HEAT VISION 2030

Accelerating Heat Network Deployment

CASE STUDY

A District Heating Network for Glasgow

heatvision2030.com

Contents

Summary

What contribution can we make to a vision for zero carbon heat networks?

We asked ourselves the question, **'is it possible to deploy city-centre heat networks across the UK by 2030?'** This whitepaper explains the methodology we have followed to try and answer that question. Glasgow City Council has clear ambitions to achive carbon neutrality by 2030. With its dense city centre next to a constant, local source of heat from the river Clyde, Glasgow is an ideal candidate for study. What we discovered is that:

- The prevailing national political vision and legislation is unlikely to accelerate the successful deployment of city centre heat networks- major doubts exist about how forcefully a switch from gas can be driven.

- Successful deployment is a function of investability. This will come as a result of clear and comprehensive mix of policies designed to maximise the inclintation to change from existing fuel, whilst ensuring a minimum additional cost of consumption, relative to natural gas.

- All building owners should be incentivized to invest in energy efficiency measures and in fuel switching from gas through access to government support (funding) and by gradually increasing the burden and barriers of continuing to consume natural gas

- Trenching and digging is the single most problematic and costly element of a city centre heat network and should be pre-emptively supported with city wide ground penetrating radar surveys

- Transforming thousands of buildings using independent gas boilers over to a multi-heat source zero carbon heat network involves a variety of utilities that need to be coordinated, with leadership from the local authority. Preparation work can start now to audit and prepare secondary side improvements to manage temperature regimes once district heating arrives.

- Power supply requirements both in terms of "price paid for clean heat devices" and source of power should be actioned as priorities ahead of next steps in district heating.

- Stakeholders from public, private and civic society must all be included and support each other to make the vision a reality.

This whitepaper focuses on the process that we followed to understand the context and the vision, and ambition necessary. We now have a much firmer grasp on the size of the challenge, but also the size of the prize.

As a result of our work, we are now in contact with many of the key projects and stakeholders within the Glasgow context. Our work is adding value and empowering key decision-makers to deliver plans with greater ambition.

Introduction

Heating accounts for over 50% of the final energy consumption. 75% of European heat is still generated using fossil fuel-based sources, almost half of which is natural gas. There are initiatives all across Europe to make the switch toward carbon neutral heating. District heating (DH) technology is one of the most effective, economically viable and readily available options.

Heat Vision 2030 is a joint project, developed by innovative companies, which have the technology and capacity to plan, design, build and manage DH networks across the United Kingdom. We are convinced that large-scale, urban, DH projects are possible and economically viable. The technology and expertise is tried and tested, and already exists today.

In this whitepaper we present and focus on the Heat Vision 2030 methodology. We demonstrate the visual and numeric scenarios that have been developed. Future questions that we expect to address include the learnings, business modelling, policy implications and engagement work required to successfully accelerate the deployment of heat networks.

With Glasgow as our case-study, we have chosen to assume the heat will come from large river source heat pumps. This is replicable given the ubiquitous co-location of cities to large bodies of water that provide a low risk heat source far in excess of typical demand. The same modelling and methodology can be applied to Energy from Waste plants or other sources.

The Glasgow case

Like many cities across the UK, Glasgow City Council has declared a climate emergency and set ambitious decarbonisation targets.

DH network deployment requires a significant financial investment leveraged through the goodwill and ambition of the municipal, political and civic stakeholders. The financial investment will come from the companies and/or local authorities involved.

Meanwhile, do the local residents, city centre visitors and businesses understand the value of DH and therefore support the disruption caused by noise disturbance and traffic jams during construction?

One of the goals of successful deployment is to keep the strain on the commercial heart of Glasgow to a minimum and build up goodwill and support for the project. As such, we need to get the network budget and designs right from the start. This means pooling ideas, to develop scenarios and refine assumptions.

For a network of this size, computational power empowers designers and decision makers. That is why Comsof Heat was used to calculate all important numbers and designs. Comsof Heat is a DH planning and design automation software. It provides a detailed and accelerated pathway to understanding the impact of a network design and different design scenarios to highlight the scale of the challenge to embolden a similarly large response with respect to breaking down barriers.

"For a network of this size, computational power empowers designers and decision makers."

Glasgow City Centre (GCC) facts:

- The final GCC area studied has over 1,300 buildings (mainly commercial and residential)
- An approximate population of 17,000 permanent residents
- The local council has a long-term plan to increase the number of permanent residents
- The yearly heat demand is approximately 140GWh
- The river Clyde is an abundant energy source with the section in line with the city centre capable of providing in excess of 250MWth peak or 2000GWh annually. (15 X required)
- Glasgow has a goal to reach carbon neutrality by 2030

Finding the optimal network design

Finding the optimal network design for such a vast area is a journey. The first hurdle is finding the right data.
Data input is key for any network design. We used GIS and Hotmaps data to produce a map with all dwellings and street centre lines and then to figure out the heat demand. Based on this data Comsof Heat automatically creates demand points and calculated heat demand per dwelling based on the imported Hotmaps open source data. The intensity of the colour relates to the heat demand density of the buildings. The darker the block, the greater the heat demand density.

