Programme Area: Energy Storage and Distribution

Project: Heat Infrastructure Development (HID)

Title: Solution Route Maps Report

Abstract:

In Stage 1 of the project, work comprised assessment and synthesis of the current baseline practice and costs in the UK and overseas, and relevant technologies and practices from other industries which could potentially be used in future, from which key challenge areas were identified for targeting of cost reduction solutions during Stage 2 of the project. In Stage 2 of the project work comprised the identification and development of solutions in each of these challenge areas, the assessment of the key solutions against a range of criteria, and the selection of certain solutions to have route maps developed. This report sets out the route maps developed during Stage 3 of the project to achieve full commercial deployment of each of the highest priority solutions. Each route map sets out the challenge addressed, the proposed solution, the barriers to development, development requirements, commercialisation requirements and a plan of work comprising a number of activities.

Readers may find it useful to study the Summary Report, which summarises the entire project, prior to studying the detailed engineering reports.

Context:

This project seeks to identify the innovative solutions needed to deliver major reductions in the capital cost of heat network infrastructure and accelerate its deployment. Examining the technical, process and system developments needed to deliver a step change reduction in the capital costs, along with cost estimates and time frames for undertaking these developments. District heat networks supply heat to homes and businesses through pipes carrying hot water. They have great potential to deliver CO2 emissions reductions and cost benefits through the use of low carbon heat, waste heat from power stations, industry and other sources, combined heat and power, and large-scale heat pump deployment.

Heat Infrastructure Development Project

Deliverable EN2013_D04

Solution Route Maps Report

September 2017

This report is produced under the Heat Infrastructure Development project, commissioned and funded by the ETI

Contributions from Cowi and Loughborough University

Under the terms of the project contract between the ETI and AECOM Ltd, all information in a deliverable which is based on input from two specific subcontractors, namely COWI A/S and Loughborough University Enterprises Ltd, must be expressly identified. Users of this report should note the following:

1. In respect of information based specifically on input from COWI A/S, the intellectual property provisions in Schedule 1 of the project contract are amended by those in clauses 22.7, 22.8 and Appendix 4 of the project contract.
2. In respect of information based specifically on input from Loughborough University Enterprises Ltd, publication by the ETI is subject to additional provisions in clauses 21.1 and 31.6 of the project contract.

Specific content in this deliverable report from COWI A/S is as follows:

- COWI A/S supported the work for Stage 1 which was reported in Deliverables D01 and D02. The work in this report builds on Stage 1. There is no additional content in this deliverable report from COWI A/S.

Specific content in this deliverable report from Loughborough University Enterprises Limited is as follows:

- Loughborough University Enterprises Limited supported the work for Stage 1 which was reported in Deliverables D01 and D02. The work in this report builds on Stage 1. There is no additional content in this deliverable report from Loughborough University Enterprises Limited.

Version Control

Rev	Comments	Prepared by	Checked by WP Lead	Checked by CTO	Approved by PM/PD	Date
1	Deliverable for issue to ETI	Various	DR	PW	MA	26.05.17
2	Deliverable for issue to ETI	Various	DR	PW	MA	19.07.17
3	Deliverable for issue to ETI	Various	DR	PW	MA	04.08.17
4	Deliverable for issue to ETI	Various	DR	PW	MA	18.08.17
5	Deliverable for issue to ETI	Various	DR	PW	MA	24.08.17
6	Deliverable for issue to ETI	Various	DR	PW	MA	30.09.17

Aldgate Tower, 2 Leman Street, London, E1 8FA
Telephone: 020 7645 2000 Website: http://www.aecom.com

Job No: 60477549 Reference: ETI: Reducing costs of DH Date Created: September 2017

Contents

Glossary

3-D	Three Dimensional
4DH	4th Generation District Heating, which principally includes lower distribution temperatures
4GDH	4th Generation District Heating, which principally includes lower distribution temperatures
ΔT	delta T/ delta temperature i.e. flow temperature minus return temperature
ADE	Association for Decentralised Energy
BS	British Standard
ASHP	Air Source Heat Pump
CAPEX	Capital Expenditure
CDM	Construction (Design and Management) Regulations
CHP	Combined Heat and Power – a common heat source for DHNs where electricity and heat are produced from a single machine
CIBSE	Chartered Institution of Building Services Engineers
CO_2	Carbon Dioxide
CSH	Code for Sustainable Homes
CTO	Chief Technology Officer
DEC	Display Energy Certificate
DECC	Department of Energy and Climate Change (now part of the Department for Business, Energy and Industrial Strategy)
DH	District Heating - The practice of supplying heat energy to commercial and industrial buildings, homes and other public buildings through pipes carrying hot water (or other appropriate working fluid).
DHA	District Heating Area
DHC	District Heating and Cooling
DHN	District Heat Network: A system which supplies heat energy to commercial and industrial buildings, homes and other public buildings through a network of pipes carrying hot water (or other appropriate working fluid). For the purposes of this Project, a complete DHN system will be considered to comprise (a) a distribution network and (b) the upstream generation and downstream demand components which interface with the distribution network.
DHST	District Heating Storage Tank
DHW	Domestic Hot Water supply
District Heating	The practice of supplying heat energy to commercial and industrial buildings, homes and other public buildings through pipes carrying hot water (or other appropriate working fluid)
DIY	Do It Yourself
DN	Diameter Nominal; e.g. DN300 being a pipe of 300mm nominal diameter
DNO	Distribution Network Operator
DSR	Demand Side Response – adapting local consumption in line with system demand
DT	Delta Temperature (see above)
DTH	Down the hole
DTU	Danish Technical University
ECCR	The workshop systematically reviews a work activity to look to reduce

workshop	cost through the following four means § **E**liminate unnecessary material, capital or labour cost e.g. avoid the need for a heat exchanger (use direct HIUs) § **C**ombine components or processes to reduce material, capital, operating or labour cost. § **C**ombine operations to deliver multiple activities simultaneously to save time and labour cost e.g. install longer lengths of DHN pipes simultaneously to reduce crane and labour time § **R**educe time or cost of any residual operation or component e.g. use cheaper materials that still meets performance requirements
Emitters	Domestic or commercial radiators or equivalent (e.g. underfloor heating)
EN	European Norm
EPC	Energy Performance Certificate
ESCo	Energy Services Company; they provide a broad range of energy solutions which can include the construction, finance and/or operation and management of district heating
ETI	Energy Technologies Institute
EU	European Union
EVOH	Ethyl Vinyl alcohol copolymer
FEED	Front End Engineering Design
FEM	Finite Element Modelling
FDD	Fault Detection and Diagnosis
GIS	Geographic Information System
GLA	Greater London Authority
GPR	Ground Penetrating Radar; for sub-surface surveying.
GPS	Global Positioning System
HDD	Horizontal Directional Drilling
HDPE	High-Density Polyethylene
HID	The ETI's "Heat Infrastructure Development" project under which this work was carried out
HIU	Hydraulic Interface Unit – A pre-fabricated assembly of components that forms the interface between a District Heat Network and a building's heating and/or hot water systems, and which may typically include (a) isolating valves, balancing valves, control valves and a heat meter, (b) a heat exchanger to separate the heat network from the building's heating system, and (c) a heat exchanger to produce domestic hot water. The terms "Heat Interface Unit" and, for a non-domestic property, "Heat Substation" are also sometimes used, and these have the same meaning.
HNDU	The UK government's Heat Networks Delivery Unit
HP	Heat Pump
HVAC	Heating Ventilation Air Conditioning
ICC	ETI's Infrastructure Cost Calculator
IEA	International Energy Agency
IRR	Internal Rate of Return; a financial measure to assess the viability of an investment such as a district heating scheme
ITHE	Instantaneous Heat Exchanger
LA	Local Government Authority
LCA	Life Cycle Assessment
LUEL	Loughborough University Enterprises Limited
LTDH	Low Temperature District Heating
MIH	Man in hole
MVHR	Mechanical Ventilation and Heat Recovery

NDT	Non-Destructive Testing
NGO	Non-Governmental Organisation; not for profit, may receive public and/or private funding
OD	Outside Diameter
OFGEM	Office of Gas and Electricity Markets; the energy regulator; may have a future role in the regulation of DHN
OJEU	Official Journal of the European Union
OPEX	Operational Expenditure
PB	Polybutylene
PE	Polyethylene
PE-RT	Polyethylene of Raised Temperature resistance
PET	Polyethylene Terephthalate
PEX	Cross-linked Polyethylene
PMM	Primary Metering Module
PN	Pressure Normalised
PP	Polypropylene
PUR	Polyurethane
PV	Photovoltaic
PVC	Polyvinyl Chloride
R&D	Research and Development
RAMS	Risk Assessment and Method Statement
RHI	Renewable Heat Incentive; UK Government subsidy for low carbon heat sources
RoI	Return on Investment
RP	Registered Provider of social housing
RSL	Registered Social Landlord
SBRI	Small Business Research Initiative
SCADA	Supervisory Control And Data Acquisition
SEF	Strategic Energy Funding – a generic term to cover future government energy investment
SPV	Special Purpose Vehicle; legal entity set up for a specific function, e.g. a joint venture between a Local Authority and others to create a Heat Network
SUDS	Sustainable Urban Drainage System for flood mitigation; now not exclusively Urban
Supply Chain	Organisations involved in the supply of materials or direct services to a project
TOTEX	Total System Cost – CAPEX + OPEX over the project design life (Whole Life Cost)
TPL	Target Pressure Loss
TRV	Thermostatic Radiator Valve
TT	Trenchless Technology
Value Chain	All organisations with involvement in the DHN project from designers to manufacturers, clients to building control
WP	Work Package

Executive Summary

Introduction

This report principally summarises the results for the final, route mapping phase of ETI's Heat Infrastructure Development (HID) project. It also includes an over-arching review of the work within the project.

The primary objective of this project is to identify and then assess innovative solutions with the potential to deliver a substantial step change reduction in the capital cost, and contribute to overall lifecycle cost reduction, of District Heating Networks (DHNs). The project has three stages:

- Stage 1: System review and target setting
- Stage 2: Solution development, analysis and selection
- Stage 3: Development of route maps

Stage 1 of the project comprised a number of research and engagement activities to provide a solid foundation to this project. This included analysing key stakeholder requirements for DHNs, a literature review and horizon scanning of potential innovative solutions, and an investigation of the differences in practice between the UK and leading countries where district heating is more established. In parallel with the research, an Excel-based model of current DHN costs was developed and 'baseline' costs analysed.

This information was used to prioritise a set of five challenges to which solutions would be identified during Stage 2 of the project. It was also used to develop a set of quantitative and qualitative evaluation criteria for the assessment of each solution and an accompanying solution template to capture and present this information in a common format.

The five prioritised Challenges which have focussed activity in Stage 2 were as follows:

- Challenge 1 - System Design Architecture
- Challenge 2 - Civil Engineering CAPEX
- Challenge 3 - Pipes and Connections CAPEX
- Challenge 4 - Internal Connections CAPEX
- Challenge 5 - New Network Income

Stage 2 of the project identified, developed and evaluated innovative solutions to address each of the five challenges. Overall, 13 'Green' solutions (the most promising ideas) were identified which if applied together in an optimum mix across different building typologies, it is estimated, could achieve a 32% reduction in DHN CAPEX. It is estimated that the other solutions identified could generate up to an additional 6% DHN CAPEX saving.

It was agreed that 11 of the 13 Green solutions should be taken forward for route mapping in Stage 3. Two of the Green solutions were not taken forward due to the relatively small DHN CAPEX saving and/or due to the limited additional benefit which a route map was likely to provide for these specific solutions. Two of the route maps comprise multiple solutions as the individual solutions are closely linked, which resulted in a total of 8 route maps.

Stage 3 is the final part of this project.

- This Deliverable EN2015_D04 presents the findings from Work Package 7. Its objective is to develop the 8 route maps which describe the work required to bring the 11 Green solutions from their current state to commercial deployment. It also presents an overarching review of the project including the process undertaken, the potential for combination of solutions and success against the project objectives.

- Deliverable EN2015_D05 comprises the output from Work Package 8 and provides a summary of the findings from across the whole project.

Summary of each Route Map

Each route map has been written using a common template detailing: the challenge addressed, the proposed solution, the barriers to development, development requirements and commercialisation requirements and a plan of work comprising a number of activities. Each activity has been separately defined with a scope of work and estimated cost and programme.

Route Map A – Knowledge Management, Research and Training

In Stage 3 further consultations were held with stakeholders and the solution was developed to set up a District Heating Knowledge Centre (DHKC) which would be funded by BEIS-HNDU, managed by a Board with representatives from key industry organisations and with a Delivery Partner appointed who would commission research, guidance documents and training programmes as defined by the Board. It is proposed that further research and consultation should be held to achieve consensus for the structure, scope and funding of the DHKC. There would then be a set-up stage when the work plan for the first few years of operation is defined and the Delivery Partner appointed.

Route Map B – Low Flow Rate Design

This solution aims to reduce the flow rate required to supply the heat demand by a factor of two by minimising the design heat demand and reducing return temperatures. The activities proposed are the development of software tools to help the designer, including using smart meter data to estimate peak demands. Market research will be carried out with the design community to understand how work is carried out at present and what would be helpful to enable the solution to be implemented widely. A demonstration project is planned with dissemination of the results to show how cost reduction can be made with appropriate designs.

Route Map C – Radical Routes

This route map covers two solutions – installing the DH pipes on the external wall of housing or within the loft space. Research will be carried out into the types of dwellings where this solution would be most viable to determine the range of house designs that the solution needs to address. Market research of potential DH customers is proposed to understand better the likely concerns over the solution, especially visual impact or risk of damage to property. A product development stage is proposed where specific product designs will be developed to suit a range of applications. These are expected to use standard components already available (pipes, supports, cladding extrusions etc) but put together in a novel way. A prototype stage is proposed using either a full-scale factory mock-up or on a site where several dwellings are being full renovated and a DH connection is feasible. A demonstration scheme is then proposed for 50-100 dwellings of different types where all of the solutions will be trialled. Work on legal agreements is also proposed which would be needed for the demonstration project to provide the permissions needed to install pipes within a property and to grant access rights. The product development stage is expected to be of interest to a number of pipe suppliers and initial discussions with two suppliers proved positive.

Route Map D – Trenchless Solutions

During Stage 3 a further workshop was held bringing together suppliers of trenchless technology, pre-insulated pipe suppliers, civil engineering contractors and DH scheme owners. This identified the need to develop some new pipe products and new techniques for remote jointing. The trenchless technology itself – horizontal directional drilling and 'core and vac' holes were considered well established. In addition to this product development work, market research into current attitudes to the solution will be carried out followed by an educational activity to explain the potential benefits.

Route Map E – Improved Front End Design and Planning

This route map addresses both solutions which improve the process of front end design including surveying techniques and alternative contractual arrangements which would allow better processes to be used. The main barrier to be overcome is lack of understanding about the impact on costs of limited front end design so the first activity is to carry out a survey of 3-5 sites to establish in detail how costs are incurred for e.g. waiting time, rework etc and hence the potential for reducing costs through improved activity. New contractual arrangements would then be developed. The solution will then be disseminated to industry using detailed guidance documents. A demonstration project is proposed to test out this solution.

Route Map F – Shared Civils

This solution aims to reduce the costs of installing DH network by combining the work with other similar work that could be planned at the same time in the same area. Although simple in concept it has been very difficult to achieve in practice. Most synergy has been found with the water industry where in some areas significant upgrading works are needed and reducing water leakage is a major driver. The route map proposes developing a sample business plan and other planning tools that could be used to identify opportunities. A demonstration project is proposed to test out not just the physical benefits of sharing the construction work but how the business models would work. Market research and the development of model forms of agreement are included.

Route Map G – Direct HIU System and Existing DHW Storage

This route map covers two solutions both aimed at reducing the cost of HIU by taking a different design approach. The proposed solution is not universally applicable but can offer significant cost advantages. Market research to understand the concerns of designers and the preferences of customers is proposed. To assist the designer a process map will be produced to guide the decisions needed together with research to identify potential OPEX benefits. The products required are generally available in the market although some product development to reduce the risk of damage from leaks is proposed. A demonstration project will be implemented to help provide confidence to designers and this project will be monitored and reported on.

Route Map H – HIU Optimisation

This route map covers a number of solutions which were identified with the aim of bringing down the cost of HIUs to at least as low as a typical gas boiler. This will require much greater standardisation to enable higher volume production, the development of a low cost heat meter and a primary control valve and, where applicable, taking into account the simplifications proposed in Route Map G. With greater volumes of production new manufacturing techniques including injected moulded plastic components would be viable. Significant product development is proposed with the potential for collaboration between manufacturers, to give a rigorously designed product to a target cost. Market research with stakeholders including customers is also proposed.

Commercialisation Requirements

An Ansoff Matrix was used to help determine the nature of the activities needed to bring each solution to market. The results of this analysis are shown in Figure 1.

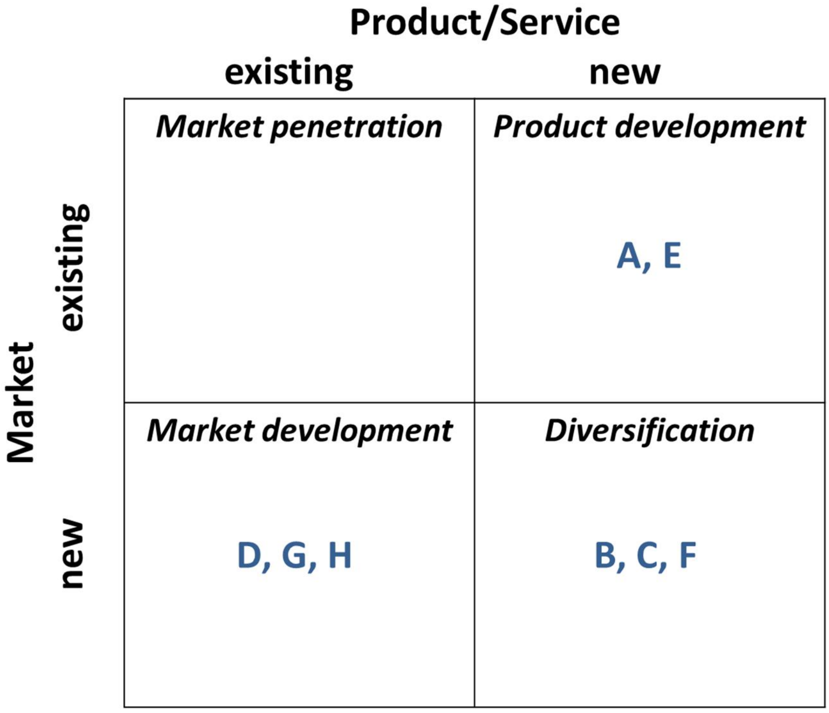

Figure 1: Ansoff Matrix analysis of Route Maps

The Ansoff Matrix is a framework for organisations to consider whether the commercial offering proposed is either a new product / service and whether it is being sold into a new market or an existing one. The approach to commercial deployment varies depending on which quadrant of Figure 1 the solution lies.

- **Market penetration:** The commercial strategy of solutions in this quadrant is to encourage existing clients to take more of current solutions. There are no route maps in this quadrant.
- **Product development:** The commercial strategy of solutions in this quadrant is to sell new products or services to existing clients. Route Map A: Knowledge Management, Research and Training & Route Map E: Improved Front End Design and Planning are both in this quadrant as they encourage existing DHN developers to work in new ways to improve delivery.
- **Market development:** The commercial strategy of solutions in this quadrant is to sell existing products to new markets. Route Map D: Trenchless Solution, Route Map G: Direct HIU System and Existing DHW Storage and Route Map H: HIU Optimisation are all in this quadrant as take existing solutions and encourage take-up by new clients.
- **Diversification:** The commercial strategy of solutions in this quadrant is to develop new products for new markets. Route Map B: Low Flow Rate Design, Route Map C: Radical Routes and Route Map F: Shared Civils are all new products being offered to new clients.

The activities to deliver these commercial strategies are covered in the individual route maps.

Programmes

Typically, the route map activities encompass four stages: research, product or market development, demonstration projects and deployment. The overall programme for the route maps is shown in Figure 2.

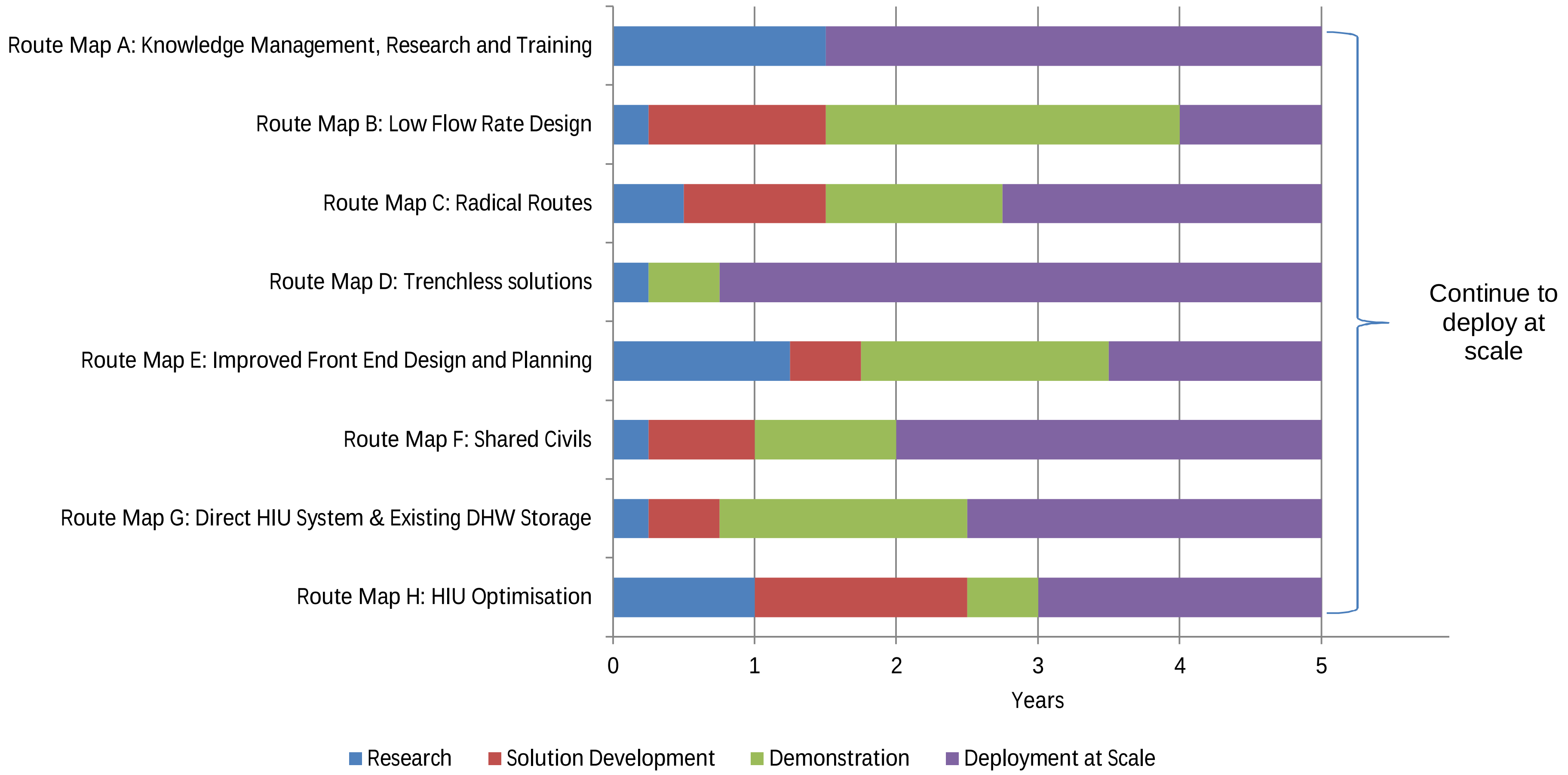

Figure 2: Overview of programmes for route maps

Costs for the Route Maps and Funding

The funding of the route maps is expected to be obtained from four sources[1]:

- **BEIS-HNDU** funding will be used for fundamental research work and its dissemination. This research would be for activities at low Technology Readiness Levels (TRL 1-3).
- **Innovate UK** funding will be used to support manufacturers developing products, and operates effectively at TRL levels 3-7.
- **Strategic Energy Funding** (SEF) refers to demonstration project and dissemination investment where public investment ensures data is captured objectively and insight is made public. Over the last decade, the ETI has provided leadership, systems thinking and a source of such funding. It is unclear how such strategic energy investments will be funded in future.
- **Industry** funding, especially manufacturers who will be developing new products; by this stage the commercial opportunities are clear and activities would be at TRL levels 8-9.

Estimates have been provided for these sources for each route map; with industry funding matching the Innovate UK funding. Table 1 summarises the cost estimates made.

Route Map	BEIS-HNDU (£k)	Innovate UK (£k)	Industry Match Funded (£k)	Strategic Energy Funding (£k)	Total (£k)
A	2,135	-	-	-	**2,135**
B	172	-	20	141	**333**
C	187	120	120	15	**442**
D	40	1,600	1,600	70	**3,310**
E	194	-	-	55	**249**
F	271	-	-	95	**366**
G	£97	90	90	139	**416**
H	158	3,700	3,700	-	**7,558**
TOTAL	**£3,255k**	**£5,510k**	**£5,530k**	**£515k**	**£14,809k**

Table 1: Summary of Costs for the Route Maps

Table 1 demonstrates a mix of funding sources; importantly emphasising industry investment accounting for over a third of the total £14.8M investment on a match funding basis. In addition to the Industry Match Funding there will be significant industry investment as part of DHN delivery (including for example certain demonstration activities identified in the route maps, with industry investments of many multiples of the £5.5M in Table 1), albeit this investment will be as part of a business case for each network.

Overarching Project Review

Part B of the report contains a technical review of the project using the critical success factors set out in the contract as the basis for the review. It was found that the project scored well against all these factors, for example:

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[1] Organisations current at time of publication of report e.g. Innovate UK becomes a part of UK Research & Innovation from April 2018 http://www.ukri.org/our-organisations/.

- A large number of solutions had been identified through successful collaboration with industry with sufficient innovation to achieve nearly 40% reduction in capital cost.
- The solutions were tested at a stakeholder event and a positive response obtained.
- The solutions had been assessed in detail taking account of not just capital cost but also operating costs and performance and ensuring that the customer value proposition has been maintained or enhanced.

Part B also considers the potential additional benefits that would arise if the solutions are combined. Reducing flow rates and pipe diameters (Route Map B) would be an advantage when implementing external pipe routes (Route Map C) as there will be less visual impact and would also enable greater use of trenchless technology (Route Map D). The use of trenchless technology will benefit from the improved front end design proposed (Route Map E). All of the route maps will benefit from improved knowledge management (Route Map A) as this will be the principal way in which new innovations will be promoted to the industry.

The final section of Part B demonstrates that the project has met the Primary Objective to identify and assess solutions that would make a significant step-change in cost of DH Networks. It also shows that the Purpose of the project to provide information to the ETI in 8 specific areas and the Required Outcomes have been achieved.

1 Introduction to this Deliverable

1.1 Introduction

This report is Deliverable EN2013_D04 “Solution Route Maps Report” of ETI’s Heat Infrastructure Development (HID) project and describes the findings from Stage 3 of the project. This project is being led by AECOM and supported by a team comprising Total Flow, ENGIE, Cowi and Loughborough University.

The background to this project is the need to develop cost effective ways for providing low carbon heat to buildings - by the year 2050 the UK will need to meet stringent targets requiring an 80% reduction in CO_2 emissions compared with 1990 levels, whilst still providing the end-user services that consumers require. The ETI has identified significant potential from district heating in terms of CO_2 and cost benefits. Although currently only 1-2% of UK buildings are connected to district heat networks (DHNs), analysis by the ETI indicates that close to half of existing UK heat demand could be economically connected to heat networks. A key barrier to wider uptake of district heating is seen to be the high initial capital investment for network installation. A high proportion of this capital cost is from the DH distribution system which for the purposes of this project is defined as being between: (a) on the supply side, the output terminals of generation and other heat source/recovery plant and (b) on the demand side, the output terminals of any Hydraulic Interface Units (including the HIUs themselves but excluding any consumer-side plant).

The primary objective of this project is to identify and then assess innovative solutions that would deliver a substantial step change reduction in the capital cost and contribute to overall lifecycle cost reduction of the DH distribution system. Whilst focussing on this primary objective, the project has also considered the value of the DHN system to relevant stakeholders and the possibilities for optimising value and business cases for stakeholders, even where this may result in a slightly smaller cost reduction.

The project is being delivered in three Stages and comprises seven Work Packages. These Stages and Work Packages are shown in Figure 3.

Stage 1 included understanding key stakeholder requirements for DHNs, an initial technical review of potential innovative solutions, an Excel-based model of current DHN costs and an analysis of the cost breakdown. This work is reported in Deliverables EN2013_D01 and EN2013_D02.

Stage 1 prioritised five challenges to take forward to Stage 2.

- Challenge 1 - System Design Architecture
- Challenge 2 - Civil Engineering CAPEX
- Challenge 3 - Pipes and Connections CAPEX
- Challenge 4 - Internal Connections CAPEX
- Challenge 5 - New Network Income

In addition, a set of evaluation criteria was developed to assess the solutions in Stage 2 and a solution template produced to capture this evaluation.

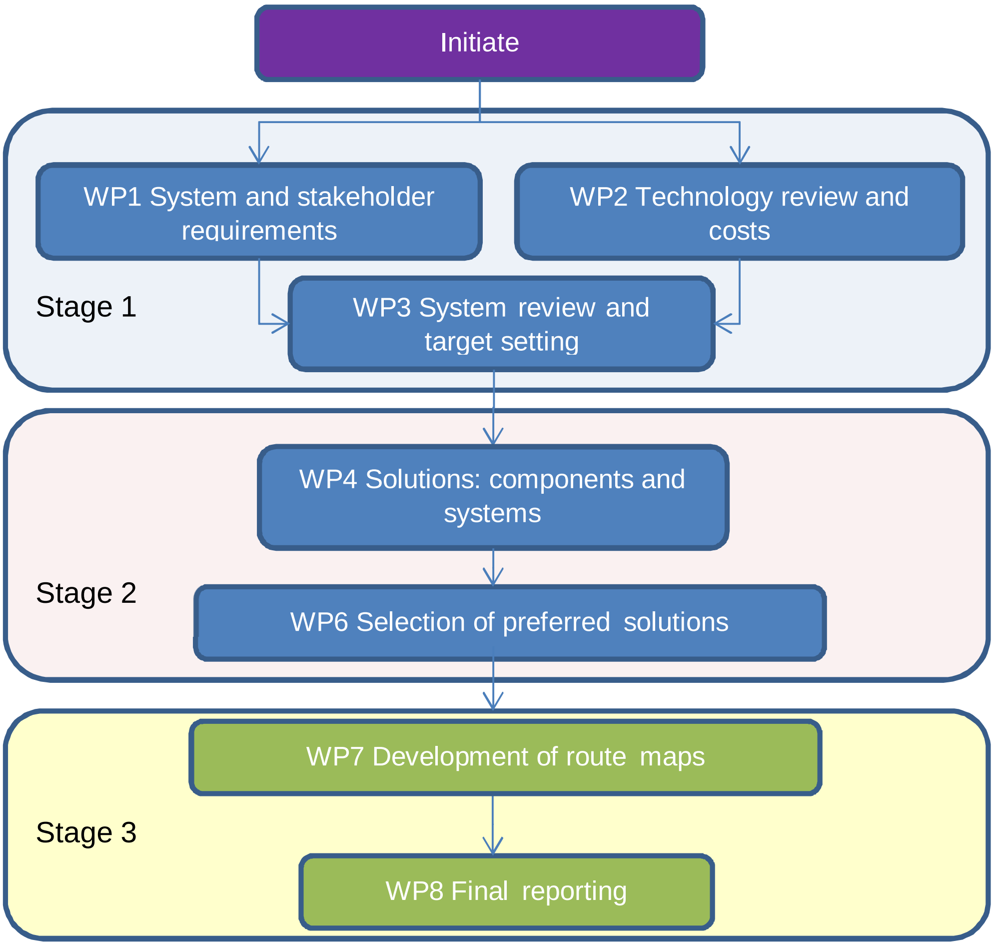


Figure 3: Overview of Stage and Work Packages [2]

Stage 2 initially identified, developed and evaluated innovative solutions within each of the five challenges, and then selected the most promising solutions (‘Green solutions’) for more detailed description and evaluation. These Green solutions are shown in Table 2. Overall, 13 Green solutions were identified which if applied together in the most optimum way across each building typology, it is estimated, could achieve a 32% reduction in DHN CAPEX, with an uncertainty range from 26% to 39%. It is estimated that the other solutions could generate up to an additional 6% DHN CAPEX saving. The greatest DHN CAPEX savings originate from those Green solutions which reduce the costs of either civil engineering or Heat Interface Units (HIUs), which were the two largest components of current DHN CAPEX as identified in Stage 1. This work is reported in detail in deliverable EN2013_D03.

[2] Work Package 4 is a combination of two Work Packages in the original project plan (Work Packages 4 and 5) which focussed on component/process and system-level solutions respectively. During Stage 1 it was agreed to combine Work Packages 4 and 5, with a single Work Package Lead, and an integrated approach to the development of solutions. It was also agreed to place less emphasis on developing alternative Value Propositions within this project.

Solution	Description
1. Knowledge Management, Research and Training	Formation of a District Heating Knowledge Centre (DHKC) to provide co-ordination and funding for knowledge management, research and training at a national level
2. Reduced Peak Demand and Peak Flow Rate	Reduce the pipe diameter and hence the cost of both the pipes and the associated civil engineering works through: · reducing the design peak demand through better estimation of peak load, the inclusion of a hot water priority system and better demand management · maximising Delta T through better balancing of radiators
3. District Heating Wall	Reduce the need for trench excavation which forms the major component of DHN CAPEX by running pipes along the external walls of houses
4. Loft Space / Cellar Route	Reduce the need for trench excavation which forms the major component of DHN CAPEX by running pipes either within the loft space or within cellars, passing through party walls as necessary
5. Trenchless Solutions	Adopt trenchless approach to excavation. In particular, adopt two components which have the potential for considerable cost savings · Horizontal Directional Drilling (HDD) for installing both the street and branch pipework · 'Core and Vac' excavation to provide a faster and less disruptive access to the street mains pipe to form branch connections than digging pits
6. Improved Front End Design and Planning	Improve civil engineering productivity through better upfront survey, design and planning prior to starting work on site. Additionally, adopt alternative contract framework(s) that minimises pricing of risk into the contract and encourages contractors to find ways to reduce cost.
7. Pipe Crossings	Alternative contractual framework to reduce the significant commercial liability that can be placed on the developer to utilise existing bridge structures to support the district heating pipes over a major crossing e.g. railway or canal. It is significantly cheaper to use existing infrastructure than the alternative of tunnelling.
8. Shared Civil Engineering Costs	DH developers collaborate with other utility providers and Local Authorities to combine and share the cost of street works
9. Direct HIU System & Existing DHW Storage	Combination of two ways to simplify the design and reduce the cost of the building's heating system · Direct Connection HIU: DH network water is circulated directly through the building's radiators. Saves the cost of a heat exchanger and associated equipment · Reuse of existing hot water cylinder: Cylinders retained where available. Avoids the cost of the hot

	water heat exchanger and associated control valve
10. HIU (1) Design for Manufacture and Assembly	Reduce the cost of the HIU through: · simplification and standardisation of components · reduction in parts count through common sub-assemblies and reduced duplication / redundancy · use of components that are quick and easy to install correctly to reduce labour time and joint failures
11. HIU (2) Further Simplification & Value Engineering at Scale	Builds on Solution 10 to further reduce the cost of the HIU by challenging existing specifications and identifying potential process cost benefits of production at scale. In particular, components have been identified as having potential for elimination or substitution as a result of · duplication of functionality – within the HIU or elsewhere in the system · over-engineering – refinements or additional functionality above the basic requirement · optional items which could be designed as chargeable upgrades; enabling users to make an informed choice whether to include in their specification.
12. HIU (3) Value Engineered Direct HIU & DHW Storage	This solution integrates the benefits from Solutions 9 to 11
13. Internal Connections – Pipework & Connections within the Property	Opportunities to eliminate excessive material waste and reduce labour requirements associated with installing internal connections with the building

Table 2: Summary of the Green Solutions

It was agreed that 11 of the 13 Green solutions should be taken forward for route mapping in Stage 3. The Green solutions and the route maps are shown in Figure 4. Two of the Green solutions (numbers 7 and 13) were not taken forward due to the relatively small DHN CAPEX saving and/or due to the limited additional benefit which a route map was likely to provide for these specific solutions. Two of the route maps comprise multiple solutions as the individual solutions are closely linked, which results in a total of 8 route maps.

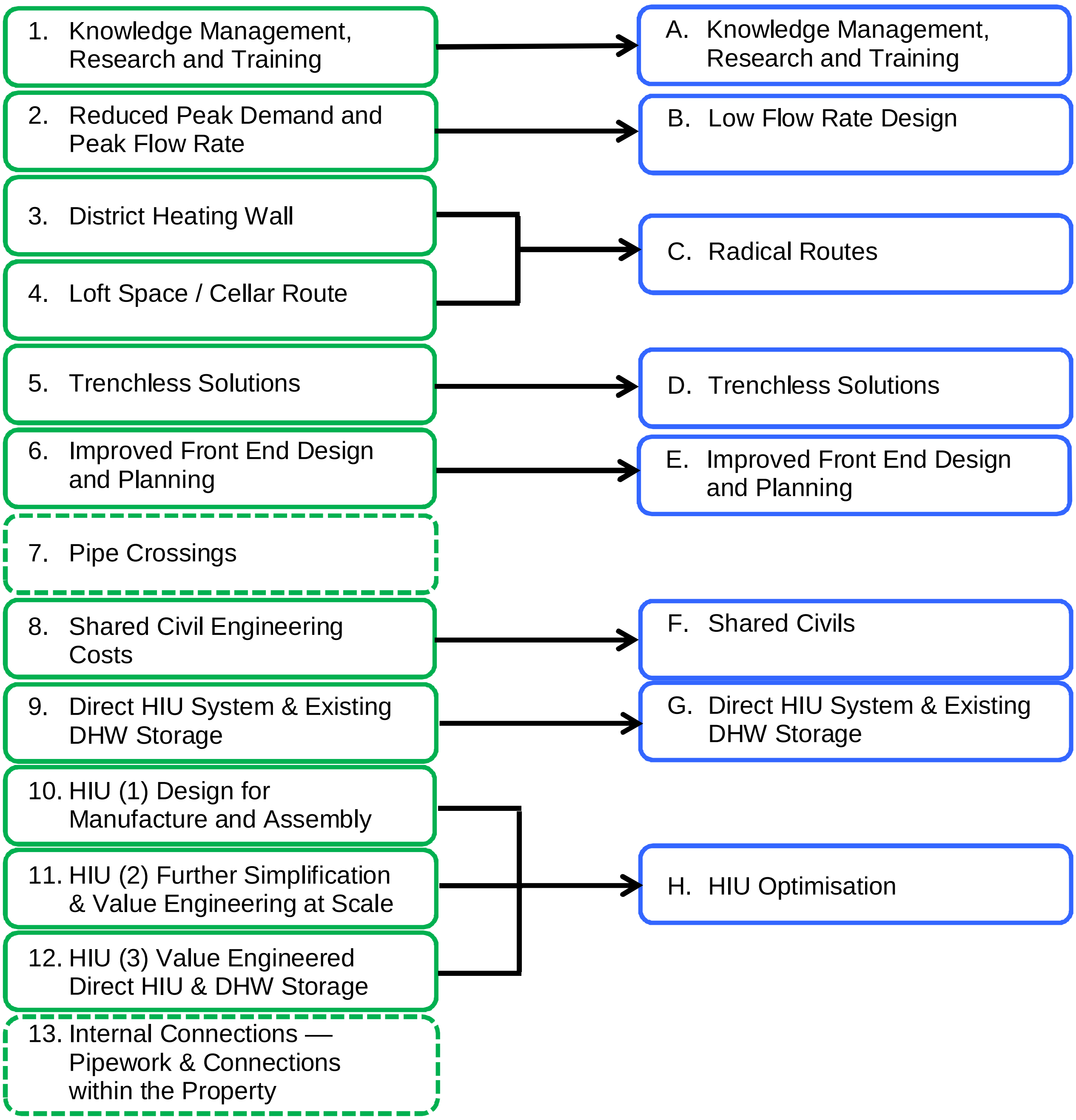


Figure 4: ‘Green’ solutions and route maps

Stage 3 is the final part of this project.

- This Deliverable EN2013_D04 presents the findings from Work Package 7. Its objective is to develop the 8 route maps which describe the work required to bring the 11 Green solutions from their current state to commercial deployment. It also presents an overarching review of the project including the process undertaken, the potential for combination of solutions and success against the project objectives.
- Deliverable EN2015_D05 comprises the output from Work Package 8 and summarises the findings from across the whole project.

1.2 Outline of report content

Part A of the report presents the 8 route maps.

- Section 2 provides a summary of the process undertaken to develop the route maps.
- Section 3 presents a high-level overview of all of the route maps, including identification of dependencies and interactions between individual route maps.
- Sections 4 to 11 present the individual route maps.

Part B of the report presents the overarching review of the project.

The report references five building typologies (Typologies A to E) that have been analysed as part of this project. These typologies are detailed in Appendix A.

Part A – Route Maps

2 Methodology

2.1 Introduction

The project team developed the route maps through first identifying and then scoping the activities to take each solution to commercial deployment. The activities were identified from an analysis of the barriers and risks to deployment, and technical and commercial development requirements. The scope of each activity was then defined and the necessary timescale and investment estimated. This work drew on the breadth of expertise within the project team, and significant engagement with specialists from Government, academia and industry to help both scope the route map activities and ensure that the delivery requirements were realistic based on their knowledge and experience.

Each route map adopts a common template:

- A description of the challenge and proposed solution
- An assessment of barriers and impediments to development and deployment
- Identification of the technical and commercial developments required
- Proposals for research, development and/or pilot or demonstration projects to take the solution to market deployment

Two frameworks were used to aid analysis and achieve consistency across the route maps. The first helped identify the commercial activities necessary for the different solutions and the second helped identify the sources of funding needed for the activities to take the solutions to market deployment. These are described below in Sections 2.2 and 2.3 respectively.

2.2 Commercial activities in the route maps

Each route map describes the commercial (non-technical) activities needed to take the solution from its current state to commercial deployment. The focus is on activities specific to the solution rather than generic activities such as marketing and advertising. Some examples include focussed market research and activities to build confidence in the solution.

A crucial aspect of building confidence is to encourage manufacturers and other suppliers to invest commercially in new technology and standardised solutions. A significant part of achieving this is to generate momentum in Heat Network developments through:

- Innovate UK funding and collaboration opportunities.
- Consistent and well-publicised policy supporting DHNs.

As part of project stakeholder engagement activities and workshops there have been a number of instances of organisations recognising new potential for collaboration and commercial opportunities for their products or services in DHN delivery. This applies to trenchless technology and HIU development in particular. It is encouraging that this has occurred without funding and bodes well for collaborative route map deployment activities described in the route maps that follow.

The Ansoff Matrix has been used to help identify the commercial activities. It is an established business analysis technique that can help an organisation devise strategies for growth and to consider the implications of growing the business through new products and into new markets.

Four alternative growth strategies are identified in the Ansoff Matrix (see Figure 5) and are described below:

1. Market penetration: a strategy to increase sales without departing from the original product-market strategy. This involves increasing sales to existing customers and finding new customers for existing products
2. Market development: a strategy to sell existing products to new markets (normally with some modifications).
3. Product development: a strategy to sell new products, with new or altered features, to existing markets.
4. Diversification: a strategy to develop new products for new markets.

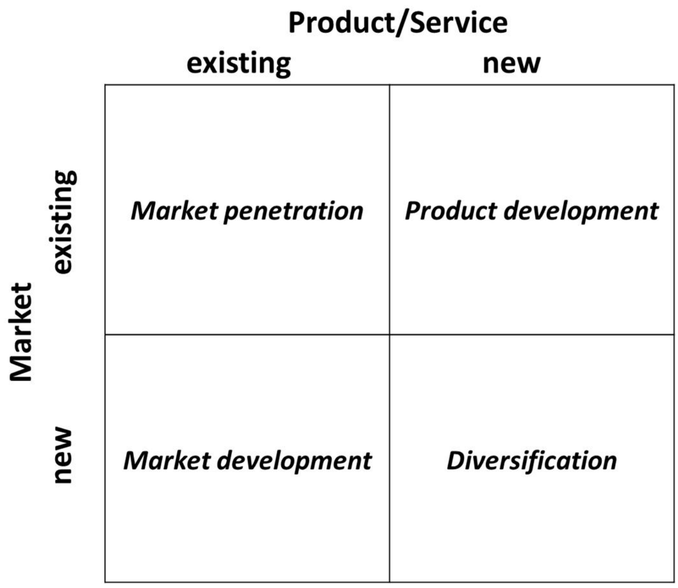


Figure 5: The Ansoff Matrix

The Ansoff Matrix has provided a common framework for the identification of commercial barriers and activities in developing each route map. The following process steps were followed for each route map:

1. Consider the position of the organisation, or group of organisations, who would be commercialising the solution. Ask:
    a. Is it a new or existing product/service?
    b. Is it a new or existing market?
2. Position each solution in the appropriate quadrant (see Table 3 and Figure 6).
3. Identify and document required commercialisation activities specific to each route map using the example activities in Table 4 to stimulate thinking.

Route map	Commercialising Organisation	Product/service	Market
Route Map A: Knowledge Management, Research and Training	Organisation responsible for sharing DH knowledge	Knowledge provision is a new product (service)	Existing market of DH designers and developers
Route Map B: Low Flow Rate Design	Companies developing optimisation software	New product needed to optimise performance	DH will be a new market for software developers
Route Map C: Radical Routes	Manufacturers developing products and solutions for radical routes	New products and solutions needed	DH will be a new market for these products
Route Map D: Trenchless solutions	Companies supplying trenchless equipment	Existing products already feasible for DH projects (but can be improved)	DH will be a new market for these products
Route Map E: Improved Front End Design and Planning	Designers and developers planning DH projects	New approach to designing and planning projects	Designers and developers already working in DH market
Route Map F: Shared Civils	Local authority (although in future utilities may develop joint ventures at scale)	New service of integrated street works planning	New market with DH developers working in consortium with other utility companies
Route Map G: Direct HIU System & Existing DHW Storage	Organisation responsible for promoting DH uptake and DHN developers.	Existing products	New retrofit market of appealing to developers and designers
Route Map H: HIU Optimisation	HIU manufacturing company	Existing product needing improvement. Options for new concepts in this route map.	New retrofit market of appealing to developers and designers

Table 3: Analysis of each solution using the Ansoff Matrix
(Note that the details are explained and elaborated in each of the route maps set out in subsequent sections of this report.)

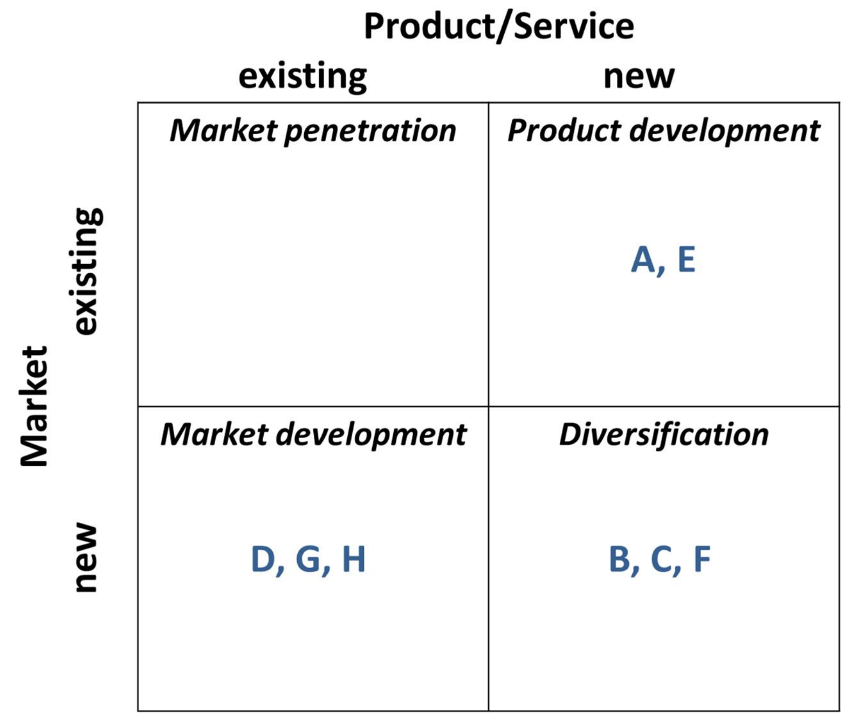


Figure 6: Route map commercialisation strategies

Quadrant	Example activities
Market penetration	· Advertising to promote the product or reposition the brand · Special promotions and/or customer loyalty schemes · Improving the quality or size of the sales force · Modifying the products or product packaging to broaden their appeal · Changing product pricing
Product development	· Developing new products through R&D and innovation · Acquiring a competitor, forming a joint venture or strategic alliance with a complementary firm · Licensing new technologies · Extending an existing product by producing different versions
Market development	· Market research to determine which segments are worth pursuing · Developing value propositions and strategies to penetrate the new market · Marketing products in new locations to expand regionally, nationally or internationally · Advertising through different media to reach different customers · Utilising new distribution channels to reach new market segments · Modifying the pricing policy, products or product packaging to appeal to different customer demographics
Diversification	· Simultaneous adoption of some of the activities suggested above for Market Development and Product Development · Acquisition of new skills and knowledge · Acquisition of new resources including new technologies and facilities

Table 4: Examples activities for each quadrant of Ansoff Matrix
(adapted from: http://www.spencertom.com/2013/10/09/ansoff-matrix/#.WSWNToWcFYc)

2.3 Funding sources

Each route map is likely to require several sources of funding as summarised in Table 1 above. Each route map comprises multiple activities and the source of funding will depend on the nature of each activity.

