LV substation and downstream connections or LV feeder and downstream connections). The capacity of the heat pipes will be modified to meet the demand of any buildings connected by EnergyPath but the length of pipe remains constant.

The main implication is that EnergyPath does not generally choose to build heat networks in large clusters (e.g. large numbers of buildings fed by a single HV substation), even if there are groups of buildings where heat connections are appropriate. Furthermore, when a small number of heat connections within a cluster are forced in order to reflect LA plans, heat pipes are automatically built across the entire cluster. This leads to an over-estimation of the cost of the heat network.

Smaller clusters can be defined but not across the entire study area, since this would greatly impact the run time of the tool. For example, there are 11 HV substations within the Bridgend study area, but there are 840 HV feeders. The Newcastle study area has 18 HV substations. For the Bridgend study, the optimiser takes half an hour to run on average, whereas for Newcastle the run time was around two days. Of course, there have been improvements to the optimiser under R2.1 so it impossible to know how much of the run time improvement can be attributed to the decrease in the number of clusters. However, we do know that the relationship between run time and clusters is not linear. That is, as the number of clusters increases, the problem complexity increases at a growing rate.

Currently, desirable areas for defining more granular clusters can be only be identified once the tool has been run with HV substation level clusters. However, it cannot be guaranteed that this method with highlight areas suitable for heat networks. Having the ability to consider clusters with partial heat pipe installation as an option would give a less biased view of heat network suitability.

Recommended action

It is recommended that the options for extending the heat network functionality of the EnergyPath Networks tool are scoped. This item would be a major change to the networks module so it is necessary for scoping to include a workshop outlining the options for updating the methodology for defining and costing district heat network investments. All options will need to be balanced with the associated increases in complexity and run time. An initial proposed implementation methodology will then be developed with cost estimates.

The cost of this scoping is estimated to be £16,000.

5) Output Presentation

It can be hard to know how to present outputs for different types of stakeholder. Politicians, council officers, network operators and local residents will all have different interests and different levels of engagement and understanding. The difficulty is partly related to the complexity of the outputs with multiple interlinked factors (technology types, technology capacities, different archetypes, different networks etc.) all changing over space and time.

The Energy Systems Catapult has developed an output dashboard to help with this issue. It allows users to slice the data in different ways to see what they are interested in. It works at a ward or analysis cluster level of disaggregation. This is considered to be the level at which outputs are most robust. A prototype version has been shared with Newcastle City Council who found the dashboard helpful but desired a greater level of disaggregation and found cost and emissions graphs difficult to interpret. However, there is a risk that providing outputs at a higher level of granularity will increase confusion. The EnergyPath Networks team have developed outputs that attempt to balance these requirements to provide stakeholders with the “right” level of detail but the team do not have prior experience in data visualisation with so many dimensions. Going forward it will be necessary to determine methods for engaging stakeholders by providing an evidence base to enable local decision making, without providing house by house and street by street results that are not enlightening. It would be hugely useful if results could be interrogated easily so that stakeholder questions can be answered efficiently. For example, Local Authorities will be interested in using EnergyPath analysis to answer questions on specific projects and funding opportunities, such as

1) Which types of buildings in which areas should be targeted for given retrofit measures? How many buildings can be retrofitted with the funds available?
2) On a demonstration project to fit heat pumps into homes: What buildings are most suitable for ASHPs? Are there areas where this is likely to cause network constraints that should be avoided?

In contrast a network operator might be interested in

1) The phasing, magnitude and cost estimates for network reinforcement. This might be for strategic planning, or could relate to detailed planning to deal with a network constraint that has been identified. In this case they might wish to consider ‘over reinforcement’ now if significant extra capacity is likely to be required in the longer term.
2) The geographic locations and estimated heat demands of domestic buildings that have been identified as low regret choices for connection to a heat network that is currently being planned for a neighbouring area (for example, the Science Central site in Newcastle where the planned network is predominantly non-domestic).

These examples are based on discussions with the stakeholder working groups for the three prioritised local areas. There will, of course, be many more stakeholder questions which will need to be understood.

Recommended action

In order to take the visualisation of outputs further, it is recommended that the EnergyPath Networks team collaborate with parties who have expertise in visualisation and communication of complex data. Internal resource will be required to identify and select third parties with the necessary skills. Previously potential collaborations with Newcastle University were discussed but the internal resources to explore the opportunity further were not available.

It will be necessary to assess the needs of local stakeholders and scope output visualisation options that meet these needs. The cost of this work is estimated to be £30,000.

Bibliography

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Appendix A – All Options Considered

The table below shows the full list of development options considered for EnergyPath Networks. Each item is rated in terms of desirability and achievability (where possible). The desirability rating is a subjective judgement based on

1) How often studies requiring these functionality/data improvements have been requested by stakeholders.
2) How much the credibility of the model is affected by not having these improvements.

The achievability rating is also a subjective judgement based on

1) An order of magnitude estimate of the time necessary to implement the improvement.
2) An understanding of how availability of the input data necessary to credibly represent/support implementation.

