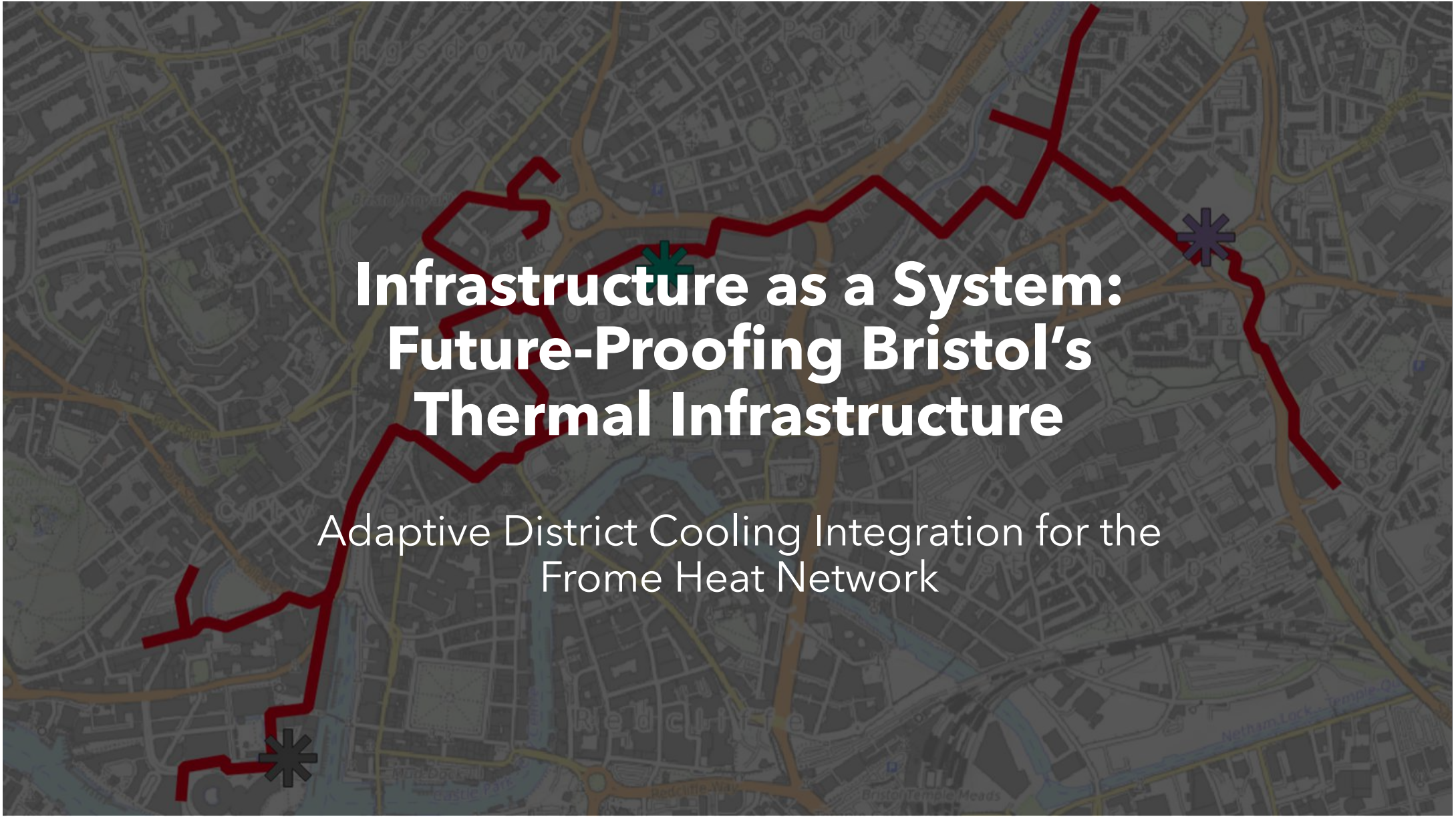
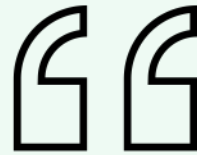




Infrastructure as a System: Future-Proofing Bristol's Thermal Infrastructure

Adaptive District Cooling Integration for the
Frome Heat Network



If we want to make the energy transition happen in cities, we need to look at heating, cooling and electricity in an integrated way. This is the only way we can make the best use of the available resources.