(Certain sources may change over time, particularly those from the public sector which are typically subject to governmental reorganisation; these recommendations therefore relate to specific organisations which are correct at the time of publishing of this report).

Nature of route map activity	TRL Level	Funding Source	Comments
Fundamental technical research Market research Dissemination Training	1-3	HNDU	HNDU are being proposed as the lead organisation in Route Map A: Knowledge Management, Research and Training and as the holder of funds to support a District Heating Knowledge Centre (DHKC). The role of the DHKC will be to: (i) fund research, (ii) disseminate knowledge and best practice, and (iii) identify and commission training providers. If Route Map A: Knowledge Management, Research and Training is not taken forward, such activities would still require central Government investment. Note that the market research costs include incentives for participant participation.
Product or Service Development Prototype and pilot activities to test solutions	3-7	Innovate UK	This funding stream reduces the risk of DHN technical development for both large and small organisations. It will typically require 30%-60% matched funding from the applicant, depending on their size.
Product or Service Development Pilot activities to construct and test solution	3-7	DHN Industry and supply chain	This is linked to the Innovate UK finding above, where the proportion of match funding depends on the risk / TRL level of the proposed innovation and the scale of the organisation. In the route maps a standard 50% is proposed for simplicity.
Demonstration Projects	8-9	Strategic Energy Funding (SEF)	For data gathering and assessment of DHN demonstration projects; funding is required to ensure insight is made public. There is merit in differentiating such funding from HNDU investment described in TRL 1-3 above. Throughout this report, Strategic Energy Funding (SEF) funding refers to marginal investment in demonstration projects and dissemination, above the DHN business case; (thus typically the DHN design and build incorporating innovative features would be funded by industry, and the marginal scope for monitoring, dissemination, etc might

			require SEF). Over the last decade, the ETI has provided leadership, systems thinking and a source of such funding. It is unclear how such strategic energy investments will be funded in future.

Table 5: Funding sources for route map activities

The DH industry and its supply chain are key sources of funding. Industry will be willing to invest in new product and service offerings where there is a clear market opportunity. However, particularly given the novel nature of some of the work and the uncertainty in the size of the future DH market, it is expected that additional sources of funding will be required to deliver each route map.

The intention is for demonstration projects, where possible, to be self-funding as they will have a long-term income stream. However, there is likely to be gap funding required to carry out activities which are specific to a demonstration project such as monitoring and customer engagement.

The principal funding sources in Table 5 do not include research councils. Given the applied nature of the proposed research, feedback from academia is that it is unlikely that research councils, such as the Engineering and Physical Sciences Research Council (EPSRC), would be a key funding source.

The mix of funding is shown in Table 6. This illustrates a clear expectation that the route maps will encourage significant Industry investment, accounting for over a third of the total £14.8M investment on an Industry Match Funding basis. In addition to the Industry Match Funding there will be further industry investment as part of DHN delivery (including for example certain demonstration activities identified in the route maps, with industry investments of many multiples of the £5.5M in Table 6), albeit this investment will be as part of a business case for each network.

Route Map	BEIS-HNDU (£k)	Innovate UK (£k)	Industry Match Funded (£k)	Strategic Energy Funding (£k)	Total (£k)
A	2,135	-	-	-	**2,135**
B	172	-	20	141	**333**
C	187	120	120	15	**442**
D	40	1,600	1,600	70	**3,310**
E	194	-	-	55	**249**
F	271	-	-	95	**366**
G	97	90	90	139	**416**
H	158	3,700	3,700	-	**7,558**
TOTAL	**£3,255k**	**£5,510k**	**£5,530k**	**£515k**	**£14,809k**

Table 6: Summary of Costs for the Route Maps

Note that the costs in Table 6 include sums for project management, HSE management and data protection management etc.

Investment case for Government

The Government has set up the Heat Networks Investment Project to support district heating projects with capital grants. The pilot stage has already provided c£25m of grant funding with the total proposed funding of c£300m. It will be beneficial to the Government and each of the project sponsors if the projects supported through this programme are able to exploit the solutions identified by this ETI Heat Infrastructure Development project to reduce capital costs by c40%. There is therefore a strong case for Government to support the further development of the solutions as set out in the Route Maps, given that the total cost to Government of c£9m is only 3% of the proposed grant funding.

Investment profile

The route maps also propose timings and phasing to deliver the target outcomes with the bulk of the work anticipated within four years of launch. This is shown graphically in Figure 7.

The eight route maps are planned to run in parallel with minimal dependencies between them. There is benefit in launching in Q4 2017 linked to the Water Company regulatory programme (AMP) for Route Map F, but this is not crucial to success. As the figure shows there is a rapid build-up of investment in year 1, with the bulk of funding in years 2 and 3. The aspiration is that all DHN organisations and solutions will be self-funding by the end of year 4.

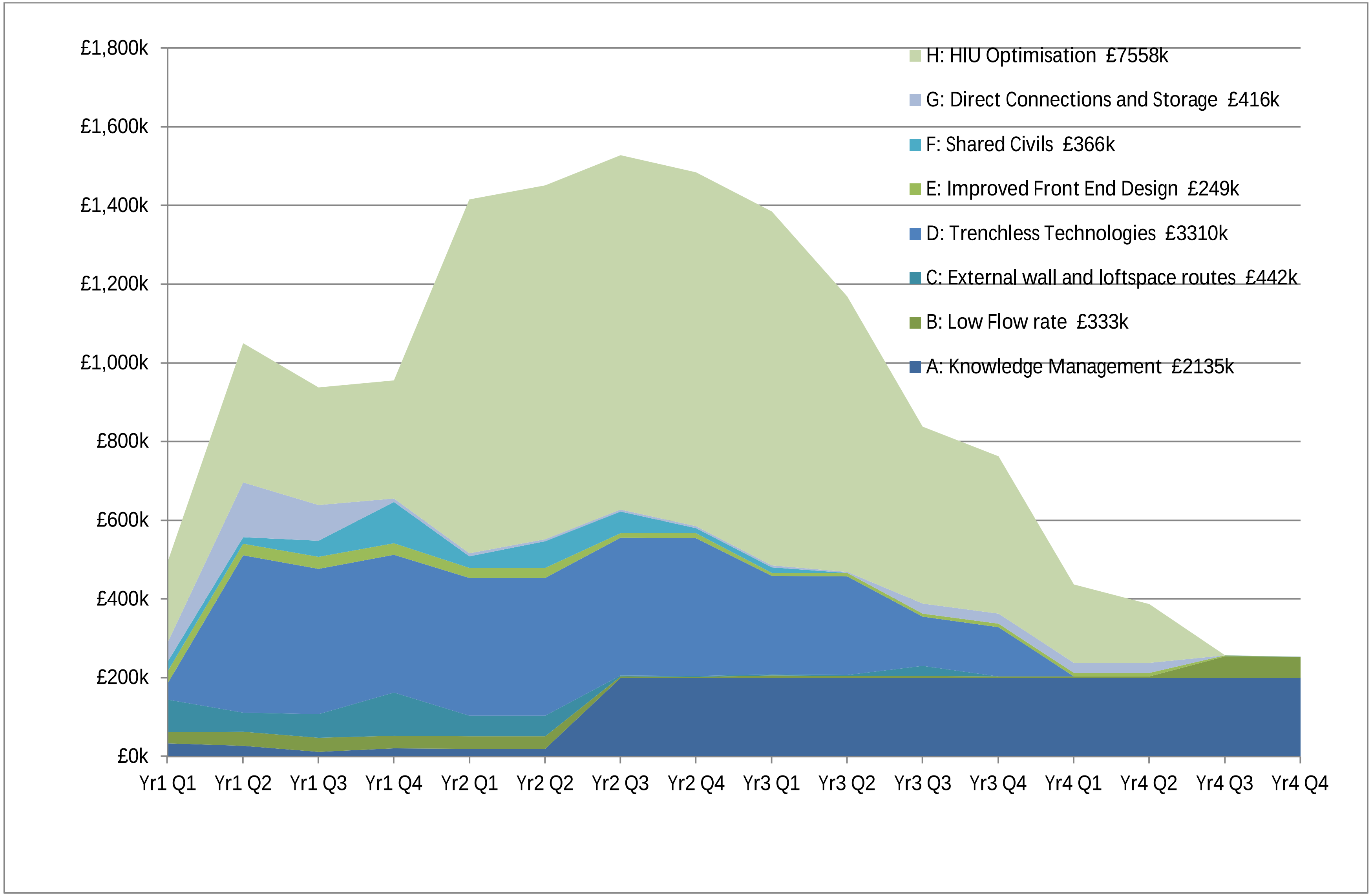


Figure 7: Investment Profile for Route Maps

3 Overarching Route Map

3.1 Introduction

Eight route maps have been prepared for the different solutions, as summarised in Figure 4. The route maps focus on activities specific to the solutions, rather than items such as generic marketing activities.

Figure 8 provides a top level overview of the route maps, showing how each Route Map applies to the different parts of the heat network and to different building typologies. In particular:

- Route Map A applies to all parts of the network
- Route Maps B to F apply to the transmission and distribution pipework and/or the civil engineering works
- Route Maps G to H apply to the HIUs (and heat storage) located within the buildings

An overview of the 8 route maps is shown in Figure 9. The activities in the route maps have each been classified into one of the following categories:

- Research
- Solution development
- Demonstration and associated activities to build consumer and DHN investor / developer confidence and raise awareness of the DHN solutions.
- Deployment at scale and industrialise

The solutions are expected to achieve commercial viability during the deployment at scale and industrialise stage of each route map, as organisations build up their capability to deliver. For example, the demonstration activities are intended to demonstrate and provide confidence in a commercially ready solution. Precise timing is not predictable (being dependent on market demand) but equivalent new product and solution developments suggest that 1 – 3 years beyond successful demonstration is the likely range for Route Maps B – H. Route Map A is not a commercial activity.

Product or service development does not stop at the point of commercial deployment. This will continue, for example based on market feedback upon deployment and the identification of opportunities for further cost reduction and improvements to their value proposition. Hence it is important to monitor the market and performance of the products and service and use the feedback to improve the offer.

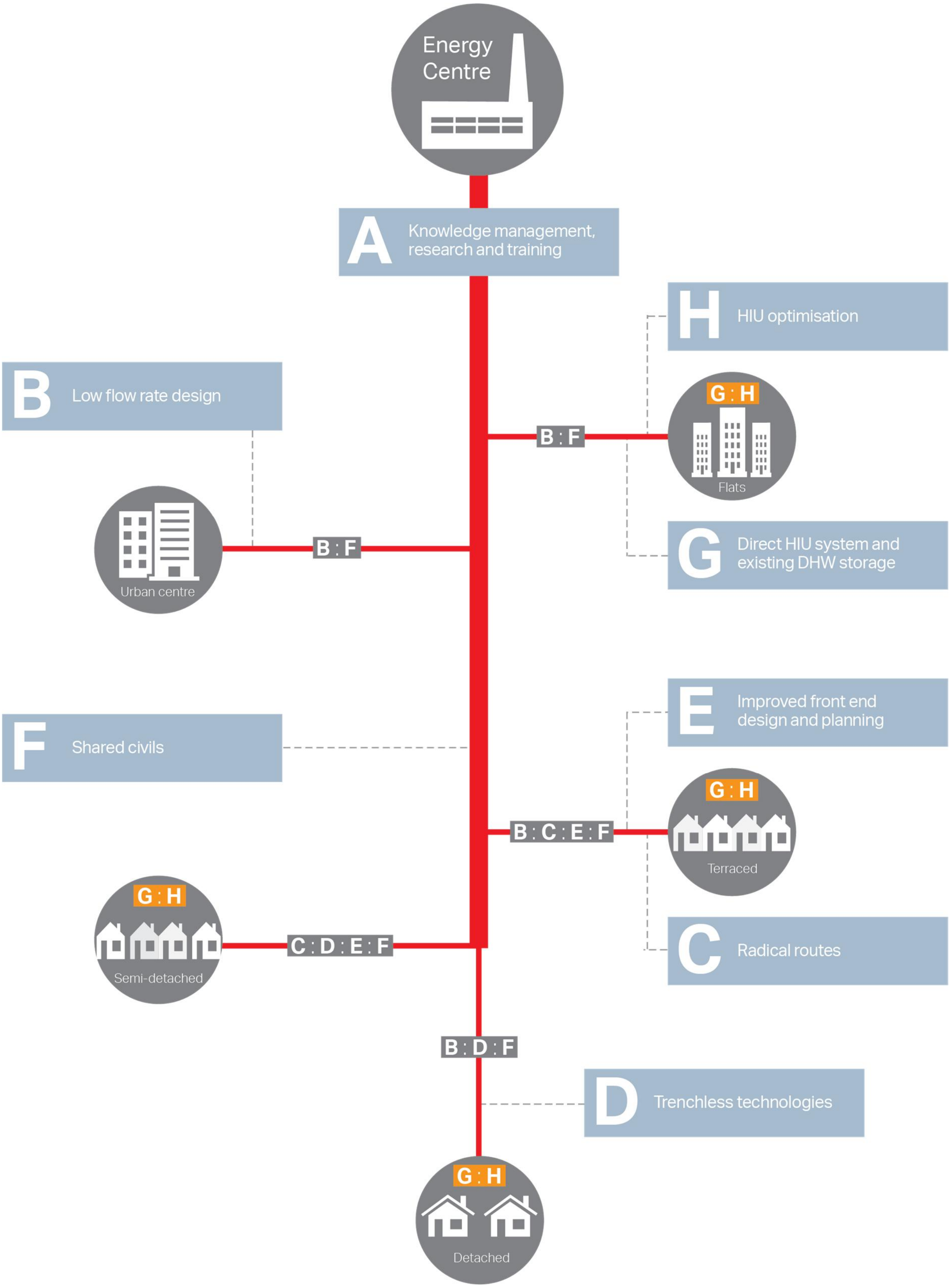


Figure 8: Top-Level Overview of Route Maps

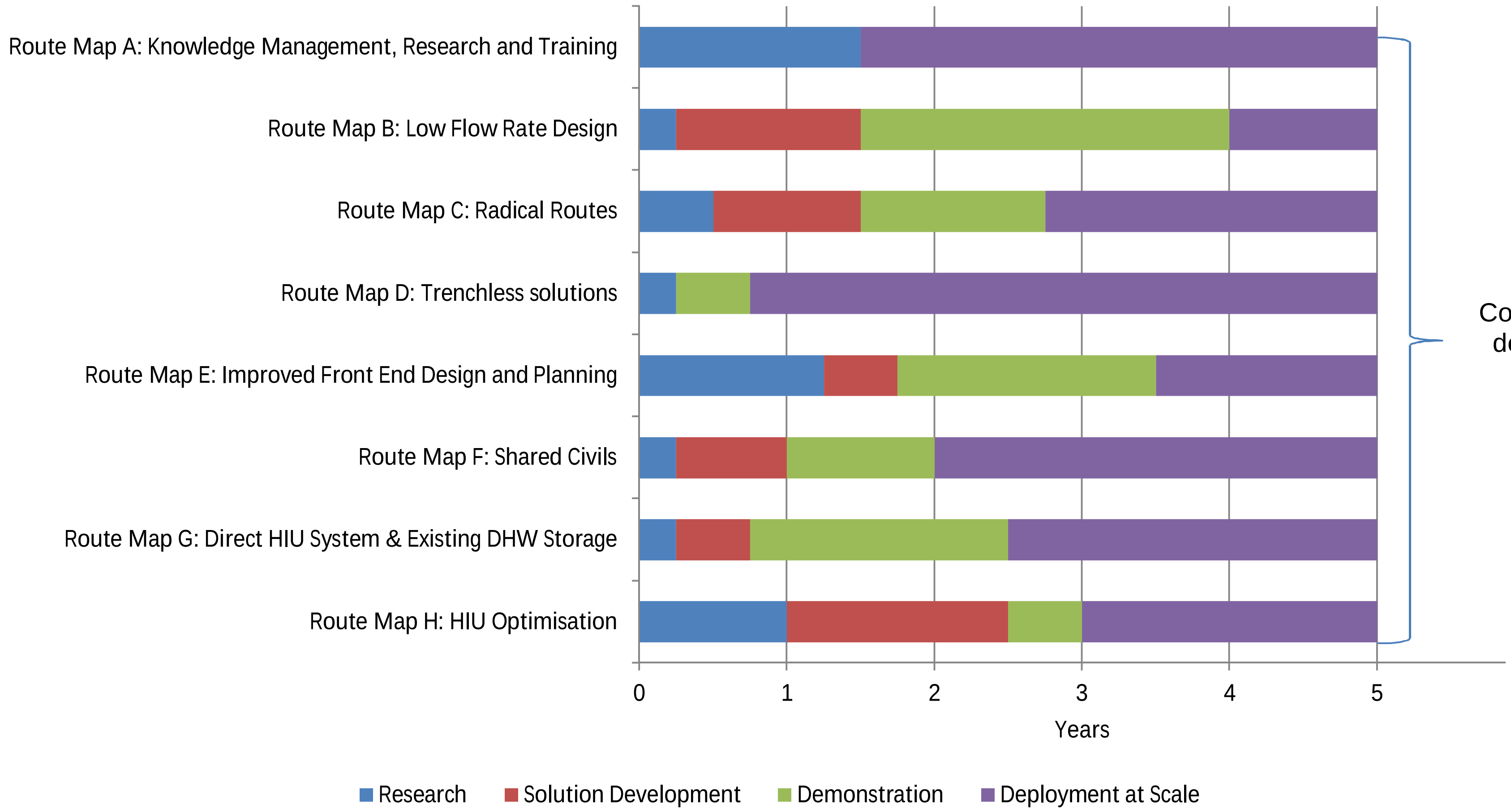


Figure 9: Overview of the timetable for activity categories within each route map

Not all route maps include all four components. In particular:

- Route Map A: Knowledge Management, Research and Training itself does not have a Demonstration phase, albeit it is integral to dissemination activities for other route maps.
- Route Map D: Trenchless Solutions does not have a Solution Development phase. The intention is an early demonstration phase to highlight the potential of trenchless approaches currently available. During the final phase, Deployment at Scale, there will be further development activities to make the solution more widely applicable and/or enhance the value of the solution further.

3.2 Synergies between Route Maps

There are two activities common across most route maps: market research and demonstration activities. If multiple route maps are progressed concurrently, there is a potential for cost reduction in combining activities if the timetables allow.
It is noted that in practice it may prove challenging to implement all, or multiple, projects simultaneously. None of the route maps are reliant on any of the others for their delivery and it may be better to progress independently if an opportunity is afforded.

Market Research

Market research work has been proposed for many route maps as summarised in Table 7. Where the target of the research is the same, the costs should be able to be reduced. This is the case here with the activities commonly focussing on either the end-users (owner occupiers, landlords and tenants) or the DH developers and designers.

The market research activities are proposed towards the start of each route map. Hence, in general, there is greater opportunity to combine activities if the route maps are commenced together.

It is difficult to quantify exactly the cost savings if market research activities were combined across route maps. It is suggested that there would be a 10% to 20% cost reduction from combining market research work with DH developers/designers and 30% to 40% cost reduction from combining market research work with end customers. The difference reflects the greater costs associated with engaging with customers and thus the greater cost savings of combining activities.

Route Map	Target of the market research activities	Planned work
Route Map B: Low Flow Rate Design	DH developers and designers	Understand attitudes to changing to the proposed solution and suggestions to overcome any drawbacks
Route Map C: Radical Routes	End users (e.g. owner occupiers, landlords and tenants)	Understand attitudes to the proposed solution and suggestions to overcome any drawbacks
Route Map D: Trenchless Solutions	DH developers	Research understanding of and attitudes to trenchless solutions
Route Map G: Direct connection and retention	End users	Understand user preferences for space heating and hot water systems

of existing cylinders	DH developers and designers	Understand attitudes to changing to the proposed solution and suggestions to overcome any drawbacks
Route Map H: HIU Optimisation	DH developers and designers	Understand the underpinning technical requirements of individual HIU units
	End users and network operators	Understand user preferences for space heating and hot water systems

Table 7: Market research activities in the route maps

Demonstration Projects

Demonstration projects have been proposed for a number of the Route Maps, summarised in Table 8. In particular, there could be value in having a combined demonstration project covering Route Maps B to E. Route Map B will result in smaller pipe diameters which will mean less visual impact for the external wall route for Route Map C and more use of trenchless technology in Route Map D. The level of disruption and visual impact at a street level between the use of a conventional design, trenchless technology and above ground routes would best be established through a combined demonstration project where all three solutions can be implemented in the same area. As Route Map E is principally concerned with civils work, it would be sensible to include it in the combined demonstration project, and in particular the greater upfront surveying would be of benefit when deploying trenchless technology in Route Map D.

Route Map	Demonstration project proposed
Route Map B: Low Flow Rate Design	To show how low flow rate design can result in smaller pipes, to prove processes for survey and calculation
Route Map C: Radical Routes	To show external wall and loft space routes in a range of properties
Route Map D: Trenchless Solutions	To show trenchless solutions in different applications – probably street mains in suburban environment, branch connections to low density housing
Route Map E: Improved Front End Design and Planning	To show cost savings from both better upfront survey and design and application of alternative contractual framework
Route Map F: Shared Civils	To show joint commissioning of the work between the DHN developer, another utility company and the local authority
Route Map G: Direct connection and retention of existing cylinders	To show the benefits of the use of direct connection and retaining cylinders
Route Map H: HIU Optimisation	No specific demonstration proposed, but individual or multiple units will be tested as part of existing DHN deployment, or linked with other demonstration projects

Table 8: Demonstration activities in the route maps

It is likely to be more challenging to integrate multiple solutions into a single demonstration project.

- The DH developer will need to be happy to undertake multiple trials
- A greater mix of stakeholders would need buy-in representing the different interests of the various solutions
- It will logistically be more complex to co-ordinate

Reviewing Figure 9, most of the civil engineering route maps intend to undertake their demonstration project at a similar point in their timetable. Hence, if the route maps are commenced together, the demonstration projects should align. The most significant difference is Route Map D where the intention is to undertake a demonstration project early to highlight current capability. If this route map is integrated with others, it may be necessary to delay Route Map D demonstration activities by around one year. Alternatively, if the DH scheme is sufficiently large, it may be possible to demonstrate Route Map D in an earlier phase of the project without impacting on its timeline.

It is estimated that there would be a 20-30% cost saving if these four demonstration projects can be combined. The resources required for much of the work content will remain the same. However, the set-up and stakeholder engagement activities, for example, can be shared across projects.

3.3 Dependencies between Route Maps

None of the route maps are reliant on any of the others for their delivery. However, in some cases, the commercial deployment of one solution will reduce the cost and/or improve the value of another solution.

- Route Map A: Knowledge Management, Research and Training supports all of the other route maps. In particular, the role of the District Heating Knowledge Centre (DHKC) is to fund some of the research identified in other route maps, disseminate the knowledge and best practice gained and support industry training. It is expected that without this route map, all others will be less effective in terms of both their scale of deployment and the resultant cost savings where they are employed.
- Route Map B: Low Flow Rate Design will result in smaller diameter pipework which will aid other solutions. It will assist in minimising visual impact especially for the external wall route in Route Map C: Radical Routes. It is also advantageous for Route Map D: Trenchless Solutions as there is currently a size limit for horizontal directional drilling which means that a trenchless approach could be applied more widely if smaller pipes are used.
- Where cylinders are retained in Route Map G: Direct HIU System and Existing DHW Storage, the branch pipe to the dwelling can be smaller and this will also assist the external wall solution option in Route Map C: Radical Routes and Route Map D: Trenchless Solutions.
- One of the constraints on using trenchless technology is the level of confidence on knowledge of existing buried services, so there is a link here to Route Map E: Improved Front End Design and Planning.
- There is a link between Route Map G: Direct HIU System and Existing DHW Storage which develops the HIU design for direct connection and retaining existing cylinders at a system design level and Route Map H: HIU Optimisation which aims to reduce the costs of HIUs through better design at a detailed manufacturing level.

3.4 Safety and reliability of solutions

It is not envisaged that any solution will negatively impact on the safety or reliability of the DH Network. Furthermore, safety and reliability assessments are inherent in the product development in the individual Route Maps.

Indeed, it is expected that the solutions should result in some significant benefits. For example:

- Route Map A: Knowledge Management, Research and Training should improve practice and thus improve safety and the quality of delivery
- Route Map B: Low Flow Rate Design should result in smaller diameter pipes and less civil engineering work being required
- Route Map F: Shared Civils will result in only one trench needing to be excavated rather than multiple trenches
- Route Map H: HIU Optimisation should simplify the HIU and standardise the process, and thus improve product reliability

4 Route Map A: Knowledge Management, Research and Training

Route Map Summary
Cost savings could be achieved if standards of design, construction and operation were improved. A key enabling solution was developed to encompass knowledge management, research and training and with the proposal to develop a new industry initiative, now termed the District Heating Knowledge Centre (DHKC), to co-ordinate activities at a national level. It is proposed that the DHKC would be funded by BEIS/HNDU and consist of a Management Board with representatives from the organisations most closely involved in the industry (HNDU, ADE, UKDEA, CIBSE and BESA) and a Delivery Partner who would manage the delivery of individual work packages – such as a research contract, a guidance publication or a training programme. This arrangement is the output from Stage 3 of the ETI project following limited stakeholder engagement. A further stage of research and consultation is proposed to maximise buy-in from all parts of the industry and an alternative structure may result. This route map sets out the activities required to set up the DHKC and deliver its initial work plan which are: 1. Research into models of knowledge management in similar industries 2. Consultation with industry representative organisations 3. Set-up of DHKC governance structure and obtain funding 4. Selection of Delivery Partner 5. Definition of initial work plan 6. Management of individual work packages to completion by Delivery Partner The total cost of the route map is estimated at £2,135,000. The majority of this is the delivery of the work plan estimated at £2m over two years with the balance being the cost for setting up the DHKC and selecting a Delivery Partner. Funding is proposed to be from BEIS/HNDU for the initial years. As the industry grows it would be possible for industry to provide more of the funding through an industry-wide voluntary levy that could be collected from DH heat suppliers above a certain threshold based on the amount of heat sold in a year so that a predictable annual fund can be relied upon for future activities. At present, the industry is small and would not be sufficiently confident in the outcomes of the DHKC to provide the funding. Hence the initial funding from Government is seen as necessary. The programme allows for 18 months to plan and set-up the DHKC, followed by an expected 2 - 5 years of contracted work with the Delivery Partner. This route map is considered an essential enabler for the other route maps as it will provide the main way in which new approaches delivering lower costs can be rapidly disseminated to the industry.

Solution Description

Current challenge

One key reason identified in stakeholder discussions for higher costs in the UK compared to those on the continent was a lack of embedded knowledge on how to design and construct heat networks cost-effectively. There are three key aspects to this:

- ***Knowledge management:*** There is a lack of co-ordination of expert knowledge and the potential for confusion and overlap. Many guidance documents exist but it is unclear what represents the most authoritative guidance on different issues especially where there is conflicting advice. DH developers may be reluctant to share knowledge as it is commercially valuable or they may not have the time and resources to commit to the knowledge sharing process. Further details of the current knowledge management activities and the key players are given in Annex 2.
- ***Research:*** Applied research is required both to provide better information that will assist designers and to monitor and learn from successful and non-successful schemes. At present, there is no central co-ordination of DH research work in the UK to focus on the priority research questions and ensure sufficient collaboration. There is also limited review of the more extensive research work being carried out internationally and integrating relevant findings into UK practice. Due to a lack of data from research programmes, opinions on optimal solutions vary and consensus is difficult to achieve as the facts are not well established.
- ***Training:*** The DH industry requires skilled people at all levels from a wide range of engineering sectors to make DH schemes cost-effective and efficient and this will be difficult to achieve for a rapidly expanding industry without a co-ordinated training programme and established qualifications which are not currently in place. Limited training programmes are available in district heating in sufficient depth, as at present it is seen as too specialised. The value of an authoritative guide is limited unless practitioners are trained to understand and apply the guidance. To improve quality standards in the DH industry it may be necessary to introduce regulations requiring certification of designers, installers or equipment similar to that found in the domestic renewable energy field (the Microgeneration Certification Scheme) and the associated training programme would then be essential especially for new entrants to the industry.

Although there are significant challenges there are also several activities which can be built on. Some examples of recent and ongoing work by various organisations are given in Annex 2.

Proposed Solution

A **District Heating Knowledge Centre** would be formed to provide co-ordination and funding for knowledge management, research and training at a national level. Specific objectives of this body would include:

- Identifying gaps in knowledge and either commissioning research or liaising with other funding bodies to ensure these gaps are filled
- Commissioning work to gather data on the operation of schemes, assessing their performance and publishing results
- Preparing case studies on innovative projects that reduce costs and/or improve performance to disseminate good practice (including for the other solutions identified in this ETI project)
- Monitoring research work being carried out internationally and ensuring this is

disseminated in the UK where appropriate
- Reviewing the various standards, codes of practice and guidance documents that are available and by working with the sponsors of the documents enabling regular updating and ensuring as far as possible that they are consistent with each other and can be relied on by practitioners as authoritative sources
- Commissioning additional guidance or other documents as may be required and ensuring these are reviewed appropriately
- Setting up a comprehensive training programme to upskill the expanding workforce at all levels from technician to Masters students with recognised qualifications specific to DH
- Liaising with the Government to establish how this work can inform regulations or be used by regulations to provide higher quality DH schemes to benefit consumers and the UK as a whole

It is expected that in the early years at least the majority of the work (c70%) will be associated with consolidating existing knowledge and disseminating this through publications and training programmes. This will result in an overall improvement to a good practice level consistent with the baseline costs in the project cost model. The remaining effort will be devoted to research, innovations and delivering best practice as well as promoting the solutions identified in the other Route Maps.

The overall aim of this solution is to establish a continuous quality improvement process where projects are evaluated and improvements identified, research carried out to develop new techniques, and designers informed and trained so that the next project is more successful (see Figure 10).

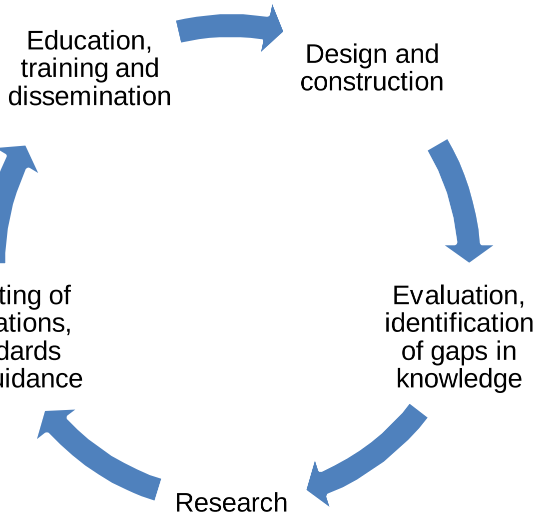


Figure 10: Continuous improvement process

The key benefits that would flow from this solution are:

- Reduced CAPEX costs to compete better with alternative low carbon options and so achieve a larger share of the market which will benefit the UK as a whole
- Improved reliability and operational efficiency to reduce OPEX costs
- Lower levels of risk for construction and operation enabling greater investment
- Potential customers will have confidence that their DH system will be well executed and reliable with minimum disruption

- New, innovative, lower cost solutions will be evaluated and disseminated to the industry rapidly (including the other solutions identified in this ETI project)

Specific examples of the potential benefits include:

- CAPEX cost reduction from:
  - Avoidance of oversizing due to uncertainty in peak demands needed and diversity factors
  - Avoidance of over-specifying e.g. incorporating unnecessary equipment
  - Rapid dissemination of best practice
  - Promotion of innovation
  - Dissemination of other solutions which have been identified through this ETI project

- OPEX cost reduction from:
  - Lower heat losses
  - Lower pumping energy
  - Improved quality of installation resulting in less work correcting faults
  - Design to reduce maintenance requirements

- Lower risk:
  - Better design and installation will also reduce risks of overrun of cost and programme and residual technical risk on performance. At present, additional costs will be added to a scheme to reduce risks which may be unnecessary as often there is insufficient understanding of the causes and likelihood of different risks.

- Quality of service:
  - Customers will expect a high quality of service. But without new research it will be unclear what constitutes good quality for the DH supply to existing owner occupier properties as this market is largely untapped. It is likely that service levels will need to be higher than for other utilities to counteract the natural monopoly position of a DH supply. The ability to demonstrate that the costs of heat supply to customers by DH is lower than the best alternative is also critical to grow the market.

Further detail on some specific benefits that could flow from the solution is provided in Annex 3.

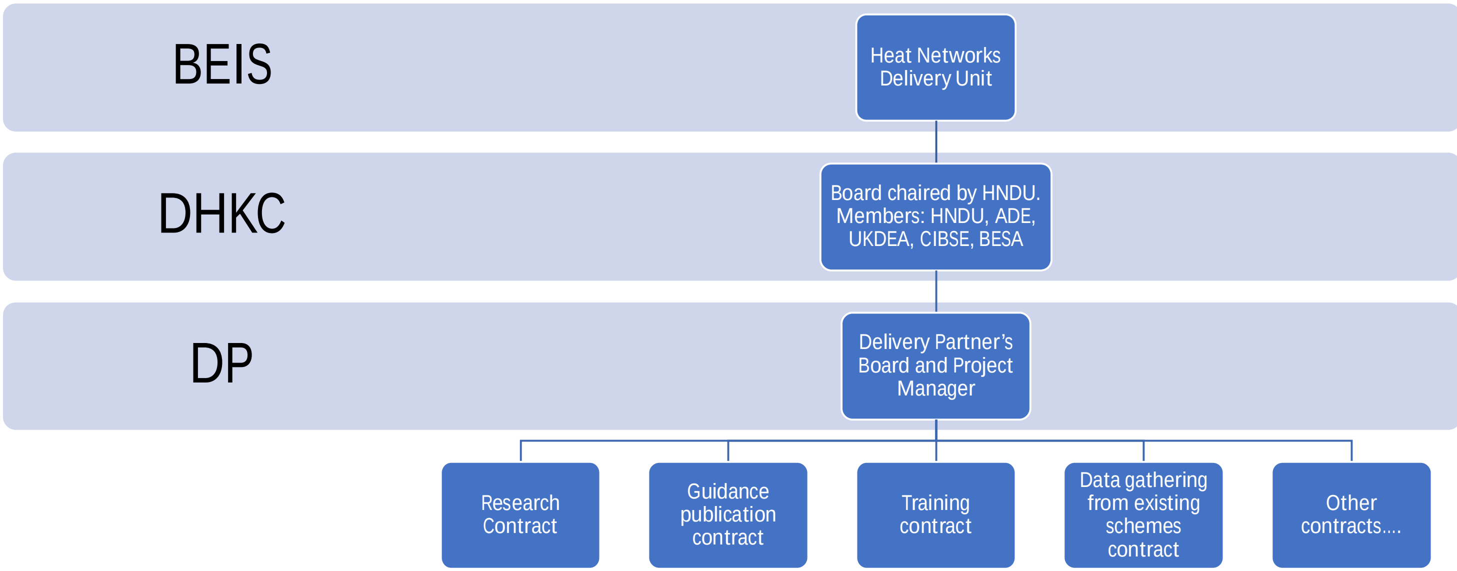
Structure and Funding of the Solution

During the development of this route map telephone discussions were held with a number of organisations active in the field to review options for the proposed DH Knowledge Centre (DHKC) (see Annex 4). This has informed the proposal below.

It is proposed that the Heat Networks Delivery Unit (HNDU) within BEIS will provide the initial funding for the project and the overall leadership, at least for the first year. As the industry grows it would be possible for industry to provide more of the funding through an industry-wide voluntary levy that could be collected from DH heat suppliers above a certain threshold based on the amount of heat sold in a year so that a predictable annual fund can be relied upon for future activities. At present, the industry is small and would not be sufficiently confident in the outcomes of the DHKC to provide the funding. Hence the initial funding from Government is seen as necessary. Industry would be more willing to contribute to the work of the DHKC when it has been established and it is clear that its work will result in lower costs and improvements in quality standards leading to growth in the DH market. It is envisaged that a budget of £1m p.a. will be needed in the first few years with the budget increasing as the market expands.

The DHKC will be governed by a Board with representatives from ADE, UKDEA, CIBSE and BESA as these are the organisations most actively involved and who recognise their responsibility to raise standards. Representatives will be funded for their time on the Board, which recognises a significant level of commitment. The Board will be chaired by a member of HNDU. The Board will set the direction and priorities for the work of the DHKC. Given the range of work involved, the Board will then contract with a Delivery Partner (DP) who would be responsible for delivering the work of the DHKC, procuring individual packages of work as required, which may be from sub-contractors or from in-house resources, subject to market testing. The DP would receive funding from HNDU but also obtain separate funding for specific activities such as training courses, events and publications. Most information would be provided free on-line subject to a registration process including soft copies of publications - hard copies would be available for sale. Organisations who would be able to carry out this DP role include: BSRIA, CIRIA, Energy Systems Catapult, large consultancies or Universities (see Annex 2 for a list of these) and it is envisaged that a tender process would be arranged to provide value for money. A consortium could be formed (either formally or with a lead organisation and additional organisations subcontracted) to bid for this role.

The above structure is set out in Figure 11.



BEIS: Department of Business, Energy and Industrial Strategy

DHKC: District Heating Knowledge Centre

DP: Delivery Partner

Note: The Delivery Partner may also be responsible for undertaking the individual contracts for research, guidance documents, training etc using in-house resources

Figure 11: Structure of proposed District Heating Knowledge Centre

Current Barriers to and Requirements for Implementing Solution

Assessment of Barriers

Although the industry recognises the need for this solution, existing barriers limit progress. These include:

- The industry is currently relatively small which means limited resources to carry out knowledge sharing and research work
- There can be a lack of willingness to share knowledge with competitors as specialist knowledge is seen as high value (although this attitude is not universal)
- The large number of existing organisations with an interest in DH makes it more difficult to manage the process of knowledge management and risks overlap and conflicting information. It is unclear what constitutes the most authoritative guidance
- Some standards and research outputs developed elsewhere in Europe are not easily transferable either due to language barriers or the differing context for implementation of DH
- There are no regulations that require individuals to be qualified or undertake training programmes on either technical standards or operational aspects so no specific motivation to deliver training
- Research work is spread across a number of universities with limited collaboration and no co-ordinated programme
- There is a lack of a clear process to enable lessons learned and results of monitoring of schemes to be disseminated rapidly to the industry i.e. current knowledge could be described mainly as tacit (know-how held by individuals) and there is a need to translate this into explicit knowledge (guidance, standards and regulations)

Development Requirements

The development requirements are to set up a new structure within the industry which will be well supported by all parts of the industry. Further research into the ways in which other industries are addressing the knowledge management issue is required followed by a period for consultation with the organisations involved in the industry.

Commercialisation requirements

Analysis using the Ansoff matrix indicated that this solution is offering a new service to an existing market of DH developers and their design and construction supply chain. At present the existing market is small and there could be new entrants in the future. The commercialisation requirement is therefore one of product/service development.

Following the research and consultation work described under development requirements there will be four stages to the commercialisation:

- Set-up the DHKC governance structure and obtain funding
- Select a Delivery Partner (DP)
- Define workplan for the first phase
- DP procures individual work packages

This Route Map will support all the other Route Maps by acting as a route to disseminate knowledge of new solutions across the industry.

If the Government introduced new regulations, e.g. to strengthen consumer protection or to stimulate the market in certain ways, then the need for more specific training and qualifications may become apparent which would influence the solution. For example, if DH schemes could only qualify for a grant if they were designed by a professional with a certain qualification or if carbon emissions on which an incentive scheme was based could only be calculated by an approved person.

The industry could itself introduce additional requirements to improve the reputation of the industry e.g. granting a Quality Mark by meeting certain standards. This would also influence the development of any training programme.

Route Map Proposal

The activities identified requiring further work and validation for this route map are:

1. Research of knowledge management models in similar industries
2. Consultation with industry representative organisations
3. Set-up of DHKC governance structure and obtain funding
4. Definition of initial work plan
5. Selection of the Delivery Partner
6. Management of individual work packages to completion by Delivery Partner

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. See Annex 1 to this route map.

Funding

The external funding of Activities 1-5 is estimated at £135,000 which is proposed to be funded by BEIS-HNDU directly. The cost to deliver the work programme itself (Activity 6) is estimated at £2m over 2 years. This can be compared to the aspiration of the Government's Heat Network Investment Project to provide grants of c£300m over 5 years to trigger up to £2,000 million investment in heat networks. Additional income from training courses and publications will be sought by the Delivery Partner and in the longer term the work of the DHKC is expected to be supported by the DH developers and operating companies through a levy based on the volume of heat sales.

Activity 1: Research of knowledge management models used in similar industries

Aims
To learn from other organisations who have been in a similar position how the issue of knowledge management, research and training has been approached so that the structure and management of the DH Knowledge Centre can be better planned.

Introduction
This route map has identified the need for the DH Knowledge Centre and outlined a potential structure; the time available for this work was limited and further research is recommended. This research would investigate ways that other similar industries are organised and are developing, especially newly emerging ones in the energy sector such as biomass, solar and heat pumps.

The areas of interest will include:
- Structure and governance
- Scope of activity
- Funding and resources
- Links to regulations

Work programme
- Prepare list of organisations to study
- Research each industry including interviewing key people
- Prepare report on findings
- Make recommendations for the DH Knowledge Centre structure, scope and funding

Team
- The work would be delivered by a consulting organisation familiar with the issues of knowledge management and the construction or energy industry.

Timescales
- 3 months

Costs
- Research fee £19,000 based on:
  - Planning and reviewing work, Partner/Director 5 days at £1000 per day (£5,000)
  - Interviews and research of 10 organisations, Senior Researcher 20 days at £500 per day (£10,000)
  - Report writing, 8 days at £500 per day (£4,000)

Funding & motivation for investment
- Funding could be provided by HNDU
- HNDU's motivation would be to provide a strategic framework for DH innovation and knowledge management to accelerate development of technologies that will reduce the cost of DH networks

Success Criteria
- A clear set of recommendations, based on evidence drawn from experience of existing organisations, that can inform the development of the DH Knowledge Centre.

Activity 2: Consultation with industry representative organisations

Aims

To reach agreement with all parts of the industry on the setting up of the DH Knowledge Centre and its governance structure.

Introduction

Following the research phase (Activity 1), it is expected that a suitable structure will have emerged which can be presented as a firm proposal to the industry. Discussions would be held with the various DH industry bodies with the aim of achieving a consensus for the structure, scope and funding of the DHKC. This work would also provide an opportunity to document the status of various initiatives that are already in progress so that the DHKC can support these and incorporate them rather than undermine them or cause delay. Any emerging ideas on regulations that might be introduced for heat supply from DH will also be captured as this may influence the proposed organisational structure, e.g. a need for a compliance or accreditation body. In addition to the established organisations, other stakeholders will also be contacted including those that have participated in the ETI workshops to date. Annex 4 summarises the discussions held to date with various parties.

Work programme

- Identify list of consultees
- Prepare presentation of structure of proposed DHKC
- Arrange and hold interviews
- Prepare report on interviews
- Establish a viable solution as necessary that will achieve a consensus
- Inform consultees of final proposal

Team

- This consultation would be best carried out by a senior independent person who could take a neutral position and would be appointed by BEIS

Timescales

- 6 months

Costs

- Specialist consultancy fee £30,000 based on:
  - Planning and preparation, senior negotiator 5 days at £1000 per day (£5,000).
  - Interviews with 10 organisations and 10 other stakeholders (some may be grouped together), 10 days at £1000 per day (£10,000)
  - Prepare report 5 days at £1000 per day (£5,000)
  - Propose preferred structure and draw up final proposals 10 days at £1000 per day (£10,000)

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to lead the alignment of DH stakeholders, in order to give confidence that future investment in the DHKC will achieve the cost savings and market growth for DH networks.

Success criteria

- Structure, scope and funding of the DH Knowledge Centre clearly defined and with high degree of support from all parts of the industry.

Activity 3: Setting-up of DHKC governance structure and obtain funding

Aims

To set up the governance structure for the DHKC and agree funding.

Introduction

In this activity the new District Heating Knowledge Centre will be set up with the fundamental documentation in place, structure and accountabilities defined and funding agreed.

Work programme

- Prepare the business case and obtaining funding
- Document the purpose and aims of the organisation
- Establish governance structure and Board membership
- Establish financial arrangements and accountability
- Legal review of proposals

Team

- As BEIS/HNDU are the proposed funders this activity will be largely carried out in-house by BEIS in consultation with other Government Departments and internal legal specialists

Timescales

- 6 months

Costs

- A budget for in-house costs of BEIS is proposed at £25,000

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to prepare the business case and structure for the DHKC in advance of committing the more significant delivery funding.

Success criteria

- Structure of organisation agreed and passed legal review. Funding agreed in principle, ideally to be committed for more than one financial year. Financial arrangements, accountability and reporting lines established.

Activity 4: Definition of initial work plan

Aims

To set out a work plan in sufficient detail to inform the Delivery Partner and the wider industry of the likely scale and diversity of the work.

Introduction

Before selecting a Delivery Partner it will be necessary to draw up a schedule of planned activities that the DHKC will seek to deliver in the first few years. This will be subject to ongoing development and change and the contract with the Delivery Partner will need to be flexible enough to allow changes. Nevertheless, there will be some activities that could be commenced immediately. This might include:

- Technical research into the areas described in Annex 3 which will have an impact on costs e.g. research into optimal pipe sizing and publishing of guidance
- Monitoring of existing schemes e.g. to establish diversity factors, new benchmarks
- Training modules for practitioners
- MSc modules in DH
- Update of CIBSE/ADE Code of Practice and a compliance process
- Dissemination of good practice based on case studies of exemplary schemes (including demonstration schemes identified in this ETI project)
- Review of existing guidance documents and on-going research work, and the need for further publications (see Annex 2 for a summary of these aspects)
- Review of research work from overseas and its applicability to the UK
- Dissemination of learning from other sources (including the ETI's Heat Infrastructure Development project)

Work programme

- Establish a working group to develop the work plan
- Convene meetings to brainstorm ideas (this could include an industry-wide consultation event)
- Review and prioritise activities
- Prepare work plan and initial budgets

Team

- The work would be largely carried out by the DHKC Board and their technical advisers

Timescales

- 3 months

Costs

- £21,000 based on:
  - 5 Board participants providing three days each at £1000 per day (£15,000)
  - Additional expert level technical advice 8 days at £750 per day (£6,000)

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to build a robust plan and budget for the DHKC in advance of committing the more significant delivery funding.

Success Criteria

- A work plan with strong support from the DHKC Board with sufficient detail to inform the process of selecting a Delivery Partner

Activity 5: Selection of the Delivery Partner

Aims

To select a Delivery Partner with the right skills and experience to deliver the work plan over a period of up to 5 years, using a competitive procurement process.

Introduction

A Delivery Partner (DP) will be appointed by a competitive process. Some of the work plan is expected to be delivered in-house by the DP and some of the work will be carried out by sub-contractors to the DP where there will be a further competitive bidding process at a later date. The tender process will include both the core management work and the capabilities of the bidders to deliver the programme of work in-house. Where the work can be carried out in-house this will need to be defined in sufficient detail for competitive tenders to be obtained. Where the scope is as yet unclear the DP may still offer to provide the service but would need to ensure value for money through a market testing process or formal tender. The tender process will be conducted by specialists familiar with this type of procurement and the public procurement regulations.

Work programme

- Define overall tender process
- Prepare invitation to tender document including the work plan
- Establish work that can be tendered as a fixed fee and work that will be cost plus or cost pass through
- Establish requirements for the DP to procure sub-contracts for specialist work
- Develop qualitative questions for the tender to respond to e.g. experience in similar work, approach to managing risk etc
- Publish the opportunity and invite pre-qualification responses
- Review and finalise list of pre-qualified bidders
- Invite tenders
- Review tenders received and interview
- Make recommendation to DHKC Board on the preferred Delivery Partner
- Conduct final negotiations
- Sign contract with Delivery Partner

Team

- The process will be managed by the DHKC Board but carried out by a specialist procurement team either within BEIS or appointed by BEIS

Timescales

- 6 months, approximately divided as 2 months preparing tender documents and pre-qualification, 2 months tender period and 2 months evaluation

Costs

- £40,000 based on:
  - DHKC Board members, 10 days at £1000 per day (£10,000)
  - Procurement specialists, 40 days at £750 per day (£30,000)

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to identify a capable delivery partner for the programme that will deliver technologies and processes to enable the cost reduction of DH networks

Success Criteria

- Delivery Partner appointed following a transparent process in accordance with best practice public procurement providing good value

Activity 6: Management of individual work packages to completion by Delivery Partner

Aims

The Delivery Partner to deliver the work packages whether for publications, training or research within a clear definition of scope, budget and timescale, using either in-house resources or through competitive procurement from sub-contractors.

Introduction

The Delivery Partner will be responsible to the DHKC Board for the implementation of the work plan which is likely to involve a large number of individual projects which will need to be carefully managed. These may be delivered in-house (subject to market testing or tendering) or by sub-contracting out to specialist organisations. In the latter case, the work will include: managing the process from receiving the work plan with outline requirements, developing a detailed brief, procuring a supplier, managing their work, reviewing outputs and reporting back to DHKC.

Other support activities will be required including providing information to industry, maintaining a website and holding events.

Work programme

- Establish procurement process for each work package
- Invite tenders to deliver work package
- Appoint sub-contractors
- Monitor outputs of sub-contractors
- Provide reports to DHKC Board on progress and expenditure
- Maintain a forward look work plan
- Arrange industry events to provide information on the work being carried out
- Maintain a web-site detailing all of the projects, calls for tender etc

Team

- The work would be carried out by the Delivery Partner and their sub-contractors

Timescales

- Initial programme of 2 years work would be the minimum needed to appoint a Delivery Partner given the set-up costs. However, it is envisaged that the arrangement would be ongoing, although funding of the DHKC may change as the industry grows.

Costs

- £2,000,000 over 2 years is proposed to include both the delivery of the work package and the administration of the work. However, the exact level of funding will be determined by the scope and breadth of the proposed work plan and can be adjusted to suit available resources

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to support the cross-industry development of technologies that will reduce the cost of DH networks, and accelerate the market and deployment of DHN.