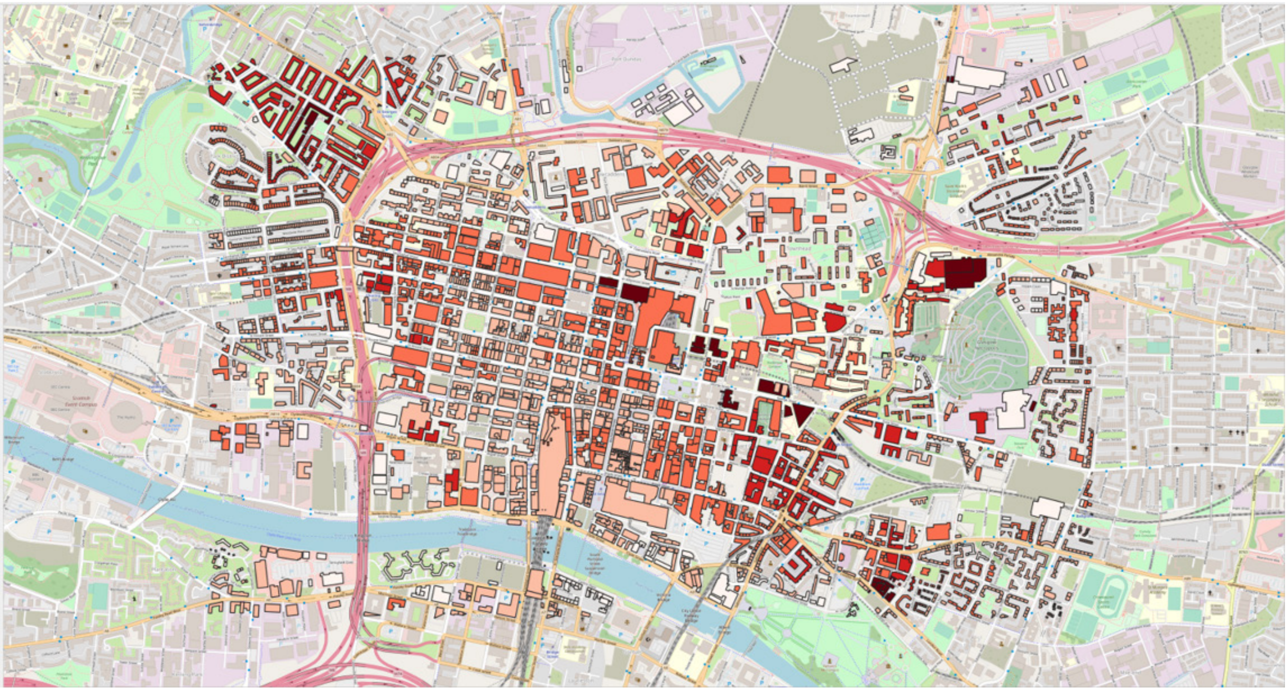

Figure 1. Using Hotmaps we overlay the heat demand density (HDD) over the selected area

Scenario development: first iteration

As a next step, we selected key criteria to come up with the network we expect:

- Area covered
- Target flow and return temperatures
- Heat source(s)
- Pipe system diameter
- Related costs of kit and installation

We plugged this information into the software with the following result. The lines represent the transport and distribution pipes. The red dots represent distribution points.

Our approach to design is iterative. Without software automation this is time consuming and error prone.
As the software does automated clustering and proposes rollout scenarios, we came up with the following plan, characterized by many different smaller heat clusters; each one with a dedicated distribution point. Based on this first