Functionality	**Foreseeable risks associated with current functionality**	**Desirability (at present)**	**Achievability (at present)**	**Justification**
Potentially integration of non-domestic building model (e.g. static SBEM).	Stakeholders may not have confidence in non-domestic demand estimates.	Medium	Low	Lack of non-domestic data means that input data required for building model is unavailable. This current functionality has been discussed with stakeholders in the three local authority areas and, so far, there has been no impact on credibility.
Monte Carlo simulation of further parameters. Currently, we have the ability to perform Monte Carlo analyses for technology costs, resource costs and domestic building U-values.	Avoids having to do "manual" sensitivity testing for potentially important inputs. Also, allows representation of correlations in costs.	Low	Low due to implications on run time.	There are two consequences of simulation of further parameters: (1) Run time of the tool increases with the number of simulated parameters. (2) Increasing the number of included simulated parameters requires the number of simulations to be increased. Otherwise the analysis is not credible.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
				In the most recent Monte Carlo for Bridgend, we ran 100 simulations which takes around three weeks to complete. The effects of fluctuations in energy prices are investigated in a separate sensitivity, and U-value parameters have not yet been simulated for any local authority area. The EnergyPath team needs to understand the implications of including U-value and resource price simulations before the Monte Carlo functionality is reviewed.
Consideration of new build hydrogen networks/ steady state modelling for gas network.	Gas network operator may doubt accuracy of solutions due to simplicity of approach to modelling gas network.	Medium for gas, low for new build hydrogen.	Unknown without further scoping.	This would require Sincal gas module, which would be a significant cost to the project. The Sincal modules currently used in EnergyPath Networks are the electricity and heating and cooling modules, which cost €12,000 and €7,200 respectively. The gas network representation has not raised concern amongst stakeholders so far. The importance of including new build hydrogen should be reassessed when/if model results from repurposing to hydrogen are available.
Fill data gaps for repurposing of gas network to transport hydrogen.	Risk that stakeholders do not consider EnergyPath to be unbiased tool as it does not include hydrogen as an option for transition.	High	Medium	Discussed in main body of report.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
Ability to call more than one EnergyPlus weather file.	Risk that credibility of tool is questioned when stakeholders realise annual weather is assumed to be constant out to 2050.	Medium	High	Discussed in main body of report.
Altitude differences across heat transmission pipes represented.	Risk that cost of heat network is underestimated due to need for pumps to allow heat network layout that crosses hills.	Low	Unknown without further scoping.	This item is not something that has caused concern amongst stakeholders.
Further modifications to improve optimiser performance.	Risk that run time of optimiser causes delays in projects.	Low	Unknown without further scoping.	Optimiser performance is much better in R2.1. The EnergyPath team need more time to judge how much of this is due to changes in R2.1 and how much is due to reduced problem complexity in Bridgend from Newcastle.
Proper accounting for emissions from gas networks – conversion of CH_4 and HFCs to CO_2 equivalent.	Emissions are underestimated in EnergyPath networks.	Low	Medium	This item cannot be implemented until the Bridgend and Bury projects are finished, as the assumptions cannot be changed part way through sensitivities. This item was partially investigated during the data collection phase for the “green gas” sensitivity in Bridgend so could be revisited by the EnergyPath team. This would also require adjustment to the local area emissions reduction targets, which currently only consider CO_2.
Data validation / error logging	It is often difficult to debug errors in the EnergyPath Networks tool. Some errors are reported effectively by the tool and can be fixed quickly but many errors require time to debug. Sometimes it is necessary to go	Low	Unknown without further scoping.	The EnergyPath team are developing methodologies for data validation all the time and record run fails and fixes for future use but there are still changes that could be made to the code to improve this further. Currently, this is a low priority item since there are so many errors/data validation issues that could be