Success Criteria

- The work plan being delivered to time and budget and with sufficient quality to have impact on raising standards in the industry and reducing costs

4.1 Annex 1: Work programme

Route Map A - Knowledge Management, Research and Training - Activities, costs and timescales

Activity	Cost	Year 1				Year 2				Year 3				Year 4			
	£	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Research into knowledge management options	19,000																
2. Consultation with industry organisations	30,000																
3. Set up DHKC and obtain funding	25,000																
4. Define initial workplan	21,000																
5. Select Delivery Partner	40,000																
6. Deliver initial work plan	2,000,000																ongoing
TOTAL	2,135,000																

4.2 Annex 2: Current State of Knowledge Management for District Heating in the UK

The DH industry in the UK is relatively small and so there is limited resource to devote to knowledge management research and training. Nevertheless, there have been a number of activities in this area in recent years. This covers regulation, standards, guidance and other advice, as well as training and research. These are described below together, beginning with current Regulations, with some discussion on the limitations of the scope and status of each.

New Road and Street Works Act
This Act governs the installation of utility apparatus below public roads and so governs much of the DH work. There are a number of associated Codes of Practice that must be followed e.g. on traffic Management, response to faults etc. There is a National Joint Utilities Group that acts as a co-ordinating body and publishes case studies and guidance in association with the Highway Authorities and Utilities Committee.

Building Regulations Part L
This regulation governs the quality of installation of certain parts of a building with respect to energy efficiency. For new build the primary requirement is to achieve a given carbon performance but there is secondary guidance which provides requirements related to individual technology and DH systems is covered in the Compliance Guides for dwellings and non-dwellings. These guides do not contain much detail on DH as they have to cover all types of heating system, but could be expanded when the Part L regulations are next updated. This would help in governing the design of new build schemes but would have little impact on the retrofit of DH to existing buildings as the Part L regulations were not be triggered unless there was significant other work being carried out on the building to be connected. Some have argued that DH is not fairly represented in the current regulations with the compliance tools being criticised for not reflecting well the benefits of DH.

Metering Regulations
The Metering Regulations became law in October 2015 and require certain standards for metering in new buildings and for meters to be retrofitted where cost-effective to do so. The Regulations also require DH heat providers to provide data to Government on their schemes. The Regulations are supported by the Metering and Instrumentation Directive and EN Standard EN1434.

BSI/CEN
There are a group of European Standards that were originally developed as product standards for pre-insulated pipe (EN253 and associated standards) and have subsequently been extended to cover the design and installation of pre-insulated pipe (EN13941) and newer products, including flexible pipe, twin pipes and the surveillance system. The nature of the EN standard process is that it tends to follow practice and consolidate knowledge rather than lead new techniques.

CIBSE/ADE Code of Practice CP1 Heat Networks
In response to concerns in Government and the industry that there was a lack of standards for the industry, ADE carried out a review of available standards and established that there was a gap in the area of heat network design and a Code of Practice was developed by CIBSE and the Association of Decentralised Energy (ADE) with funding provided by CIBSE. This was a departure in style for CIBSE as the Code sets out a large number of specific requirements that need to be followed for the scheme to be compliant with the Code. Most CIBSE publications previously have been more in the nature of design guidance and so less prescriptive. The Code covers all aspects of the development of a scheme from initial briefing and feasibility work through design, construction commissioning and operation

together with a section on customer service standards which refers to the Heat Trust. Compliance with the Code has been a requirement for feasibility work commissioned by local authorities with the support of BEIS Heat Network Delivery Unit. The Code was published in July 2015 and feedback on the Code is beginning to emerge with discussions starting on how to make the first revision. There is concern over how to monitor compliance with the Code and a Compliance checklist is under development by the ADE who are particularly concerned about reputational damage from poorly designed schemes.
One of the drawbacks of the Code is that there was limited space to explain the reasoning behind each of the requirements and a supplementary text providing more justification could be of value.

There is a CHP/DH Special Interest Group within the CIBSE structure which has a very large number of members (14,000) not all of whom are members of CIBSE. This group has a steering committee that meets regularly to co-ordinate activity and organises seminars. There is a website specific to the group with some information that can be downloaded for free. A small number of factsheets have been produced but these have mainly been associated with CHP rather than DH. This group relies heavily on voluntary time and effort from a few people and the frequency of seminars reflects this.

Other CIBSE publications relevant to DH
The second Code of Practice CP2 on water source heat pumps has also been published using a similar format. AM12 – CHP for buildings includes a chapter on district heating and AM15 on the use of biomass both have relevance for district heating. Energy benchmarks which are often used in early stage design of DH are published in CIBSE TM46.

CIBSE offer a large number of training courses on a wide range of subjects including CHP. Courses were set up to support the Code of Practice and there is an accreditation scheme for delegates who have completed a 2-day course as a DH assessor. This course is designed for people who already have knowledge of DH to understand the Code of Practice and some of the key requirements that are given there so that they can use the Code. It was criticised by some as being of too limited duration to impart sufficient knowledge of DH to be of value and the title DH assessor accreditation may be unhelpful in indicating a level of knowledge that in fact is less than it might appear.

ADE hold a number of meetings through the year to share information however much of this is related to policy development and regulatory impacts rather than specific technical issues. There is an annual conference which is mainly devoted to policy or commercial aspects of DH.

BRE Trust – Technical Guide to District Heating
The BRE were commissioned by DECC to produce a Technical Guide to DH and this was published by the BRE Trust in 2014. It was a development of the technical sections of an earlier Good Practice Guide 234 published by the Government under the Energy Efficiency Best Practice Programme. GPG234 was in turn a development of an earlier DH guide published by the CHP Association (the fore-runner to the ADE). All of these documents were funded by central Government. The bulk of the work on the Technical Guide was carried out in 2011 and so work on an update would be timely to reflect latest developments.

Building Services Research and Information Association
BSRIA was formed to provide a focus for research information sharing for the building services industry and so is a potential model for the solution identified for the DH industry. It is funded partly by subscriptions from the major consultancies active in building services and partly by commissioned research, training and publications.
BSRIA have been involved in the DH industry in various ways over the years. Most recently by drafting a guide for DH for the UKDEA (see below). Also, a guide to hydraulic interface

units (HIUs) was produced. A number of BSRIA guides are relevant, especially the guide to variable volume heating systems, guides on cleaning of pipe systems, water treatment and the Rule of Thumb booklet which gives benchmark figures for peak heating and cooling demands for a wide range of types of buildings.

UK District Energy Association
The UK District Energy Association (UKDEA) was formed with the specific aim of sharing best practice. The website states the first objective as:

- "Increase the flow of information between Members to jointly tackle obstacles and jointly develop knowledge, understanding and good practice concerning District Energy and other related matters."

It does this by means of a regular newsletter and an annual conference. It has also published a guide to the development of DH schemes which is available as an App. This covers the steps needed to develop a DH project in terms of procurement of an ESCo partner rather than engineering and design aspects. The UKDEA has an aspiration to publish specific design notes on a range of subjects. The UKDEA commissioned BSRIA to produce a technical guide to DH and this has reached a third draft.

BEIS SBRI
In 2014 BEIS (then DECC) ran a Small Business Research Initiative (SBRI) which funded research into a number of areas of DH with the aim of promoting innovation. Further work is planned. Currently the full publication of this research is awaited.

International Energy Agency
For many years the IEA has sponsored research into DH under the District Heating and Cooling Annex. This typically works on a 3 year cycle of commissioning research and publicising the results. These reports contain valuable information on new developments in technology and often with feedback from actual projects. The UK Government has contributed to funding the Annex for over 20 years but not consistently, although Dr Robin Wiltshire from the UK has chaired the group for many years. As the research projects are carried out by multi-national teams, the subject area and relevance for the UK is not always well aligned.

Euro Heat and Power
This is the trade association representing the DH and CHP industry at a European level. It has published two technical guides; one is a guide to substations (2008) which is very comprehensive and in fact covers more than substations and one for qualifications for pipe fitters and HDPE welding (2010).

Local Government
The GLA published the London Heat Network manual in April 2014 to guide developers and customers of DH in the capital. Islington Council have produced a guide to the connection of buildings to district heating.

HIU testing and BESA
Following the DECC sponsored SBRI research project to study the operation of HIUs in the field it became apparent that there was significant variation in performance and a standardised performance test would be helpful for specifiers to enable products to be easily compared on a like-for like basis. Currently testing is carried out by a Swedish test facility using tests that are not aligned with typical UK conditions. The SBRI research contractor (Fairheat) took the initiative to develop a standard test procedure and sought views from industry on this standard. Following a measure of agreement this test standard is now being offered to industry through the Building Engineering Services Association (BESA).

Other industry initiatives
Some companies are also active in producing guides and arranging conferences. For example:

- SAV who are a market leader in HIUs and small-scale CHP produce a number of technical guides.
- Rehau as pre-insulated pipe supplier organise an annual technical conference.

Standard Textbooks
There are relatively few textbooks available on District Heating. However, the comprehensive textbook ‘District Heating and Cooling’ by Professor Sven Werner and Professor Sven Fredriksen is now available in English (publisher Studentlitteratur AB) and benefits from research work carried out on Scandinavian schemes.

Academic Interest in DH
Some work has been carried out by UK Universities into DH although often as part of a wider project investigating energy policy options at a national level rather than the engineering aspects of delivering schemes.

The most active is Edinburgh University where research has focused on the social policy aspect rather than the engineering (where arguably the challenges are more significant). This group publishes the Vanguards newsletter.

Other universities who have been involved or expressed an interest in becoming involved include:

- Cardiff University – Institute of Energy – a number of PhDs completed with DH as a theme. FLEXIS project funded by ERDF is a major research programme (c£24m) which includes DH as part of the scope. The University is a member of the UKDEA.
- University College London – produced a local authority energy planning model with elements of DH
- Leicester University Dr Audrius Bagdanovich has led research on DH and Exergy analysis (previously at Cardiff University)
- Nottingham Trent University, Professor Anton Ianakiev is developing a novel demonstration project for low temperature DH
- University of Brighton have expressed an interest in being a lead organisation for training including setting up a Masters in DH engineering
- Warwick University – interest from both academic departments and the estates department as there is an extensive DH system at the University, providing an opportunity for first hand practical demonstrations
- Birmingham University – also has a DH network and is taking a leading role on the Thermal Energy Research Accelerator
- Leeds University – active in the area of energy masterplanning for cities, led by Dr Catherine Bale
- Imperial College London, activity in energy system optimisation and city planning
- Manchester University has interests in optimised operation of energy systems and has contributed to previous ETI work

Other bodies carrying out research recently into DH

- Energy Networks Association
- National Grid
- Rowntree Trust
- Energy Technologies Institute
- Energy Systems Catapult
- Committee on Climate Change

Implicit Knowledge

The above descriptions have concentrated on explicit knowledge, i.e. custom and practice that has been consolidated into written material often previously published as hard copy. A second group of knowledge - implicit knowledge - exists in the minds of people involved and the ways of doing things that are part of company's intellectual property which may be less codified. One area of recent growth is the use of on-line discussion groups. There are 3 of these active in the UK:

- Google discussion group district heating/cooling
- CIBSE CHP/DH Group discussion on Linked In
- UKDEA discussion group on Linked In

Of these, the Google group is the more active although the CIBSE one is set up specifically to provide feedback on CP1.

One of the difficulties with these groups is the process of establishing a consensus view from the discussion and then a path for this consensus can be transferred into explicit knowledge such as published guidance, Codes of Practice etc.

Other organisations with a legitimate interest in DH and potential for contributing to knowledge management

- Institution of Mechanical Engineers – the sustainable energy group have organised a number of seminars – Birmingham in 2015, and Sheffield in 2013 on district heating
- The Energy Institute
- Institution of Civil Engineers – sponsored a major study led by Southampton University on the potential for DH and the use of existing power stations
- Chartered Institution of Highways and Transportation
- The Institution of Engineering and Technology
- Heating Industries Council – has published a checklist for commissioning of HIUs
- Department of Transport – with interest in how DH pipes cross major roads and railways
- Defra – with environmental impacts generally and is ultimately responsible for the Canals and Rivers Trust
- The housebuilding industry
- BEAMA
- Institute of Domestic Heating and Environmental Engineers
- British Standards Institute

4.3 Annex 3: Specific areas of known knowledge gaps for design and construction

The specific areas identified where currently the lack of good knowledge management, training and research is causing higher costs, risk and lower quality are discussed below. These also reflect some of the other solutions identified within this ETI HID project. This is not an exhaustive list and is intended as an illustration of the range of areas where better knowledge management could lead to significant benefits.

Energy use of buildings
Feasibility studies and often initial business cases depend on estimates of the heat demand of the buildings to be connected and their peak heat demands. In some cases this can be obtained directly from users but often reference needs to be made of published benchmarks. These may be adequate for use in building services but were not collated with district heating in mind and do not always reflect the variations that occur in practice. The use of display energy certificates is helpful however these have only been a requirement for public buildings so far. Further work to collate and publish information from DH providers on the heat demands for a range of buildings would greatly assist the industry. At present energy companies would be reluctant to do this has the data has commercial value to them but if all DH providers participated and the data anonymised then the whole industry would benefit. Without this data designers will tend to take a pessimistic view leading to over design and a less ambitious network would result. To be of value a rigorous analysis of data would be needed e.g. to provide corrections to an average weather year and to take account of locations within the country, combined with surveys of the building involved to establish not just type but age and occupancy.

Diversity factors for space and water heating
A key issue for network designers is an assumption on diversity factors i.e. does the network have to be designed to supply all contracted loads at the same time. The CIBSE/ADE Code of Practice provides some data for use with domestic hot water diversity in residential schemes but new data from UK housing is emerging which appears to indicate that the Danish curve commonly adopted leads to a degree of over design at large numbers of dwellings (see the BEIS-SBRI funded work carried out by Guru Systems). The Code gives little information on diversity factors for space heating and for large mixed use schemes. Suitable data could be obtained from existing UK schemes to enable a diversity factor to be proposed and relied upon by designers for a range of different types of scheme. Without this data, a scheme could be significantly oversized (perhaps by 30%) leading to higher costs and inefficiencies.

Pipe sizing and pressure regimes
There is currently some debate in the industry about methodologies to size pipes in an optimum way as there is a need to balance initial cost with pumping energy and heat loss. These calculations have a number of variables and are also influenced by the geometry of the network. The problem is complex and there is a risk that simple rules of thumb based on maximum velocity or maximum pressure drop per meter are employed. This leads to oversizing in many cases. Although some software is available to assist it tends to be not widely used and is complex or cumbersome to use.

Use of plastic pipes, twin pipes, GRE pipes – feedback on costs and benefits
A number of newer products are available in the market place but there is a reluctance to specify these unless there is good independent evidence as to the benefits. As a result, cost benefits are not taken up rapidly. The building industry is a relatively conservative industry and it took many years for alternative pipe plastic materials to be used for drainage and hot and cold water services for example. A good knowledge management system would gather

data from sample schemes and publish this as independent advice in the form of case studies to allow specifiers to make informed choices.

Trenchless Technology
One of the solutions identified within the ETI Project was the greater use of trenchless technology. This is an area where good knowledge management will be needed for the development of the most appropriate applications and the dissemination of this to the DH industry so that design and construction practice can change rapidly to take advantage of this new approach.

Operating temperatures
This is an area where there is often a range of views and yet design decisions need to be made early. In particular, the selection of design return temperatures for the network will impact on the cost of the network. If a higher return temperature is selected then the network could be over-sized and cost more, but selecting a low return temperature which is then unable to be achieved could risk being unable to supply buildings on the extremity of the network in cold periods with consequent loss of income and reputation. Practical solutions for adapting existing building's heating systems and modifying controls to achieve low return temperatures at moderate cost would be a key aim of the solutions research and dissemination activity.

For new buildings the emphasis will be more on educating building services designers on the importance of low return temperatures for district heating systems and how these can be achieved consistently for all loads. The challenge here is that there are a very large number of practitioners to reach with what is at present a relatively niche subject area.
For new residential buildings it is also critical to ensure radiator circuits are correctly balanced and this is often omitted and not properly monitored. Training of designers, specifiers, contractors quality control staff and heating fitters is required - again there are large numbers of people to reach.

Pipe flushing and cleaning
This aspect of the construction process was discussed in a Stage 2 workshop and alternative solutions put forward. They were classed as amber mainly because this is a small element of the cost. There is uncertainty around the benefits of chemical cleaning and also the difficulty of achieving sufficient velocity for flushing large diameter pipe adequately. Alternative solutions and guidance which provide definitive recommendations would be welcomed and would reduce costs albeit marginally but improved reliability could also result.

Demand side management of existing buildings
A relatively new area of interest is the use of smart controls to manage the demand of buildings connected to the heat networks so as to minimise peak demands. Successful applications of this technique have been demonstrated in Gothenburg and achieving a more rapid take-up in the UK would be the main objective of the solution.

Pipe Crossings
A set of standard designs approved by the major infrastructure owners (roads, railways, canals etc), together with standardised legal agreements and national charges would be of value in reducing the time for negotiation. See also Solution 7 in Deliverable EN2015_D03.

Contracts
Much time and effort is spent in negotiating bespoke contracts for the construction and operation of DH networks and for the sale of heat. It is recognised that greater standardisation would assist in reducing these costs. The actual form of contract used for construction is also important to provide incentives to reduce costs and to provide sufficient time for front end design to be carried out and for contractors to be able to provide input to

the design stage. This area is discussed in Route Map E: Improved Front End Design and Planning. Heat sales contracts are beginning to be standardised across the industry through the work of the Heat Trust that sets certain customer service standards such as response times, penalties for failure to supply, dealing with bad debt, policies for vulnerable customers etc. More could be done in this area to build customer confidence and reduce costs during the development phase. Standard forms of lease, wayleaves and easements to enable DH to cross private land and other infrastructure that have been pre-negotiated with other agencies and utilities would also be of value.

Impact of Regulations on DH

A few Regulations impact DH design especially in the new build sector where Part L of the Building Regulations apply. The compliance tools for Part L (SAP and SBEM) have been criticised for not reflecting well the benefits of DH. For example, the time varying nature of CO_2 emissions cannot be modelled and a grid average figure is used. In the future, this will under-estimate the CO_2 reduction from a flexible CHP system with thermal storage. More research into this aspect is needed and more advanced compliance tools are required.

4.4 Annex 4: Analysis of options for the DH Knowledge Centre

Organisational structure

During the development of this route map, telephone conversations were held with representatives of BEIS, ADE, CIBSE, UKDEA, BESA, BSRIA and two universities. There was widespread support for the proposed solution and recognition that a new approach was needed. Recent negative publicity about district heating, directed at new build schemes particularly, has highlighted the issue and the point was made that an emerging technology cannot afford to have a poor reputation if it is to gain market share.

There was also a general view that a new organisation was not the answer. Indeed, the number of existing organisations involved was part of the challenge in making progress. In a discussion paper circulated to the above stakeholders two further options were presented:

1. A committee would be formed which allocated tasks between the various organisations with funding being sought as required for each task. This was felt to lack the necessary structure to drive progress and would be time consuming in organising a large number of small individual projects. If the committee was too large in composition it would be harder to reach agreement and yet many organisations could legitimately be included.
2. One of the existing organisations would be asked to take a lead role and be accountable for the delivery of a programme of work and obtain the necessary funding. The difficulty with this approach is that more than one organisation would be able to fulfil the role and those not selected would feel excluded and the strong buy-in needed from the industry might be compromised. The exception to this would be the Heat Networks Delivery Unit (HNDU) part of BEIS which would be seen as a suitable lead organisation by all parties.

Following these discussions, a structure has emerged which is the basis for the proposed solution presented in the route map. This requires HNDU to take a leading role but primarily to give strategic direction and to provide an overall fund to a District Heating Knowledge Centre (DHKC). The DHKC would be managed by a committee involving the principal organisations involved in the industry. At present the membership of the committee is expected to include representatives of HNDU, ADE, UKDEA, Heat Trust (to be the voice of the customer), CIBSE and BESA although other representatives or individuals with particular expertise could also be appointed. This committee would develop and agree a programme of work.

The DHKC would then contract with a Delivery Partner, selected after a competitive process and for a pre-determined time period (say 2 - 5 years), who would be responsible for delivery of the agreed programme. The Delivery Partner could be a body such as BSRIA or CIRIA, or a consultancy or a University.

The work itself may be carried out in-house by the Delivery Partner or more likely sub-contracted to the most appropriate organisation to undertake the work, whether a specialist consultant, university department or an industry membership based organisation.

Funding

Funding would be provided at least for the first few years by HNDU which is justifiable given the significant investment the Government is making through the Heat Networks Investment Project. It would be logical to invest in the DHKC to enable the projects supported to benefit from the latest thinking and training and to contribute to the development of knowledge through research and monitoring of these projects. The Delivery Partner would be encouraged to seek additional income streams where possible provided these did not diminish the impact of the work. For example, charging a reasonable fee for training courses would be possible as would a charge for hard copies of publications. In the longer-term, as the industry grows, it would be expected that an industry-wide levy could be collected from DH heat suppliers above a certain threshold based on the amount of heat sold in a year so that a predictable annual fund can be relied upon for future activities. At present, the industry is small and would not be sufficiently confident in the outcomes of the DHKC to provide the funding. Hence the initial funding from Government is seen as necessary.

Summary

In summary, the proposed arrangement is designed to provide:

- A secure funding stream from the outset enabling a strategic work programme to be developed
- Enough representation from industry to provide suitable coverage of the issues without becoming too complex to manage
- A separate organisation to the management group that is clearly responsible for controlling the budget and delivering the work programme in a timely manner; this organisation being competitively procured and with an incentive to perform so as to maintain its role in the long-term

5 Route Map B: Low Flow Rate Design

Route Map Summary

A fundamental determinant of the cost of the heat network is the diameter of the pipe needed to transport a given rate of heat energy. This in turn is a function of the volume flow rate which is calculated from the required peak heat demand and the temperature difference between the flow and return. If the peak heat demand can be reduced and/or the temperature difference increased then flow rate and costs will be reduced.

The solution addresses each of these aspects as follows:

- **Low flow rate:** The advantage of supplying existing buildings is that actual fuel data can be used to estimate the required peak demand which is likely to be more accurate than an approximate heat loss calculation which would be the typical current approach. With the advent of smart meters, half-hourly fuel use data is expected to be available from which peak demands can be deduced. A software tool will be required to enable the data to be rapidly analysed for a given street of houses.
- **Temperature difference:** The temperature difference is maximised by reducing the return temperature as far as possible and this requires knowledge of the impact of lower temperatures on radiator output. A software tool that enables rapid selection of the required flow rate for each existing radiator to suit the room heat loss will help ensure that return temperatures are minimised.

Although the above tools will assist, the main barrier is lack of knowledge of best practice in design and this will be addressed through a demonstration project.

The activities identified in the route map are:

1. Market research into DH developer attitudes
2. Review of existing products
3. Use of smart meter data to derive peak demand
4. Radiator performance software tool
5. Demonstration project
6. Case study and report on demonstration project
7. Further demonstration projects

The total funding required is estimated at £332,700. Funding is expected to be available from HNDU for this work given its widespread applicability. Software companies are also expected to invest in commercialising the tool. Support to disseminate the results of the demonstration project is proposed through the Strategic Energy Funding.

The work is closely linked to that of Route Map A as following a demonstration project it will be necessary to actively promote the solution and share knowledge of the benefits.

The overall timescale for this route map is 33 months including delivering and monitoring of a demonstration project.

Solution Description

Current challenge

The cost of the DH network is in part a function of the diameter of the pipes. This is dependent on the peak flow rate estimated by the designer. The flow rate is calculated from two parameters: the peak heat demand of the property (i.e. on the design day at a specified external air temperature) and the temperature difference between flow and return – the delta T. Often the peak heat demand is over-estimated and the delta T is not maximised adequately which can both significantly increase the diameter and cost of the pipes.

If a lower peak demand can be justified and if the delta T is maximised the cost of the network can be reduced by using smaller pipes and hence narrower and shallower trenches. There needs to be a significant reduction in flow rate to have an impact on costs; to reduce the pipe diameter by one standard size requires about a 50% reduction in flow rate. The main impact on cost is seen with reducing the pipe size for the larger diameters (see Figure 12).

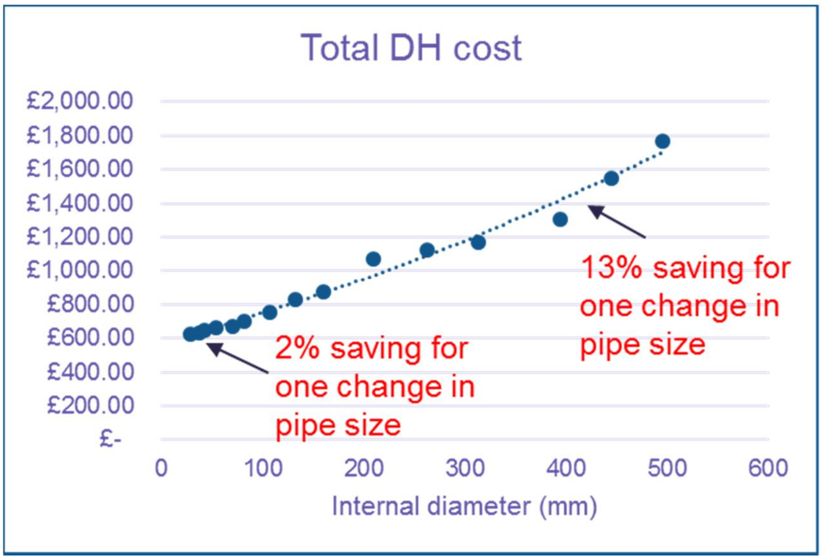


Figure 12: Impact on cost from reducing pipe diameters

Proposed Solution

The solution addresses both aspects of the challenge – i.e. reducing peak demand and maximising delta T.

1. Reducing Peak Demand

Space heating demand

The conventional approach to estimate peak space heating demand is to measure the area of each element of the external building fabric, estimate the thermal transmittance (U-values) of each element from knowledge of its construction and calculate the heat loss. An allowance is then made for ventilation loss depending on the estimated air tightness of the building. This process is currently laborious and a number of assumptions made which are not always well founded.

The proposed solution would develop a new design process to improve the accuracy of the peak demand estimate, It will use data from smart meters to predict demand on the coldest day. The Government is intending to roll-out smart meters across the UK by 2020. This will be applied to residential and non-residential buildings and include separate meters for both gas and electricity supplies.

It is also conventional to add a margin to the design heat demand to enable the building to heat up rapidly after, say, a night set back. It is proposed that customers will be advised that, when the external temperature is below a certain level night set back should not be used and/or an optimum start control system utilised so that the need for the additional margin on the estimated peak heat demand to enable rapid heat up in cold weather is avoided.

Smart control systems

Although not essential for delivering the low flow rate solution an advanced control system that incorporates an optimum start algorithm would be helpful in ensuring that comfort conditions are maintained during cold weather in an optimal way without the need for the customer to intervene. Such a control system is also likely to result in lower heat use over the year, although this is not the aim of this solution.

Hot water demand

A hot water priority system will be used so that the space heating circuit is shut off whenever hot water is drawn off. This means that the hot water demand does not need to be simply added to the space heating demand for each customer connection thus reducing the peak demand on the network. This facility is already available on the market with some designs of HIUs.

2. Maximising delta T

To maximise delta T the solution concentrates on reducing return temperatures as far as possible. The main constraint is the size of the existing radiators, as it will be most economic to retain these. To achieve lower temperatures from the radiator it will need to be balanced so that the flow rate is restricted.

To do this accurately and speedily it is proposed that a new thermostatic radiator valve (TRV) with a calibrated pre-setting device is installed on all radiators. The lower flow rate and return temperature will also reduce the output of the radiator so it will be necessary to set the TRV so that the radiator output is sufficient for the calculated room heat loss. A quick way of assessing the radiator characteristic from a visual inspection and measurement of the radiator dimensions is needed.

A software tool which contains a look-up table covering the majority of radiator designs from a range of manufacturers will be produced which will predict the lowest return temperature to achieve the required heat output at a given flow temperature. From the required heat output and return temperature the flow rate is determined. The required setting of the TRV can then be established for the given differential pressure being produced by the circulating pump or differential pressure control valve.

In some cases, e.g. a block of flats where radiators will have been installed at the same time and probably to the same design, the calculations would only need to be performed for sample dwellings. However, in other situations (a street of houses) it may not be possible to rely on a level of similarity between properties and their heating systems even if they initially look identical.

In general, much lower return temperatures have been obtained for DH schemes in Denmark than in the UK. The research work associated with 4th Generation DH is also relevant in developing ways to reduce return temperatures.

Current Barriers to and Requirements for Implementing Solution

Assessment of Barriers

Market Related Barriers

The main barriers are:

- A view amongst professionals that it is better to take a cautious approach to design rather than risk undersizing the heating system and unsatisfied customers
- A lack of knowledge of the opportunity and evidence that a viable solution that will meet customer requirements can be achieved

These barriers will be overcome by providing better design tools and disseminating the results of a demonstration project, providing the evidence that will enable designers to be more confident in the approach and so avoid being over cautious. This aspect of the route map is closely linked to Route Map A: Knowledge Management, Research and Training.

Technical Barriers

The main barriers are:

- Information on existing fuel use in sufficient detail (e.g. half-hourly demand) from which peak heat demands can be estimated is not available, especially for the domestic market
- Software to analyse existing fuel use to automatically calculate peak heat demands is not available
- A software tool to provide a calculated heat output for a wide range of radiator sizes and types and with a range of flow and return temperatures, backed up by test data, is not available

These barriers will be overcome by establishing a process by which smart meter data can be made available (without breaching data protection law) and by developing new software tools.

Development Requirements

The development requirements are in 2 key areas:

1. Software which uses smart meter data to determine peak demands. There is an advantage when installing district heat networks in existing buildings in that the current energy use is known. Typically, existing fuel use will be given on monthly or quarterly utility bills. However, these do not separate out space heating and hot water loads and are insufficiently granular to determine peak demands. The solution therefore proposes to make use of smart meter data to improve the estimate of peak demands. In discussions with BEIS, third parties will be able to access half-hourly data from the central Data Communications Company (DCC) for at least the last 13 months with customer's permission.
2. Design software to assist the designer in rapidly determining flow rates and radiator valve settings for each radiator in the building so as to minimise return temperatures. The software will include a look-up table so that the heat transfer characteristics can be calculated knowing its size and type. Where data is not available from manufacturers, heat output tests on radiators will be carried out to prove the relationship between heat output and flow rate for specific radiator

designs.

Commercialisation requirements

This solution will require a relatively new approach and a new software tool for the UK at least. This will be targeted at a new market as most DH in the UK is either new build housing, social housing or non-residential buildings whereas the target in this case is existing housing of mixed tenure. The specific market for the solution is a DH developer and their designers which, although small, does currently exist at limited scope. The approach needed in this case is Diversification which requires both product development and market development activities.

The key commercialisation activities are:

Product development

As a first step in product development, a software company will need to be identified and funded to conduct market research and define the requirements for the new software tools. Using these requirements, the product design can then be developed including the best format for and the desired features of the tools. The research would lead to a compelling value proposition being documented as a reference point. In parallel, the business model would be researched and designed, including how the development costs would be recovered e.g. through licence fees, one-off purchase etc.

Market development

The DH developers and their designers need to gain confidence in the use of the software tools before they will be adopted for all new schemes. This is best achieved by:

- The software tools being produced by a well-known company already servicing the market
- The software tools being produced in consultation with the industry
- A demonstration project including monitoring after completion, preferably undertaken by a DH company recognised as a market leader
- Dissemination of the results of the demonstration project including a written case study and papers/presentations suitable for industry forums
- A training programme in the techniques involved

In parallel with this work a review of existing products will be undertaken to ensure that there are no equivalent competitors for each of the various elements of the proposed solution.

Aspects Beyond the Scope of this Route Map

The demonstration project could be combined with:

- Route Map A: Knowledge Management, Research and Training. Knowledge sharing of the potential benefits of low flow rate design, especially by disseminating the results of the demonstration project
- Route Map C: Radical Routes. External wall routes and loft space routes will be easier to implement if the pipe size is reduced as far as possible
- Route Map D: Trenchless Solutions. A reduction in pipe size increases the potential scope of applicability of trenchless technology
- Route Map G: Use of direct connection would lead to lower return temperatures and a further reduction in flow rate

The route map would aim to prove the hypothesis that, by following low flow rate design principles, the flow rate can be 50% of that which would occur from a conventional design that took a more conservative approach. Some elements of the solution are already available:

- Hot water priority at a dwelling level is available from some HIU suppliers
- The concept of operating heating in a more continuous manner has been discussed in the context of air source heat pumps to avoid the need for additional direct electricity use and limit the heating capacity of the heat pumps which are also a high capex item
- Thermostatic radiator valves suitable for balancing radiators with low flow rates are already available in the market place

Route Map Proposal

The activities identified requiring further work and validation for this route map are:

1. Market research into DH developer attitudes
2. Review of existing products
3. Use of smart meter data
4. Radiator performance software tool
5. Demonstration project
6. Case study and report on demonstration project
7. Further demonstration projects (including commercialisation of software)

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The external funding of activities 1-7 is estimated at £332,700.

Activities 1-4 are generic research activities for DH which would be best funded principally by BEIS-HNDU managed by the proposed DH Knowledge Centre (see Route Map A).

The demonstration project (Activity 5) is expected to be funded by a DH developer as it is intended that this will be a fully commercial investment. Support funding for monitoring, customer research and reporting (Activity 6 and 7) will be required and Strategic Energy Funding (SEF) is the proposed source of investment for these activities.

Activity 1: Market research of DH developers and their designers

Aims

To understand the attitudes of designers to changing to the low flow rate solution and the drawbacks they see in the solution and any suggestions for software development to overcome these.

Introduction

Market Research will be carried out by a specialist market research company through direct interviews of a sample of DH developers and their designers. This will aim to:

- Understand how a company would approach the issue at present
- Confirm interest in the solution proposed and establish the key features designers would like to see
- Identify the reasons why the solution is not more widely adopted so that the work in the remainder of the route map can address these

Work programme

- Profile DH Developers and Designers and develop groups with similar characteristics. A maximum of 10 groups to be approached each of which would comprise one or two people from the developer and designer companies (it may be valuable to interview DH developers with their designers present).
- Understand the benefits and sacrifices they experience with the current solution
- Explore their attitudes to the potential solution
- Develop value propositions (e.g. function, speed, dependability, flexibility, price)

Team

- The work would be delivered by a market research organisation with experience in working with professional groups involving engineering design and energy projects

Timescales

- 3 months

Costs

- Market research fee £18,000 based on:
  - Planning of work and preparation of framework for discussions: senior researcher 10 days at £500 per day (£5,000)
  - Setting up and carrying out face to face interviews: researcher 20 days at £400 per day (£8,000)
  - Collate and prepare report: senior researcher 10 days at £500 per day (£5,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to understand better the current attitudes of developers and designers to low flow rate design and the perceived barriers that prevent the deployment of lower cost DH networks

Success Criteria

- Completion of in-depth interviews with sufficiently robust sample from appropriate representatives within the industry to provide high quality insights into attitudes of designers and developers to the proposed solution

Activity 2: Review of existing products and services

Aims

To establish whether there are already products and services available in the market that would deliver the low flow rate solution proposed.

Introduction

A review of existing products and services available in this area will be undertaken by a specialist consultant to establish if there are already offers in this space and whether there is a significant competitor. This will cover products relating to surveys, radiator outputs, smart meter energy data analysis, control valves and advanced controls for domestic systems. This work may also identify companies who would be interested in being involved in the later activities in the route map.

Work programme

- Plan the work and define key areas of interest
- Research specific calculation tools for radiator sizing and heat loss calculations
- Research products designed to control flow rates and return temperatures
- Research software available to analyse half-hourly data from multiple customers

Team

- A specialist engineering consultancy will be required for this activity with understanding of district heating and its wider context

Timescales

- 3 months

Costs

- Specialist consultancy fee £9,200 based on:
  - Principal engineer to set objectives and plan and review the work, 1 days at £700 per day (£700)
  - Design engineer to carry out research work, 10 days at £500 per day) (£5,000)
  - Specialist for software related research, 5 days at £700 per day (£3,500)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to understand the current availability of tools and software that can assist designers in delivering the low flow rate solution

Success criteria

- A report that provides data based on thorough research that will have impact on the later activities of the route map

Activity 3: Use of smart meter data to establish peak demands

Aims

The aim of this work is to develop software which uses smart meter data to determine peak demands.

Introduction

With the advent of smart meters, there is the opportunity to use this data to estimate peak heat demands and thereby help ensure that the design is not based on conservative assumptions and hence oversized systems.

Some underpinning research would be needed to develop a calculation procedure to isolate out the space heating and domestic hot water loads from the energy consumption data based on different patterns of use and variation by season. This would likely require the use of existing sets of sub-metered energy consumption data to develop and assess the calculation procedure e.g. from the completed Innovate UK Building Performance Evaluation study. Research is also needed to develop a calculation procedure to determine the peak winter heat load from the smart meter data; adjustments are needed to size the DH system based on a specific external temperature. This research needs then to be captured in a software tool.

It is assumed that the customer will want district heating and hence it is expected that a high percentage of customers will opt-in for the DH company to access their energy data. However, it should not be necessary for all customers to opt-in to have a good estimate of heat load. Research should evaluate the percentage of customers that need to opt-in for a sufficiently accurate determination of peak load demand to check that it is realistic.

Most of the costs of implementing this part of the solution are known and relatively small per home. In particular, the DH company will already be engaging with households around the installation of district heating and at the same time can gain households' permission to use their smart meter data and gather data on the heating characteristics and usage in the buildings for use by the software tool to determine peak heat demand. The most significant costs are expected to be to access the smart meter data, including set-up and on-going costs around the IT equipment and systems that will be needed to connect to the Data Communications Company (DCC) infrastructure and meet specific Government requirements around security. In discussions with BEIS, companies are going through the process of setting themselves up as a DCC data user and the costs are not known. However, the expectation is that it would be cheaper for a DH company (that has relatively limited need for smart meter data) to use a specialist service provider that accesses the energy data for multiple clients and can spread the IT costs between clients. There is no such specialist service provider at present but they are expected to emerge. To confirm the viability of this approach, discussions should be held with BEIS and/or the DCC data users to better understand the IT requirements, costs and the potential for specialist service providers.

Work programme

- Research to develop algorithms to determine peak load demand from smart meter data, and then implementation in software tools
- Research to determine the percentage of customers that need to opt-in to accurately determine peak load demand
- Research to determine the IT costs associated with accessing smart meter data

Team

- The research on heat demand would best be undertaken by academia or a specialist consultancy
- The software could be developed by the DH developer in-house or by an external provider
- The estimate of costs for access for smart meter data would be best undertaken by an expert in IT systems and cost

Timescales

- 12 months
- The solution will be most applicable post 2020 when the roll-out of smart meters is expected to be substantially complete. From 2019, more services around smart meter data may be available that this solution can build upon and reduce the scope of activities necessary here. Hence this activity is programmed to be completed during Year 2

Costs

- £95,000. This is based on the following:
  - The research on heat demand would take around 60 days at £750 per day (£45,000). This includes: (i) generating profiles of energy demand for different building types and energy use behaviour (15 days), (ii) developing the most appropriate algorithm to isolate out space heating and hot water demands (30 days), (iii) developing an algorithm to determine peak winter heat demand (5 days), (iv) specifying the algorithms for use by software developers (5 days), and (v) analysis of impact of customer numbers on accuracy of calculation of peak load demand (5 days).
  - The cost of the software is estimated at £20,000. It is expected to be a simple application of the algorithms.
  - It is expected that if this work is not commissioned for another 1-2 years, greater information should be freely available on the costs to access the smart meter data. If not, it is estimated that this is a relatively small piece of consultancy work i.e. less than 30 days at £1,000 per day (£30,000).

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre. HNDU's motivation would be to support the development of software that would provide a tool for designers to rapidly determine peak heat demands from smart meter data thus avoiding oversizing and higher cost DH networks
- It is expected that the software itself (£20,000) would be funded by the software developer(s) and purchased by the DH developer, with the motivation of achieving future software sales.

Success criteria

- The cost of implementing this part of the solution by the developer, in particular accessing the smart meter data, is relatively low such that the overall solution is viable. As an indication, it should be below £50 per building (i.e. less than 0.5% of DHN CAPEX).

Activity 4: Radiator performance software tool

Aims

The aim is to develop a design tool to assist the designer to determine the setting of radiator valves such that the return temperature from the dwelling is minimised. The time to carry out the calculation should be less than 15 minutes per average dwelling assuming the site survey information is available.

Introduction

To develop a calculation procedure and software tool to calculate the required settings for new TRVs installed to minimise return temperatures.

- The inputs would be: details of each radiator (type and size) and the required heat output for each room (from calculations of heat loss and the smart meter data analysis) and the pressure difference across the heating circuit.
- The outputs would be: the optimal flow rate into each radiator and hence the required setting for each radiator valve that will achieve these flow rates for a given pressure difference across the circuit, together with the return temperatures from each radiator and the average return temperature.

Data on radiator outputs and performance characteristics would be obtained from manufacturers of radiators supplemented by further performance testing as required. Where it is known that radiators in common use are no longer manufactured reference will be made to historic information. Data on thermostatic radiator valves would be provided by manufacturers of the valves.

Work programme

The work plan will consist of three stages:

Data gathering

Data will be obtained on radiator performance from manufacturers and a series of look up tables created for each type, size and for a wide range of flow and return temperatures. Calibration charts will be obtained from manufacturers of pre-settable TRVs and converted to look-up tables so that a required flow rate can be converted into a valve setting for arrange of pressure differences.

A similar tool has already been produced by the BRE for use with the Standard Assessment Procedure (SAP) software to be used when assessing efficiencies of condensing boilers and heat pumps and this contains a number of sets of radiator output data (Calculation tool for the design of low temperature domestic heating systems V1.2.xlsm). This uses the methodology in the Domestic Heating Design Guide (CIBSE 2015) to determine output reduction factors for non-standard mean water temperatures. This software would be used as a guide for the development of software specific to district heating.

Radiator output testing

Radiator testing has in the past used conventional heating temperatures and not the full range of possible flow and return temperatures that is used for district heating and so further tests are recommended on a sample of radiators to calibrate the model. The tests would determine the heat output of radiators for all possible DH temperatures and also top entry bottom exit arrangements which will increase the output of the radiator.

Software development and testing
The software will be developed together with an easy to understand user interface. The software will be tested prior to release using the full range of possible applications.

Team

- Building services consultant supported by:
  - a software developer
  - a testing laboratory

Timescales

- 6 months
- The software required is not complex, although it may take time to assemble the necessary data and carry out any further testing. It is expected that 6 months will be required for this activity.

Costs

- £70,000. This is based on the following:
  - It is anticipated that the software development and testing will cost of the order of £50,000 and radiator testing is estimated to be £20,000 although the latter will depend on what test data is already available.

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to support the development of a software tool that would assist designers in rapidly determining the optimal flow rate for each radiator to achieve low flow rate systems and hence reduce costs of DH networks.

Success Criteria

- Software shall be easy to understand and use, reliable and robust in use and enable the results from the calculation to be obtained for an average dwelling in less than 15 minutes (this time excludes the time spent on site surveying the buildings and radiators).

Activity 5: Demonstration project

Aims

To deliver a demonstration project that shows how the use of low flow rate design delivers cost reductions whilst meeting customer requirements.

Introduction

Confidence in the low flow rate design concept will be obtained through implementation in a demonstration project. This would take the form of a group of c50-100 houses to allow for a range of house types with the new process being followed throughout. After the project has been constructed the scheme will be monitored both at a technical level and by customer research to establish whether comfort levels have been met, whether the peak demands are as expected and whether the design return temperatures are being achieved (see Activity 6).

Although not essential, the demonstration project could also provide a platform for the testing of advanced controls which would manage on/off times to minimise energy use whilst maintaining comfort conditions even in cold weather.

Work programme

- Identify suitable site
- Carry out site surveys and customer engagement
- Collect smart meter data
- Follow the design process methodology to minimise flow rates
- Design the new installation
- Install the new installation, including new TRVs
- Commission the new system and commence operation

Team

- DH company and their designers supported by:
  - Specialist software developer
  - Building surveyors

Timescales

- 27 months (6 months to identify a suitable project site, 3 months to plan, 6 months to construct, 12 months operation)

Costs

- The DH company to finance the scheme itself
- 20 days of senior DH specialist @ £750 (£15,000) to identify demonstration project and negotiate with DH developer.

Funding & motivation for investment

- The cost of the demonstration project will be financed by the DH company as heat sales will be received over the lifetime. The motivation for the DH company will be the opportunity to learn a new more cost-effective approach and to show leadership to the industry, thus increasing the DH market and their share of this market
- Strategic Energy Funding (SEF) will be used for collating demonstration project data and insight; also for dissemination via the DHKC. Provision of SEF will be

motivated by supporting a cost-effective, innovative project which has national impact.

Success Criteria

- Delivery of a demonstration project that shows how flow rates can be reduced to c50% of what they would have been taking a more conventional and conservative approach to design

Activity 6: Monitoring and report on demonstration project, dissemination of results and production of guidance

Aims

To prepare material that captures the benefits of the demonstration project in a way that can be disseminated to the industry in an accessible and informative way to encourage take-up of the solution.

Introduction

The value of the demonstration project will only be realised if the results are widely disseminated. This activity will produce the following outputs:

- A detailed technical report on the project
- A report on the customer experience of both construction and operation
- A case study paper that contains the main results from the project and demonstrates the cost and other benefits in a readily accessible way. This could be presented at a conference or published in an appropriate journal
- A Powerpoint presentation/video which again explains the main benefits of the solution and the results of the demonstration project

These outputs will be made freely available on-line and accessed via a number of websites. In addition, dissemination will take place through technical journals and presentations at conferences.

Following the monitoring and reporting of the demonstration project, guidance documents will be produced for the various elements of the solution.

The dissemination work is expected to be co-ordinated through the DHKC (see Route Map A)

Work programme

- Engage early with the team delivering the project and their customers
- Monitor the project through its design and construction stages, attending regular site meetings
- Establish the costs of the project for comparison with a conventional approach
- Carry out a post completion survey of the customer experience, shortly after completion of the construction and after 12 months operation
- Establish from monitoring data on energy and temperatures any operational benefits
- Review the operational experience with the DH company after 12 months of operation
- Prepare the detailed technical report, the customer experience report, the case study and the Powerpoint/video presentation

Team

- Engineering researchers familiar with the technology
- Social researchers skilled in obtaining customer feedback from novel energy systems

Timescales

- 24 months (21 months work in parallel with the demonstration project plus 3 months to finalise documentation)

Costs

- £25,500. This is based on the following:
  - Monitoring of design and construction, engineer one day a month for 9 months, 9 days at £500 per day (£4,500)
  - Cost comparison, cost consultant for 5 days at £600 per day (£3,000)
  - Social researcher for customer surveys 10 days at £500 per day (£5,000)
  - Technical review of efficiency gains, engineer 6 days at £500 per day (£3,000)
  - Preparation of reports and case studies, engineer 20 days at £500 per day (£10,000)

Funding & motivation for investment

- It is proposed that Strategic Energy Funding (SEF) is used to support demonstration projects in this area
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success Criteria

- Documentation produced on the demonstration project that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer

Activity 7: Further demonstration projects (including commercialisation of software)

Aims

To develop a number of projects using this solution in a variety of geographies and housing types to further show the benefits especially from lower CAPEX and OPEX.

Introduction

A single demonstration project will not have the necessary impact for the whole of the industry so further projects will be encouraged and nurtured. These projects will be subject to further monitoring so that feedback can be provided to designers using the dissemination route in Route Map A.

It is expected that the demonstration projects will be self-funded by DH developers but the support work will be carried out by a specialist research organisation on behalf of the industry as a whole and would require a two year period.

Although it is expected that the software would be fully developed prior to use in the first demonstration scheme there is likely to be further developments needed to take into account lessons learned and to make the products fully commercial. There will also be a need to prepare full documentation and decide how the software and design tools will be marketed, sold and supported. This work is expected to be financed by the software developer company on the basis of future sales and would be expected to take 6 months.

Work programme

- Maintain dialogues with the leading DH developers
- Promote the solution using the material developed in Activity 6
- Monitor the development of each project responding to queries and providing general advice
- Commercialise the software (funded by software company)
- Obtain technical data and cost information from each site
- Obtain customer feedback from each site
- Prepare a case study on each project for wider dissemination, identifying both positive and negative results

Team

- DH Developer companies
- Engineering researchers familiar with the technology
- Social researchers skilled in obtaining customer feedback from novel energy systems
- Software developers

Timescales

- 24 months

Costs

- £100,000 for 10 further schemes based on approximately half the effort assumed for Activity 6 as there will be benefits from replication and familiarity and the work will be less detailed
- This is based on the following for each scheme:
  - Monitoring of design and construction, engineer half day a month for 6 months, 3 days at £500 per day (£1,500)
  - Cost comparison, cost consultant for 2.5 days at £600 per day (£1,500)
  - Social researcher for customer surveys, 5 days at £500 per day (£2,500)
  - Technical review of efficiency gains, engineer 3 days at £500 per day (£1,500)
  - Preparation of reports and case studies, engineer 5 days at £500 per day (£2,500)
  - Total £95,000 for 10 schemes. A further £5,000 is allowed for initial promotional activity
- During this period it is also anticipated that there will be further development of the software tools leading to full commercialisation and deployment to the market. This work is expected to be funded by the software company and could be of the order of £50,000.