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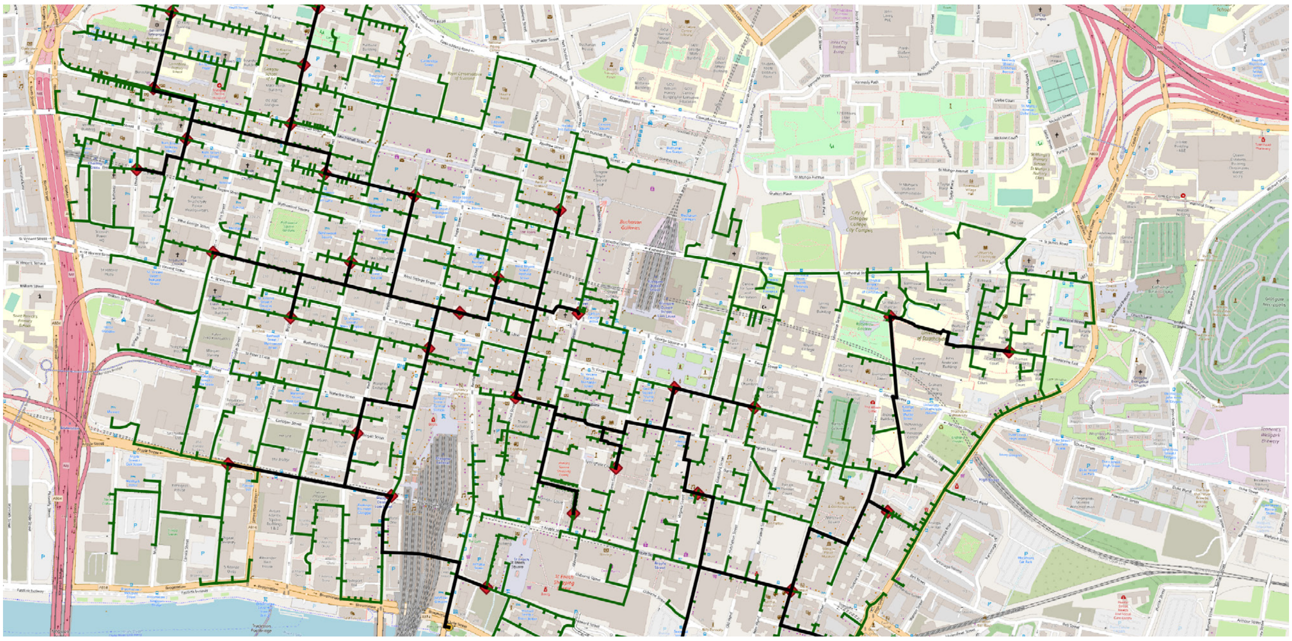


Figure 2. Demonstrating the DH network route
and booster stations-iteration 1

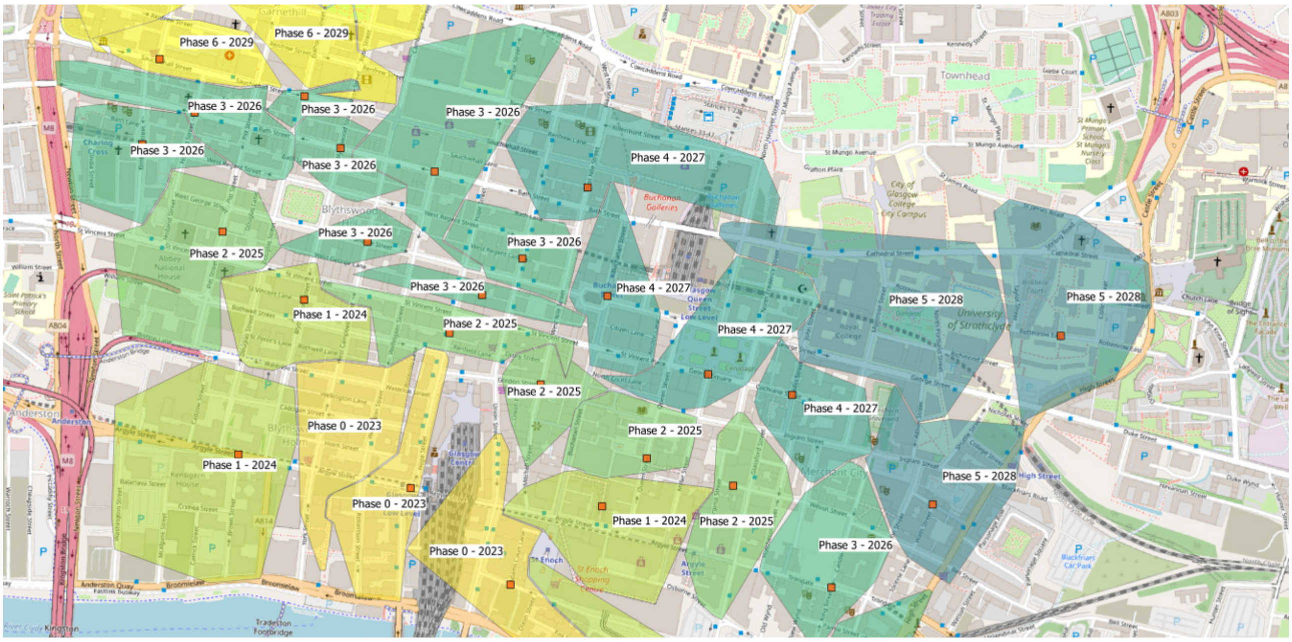


Figure 3. How each section of the city will be
integrated onto the DH network – iteration 1

proposal, we concluded deployment could be finished within 7 years, and consequently reach the Glasgow 2030 target.

Our goal is to offer a realistic DHN. It is impossible to invest and deploy all elements of the DHN in one go. Furthermore, as we want to minimise disruption to the community we propose a phased roll-out starting in 2023, ending in 2029.

After several iterations and calculations we concluded it makes the most economic sense to create four larger clusters, and use four heat pumps, each deployed on the river Clyde to provide each large cluster with sufficient heat. Below you can find a visualization of the final optimised design. These clusters could be interconnected at a later stage. We also applied our local knowledge to make specific manual modifications. For example, we required the software to route pipework via the least busy streets.

Figure 4. Glasgow city centre divided into four parts
- each heated by its own heat pump-iteration 2

We calculated the total cost of this network amounts to £84 million and produced a bill of materials.