Tanja Wielgoß, Vattenfall Wärme Berlin AG

Infrastructure in Transition

Recent years have highlighted the increasing impact of climate change on the UK's built environment. Buildings, infrastructure, and design standards were developed for a predominantly heating-dominated climate. As temperatures continue to rise, cooling is becoming an essential urban utility rather than an occasional comfort.

This transition requires cities to evolve from systems designed solely to provide heat towards integrated thermal infrastructure capable of responding to both heating and cooling demand.

Achieving this transition, however, is not simply a technical challenge. Infrastructure investments made today will shape cities for decades, despite uncertainty surrounding future climate conditions, cooling demand, and energy systems. The challenge is therefore not whether this transition will occur, but how it can be delivered at the right pace while remaining flexible and sustainable. For UK cities, this represents a fundamental shift in the planning of urban thermal infrastructure, requiring long-term decisions to be made under significant uncertainty.

UKHSA updates heat health alerts across England

From homes to hard infrastructure, the cost of climate risk is growing

UK "Built for a Climate That No Longer Exists", Warns Climate Change Committee

**Overheating and planning for the new reality
Amber heat-health alerts issued as UK could see 10 consecutive days of temperatures over 30C**

White paint, trees or air con? What parents and teachers can do to cool UK's overheating schools

The UK's summers are getting hotter - but how prepared are we?

'Unprecedented' changes in UK climate are normalising extremes, report says

Fourth heatwave grips parts of UK with 35C forecast

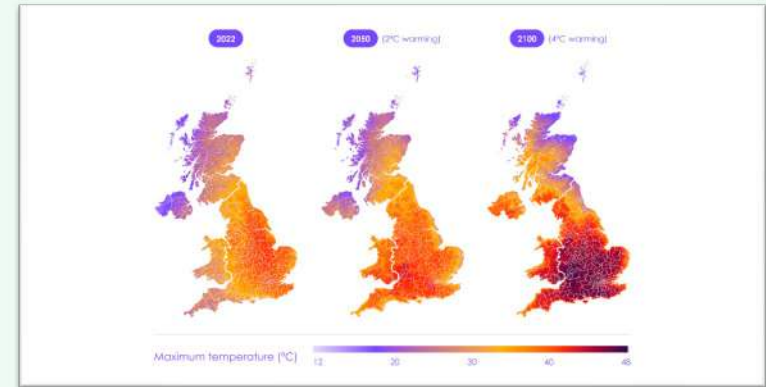
Bristol's Thermal Transformation

In *A Well-Adapted UK*, the Climate Change Committee (CCC) identifies reducing cooling demand as the first priority through passive measures such as building standards, retrofit and urban greening. However, it also recognises that active cooling will become necessary in some locations and recommends that it should be delivered in ways that support long-term decarbonisation.



Source: Bristol City Leap

Source: CCC



One way to reconcile the growing need for cooling with long-term decarbonisation is through shared thermal infrastructure. In Bristol, Vattenfall, through Bristol City Leap, is currently investing over £1 billion in transforming the city's energy system by replacing decentralised heating with a district heat network, creating the backbone of Bristol's long-term low-carbon thermal infrastructure.