Funding & motivation for investment

- It is proposed that Strategic Energy Funding (SEF) is used to support demonstration projects in this area
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success criteria

- Documentation produced on all of the demonstration projects that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer

5.1 Annex 1: Work programme

Route Map B - Low Flow rate - Activities, costs and timescales

Activity	Cost	Year 1				Year 2				Year 3				Year 4					
	£	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
1. Market Research	18,000																		
2. Review of existing products	9,200																		
3. Use of smart meter data	95,000																		
4. Radiator performance software tool	70,000																		
5. Demonstration project	15,000							identify project		design	construct		initial operation over 12 months						
6. Monitoring, reporting and dissemination	25,500																		
7. Further monitoring of projects and commercialisation of software	100,000																	ongoing	
TOTAL	332,700																		

6 Route Map C: Radical Routes

Route Map Summary

This solution reduces the cost of DHN installations by replacing trench excavation with routes that are above ground – the pipes are installed either on the external wall of buildings or within the loft space or cellars.

The component products are available but there is a need to develop standardised design solutions that can be applied to a wide range of house types. The main barriers to wider deployment in the UK have been identified as:

- Acceptance of the above ground routes by the building owner
- Planning permission will be needed
- Standard legal agreements will be needed for permissions to install pipes and have access to them for maintenance
- Lack of knowledge on the design of existing housing stock to establish variations needed in a basic design

Commercialisation requirements include: market development activities to understand the concerns of customers, development of value propositions that will encourage take-up of this solution, and some product development to provide a standardised solution with variants to suit the house type and which maximises off-site construction.

The main activities proposed in the route map are:

1. Research into aspects of housing design relevant for above ground routes
2. Market research into customer attitudes
3. Planning study
4. Produce concept designs
5. Prototype the designs
6. Legal requirements
7. Demonstration Project
8. Monitoring and review of the demonstration project and publication of designs and results
9. Further demonstration projects

Activities 1-3 will take up to 6 months (once a suitable project has been identified) and are estimated to cost £132,000. This research could be funded by HNDU managed through the DH Knowledge Centre (Route Map A).

Activities 4-5 will take a further 6 months and are proposed to be 50% funded by pipe manufacturers with Innovate UK providing match funding at a cost of £120,000 with Industry investment of £120,000.

Activities 6-8 will take up to 12 months and require support from HNDU or Strategic Energy Funding to collate demonstration project data and insight; also for the legal requirements and the monitoring and reporting on the project at a cost of £55,000 but the capital works would be financed by a DH developer on the basis of future heat sales.

Activity 9 will involve further demonstration projects which are expected to be self-financing.

The route map is dependent upon Route Map A: Knowledge Management, Research and Training for greatest effectiveness and will benefit from smaller pipe diameters advocated in Route Map B: Low Flow Rate Design.

Solution Description

Current challenge

Stage 1 showed that civil engineering contributes around 40% of the overall capital costs of DHNs. This challenge aims to reduce those costs by replacing trench excavation with above ground routes. In particular, the majority of this cost is in the street mains and branch mains to each house as this is by far the longest length of network. The cost of burying the pipework below ground is very high in low density housing and this will limit the scope of a DH network.

Proposed Solution

It is proposed to install much of the street and branch mains pipework above ground. This involves routing the flow and return pipes either by: (i) attaching them to the external wall of the buildings, or (ii) including them within the buildings themselves (either through loft space or cellars). This is generally cheaper than the current approach as the civils work for excavating and reinstating trenches is avoided. Both of these routing solutions are included within this route map as they share common issues and are described further below.

External Wall

In this solution, the pipes run along the external wall of the houses and will be insulated and covered in a suitable cladding to provide an aesthetic finish. The route could be on either the front or rear elevation depending on visual impact and available space. Three options for height exist: (i) below the doorway or ground floor windows, (ii) above the ground floor doorways and below the first floor windows, or (iii) at eaves level. The branch pipes into the dwelling could enter through the soffit boards into the attic space, through the wall into the first floor or through the wall at ground floor level. For semi-detached and detached houses a pipe bridge would be required to span between the properties at the level of the main run.

A further variant is to incorporate this solution with external wall insulation which avoids the need for pipe insulation or a specific cladding of the pipework as this would be run within the thickness of the wall insulation. However this option has not been included in the cost analysis and the solution is not dependent on external wall insulation.

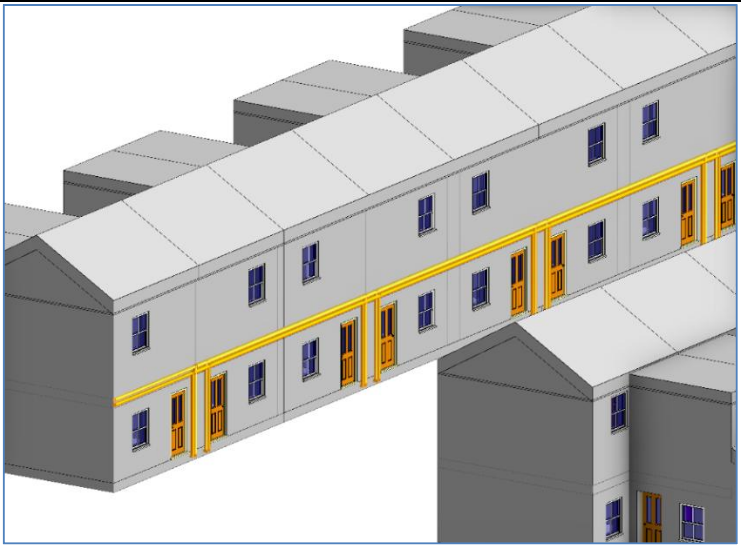


Figure 13: Typical arrangement of external wall pipe on front elevation about doorways with entry at ground floor level

Loft space/Cellar

In this solution, the pipes are installed either within the loft space or within cellars where these exist, passing between properties through the party walls. This has the benefit of less visual impact and very short branches within the property. For the loft space the pipes would be routed at low level at one side of the attic to minimise impact on storage space. For semi-detached and detached houses a pipe bridge would be required to span between the properties at the level of the main run.

Figure 14: Typical arrangement of loft space route for detached houses

Applicability

Both of these solutions could be applied to terraced, semi-detached and detached houses, with pipe bridges being required for the semis and detached. The use of pipe bridges will add to the cost and be more visually intrusive, and so the solution will be most suitable for semi-detached and detached houses that are built relatively close together. The main constraints will be visual impact on historically important elevations, and the presence of features such as mouldings and bay windows. The eaves route would have less visual impact but may only be feasible where there is significant projection of the roofline. The most suitable application would be for pre-1919 terraces, of which there are 2.5 million in the UK, and for which (as these are often relatively small) the conventional approach results in disproportionately high costs per kW of connected load.

Figure 15: Typical pre-1919 terraced housing – note electricity distribution is external at eaves level from junction box on wall

Current Barriers to and Requirements for Implementing Solution

Assessment of Barriers

The main barrier to this solution is customer acceptance given the more direct impact on the property and the need for most customers in a street to agree to have pipework installed on their property which will serve other properties in the street. This barrier could be addressed if there were regulations that mandated connection to DH in certain areas or a policy that restricted the use of gas in such areas. Whilst a regulatory regime which required all householders to connect would be very advantageous for this solution (and for DH generally) it is not essential as if a few householders did not agree to allow the pipes on their property this would not rule out the solution although the benefits would be reduced.

There will be a need to develop a wide range of design solutions to suit different house types and to deliver acceptable aesthetics. These solutions will need to be readily available and not designed as a bespoke item for every street otherwise design costs would be too high. There is a lack of knowledge about the details of the designs of existing housing facades, dimensions, finishes, features as well as loft space and cellar details, etc which will be needed so that standardised solutions can be developed to cover the most common applications.

Other technical issues will include the need to ensure high integrity of joints to minimise the risk of leaks or a method to prevent leaks causing damage to the property, especially for the loft space route.

It will be essential to ensure that fire separation is not degraded and no other new health and safety risks are introduced.

There will need to be standard legal agreements for the householder to sign to accept the pipe installation and provide access for maintenance at all times, and arrangements for the transfer of the agreement when the property is sold.

Planning permission would be needed and this would need to be for the whole installation as a separate planning permission for each house would be impractical. It is possible that planning authorities may allow some routes to be installed under permitted development rights.

Health and safety issues include working at height especially for pipe bridges when using the loft space route and risks of working in a constrained space in the attic area. These risks will be minimised by the use of pre-fabrication wherever possible so that site working is reduced and by the use of lightweight materials i.e. plastic pipes rather than steel.

Development requirements

Technical

The technical developments required and areas where design decisions are needed include:

- A set of pipe products suitable for the application including joints, supports and tees
- Pipe cladding on external wall for a range of existing finishes and details to minimise visual impact
- Design of a system which replaces soffit and fascia boards and gutters with a unit providing these functions and incorporating insulated pipes (may be an option for properties where these parts need replacing anyway)
- Pipe bridges for semi-detached and detached for both loft space and external wall routes to minimise visual impact
- Methods to deal with thermal expansion
- Methods to deal with change of level between properties
- Type of fire stopping at party walls in loft spaces and cellars
- Type of pipe insulation and whether pre-insulated or site insulated
- Method of entry into loft space from outside
- Entries into living space (through external wall) or through ceiling (from loft space).
- Leak detection system to provide greater assurance to property owner
- Damage limitation from leaks e.g. pipe in pipe system or drip tray
- Protection from vandalism
- Method for rerouting of other services as necessary e.g. rainwater down pipes, power cables, communications and satellite cables

Planning

Local planning policy would need to be developed to classify this solution as 'permitted development' i.e. not requiring a full planning permission for each property, subject to following local rules controlling the appearance and design.

Legal implications

A standard form of agreement for a wayleave or easement would be required to provide for the route for DH and to provide access to the pipe route for maintenance. These provisions will need to exist as a standalone agreement whether or not the customer takes heat, and could include a one-off payment or an annual fee for the rights to the route. Termination of the agreement by the DH company would be permitted with 12 months notice. Termination by the owner of the building would only be possible in the event of exceptional defined circumstances such as demolition of the building or in the event of fire, major subsidence etc or if the DH company was in breach of its obligations.

Commercialisation requirements

An analysis using the Ansoff matrix was carried out. The proposed external wall and loft space / cellar route is a new product – it is a novel approach as there have been few examples of this solution especially within the context of existing mixed tenure housing.

The commercialisation requirement is therefore one of Diversification and the commercialisation activities identified needed are:

Market Development

It will be important to understand the view of the customers on the proposed routes for DH and especially their likely concerns on risks to their property and impact on property values. The context will need to be explained carefully as the benefits of the solution are likely to emerge in the longer term when gas is either more expensive or less widely available or if regulations restricting the use of gas are brought in. The results of the market research will inform the designs to address particular concerns that the customer has. In selling the concept the customer will need to be convinced that the visual impact and providing a route for pipes to serve the whole street is more than compensated for by achieving a lower heat price compared to the conventional approach.

Product/Design Development

Based on a design workshop held with interested manufacturers and designers and other discussions, many of the fundamental components needed (pipes, insulation, fittings, joints etc) already exist and the emphasis is mainly on developing a family of designs using standard components that would be acceptable in terms of visual impact and low cost to install. There was a desire to maximise the use of off-site fabrication. The initial need was for further research to categorise the design of various house types so that design work could be undertaken with a better knowledge base. A prototype stage to prove the concept is envisaged followed by a demonstration project which will provide the opportunity for further refinement but also assist in the development of the market.

Supply chain and logistics

From the designers' workshop it was concluded that all of the supply chain already exists in terms of individual products. The installation work would also be similar to other work that might be carried out in housing e.g. roof repairs, gutter replacement etc. The logistics of carrying out an installation efficiently over a number of streets at a time would need to be studied after further knowledge has been gained from the prototype and demonstration projects.

Aspects Beyond the Scope of this Route Map

This route map will benefit from the work in two other route maps being taken forward at the same time:

- Route Map A: Knowledge Management, Research and Training. Knowledge sharing of the potential for using above ground routes, especially by disseminating the results of the demonstration project.
- Route Map B: Low Flow Rate Design. Low flow rate leading to smaller pipe diameters which will assist in minimising visual impact especially for the external wall route.

Route Map Proposal

The activities identified requiring further work and validation for this route map are:

1. Research into aspects of housing design relevant for above ground routes
2. Market research into customer attitudes
3. Planning study
4. Produce concept designs
5. Prototype the designs
6. Legal requirements
7. Demonstration Project
8. Monitoring and review of the demonstration project and publication of designs and results
9. Further demonstration projects

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The external funding of Activities 1-9 is estimated at £427,000 including £120,000 industrial investment on an Innovate UK match-funded basis.

Activities 1, 2, 3 and 6 are generic research activities for DH which would be best funded by BEIS-HNDU managed by the proposed DH Knowledge Centre (see Route Map A). Activities 4 and 5 will be led by manufacturers and it is envisaged that Innovate UK could match fund these projects.

The demonstration projects are expected to be funded by a DH developer as it is intended that this will be a fully commercial offering. Support funding for monitoring, customer research and reporting will be required and Strategic Energy Funding is a potential source for this stage.

Activity 1: Research of Aspects of Housing Design relevant for above ground routes

Aims

To better understand the range of designs of UK housing and the likely constraints for the solutions which will enable specific design solutions to be developed for a wide range of applications.

Introduction

It is proposed that this research will identify the range of designs which would cover the majority of urban housing. The parameters defining the designs would include: age of property, number of storeys, external finish, colour and materials used for each external finish, height above first floor windows, height of door threshold, front elevation design (e.g. bay windows), rear elevation designs (e.g. rear extension), loft conversion actual and potential, separation distance from adjacent houses (for semis and detached), amount of eaves projection, distance of front wall from pavement, height of door threshold, size and depth of cellars etc. Whilst some data may be available from national databases it is likely that sample survey work would be required for areas in a number of sample cities (to establish regional variations) with extrapolation to a national level.

Work programme

- Define the parameters to be established
- Review existing data sources and published research work
- Select the cities to be sampled
- Select the broad residential areas to be surveyed, reflecting a spread of age and type but concentrating on the most prevalent types
- Carry out sample survey and record results (using a mix of fieldwork and street view web-based mapping or other techniques)
- Create categories of housing types with sub-categories to cover the majority of the houses surveyed
- Prepare report including diagrams, drawings, data tables

Team

- Architectural practice or an architectural historian in an academic institution. A DH engineering consultancy would need to be part of the team to define the level of detail and importance that would be needed for each design aspect.

Timescales

- 6 months

Costs

- £75,000 for consultancy fees. This is based on the following:
  - Engineering work to define the parameters and review the outputs and final report, 10 days at £500 per day (£5000)
  - Architectural consultancy to review existing data and to plan the survey process, 10 days at £500 per day (£5,000)
  - Surveying work in 10 cities, 10 areas in each, 2 days per area, 200 days at £300 per day (£60,000)
  - Architectural consultancy to prepare final report, 10 days at £500 per day (£5,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to support the basic research on house design that will enable more radical routes for DH to be designed and installed to reduce DH network costs especially in lower density housing

Success criteria

- Housing categories defined with sub-categories for e.g. wall material finish that cover 80% of the urban housing market (excluding flats)

Activity 2: Market research into customer attitudes

Aims

As customer acceptance is a critical element of the solution, market research is proposed to understand the customer concerns and attitudes relating to installing DH in this way. This will enable the design to be developed taking account of these concerns.

Introduction

As the concept of DH is not well understood there will be a need to carry out qualitative research by means of focus groups and one to one discussions rather than a general survey/questionnaire. The research will need to consider owner-occupiers, landlords and tenants and a range of socio-economic groups in a number of geographical locations where DH might be developed. The areas to explore include:

- Impact of route on property – risk of damage during construction and operation
- Impact of route on value of house
- Benefits of lower cost of heat supply vs the above
- Relative merits of the various designs that have been proposed
- Legal agreements – willingness to sign long-term wayleave/easement and key issues and concerns

Work programme

- Develop an introductory information pack on DH
- Define the key questions which form the substance of the research
- Identify groups of participants – tenures, socio-economic groups, geography
- Set-up focus groups and face to face interviews
- Carry out research work with the focus groups and other respondents, as required
- Collate information and prepare report

Team

- The work would be delivered by a market research organisation with experience in domestic heating issues.

Timescales

- 3 months

Costs

- Market research fee £35,000. This is based on the following:
  - Planning of survey work and preparation: senior researcher 20 days at £500 per day (£10,000)
  - Setting up and running up to 12 focus groups and face to face interviews: researcher 50 days at £400 per day (£20,000). This fee allows for respondent incentives to participate.
  - 12 focus groups would be a sufficiently robust sample size for work of this nature but more groups could be added to provide more comprehensive geographic coverage, if required

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to understand customers' and homeowners' views with respect to the use of alternative routes for DH networks to assist in the delivery of lower costs

Success Criteria

- Completion of research to understand range of views that consumers have when considering DH compared with a conventional heating system, with the characteristics of the different segments identified

Activity 3: Planning Study

Aims

To establish the views of planning authorities in relation to the above-ground routes to inform the design development stage. If the planning views are very negative then the solution will need to be realigned or cancelled.

Introduction

It will be important to understand the likely response of planning departments to these proposals. For example, in some areas the front elevations of houses are seen to have a high heritage value where brick patterns and moulding details have been used. Often in these cases the rear elevation may be a preferred option. The impact of pipe bridges between properties would also be of concern with respect to visual impact of the streetscape.

It is proposed that 10 planning departments will be contacted in various areas of the country to establish the planning concerns and how these can be addressed. The aim would be that a single planning application would be submitted for a community area on behalf of residents and the mechanism for doing this (e.g. under permitted development rights) will also be discussed.

This work will be carried out in parallel with the research on housing typologies and market research. The conclusions reached would be influential in determining the designs so that an acceptable solution in terms of planning is developed.

Work programme

- Prepare work programme
- Prepare questionnaire
- Produce information pack with sample designs for a range of routes/typologies and background on DH and its potential role in combating climate change
- Set up and interview planners from 10 planning departments with geographic spread
- Review results and hold further follow-up discussions
- Collate results and prepare report

Team

- A specialist planning consultancy will be required for this activity with understanding of both energy issues and the domestic architecture involved, supported by an engineering consultancy with knowledge of the DH industry

Timescales

- 6 months

Costs

- Specialist consultancy fee £22,000. This based on the following:
  - Prepare work programme and interview questionnaire: senior planner 10 days at £700 per day (£7,000)
  - Produce information pack together with sample drawings and materials: engineer 6 days at £500 per day (£3,000)
  - Carry out face to face interviews with 10 planning departments: planner 10 days at £500 per day (£5,000)
  - Review results and hold follow up discussions: senior planner 5 days at £700 per day (£3,500)
  - Prepare report: senior planner 5 days at £700 per day (£3,500)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to establish the position of planning authorities regarding the installation of DH pipework externally on buildings so that the design can take account of the planning constraints whilst delivering lower cost solutions

Success criteria

- From the research establish the likelihood of planning permission being granted for the novel routes in a range of typologies and the way in which this would be obtained. Provide information to designers to maximise the likelihood of planning being granted or alternatively provide information to stop further work on this route map if planning views are too negative.

Activity 4: Produce concept designs

Aims

To develop a family of designs that can be applied to the majority of the urban housing stock to reduce costs of DH significantly, whilst also meeting the concerns of building owners and residents and the planning authority.

Introduction

With the knowledge gained from the research into housing characteristics, the market research of customers and feedback from planners, a number of designs will be developed for each of the identified typologies. Each design may then lead to the need for a specific product development e.g. for a particular UPVC extrusion. The number of permutations of designs is expected to be relatively limited in scope and would be customisation of existing component ranges rather than the development of completely new components. The main area of development work would be the outer cladding for the external pipework. The loft space and cellar route would use available conventional products.

Manufacturers have expressed interest in developing products with their own resources although some funding to support is proposed.

Work programme

- Review housing typologies report, market research report and planning report
- Develop designs for loft space route
- Develop designs for external wall route
- Define need for specific product developments
- Develop products and manufacturing process
- Establish sequence of work on site and review 'buildability' of design
- Refine design for loft space route
- Refine design for external wall route
- Prepare final designs ready for prototyping

Team

- DH pipe manufacturer(s) or installer(s) to lead
- Supported by engineering design consultancy and architectural practice as required

Timescales

- 6 months

Costs

- Each of 3 manufacturers is assumed to invest the following in developing suitable designs for the solution:
  - Design engineer/architect development time:
    - Review reports: 2 days at £500 per day (£1000)
    - Loft space design: 5 days at £500 per day (£2,500)
    - External wall design: 10 days at £500 per day (£5,000)
  - Specific product development: 10 days at £500 per day (£5,000)
  - Review site work and buildability: 2 days at £500 per day (£1,000)
  - Refine design loft space: 5 days at £500 per day (£2,500)

- Refine design external wall: 10 days at £500 per day (£5,000)
- Final designs for prototype: 10 days at £500 per day (£5,000)
- External design review: 6 days at £500 per day (£3,000)

- Total £30,000, or £90,000 for three projects arising from an Innovate UK call.

- Assuming 50% contribution from Innovate UK: £15,000 per manufacturer.
- Total contribution from Innovate UK for three separate teams £45,000.

Funding & motivation for investment

- Funding would be by the pipe manufacturer based on the commercial potential. Manufacturers would be motivated by the potential for significant future sales if a cost-effective solution is developed for lower density housing
- Match funding by Innovate UK to develop the technology in the UK and have the capability for export. Innovate UK would be motivated to support UK industry in meeting this need for the innovative solution, in contrast to the conventional solution which mostly involves imported pre-insulated pipe

Success Criteria

- Develop the design sufficiently that the prototype stage can be taken forward.

Activity 5: Prototype the designs

Aims

To prove the designs developed under Activity 4 in as close to a real application as possible so that the designs can be further refined prior to delivering the demonstration project. To develop the designs so that site work is minimised and health and safety risks are reduced or mitigated.

Introduction

Once the design work has been completed to a certain level of detail it is proposed to carry out a trial installation to test a range of designs on an actual group of buildings. Ideally this would be undertaken in conjunction with a general renovation of a group of houses that would be unoccupied during the works. As a suitable group renovation project may be difficult to identify, an alternative would be a full-scale mock-up in a factory. It is envisaged that the three manufacturers involved in Activity 4 would proceed with prototyping.

Work programme

- Identify suitable sites that provide the opportunity to prototype a range of designs
- Co-ordinate work with other teams to ensure a spread of applications
- Prepare specific designs for the site identified
- Produce product assemblies
- Carry out site installation
- Review work at key stages
- Modify design for next dwelling (iterative process)
- Complete the installation
- Document the design improvements made
- Remove prototype installation and make good or leave in place if of value to owner (e.g. if it is likely to be connected into a DH network in the near future)

Team

- DH pipe manufacturer(s) or installer(s) to lead
- Supported by engineering design consultancy and architectural practice as required
- Building owners to provide permission and support

Timescales

- 9 months (may be longer if site proves difficult to identify and permissions take time to obtain). However the fall back would be a full-scale factory mock-up.

Costs

- The site identification, design and further development work would be carried out and funded by the manufacturers. At this prototype stage, significant costs would be incurred for materials, product assembly and site labour. This is estimated at £5,000 per property so £25,000 for a single group of 5 houses or £75,000 for 3 sites developed by 3 separate suppliers.

Funding & motivation for investment

- Funding for the design and development work would be by the pipe manufacturers for commercial potential. Manufacturers would be motivated by the potential for significant future sales if a cost-effective solution is developed for lower density housing
- The additional funding for the three prototype installations (£75,000) would be obtained from Innovate UK as a continuation of the product/design development in Activity 4. Innovate UK would be motivated to support UK industry in meeting this need for the innovative solution, in contrast to the conventional solution which mostly involves imported pre-insulated pipe

Success Criteria

- Provide the necessary design development knowledge that will enable the demonstration project design to proceed without further prototyping

Activity 6: Legal Requirements

Aims

To develop standard agreements that can be used in conjunction with the loft space and external wall routes to provide the necessary rights to the DH developer and to protect the customer's interests. To provide these for the long-term and also for use in the demonstration project.

Introduction

As preparatory work for the demonstration scheme it will be necessary to develop standard agreements for wayleaves or easements for the proposed pipe route. These would be signed between the building owner (freeholder and leaseholder) and the DH company. There may need to be standard amendments to rental agreements produced as well.

Work programme

For both the loft space and external wall route wayleaves or easements will be needed. The agreements will need to cover issues such as:

- Rights to install pipes within property boundary
- Rights of access for maintenance
- Liability for damage to property
- Liability for damage to the DH pipework
- Liability for planning permission
- Responsibility for insurance provision
- Termination rights
- Payments
- Dispute resolution

The draft agreements will be tested by sharing with legal firms who act as property lawyers for local authorities and housing associations.

Team

- Legal practice familiar with wayleaves and easements for utilities

Timescales

- 6 months

Costs

- £30,000. This is based on the following:
  - Lawyer: 10 days for loft space route at £1500 per day (£15,000), 10 days for external wall route at £1500 per day (£15,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to establish the legal issues surrounding installing DH mains within the boundary of individual dwellings and whether a form of legal agreement acceptable to all parties can be established to enable the lower cost solution to be implemented

Success criteria

- Two draft legal agreements produced that can be used for the loft space route and external wall route, initially for the demonstration project

Activity 7: Demonstration project

Aims

To install a DH supply to a range of house types using both external wall and loft space routes. The project will be used to demonstrate the benefits of the approach and so promote its use on other schemes.

Introduction

A demonstration project is proposed as a way of marketing the concept. Visual impact is difficult to judge in the abstract and an actual project will allow potential heat customers and DH developers to physically see the end result. It will also allow the installation to be undertaken at a reasonable scale and the impact of the construction process on residents can be judged accordingly.

The first full demonstration project will involve a street or streets of houses occupied by residents, preferably all able to commit to connection (ideally the majority would be in social housing ownership). The area would have a mix of housing types (ideally Typologies C, D and E) and where both external wall and loft space concepts can be trialled. Ideally it could connect to an existing district heating scheme, if not a small-scale Energy Centre will need to be constructed. About 50-100 dwellings are envisaged.

Finding the most suitable location would be the first step which may take a few months together with establishing the necessary legal agreements with the property owners.

A DH developer company would need to take the lead in this project as they will be the long-term supplier of heat to the customers and will finance the investment in the network. There will need to be a very high degree of market penetration. If a social landlord is involved for a majority of the property that would be an advantage in delivering market penetration and providing confidence to other residents. The motivation for a social landlord would be in obtaining a low cost low carbon heat solution for their tenants and in being involved early in an emerging heat technology. Other residents would be motivated primarily as a means of saving money on their heat supply. Designers would be appointed by the DH company (or may be in-house). An independent monitoring and evaluation consultant would also be appointed through the DH Knowledge Centre (see Activity 8).

The intention would be that the demonstration project would be commercially viable so the cost of the design and installation would be financed by the DH company.

This demonstration project could be combined with the one proposed for Route Map B - Low flow rate design - as this solution will benefit from low flow rates and smaller diameters.

A stakeholder consultation group will be formed at the start of the demonstration project so that DH developers, social housing providers and end users can be informed about the project at an early stage and offer suggestions regarding the design, installation and other aspects.

Work programme

- Identify locations for demonstration project
- Marketing of scheme to customers and local authorities
- Obtain sales agreements and other permissions
- Design and construct the scheme
- Commission and commence operation
- Review the design and construction and lessons learned

Team

- DH developer company
- DH designers
- Supply chain for pipe products

Timescales

- 18 months

Cost

- Demonstration project delivery financed by DH company
- Strategic Energy Funding (SEF) will be used for identifying the demonstration site and negotiating with the DH developer, a sum of £15,000 has been allowed based on 20 days of a senior DH specialist at £750 per day.

Funding & motivation for investment

- The DH company will finance the demonstration project mainly through the long-term heat sales from the customers. If the business case is insufficient for this then additional funding would be available because of the opportunity to develop a new approach that could be more cost-effective in the future with replication and to demonstrate thought leadership in the industry.
- Strategic Energy Funding (SEF) will be used for setting up the demonstration project.

Success Criteria

- Delivery of a demonstration project that shows how costs can be significantly reduced compared to a conventional design with acceptable visual impact and with a positive response from customers

Activity 8: Monitoring and review of the demonstration project and publication of designs and results

Aims

The aim is to capture the knowledge from the demonstration project and identify the benefits and produce information in a variety of formats so that the concept can be marketed to other DH companies, the DH design community and local authorities considering DH schemes.

Introduction

An independent monitoring and review consultant will be appointed to review the design and construction phase and establish the costs and benefits compared to the conventional approach. Customer experience will also be obtained through interviews with a sample of residents. The demonstration project will be written up as a case study with standard design details published for each typology so that the designs can be easily replicated for the most common situations. This material will also be used as the basis for presentations at conferences and as part of training programmes. The DH Knowledge Centre described in Route Map A will lead this activity, appoint the authors and be the vehicle for dissemination of the solution and training in its application. The target audience will be other DH developers, their designers and social housing providers as well as local authorities who are planning DH schemes.

Work programme

- Monitor the design and construction activity and obtain costs
- Compare costs with conventional designs
- Carry out customer surveys with respect to the construction phase and the design and visual impact
- Prepare a detailed technical report on the project including standard design details
- Prepare a shorter case study paper for use in journals, conferences etc
- Prepare a Powerpoint presentation to accompany the case study

Team

- Engineering design consultant
- Customer research company

Timescales

- 3 months

Costs

- £25,000. This based on the following:
    - Monitoring of design and construct work over 12 months: 24 days at £500 per day (£12,000)
    - Cost comparison: 5 days at £500 per day (£2,500)
    - Customer surveys of 25 residents, 14 days at £500 per day (£7,000)
    - Prepare detailed report incorporating design details: 5 days at £500 per day (£2,500)
    - Prepare case study report and Powerpoint presentation: 2 days at £500 per day (£1,000)

Funding & motivation for investment

- It is proposed that Strategic Energy Funding (SEF) will be used.
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success Criteria

- Documentation produced on the demonstration project that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer and including details on the customers' response to the solution

Activity 9: Further demonstration projects

Aims

To further market the concept nationally further demonstration projects will be initiated in locations where they will enhance and extend the planned DH network.

Introduction

A further 5-10 projects of a similar size will be implemented concurrently following the demonstration project. They will be selected to demonstrate the concept in a wider range of dwelling types and locations across the UK. This will provide real examples of the approach which will help convince local customers and DH developers of the benefits. Potential customers will be able to see the level of visual impact and read the feedback provided by the residents involved. The cost reductions can be demonstrated for an actual installation in a local city which will feed into economic assessments of DH in any given area and this will in turn lead to a greater market share for DH. The projects will be selected where DH is already being considered for the city and where a reduction in cost using this approach will have a significant impact on the overall direction of the scheme e.g. developing the DH scheme into a geographical area containing a large number of terraced houses where this solution could be successfully applied.

Work programme

- Identify locations for demonstration project
- Marketing of scheme to customers and local authorities
- Obtain sales agreements and other permissions
- Design and construct the scheme
- Monitor scheme and obtain customer feedback
- Prepare report on the project
- Prepare marketing materials to publicise the project nationally

Team

- DH company
- Local Authority

Timescales

- 12 months – 24 months depending on scale

Costs

- Self-financing – case study material and reports provided by the DH company

Funding & motivation for investment

- DH company will wish to demonstrate benefits of the project to future customers so as to expand the network and show thought leadership within the industry
- Strategic Energy Funding (SEF) will be used for collating demonstration project data and insight; also for dissemination via the DHKC.
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success Criteria

- Documentation produced on all of the demonstration projects that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer and including details on the customers' response to the solution

6.1 Annex 1: Work programme

Route Map C - External wall route and loftspace route - Activities, costs and timescales

Activity	Cost	Year 1				Year 2				Year 3				Year 4			
	£	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Research on housing designs	75,000																
2. Market Research	35,000																
3. Planning study	22,000																
4. Product concept design	90,000																
5. Prototype and development	150,000				identify site	design and construct											
6. Standard legal agreements	30,000																
7. Demonstration project and monitoring	15,000					identify project		design		construct							
8. Publication of results and training materials	25,000																
9. Further demonstration projects	-															ongoing	
TOTAL	442,000																

7 Route Map D: Trenchless Solutions

Route Map Summary

This solution aims to reduce the cost of DHN installations by replacing trench excavation with trenchless approaches; specifically, horizontal direct drilling (HDD) and 'core and vac' excavation.

The core technologies for these techniques currently exist. However, the following barriers to wider deployment in the UK have been identified:

1. DH developer and designer's attitudes to and understanding of the capabilities of trenchless technologies
2. Ability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for street main piping
3. Ability to achieve HDD branch pipe installation to properties from 600mm core and vac holes
4. Down-the-hole (DTH) remote live tapping adapted for connecting insulated DHN branch pipes to insulated street mains from the street surface.

The main activities proposed in the route map are to:

1. Research DH developers' understanding of and attitudes to trenchless solutions and develop value propositions to encourage adoption of these technologies
2. Demonstrate what is possible now through trenchless technologies
3. Learn and disseminate the findings
4. Develop the capability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping
5. Develop the capability to HDD property branch pipes from 600mm core and vac holes
6. Develop the capability to DTH remote live tap branch pipe connections

The total cost of Activities 1-3 is estimated at £110,000 plus capital costs of pipes and developer time for the demonstration project (which are assumed to be included in the capital cost of the project). This could be funded by HNDU and Strategic Energy Funding.

Activities 4, 5 and 6 will require industrial research and development projects from pipe and HDD equipment manufacturers. Each has been estimated to take at least 2-3 years with costs between £700k and £1.5m. Innovate UK could match fund these projects at an estimated cost to Innovate UK of between £350-750k each.

Solution Description

Current challenge

Stage 1 showed that civil engineering contributes around 40% of the overall capital costs of DHNs and identified the need for solutions to reduce this. Trench excavation is a key factor in the civil engineering costs as it is a timely process. It is also disruptive to road users and other stakeholders.

Figure 16: Trench-installed DH pipe (Source: Rehau UK)

Proposed solution

This is a cluster of solutions with the aim to reduce the costs of civil engineering where possible by replacing trench excavation with trenchless approaches. These are faster, less disruptive and deliver considerable cost savings compared with traditional trench excavation.

The solution particularly focusses around the use of horizontal directional drilling (HDD) coupled with “core and vac” excavation both within the street and for the branches between the street and the property.

- Horizontal Directional Drilling is a guided trenchless method in which a pilot borehole is drilled along a pre-determined bore path from the surface with minimum disturbance. Subsequent hole enlargement follows the path set by the pilot bore and the DH pipe is then pulled through the resulting hole.

Figure 17: HDD equipment (Source: Tracto Technik)

- Core and vac excavation involves drilling a hole through bound or concrete surface layers, removing the resulting core, then removing any unbound material through vacuum extraction to gain access. Following work in the hole, the unbound material is returned to the excavation and compacted in layers. The core is then grouted back into place to match the original surface level.

The solution is assumed to be particularly applicable for the following typologies:
- Typology C: Terraced
- Typology D: Semi-detached
- Typology E: Detached.

These typologies have a reduced risk of the drilling machine hitting underground objects including services (as the density of existing services is much less in lower density areas) and less need for any additional trench excavation works for both the main and branch pipes (e.g. excavated holes to confirm safe passage of drilling past services). Branch connection pipe lengths are also greater per property so the benefits of the approach are more significant.

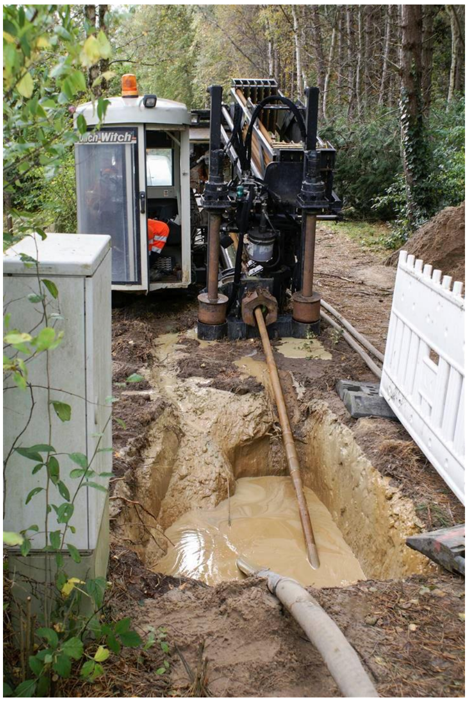


Figure 18: HDD in Operation (Source: Rehau UK)

Current Barriers to and Requirements for Implementing Solution

Assessment of barriers
The key barriers to wider deployment of this solution are:

- Market attitudes to and understanding of the potential of trenchless technologies
- Ability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping
- Ability to install by HDD a property branch pipe installation from 600mm core and vac holes
- Ability to perform down-the-hole (DTH) remote live tapping for branch pipe

connections

Each barrier is assessed in more detail below.

Designer and Developer Attitudes and Understanding

Currently feasible: The following maximum DH pipe diameters are already feasible with a 300mm diameter hole drilled by a standard HDD rig (source Rehau UK):

- Largest single pipe coil: 1 x 140mm OD PEX pipe, 202mm outer jacket (i.e. 2 drill holes are needed for flow / return)
- Largest twin pipe coil: 1 x 75+75mm OD PEX pipe, 202mm outer jacket (only 1 hole required as flow and return)
- Two largest single flow and return pipes to fit in 1 x 300mm hole: 2 x 63mm OD PEX pipe, 142mm outer jacket

Future potential: When reduced peak flow rate designs (route map B) have become the norm, Typologies C, D and E will then typically have maximum pipe diameter requirements of 80mm for street mains in the target typologies. As the largest twin pipe coil that can currently be used with HDD has a bore diameter of 75mm, HDD could be then used on more sections of projects in these typologies (depending on length of streets).

Despite these current and future opportunities, many DH designers have limited understanding of what is feasible and viable with trenchless technologies. As a result, they are rarely selected except to overcome situations where trenches are not practical e.g. crossing rivers or streams.

Ability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping

Trenchless HDD currently has a maximum of 300mm diameter holes using standard rigs. (Larger rigs will go to 450mm diameter but require much bigger machines that would take up considerable space on the road around each pit and are not considered viable for DH application).

A hole of 300mm will theoretically permit pipe diameters up to 280mm but current pipe materials and designs do not allow DH pipe with outside diameters greater than 202 mm to be coiled and continuously fed into the HDD equipment.

Figure 19: Coiled DH Pipe (Source: Rehau UK)

To be able to deliver heat for all Typology C, D & E requirements a twin-bore pipe with 80mm bores and up to 280mm outer diameter is required. Whilst this size of pipe can currently be fed in individual sections into an HDD hole and welded, to be efficient a solution will need to be found to continuously feed wider diameter pipe from a reel. As well as the technical challenges of coiling the pipe this solution will also need to ensure that the pipe can be transported to site and physically handled safely and efficiently on site.

HDD property branch pipe installation from 600mm core and vac holes

HDD to install branch pipes to properties is currently feasible using pits at both ends but digging pits is costly, disruptive and time consuming. HDD technology also already exists to drill to properties from street using core and vac holes as small as 600mm. However, this combination of HDD and core and vac technology cannot currently be used to install branch DH pipes. The main barrier is the ability to bend DH pipe through a 90-degrees radius in narrow diameter holes as indicated in Figure 20.

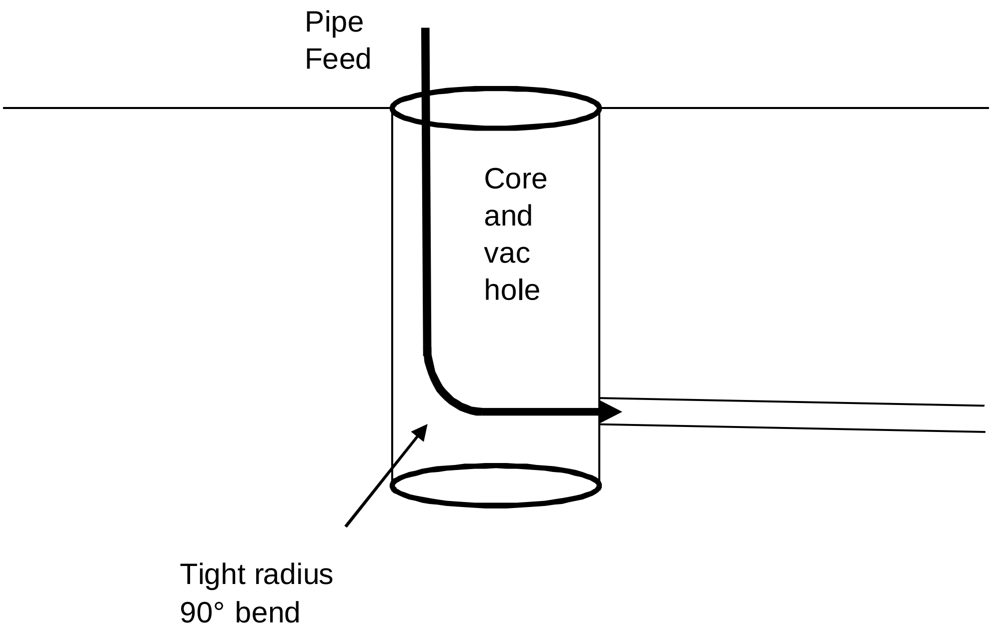


Figure 20: Difficulty in installing DH pipe

Down-the-hole (DTH) remote live tapping for branch pipe connections

Currently to weld/join every DH branch connection to the main pipe requires a welder/joint fitter to work man in hole (MIH). If a solution can be found to remotely live tap branch DH pipes to the main pipe without needing manual welding/jointing it will avoid the need for the costs of an operator working down the hole and time- and resource-demanding temporary works permits.

Development requirements

As previously discussed much of the underlying technology for this solution is already available. However, the following technical developments would overcome the barriers to wider deployment as identified above:

- Ability to continuously feed wider diameter DH pipe into HDD equipment
- Ability to install by HDD property branch pipe installation from 600mm core and vac holes
- Ability to perform a down-the-hole (DTH) remote live tapping for branch pipe connections.

Commercialisation requirements

This solution uses established products which will be mostly new to the DH market and hence the solution is described as Market Development: existing products into new markets.

A consortium of pipe manufacturers, directional drilling equipment manufacturers, and welding partners will be needed to commercialise this solution. A mechanism to pull them together and funding will be needed.

The key commercialisation requirements are:

- Market research. As this is mainly established products entering a new market the first requirement is market research to fully determine the level of understanding

and attitudes of developers and installers to the current and intended solutions. From these a set of commercial requirements can be developed.
- Compelling value propositions for the consortium to deliver the requirements.

There are also potential commercial synergies between this route map and the Shared Civils Solution (Route Map F): With the limitations on trenchless pipe diameter success is most likely with Fibre to the Home data connections. This addition of high speed data may also be an attractive addition to the consumer value proposition.

Aspects Beyond the Scope of this Route Map

Orpheus Project

The Orpheus Project is an EU funded project into HDD forward visibility and directional control. This route map has not attempted to replicate the Orpheus project but it should be monitored and lessons adopted from it.

Utility and Other Sub-surface Mapping

Whilst Orpheus aids live drilling; greater confidence in what lies beneath the surface will further improve the success and applicability of trenchless solutions. This is covered in:
- Route map E: Guidance & training for sub-surface mapping, survey & design
- Route map A: Updating standards and best-practice guidance.

Route Map B: Low Flow Rate Design

Whilst this route map is not dependent upon Route Map B, reduced peak flow rates are an enabler to lower diameter pipes which will in turn enable trenchless approaches to be used for a greater proportion of any DH network.

Route Map Proposal

The main areas requiring further work and validation for this route map are:
1. Research DH developers' understanding of and attitudes to trenchless solutions and develop value propositions to encourage adoption of these technologies
2. Demonstrate what is possible now
3. Learn and disseminate the findings
4. Develop the capability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping
5. Develop the capability to HDD install property branch pipes from 600mm core and vac holes
6. Develop the capability to DTH remote live tap branch pipe connections

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The total cost of Activities 1-3 is estimated at £110,000 plus capital costs of pipes and developer time for the demonstration project (which are assumed to be included in the capital cost of the project). This could be supported by HNDU and Strategic Energy Funding.

Activities 4, 5 and 6 will require industrial research and development projects. Each has been estimated to take at least 2-3 years at costs between £700k and £1.5m. Innovate UK could match fund these projects at an estimated cost to Innovate UK of between £350k-750k each.

This is a significant requirement for industrial funding and will need to attract participants to provide investment on a match funded basis. Instances of commercial collaboration occurred between stakeholders involved in project workshops (without financial stimulus) and this gives a good indication that there will be a positive response to the route map from industry.

Activity 1: Research DH developers' understanding of and attitudes to trenchless solutions and develop value propositions to encourage their adoption

Aims

To carry out market research to determine how well DH developers understand the current capabilities of trenchless technologies and their attitudes to the intended solutions. From these a set of commercial requirements can be defined and value propositions developed to enable industry players to deliver the requirements.

Introduction

A specialist consultancy/research company will be required to profile DH developers and identify groups with similar characteristics. Individual in-depth interviews will then be required to explore and understand the benefits and sacrifices they experience with the current solution as well as their understanding of and attitudes to trenchless solutions.

The specialist consultancy would then work with a consortium of drilling and pipe manufacturers to develop value propositions (e.g. function, speed, dependability, flexibility, price) that will be attractive to the Developers and Designers and how these can be used to develop the market.

Work programme

- Understand and profile the players in the market
- Select a sample of individuals to participate with appropriate expertise
- Qualitative research comprising in-depth interviews with individual organisations
- Review and adjust the profiles in the light of the interviews
- Develop market requirements and document findings
- Develop value propositions and approach to developing the market using a further workshop with industry as appropriate (participants could include some or all of those who participated in the depth interviews, if required).

Team

- Consulting organisation skilled in market research and value proposition development
- Consortium of HDD and pipe manufacturers

Timescales

- 6 months

Costs

- £40,000 for consultancy. This is based on the following:
  - 1 days at £1,000 per day to plan project and profile customer groups (£1,000)
  - 30 days at £500 per day for market research (£15,000)
  - 12 days at £750 per day to develop market requirements (£9,000)
  - 20 days at £750 per day to develop value proposition (£15,000)

Funding & motivation for investment

- Funding could be provided by HNDU
- HNDU's motivation would be to understand the attitudes of the market stakeholders in preparation for deploying Trenchless Solutions to reduce the cost of DH networks
- Industry participants would be motivated to contribute to the development of solutions and propositions that will reduce the time and cost of their projects

Success criteria

- Sufficient understanding is gained to be able to document the barriers to adoption of trenchless technologies (either perceived or real) and the development of value propositions that would make them attractive

Activity 2: Demonstrate what is possible now

Aims

To increase confidence in current trenchless capabilities through a part-funded demonstration project. The goal of the project will be to demonstrate that trenchless can be viable with current technology.

Introduction

The demonstration project is expected to take the form of a group of ~20 properties in one or more of typologies C, D and E. This number of properties should be sufficient to demonstrate the capability of trenchless technologies without being too time or cost demanding.

One proposal would be to use a semi-rural off-gas village with a new heat source and a small network. Alternatively, another could be an extension of an existing network (e.g. extension of the Olympic Park network into nearby properties if connections to suitable typologies are viable).

The demonstration project should include the following currently available solutions:

- HDD for main pipes with either
  - Twin pipe coil: 1 x 75+75mm OD PEX pipe, 202mm outer jacket or
  - Two single flow and return pipes in a 300mm hole: 2 x 63mm OD PEX pipe, 142mm outer jacket
- HDD for property branch pipes from pits – to build confidence that this use of HDD is feasible, even if not from a narrow core and vac excavated hole
- Man-in-hole live tapping of twin bore pipe
- Digging small pits or trenches at each property to allow pipes to surface and connect into property systems.

This is indicated in the diagram overleaf.

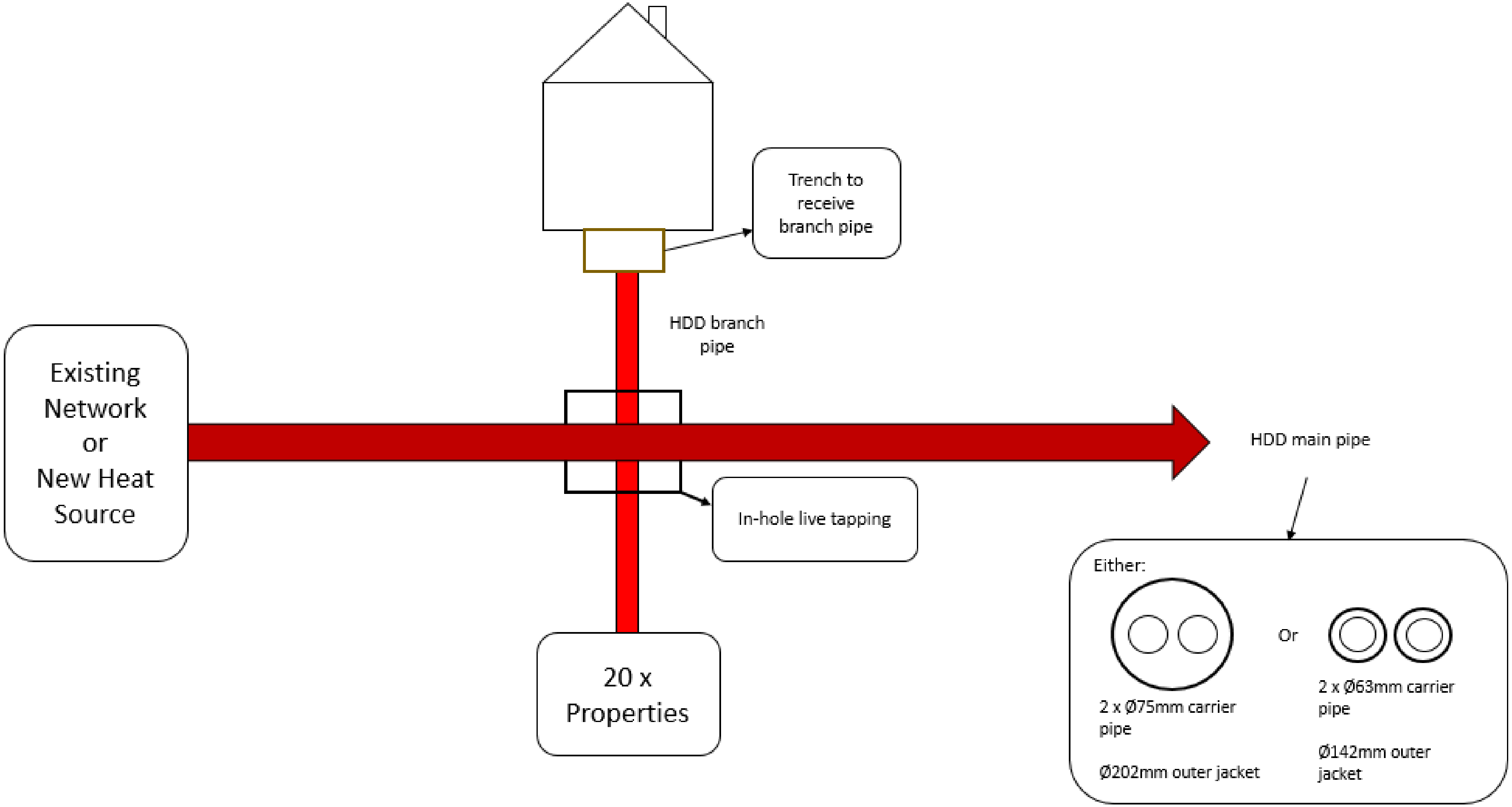


Figure 21: Demonstration project

Work programme

- Preparation
- Dig main pipe pit
- HDD install main pipe
- Reinstate
- Dig pits and HDD install 20 properties
- Man-in-hole live pipe tapping (parallel)
- Reinstate and clear site post street to home connections

Team

- The delivery team would be an established DH developer supported by specialist directional drilling and pipe equipment providers.