Distribution includes: the cost of the heat pump energy centres, all ancillary equipment and all pipework.

Service connection includes: the cost of connecting from the main heat network to each building.

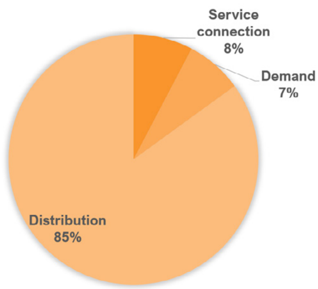
Demand includes: the integration of heat interface units and building efficiency measures within each building to ensure it is heat network ready.

We estimated, with extra costs, the total investment at £100M. This means £100M for this city centre network with an energy usage of about 110GWhr/year. The lifespan of a DH network, is about 40 years. Which results in an investment of £2.5M spread over 40 years.
Below you can find the summary of the bill of materials. You will discover that trenching costs or 'Distribution' accounts for 82% of the total network cost. Both service connections and the heat pumps are 9% of the cost in this model.

The economics make sense, as well as the benefits to the environment. If we keep the heat demand fixed and assume all current heat is derived from natural gas (40,000 tonnes of CO_2) then we can expect carbon savings in the order of 25,000T annually. This is the equivalent burning 8M litres of diesel every year. With this measure, the city of Glasgow can make a huge leap forward towards its goal of carbon neutrality by 2030.

Results

Total Cost of Project	£104,260,323.38
Total Public trench length (m)	47,354.03
Total Network linear heat density (MWh/m)	2.408
Deployment Cost per Home	£91,376.27



Cost Breakdown

	Network Cost	%
Service connection	£8,032,470.92	8%
Demand	£7,635,000.00	7%
Distribution	£88,592,852.45	85%
Total	£104,260,323.38	100%

Figure 5. The first pass bill of materials in summary-iteration 2

Scenario development: third iteration

After presenting our initial set of results in a webinar we determined that a truly successful heat network would deliver 100% supply of heat to ensure total decarbonisation and 100% offtake surety to ensure low risk investment. We sought greater accuracy and granularity. As such, we still needed to understand the factors contributing to the cost of heat, the bill of materials, the business model and discover whether other stakeholders have a shared interest.

As such, we agreed on new variables to input into the modelling. We wanted to know what a heat network that would have a 60-year lifetime and a larger total area increased to match up with the (Y)Our City Centre programme[1] would look like in terms of cost and return on investment. We retained the assumption of 100% offtake.

The DH network requires 74km of pipework and 49MWth heat supply from heat pumps sourced from the Clyde. 140GWhth of heat per annum will be drawn from the river, which is still a tiny fraction of the total available. 140GWhth of clean, zero carbon heat will reduce the city's greenhouse gas emissions by 31.5 kilotonnes every year.

This had a corresponding impact on the bill of materials with the cost of the project now estimated at £250 million pounds. We have now separated out the main categories to demonstrate the cost of the energy centre that now includes for a pontoon, grid connection, back up boilers with flues, abstraction etc.

"140GWhth of clean, zero carbon heat will reduce the city's greenhouse gas emissions by 31.5 kilotonnes every year."