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
	back to the contractors for support, which requires extra spend.			reported. The team need to finish working with the three prioritised LAs before judging which are of greatest interest.
More granularity in post-1980 categorisation. Automated	GeoInformation supply a post-2000 category now so an extra category could be added to split the "post-1980" category into "1980-1999" and "post-2000". 1980 properties could have very different thermal efficiency to 2016 properties so there is a risk that the EnergyPath Networks tool over-estimates heat demand with this approach.	Low	Unknown without further scoping but would have implications on run time.	Can be done with current functionality but cannot do part way through Bridgend and Bury studies. EnergyPath team should revisit this point once the three studies are completed.
Ability to force/restrict techs to a given threshold, e.g. no more than 1/3 of properties can have GSHPs to stop ground freezing.	Risk that schemes suggested by EnergyPath are not credible.	Low	Unknown without further scoping.	Could be represented using building level constraints functionality in release 2.1, which could be time consuming but need to test this approach before considering adding further functionality.
Removal of diversity scaling of EV demand.	Currently scaling is applied twice - once through data and once by code so the variation in EV demand is over estimated in EnergyPath Networks.	Low/medium	High	The EnergyPath Networks team may be able to do this without support from contractors.
Implementation of BAU archetype attribute changes e.g. inclusion of single glazing replacement with double glazing.	This means that replacement costs for single glazed windows are not included in the tool.	Medium	Low	Discussed in main body of report.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
Inclusion of cooling	Extra load of cooling on electricity network is not accounted for in EnergyPath Networks.	High	Depends on how cooling is represented.	Discussed in main body of report.
Representation of flats with communal boiler.	Communal boilers can be modelled by creating energy centres that feed a single block of flats. However, there are 100 social properties with communal heating in Bury so have represented by individual heating systems instead. There is a risk that stakeholders will feel that EnergyPath is not representing communal heating systems properly.	Low	Unknown without further scoping.	Too late to implement this change for Bury. This item should be reviewed once the three studies are finished. Need to make a judgement based on how likely this is to occur.
Defining address level attributes in DB rather than through GIS.	Currently, building data is loaded into EnergyPath Networks through ArcGIS. It is then combined with other datasets and brought into SQL. Sometimes it is easier to update the SQL tables directly. However, there is a risk that data will be overwritten by ArcGIS inputs.	Low	Medium	EnergyPath team need more time to judge which data items it would be most useful to be able to enter through SQL. Will revisit once all three projects are complete.
Increasing reduced archetype energy states to better estimate the energy demands	The clustering of energy states is targeted by floor area bands, hence the resulting energy states are mainly concentrated in one floor area band. This implies that very different buildings are assumed to have similar demands in EnergyPlus. This could lead to demand that is under-estimated or over-estimated.	Medium	Unknown without further scoping.	This item has not affected credibility with stakeholders.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
Running Monte Carlo simulations on aggregated parameters after optimiser pre-processing.	Monte Carlo run was very slow for Newcastle. The main risk here is for project timelines.	Low	Unknown without further scoping.	Improvements to Monte Carlo run time were made for R2.1. The EnergyPath networks team need time to judge whether further improvements are necessary once the Bridgend Monte Carlo is complete.
Parallelising requests sent to SQL server.	There have been issues with fails in the tool due to several cores trying to write to SQL at the same time. The steps that require parallelisation are very long so this can lead to a lot of wasted time.	Low	Unknown without further scoping.	SQL will need to be updated to SQL 2014 for security reasons. This could fix the issue.
Investigating multi-core computing with ArcGIS. Involves checking current license restrictions as well as python code update.	This could improve the run time of the spatial steps in the tool.	Low	High	There are other steps that take longer to run. Also, this could easily introduce further coding errors.
Report optimiser results by vintage (build years)	EnergyPath input tables are split by build year and time period, e.g. the cost in the 2040 time period of technology x with built year 2020 is £y. Results tables are split by time period only. The risk is that it can be impossible/more difficult to draw out results that are useful to the stakeholders.	Low	Low	The EnergyPath Networks team need more time to judge which outputs are most useful to stakeholders. This item should be revisited once the three projects are finished.
Add diversity scaling for ND buildings demand	Currently non-domestic building demand is calculated using Carb2 data, which estimates energy usage per m^2 based on building use. However, in reality, there will be variations in demands between buildings.	Low	Low	No credible data currently available for inclusion of this functionality. This should be reviewed when/if data becomes available.
Heat network costing considers that heat network	Risk that EnergyPath will not build heat networks in large clusters, purely because	High	High but depends on	Discussed in main body of report.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
is not build across entire cluster	of the costs of installing pipes across the cluster and not because no areas within the cluster are not suitable for heat network deployment.		methodology for implementation.	
Further improve performance of archetype costing.	This would involve splitting the cost calculation between heating system retrofitting (reduced archetype transitions) and insulation measure retrofitting (base archetype transitions). Risk that run time of archetype costing slows down process and makes project deadlines difficult to meet.	Low	Unknown without further scoping.	The archetype costing has already been improved in R2.1 but this item should be reviewed once the three projects are complete.
Report detail of final network cost curves in networks module.	Risk that it would be useful to share this information with DNOs or other third parties. This could lead stakeholders to think that EnergyPath is a "black box" and question its credibility.	Low/medium	Unknown without further scoping.	Not currently perceived valuable because DNOs have indicated that they would always do their own analysis using in house tools anyway. Newcastle university will be looking at methodology to disaggregate optimiser outputs to network level.
Allow variation in shape of electrical demand, based on propensity to electrify.	Currently the shape of demand in a cluster (i.e. the geographical spread of demand) is assumed to be fixed at current levels in all future years and pathways – the absolute level rises and falls depending on changes in demand but the shape that the networks sees is fixed. This may under/over-estimate network costs if changes in demand are more localised.	Low/medium	Unknown without further scoping.	This item should be reflected on once the three projects are finished. Currently, it is not clear how material this is.

Functionality	Foreseeable risks associated with current functionality	Desirability (at present)	Achievability (at present)	Justification
Update fuel cell parameterisation to reflect PEM	Currently, fuel cell representation in EnergyPlus is not that of a PEM (Proton Exchange Membrane) fuel cell but of a SOFC (Solid Oxide Fuel Cell). This risk is that the differences in the associated technical parameters influence whether fuel cell technologies are chosen in the optimiser.	Low at the moment	Medium/high	The EnergyPath team have not yet made use of the existing fuel cell functionality.

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