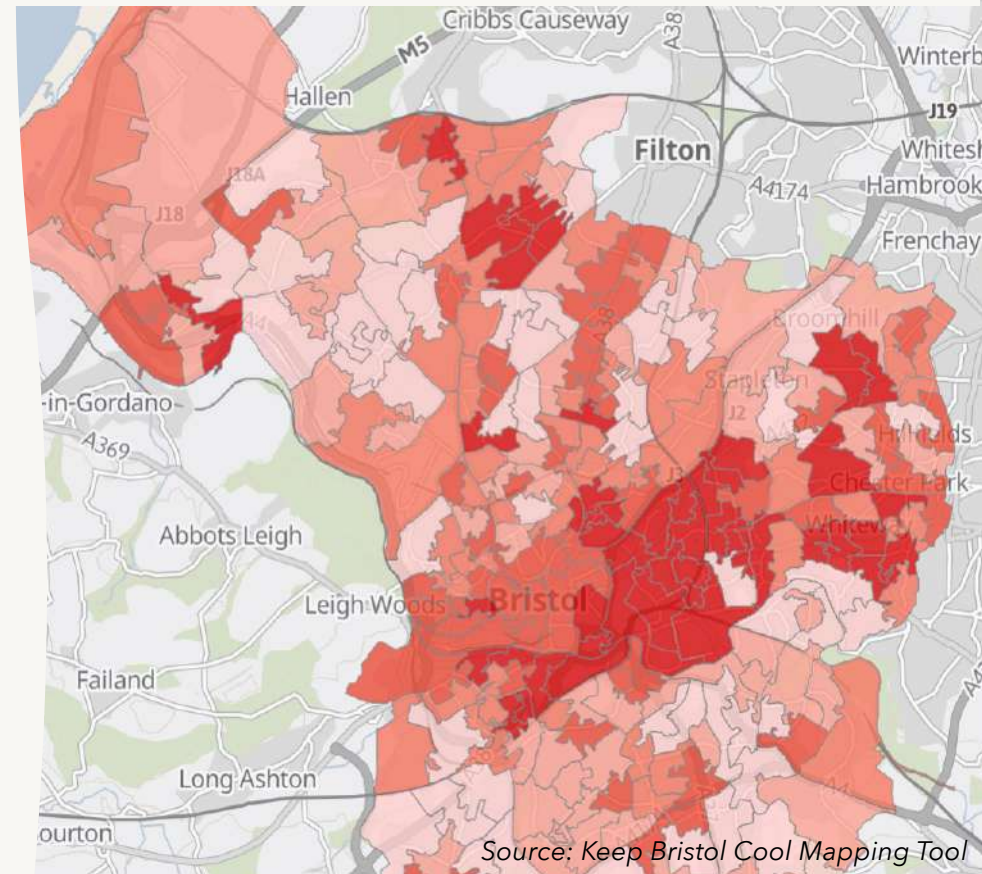
Current plans remain primarily focused on heating. Vattenfall recognises that where there is a cluster of buildings with genuine cooling needs, local cooling loops could be introduced to feed recovered heat back into the district heating network. In practice, such clusters are most likely to correspond to commercial anchor loads where cooling demand already exists and can justify investment.

Why Current Thinking May Not Be Enough

Several trends suggest Bristol's cooling demand is likely to evolve beyond today's commercial clusters:

- Keep Bristol Cool projects approximately 22 days above 25°C during 2021-2039, increasing to around 55 days annually by 2061-2079, with temperatures above 25°C recognised as detrimental to indoor comfort and sleep quality.
- Existing housing stock is particularly vulnerable because passive retrofit opportunities are often limited.
- Fewer than 5% of UK homes currently use air conditioning, yet installation rates continue to rise.

These trends suggest that cooling demand will expand beyond today's commercial anchor loads into residential neighbourhoods. However, when and where this demand will emerge remains uncertain.



How can district cooling build upon today's assets and opportunities while remaining adaptable to future demand that may, or may not, materialise?

Project Proposition

Vision

As a continuation of the Bristol City Leap programme, integrate future cooling opportunities into heat network expansion, ensuring the network remains adaptable to uncertain future demand.

Value Creation

1. Reduce future excavation and retrofit by preserving cooling opportunities during heat network construction.
2. Support a low-carbon energy transition by enabling integrated district cooling that can reduce reliance on dispersed building-level systems and optimise electricity use.
3. Improve investment efficiency by matching infrastructure deployment to demonstrated demand while preserving flexibility for future uncertainty.

Central Trade-off:

Additional upfront investment under uncertain future demand in exchange for long-term system flexibility.