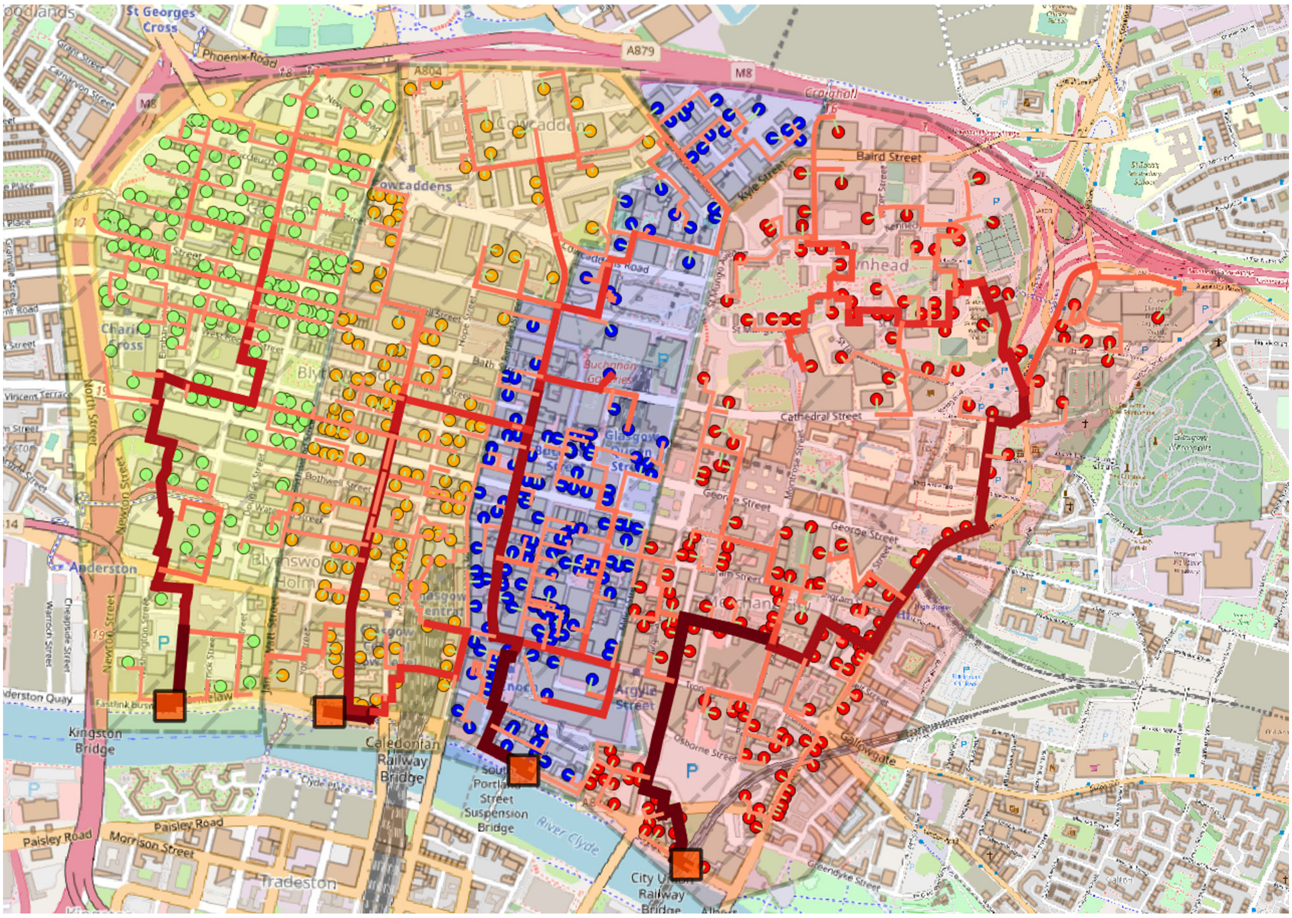
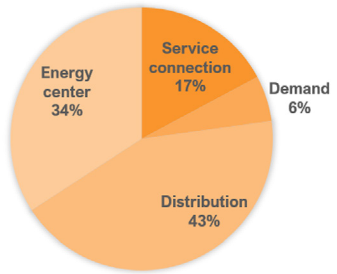


Figure 6. The expanded heat network area-iteration 3

[1] https://yourcitycentre.commonplace.is/

Results

Total Cost of Project	£252,394,095.39
Total Public trench length (m)	73,674.32
Total Network linear heat density (MWh/m)	1.904
Deployment Cost per Home	£188,213.34



Cost Breakdown

	Network Cost	%
Service connection	£43,419,181.63	17%
Demand	£14,223,250.00	6%
Distribution	£108,498,847.76	43%
Energy center	£86,252,816.00	34%
Total	£252,394,095.39	100%

Figure 7. Better cost data gives a more accurate estimate of the bill of materials budget-iteration 3

We turn now to the financial analysis.

1. Can such an investment produce a return and under what circumstances?
2. How should a project like this be valued?
3. How can we make such a project add value to other, related strategies?

What are the challenges to investing in a city centre heat network?

With a more realistic estimate of the total deployment cost we went on to use the financial modelling capability of the software to determine what sort of cashflow model is feasible.

Our capital expenditure is in the region of £250 million pounds. The operating expenditure is highly dependent on the cost of electricity as power is the principal input to produce the heat and operate all other components. Estimated maintenance and management costs (administrative, technical, financial etc.) have also been included. The main revenues are the sale price of heat and the recurring management fees per building. The parameters that we tested were as follows:

- Project lifetime of 60 years
- Full deployment of heat network to 1,314 buildings achieved by year 12
- All heat from a water source heat pump with a coefficient of performance (COP) of 3
- Grid electricity price of £100 per MWh for a heat cost of £33 per MWh
- Private wire electricity price of £45 per MWh for a heat cost of £15 per MWh

- Heat pricing at 12p, 10p, 8p and 6p per kWh
- Management fee of £15 per building per month
- No grant or subsidy
- No connection fees
- All buildings connected
- 100%, 75% and 50% offtake

The private sector will invest when the internal rate of return (IRR) over the project lifetime of 60 years is 4%. We selected a 4% discount rate in all scenarios.[2] Our modelling shows that, to reach zero net present value (NPV) at a discount rate of 4% we need a private price of electricity of £45/ MWh and a sale price of heat of £120/MWh, or 12p/ kWh. The payback is achieved in the 26th year.

In all other scenarios the NPV is negative. However, the negative NPV does not account for the contribution towards avoiding cataclysmic climate impacts for local social drivers, such as job creation, economic spillover etc.

In the table below we can see the impact at two different electricity prices, assuming 100% offtake.

The net cost of carbon abatement is about £132 per tonne over the lifetime of the project[3]. This compares favourably with the social cost of continuing to emit at current levels of £350 per tonne of carbon emitted[4].