Timescales

- Up to 25 days (to allow for overcoming unexpected obstacles and delays)

Costs

- Project coordination and observation by specialist consultancy ~14 days at £1,000 per day (£14,000)
- HDD cost estimated at 12 days at £2,500 per day (£30,000)
- DH pipes – assumed to be included in the capital costs of the development and not additional for this demonstration
- Other costs such as welder, site set-up, etc. are also assumed to be included in the developer's budget and at no additional cost to this project
- Including £6,000 contingency, total = £50,000

Funding & motivation for investment

- Investment could be provided by Strategic Energy Funding plus a LA/Developer
- The motivation for providing funding would be to test the solutions in a live environment and to learn from the experience
- The motivation for the pipe provider will be to demonstrate capability, learn for future product developments, and to increase their market presence
- The motivation for the HDD equipment supplier will also be to demonstrate capability, learn for future product developments, and to increase their market presence
- The motivation for the developer will be to learn how trenchless could reduce costs for their future developments and to be seen to be pioneering new technology

Success criteria

- ~20 properties connected to a new or extended DH network using trenchless technologies

Activity 3: Learn and disseminate the findings

Aims

The value of the demonstration project will only be realised if the results and learnings are widely disseminated.

Introduction

This activity will build on the demonstration project and prepare both:

- A case study report which:
  - Demonstrates that trenchless solutions are feasible and viable in comparison with trench alternatives:
  - Documents the learnings for developers, HDD equipment and pipe manufacturers
  - Outlines the cost and other benefits in a readily accessible way
- A power-point presentation/video which again explains the main benefits of the solution and the results of the demonstration project, as well as demonstrating that the solution is feasible and viable

These will be made freely available e.g. by circulating through the DH Knowledge Centre (see Route Map A), industry bodies and presenting at conferences.

Work programme

- Capture observations during demonstration project (see activity 2)
- Consolidate findings and validate with stakeholders
- Document report
- Prepare presentation
- Share report and presentation widely to DH designers and developers

Team

- A specialist consultancy will be required for this activity

Timescales

- Time for observing the demonstration project is included in Activity 2
- These follow-on activities are estimated to take up to 40 days

Costs

- Costs for observing demonstration project are included in Activity 2
- Specialist consultancy to consolidate and validate findings, document report, and prepare presentation = up to £20,000 (40 days at £500 per day)

Funding & motivation for investment

- Investment could be provided by Strategic Energy Funding (SEF).
- Their motivation would be to share practical learnings to improve the use of trenchless solutions more widely than through individual company projects.

Success criteria

- A compelling case that demonstrates that trenchless solutions are feasible and viable in comparison with trench alternatives is shared with and understood by the UK DH developer community

Activity 4: Develop the capability to continuously feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping

Aims

To ensure that all pipe size requirements for Typologies C, D & E after the application of peak flow reduction can be met with HDD, the capability to continuously feed twin-bore DH pipe with inside bore diameters of 80mm and outside diameter less than 280mm into HDD machines is required.

Introduction

This activity will be an industrial R&D project to explore the physical and logistical barriers to being able to continuously feed wider diameter twin-bore pipe into an HDD rig and to develop new technical solutions and pipe products. The requirement is to have:

- Two bores of at least 80mm, with a stretch target of 100mm for higher capacity network areas
- Outside diameter of 280mm or less (to fit into 300mm drilled hole)

As well as pipe flexibility, the solution will also need to address the logistics and handling to get the pipe product from factory to site and to be able to safely use the pipe on site.

Work programme

- Develop technical specification
- Design potential solutions
- Develop new materials (if needed)
- Develop and test prototype

Team

- DH pipe manufacturer to lead
- Supported by HDD equipment manufacturer
- It is envisaged that a core group of organisations will work collectively on Activities 4, 5, and 6 thereby ensuring consistency and integration of the arising solutions

Timescales

- Estimate based on previous pipe manufacturer experience = 3 years

Costs

- Estimate based on pipe manufacturer experience = £1.5m
- This could be comprised of:
  - 3 engineers for 3 years = £900k
  - Tools and rigs = £600k

Funding & motivation for investment

- Funding would be by the pipe manufacturer for commercial potential
- Potential match funding by Innovate UK to develop the technology in the UK and have the capability for export. Assuming that the cost to develop and test a prototype is £1.5M and that Innovate UK provide 50% of this funding it is envisaged that the cost to Innovate UK could be £750,000

Success criteria

- The capability to continuously supply and feed twin-bore pipe from a coil with sufficient heat capacity and insulation for all Typologies C, D & E street main piping is prototyped and capable of subsequent commercial deployment

Activity 5: Develop the capability to HDD install property branch pipes from 600mm core and vac holes

Aims

To develop the ability to use HDD to install property branch pipes from a 600mm core and vac excavated hole.

Introduction

This activity will be an industrial R&D project to develop solutions to the physical barriers preventing installation of property branch pipes from a 600mm core and vac excavated hole. Two potential solutions can currently be imagined – one at each end of the pipe:

- Increase the flexibility of the pipe so it can bend in the core and vac excavated hole as in Figure 20 above.
- Develop a solution that enables pulling of the property pipe back through the HDD drilled hole (with current coil radius of >1m) with minimal disruption to the property.

Work programme

- Develop technical specification
- Design potential solutions
- Develop new materials (if needed)
- Develop and test prototype

Team

- A consortium of developer(s), HDD equipment manufacturer(s) and pipe manufacturer(s) will be required
- It is envisaged that a core group of organisations will work collectively on Activities 4, 5, and 6 thereby ensuring consistency and integration of the arising solutions

Timescales

- Estimate based on previous pipe and HDD manufacturer experience = 3 years

Costs

- Estimate from manufacturers based on previous experience = £1m
- This could be comprised of:
    - 2.5 engineers for 3 years = £750k
    - Tools and rigs = £250k

Funding & motivation for investment

- Funding would be by a consortium of pipe and HDD equipment manufacturers for commercial potential
- Match funding by Innovate UK to develop the technology in the UK and have the capability for export. Assuming that the cost to develop and test a prototype is £1M and that Innovate UK provide 50% of this funding it is envisaged that the cost to Innovate UK could be £500,000

Success criteria

- The capability to HDD install property branch pipes from 600mm core and vac holes is prototyped and capable of subsequent commercial deployment

Activity 6: Develop the capability to DTH remote live tap branch pipe connections

Aims

To develop the capability to connect the property branch pipe to the street main using a DTH remote live tap; all manual operations from the surface.

Introduction

This activity will be an industrial R&D project to develop the capability to remote live connect branch DH pipes down a 600mm core and vac excavated hole. This will overcome the current need to excavate a larger hole/pit and manually connect the branch.

Work programme

- Develop technical specification
- Design potential solutions
- Develop and test prototype

Team

- DH pipe manufacturer to lead

Working with:

- Keyhole excavation solutions provider
- Experienced trenchless contractor
- Research centre
- It is envisaged that a core group of organisations will work collectively on Activities 4, 5, and 6 thereby ensuring consistency and integration of the arising solutions

Timescales

- Estimate based on previous pipe manufacturer experience = 2 years

Costs

- Estimate based on pipe manufacturer experience = £700k
- This could be comprised of:
  - 2 engineers for 2 years = £400k
  - Tools and rigs = £300k

Funding & motivation for investment

- Funding would be by the pipe manufacturer for commercial potential.
- Potential match funding by Innovate UK to develop the technology in the UK and have the capability for export. Assuming that the cost to develop and test a prototype is £700,000 and that Innovate UK provide 50% of this funding it is envisaged that the Innovate UK investment would be £350,000.

Success criteria

- The capability to DTH remote live tap branch pipe connections is prototyped and capable of subsequent commercial deployment

7.1 Annex 1: Work programme

Route map D - Trenchless Solutions																	
Activity	Cost	Year 1				Year 2				Year 3				Year 4			
	£k	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Research DH developers and develop propositions	40																
2.. Demonstrate what is possible now	50																
3. Learn and disseminate the findings	20																
4. Develop capability to continuously feed twin-bore pipe for Typologies D & E	1,500																
5. Develop capability to HDD install branch pipes from core and vacuum hole	1,000																
6. Develop capability to DTH remote live tap branch pipes	700																
	3,310																

8 Route Map E: Improved Front End Design and Planning

Route Map Summary

This solution reduces the cost of civil engineering through both improved front end design and planning which increases contractor productivity and reduces time on-site, and the use of an alternative contractual framework to achieve lower contractor tender prices.

The main components of this solution are available but there is the need to tailor them to the DH market and encourage uptake. The main barriers to wider deployment in the UK have been identified as:

1. Risks associated with funding detailed upfront survey and design work: (a) potential loss of money if work undertaken prior to DH developer entering into contract with client (e.g. Local Authority) as heat network may not be implemented, or (b) potential delay to network delivery and associated penalties if work undertaken once in contract with client.
2. Developers prefer Design and Build contracts as the level of investment and viability of the scheme is more certain. However, the contractor prices risk into the contract based on many unknowns, when these costs may never be realised.
3. The contractor considers the survey and initial design work to be insufficient and unreliable and hence does not reduce their contract price accordingly.

Development requirements include:

1. Better characterise and quantify the cost saving opportunities from this solution to encourage take-up
2. Develop guidance and training on upfront survey and design work to best realise these cost saving opportunities
3. Identify the most appropriate contractual framework to facilitate and encourage lower contractor tender prices.

The main activities proposed in the route map are:

1. Project activity analysis to better characterise and quantify the cost saving opportunities
2. Guidance for comprehensive survey and detailed design
3. Identify an improved contract framework
4. Undertake and monitor a demonstration project

These activities will take up to 4 years and are estimated to cost £250,000. It is envisaged that this research could be funded by HNDU managed through the DH Knowledge Centre (Route Map A).

The route map is dependent upon Route Map A: Knowledge Management, Research and Training to be most effective e.g. to support the dissemination of the guidance material produced.

Solution Description

Current challenge

There are two main challenges:

1. Inadequate Front End Design and Planning

Contract negotiations between the network developer and, commonly, the local authority can be lengthy. During this period, limited detailed design is typically undertaken by the developer as there is the risk that the heat network may not be implemented, e.g. due to commercial/legal issues or changes in central or local Government energy policy. Hence the network developer wishes to minimise any additional cost until the Energy Services Agreement is signed.

Energy Services Agreements typically have a fixed Operational Start Date for heat supplies to commence and may contain penalties for delays. Funding, such as grants, may have specific time limits by which the money must be spent. Hence, once signed, there is immediate pressure on delivery (albeit few of the actual delivery risks will have been identified). As a result, whilst more detailed design work is undertaken prior to construction, it is typically limited in terms of its scope. Furthermore, it is a specialist activity and may not be carried out to high enough quality and thoroughness.

In addition, at least some projects suffer from inadequate forward planning. This includes not obtaining upfront permissions in time, such as the Section 50 traffic management plan (http://www.legislation.gov.uk/ukpga/1991/22/section/50). It is important to engage early with relevant external parties (e.g. the local council and other utilities) such that there is an existing communication route if unexpected issues are identified whilst excavating.

Inadequate upfront design and planning typically causes delays and reduces productivity throughout the excavation process. For example, identification of unknown underground services or obstructions will require pipe routes to be redesigned, special fittings to be transported from abroad and any further permissions to be gained. Contractor staff will stand idle which adds to costs unless a contractor is able to deploy staff elsewhere. The contractor may cover the additional costs but they often lead to claims which add to the total cost of the project; there will be further costs in time spent considering and negotiating these claims. These delays feed into the general level of costs in the industry and are particularly an issue in rigid pipe installations in complex areas with high densities of existing services. More flexible plastic pipes still have potential for inefficient installation and additional costs unless the design is fully defined and proven in advance of construction.

2. Risk Priced in Contract Fee

An associated issue is how risk is managed in the contract price. At an early stage, the network developer agrees a contract sum with a contractor for the works associated with civils and pipe-laying. This is needed to assess the viability of the scheme. The contract sum is based on an outline network design, which can simply be a route line on a map between heat source and buildings, with limited route optimisation and knowledge of underground conditions.

A Design and Build contract is commonly used, in which the contractor needs to price risk into the contract based on many unknowns, when in fact these costs may never be realised. These risks in particular relate to the presence, or otherwise, of underground services and other buried features or obstructions related to the historical use of the site.

Hence this results in a higher contract price than perhaps necessary. Furthermore, it may affect the viability and deployment of the district heating scheme.

Proposed Solution

There are three components to this solution

1. Improve the design and contracting process to allow more detailed design work prior to agreeing a price

Stakeholders have proposed an initial tender stage to carry out a more comprehensive survey and detailed design work. Contractors are then asked to tender at a later stage for the civil engineering works based on this initial survey and design work, when, through the greater upfront knowledge of underground conditions, the risk element in the contract should now be reduced. It may also be possible for a single tender process where a price is agreed prior to the survey and allowed variations set out dependent on the survey results.

It should be possible to adopt alternative contract frameworks to minimise the pricing of remaining risk into the contractor's fee. For example, a Target Cost approach to contracting can include a provisional sum in the contractor's fee for anticipated risks which can be adjusted at a later date to take account of the contractor's actual costs. The contract can also include a pain/gain share mechanism to incentivise the contractor to find ways to reduce costs. Indeed the potential gain to the contractor may be sufficient to incentivise them to carry out the comprehensive survey and detailed design work. The Stage 2 work showed that the additional upfront survey and design work could amount to around £0.3M against an overall saving of £4M which could be shared between the client and contractor.

2. Undertake more comprehensive survey and detailed design work up-front

The solution form provided an outline of the survey and design works necessary for each project which can be usefully refined in the future. In particular, it is proposed that this work builds from PAS 128:2014 "Specification for underground utility detection, verification and location". This work may be carried out by a consulting engineering firm or by a DH specialist contractor or by a combination of the two. It is important for the experience of contractors to be used at this stage to optimise routes and identify the most cost-effective solutions.

3. Obtain consents to carry out the work earlier

Complementary to better design is obtaining appropriate permissions in a timely fashion. It also includes developing good communication routes with relevant external parties at an early stage to quickly address any unexpected issues identified whilst excavating.

Current Barriers to and Requirements for Implementing Solution

Assessment of Barriers

The main barrier to implementation of this solution is that a sponsoring organisation needs to invest more money at risk for the upfront survey and detailed design work. This would be required during a period when there is still significant uncertainty whether the DH scheme will happen.

- In the longer term, the intention is for the network developer to judge that the reward from undertaking the upfront survey and detailed design work outweighs the risk that the DH scheme will not happen. To achieve this it is important to demonstrate the significant rewards of upfront survey and design work on reducing the costs of district heating, and this activity is captured below in Activity 1 of this route map. It is also important to improve the certainty that the DH scheme will happen which could include stronger local or national policy.

- In the shorter term, to help drive implementation of this solution, HNDU funding to local authorities does include upfront survey and design work.

A second barrier is that investors currently prefer fixed-price Design and Build contracts as the level of investment and viability of the scheme is more certain. Hence, there is a need to demonstrate the value of adopting an alternative contractual model.

A third barrier is the risk that the contractor considers the survey and initial design work to be insufficient and unreliable and hence does not reduce their contract price accordingly. It is important that this work is undertaken by an organisation with relevant expertise and it is likely that the contractor fee will reduce over time with experience of the quality of the findings and the benefits of continuous learning. It may also point towards the use of alternative contractual arrangements as discussed further below.

A final barrier identified is that the contractor may be unable to rely commercially on the survey and initial design work. Clauses related to ‘third-party reliance’ could be added to the survey team contracts if acceptable. Alternatively, there could be a single tender which comprises both the survey and initial design work as well as the subsequent excavation work.

Development and Commercialisation requirements

This solution uses a new (adapted) service offering to the existing DH market and hence the solution is described as Product/Service Development: new services into existing markets. The activities needed are as follows.

Service Development

It would be beneficial to better understand how the uncertainties of underground conditions affect cost to ensure that the upfront survey and design work is best targeted. This will also demonstrate the benefits of upfront survey and design work to provide confidence in paying for this work upfront. This is captured in Activity 1 of this route map.

Legal Development

There should be an evaluation of the most appropriate contract framework(s) to minimise the costs associated with DHN delivery. This is captured in Activity 3 of this route map.

Continuous Learning

This solution would particularly benefit from continuous learning within the industry. Sharing practices of successes and failures to reduce costs will help the industry as a whole to more quickly reduce cost and provide greater confidence to the contractor of the outputs of the survey and initial design work.

Funding

The intention of this solution is to change practice within the industry. It is proposed that this solution would be best realised through being owned and funded by the District Heating Knowledge Centre (DHKC) though Route Map A: Knowledge Management, Research and Training. To achieve improvement in industry practice, it is important that the DHKC is respected by the industry and/or the proposed improvements are underpinned by regulation. This is discussed further in Route Map A.

Aspects Beyond the Scope of this Route Map

This route map will benefit from the work in one other route map being taken forward at the same time:

- Route Map A: Knowledge Management, Research and Training. Initial knowledge sharing of the potential for using improved front end design and planning, and continuous learning to improve its value upon application.

There are some local initiatives to develop underground maps of utilities. For example, Scotland has developed the Vault to contain combined underground information (http://www.roadworksscotland.gov.uk/LegislationGuidance/Guidance/Vault.aspx). An accurate map of the underground should significantly reduce the costs of the upfront survey. Key complexities to date include gaining approval of all utilities to provide data and the accuracy of the data available.

Route Map Proposal

The activities identified requiring further work and validation for this route map are:

1. Project activity analysis
2. Guidance for comprehensive survey and detailed design
3. Improved contract framework
4. Undertake a demonstration project
5. Monitor and review the demonstration project and publishing findings

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The external funding of Activities 1-5 is estimated at £250,000. Activities 1 to 3 are research activities for DH which would be best funded by BEIS-HNDU managed by the proposed DH Knowledge Centre (see Route Map A). The demonstration project is principally expected to be funded by a DH developer as it is intended that this will be a fully commercial offering. Support funding for initially engaging with the developer to organise the demonstration project and then subsequent monitoring and reporting will be required and Strategic Energy Funding is a possible source for this stage.

Activity 1: Project Activity Analysis

Aims

To detail the whole-project time and cost saving opportunities from adopting this solution.

This in turn will help enable:

- Stakeholder alignment on the value of this solution and an appetite to develop it further and adopt it.
- Greater targeting of the upfront survey and design work to most effectively reduce the risks and costs associated with excavation (see Activity 2).
- The evaluation and development of the most appropriate contractual models/frameworks to minimise the costs associated with DHN delivery (see Activity 3).

Introduction

Detailed “project activity analysis” will be undertaken of works on 3-5 live DH project sites. The sites should be selected to maximise the chance of delivering the desired outcomes and to gain the support of a cross-section of key project stakeholders. The selected projects will ideally: (i) cover each of the five typologies (see Appendix A), (ii) be in different cities and environments, (iii) involve a cross-section of different developers and contractors and (iv) be in the “pre-construction” phase when starting the analysis (see below).

The projects identified are likely to be for the higher heat density typologies. This may be sufficient if the processes are similar to those typologies not directly investigated (it is expected that the greatest challenges around excavation are within the higher heat density typologies). Additional project activity analysis could be undertaken in the future to refine the process for other typologies.

Work programme

- Identify 3-5 live projects to study
- Identify and map the top level activities for each project: (i) key activities undertaken, (ii) number of people and time spent on each activity, and (iii) how much and which resources are consumed
- Select activities for more detailed field study
- Conduct field studies which will include a combination of on-site observation, site video cameras or simple activity tracking and time recording
- Analyse findings to identify unnecessary time and cost, and how they could be reduced or eliminated
- Review and agree potential time and cost savings with industry stakeholders
- Agree how best to disseminate outcomes to gain wider acceptance

Team

- A specialist organisation (or organisations) to undertake work with expertise in stakeholder engagement, activity analysis and solution design and development.
- Stakeholder involvement including network developers, contractors, designers and planners. It is expected that these stakeholders will participate for free. It should not be a significant use of their time and should help to grow the industry which would benefit them all.

Timescales

- Around 12 months. This allows an initial period of 3 months to identify projects. Each project will be monitored for 3 months but due to the phasing and availability of the projects, a total elapsed time of 9 months has been allowed for monitoring and analysis.

Costs

- £119,400 for consultancy fees for 4 projects. This is based on the following:
  - Expert to set up study and lead analysis and stakeholder engagement. 15 days at £1,000 per day (£15,000)
  - Per project:
    - Expert to provide lead. 4 days at £1000 per day (£4,000)
    - Analyst to spend 1 day per week at the project site to direct the activities of the Site Surveyor, gather and analyse data. 16 days at £800 per day (£12,800).
    - Site surveyor for detailed observation and recording of activities and their duration on a daily basis. 62 days at £300 per day (£18,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to support the development of services that will reduce the cost of DH networks and accelerate the market and deployment of DHN.

Success criteria

- Industry stakeholders involved agree that the findings demonstrate this solution presents an attractive opportunity to significantly reduce the costs of district heating

Activity 2: Guidance for Comprehensive Survey and Design

Aims

The aim of this task is to provide effective guidance and training to support projects wishing to undertake comprehensive surveys and earlier and/or improved detailed design.

Introduction

Guidance and training should be produced on the techniques to be used for the survey works necessary. This work should build from both PAS 128:2014 "Specification for underground utility detection, verification and location" and the findings of Activity 1 such that survey activities target those elements which should deliver the greatest cost savings. This links with Route Map A: Knowledge Management, Research and Training to most effectively disseminate the guidance and training.

Work programme

- Review existing guidance
- Develop new guidance and training material
- Disseminate guidance and deliver training

Team

- An industry expert to lead the development of guidance and training material
- Stakeholder group to provide suggestions and review the guidance document. Ideally including some involved in Activity 1 for continuity

Timescales

- 6 months to develop guidance and training material

Costs

- Consultancy fee of £50,000 to develop the guidance and training material (50 days at £1,000 per day)
- The expert group would be unpaid; members would benefit from the opportunity to shape the document and being formally recognised as part of the expert steering group
- The costs of training would be recovered from training fees

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to support the development of services that will reduce the cost of DH networks and accelerate the market and deployment of DHN.

Success Criteria

- Production of guidance and training material that has buy-in from industry expert group
- Route to disseminate material

Activity 3: Improved Contract Framework

Aims

The aim is to identify the most appropriate contract framework(s) to minimise the cost for district heating.

Introduction

The key activity is to review alternative contract frameworks to reduce the cost for district heating whilst still providing the investor with confidence up-front as to the viability of the project. The civil engineering contractor needs also to be able to contractually rely upon any upfront survey and design work.

Work programme

- Review and evaluate alternative contract frameworks; investigations of approaches in other utility sectors and district heating in other countries
- Hold a workshop with DH developers and contractors to gain feedback on the evaluation of alternative contract types
- Produce guidance on the most appropriate contractual framework(s) and key information to be included

Team

- Led by an expert in procurement who is knowledgeable of the different contract types and, ideally, has experience in different utility industries
- Stakeholder group to attend workshop. Ideally including some involved in Activities 1 and 2 for continuity

Timescales

- 4 months

Costs

- Specialist consultancy fee £25,000. This based on the following:
  - Review and evaluate alternative frameworks: 10 days at £1,000 per day (£10,000)
  - Prepare for and attend workshop: 5 days at £1,000 per day (£5,000)
  - Refinement upon workshop outcomes and produce guidance: 10 days at £1,000 per day (£10,000)
- The expert group would be unpaid. The group benefit from the opportunity to shape the document and being formally recognised as part of the expert steering group.

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to support the evaluation of alternative contractual frameworks that will reduce the cost of DH networks and accelerate the market and deployment of DHN.

Success criteria

- A contractual framework(s) identified that reduces cost and meets the needs of the DH developer and contractor

Activity 4: Demonstration project

Aims

The project will be used to demonstrate the benefits of the approach and so promote its use on other schemes.

Introduction

A demonstration project is proposed as a way of marketing the concept. Whilst the cost savings will be understood in principle, an actual project will allow DH developers and contractors to confirm that the benefits can be realised in practice.

It is recommended that the first demonstration project would be for Typology C (terraced houses); this typology is likely to have underground obstacles that would result in significant benefits from this solution and it complements the Route Map D Trenchless Solutions that appear more beneficial for Typologies D and E. However, Typologies A, D or E could be used alternatively (there is relatively limited civil engineering and benefit from this solution for Typology B).

It is expected to take a few months to identify a developer with both a suitable scheme and the willingness to trial the new contract framework.

The intention would be that the demonstration project would be commercially viable so the cost of the design and installation would be financed by the DH company. There will be additional expense to cover: (i) the time to identify and reach agreement with a developer and (ii) the additional fee associated with the extra survey and design activity.

Work programme

- Agree with a developer to participate in this demonstration project
- Undertake the front-end more detailed survey and design activity
- Agree contract under the new framework with the contractor
- Construct the scheme
- Review the approach and lessons learned

Team

- DH developer company
- DH designers
- Contractor

Timescales

- 18 months

Cost

- The DH company to finance the scheme itself
- To identify and seek agreement with DH developer company including adoption of the new contract approach
    - 20 days of senior DH specialist @ £750 (£15,000)
- To undertake the detailed upfront survey and design work
    - The Stage 2 analysis provided an additional cost of £305k for the 17km network with the majority of cost proportional to the length of the network. It is assumed that the demonstration project would be of the

order of 1km and so the additional cost would be around £20,000.

Funding & motivation for investment

- The DH company will finance the demonstration project mainly through the long-term heat sales from the customers.
- Strategic Energy Funding (SEF) will be used for collating demonstration project data and insight, as well as for dissemination via the DHKC, in order to assess reduced cost DH solutions and accelerate their deployment.
- Industry participants would be motivated to contribute to the development of solutions and propositions that will reduce the time and cost of their projects.

Success Criteria

- Delivery of a demonstration project that shows how costs can be significantly reduced compared to a conventional design

Activity 5: Monitoring and review of the demonstration project and publication of designs and results

Aims

The aim is to capture the knowledge from the demonstration project and identify the benefits and use this information to market the concept to other DH companies, the DH design community and local authorities considering DH schemes.

Introduction

An independent monitoring and review consultant will be appointed to review the design and construction phase and establish the costs and benefits compared to the conventional approach. The demonstration project will be written up as a case study. This material will also be used as the basis for presentations at conferences and as part of training programmes. The DH Knowledge Centre described in Route Map A will lead this activity, appoint the authors and be the vehicle for dissemination of the solution and training in its application. The target audience will be other DH developers, their designers and social housing providers as well as local authorities who are planning DH schemes.

Work programme

- Monitor the design and construction activity and obtain costs
- Compare costs with conventional designs
- Feedback on the experience both from the DH developer and the contractor
- Prepare a detailed technical report on the project
- Prepare a shorter case study paper for use in journals, conferences etc
- Prepare a Powerpoint presentation to accompany the case study

Team

- Engineering design consultant

Timescales

- 21 months (18 months for Activity 4 plus 3 months to complete analysis and write-up)

Costs

- £17,000. This based on the following:
  - Monitoring of design and construct work over 18 months: 24 days at £500 per day (£12,000)
  - Cost comparison: 5 days at £500 per day (£2,500)
  - Discussion with developer and contractor: 2 days at £750 per day (£1,500)
  - Prepare case study report and Powerpoint presentation: 2 days at £500 per day (£1,000)

Funding & motivation for investment

- It is proposed that investment is sought from Strategic Energy Funding.
- Motivation would be to evaluate and disseminate solutions for lower cost DH networks and accelerate the market and deployment of DHN.

Success Criteria

- Documentation produced on the demonstration project that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution

Other

This solution will particularly benefit from continuous learning and dissemination. It is expected that as this solution is implemented:

- Opportunities to further reduce risk and cost will be identified.
- New challenges will be highlighted and solutions identified to overcome them.

8.1 Annex 1: Work programme

Route Map E - Improved Front End Design and Planning - Activities, costs and timescales																
Activity	Cost	Year 1				Year 2				Year 3				Year 4		
	£	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
1. Project activity analysis	119,400															
2. Guidance for comprehensive survey and detailed design	50,000															
3. Improved Contract Framework	25,000															
4. Demonstration project	35,000															
5. Review demonstration project and publish results	20,000															
TOTAL	249,400															

9 Route Map F: Shared Civils

Route Map Summary

In the laying and renewal of underground services, the majority of the cost is in the civil engineering that enables it. For the water industry these costs typically account for 80% or more of the cost of installing or renewing a section of the water network. In the baseline DHN model from Stage 1 of this project, the civils costs account for around 75% of the network (excluding above ground pipes, internal connections and HIUs).

If these civil engineering costs can be shared between two, or more, utility programmes the net benefit will be significant provided there is not an increase in costs elsewhere or administration burden. For the shared civil engineering costs to deliver savings, four distinct areas of challenge need to be addressed:

- Technical: Barriers to successful installation and operation of multiple utilities in the same project
- Scope: Maximising the overlap of viable utility renewal with the DHN roll-out programme
- Programme: Ensuring the phasing and connection timing requirements of all parties are met
- Commercial / Contractual / Legal: Keeping the contractual arrangements robust but with minimal administrative burden

The proposed solution is to develop:

- Technical solutions for the physical delivery of multiple utilities in close proximity
- Commercial frameworks for shared civils which meet the specific requirements of the main stakeholders: DHN developer, other utility company, local authority, civil engineering contractors

The main activities proposed in the route map are:

1. Develop an Example Business Case
2. Technical Solution Development
3. Scope Assessment Tool
4. Demonstration Project Proposal & Deployment
5. Programme Deployment Model
6. Market Research to Test the Solution and Commercial Models
7. Develop Commercial / Contractual / Legal Models

The overall route map is planned over the period October 2017- the end of 2019. This is based on the timing for Bristol Water for a potential pilot study. The total cost of the route map is estimated to be £366k.

Solution Description

Current challenge

The cost of the civil engineering and its enabling works accounts for around 40% of total DHN baseline CAPEX, excluding the cost of pipe and connection, yet the works themselves add no lasting value to the network. If the civil engineering costs can be reduced and also shared there is potential for a significant impact on DHN CAPEX and hence their viability at scale.

Proposed solution

The proposed solution is to research and develop mechanisms by which DHN developers are able to collaborate with other utility providers and Local Authorities to share the cost of street works for DHN implementation. The range of solutions to be explored are:

1. Individual case by case shared civils

   This is broadly the approach taken by existing utility companies who will share their plans for network renewals and look for an overlap in planning. A difficulty is expected to be the lack of alignment and scale on an ad hoc basis.

2. Aligned planning cycles

   For a local area (e.g. City or Metropolitan Authority) streetworks are proposed to be centrally planned for utilities and strategic DHN development. This increases the potential for scale over a longer time period and the Local Authority is best placed to lead the coordination.

3. A streetworks partnership

   A more formal version of #2 with a top-down ambition to minimise duplication of road works and the reduction of disruption. This option and #2 rely on the leadership and drive of the Local Authority to instigate changes of commercial behaviour in utility companies. This can be challenging as regulated utilities have considerable corporate scale and greater organisational inertia which gives a tendency to resist change.

4. A DHN and Utility Joint Venture

   This option and #5 shift the emphasis from being an externally driven requirement on the utilities to developing a mechanism by which a DHN developer, working with one or more utilities, can align their ambitions and value propositions to generate a mutually beneficial joint venture company.

5. A Utility Led Heat Network Development

   This shifts the emphasis further towards the utility company leadership and has the potential to drive the development of DHN in line with infrastructure renewal in towns and cities. This gives the utility companies an opportunity to develop a new revenue stream and also consolidate operating costs (e.g. metering, customer service, network maintenance and repair).

There is also the potential for a UK Government regulatory requirement for other utilities to align with a DHN programme. This is considered to be outside the scope of this project.

In the above solutions the utility links have been considered to be generic. Research thus far has identified that the greatest interest and potential synergy is with water supply.

- Bristol Water recognise the potential for links with DHN deployment and their need to upgrade existing water supply pipes (to reduce leakage, repair cost and improve service). Initial analysis in Stage 2 suggests that between 4% and 20% of the DHN pipework might align with water main renewal.

As a result the following proposals are based on a water utility model. However, once tested and a business case demonstrated, the potential will be explored with other utilities:

- Electricity: A need for significant change in District Network Operator (DNO) supply capability is needed to cope with local electricity generation, increased use of heat pumps, vehicle charging, battery storage and other Demand Side Response changes.
- Data / Telecoms: As consumer data usage escalates there is likely to be a continued increase in superfast Fibre-To-The-Home (FTTH) connections. There are currently less than a million domestic connections equivalent to less than 5% of homes [Point Topic Ltd]. Fibre optic cables are technically the least difficult to combine with a DHN.
- Gas: Possibly the least likely to be aligned with DHN deployment as the local Gas Distribution Network (GDN) operators are between 50% and 80% [Utility Week, 2016] of the way through the regulator mandated replacement of their old cast-iron mains with plastic piping. As a contrast to DHN delivery of 50km per network: replacement rates across the four mainland UK GDNs is approximately 3,500km per year. Aligning this requirement with DHN delivery will enable GDNs to offset some of their £500M/yr investment in replacement and potentially establish a future revenue stream when the long-term future of domestic gas supply is uncertain.

Current Barriers to and Requirements for Implementing Solution

Assessment of barriers

1. Technical

   The technical challenges are to confirm that the DHN pipework can be laid in tandem with other services in the same (or worst case; adjacent trench), without detrimental impact on the performance, accessibility or lifespan of either (e.g. potable water temperature raised by adjacency of poorly insulated heat pipes). In addition, to deliver the full benefits, the multiple services should be delivered simultaneously by a single contracting team to avoid increased cost and programme.

2. Scope

   The drivers behind installation of a DHN are very different from those of other utilities, particularly in the retrofit of existing buildings, which is the key focus of this project. The challenge is to maximise the overlap between the DHN roll-out and other utility renewal or upgrade. The greater the net cost saving from combined civils works, the more potential for increased scope, as previously unviable or marginal upgrades will become cost effective. This has the double effect of increasing scope and enabling the other utilities to improve operational and customer service rankings.

3. Programme

   The roll-out of a DHN is typically set radially from the energy centre, with new areas being commissioned incrementally. The renewal / upgrade of water or other utilities will be targeted at areas of under-capacity or service impairment / failure. Aligning the timing of existing utility renewal (and even new connections to greenfield sites) has proven difficult so this challenge must not be underestimated.

4. Commercial / Contractual / Legal

   With multiple parties involved in the works to deliver new and upgraded utilities, there needs to be clarity of roles and responsibilities and also accountability and liabilities in the event of failures or delay. The administrative burden of forging these agreements has been one of the key reasons combined utility works have not become more widespread. Models for the on-going ownership, liability and repair also need careful consideration.

   Leadership of the Shared Civils model is also important to enable this solution to deliver at scale. In a city or metropolitan area it is likely that the Local Authority will play an important leadership role. To avoid each Authority developing a local solution, the DHKC (Route map A) should be the custodian of best practice commercial models and templates; this will reduce the Local Authority leadership burden.

Development requirements

The barriers described above provide a significant obstacle to the adoption of a shared civils approach for DHN delivery. No documented examples of previous approaches to sharing civil engineering costs have been identified (whether successful or not).
As a result this route map describes proposed activities which are intended to reveal whether the solution has significant potential for savings, or alternatively that the benefits are outweighed by the resource needed to deliver them. A consortium of utilities in North East England is exploring the potential of shared civils, but this is at a very early stage.

The desired outputs are:

- An evaluation tool for rapid assessment of the potential for shared civils on any site
- A mechanism for overlaying DHN network layouts on exiting utility maps and ages
- One or more demonstration projects to build confidence in the wider DHN sector
- A range of shared civils templates and commercial frameworks for future adoption

Commercialisation requirements

This solution was analysed using the Ansoff matrix approach. The Shared Civils solution was assessed to be an entirely new service. The customers of the solution are both DHN developers and the other utility partners. Although DHN developers are an existing market; other utilities are new market for participating in DHN deployment.
The approach needed in this case is therefore described as Diversification, but is in effect a wholly new entrant into the Retrofit sector.

The key commercialisation activities are:

- Market Research to Test the Solution and Commercial Models: If shared civils is to be a standard solution for DHN cost reduction, it is essential to clarify specific requirements of DHN Developers, local authorities and other utilities.
- Develop Commercial / Contractual / Legal Models: There is significant advantage in developing a standard commercial model for the Shared Civils approach which

is agreed by all parties and straightforward to adopt.

There are also potential commercial synergies between this route map and the Trenchless Solutions (Route Map D): With the limitations on trenchless pipe diameter success is most likely with fibre to the home data connections.

Aspects Beyond the Scope of this Route Map

The shared civils solution has additional potential for quantifiable benefit beyond the core solutions described above. Once the core aspects are proven there will be opportunities to investigate additional value from:

- Reduced leakage failures and operating cost
- Improved customer service scores
- Reduced disruption in the community
- Addressing road surface issues
- Utilisation of abandoned / redundant / underutilised assets
- Easier future upgrade, fault finding and repair
- Development of a grey water network to utilise rainwater for toilet flushing etc.

Route Map Proposal

The following series of activity summaries describe the tasks and resource plans which are designed to prove or disprove the viability of the shared civils solution. The programme should be curtailed if, at any point, it becomes apparent that the challenges and barriers permanently outweigh the potential benefits.

1. Develop an Example Business Case
2. Technical Solution Development
3. Scope Assessment Tool
4. Demonstration Project Proposal & Deployment
5. Programme Deployment Model
6. Market Research to Test the Solution and Commercial Models
7. Develop Commercial / Contractual / Legal Models

Once the Shared Civils business case is clear (Activity 1), Activities 2-5 are designed to demonstrate the physical and technical viability of the solution. In parallel with the technical solution development, there is a need to explore the commercial / legal frameworks which can enable the solution to be deployed at scale. These activities are described in Activities 6 and 7.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The total cost of the route map is estimated to be £366k.

Activities 1-3:

- (Example Business Case, Technical Solution Development, Scope Assessment)
  Total: £141,000

Funding proposed to be by HNDU to develop market confidence.

Activity 4: Demo project

- Total: £95,000
  Strategic Energy Funding (SEF) will be used for developing the collaborative approach, collating demonstration project data and insight; also for dissemination via the DHKC, unless it is seen as increasing risk for the DHN developer.

Activities 5-7:

- (Programme Deployment Model, Commercial Research & Contractual Models) Total: £130,000

  The deployment model is expected to be a 'best practice guide' held by the DHKC (Route Map A). Funding is proposed via HNDU to support best practice.

Activity 1: Example Business Case

Aims

To test the shared civils concept by exploring opportunities as a worked example for Bristol (or other city) in detail and develop a business case for commercial deployment.

Introduction

The initial steps of this activity were originally intended to be completed during development of this route map. However, the timing did not align with the water company annual planning cycle. As a result scheduling of activities needs to fit in with both the company's strategic planning calendar and also a phase of the five year regulatory cycle. The current Asset Management Programme (AMP) runs until 2020 and if a robust business case and deployment plans can be developed by the end of 2018 there is a greater opportunity for their inclusion in the next AMP framework for 2020 to 2025. The timings in the Annex 1 planning reflect this.

This activity is a thought experiment to analyse water network renewal / repair priorities and align with a hypothetical DHN. The water company and city council have an interest in the potential of shared civils and heat networks, but need external impetus and facilitation to develop the idea further.

Work programme

- A workshop with the utility company planning, asset management and technical teams to test the concept of the shared civils solution
- Engagement with the local authority (Bristol City) to test the alignment with energy, highways and strategic planning policies
- A review of a city scale water utility asset map to identify areas of planned renewal, areas where repair or upgrade would be valuable and locations of abandoned assets which could be linked to DHN deployment
- Preparation of a concept DHN design aligned with water asset and city plans
- A combined workshop to test and challenge the alignment of city, water and DHN requirements
- Updated top-level cost modelling of the potential benefits of the solution
- Review the commercial options between utility, local authority and DHN developer.
- Preparation of a structured business case

Team

- Lead organisations: Water Company, City Council, DHN developer
- Participating: Master Planning Engineers, Process facilitation, DHN designer, contractor, cost consultancy
- Consulted or informed: Other local utilities (gas, electricity, broadband data)

Timescale

- Commence October 2017 (as suggested by Bristol Water to align with the Water sector AMP programme – not the only option, but preferred by stakeholders)
- 3 months duration

Costs

- External programme management and facilitation: 10 days at £1,000/day (£10,000)
- DHN design resource: 8 days at £600/day (£4,800)

- Infrastructure master-planning: 8 days at £600/day (£4,800)
- Specialist cost consultancy: 5 days at £600/day (£3,000)
- Report preparation for wider circulation: 4 days at £600/day (£2,400)
- Local authority, utility company and DHN developer resource is unlikely to be charged as this will contribute to their organisational development

- Total: £25,000 + limited expenses

Funding & motivation for investment

- Funding by HNDU would enable a short programme to test the concept in sufficient detail and ensure that the results could be made public.
- There may be value in developing more than one business case to reinforce the potential of the concept, or confirm the barriers to successful deployment

Success Criteria

This activity will be considered to be successful if it gives clarity that there is either:

- Demonstrable value from the shared civils concept and greater understanding of the conditions under which the concept becomes viable, or
- A clear case to show that the costs and risks outweigh the benefits of shared civils, whilst highlighting the potential conditions under which viability can be achieved

Activity 2: Technical Solution Development

Aims

To build confidence in the technical compatibility of multiple utilities in a single trench. (this will not include the development of full technical standards).

Introduction

A detailed review of the potential technical challenges for combining DHN piping with potable water supply in close proximity and consideration of other utilities.

When there is a request from one utility provider to lay new services close to another pre-existing utility in the highway; the existing utility has a predisposition to be cautious and request as great a clearance between services as possible. This is intended to minimise the risk of disruption to supply, but such caution risks sub-optimising the end result.

This activity will align the technical requirements of water and DHN piping with an intent of minimising clearances for mutual benefit of reduced civils cost, whilst maintaining accessibility and quality of supply. Other utilities will be considered in less detail.

Work programme

- Establish key installation criteria for water and DHN piping
- Identify risks and failure modes of piping in close proximity
- Establish the optimal trenching solution depths and widths for shared civils
- Review of the physical challenges to deliver a single trench, multi-utility solution
- In parallel: explore the opportunities and barriers for achieving the same results with trenchless technologies (route map D)
- Develop a matrix of compatibility between water and DHN installations to include:
  - technical requirements and
  - commercial requirements for future deployment

Team

- Lead organisations: Water Company, DHN developer
- Participating: Process facilitation, contractor, NJUG[3], Other utilities
- Consulted or informed: Utilities from other regions, ADE

Timescale

- Timing / programme: Limited to 3 months to avoid drift and scope creep
- Greater likelihood of success if it follows a compelling business case (Activity 1)

Costs

- Utility company and DHN developer resource is unlikely to be charged as this will contribute to their organisational development.
- Specialist civils contractor resource: 4 days at £600/day (£2,400)
- DHN design resource: 4 days at £600/day (£2,400)
- NJUG membership access to expertise and resources: £2,000
- External programme management and facilitation: 4 days at £1,000/day (£4,000)
- There is a risk that lead organisations will be not be able to commit scarce

[3] National Joint Utilities Group – membership body promoting improved streetworks.

resource to speculative technical development, therefore a contingency of £5,000 is suggested to involve consulting engineers as an alternative

- Total: £16,000 + limited expenses

Funding & motivation for investment

- A directly commissioned piece of work by HNDU or as part of a wider Shared Civils project

Success Criteria

- This activity will be considered to be successful if it confirms that there is potential to install DHN piping and other services in close proximity

Activity 3: Scope Assessment Tool

Aims

To create a straightforward tool which enables Local Authorities and utility companies to rapidly assess the potential viability of a DHN and Shared Civils deployment.

Introduction

Once the business case for shared civils is confirmed, there is a need to create a light-touch assessment tool which enables local authorities, utilities and DHN developers to rapidly assess the likelihood of success in a specific area.

The aim is to create an approach which aligns multiple utility asset maps with Local Authority housing plans and existing (proprietary) cost data. This will build on the single City business case study and create a template or tool that can then be rolled out nationally.

The precise details, scope and costs will be confirmed during this activity, but the goal is to enable multiple overlays of:

- LIDAR geographic data
- Utility assets highlighting those due for replacement and redundant assets
- DHN potential linked to project typologies, energy centre locations etc.
- Housing, highways condition and other local authority plans

This will lead on directly from Activity 1 and the activity should led by individual who was part of the core team that developed the business case. The general case of developing a more nationally applicable tool is anticipated to take up to a year of development and testing.

Work programme

- Use the information form activity 1 to assess the requirements for utility asset data: Scope, level of detail, accuracy format
- Research the availability and consistency of such data across multiple local authorities and utilities
- Research the availability of planning overlays and highways condition assessments etc. across multiple local authorities
- Develop a method to easily categorise street geography for DHN deployment:

e.g. by typology, suitability for energy centre, challenges for installation

- Design a method of showing LIDAR geographic overlays of utility, local authority and DHN data in order to assess the viability of DHN and shared civils alignment

Team

- Lead organisations: District Heating Knowledge Centre (Route Map A) Infrastructure master-planning engineers, DHN designer/developer
- Participating: utility companies, local authorities, specialist cost consultants
- Consulted / Informed: HNDU, DCLG

Timescale

- Phase 1: Research
  - 1 month to review Activity 1 outputs and develop a clear set of data requirements
  - 2 months to research the availability and formats of equivalent data in other local authority and utility provider areas
- Phase 2: Design
  - 6 months scoping tool development
  - Phase 3: Testing 6 months testing with DHN developers, utilities and local authorities

Costs

- Phase 1:
  - Infrastructure engineers and researchers: 25 days at £600/day (£15,000)
- Phases 2 & 3:
  - Infrastructure engineers and tool developers: 100-200 days at £600/day (£60,000 - £120,000)
- Total: £75,000 - £135,000 (estimate for summary: £100,000)

Funding & motivation for investment

- This could be a proprietary tool developed commercially by an infrastructure engineering organisation, funded by fees for DHN development.
- However, the tool is intended as 'best practice' example held by the District Heating Knowledge Centre (Route Map A). For it to be used industry wide the recommendation is that the UK wide tool is directly funded by HNDU. This will act as significant enabler for future DHN projects and ensure that it is updated as networks are delivered to ensure it continues to be a best practice resource.

Success Criteria

- This activity will be considered successful if it results in a tool which enables local authorities and utility companies across the UK to rapidly assess viability of shared activity with modest cost as resource implications

Activity 4: Demonstration Project Proposal & Deployment

Aims

To design and deliver a demonstration project for physical delivery of adjacent pipe / cable laying with DHN installation, to establish whether the concept:

- Is technically achievable and meets DHN, utility and safety requirements
- Delivers, or has the potential to deliver, significant cost savings for DHN delivery

Introduction

A demonstration project is essential to prove both the technical and cost viability of a shared civils solution. In contrast to demonstration projects in other route maps, the testing of a shared civils solution is likely to require the joint commissioning of the work between the DHN developer, another utility company and the local authority. Additional funding will also be needed to support the investment in technical, legal and commercial solutions needed to support delivery ahead of Activities 5, 6 and 7 which aim to develop a generic approach.

The demonstration project will have two phases (development and delivery), with a gate review of viability at the end of the first phase. As a new and uncertain innovation the demonstration project should be at a modest scale: either as a section of an extension to an existing DHN project, or as part of a research demonstration project associated with multiple route maps. A dense village scale project has been identified as a potential research network and the shared civils model would align with this.

Work programme

- Phase 1: Proposal Development
  - Identification of a target demonstration area based on the findings from Activity 1
  - Preparation of a specific business case at a scale of between 10 and 50 homes in order to generate sufficient insight to assess the viability of the solution
  - Clarity of the commercial / legal challenges and development of a pragmatic contract solution to enable project delivery with appropriate apportioning of risk
  - Development of a plan to maximise the benefit of shared civils across the project
  - Identification of one-off project costs which should not be included in the assessment of shared civils viability
  - Planning of additional technical support, project management and data collection resource to ensure lessons learned are captured and documented
  - Approval of the project business case by lead organisations
- Phase 2: Demonstration Project Delivery
  - Execution of the project plan
  - Collection of research data relevant to the shared civils solution: Identification of benefits, challenges, opportunities and risks associated with the delivery.
  - Post-completion data collection of any on-going performance or repair and maintenance issues associated with the solution
  - Summary report

Team

- Lead organisations: DHN developer, local authority, water company (or other utility), combined civils contractor
- Participating: Infrastructure master-planning engineers, specialist cost consultants,

commercial / legal advice

Timescale

- Phase 1: 3 – 6 months to identify locations, plan and resolve commercial issues
- Phase 2: 6 – 12 months project delivery, depending on scale
  (target to commence early 2019 to align with water company AMP 7 programme)

Costs

- Underlying DHN costs financed by the DHN company based on future revenue
- Phase 1
  - Shared civils project direction and solution design: 20 days at £1,000/day (£20,000)
  - Shared civils project and technical planning 30 days at £600/day (£18,000)
  - Shared civils commercial / legal costs: 15 days at £2,000/day (£30,000)
- Phase 2
  - Additional technical support in delivery
  - Site data collection and documentation: 50% x 90 days at £600/day (£27,000) (assume time on site and documentation is shared 50% with another route map)

- Total: £95,000 (there may be additional cost to underwrite the solution with project insurance, based on the uncertainty of a new technical and commercial approach

Funding & motivation for investment

- The shared civils solution has already been identified as having high levels uncertainty and it has not attracted entrepreneurial investment. As a result it is unlikely to attract commercial or industrial funding.
- Therefore the investment for a proof of concept demonstration is best supported publicly by HNDU or Strategic Energy Funding (SEF). This will also enable the widest sharing of project learning and insight.