Success Criterion:

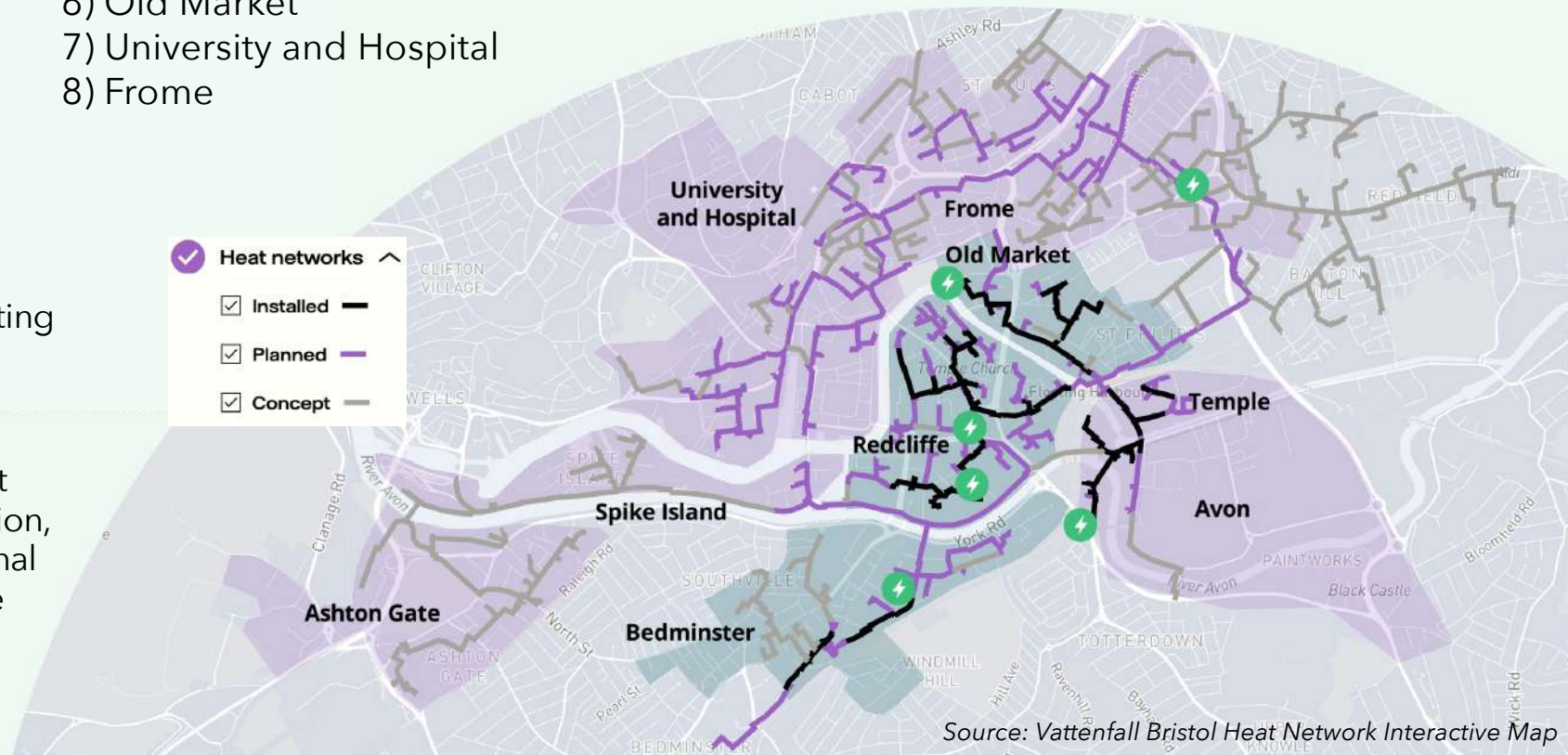
The network can adapt to both high- and low-cooling-demand futures with minimal retrofit and no stranded cooling assets.

Bristol Heat Network Context

Vattenfall divides Bristol centre into 9 thermal development districts:

- 1) Ashton Gate
- 2) Spike Island
- 3) Bedminster
- 4) Redcliffe
- 5) Avon
- 5) Temple
- 6) Old Market
- 7) University and Hospital
- 8) Frome

- Each district has an independent energy centre and district heating loop supplying space heating and hot water.
- Districts are at different stages of implementation, ranging from operational schemes to early-stage concepts.