Cost of heat produced from grid electricity (£100/MWh)	£33/MWh		
Price of heat	**IRR**	**NPV**	**Payback time**
£0,12	3,00%	-£37.212.251,00	32,00
£0,10	1,47%	-£87.247.726,00	43,00
£0,08	-0,049%	-£137.283.201,00	N/A
£0,06	-3,96%	-£187.318.676,00	N/A

Cost of heat produced from private wire electricity (£45/MWh)	£15/MWh		
Price of heat	**IRR**	**NPV**	**Payback time**
£0,12	4,40%	£15.778.670,00	26,00
£0,10	3,08%	-£34.256.804,00	32,00
£0,08	1,570%	-£84.292.279,00	42,00
£0,06	-0,35%	-£134.327.755,00	N/A

Figure 8. Financial outcomes at 100% offtake varying price of electricity at a COP of 3- iteration 3

"The net cost of carbon abatement is about £132 per tonne over the lifetime of the project. This compares favourably with the social cost of continuing to emit at current levels of £350 per tonne of carbon emitted."

[2] The discount rate is like an interest rate or the return you might reasonably assume to get from an alternative investment. In a typical analysis the IRR should equal or better the discount rate. At a discount rate of 4% we need an IRR of 4% and that gives us a NPV of 0. The net present value of a project is what you are left with, in cash terms, over the whole accountable period of the project, after you have accounted for the cost of capital. If it is above 0 then it is a better than the alternative, say, leaving it in the bank.

[3] Total revenues less total cost equals £250 million. This is divided by total carbon emissions abated over 60 years of 1,890kT. Cost per tonne is £132.

[4] 'The cost of climate inaction' Nature, September 2018 https://www.nature.com/articles/d41586-018-06827-x

Policy levers and strategy mind map

What are the optimal conditions necessary to give clean the best chance of supporting net zero ambitions in dense urban areas? We have developed a map to demonstrate how the variables relate to this goal. By establishing these conditions we can ensure the maximum inclination to change from existing fuel whilst ensuring the minimum additional cost relative to natural gas.

For example, one of the factors to drive the maximum inclination to change from gas, we must pursue the highest possible cost of gas. To do so, we must minimise the subsidy on gas whilst maximising the tax on gas. These are key points that must borne in mind when developing policy, strategy and planning.

An open project

With each iteration, new questions are raised and barriers identified to the viability of such a project. This only serves to highlight the importance of giving such an endeavour the resources to investigate and produce a solid plan and design.

It is a project open to all innovators who want to contribute to making this project a reality. If more innovators and expertise are involved, this project becomes stronger which will hopefully result in convincing relevant stakeholders to become a believer and to do their part. The Heat Vision 2030 project has taken contributions from Comsof Heat, IES, Minibems, Star Renewable Energy and Vital Energi.

The fact that all companies are giving their time freely with a clear and shared mission allows us to really focus on the ultimate goal without any other type of incentive or distraction.

"With each iteration, new questions are raised and barriers identified to the viability of such a project."

We have also shown in our webinars that there are many stakeholders with whom we liaise that can be convinced of putting more effort into accelerating low carbon heat networks. There is also a lot of consensus within these stakeholders in terms of what policies should be implemented. These are shown in the polls we have conducted, the results of which can be seen in appendix 2.

Conclusion

Things are moving in the DH sector, but they are not moving fast enough.

If we want to create sustainable DH networks, we need state of the art tools such as Comsof Heat for rapid planning and design. Networks and zones must be based on large scale clean sources of heat such as from river source heat pumps as provided by Star Renewable Energy and feed thermally optimised networks as achieved using Minibems. Firms such as Vital Energi are experts in deploying heat networks at scale, whilst IES provide in depth, invaluable building performance data.

All these tools are available right now, and we are convinced that they are the game changer to make best economic DH networks such as the one proposed for the centre of Glasgow.

"As shown in the financial appraisal this is a challenging task unlikely to offer a saving in the cost of heat vs cheap gas. A heat selling price of 6p/kWh is hardly enough, even with100% uptake. "

As shown in the financial appraisal this is a challenging task unlikely to offer a saving in the cost of heat vs cheap gas. A heat selling price of 6p/kWh is hardly enough, even with 100% uptake. How do we make it more viable? Cheaper electricity? Selling cooling too? Lower capex? How would his come about? Selling more heat?
In addition and somewhat undermining existing DH

"It is up to the other stakeholders to get on board and take bold decisions with a positive environmental and economic impact."