Success criteria

- Planning and execution of a shared civils demonstration project which gathers sufficient data and insight to either:
- Confirm the value of the shared civils approach, identifying opportunities to refine the solution, even though the project may not have delivered savings, or
- Identify additional challenges and obstacles that defeat the potential of the solution to repeatedly make savings in DHN CAPEX even after further development

Activity 5: Programme Deployment Model

Aims

Building on Activities 3 and 4, this is the creation of a deployment model as a template for testing the viability and implementing a shared civils solution in specific locations.

Introduction

This activity is the development of the standard approach to assessing the value of shared civils to specific DHNs during the project planning phase. The model needs to enable DHN developers and designers to make a straightforward assessment of the likelihood that a shared civils solution will have a positive impact on project financial viability.
The deployment model will use the scope assessment tool from Activity 3 and the commercial and legal frameworks from Activity 7 to develop a repeatable process for routine use in DHN planning.

Work programme

- Summarise the information requirements for the scope tool and the legal / commercial model
- Identify the sources of information needed for the assessment in local authorities, utility companies and other stakeholders
- Develop a simple, light-touch, data gathering approach and database for collating both project specific data (e.g. geographic / typology data) and generic shared civils insight (e.g. utility company contact points and attitude to shared civils)
- Develop a decision tree process for shared civils planning
- Gain permission to test the process on specific DHN projects (even if shared civils are not seen as a priority and are unlikely to be used)
- Refine the model and standardise the approach as a best practice tool

Team

- Lead organisations: District Heating Knowledge Centre, or specialists contracted to deliver the activity whilst this organisation is established, and DHN developers
- Participating: utility companies, local authorities, DHN designers, cost consultants
- Consulted / informed: HNDU, DCLG

Timescale

- Data gathering approach and database: 6 months in parallel with Activity 4.
- Decision tree process, testing and refinement: 6 months

Costs

- Process design specialists: 15 days at £1,000/day (£15,000)
- Project delivery, documentation and database tool development: 30 days at £600/day (£18,000)
- DHN design resource: 5 days at £600/day (£3,000)
- Cost consultancy: 5 days at £600/day (£3,000)

- Total: £39,000 + limited expenses

Funding & motivation for investment

- The deployment model is expected to be a 'best practice guide' held by the District Heating Knowledge Centre (Route Map A). For it to be an industry wide tool it is appropriate to fund its creation publicly via HNDU.

Success criteria

- Creation of a workable deployment model to support first time adopters of the approach in planning and execution of a shared civils approach

Activity 6: Market Research to Test the Shared Civils Commercial Models

Aims

To clarify the specific requirements of DHN Developers, local authorities, other utilities and contractors in order to maximise the benefits of a shared civils solution and reduce the challenges and sacrifices of combining the activity between multiple organisations.

Introduction

It is essential to understand the specific requirements of all parties participating in a shared civils activity. For example their organisational priorities and attitudes to risk are likely to be very different. Without this alignment it is unlikely that shared civils will be adopted a standard solution for DHN cost reduction.

A specialist consultancy/research company will be commissioned to test the attitudes to civil engineering contracts in general, then to understand the particular challenges of street works for clients, contractors and the local authority.

Next step is then to understand each group's and individual organisation's reaction to the five shared civils models presented in the **Proposed Solution** section above.

Work programme

- Develop a common structured interview for use with shared civils stakeholders
- Select a sample of local authorities, utilities companies, DHN developers and contractors to represent a cross section of the shared civils market
- Carry out a series of interviews to explore their attitudes to the potential solution from both commercial and operational perspectives
- Collate information, feedback to participants and prepare a summary report
- Propose the commercial solutions to be developed in Activity 7

Team

- Consulting organisation skilled in market research and value proposition design
- Participants from a representative sample of:
- Local authorities (10)
- Water companies (6)
- Electricity DNOs (3)
- Gas GDNs (2)
- Digital infrastructure companies (2)

Timescales

- 3 months

Costs

- Programme design, specialist consultant: 5 days at £1,000/day (£5,000)
- Setting up surveys and collation of findings: researcher 10 days at £400/day (£4,000)
- Interview planning and execution: senior researcher 30 days at £500/day (£15,000)
- Collate and prepare report: senior researcher 10 days at £500/day (£5,000)

- Total: £29,000 + £2,000 travel and expenses.

Funding & motivation for investment

- This research will support successful commercial deployment of alternative civil engineering approaches including shared civils. It potentially has a wider benefit than for DHNs and so funding could be provided by HNDU or the broader Infrastructure Projects Authority

Success criteria

- Sufficient understanding is gained to be able to document the opportunities barriers to adoption for shared civils solutions and understand the commercial and technical innovations needed to make them attractive and viable

Activity 7: Develop Commercial / Contractual / Legal Models

Aims

There is an advantage in a single commercial model for the Shared Civils approach and an effort should be made to limit the number of variants to achieve a common approach.

Introduction

The cost of negotiating individual collaborative contracts between DHN developers, utilities local authorities and contractors will come at significant cost of commercial / legal expertise. A single commercial model and contractual documentation for the Shared Civils approach is advantageous, but it is likely that market research (Activity 6) will reveal the need for more than one. Even so effort should be made to limit the number of variants so that each is robustly developed and regularly used.

As described in the solution description, 5 approaches are considered likely and worthy of exploration and market research to test. If these options can be narrowed down to two or three, it will support the ambition of simplicity and increase the likelihood of shared civils adoption in DHN delivery.

Work programme

- Review and summarise the commercial findings from the market research
- Distil these into the crucial requirements and barriers for each stakeholder
- Summarise into a set of aligned requirements which define commercial models
- Confirm the minimum number of commercial models and clarify their key aspects
- Propose a framework for allocation of risk and reward (savings) for each party to the commercial agreement across the required approaches

Team

- Lead: Consultancy specialising in alternative delivery models
- Participants: DHN Developer, commercial legal advice, utility companies

Timescale

- 3 – 6 months development
- Further time and investment will be needed to formalise a commercially robust model and this is beyond the scope of current research.

Costs

- Lead specialist consultant: 40 days at £1,000/day (£40,000)
- Legal advice 10 days at £2,000/day (£20,000)

- Total: £60,000

Funding & motivation for investment

- This activity is designed to develop an initial commercial framework to a level where the solution can be tested
- As with the Activity 6 research, which underpins it, the commercial framework has a wider benefit than for DHNs and so funding could be provided by HNDU or the broader Infrastructure Projects Authority

Success Criteria

- One or more commercial frameworks for shared civils delivery have been developed to a point where the principles can be evaluated with stakeholders and potentially tested on demonstration projects

9.1 Annex 1: Work programme

Route Map F - Shared Civil Engineering Costs										
Activity	Cost (£k)		Year 1				Year 2			
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1: Example Business Case	£ 25									
2: Technical Solution Development	£ 16									
3: Scope Assessment Tool	£ 100			Phase 1	Phase 2: Design		Phase 3: Testing			
	(+/-£30k)									
4: Demonstration Project	£ 95	Engage / Initiate			Phase 1:	Proposal	Phase 2: Delivery			
5: Programme Deployment Model	£ 39						Phase 1		Phase 2	
6: Market Research	£ 31									
7: Commercial / Contractual / Legal	£ 60									
Total :	£ 366									
			Legend							
			Phase 1: Activity		Contingency					
			Phase 2: Activity		Contingency					
			Phase 3: Activity							

10 Route Map G: Direct HIU System and Existing DHW Storage

Route Map Summary

The cost of Hydraulic Interface Units (HIUs) is a significant component of the total cost. The baseline design was for an indirect connection with a heat exchanger separating the DH circuit from the dwelling radiator circuit, and for domestic hot water an instantaneous hot water heat exchanger to replace an existing hot water cylinder if installed. A simpler and lower cost design is to directly connect the DH circuit to the radiator circuit and where a hot water cylinder exists to retain this for the hot water production.

The solution does not require a new product but requires a change in design approach and certain risks and concerns to be addressed which would involve some improvements in products and designs. In addition, a process needs to be developed to establish the best type of installation for a given existing system taking account of customer choice.

The activities proposed are:

1. Market research to establish the preferences of customers
2. Market research to understand views and priorities of designers
3. Technical studies to establish potential impacts on OPEX
4. Product development to reduce risks from leakage
5. Development of a design process to arrive at the best solution for any given situation
6. Demonstration project to showcase the concepts and the cost saving potential
7. Reporting the results of demonstration project and provision of guidance
8. Further monitoring of follow-up projects and reporting as case studies

The external funding of Activities 1-8 is estimated at £416,000. Activities 1, 2, 3 and 5 are generic research activities for DH which would be best funded by BEIS-HNDU managed by the proposed DH Knowledge Centre (see Route Map A). Activity 4 will be led by manufacturers and it is envisaged that Innovate UK could match fund the development work. The demonstration project (Activity 6) is expected to be funded by a DH developer as it is intended that this will be a fully commercial offering. Strategic Energy Funding (SEF) will be used for collating demonstration project data and insight; also for dissemination via the DHKC. Funding for monitoring, customer research and reporting on the demonstration project (Activities 7-8) will be required and HNDU or SEF will be used as a source for this stage.

The overall timescale for this route map is 33 months including delivering and monitoring of a demonstration project.

Solution Description

Current challenge

The baseline cost model shows that the HIU is a significant element in the total cost. The baseline design assumes an indirect connection to the space heating system and a new instantaneous hot water system. This design requires two heat exchangers and associated controls and alternatives which involve a simpler design will lead to a significant cost reduction.

Proposed Solution

The solution aims to ensure that the optimal selection of the type of HIU is chosen by designers to consider cost, performance and customer preference, rather than always choosing the indirect and instantaneous hot water solution that formed the baseline design. The emphasis is on conversion of an existing system to work with DH, retaining existing equipment where possible rather than installing a completely new system in every dwelling.

The route map focuses on providing information to designers and specifiers rather than developing a new product as the technological solutions are largely in place, although in a few cases some further product development could enhance the performance.

There are two system design options that simplify the HIU design and reduce cost and which can be implemented either separately or together:

Direct Connection HIU
The baseline network assumes that an indirect connection HIU is used where a heat exchanger is used to separate the DH system water from the building's heating system. This is the most common approach today within the UK. The solution proposes that a direct connection HIU is used for dwellings and smaller non-domestic buildings which is simpler as the DH water is circulated directly through the radiators. This saves on the cost of the heat exchanger and associated equipment: a control valve which controls the secondary flow temperature, a circulating pump and its power supply and a pressure/expansion vessel for the dwelling side heating system. There will also be OPEX savings as return temperatures will be lower and there is less equipment to maintain. In some low temperature applications direct connection may also have a small benefit on network CAPEX as design return temperatures can be lower.

Direct connection will not be feasible where pressures in the DH network exceed radiator pressure ratings. Examples would be very high blocks of flats and schemes with a large variation in ground level with high static pressures or very large networks with high pumping pressure. Direct connection will be particularly appropriate for Typology B (flats) where it has been assumed that there is a heat exchanger substation at the entrance to the block and so pressures will be relatively low and below radiator pressure limits in most cases except for tower blocks over c12 storeys.

Reuse of existing hot water cylinder
The baseline cost model assumes that a new HIU incorporating an instantaneous hot water heat exchanger is installed in each dwelling. For dwellings where there was a combination boiler this would provide a similar facility. For dwellings where there was an existing hot water cylinder this would be removed. It was established that about 50% of existing dwellings have a hot water cylinder and the other 50% have a combination boiler.

The solution proposes that the existing cylinders are retained where available, subject to being in satisfactory condition. This avoids the cost of the hot water heat exchanger and associated control valve within the HIU. It is further assumed that the existing temperature control for the cylinder is retained. This would reduce the cost of the HIU and also in some types of dwelling lead to OPEX savings from lower heat losses and wider system benefits.

Figure 22 shows schematically the baseline solution (indirect and instantaneous hot water). Figure 23 shows the proposed solution of direct connection and instantaneous hot water (for dwellings with existing combination boilers) and Figure 24 shows the proposed solution of direct connection and retention of existing cylinder. These diagrams are for illustration of the concept only and there are a number of variations in design possible (for example some manufacturers use two separate control valves for each heat exchanger).

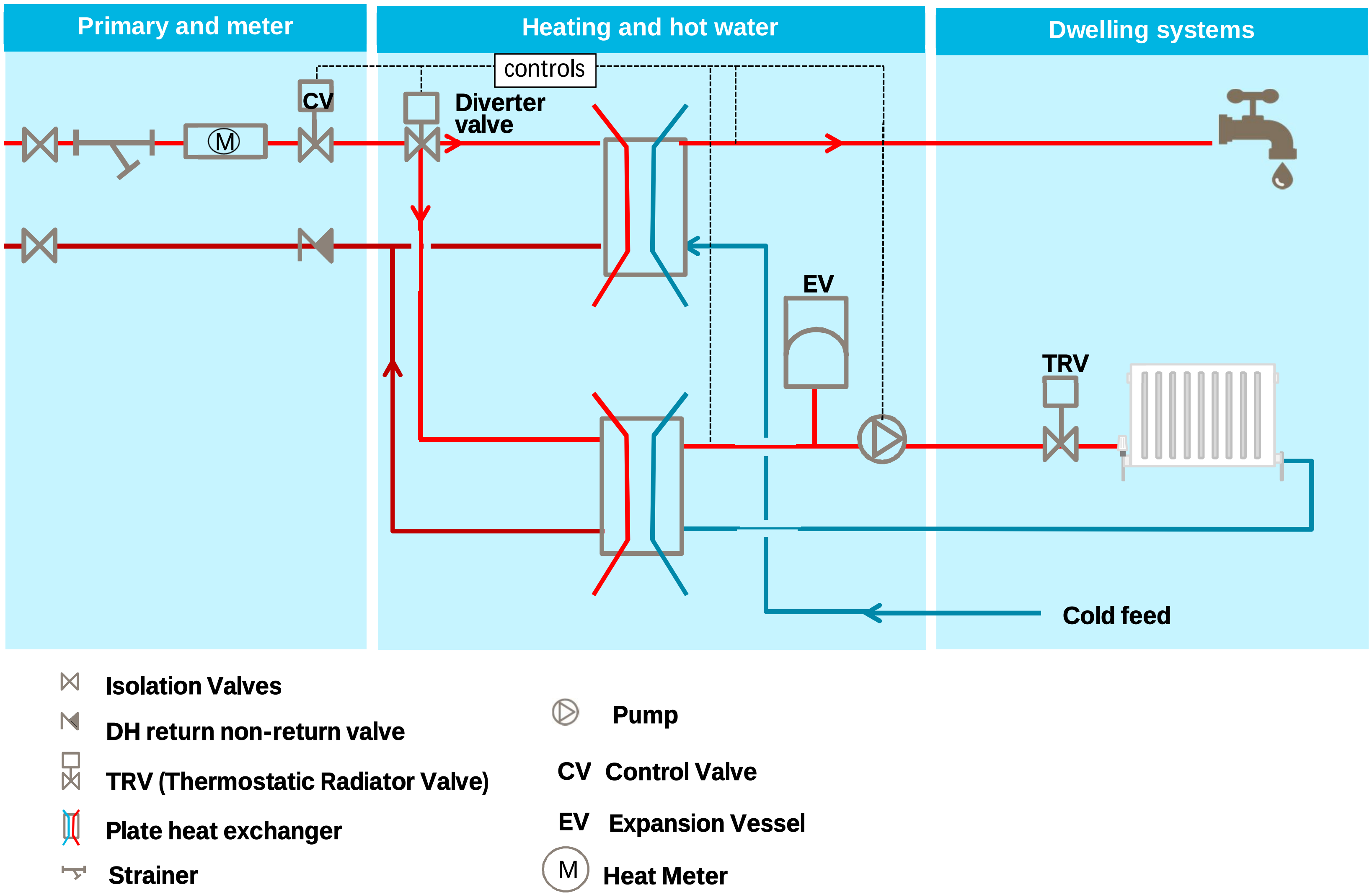


Figure 22: Indirect connection and instantaneous hot water

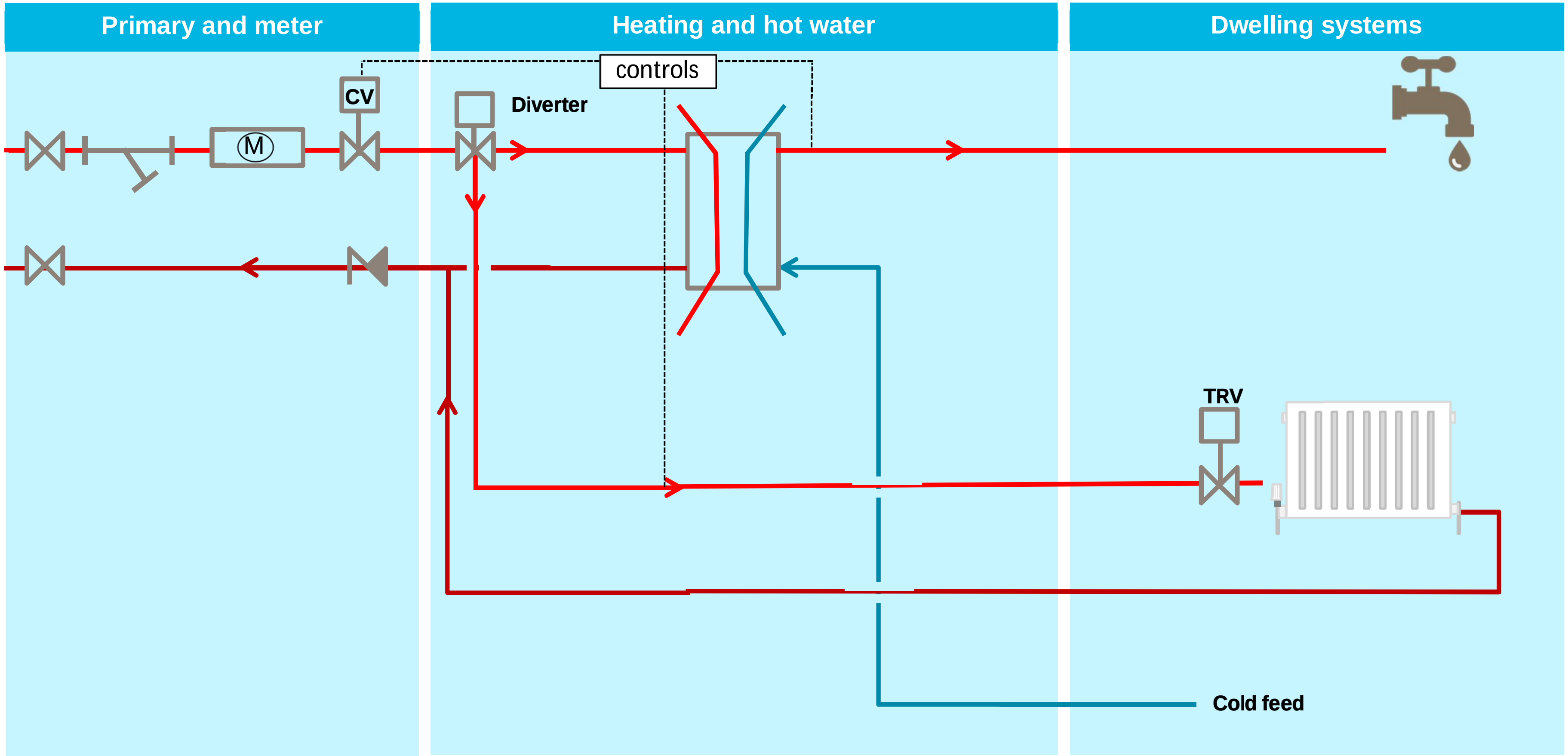


Figure 23: Direct connection and instantaneous hot water (see Figure 22 for legend)

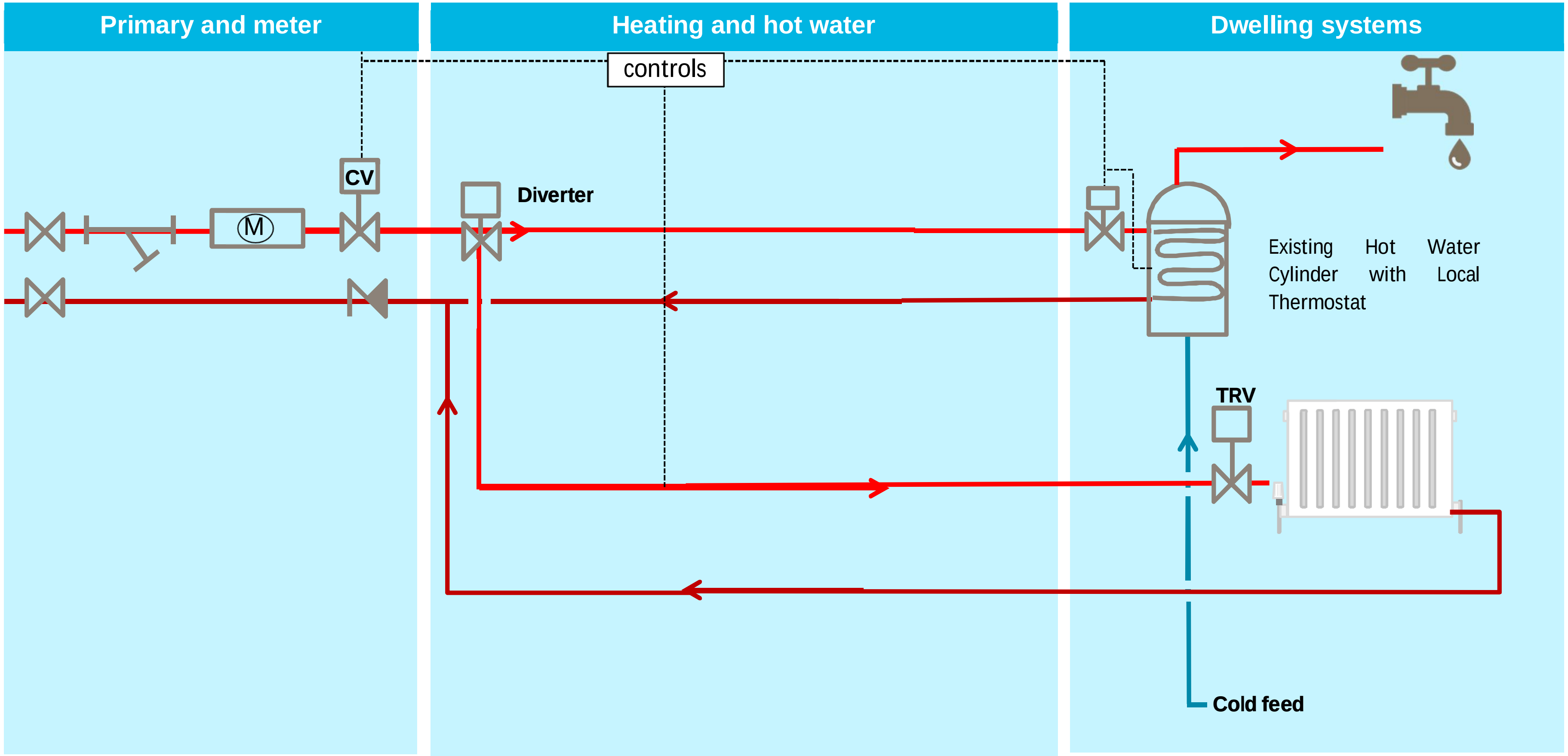


Figure 24: Direct connection and retention of hot water cylinder (see Figure 22 for legend)

Current Barriers to and Requirements for Implementing Solution

Assessment of Barriers

Both aspects of the solution are well proven technically although as with any retrofit system there are risks in either retaining or connecting to existing equipment.

Direct connection

There will be a need to confirm design pressure ratings of all components, the type of pipe and joints used and the general condition of the system. It has been assumed that any existing system will need to be cleaned before connecting and this would also provide information on its condition.

From the customer perspective, the main barrier to direct connection will be around the potential for greater damage to the property if there is a leak, even if it is accepted that this is a remote possibility. Given this perception, a product that detects leaks and automatically shuts off the DH supply would be a valuable technical development.

From a DH developer perspective, direct connection brings some performance benefits and lower costs making the DH supply more attractive but has the potential for additional risks caused by connecting to existing equipment e.g. contamination of the water or loss of water, which although the responsibility of the customer may result in a contractual dispute.

Direct connection means that the flow temperature onto the radiator is equal to the DH supply temperature which will constrain the design of the network.

Retention of existing hot water cylinder

Whether the existing hot water cylinder is retained or not will be partly driven by customer preference. The use of combi boilers is increasingly popular due to the potential to release space by removing the hot water cylinder and so changing to instantaneous could be attractive to some customers. In addition, the transfer to mains pressure hot water can be easily achieved with an instantaneous unit. Heat loss from the cylinder itself will be higher than from the instantaneous heat exchanger. This heat loss may be seen as useful in winter and for airing clothes in an airing cupboard but could add to overheating in summer especially in newly built small flats.

For the DH supplier, the retention of the cylinder will be a matter of a cost benefit analysis. If the existing cylinder is retained, return temperatures will generally be higher than for instantaneous heat exchangers during periods when hot water is generated except for the relatively rare situation when the cylinder is heated up from cold. However, for larger properties with long branch connections the use of a hot water cylinder will lead to lower heat losses from the branch. To overcome the higher return temperatures from a cylinder coil an external plate heat exchanger could be used to provide the heating; however, this would add to the cost.

To prevent legionella formation in stored hot water the cylinder needs to be heated to 60C regularly. This will set a minimum flow temperature for the DH network of around 70C whereas for instantaneous heat exchangers the minimum flow temperature could be around 55C.

After further discussion with stakeholders this solution has evolved further to recognise that there are a number of connection options available (see Figure 3) which need to be fully assessed for each dwelling and that customer choice is an important factor especially

as differing connection charges could be applied for the different options. The type and size of dwelling and the length of branch connection will be important factors in determining the optimum connection strategy.

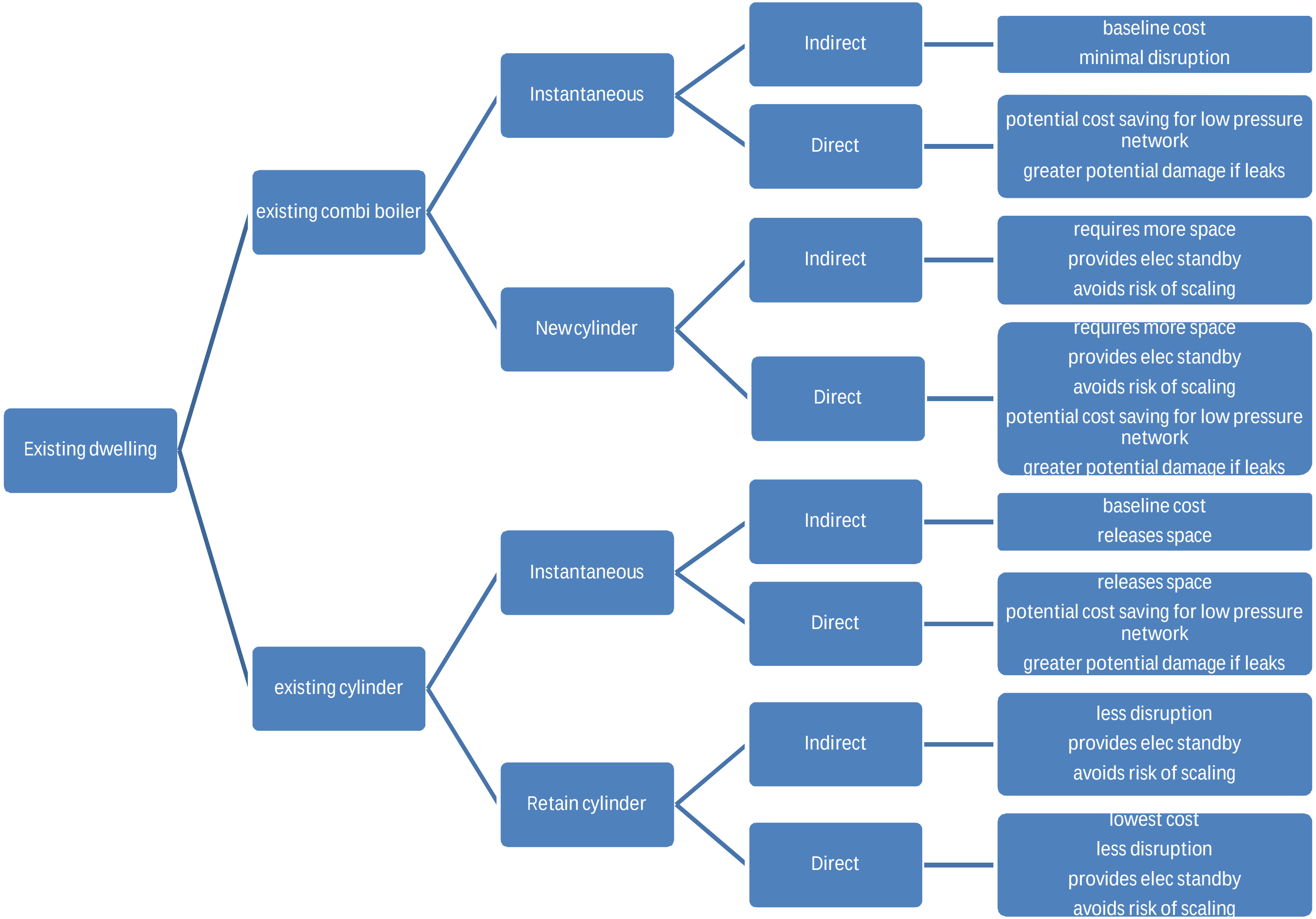


Figure 25: Options for connection of existing dwellings to a DH network

Development Requirements

Few technical developments are needed as the solution has been used in many applications. However, there are some developments which would make the solution more attractive, especially to ensure that operational risks and costs do not increase:

For direct connection

- A methodology to determine a safe working pressure for an existing system. This could involve collating data on existing products that are commonly used – radiators, pipework, valves, joints etc. or establishing an approach to the pressure testing of existing systems.
- A methodology for cleaning and flushing of an existing system to a defined standard suitable for direct connection to DH and for carrying out inspections during this process to determine the condition of the system (this would be a modification of established cleaning processes).
- A product that provides for automatic isolation of the dwelling system in the event of a leak (a number of such products already exist but further development is possible to provide greater surety and lower cost)

For the retention of existing cylinder

- A calculation procedure to determine whether retaining the cylinder will reduce heat losses compared to an instantaneous unit (dependent on size of connection, length of branch, planned operating temperatures)
- An assessment of the benefits of retrofitting a return temperature limiter which will ensure return temperatures are no more than say 60C
- The addition of a control system which can receive a signal from the DH company to heat the cylinder allowing the DH company to carry out a degree of demand side management to realise system benefits e.g. heating the cylinder overnight or mid-afternoon
- The provision of an external heat exchanger retrofitted to an existing cylinder (in place of an indirect coil within the cylinder) as an optional extra which would result in lower return temperatures and hence an OPEX benefit but higher CAPEX

Commercialisation requirements

This solution was analysed using the Ansoff matrix approach. It was found that this solution generally uses established products. It is to be introduced to a new market as most DH in the UK is either new build housing, social housing or non-residential buildings whereas the target market in this case is existing housing of mixed tenure. The customer for the solution is a DH developer and their designers. The approach needed in this case is therefore described as Market Development - existing products into new markets.

The key commercialisation activities are:

Market development

As this is an established product entering a new market the first step is to carry out market research to fully understand attitudes and preferences for the available solutions for interfacing with the DH system. There are two elements to this:

- Market research with potential end users of heat: The first step will be to understand the benefits and sacrifices that end users experience with their current heating system and their attitudes to the potential solution. This will explore issues such as: how space is valued, the benefit of having alternative back-up electric hot water heating, perception of risk of damage from leaks, relative merits of hot water storage and instantaneous hot water, acceptable levels of cost for connection to DH. Using the benefits and sacrifices a set of user requirements can be defined and then new value propositions developed to satisfy these requirements.

- Market research with DH Developers and their Designers: The benefits and sacrifices experienced by Developers and Designers also need to be understood as well as their attitudes to the potential solution. This will include issues such as: anticipated CAPEX savings, performance benefits/drawbacks from the solution, wider system benefits, risks of complaints, cost of call-backs, failure of existing systems, contamination of DH water, risk of damage from leaks, and risk of loss of water from system. From this a set of parallel requirements can be developed to those of end users and value propositions defined to satisfy the Developers and Designers.

It will also be important to create an environment in which the DH developers and their designers can gain confidence in the use of direct connection/existing cylinders. This is best achieved by:

- A demonstration project
- Monitoring of the demonstration project after completion and dissemination of the results including a written case study and guidance materials
- A training programme in the techniques involved

Product Development

Although the above has concentrated on market development there is in parallel some scope for product enhancements as described above under Technical Requirements. The route map proposes work in this area will take place following the market research to see if any concerns raised can be addressed through further product development to deliver the new value propositions.

Some stakeholders are concerned that return temperatures will be higher with cylinders and hence network heat losses will be higher. Others argue that heat losses will be lower as branches can cool down during the off periods. A more detailed study of this question for a range of typologies would be valuable.

The wider system benefits of retaining thermal storage in the form of hot water in dwellings is also not fully understood and will in any case vary depending on the type of heat source used so again a technical study would be valuable.

Aspects Beyond the Scope of this Route Map

The demonstration project could be combined with:

- Route Map A: Knowledge Management, Research and Training. Knowledge sharing of the potential for using direct connection and retaining existing cylinders, especially by disseminating the results of the demonstration project
- Route Map B: Low Flow Rate Design. One of the options for reducing flow rate is to use hot water cylinders with a long heat up time.
- Route Map H: HIU Optimisation. The work of this Route Map will be very relevant to the Route Map H which is developing low cost HIUs for any connection type but especially focusing on the solution presented here

Route Map Proposal

The activities identified requiring further work and validation for this route map are:

1. Market research into customer attitudes
2. Market research of DH developers and their designers
3. Technical supporting studies
4. Product design and development
5. Process methodology for designers
6. Demonstration project
7. Monitoring and report on demonstration project, dissemination of results and production of guidance
8. Further demonstration projects

This section proposes the route to address each area.

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding

The external funding of Activities 1-8 is estimated at £416,000.

Activities 1, 2, 3 and 5 are generic research activities for DH which would be best funded by BEIS-HNDU managed by the proposed DH Knowledge Centre (see Route Map A). Activity 4 will be led by manufacturers and it is envisaged that Innovate UK could match fund the development work.

The demonstration project (Activity 6) is expected to be funded by a DH developer as it is intended that this will be a fully commercial offering. Strategic Energy Funding (SEF) will be used for collating demonstration project data and insight; also for dissemination via the DHKC.

Funding for monitoring, customer research and reporting on the demonstration project (Activities 7-8) will be required HNDU or SEF will be used as a source for this stage.

Activity 1: Market research of customers

Aims

To understand customer preferences with respect to their heating and hot water choices to inform the design process and selection of connection type.

Introduction

Market research is proposed to understand better the customer preferences with respect to the type of hot water system they have and how a DH system would provide benefits. In particular, the research will examine how customers might view:

- Initial cost of connection
- Running costs and standing charges
- Space required for hot water cylinder
- Security of having electric immersion heater as a back-up supply
- Having unlimited supply of hot water from instantaneous heater vs using a stored system which takes time to reheat
- Risk of leaks and potential for property damage

Using the benefits and sacrifices, a set of user requirements can be defined and then new value propositions developed to satisfy these requirements.

Work programme

- Qualitative research comprising focus groups to profile customers and develop a consumer segmentation model, building on work already carried out by the Smart Systems and Heat Project
- Understand the benefits and sacrifices they experience with the current solution
- Explore their attitudes to the potential solution
- Prepare report on results
- Develop value propositions (e.g. function, speed, dependability, flexibility, price)
- Conduct quantitative research to validate the segments and size the market opportunity, if required

Team

- Market research consultancy with experience in domestic heating issues

Timescales

- 3 months

Costs

- £30,000 for market research company fees based on:
  - Planning of qualitative work and preparation: senior researcher 20 days at £500 per day (£10,000)
  - Setting up focus groups and carrying out face to face interviews: researcher 50 days at £400 per day (£20,000)
  - Collate and prepare report: senior researcher 10 days at £500 per day (£5,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to understand the perception of customers to the proposed lower cost solution so that the new DH connections can be designed to suit customers' needs as well delivering lower costs

Success Criteria

- Completion of research to understand range of views that consumers have when considering different options for hot water heating and connection to DH, with the characteristics of the different segments identified

Activity 2: Market research of DH developers and their designers

Aims

To understand the attitudes of designers to changing to the lower cost proposed solution and the drawbacks they see in the solution and any suggestions for product development to overcome these.

Introduction

Qualitative market research is required to understand how DH developers and their designers view the connection options available and the balance between initial cost, operational costs for maintenance, impact of return temperatures, risks of damage from leaks, and opportunities for product improvements. The reasons why the solution is not adopted need to be established so that the work in the remainder of the route map can address these.

Work programme

- Profile DH Developers and Designers and categorise these into sectors with similar characteristics. A maximum of 10 interview sessions will be set up each of which would comprise one or two people from the developer and designer companies (it may be valuable to interview DH developers with their designers present)
- Understand the benefits and sacrifices they experience with the current solution
- Explore their attitudes to the potential solution
- Develop value propositions (e.g. function, speed, dependability, flexibility, price)

Team

- The work would be delivered by a market research organisation with experience in engineering design and energy projects

Timescales

- 3 months

Costs

- Market research fee £18,000 based on:
  - Planning of qualitative work and preparation: senior researcher 10 days at £500 per day (£5,000)
  - Setting up interview sessions and carrying out the face to face interviews: researcher 20 days at £400 per day (£8,000)

- Collate and prepare report: senior researcher 10 days at £500 per day (£5,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to understand the current attitudes and preferences of designers and DH developers and why lower cost solutions are not being implemented

Success Criteria

- Completion of in-depth interviews with sufficiently robust sample representativeness of industry to provide high quality insights into attitudes of designers and developers to the proposed solution

Activity 3: Technical supporting studies

Aims

To provide authoritative data to designers, in the area of heat losses and system benefits for a range of typologies and configurations, to assist in the selection of optimal connections.

Introduction

Technical studies related to the direct connection and retention of existing cylinders are proposed to provide the necessary information for designers to make informed choices for a particular situation. In particular, the following questions need to be answered:

- For a range of housing typologies how do heat losses from systems with cylinders compare to systems using instantaneous hot water?
- For a range of housing typologies how do heat losses from systems with direct connection compare to systems using indirect connection?
- Are there system benefits from the use of hot water cylinders in terms of demand management and what is the financial benefit of these for a range of different types of heat sources?
- How do maintenance costs vary with the different connection options?

It is also possible that the studies will identify enhancements to any of the connection options that would improve performance, or would reduce cost or maintenance requirements, and these will be highlighted for Activity 4 to consider.

Work programme

- Plan the work and define typologies to be considered
- Model the base case for each typology
- Model the proposed solution (separately for hot water options and direct/indirect connection)
- Model the impact of managing the demand for hot water heating on a number of different heat source types (CHP, heat pump, biomass)
- Obtain costs for maintenance of different systems from operators of DH
- Prepare report on the findings

Team

- A specialist engineering consultancy will be required for this activity with understanding of district heating and its wider context

Timescales

- 3 months

Costs

- Specialist consultancy fee £27,000 based on:
  - Principal engineer to set objectives and plan and review the work, 5 days at £700 per day (£3,500)
  - Design engineer to carry out research and modelling work, 40 days at £500 per day) (£20,000)
  - Specialist for systems modelling and wider benefits, 5 days at £700 per day (£3,500)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to provide high quality information that will encourage designers to adopt lower cost solutions

Success criteria

- A report that provides data based on thorough research that will have impact on the views of designers when considering connection options

Activity 4: Product design and development

Aims

To produce product enhancements that address the concerns of the market - both end users and DH developer and designers - to reduce cost and improve performance.

Introduction

The output from the market research (Activities 1 and 2) and technical studies (Activity 3) will be assessed and this will lead to further development of the HIU products to meet the revised value propositions.

In meetings with stakeholders during the project two areas where further product development could add value were identified (albeit adding some cost which may not be justified by reduced OPEX or reduced risk).

1. Use of an external heat exchanger to be retrofitted to an existing cylinder to produce lower return temperatures and hence lower heat losses
2. Provision of a leak detection system and automatic shut-off device for a direct connection HIU to limit damage from leaks and increase customer confidence

Other enhancements identified by the market research or technical studies will also be taken forward in this activity.

Work programme

- Review outputs of Activities 1, 2 and 3
- Identify potential enhancements
- Develop design concepts
- Prototype and test
- Refine the solution
- Finalise design ready for commercial application
- Performance testing
- Prepare marketing material

Team

- HIU manufacturers will lead the activity
- Supported by engineering consultants familiar with DH and the methods of connection
- Supported by DH developers as the purchasers of HIUs and with knowledge of potential value of system benefits

Timescales

- 6 months

Costs

- 3 Innovate UK projects. Approximately 30 man weeks @ £100k/yr = £60k each.
- £90,000 Innovate UK funding and £90,000 Industrial match funding

Funding & motivation for investment

- Funding would be provided by the HIU manufacturer for commercial potential. Motivation of manufacturers would be to have developed products that deliver extra value thus increasing their market share
- Potential match funding by Innovate UK to develop the technology in the UK and have the capability for export. Innovate UK would be motivated by assisting industry to develop innovative products in the UK that would not only assist in delivering lower cost DH networks but also have export potential

Success criteria

- Deliver enhancements to the HIU solution that enable direct connection and retention of existing hot water cylinders to be implemented more widely

Activity 5: Process methodology for designers

Aims

To develop a clear process that will enable designers to rapidly assess an individual dwelling and taking account of the customer's preferences determine the optimum connection strategy.

Introduction

To assist designers, it is proposed to develop a process to be followed for making connections to dwellings. This will establish the type of existing system, the customer's preferences and depending on these the type of connection required. This will in turn determine the design of the HIU and the installation and commissioning activities. With a defined process to follow it is more likely that the optimal solution will be selected rather than the adoption of a standard solution that is a 'safe' selection.

Work programme

- Define information required on existing system
- Define questions to ask customer
- Develop a decision tree tool based on these questions
- Define activities required to specify the details of the connection and the HIU
- Define activities required for installation and commissioning including testing and cleaning of existing system
- Finalise decision tree tool and compile accompanying report

Team

- Engineering consultancy or DH developer familiar with the issues of connecting buildings to DH

Timescales

- 3 months

Costs

- £22,000 based on:
  - Principal engineer for planning and review of work, 10 days at £700 per day (£7,000), engineer to develop process tool, 30 days at £500 per day (£15,000)

Funding & motivation for investment

- Funding could be provided by HNDU managed by the Route Map A DH Knowledge Centre
- HNDU's motivation would be to provide a methodology that will enable designers to select the optimal HIU design both to satisfy customers and to deliver the greatest cost reduction

Success Criteria

- A clear process to be followed to ensure that the best connection option is selected for delivering technical, cost and customer benefits

Activity 6: Demonstration project

Aims

To deliver a demonstration project that shows how the use of direct connection and retaining cylinders delivers cost reduction without incurring additional OPEX or operating risks.

Introduction

A demonstration project will be implemented to provide confidence to the design community in the direct connection/use of existing cylinders design concept. We expect this to take the form of a group of c20-50 houses with a range of HIU options being installed for comparison purposes. After the project has been constructed the scheme will be monitored both at a technical level and by customer research to establish the impact of the installation work in terms of disruption, how comfort levels have been met, and any technical issues that have arisen (see Activity 7).

Work programme

- Identify suitable site
- Carry out site surveys and customer engagement
- Follow the process methodology to decide on the connection strategy
- Design the new connections
- Install the new connections including testing and cleaning of the existing system
- Commission the new system and commence operation

Team

- DH company and their designers
- HIU manufacturers

Timescales

- 18 months (3 months to plan, 3 months to construct, 12 months operation)

Costs

- The cost of the project will depend on the number of dwellings served but is expected to be about £1500 per dwelling including design work, excluding the DH network.
- There will be a cost to set up the demonstration project, including identifying a suitable location and negotiations with the DH developer. A cost of £15,000 is allowed based on 20 days of a senior DH specialist at £750 per day

Funding & motivation for investment

- The cost of the demonstration project will be financed by the DH company as heat sales will be received over the lifetime and it is intended that the solution will be more cost-effective than current solutions
- Strategic Energy Funding (SEF) will be used for identifying the demonstration project and negotiating with the DH developer.
- Provision of SEF will facilitate a demonstration project so that an innovative solution can be marketed to the DH industry

Success Criteria

- Delivery of a demonstration project that shows how costs of the connection can be significantly reduced compared to a conventional design with a positive response from customers

Activity 7: Monitoring and report on demonstration project, dissemination of results and production of guidance

Aims

To prepare material that captures the benefits of the demonstration project in a way that can be disseminated to the industry in an accessible and informative way to encourage take-up of the solution.

Introduction

The value of the demonstration project will only be realised if the results are widely disseminated. This activity will produce the following outputs:

- A detailed technical report on the project
- A report on the customer experience of both construction and operation
- A case study paper that contains the main results from the project and demonstrates the cost and other benefits in a readily accessible way. This could be presented at a conference or published in an appropriate journal
- A Powerpoint presentation/video which again explains the main benefits of the solution and the results of the demonstration project

These outputs will be made freely available on-line and accessed via a number of websites. In addition, dissemination will take place through technical journals and presentations at conferences.

Following the monitoring and reporting of the demonstration project, guidance documents will be produced for the various elements of the solution.

Work programme

- Engage early with the team delivering the project and their customers
- Monitor the project through its design and construction stages, attending regular site meetings
- Establish the costs of the project for comparison with a conventional approach
- Carry out a post completion survey of the customer experience, shortly after completion of the construction and after 12 months operation
- Establish from monitoring data on energy and temperatures any operational benefits

- Review the operational experience with the DH company after 12 months of operation
- Prepare the detailed technical report, the customer experience report, the case study and the Powerpoint/video presentation

Team

- Engineering researchers familiar with the technology
- Social researchers skilled in obtaining customer feedback from novel energy systems

Timescales

- 21 months (18 months work in parallel with the demonstration project plus 3 months to finalise documentation)

Costs

- £24,000 based on:
    - Monitoring of design and construction, Engineer one day a month for 6 months, 6 days at £500 per day (£3,000)
    - Cost comparison, cost consultant for 5 days at £600 per day (£3,000)
    - Social researcher for customer surveys 10 days at £500 per day (£5,000)
    - Technical review of efficiency gains, engineer 6 days at £500 per day (£3,000)
    - Preparation of reports and case studies, engineer 20 days at £500 per day (£10,000)

Funding & motivation for investment

- It is proposed that SEF funding is sought for this
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success Criteria

- Documentation produced on the demonstration project that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer

Activity 8: Further demonstration projects

Aims

To develop a number of projects using this solution in a variety of geographies and housing types to further show the benefits especially from lower CAPEX and OPEX.

Introduction

A single demonstration project will not have the necessary impact for the whole of the industry so further projects will be encouraged and nurtured to take this approach. These projects will be subject to further monitoring so that feedback can be provided to designers using the dissemination route in Route Map A.

We expect the demonstration projects to be self-funded by DH developers but the support work will be carried out by a specialist research organisation on behalf of the industry as a whole and would require a two year period.

Work programme

- Maintain dialogues with the leading DH developers
- Promote the solution using the material developed in Activity 7
- Monitor the development of each project responding to queries and providing general advice
- Obtain technical data and cost information from each site
- Obtain customer feedback from each site
- Prepare a case study on each project for wider dissemination, identifying bioth positive and negative results

Team

- DH developers
- Engineering researchers familiar with the technology
- Social researchers skilled in obtaining customer feedback from novel energy systems

Timescales

- 24 months

Costs

- £100,000 for 10 further schemes based on approximately half the effort assumed for Activity 7 as there will be benefits from replication and familiarity and the work will be less detailed. For each scheme:
    - Monitoring of design and construction, Engineer half day a month for 6 months, 3 days at £500 per day (£1,500)
    - Cost comparison, cost consultant for 2.5 days at £600 per day (£1,500)
    - Social researcher for customer surveys 5 days at £500 per day (£2,500)
    - Technical review of efficiency gains, engineer 3 days at £500 per day (£1,500)
    - Preparation of reports and case studies, engineer 5 days at £500 per day (£2,500)
    - Total £95,000 for 10 schemes. A further £5,000 is allowed for initial promotional activity.

Funding & motivation for investment

- It is proposed that SEF funding is sought to collate demonstration project data and insight and disseminate via the DHKC.
- Provision of SEF will enable the maximum benefit to be gained from the demonstration project by providing high quality monitoring and reporting so that others can learn and replicate with confidence

Success Criteria

- Documentation produced on the demonstration projects that is engaging, attractive and conveys the message that verifiable cost savings can be achieved through the use of the solution, without compromising quality for the customer

10.1 Annex 1: Work programme

Route Map G - Direct Connection and Retain Existing Cylinder - Activities, costs and timescales																	
Activity	Cost	Year 1				Year 2				Year 3				Year 4			
	£	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1. Market Research - end users	30,000																
2. Market Research - DH developers and designers	18,000																
3. Technical supporting studies	27,000																
4. Technical product development	180,000																
5. Design process methodology	22,000																
6. Demonstration project	15,000		identify site		planning	construct		operation									
7. Monitoring, reports and guidance	24,000																
8. Further monitoring of projects	100,000											ongoing					
TOTAL	416,000																

11 Route Map H: HIU Optimisation

Route Map Summary

The baseline cost model identified the cost of Hydraulic Interface Units (HIUs) as being a significant component of the total DHN cost. The baseline design was for an indirect connection using a heat exchanger to separate the DH circuit from the dwelling radiator circuit, with a second heat exchanger for instantaneous domestic hot water.