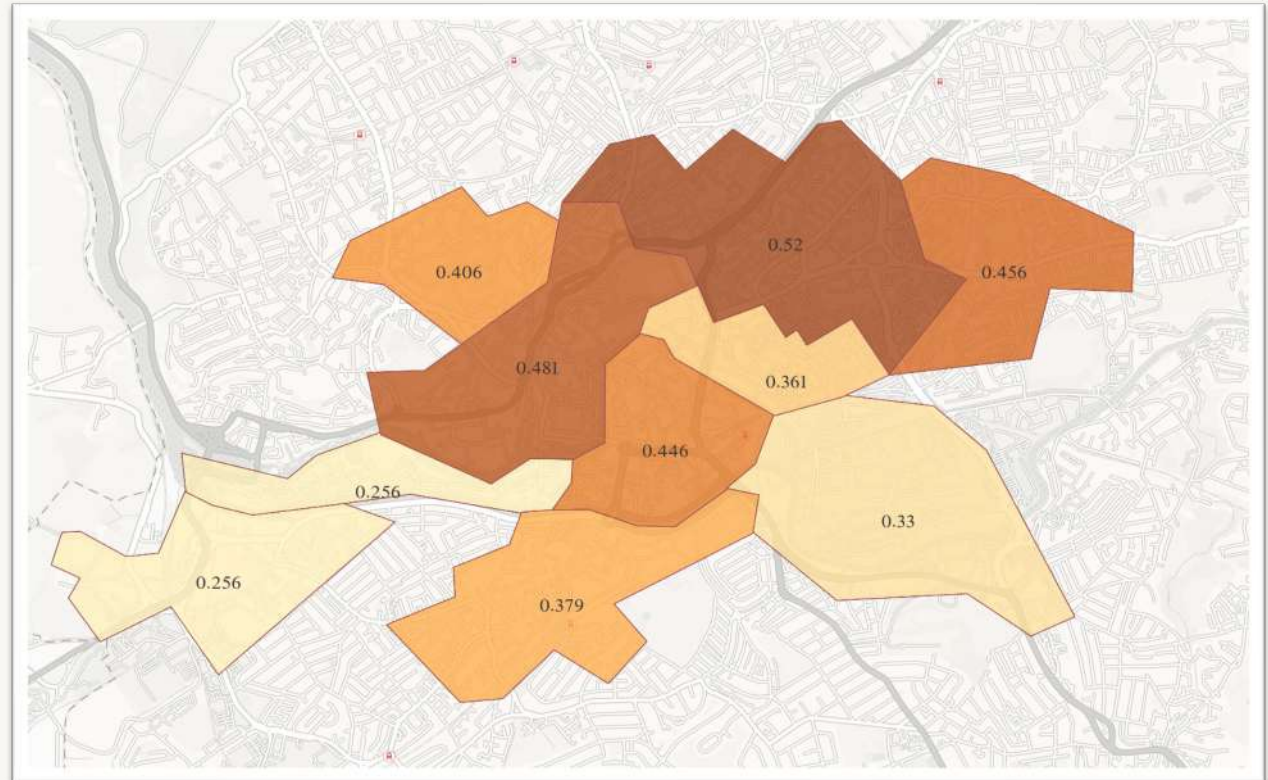
Pilot District Identification

Cooling demand will not emerge uniformly across the city. Different districts have different building types, climate exposure, and opportunities for network expansion. Rather than applying the same intervention everywhere, future-proofing should first target locations where most factors align.

To identify the most suitable pilot district, each Bristol Heat Network development area was evaluated against suitability criteria.

- Projected overheating (current and future climate risk)
- Passive retrofit potential
- Availability of green and blue infrastructure
- Anchor load potential
- Future expansion opportunities

Spatial datasets from the *Keep Bristol Cool* project were combined to produce an overall *Priority Index*, identifying districts where early cooling integration would provide the greatest long-term value. Figure on the right shows the resulting ranking.