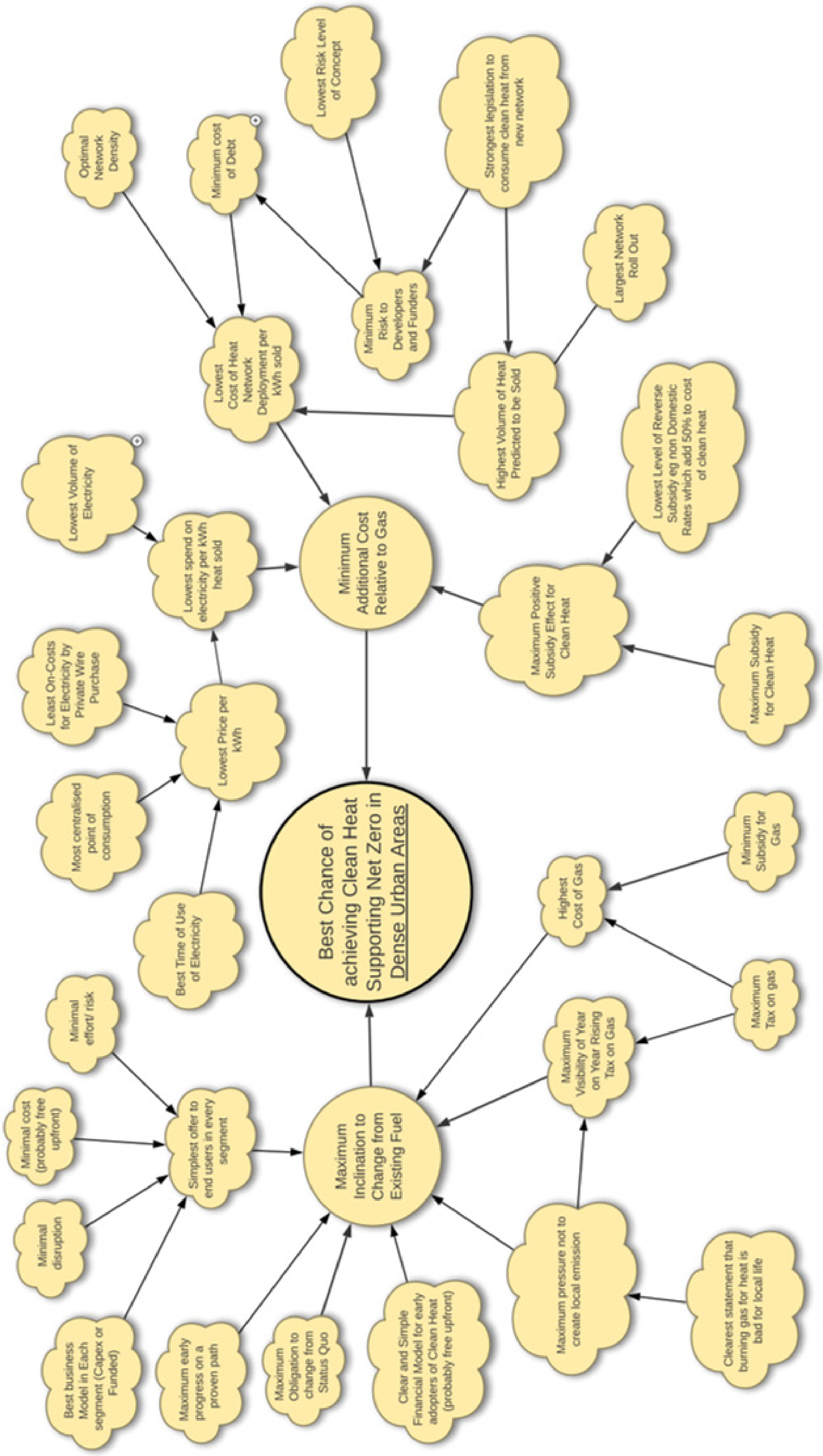
deployment, key underlying weaknesses such as non-domestic rates which simply add cost to heat provision and planning complexity (both Government in origin) have to be removed from the pathway to deliver Government policy.

What do we need?