This solution builds on the Route Map G capital cost (CAPEX) benefits of using Direct connection HIUs where feasible; whilst recognising that Indirect connections are likely to be required in some instances. As a result the HIU Optimisation route map develops solutions for direct and indirect connection and both instant and stored hot water.

This route map uses a three tier approach to reducing the CAPEX of the domestic HIU, whilst ensuring that the operational performance and cost (OPEX) are not compromised.

The tree tiers are:

- Simplification and Design for Manufacture and Assembly (DfMA)
- Value Engineering at scale
- Optimisation of: Direct vs. Indirect connections and Instant vs. Stored hot water

The solution requires reduction in costs of both existing components and HIU products. In addition the route map development has identified the potential value of a new Primary Metering Module which will enable standardisation of core components, but also supports alternative system solutions (direct vs. indirect supply, instant vs. stored hot water) and gives options to support customer choice.

The activities proposed are:

1. Market research to confirm stakeholder technical and commercial requirements
2. Market alignment to encourage stakeholders to adopt a design for target cost approach
3. A combined valve for the Primary Metering Module linked to electronic controls and communication.
4. Low-cost and low-maintenance Heat Meter for the Primary Metering Module
5. Low-cost and low-maintenance indirect instantaneous (IND/INS) HIUs
6. A low-cost plastic, standardised, stand-alone Primary Metering Module

Investment to deliver these activities is anticipated to be of the order of £7.5M (although a lower investment option is discussed), coming from a blend of public funding (HNDU / Innovate UK) and industrial investment in capability. The timescale for this route map is expected to be 3-4 years including market testing of new products.

Solution Description

Current challenges

The supply and installation of the HIU accounts for 18% of the total cost of the DHN in the baseline model based on a unit cost of £1,500. This compares to a delivered cost of less than £400 for an equivalent gas combi-boiler.

Although there is development activity in the HIU market alternative technical solutions are vying for position in a relatively small market (compared to combi boilers). If the UK takes a lead on the drive for standardisation of components and common platform the benefits of reduced costs and improved performance will be achieved earlier.

There are three challenges to cost reduction of domestic Heat Interface Units:

- Cost challenges – reducing component and overall system CAPEX & OPEX
- Technical challenges – engineering and manufacturing changes which still ensure system performance and reliability
- Commercial challenges – encouraging HIU manufacturers and suppliers to standardise, reduce costs and pass on savings to the network developer

Proposed solution

The current default solution for UK DHNs is an indirect HIU with instantaneous heating of domestic hot water (DHW), which isolates the domestic heating and hot water from the network with two heat exchangers. Cost reduction techniques applied to such units during Stage 2 of this project identified potential savings of 54% on a like-for-like basis.

In addition, there is the potential to select one of the four alternative configurations of direct connection HIU and / or DHW stored in a tank.

1. **Ind**irectly connected HIUs with **Ins**tantaneous hot water units designated: **IND/INS**
   - IND/INS Units are characterised by 2 heat exchangers, a single pump and an expansion vessel for the secondary central heating
   - This configuration is the most commonly specified in current UK DHNs
   - This is shown in Figure 26
   - Development of a low-cost and low-maintenance IND/INS HIU would have an immediate impact on the cost of the DHN. Alternative configurations have the potential to simplify the design and reduce the cost further as described below.

2. **Ind**irect with **Sto**rage of DHW in an existing cylinder: **IND/STO**
   - Characterised by a pump on the existing heating circuit and a second pump to supply the DHW storage tank. There are two versions of this configuration:
     - Single Heat Exchanger for combined Heat and DHW circuit (see Figure 27)
     - Twin Heat Exchanger – added cost and superior performance with greater heat-exchanger capacity for high DHW usage (e.g. multiple bathrooms / power showers) (see Figure 28)

3. **Dir**ect with **Ins**tant DHW: A significantly lower cost HIU: **DIR/INS**
   - Characterised by a single heat exchanger for DHW, direct connection to existing heating (radiators and other emitters) at DHN pressure. No need for pumps or an expansion vessel.
   - Direct connection with instant hot water is commonly specified in Scandinavia with a local heat exchanger as shown in Figure 29, or with a third supply pipe for DHW; which is heated at apartment block level.

4. **Dir**ect with **Sto**rage: **DIR/STO**
   - Characterised by direct secondary connections to the existing heating circuit and utilising an existing DHW storage tank. This is, in effect the simplest possible HIU solution, with the lowest number of components and cost. It also makes maximum usage of the property's existing system which householders are familiar with.
   - Figure 29 shows that there is only a diverter valve in the 'heating and hot water portion of the HIU. The bulk of the equipment is in the Primary and Meter section which provides:
     - Isolation from the DHN via valves
     - Flow control – variable flow based on demand
     - Straining solid debris from the treated heating water
     - Heat metering (regulatory requirement in most cases)

All HIU proposed options contain common elements in the Primary and Meter portion, so the following components are common to all solutions and savings have a universal impact:

- Heat Meter
- Isolation valves (2 or 4)
- DH non-return valve
- Temperature sensors (2)
- Electrical controls
- Strainer

- Return Temperature Limiter
- Flow Limiter
- Primary flow isolation
- Fail-safe shut-off

Combined Control Valve
The proposal is to combine items in a single modulating valve linked to electronic controls and communication

These elements are referred to as the **'Primary Metering Module'** (PMM) for the remainder of this Route Map. There are 3 options for including the PMM functions:

- A series of components included in each HIU option
- A sub-assembly within each HIU option (see
- Figure 31)
- A stand-alone unit (see Figure 32)

Standardising the design of the PMM will give large volumes of the core components. This is particularly important for enabling cost reductions in the modulating control valve and heat meter: which currently attract disproportionate cost. If this unit is standardised at scale there is also potential to incorporate more advanced controls at marginal additional cost. These will enable Demand Side Response capability which will support route map B (Reduced Peak Flow).

Creating a sub-assembly within the HIU box has the benefit of creating delineation between the responsibility of the DHN operator and the householder (see Figure 31).

Figure 32 also overcomes the delineation challenge with even greater clarity in separate units. The DHN operator takes responsibility for the PMM and the householder / landlord taking responsibility for all pipes and equipment downstream. However this needs to be offset against potentially marginal additional cost of second box or enclosure.

An additional opportunity is to develop an externally installed PMM which can then be serviced without gaining access to the home. This is attractive to operators (to save cost of gaining access) and householders (who would prefer not to be disrupted for repairs).

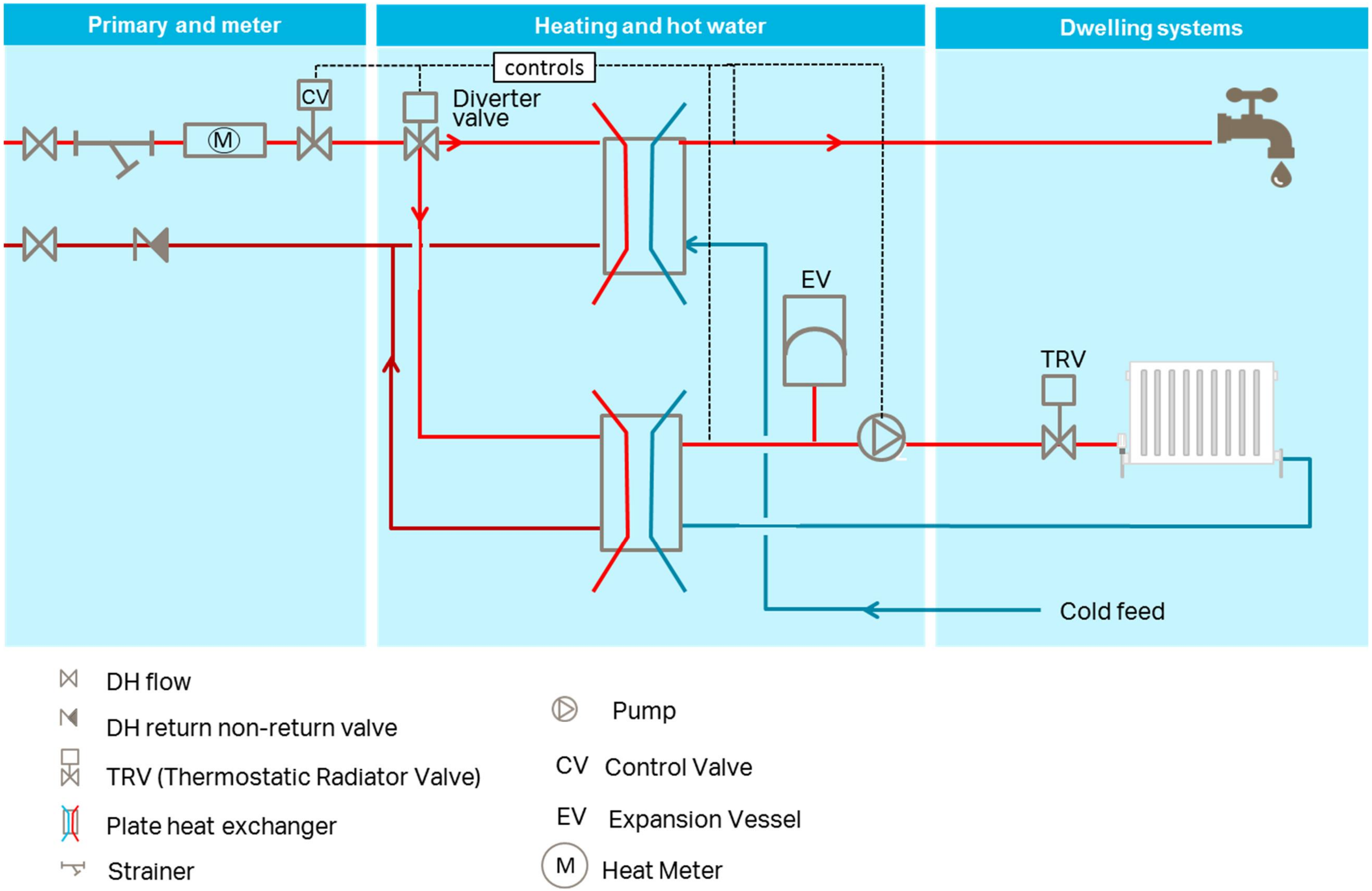


Figure 26: Indirect / Instantaneous hot water

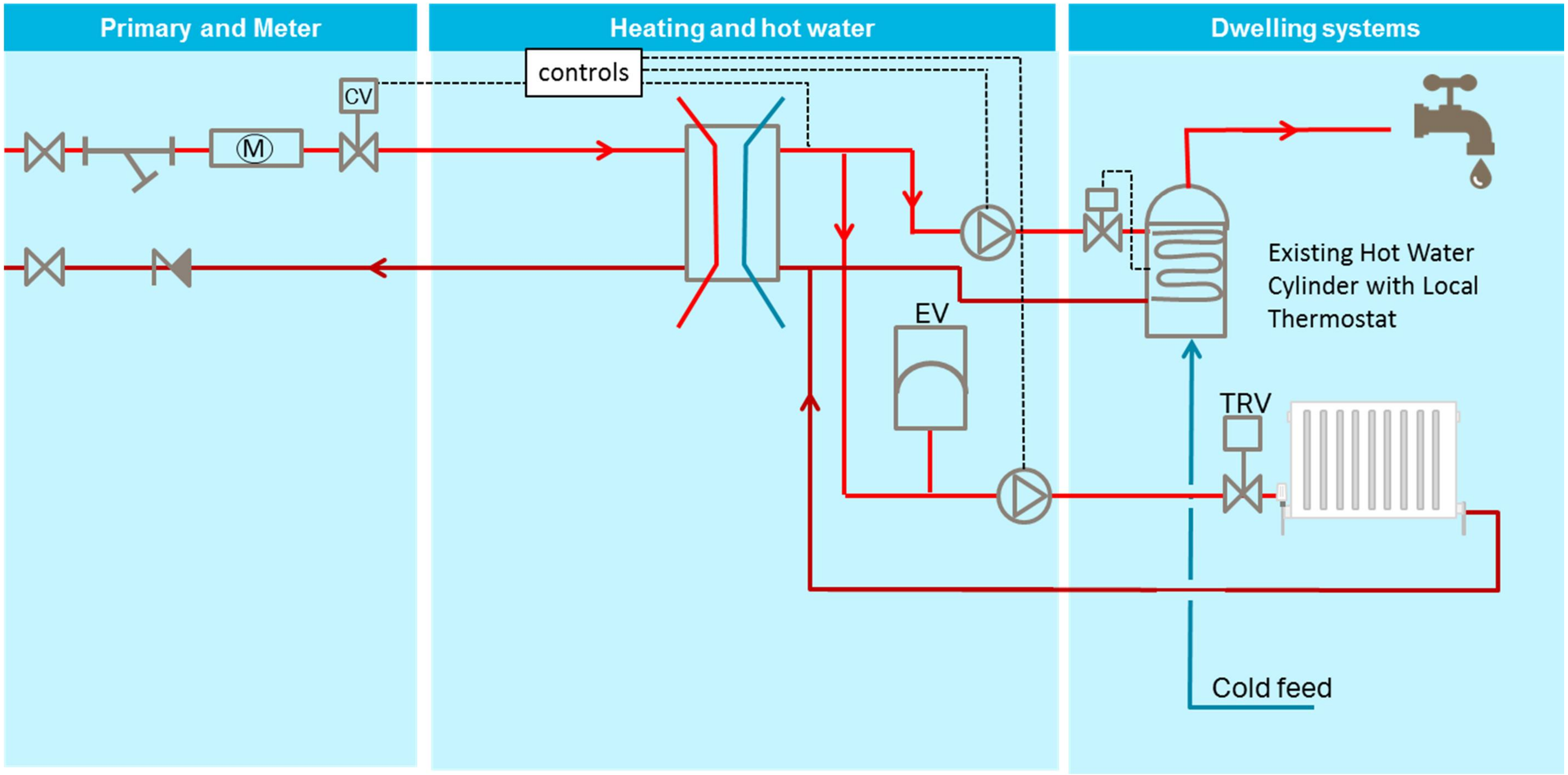


Figure 27: Indirect / Storage cylinder retained

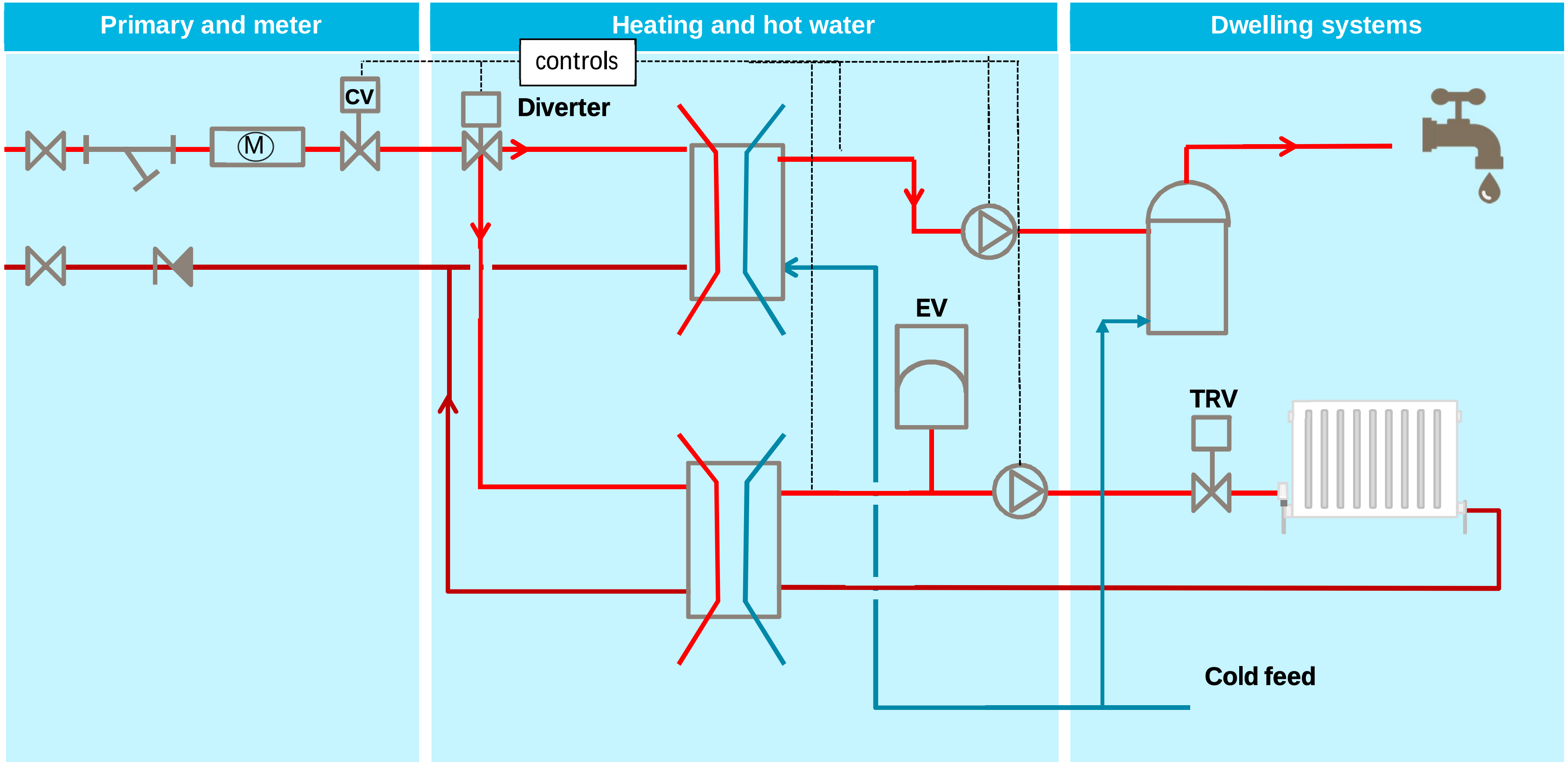


Figure 28: Indirect / cylinder retained with external heat exchanger

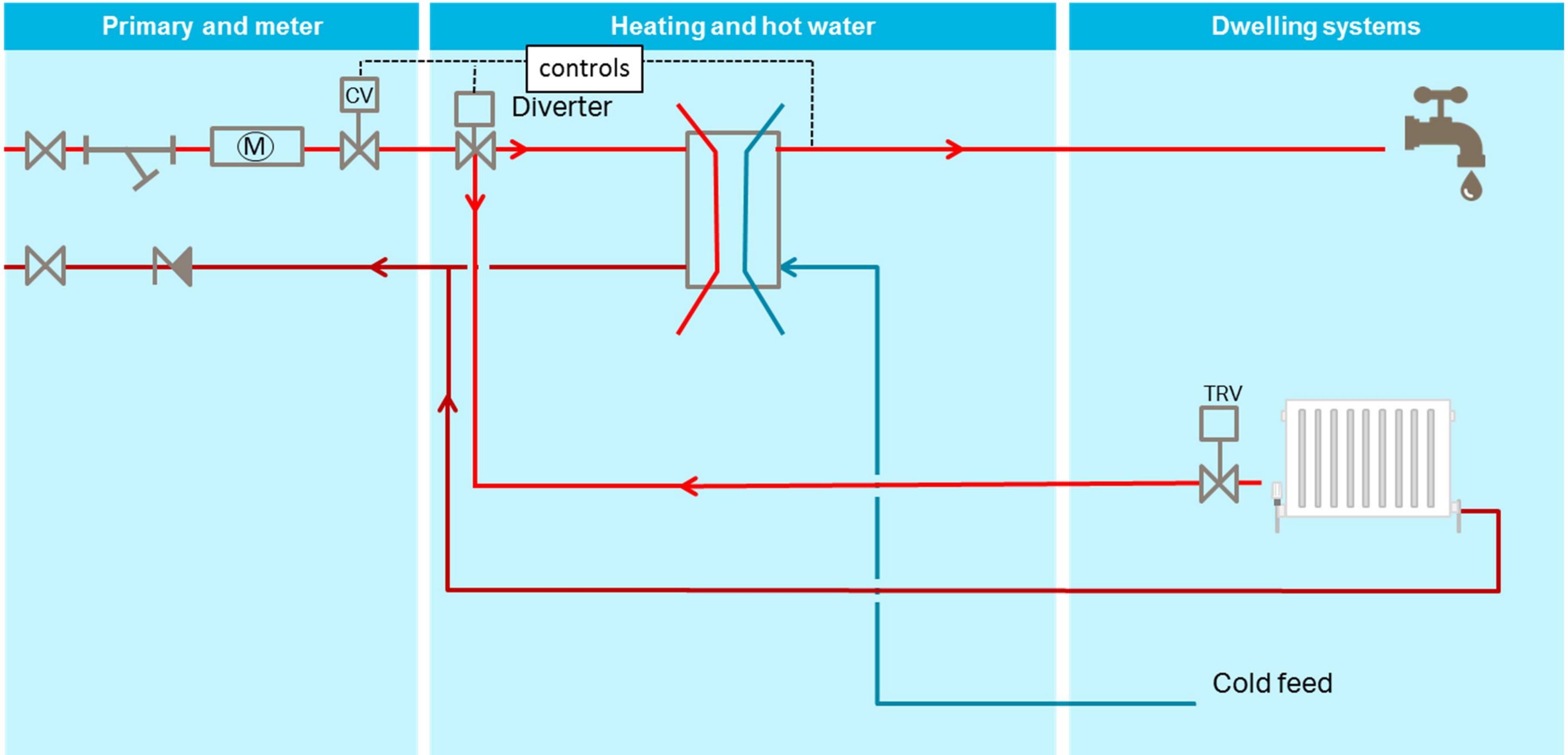


Figure 29: Direct / Instantaneous hot water

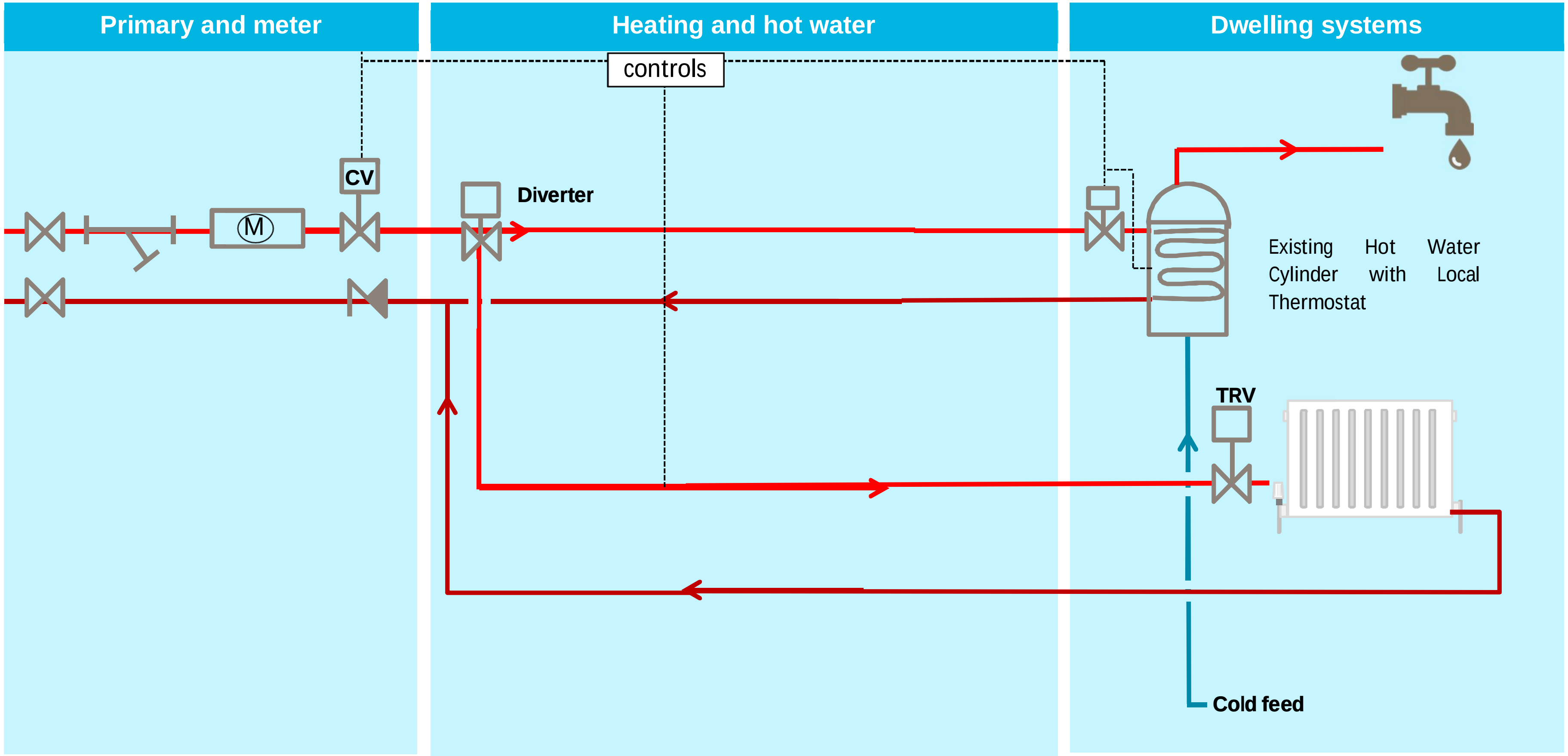


Figure 30: Direct / Storage cylinder retained

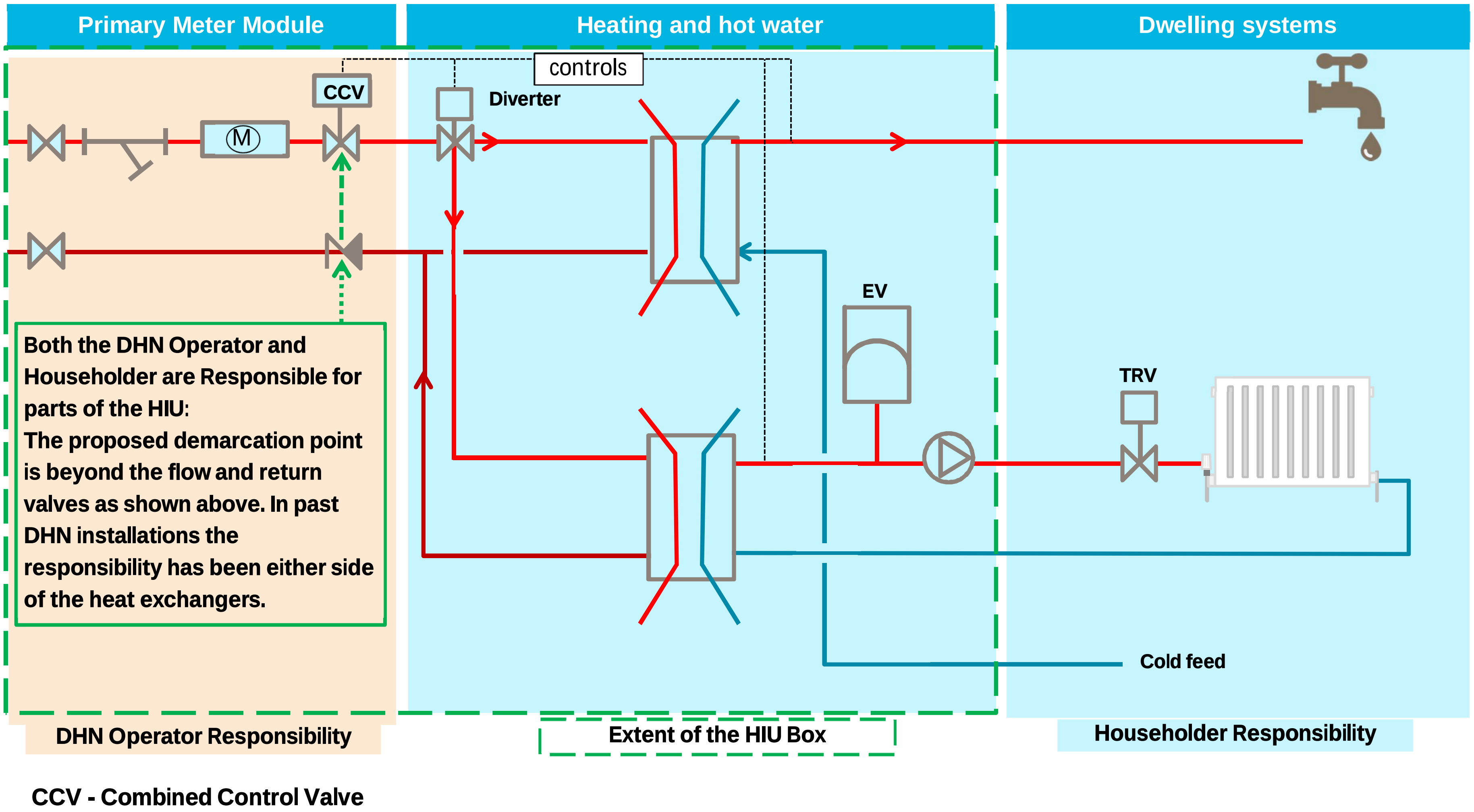


Figure 31: Primary Metering Module (PMM) – within the HIU

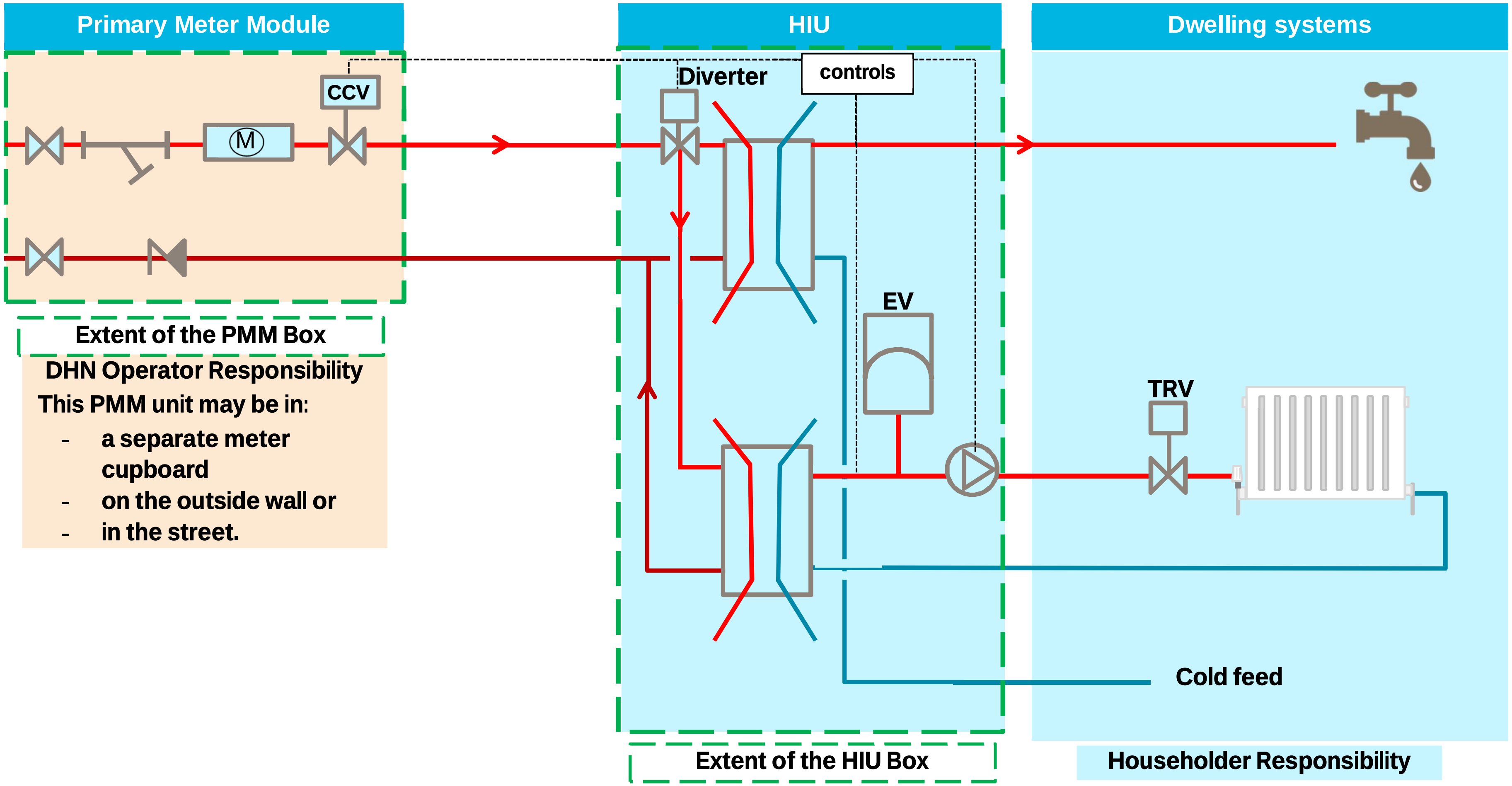


Figure 32: Primary Metering Module (PMM) – separate unit

Current Barriers to and Requirements for Implementing Solution

The route mapping process revealed that the barriers to the cost reduction in HIUs go beyond the technical and engineering challenges. The range to be considered is:

1. Technical
2. Market
3. Commercial
4. Ownership
5. Policy

Assessment of barriers

1. Technical barriers
   - The key technical barrier is to reduce cost without a detrimental impact on HIU performance and reliability. System operators and landlords (particularly for social tenants) require very high levels of reliability to reduce the cost of servicing and repair which can become dominant OPEX costs if HIUs need frequent site visits.
   - The components of the PMM are common to every HIU solution, but the current diversity of HIU design leads to low-volume manufacture and higher costs.
   - There is also a trade-off between simple controls (to minimise CAPEX) and the value of data transfer, between the HIU and the network (to improve system performance). This is an enabler of reductions in peak demand and peak flow: see Route Map B: Low Flow Rate Design.

2. Market barriers

   There are a number of market factors:

   - The market for HIUs is not homogenous: different user groups and property ownership models have differing requirements for heat and hot water usage. There will also be variety in the preference for instant hot water supply or stored hot water (see Route Map G).
   - Network developers will also need to decide whether connections will be direct or indirect via a heat-exchanger. This choice may be for the network as a whole, or on a property by property basis (see Route Map G).
   - New build properties connected to the network will almost certainly have a lower heat requirement and may include water saving features.
   - Other requirements (e.g. reliability, service options, CAPEX vs. OPEX) will vary by tenure and will be influenced by the performance of the current heating system.

   These aspects confirm the diversity of requirements across different households and demonstrate the need for a range of HIU offerings rather than a single solution. This sets a market barrier of a need for a range of product solutions which increases the diversity of products, although with significant volumes of common components.

3. Commercial barriers

   In a commercial market for HIUs which is not highly competitive, with inexpert customers, suppliers tend to set their pricing to the level the market will accept. The result is that savings that manufacturers make will be used to improve profitability rather than be passed on to the end client (network operator and consumer). Reducing the market price will require:

- Competitive pressure amongst manufacturers, or
- Shared investment in design and manufacturing to achieve reduced costs

For example, factors which contribute to maintaining a high market price:

- Manufacturers covering the cost of technical support pre- and post- network design to ensure their products are specified, installed and maintained correctly. This is a significant burden as DHN design capability in the UK is not all of a high standard. (This links closely to Route Map A: Knowledge Management, Research & Training).
- The cost of custom designs to suit consultant designer preferences.
- Manufacturers' vested interest in high technical performance and complexity of their products. This increases unit price when unique features are specified.
- A commercial imperative to secure maximum margins and a good return on their investment; even if they are able to reduce costs internally.

With collaboration, a proportion of these cost burdens can be avoided: reducing the market price whilst maintaining profitability in the supply chain. Indeed, a greatly increased level of standardisation and resultant cost reduction will be achieved with multiple manufacturers collaborating; a key motivation being to enable market growth rather than struggle for a share of a small sector.

Feedback from manufacturers is that there is a concern that there will be a 'race to the bottom' for market price. This will drive down margins, potentially leading to both poor technical performance and a reluctance for UK manufacturers to invest in innovation.

4. Ownership barriers

The point at which the ownership of piping and equipment changes from the DHN operator to the landlord or tenant is an important consideration. A clear demarcation point enables clarity of responsibility (for repair, maintenance and upgrade). Creating a separate PMM unit gives the clear delineation point and also gives potential for greater consumer choice within the property (as they could get alternative suppliers to maintain the equipment within the property). A low-cost plastic, stand-alone PMM for external use would resolve the ownership and give DH operators the ability to check meters and service units without needing property access. Plastic components would also minimise the risk of theft for metal resale which impacts copper installations.

5. Policy barriers - uncertainty

Heat Networks are not currently fully regulated as other utilities, although 'The Heat Network (Metering and Billing) Regulations 2014' Statutory Instrument is in place and due for amendment in 2017. Its three key requirements are:

- Duty to Notify – that a DHN has been created from December 2014 (new-build)
- Duty to Meter – currently on hold at the individual consumer level, but planned
- Duty to Bill – provide a clear explanation of the information contained in a bill, including how the bill was calculated and specifying fixed and variable charges

The developing policy landscape gives significant uncertainty for network developers and equipment manufacturers. As a result manufacturers may hold back on making investment in new products and designs until details are finalised.

The influence of Policy is relevant to this route map, but policy change is beyond its scope.

Development requirements

In order to deliver the proposed low cost HIU solution; there will need to be technical developments of both components and the assembled HIU products. Key areas for development emerging from the solution and barriers are:

- Reduced cost of key components which currently attract disproportionate cost
- A new Primary Metering Module (PMM) product to support standardisation for the DHN developer whilst allowing consumer choice in the home
- A fully industrialised design and manufacturing process for the most commonly specified HIUs

These translate in to the following technical development requirements:

- Indirect instantaneous (IND/INS) HIUs are currently the most frequently specified HIU option for UK DHNs. Low-cost and low-maintenance IND/INS products will deliver the greatest impact from a DfMA / Value engineering exercise. In time the market may move to DIR/INS or DIR/STO as proposed, but it is expected that there will be a significant demand for IND/INS units.
- Components for the Primary Metering Module are common to all HIU variants and, if standardised, will become very high volume items. In particular:
  - A combined modulating valve for the PMM has the greatest potential impact on cost and performance across all variants.
  - Heat meters are the next most significant cost and potential for saving.

  Reducing the cost of PMM elements will have the most significant impact on Direct connection HIUs and so Direct HIU development is not a separate requirement.
- A low cost, standardised, stand-alone PMM meets the challenges of clear delineation between the DHN / domestic equipment and gives consumer choice of heating and DHW system options in the home. A plastic PMM will have additional cost and operational benefits, if the reliability and design life can be proven

Commercialisation requirements

This solution was analysed using the Ansoff matrix approach. This solution uses *established products* although with significant technical developments. The developed HIUs are to be introduced to the predominantly *new market* of retrofit into existing properties (most current DH in the UK is new build housing, non-residential buildings or replacement of DH in social housing flats).

This classifies HIU optimisation as a Market Development need. However, some aspects of the proposed solution are substantially new (e.g. the Primary Metering Module) and so there will be aspects of Diversification in the commercial planning.

The specific market for the solution is a DH developer and their designers, but the end-user and system operator are key stakeholders that need to have confidence in the solution. Designers would normally specify indirect connection and instantaneous hot water for new build housing and will need confidence in the performance and reliability of units to specify the alternative, lower-cost HIUs.

Bringing the HIU solutions to market will need technical development from HIU manufacturers, but to do so at significantly lower cost will require collaboration with network designers, developers and operators.

The key commercialisation activities are:

- Market research to confirm the technical and commercial requirements of:
    - DHN Developers / Operators
    - DHN Designers
    - Consumers using the HIU
- Market alignment
    - To overcome the commercial barriers described (in 3 above) there is value in aligning expectations for market volume, cost drivers, margin, investment and risk across the value chain of manufacturers, designers and network operators. Combined with central government commitment to DHN delivery at scale, this will support a 'Design for target cost' approach to drive innovation.

Aspects Beyond the Scope of this Route Map

This route map is focused on the technical and commercial developments of HIUs and this section summarises additional activities, which will enable successful deployment. The following areas are beyond the solution route map scope.

Survey

To confirm the choice of HIU in each property there is a need for rapid assessment of the existing systems:

- Suitability for Direct connection
- Likely heat and DHW load
- Whether there is existing DHW storage
- Current / preferred location and space for the HIU
- Current heating controls or user's new requirements

This activity is covered by Route Maps B and G and the emerging methodologies could be included as part of the best practice in Route Map A: Knowledge Management, Research and Training.

Policy

DHN regulation is covered in 'The Heat Network (Metering and Billing) Regulations 2014' which is due for further development in 2017. The key impacts are:

- Metering requirements: Cost of accuracy vs. value to the consumer
- Duty to bill: Permissible mechanisms for the fair charging for heat

A stable and supportive policy landscape will give DHN stakeholders confidence to invest in new designs solutions.

Tariff developments

Linked to the wider Heat Network policy is the opportunity for alternative billing methods rather than the traditional cost per kWh of gas and electricity. Development of new approaches to metering are covered within this HIU route map, but the tariff and charging options are not considered in detail.

Data Protocols

To support network optimisation and the tariffs described above; there is a need for communication standards and data protocols. These will be analogous to the smart meter equivalents, but it is not clear that there are plans to align standards for DHNs.

Route Map Proposal

Commercial Workstreams

1. Market research to confirm stakeholder technical and commercial requirements
2. Market alignment to encourage stakeholders to adopt a design for target cost approach

Technical Workstreams

3. A combined valve for the PMM linked to electronic controls and communication.
4. Low-cost and low-maintenance Heat Meter for the Primary Metering Module
5. Low-cost and low-maintenance indirect instantaneous (IND/INS) HIUs
6. A low-cost plastic, standardised, stand-alone PMM

GANTT Chart for above activities

The above activities have been plotted on a chart to show the overall timescale for the route map. This is included in Annex 1 to this route map.

Funding and motivation

Activities 1&2: Market research and Alignment

- Total: £158,000
- Funding by HNDU would encourage collaboration between manufacturers and ensure results are made public to provide HIU cost transparency.

Activities 3-6: Product Development

- 4 Products: Combined Control Valve, Heat Meter, IND/INS HIU, PMM
- Total: £7.4M for design and production engineering.
- An Innovate UK match funded competition: £3.7M funding and £3.7M from industry.

This is a significant requirement for industrial funding and will need to attract participants to provide investment on a match funded basis. Instances of commercial collaboration occurred between stakeholders involved in project workshops (without financial stimulus) and this gives a good indication that there will be a positive response to the route map from industry. With some significant manufacturers in the heating sector there will be value in engaging with key players and BESA (industry trade body) to align technical standards and agree a shared ambition to reduce costs. This is the core objective behind Activities 1 & 2.

Activity 1: Market research to confirm stakeholder technical and commercial requirements

Aims

To establish a common baseline performance specification requirement for the core HIU variants, and so reduce the likelihood of over-specification and increased costs.
Confirm whether there are genuinely distinct market requirements for all 5 HIU options described in the proposed solution above.

Introduction

This research is directed predominantly at network designers and developers to understand the underpinning technical requirements of individual HIU units. Examples include:

- Maximum and minimum flow temperatures and pressures
- Maximum and minimum operational flow rate
- Control and communication requirements for effective DHN operation and monitoring

End user and operator expectations / requirements will also influence design including:

- Preferences for Direct/Indirect, Instant/Stored DHW variants.
- Performance: DHW flow rates, Time to heat from cold
- Maintenance requirements and unit reliability
- Control integration (e.g. with mobile devices)
- Aesthetics and size of units

The results from this research will steer the emphasis for the following product development.

Work programme

- Prepare research methodology and establish the questions to collect insight
- Market research – consumer focus groups and design/developer interviews
- Document findings and analyse commonalities and divergence
- Develop a limited number of technical solution requirement sets and value propositions which satisfy the bulk of the expected retrofit market

Team

- A commissioning body with a remit to share insight to aid standardisation and reduced cost (e.g. the proposed DH Knowledge Centre (see Route Map A)
- Consulting organisation for market research and value proposition development
- HIU manufacturers with an interest in standardised solutions (assumed at no cost as they gain insight in to the market as a result of the research)

Timescales

- 3 months

Costs

- £50,000 for consultancy (100 days x £500 per day average rate).
- This is based on: 10 days to prepare methodology, 40 days for market research, 20 days to analyse and document findings and 30 days to develop value propositions

Funding & motivation for investment

- Funding by HNDU would ensure that results are made public to encourage more widespread standardisation and simplification of HIUs
- The proposal is that this is part of a wider programme of targeted DHN research

Success Criteria

- This activity will be considered to be successful if it gives:
- A confirmed understanding of DHN developers' technical requirements for HIUs
- Verified user and DHN operator expectations of HIU functionality

Activity 2: Market alignment to adopt a UK DHN design for target cost approach

Aims

The goal of this Activity is for DHN developers, HIU manufacturers and the UK government to declare their joint intent to achieve a viable mass market HIU product at a target cost below £400 (based on an Indirect / instantaneous design from the Stage 2 analysis).

The ambition is to encourage manufacturers to invest in accelerating the development of lower-cost HIUs that meet agreed specification and cost criteria. This can be achieved by market stimulus (perhaps in the form of tapering subsidy) from the UK government.

Introduction

The idea is to draw on expertise from across the DHN value chain, linked with the findings from Activity 1, to confirm the range of standard specifications and costs needed to serve the UK market in HIUs.

Then, using the assembled expertise, develop future demand scenarios which would be sufficient to attract investment in capacity at the target cost. The demand can then be generated by a targeted stimulus package which bridges the gap between current and target cost on a tapering basis.

It is important to engage a sufficient range of expertise to develop a credible solution, whilst maintaining the supply chain's willingness to invest in capacity for lower cost/price HIUs. The motivation for manufacturers will be to collaborate to enable market growth rather than struggle for share of a small sector. The BEIS funded UK Catapult programme has collaboration as a core part of its remit:

"Each Catapult… offers expertise to ...enable businesses and researchers to collaboratively solve key problems and develop new products and services on a commercial scale."[4]

This approach has been successfully launched in housing innovation by the Construction Leadership Council, with department of BEIS support. Industry led collaboration has also enabled standardisation in electronics (e.g. USB standards), automotive and aerospace sectors.

[4] https://catapult.org.uk/about-us/about-catapult/

Work programme

- Launch workshop(s) for commercial teams from across the HIU value chain to:
  - Establish the ambition, scope and terms of reference
  - Clarify the UK government's commitment to DHN roll-out
- Scoping workshop to introduce the Design for Target Cost approach and confirm the basis for stakeholders' contribution to the Activity: what are industrial stakeholders offering to the process and what are they looking for in return?
- Confirmation of the technical objectives and stakeholders' commitment to participate
- Proof of concept design through a series of facilitated reviews
  - HIU specification aligned with market requirements, setting the process and resource to deliver standard solutions at an agreed target cost
- Demand Generation / Funding
  - In parallel BEIS teams to develop mechanisms / stimulus proposals which support increased HIU demand to create a market pull for technical and product solutions

Team

- HNDU to commission the project, working with other BEIS departments
- The DH Knowledge Centre (see Route Map A) as a neutral body to lead development of industry standards / objectives.
- HIU Manufacturer(s)
- DHN Design Engineers
- Valve suppliers and other key supply chain partners
- Product and process design expertise from other sectors
- Facilitation of the design of new commercial value propositions

Timescales

- Phase 1: 3 months of commercial engagement (first 3 steps of work programme)
- Phase 2: 3 months duration for technical research and current supplier engagement

Costs (based on mid-point of the resource estimates)

- Resource Phase 1:
  - Commercial teams investing time to develop future markets at no cost
- Resource Phase 2:
  - 14 - 18 Man weeks of experienced engineers working collaboratively; 80 days at £600 /day (£48,000)
  - 10 - 14 man weeks of product, process and commercial facilitation; 60 days at £1,000/day

- Total: £108,000

Funding & motivation for investment

- This Activity has the potential to greatly accelerate the cost reduction of HIUs and to enable the UK to take a lead in design and manufacturing. This warrants public funding if it can be formulated to ensure it does not count as state aid.
- Direct commissioning of the work from BEIS HNDU would ensure cost transparency.
- Innovate UK match funding, in the form of an Industrial Strategy Challenge Fund competition, would encourage the innovation, but with less likelihood of across industry collaboration in this early stage.

Success Criteria

- This activity will be considered to be successful if it confirms:
- Industrial partners' support the plan to accelerate development of reduced cost HIUs; in return for increased confidence in future demand with government support
- The agreed target cost identifies a path to step-change reduction in HIU CAPEX
- The timescale for achieving the target cost is significantly shorter than would be expected without the Activity

Activity 3: Development of a combined control valve for the PMM

Aims

The control valve components for the PMM currently account for a significant proportion of HIU cost and are produced in comparatively low volumes. The goal is to combine the key components to create an electronically controlled valve at a significantly lower target cost.

Introduction

Current flow control is through precision engineered process valves which are in effect over-specified for the solution. This Activity brings together specialists from across the DHN supply chain to achieve a step change cost reduction whilst ensuring product performance and reliability. The control valve will be designed to deliver the following functions:

- Return Temperature Limiter
- Flow Limiter
- Primary flow isolation
- Fail-safe shut-off

The proposed solution is a single valve, which combines the four primary functions above, and achieves the Stage 2 target cost reduction: £330 à £75.

Technical know-how exists to redesign and simplify the valves at reduced cost. If the market has confidence that UK demand for a common control valve will reach, then exceed, say 50,000 units / year, this is likely to be sufficient to convince suppliers to invest in design collaboration to meet the valve target cost challenge.