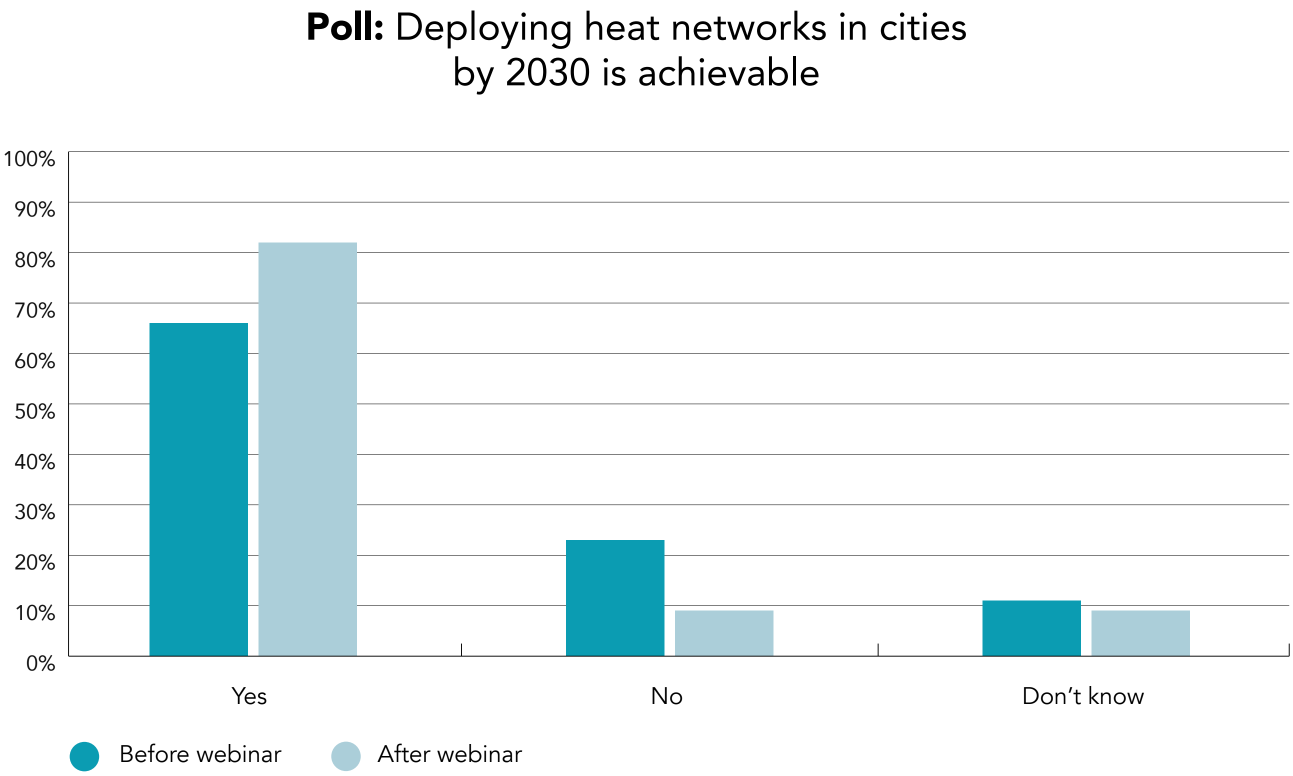
1. We need government policy and regulation to support the price of zero carbon heat supplied by heat networks to make the business model viable.
2. We need to regulate that only allowable solutions should be zero carbon and the only relevant comparators when choosing what to invest in.
3. We need business models that allow for and/or apply real value (price in) avoiding cataclysmic climate change.

It is up to the other stakeholders to get on board and take bold decisions with a positive environmental and economic impact. Swapping dirty heat for clean heat plus jobs is a viable mission but not one that will happen without total focus and even then likely to require strategic cost support to ameliorate the uplift in cost vs gas.

Appendix 1: Clean heat policy map



Appendix 2: Webinar Poll from webinars held in May, September & November 2020



QUESTION	YES	NO	TOTAL
The climate change levy on gas already exists. Should the revenues be used to fund 0 carbon solutions?	42	2	44
Should buildings in a heat network zone be obligated to reduce fossil fuel emissions or if they prefer, join a heat network?	26	12	38
To drive down fossil fuel emissions should clean air zones be declared in all city centres?	42	2	44
Do you think it is realistic to achieve net zero carbon emissions whilst allowing buildings to still burn gas?	41	5	46
So as to maximise the viability of heat networks should all buildings in a zone be obligated to draw heat from a heat network?	20	23	43
Should buildings that join a low carbon heat network be exempt from paying the climate change levy?	40	5	45

Appendix 3: Principal contributors

Comsof Heat

Comsof Heat is GIS-based district heating software which automates the planning and design process. It uses intelligent algorithms for automated & optimized clustering and routing of a district heating network.

- Build a solid business case with the right numbers
- Create high-level masterplans for multiple areas
- Select the most interesting customers and areas for a maximal return on investment
- Stay in full control over your project

comsof.com/heat

Minibems

Minibems provides heat network management expertise. The Minibems service is based on real-time verifiable data that gives confidence to commit to high delta Ts and low return temperature heat networks. Our three core services: Dynamic, Telematic and Minipay address three aspects of heat network performance: energy efficiency, maintenance and reliability, metering and billing. The outcomes are:

- More efficient systems, reducing primary fuel costs and related carbon emissions
- Enabling low carbon technologies
- Improving reliability and reducing unplanned maintenance costs

minibems.com

Star Renewable Energy

Having delivered what is still the world's largest 90C ammonia heat pump in Drammen in 2011, Star Renewable Energy have been working to convince the UK market that the best way to deliver 2050 compatible heat is to harvest open water. In Scotland, over 80% of the heat demand is located within 1000m of open water, be it a larger river, estuary or the open sea. It was this insight of the power of data and data exploitation that made Star so keen to support the work of HeatVison2030 as what was desperately needed at the crucial period was insight into the likely cost of deployment, cost of operation and ultimately the "value proposition" to the heat off-takers.

neatpumps.com

Vital Energi

With over 30 years' experience in the District Heating and Cooling industry, Vital Energi is responsible for some of the UK's first and largest award-winning district energy projects. Vital Energi offers unrivalled design, build, operation and maintenance services, and even partner with our clients to form ESCos.

vitalenergi.co.uk