To support the potential for a 'smart' DHN; it would be valuable if valves can be designed to include electronic controls and communication links at minimal additional cost.

Work programme

- This is a significant programme to develop an ultra-reliable unit to an exacting specification.
- Inputs –requirements from Activities 1 & 2
- Design reviews to confirm the specification and operating conditions for the unit (speed of response, temperature range / humidity / vibration)
- Engineering analysis of whole life cost for current valves and an understanding of the cost drivers (factors that influence cost)
- Existing product and process Failure Modes and Effects Analysis (FMEA) to establish causes of quality problems and early life failure in control valves.
- Design for Manufacture and Assembly programme: Concept, Feasibility, Prototype to meet target cost for CAPEX, OPEX, REPEX (Repair and Maintenance Cost)
- Prototype manufacture and testing

- New product and process FMEA to assess quality and reliability performance

Team

- Led by HIU Manufacturer(s) or product development specialist consultants
- Valve suppliers - Likely to include both low volume bespoke manufacturers for technical input and high volume manufacturers for expertise at scale.
- DHN network control providers and meter data expertise (for electronic valve option)
- Other supply chain partners

Timescales (for fully robust engineering design to automotive standards)

- 2 years

Costs

- 10 person years (approx.) for design, development, testing: 10 years at £100k/year (£1,000,000)
- 2 person years for production engineering: 2 person years at £100k/year = (£200,000)
- New product development process consulting: 50 days at £1,000/day (£50,000)
- Prototyping, tooling and production equipment: ~£350,000

- Total: £1.6M for design and production engineering
- Note: This is the estimate for design of a new control valve from first principles; there may be an opportunity to build on existing designs at lower cost and in less time

Funding & motivation for investment

- Without a confirmed market demand (from Activity 2) for the common valve at significant scale (manufacturers suggest ~50,000 units/yr) the supply chain is unlikely to invest on a purely commercial basis.
- An Innovate UK match funded competition (e.g. from the Industrial Strategy Challenge Fund) could be designed to stimulate development from multiple potential manufacturing consortia and linked with academic research. This is likely to meet the Innovate UK funding criteria of meeting a UK market need and in a sector where UK manufacturing has potential to be industry leading.

Success Criteria

This activity will be considered to be successful if it confirms:

- Working prototypes of standardised (or limited range of) combined control valve; which meets the required specification for performance, reliability and cost

Activity 4: Development of low-cost and low-maintenance Heat Meter

Aims

To develop a step-change cost reduction for the heat meter within the PMM through simplification of the approach to metering and the engineering.

Introduction

In addition to the target of a combined control valve; development of a greatly simplified Heat Meter could reduce the HIU cost by £100. Stage 2 proposed a reduction from a Current Cost of £150 to a Target Cost of £50.

The heat supplied (kWh) to the home, currently used to measure consumption, is not an accurate reflection of the cost to supply. This is because a high return temperature from the HIU has at least as significant an impact on system operating cost and supply capacity cost as the kWh delivered. As a result the proposed solution is to develop a new approach to billing / metering with a simplified meter. The new solution must meet the requirements for fair billing, without necessarily calculating the precise kWh used.

Work programme

- Academic and industry collaboration on alternative approaches to heat metering; researching the options for assessing the value of heat supplied beyond kWh
- Confirm required specification for the unit (temperature range / humidity / vibration)
- Engineering analysis of whole life cost for current heat meters and the cost drivers
- Failure Modes and Effects Analysis (FMEA), for existing products and processes, to establish causes of quality problems and early life failure in control valves
- Design for Manufacture and Assembly programme: Concept, Feasibility, Prototype to meet target cost for CAPEX, OPEX, REPEX
- Prototype manufacture and testing
- New product and process FMEA to assess quality and reliability performance

Team

- University (lead: Research phase)
- Heat meter suppliers (lead: Development phase)
- HIU Manufacturer(s)
- DHN Developers / Operators
- Product and process design expertise from other sectors (consultancy basis)

Timescales

- 3 years:
  - 1 year academic and industrial research
  - 2 years product development and testing

Costs

- 2 person years of academic research and 1 person year of industry collaboration: academic (2 x £75,000/year), industrial (1 x £100,000/year) = £250,000
- 5-15 person years engineering from HIU and meter manufacturers (significant uncertainty based on the unknown solutions emerging from the research): mid-point (10 x £100,000) = £1,000,000
- New product development process consulting: 50 days at £1,000/day (£50,000)
- 2 person years for production engineering: 2 may years at £100k/year (£200,000)
- Prototyping, tooling and production equipment: ~£250k

- Total: £1.75M for research, design and production engineering

Funding & motivation for investment

- The development of a low-cost, ultra-reliable heat meter is a critical enabler of a step-change in HIU cost CAPEX (and also OPEX by reducing meter service requirements)
- Innovate UK funding, to stimulate research into innovative approaches to billing for heat and the development of the underpinning technology, would reduce the cost of the HIU (CAPEX) and operation (OPEX) of the UK energy system and also potentially provide a leading technology for export

Success Criteria

This activity will be considered to be successful if it delivers:

- A simplified approach to assessing heat energy usage which can be fairly applied to domestic properties
- A working prototype of a reliable heat meter which can be produced at scale and achieves the target cost of £50 / unit or less

Activity 5: Development of a low-cost and low-maintenance IND/INS HIU

Aims

To develop a technically sound and commercially viable Indirect HIU with Instantaneous DHW heating that achieves a target cost below £400.

Introduction

This is the Activity to realise the savings from the Stage 2 Design for Manufacture and Value Engineering at Scale solution proposals. This was originally envisaged as being delivered by individual manufacturers working to create highly competitive HIUs.

However, from the route map process, it has been recognised that the solution may achieve greater savings, more quickly, by working collaboratively across the value chain and building on the outputs of Activities 1 - 4.

In the programme which follows, individual manufacturers are likely to continue to work to reduce their internal costs, but these savings may not be fully passed on to the market.

Work programme

- Inputs - market requirements from Activities 1 & 2, and market feedback
  - common component costs from Activities 3 & 4
- Establish baseline specification and the standard options (e.g. power / flow ratings)
- Confirm added value options (e.g. enhanced controls, decorative enclosure)
- Identify price / cost drivers for each component class (e.g. insulation, valve, controls, heat exchanger) by specification
- Set target price levels per class: Minimum, Probable, Maximum
- Supplier development to eliminate waste and optimise the supply of components

In parallel

- Review manual work content in assembly: Identify % of value adding activity
- Set a target assembly time in minutes (Stage 2 solution target: 4hrs à 50 minutes)
- Identify enabling design changes needed to reduce assembly time at lowest cost

Team

- DH Knowledge Centre (see Route Map A) as a neutral body to lead development of industry standard solutions.
- HIU Manufacturer(s)
- Valve suppliers and other key supply chain partners
- Product and process design expertise from other sectors
- Facilitation of the design of new commercial value propositions

- Caution is needed during joint development to avoid inadvertent contravention of competition legislation. This is achieved with clarity of objectives and rigorous application of regulatory guidelines.

Timescales (for fully robust engineering design to automotive standards)

- 2 years

Costs

- 8 person years (approx.) engineering from HIU manufacturers and suppliers: 8 man years at £100,000 (£800,000)
- DfMA product development process consulting: 50 days at £1,000/day (£50,000)
- 2 person years for production engineering: 2 person years at £100k/year (£200,000)
- Prototyping, tooling and production equipment: ~£250k

- Total: £1.3M for design and production engineering.

Funding & motivation for investment

- If Activity 2 generates manufacturers' commitment to a £400 target cost HIU: investment should come from the manufacturer on the basis of confirmed demand. However, there is likely to be a need for tapering subsidy / stimulus from HNDU to bridge the gap between the initial manufactured cost and target cost. It will take repeated volume and process improvement to achieve the target.
- If Activity 2 does not achieve a collaborative commitment to target cost HIU development: an alternative would be through an Innovate UK Challenge Fund to encourage multiple suppliers to develop reduced cost HIUs. The Challenge Fund approach will accelerate the cost reduction (compared to pure market forces), but is less likely to deliver a standard solution across manufacturers. The Challenge Fund model is to invest 30%-60% of the cost of research and development on a match-funded basis. In this instance there would also be a need for market stimulus to generate demand, with a tapering subsidy declared in advance.

Success Criteria

This activity will be considered to be successful if it delivers:

- A working prototype of a standardised Indirect / Instantaneous HIU which meets the Activity 2 performance requirements and the Stage 2 target cost of £400 or less

Activity 6: Development of a low-cost plastic Primary Metering Module - PMM

Aims

To develop a very low-cost stand-alone metering and control unit to act as the delineation between the DHN and its customer. This unit can then be used as a direct equivalent of a gas, electricity or water meter.

Introduction

The idea of the PMM arose as a solution to the challenges of:

- The delineation of ownership between the DHN and consumer
- Creating a standardised core element applicable across the majority of properties and user preferences to generate scale for new control valves
- A stand-alone PMM unit gives clarity that the pipework beyond it is the responsibility of the household and that the unit itself belongs to the DHN. To the DHN developer the costs of providing the supply connection are clear up front. The consumer is able to make an informed choice (guided by the supplier) of whether to have a direct / indirect connection with instant or stored DHW.

A design with a majority of plastic components ensures the cost and risk of theft is reduced. The variants of the plastic PMM unit should include: Internal meter unit (as gas electricity meters), Enclosure (wall mounted for external or communal space in flats), Underground (equivalent to a water supply meter)

Work programme

- Building on Activities 2, 3 & 4 this programme develops a robust stand-alone metering unit:
- Inputs - Standard specification from Activity 2
  - Valve and Heat Meter design from Activities 3 & 4
- Design reviews to confirm the specification and operating conditions for the unit
- Development of high temperature plastic connectors and HIU components
- Establish baseline specification and the standard options (e.g. power / flow ratings)
- Identify price / cost drivers for each component class by specification
- Set target price levels per class: Minimum, Probable, Maximum
- Prototype plastic component design
- Supplier development to eliminate waste and optimise the supply of components
- Product and process Failure Modes and Effects Analysis (FMEA) to minimise the risk of defects and early life failures
- Production engineering and new product introduction programme

Team

- HIU Manufacturer(s)
- DHN operators
- Plastic piping and valve suppliers and other key supply chain partners

Timescales

- 2-4 years

Costs

- 5-10 person years product development for plastic pipe / component manufacturers (significant uncertainty based on a new concept design): Mid-point: 7.5 years at £100,000/year (£750,000)
- 8-12 person years engineering from HIU and component manufacturers: Mid-point: 10 years at £100,000/year (£1,000,000)
- New product development process consulting: 100 days at £1,000/day (£100,000)
- 4 person years for production engineering: 4 person years at £100k/year (£400,000)
- Prototyping, tooling and production equipment: ~£500k

- Total: £2.75M for design and production engineering

Funding & motivation for investment

- The development of a low cost PMM (plastic or copper/brass) is a significant change to the HIU proposition; separating the control valve and metering from the domestic interface. This level of investment is unlikely to be undertaken speculatively and needs market testing (from Activity 1) and recognition from the value chain of the potential improved solution from two separate modules to the HIU.
- The self-contained PMM and modular HIU approach has the potential to shift the market in both the UK and elsewhere. With Innovate UK Challenge Funding there is an opportunity for UK manufacturing to leapfrog HIU technology ahead of other markets and create a world-leading domestic heating proposition and supply chain.

Success Criteria

This activity will be considered to be successful if it demonstrates:

- The potential cost and operational benefits of a stand-alone PMM unit
- Opportunities (cost / durability) from the use of high performance plastic components
- A working prototype of a plastic PMM attainable target cost for the of less than £190 (Stage 2 target for the equivalent Direct / Storage HIU)

11.1 Annex 1: Work programme

Route Map H - HIU Optimisation																	
Activity	Cost (£k)	Year 1				Year 2				Year 3				Year 4			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1: Market Research	£ 50	■															
2: Market Alignment	£ 108	Phase 1	Phase 2														
3: Combined PMM valve	£ 1,600		Phase 1: Design			Phase 2: Development			Phase 3: Test		Contingency						
4: Heat Meter	£ 1,750	Phase 1: Research				Phase 2: Development						Phase 3: Test		Contingency			
5: Low Cost & Maintenance IND/INS	£ 1,300					Phase 1: Design			Phase 2: Development			Phase 3: Test		Contingency			
6: Plastic PMM Module	£ 2,750					Phase 1: Plastic Components			Phase 2: PMM Development					Phase 3: Test		Contingency	
Total :	£ 7,558																
			Legend														
			Phase 1: Activity		Contingency												
			Phase 2: Activity		Contingency												
			Phase 3: Activity														

Part B – Overarching Project Review

12 Evaluation of process and technical review

12.1 Introduction

This section of the report provides an evaluation of the process followed throughout the project and a technical review of the project as a whole.

The evaluation and review has been developed based on ETI's defined critical success factors which were set-out prior to project commencement. The technically related ones are as follows.

a) The Project must generate a sufficient number of potential innovative solutions for reduction of DHN infrastructure cost. Selected solutions must be sufficiently innovative to be capable of delivering a substantial step change reduction in the capital cost of DHN infrastructure deployment.
b) The Project Team must include a broad range of specialists and/or engage with industry specialists outwith the team. This must include access to expertise from countries in which DHN deployment is more widespread than the UK, to ensure that sufficient appropriate practice and information is considered, whilst also ensuring that solutions are appropriate for UK deployment. It must also include access to the expertise and learning from other work which may be deemed relevant, such as DECC's Low Carbon Pioneer Cities projects and ongoing work on behalf of the International Energy Agency.
c) Analysis of realisable cost reductions of identified solutions must be robust, credible and evidence-based – including definition and analysis of present baseline costs and analysis of present cost drivers, and including net cost reductions at whole system level (accounting also for any increases caused by proposed solutions). Validation should be considered.
d) Identified solutions must be credible and sufficiently attractive to the industry that they are likely to be deployed. (Some, of course, may require further development of technologies or techniques before they can be deployed). Implications for heat network interconnectivity and for adaptation of common technical standards across the industry must also be addressed.
e) Analysis of further development requirements (including technical steps required for development of technologies and techniques, timescales, budgets, risks, etc) must be realistic and supported by demonstrable expertise in such projects (where available).
f) Selected solutions must preserve the benefits of heat networks as a method of heat supply – for example: the effective delivery of large quantities of heat; the ability to transfer water at different temperatures, dependent on the application; long asset life; and the ability to utilise hot water from different heat sources, without undue impact on householders.
g) In the course of reducing the upfront capital cost, solutions should not detrimentally impact the overall lifecycle cost of a DHN, and should offer enhanced overall value propositions to stakeholders.

These critical success factors have been used to develop the following evaluation criteria for the technical review of the project:

I. Has the process resulted in sufficient number of solutions and with enough innovation to deliver the 40% cost reduction aspiration? (see CSF a)
II. Has the project team engaged sufficiently with the industry both here and overseas? (see CSF b)
III. Are the cost estimates robust and do they take account of system level costs and benefits? (see CSF c)
IV. Are the solutions identified credible and sufficiently attractive for industry that they are likely to be deployed? (see CSF d)
V. Are the Route Maps developed realistic and supported by demonstrable expertise? (see CSF e)
VI. Have the selected solutions maintained the key benefits of district heating as a concept? (see CSF f)
VII. Have the solutions ensured that overall lifecycle costs have not been increased and that the value proposition to the customers has been maintained? (see CSF g)

The technical review uses the above as the structure and considers each stage of the project against these criteria.

12.2 Evaluation

I. Has the process resulted in sufficient number of solutions and with enough innovation to deliver the 40% cost reduction aspiration? (see CSF a)

In Stage 1, the cost model was set-up for a notional DH scheme which enabled the relative importance of the various elements of a DH project to be established in terms of contribution to the total capital cost. This enabled a better focus on the issues that would impact most on cost. For example, it was established that the civil engineering costs for trench excavation and the internal pipework and hydraulic interface units (HIUs) were 60% of the total cost of the defined network.

Also in Stage 1, the literature review and international survey were able to identify areas where new thinking was likely to lead to lower costs. It identified areas such as: shallow burial, re-use of backfill, new ground survey techniques but was less helpful in identifying leading edge innovations. This may have been because such ideas are either not being published for commercial reasons or because of the time lag between ideas being generated and formal papers emerging. It may also be that the leading countries, such as in Scandinavia, have already built extensive DH schemes; research identified in these countries was mainly associated with improving the operation of schemes and hence reducing OPEX rather than CAPEX. This also reflects the fact that the DH industry is relatively mature and research work is focused more in areas of energy production than heat distribution.

The Stage 1 work resulted in a set of key challenges that needed to be addressed when developing solutions. Although these were quite broad, the process still assisted in focusing the thinking in Stage 2 and led to the setting up of both internal and external stakeholder workshops and one-to one discussions for each of the challenges. The challenges can be summarised as follows.

- 10% reduction in total district heat network CAPEX from changes to System Design Architecture
- 25% reduction in Civil Engineering CAPEX

- 35% reduction in Pipe and Connections CAPEX
- 25% reduction in Internal Connections CAPEX
- New Network Income: 5% of Civil Engineering CAPEX offset from external revenue.

The process for identifying solutions involved three stages:

- A discussion paper for each challenge was produced by the CTO to prompt new thinking
- A brainstorming session was held by the project team, involving engineers from other groups within AECOM
- A series of workshops were held with external stakeholders associated with each challenge. All of the ideas mentioned were captured even if these were not discussed at length at the workshops.

The solutions were reviewed to define them more closely and remove overlapping and repeated ideas. The final list contained 91 separate solutions which were then classified as follows:

- Green solutions – the most promising solutions with high impact and high potential for successful development
- Amber solutions – considered valid solutions but with a smaller impact and less likely to be developed
- Red solutions – ideas which were considered unlikely to lead to a capex reduction or have a very marginal impact or conflicted with existing regulations.

Table 9 summarises the solutions that were defined in the Stage 2 report.

Solution category	**Total no. of solutions**	**Green**	**Amber**	**Red**
reducing flow rates	9	5	3	1
reducing return temperatures	10	6	4	0
radical routes	9	4	5	0
improved design processes	8	8	0	0
civils	23	2	21	0
HIUs and internal connections	15	7	6	2
pipes and connections	12	1	10	1
new network income	4	2	2	0
other	1	0	0	1
Totals	**91**	**35**	**51**	**5**

Table 9: Analysis of solutions generated

The total number of solutions indicates a good spread with civils, system design architecture (the first two categories) and HIUs having the largest number. This was partly because these workshops were successful in generating ideas but also because this is where the most significant impact would be achieved. Although only two green solutions were identified in the civils section, these were trenchless technology and improved design information, both of which were expected to deliver a significant saving. Furthermore, the proposals for more radical routing of the pipes and greater use of pipe crossings reduced the need for civil engineering by routing pipework above ground.

There were relatively few red solutions which indicated good quality of input to the process. The large number of amber solutions reflects a high degree of innovation indicating that there are further opportunities to reduce costs beyond the green solutions.

The 35 green solutions were clustered together to form 13 solutions that were defined more broadly but still enabled all of the solutions to be included. These 13 solutions were then reviewed against evaluation criteria that had been developed in Stage 1 through stakeholder engagement to identify the most important factors to aid wider DH deployment.

Some solutions that were initially thought to have significant potential such as the re-use of backfill were found to have a lesser impact when the cost reduction was analysed. The trenchless technology solution was originally thought to have very limited application but after further engagement with the industry was identified as being more attractive. The use of shared HIUs e.g. between semi-detached houses or flats on the same floor of a block was also found to have little benefit.

The most difficult area in which to identify specific solutions was the work within the dwellings for installing connecting pipework from the external DHN to the HIU. This was mainly because this type of work is relatively unusual in the UK (most work is in new build or non-domestic buildings) and it was difficult to engage with contractors experienced enough to contribute.

The impact on the total cost of the notional scheme for each of the green solutions was modelled using the cost model developed in Stage 1. It was found that to model some of the solutions the cost model itself had to be further developed in Stage 2 and, in the process, the baseline network design needed to be developed in more detail in places to evaluate better the benefit of the solutions (e.g. the route taken for connecting detached houses was changed to provide entry towards the rear of the house where a gas boiler is more likely to be located).

It was also necessary to consider how the solutions conflicted in assessing the overall impact. This mainly related to the civil engineering elements where the saving from reducing civils costs cannot be simply added to the savings from using radical routes (above ground pipework) as both solutions are impacting on the same cost element. The solutions could be combined in various ways with an appropriate mix of solutions resulting in a central cost reduction of 32% (range from 26% to 39%). The amber solutions were expected to produce a further 6% cost reduction. Hence the full set of solutions is estimated to deliver 38% savings, close to ETI's 40% aspiration at the start of the project.

The level of innovation across the solutions varies. The low flow rate solution is fundamentally about achieving best practice design using existing technology. The use of external wall routes and loft space or cellars routes is innovative in approach although again conventional technology is applied. The most innovative technique identified was the use of trenchless technology which appears to be little used for DH in the UK although more extensively applied in the gas industry. The developments in HIU design and manufacture will be innovative in changing the way these units are manufactured rather than developing a new product. Many of the amber solutions were more innovative but this did not necessarily mean that they were the most appropriate to take forward to the next stage within this project. The literature and technology reviews and horizon scanning did not identify any radical changes to the fundamental approach to DH although there were a number of potential technology improvements which have been captured in the ambers list: e.g. high temperature plastic pipes, shallow burial and re-use of excavated material. Much of the international innovation work is aimed at reducing operating costs and enabling the greater use of renewable energy sources for existing heat networks. This work is clearly relevant for the UK in the future but was not the main purpose of this project.

II. Has the project team engaged sufficiently with the industry both here and overseas? (see CSF b)

At the start of Stage 1 an initial workshop was held with a wide range of stakeholders. This provided a good overview of the issues and concerns of not just the designers and contractors installing DH but also customer-related organisations such as Local Authorities and property developers.

It was apparent from stakeholders across the value chain that there is a shared ambition to accelerate deployment of DHNs in the UK. Currently the UK market is on a small scale (relative to Scandinavia and some other parts of Europe) and this gives significant opportunities for growth and improvement.

Analysis was undertaken to contrast stakeholder requirements and current DHN delivery capability. This was delivered through a combination of project team insight, stakeholder engagement and desk-based review. This analysis particularly highlighted the following for the five key stakeholder groupings.

- **Users:** Currently DHNs do not offer a compelling reason for users to change from their preferred gas boiler solution. For users to choose to change to a DHN there will need to be a significant improvement in cost, performance or reliability compared to alternatives.

- **Investors:** Currently the lack of certainty of DHN programme and cost makes an investment less attractive than alternatives. In addition the complexity of project design, delivery and associated legal contracts is a burden.

- **Value Chain:** Design, development, installation and UK manufacturing organisations are cautious about investing in additional capability and capacity whilst the market is uncertain.

- **Enabling Stakeholders:** Achieving approvals from certain external stakeholders is crucial to project success and so developing an approach to minimise their resource requirements and minimise the negative impacts is important.

- **UK plc:** For HM Government here is a desire to accelerate the adoption of low carbon heating and DHNs have the potential to contribute, ideally without major policy intervention.

The analysis of stakeholder requirements against the current state of the industry concluded that there are nine key priorities to address to enable DHNs to succeed at scale. All aim to improve the viability of district heating in the UK, with the first five directly focussing on financial aspects and the latter covering broader issues.

- **Reducing Capital Cost:** Project capital delivery including planning and design.
- **Improving Cost and Revenue Certainty**: Capital, Operating Cost and Income.
- **Reducing Operational Cost:** Minimising the controllable through life costs.
- **Increasing Network Revenues:** Increasing income from heat or other revenue streams.
- **Reducing Time on Site:** To reduce disruption and associated additional cost.

- **Improving User Value Propositions:** Creating a compelling offering for User groups.
- **Improving Investor Value Propositions:** Enabling DHNs to become *bankable* investments, including reducing uncertainty and risk
- **Systems Architecture:** Developing a whole systems approach to identify opportunities for a step-change in DHN delivery and performance.
- **Reducing Complexity of Transactions Between Stakeholders:** Developing solutions to reduce the legal, commercial and transactional burdens of a successful DHN.

These priority areas set the context for developing the solutions in Stage 2. Further engagement in Stage 1 may have helped better define the challenges earlier in the process, albeit it is not considered that this had a negative impact; stakeholder workshops were held in Stage 2 which both better detailed the challenges and generated potential solutions.

Both the literature review and the specific review of overseas experience contributed to the knowledge base for the project. The review of overseas experience was conducted by Dr Robin Wiltshire who is chair of the Executive Committee of the IEA District Heating and Cooling Implementing Agreement and so has extensive contacts overseas not just in Europe but also in Canada and South Korea. This work was supplemented with further direct contact by two visits to Denmark to discuss the DH industry with COWI (an international consultancy with specialist engineering knowledge of the design, construction and operation of district heating in Scandinavia). Paul Woods (CTO for this project) also visited Professor Sven Werner and the project team in Denmark who were working on a 'Transformation roadmap to low temperature DH' for the IEA Annex XI programme. These international discussions led to new insights, not so much as to technological solutions as to the design methodology and the management and contracting methods used in construction. Some aspects of Scandinavian design such as designing for lower return temperatures are applicable to the UK. Other aspects, such as the international research into very low operating temperature schemes are driven more by the need to improve efficiency of existing networks or to enable greater use of renewable heat sources which is less of a priority in the UK at present.

During Stage 2, a number of workshops and one-to-one discussions were held with industry to develop ideas. There was good representation from the industry, including DH owners (ENGIE and Islington Council), pipe suppliers, civil engineering equipment manufacturers, designers and contractors. Two separate workshops were held with HIU manufacturers as it was recognised that there were different perspectives and that a more open discussion would be held with smaller groups.

At the end of Stage 2, a stakeholder event was held – again with very good representation from all parts of the industry.

During Stage 3 further engagement with industry took place for each of the route maps. In some cases these were in the form of workshops with several contributors present (Route Maps C, D, H), in others a series of one-to-one discussions were held (Route Maps, A, B, E, F, G). There was wide representation at the workshops with designers, equipment manufacturers and suppliers, academics, and ESCos involved. Legal, planning and market research specialists were also consulted both within and outside the project team organisations to assist in developing the route maps.

Throughout the project the ETI's project review panel made very valuable contributions. This panel included industry members (consultants and DH owners) as well as Government representatives.

Overall there was a positive response to the emerging solutions, both from the ETI's project review panel and from the majority of the stakeholders engaged, with suggestions made for areas of further development work.

III. Are the cost estimates robust and do they take account of system level costs and benefits? (see CSF c)

The cost model was developed with a number of inputs from industry, including contractors, suppliers and DH owners. Costs were compared with data from published reports, the limitations being that there has been very little work carried out in low density housing.

The cost model's structure was based on the ETI's Infrastructure Cost Calculator (ICC). It was developed further in Stage 2 to provide a flexible tool that could quickly analyse and compare different design options. During this process, some costs were updated in the light of recent information. For example, the baseline costs of the HIU were reduced from the initial model as it was found that more recent prices in the market were lower than had been assumed. Furthermore, parts of the cost model were developed in more detail, and more granular cost data added, to allow the evaluation of the benefits of solutions.

The costs were also compared to those seen in Denmark through discussions with COWI. The main difference appears to be in the cost of the supply and installation of the DH pipe (including civils) where the UK costs were found to be 70% higher for 100mm diameter. This lower cost was partly a result of lower transport costs and a larger market size but also a result of more efficient ways of working arising from having greater experience and a more favourable regulatory environment.

The system level costs and benefits were taken into account in the cost analysis with the solution forms provided in Stage 2 including CAPEX, OPEX and lifecycle costs as well as system level impacts. Examples include the saving in peak boiler cost from the use of lower peak demands and the additional cost of new radiator valves for lower return temperatures; both of these cost elements being outside the definition of the heat network.

IV. Are the solutions identified credible and sufficiently attractive for industry that they are likely to be deployed? (see CSF d)

The engagement with industry throughout the work enabled solutions to be identified that were broadly supported by the industry, and many were generated from outside the project team.

At the end of Stage 2, a stakeholder event was arranged where each of the 'green' solutions was presented and delegates were asked to score the solutions as to likelihood of deployment. As Figure 33 shows, there was good support for all solutions although the two radical route solutions (Nos. 3 and 4) were less well supported. This was due to concerns over customer acceptance rather than the technical proposals and so the route map for these solutions includes measures to address customer acceptance.

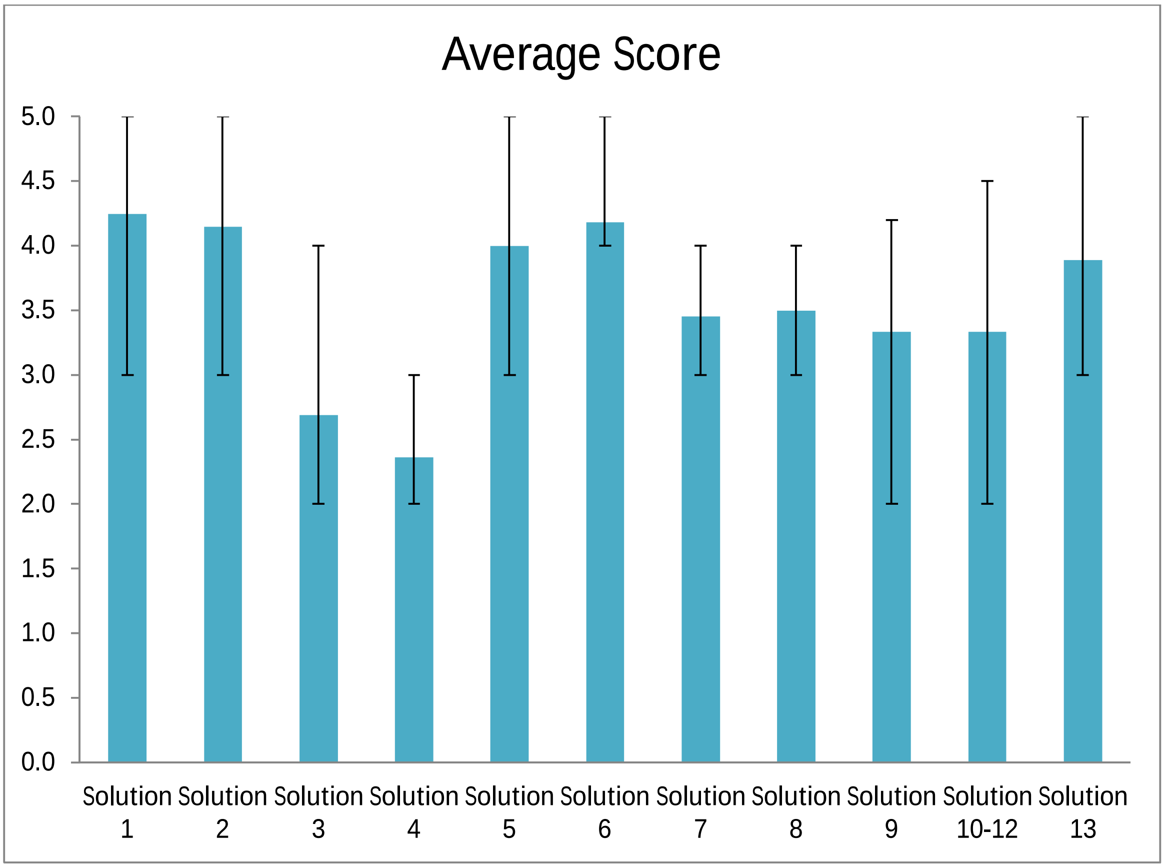


Figure 33: Feedback from delegates at the stakeholder event to the statement 'this solution is likely to be deployed following further development work' (score 5 = strongly agree, score 1 = strongly disagree, bars show 10th and 90th percentiles)
[The solutions are listed in Figure 4]

During Stage 3 there was further positive engagement with industry during route map development. Individuals were willing to devote time to meet with the project team and talk through the solutions on a voluntary basis. This indicates that the solutions were of interest and could be deployed. In some cases, the process has led to new contacts being made within the industry and work is now starting on some of the solutions independently of the ETI process now that the opportunity has been defined.

V. Are the Route Maps developed realistic and supported by demonstrable expertise? (see CSF e)

Further industry engagement during the development of the route maps in Stage 3 has helped to define a realistic programme of work. Guidance was obtained from industry as to the duration of product development stages and the level of financial support that would be required. Applying the principles of the Ansoff Matrix enabled the right emphasis to be given with respect to market development and product development activities. A specialist within AECOM was consulted to help scope market research activities proposed within the route maps and to provide cost estimates. There was general support for the concept of demonstration schemes and some initial ideas for sites for these have emerged.

VI. Have the selected solutions maintained the key benefits of district heating as a concept? (see CSF f)

None of the solutions have impacted on the fundamental concept of district heating as defined in the baseline scheme. The solutions will work with any heat sources and are not currently anticipated to compromise asset life, operating costs, reliability or quality of service. Route Map B: Low Flow Rate Design potentially enhances the DH system as the lower return temperatures could lead to a more efficient heat source and thermal storage.

The customer proposition is the same as the baseline assumption except for the Route Map C: Radical Routes solutions where the customer experience will be different due to the impact of having distribution pipes within the property boundary. This will, however, lead to a significant cost saving and market research is needed to explore whether the cost saving will be sufficient to balance any concerns.

VII. Have the solutions ensured that overall lifecycle costs have not been increased and that the value proposition to the customers has been maintained? (see CSF g)

There has been concern throughout the project that lower cost should not mean poorer value in life cycle terms. This point was also made by stakeholders. The project addressed this concern by building into the cost model the lifecycle costs for operation and maintenance of the network and in the solution evaluation forms there were criteria related to OPEX as well as CAPEX so that the impact on lifecycle costs could be assessed.

In many cases where CAPEX was reduced it was found that OPEX costs would also be reduced. For example:

- Lower return temperatures reduces CAPEX but also lowers heat losses
- Simpler HIUs are cheaper but will also involve less maintenance
- Above ground routes avoid the costs of trenching but are also less prone to third party damage and will be easier to access if repairs are needed

Value propositions were considered carefully in Stage 1 and this formed the background to the project even though this aspect was not taken forward in the same level of detail as the engineering solutions. The value propositions provided the basis for the solution evaluation criteria which were used in Stage 2 to assess solutions and iteratively identify how to improve the solutions further. The evaluation criteria included consideration of lifecycle costs with the full list of criteria being:

- Capital Cost including certainty of outcomes
- Operational Cost
- Lifecycle Cost
- System performance
- Attractiveness to users and investors
- Reduced complexity
- Health, safety and environment
- Opportunity to scale
- Increased revenue
- UK plc external stakeholder value
- Technical complexity
- Effort to implement
- Additional equipment required
- Barriers

The above criteria enabled each solution to be evaluated from a number of different perspectives to provide a fully rounded assessment.

Stage 2 involved detailed planning of the process for solution generation and evaluation which included forming a Solution Management Group so that the solutions could be looked at in the round; this helped ensure that the value propositions were not lost in the detail of an engineering solution.

12.3 Summary

This review has shown that the critical success factors have been taken into account during the project and have been met.

The solutions that have been taken forward into Route Maps could be deployed within a few years. Some of the other ideas classified as amber as well as the two Green solutions that were not taken forward into Route Maps would also be worthwhile investigating further.

Overall the solutions taken forward into Route Maps are diverse comprising:

- Improved design processes and knowledge management (Route Maps A, B, E and G)
- Innovative routes to avoid civil engineering work as much as possible (Route Map C)
- Transfer of trenchless technology from other utility industries (Route Map D)
- New HIU products which can benefit from volume manufacture (Route Map H)
- New business models by working with other utilities (Route Map F)

13 Benefits to be obtained from combination of solutions

There has been significant integration of solutions already within the project. In Stage 2, a large number of potential solutions was initially identified. Some of the solutions were then clustered together to form Green solutions that were more broadly defined and should achieve greater success together. In particular the following Green solutions were formed from a cluster of initial solutions.

- Solution 1: Knowledge Management, Research and Training. This solution contains a number of individual solutions around producing better guidance, monitoring of performance of schemes, training of people involved and sharing of best practice including the dissemination of the other solutions. All of these component parts need to work together to most effectively improve the quality and reduce cost within the industry.
- Solution 2: Reduced Peak Demand and Peak Flow Rate. This solution gathered together a number of technical ideas which reduced peak demand and lowered the return temperature. Although these are two distinct issues, the end result is the same – lower flow rate and hence smaller pipes. The combination of solutions results in a greater reduction in pipe diameter.
- Solution 5: Trenchless Solutions. A number of complementary solutions have been combined to enable an overall trenchless solution which covers both the street mains and the branch connections to the buildings.
- Solution 6: Improved Front End Design and Planning. This solution includes ideas not just about the techniques of surveying and recording of existing utilities but also the contractual framework under which the work is carried out. These both contribute to the common aim of improving the level of front end design prior to commencing construction.
- Solution 9: Direct HIU System & Existing DHW Storage & Solution 12: HIU (3) Value Engineered Direct HIU & DHW Storage. These are two system design options by which the HIU can be simplified: the use of direct connection and the retention of existing cylinders. Although separate, both solutions lead to a simplification in the design of the HIU and so have been considered together in Route Map G.
- Solution 10: HIU (1) Design for Manufacture and Assembly & Solution 11: HIU (2) Further Simplification & Value Engineering at Scale. These approaches to reducing the costs of HIUs were also combined and addressed in Route Map H.

The Stage 2 final analysis evaluated the benefits of combining individual Green solutions to produce an overall network solution. It included an analysis of alternative “Compatible Solution Groups” which combine Green solutions that could sensibly be implemented together to reduce overall DHN CAPEX. The ‘optimal’ Group is estimated to achieve a DHN CAPEX saving of 32% with a range from 27% to 39%. It recognises that for any given network it is likely that a mix of solutions will be optimal, particularly for the civil engineering component. For example, Solution 3: Loft Space / Cellar Route is very favourable for terraced housing, Solution 5: Trenchless Solutions is well suited to smaller diameter branches supplying semi-detached and detached houses and Solution 6: Improved Front End Design and Planning has its greatest impact with large diameter pipework. Further details are provided in Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report”.

At the end of Stage 2, it was judged that it could be beneficial to develop some of the Green solutions together if taken forward after this project. Several of the Route Maps were constructed covering more than one Green solution. The combination should reduce overall development costs and improve the value of the final product or service. These were:

- Route Map C: Radical Routes. Two solutions were identified for alternative routes compared to trench excavation in the road. These share some common issues and development activities. Furthermore, it is likely that there is no single Radical Route solution but the most appropriate option will depend on factors such as characteristics of the individual house and the street layout.
- Route Map H: HIU optimisation. There were three solutions grouped together covering: design for manufacture, value engineering and direct connection/use of existing cylinders. A common route map was produced for all of these aspects as development work will need to look at the problem in the round to deliver the lowest cost solution.

In developing the Route Maps, it became apparent that there were some linkages between solution development that are potentially valuable to exploit, including at a demonstration project stage. These are highlighted in Section 3 and summarised here:

- Route Map B: Low Flow Rate Design results in smaller pipes. This is advantageous particularly for the external wall solution option in Route Map C: Radical Routes as visual impact can be controlled better with smaller diameters. It is also advantageous for Route Map D: Trenchless Solutions as there is currently a size limit for horizontal directional drilling which means that a trenchless approach could be applied more widely if smaller pipes are used.
- Where cylinders are retained in Route Map G: Direct HIU System and Existing DHW Storage, the branch pipe to the dwelling can be smaller and this will also assist the external wall solution option in Route Map C: Radical Routes and Route Map D: Trenchless Solutions.
- One of the constraints on using trenchless technology is the level of confidence on knowledge of existing buried services, so there is a link here to Route Map E: Improved Front End Design and Planning
- There is a link between Route Map G: Direct HIU System and Existing DHW Storage which develops the HIU design for direct connection and retaining existing cylinders at a system design level and Route Map H: HIU Optimisation which aims to reduce the costs of HIUs through better design at a detailed manufacturing level.
- All of the Route Maps will be dependent on Route Map A: Knowledge Management, Research and Training for dissemination of the results of demonstration projects and for training of the industry in new approaches and techniques.

In summary, although each solution can be pursued independently there are advantages from combining the solutions and the Route Maps and this should be considered when developing demonstration projects. This needs to be balanced by the risk that a demonstration project could become too complicated and harder and/or riskier to implement if too many novel approaches are used on the same site.

14 Success against the Project Objectives

This section assesses the extent of the project's success against the original Project Objectives set by ETI including the Primary Objective, Purpose, Required Outcomes and each of the eight Critical Success Factors. **In all cases, the original requirements have been met.**

14.1 Primary Objective

The Primary Objective of the project is to identify and then assess innovative solutions that would deliver a substantial step change reduction in the capital cost of district heat network (DHN) infrastructure deployment and contribute to overall lifecycle cost reduction. This focuses on the upfront costs associated with heat network pipes and their installation, for the purposes of connecting to existing buildings. Whilst no target cost reduction was set, a 40% reduction of DHN CAPEX, with an equivalent CAPEX reduction of the Complete DH System and a contribution to overall lifecycle cost reduction, was viewed by ETI as a very successful outcome.

The Primary Objective of this project has been met. Stage 2 identified, developed and evaluated innovative solutions. In summary, it produced the following findings.

- It is estimated that the Green solutions, if applied together, could achieve a 32% reduction in DHN CAPEX, with an uncertainty range from 26% to 39%. It is estimated that the other solutions could generate up to an additional 6% DHN CAPEX saving. This indicates that the 40% reduction value could be achieved with appropriate investment.
- There is an equivalent resultant reduction of 23% in the CAPEX of Complete DH Systems (i.e. the distribution network above plus the energy centre and in-property components down-stream of the HIUs). There is no significant additional CAPEX to other parts of the DH System[5].
- The solutions contribute to an overall lifecycle cost reduction since, in addition to the CAPEX savings, for some Green solutions the OPEX will reduce slightly (by around 10%).

14.2 Purpose

The Purpose of the project was for its outputs to be available to be used by the ETI to assist it in eight specific areas. The table below lists these areas and demonstrates that the required information has been provided in the project outputs. In conclusion, **the Purpose of this project has been met.**

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[5] Solution 2 resulted in some additional CAPEX downstream of the HIU and some CAPEX saving at the Energy Centre (reduced peak demand). For the purposes of this analysis, the net impact of these two elements has been accounted for in the DHN CAPEX saving reducing the DHN CAPEX saving from 4.1% to 3.4%.

Purpose	Demonstration of Achievement
To understand the potential impact of technology and other developments relating to district heat network infrastructure	Deliverable EN2013_D01 “Requirements, Baseline Analysis and Target Setting Report” presents the findings from both an international comparison of DH practices and a literature review and horizon scanning activity of potential technology developments relating to DH networks. Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report” presents the findings from Stage 2. It describes the potential impact of innovative solutions on district heat network infrastructure against a number of criteria including commercial and technical performance.
To determine whether there are suitable opportunities for further investment by the ETI in projects to develop any identified technologies	Deliverable EN2013_D04 “Solution Route Maps Report” provides 8 route maps for Green solutions. It identifies activities to take solutions to commercial deployment and the level of investment necessary.
To inform further analysis of the value and applicability of heat networks throughout the UK (including the range of locations at which district heat networks could be economically deployed)	Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report” presents the findings from Stage 2. It describes the value and applicability of the Green solutions both nationally and for distinct typologies. The cost reductions predicted for each typology will enable the ETI and/or others to assess the potential coverage of DH in the UK.
To understand any new information regarding the relative difficulty of installing DHNs (compared to other network infrastructure) – including both technical issues and planning/consenting issues	Both Deliverable EN2013_D01 “Requirements, Baseline Analysis and Target Setting Report” and Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report” present information collected within this project on the challenges of installing DHNs compared to other network infrastructure. In particular this includes civil engineering issues related to the depth of pipework installation, the impact of existing services and as a result the location of a street main nearer the centre of the road.
To understand any synergies with other sub-surface infrastructure (particularly gas, hydrogen and electricity networks) and how these synergies might be exploited	The opportunities from synergies with other sub-surface infrastructure have been evaluated and presented within Solution 8 “Shared Civil Engineering Costs” (Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report”) and Route Map F “Shared Civil Engineering Costs” (Deliverable EN2013_D04 “Solution Route Maps Report”).
To inform stakeholders of potential opportunities for cost reduction, (including DECC’s Heat Networks Delivery Unit)	Deliverable EN2013_D03 “Solution Development, Analysis and Selection Report” presents the findings from Stage 2 of the project. This presents details that ETI can share with stakeholders on cost reduction. This information is summarised in Deliverable EN2013_D05 “Final Report” which includes both a final report and presentation. A stakeholder workshop was held at the end of Stage 2 to present findings to date.
To inform stakeholders regarding any specific requirements identified by the Project for policy and/or regulatory intervention in order to enable sufficiently wide-spread	Deliverable EN2013_D04 “Solution Route Maps Report” provides route maps for the more promising solutions. This includes current barriers where policy and/or regulatory intervention would help enable sufficiently wide-spread deployment of the cost reduction opportunities. ETI can

deployment of the cost reduction opportunities	share this information with stakeholders. This information is summarised in Deliverable EN2013_D05 "Final Report" which includes both a final report and presentation.
Through the above, to enable the ETI to influence the scale and timing of DHN deployment in the UK, as may be appropriate to support achievement of the UK's climate change objectives	The above have been delivered and presented using a structure that demonstrates both the underpinning analysis and the plans to enable commercial deployment of the solutions.

Table 10: Evaluation of achievement vs project Purpose

14.3 Required Outcomes

The Required Outcomes from the Project were that:

- Innovative solutions are identified and confirmed by means of robust assessment to be capable of delivering a substantial step change reduction in the capital cost of DHN infrastructure deployment, and contributing to overall lifecycle cost reduction, (or that this is proven by robust assessment not to be possible),
- The ETI is in a position to use the Deliverables for the Purpose above, and
- The ETI is equipped with robustly derived and clearly presented analysis of innovative cost reduction opportunities for DHN infrastructure, which it can use to inform and influence the development and deployment of DHNs.

The Required Outcomes of this project have been met. Deliverable EN2013_D03 "Solution Development, Analysis and Selection Report" identifies innovative solutions and provides robust and clearly presented analysis of the cost reduction opportunities. This is supplemented by an update of Deliverable EN2013_D02 "DHN Cost Model" which includes a breakdown of the component and process cost reductions for each of the Green solutions. It is estimated that the Green solutions, if applied together, could achieve a substantial step change reduction in the capital cost of DHN infrastructure deployment, and contributing to overall lifecycle cost reduction (see Section 14.1).

Critical Success Factors

The Critical Success Factors (CSFs) for the Project **have been met.** Evidence is provided in Section 12.

15 Appendix A: Summary of the Five Building Typologies

15.1 Introduction

This Appendix summarises the five building typologies which form the basic building blocks of the network design which are used in the project to evaluate the innovative solutions in comparison to current practice. A typology is based around a standard “block” which represents a sample area and, in the case of housing, is limited to a set number of houses. Where an area to be modelled is larger than the limit set for a typology (for example, 400 terraced houses rather than 200), then it is assumed that multiples of the same typologies are neighbouring each other, with a section of primary pipework used to connect them.

The network design is shown as below. The schematic shows:

- Five local distribution networks each based around one of the five typologies (A to E), each comprising one or more blocks.
- The primary network which links together the five local networks and the heat source at the energy centre (EC).
- A railway crossing (the network included 2 rail crossings and 1 canal crossing).

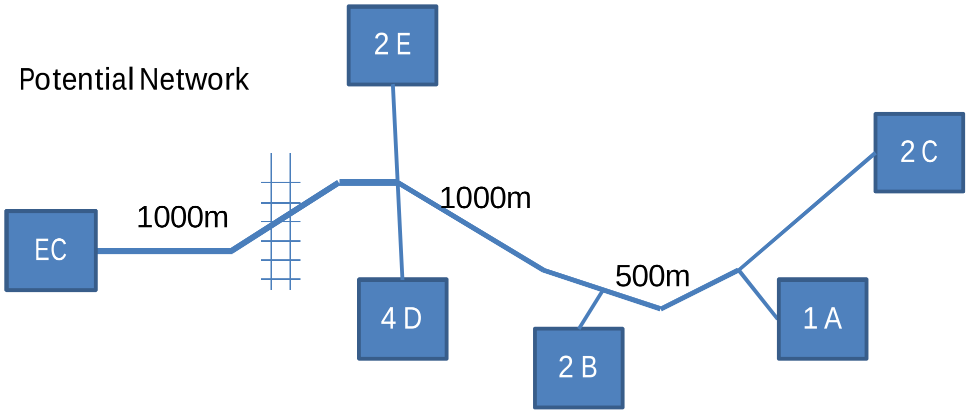

Figure 34: Schematic showing network construction concept for the cost model

15.2 Typologies

A summary of each of the typologies is given below. The final column lists the total numbers of properties in each typology block. Further details are provided in the Stage 1 report, “Deliverable EN2013_D01: Requirements, Baseline Analysis and Target Setting Report”.

Typology	Description	Number of properties in each typology block
A	City Centre - Commercial / Institutional This typology is used to represent a broad range of non-domestic areas where heat networks may be developed. Examples could include commercial offices, public sector buildings, hotels, large retail stores or complexes, etc.	9 buildings with combined peak demand of 21 MW
B	High Density Residential – Flats This typology represents higher density flats, often found in town and city centres. They fall into two main types: · High rise. Often with a common core to each building with a number of flats on each floor. · Medium rise. Typical of the mansion-type blocks found around London, or newer medium rise developments. The buildings often have more than one core.	256
C	High Density Residential – Terraced Terraced housing is characterised by long runs of identical homes, often with a regular grid pattern.	200
D	Medium Density Residential – Semi Detached Semi-detached housing is the second most common housing format in the UK, and found across many towns and cities.	400
E	Low Density Residential – Semi / Detached The low density typology is predominantly made up of detached housing and semi-detached housing.	400

Table 11: Details of the building typologies

In addition, a dense village has been modelled as a 50:50 mixture of Typologies C and D. It has been treated as a stand-alone typology (i.e. not part of the network). It has been used to assess the impact of the various solutions on the DHN capital cost for dense villages.