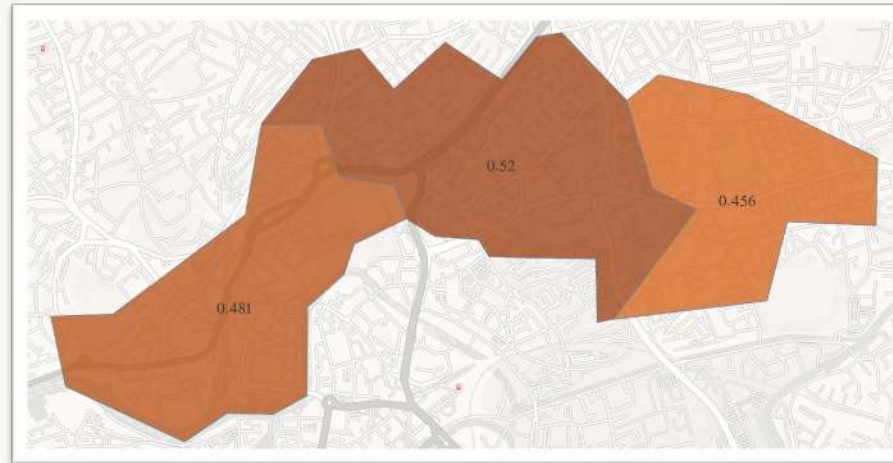
Frome

A complete urban testbed

Frome contains a diverse mix of urban typologies. This allows different cooling strategies to be tested within a single district.

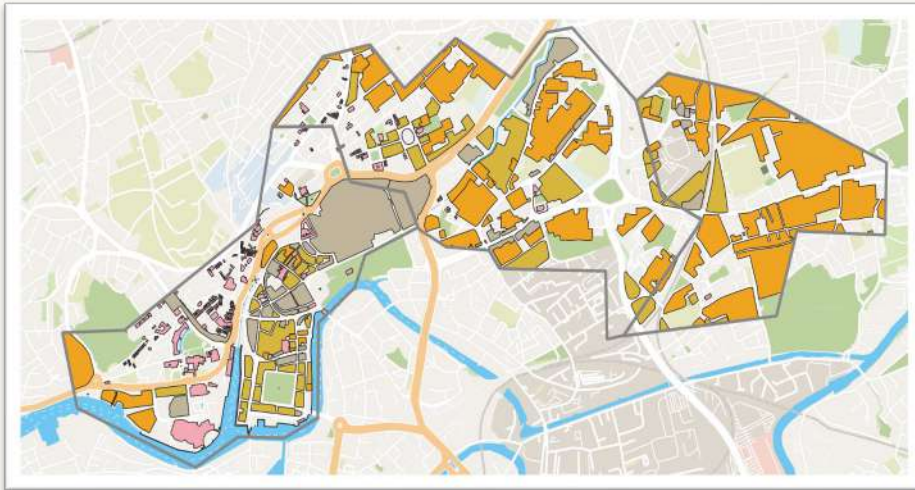
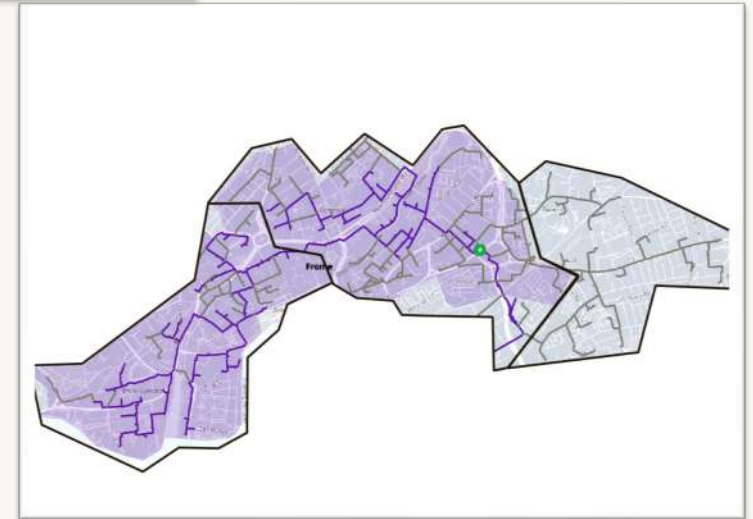
Highest future-proofing priority

Identified as the highest-ranked district.



Timely intervention

The district remains at the planning and concept stage, creating an opportunity to embed cooling-ready infrastructure before construction begins.



Window of Opportunity

Within Frome, Broadmead represents the clearest window of opportunity for introducing district cooling.

Immediate demand

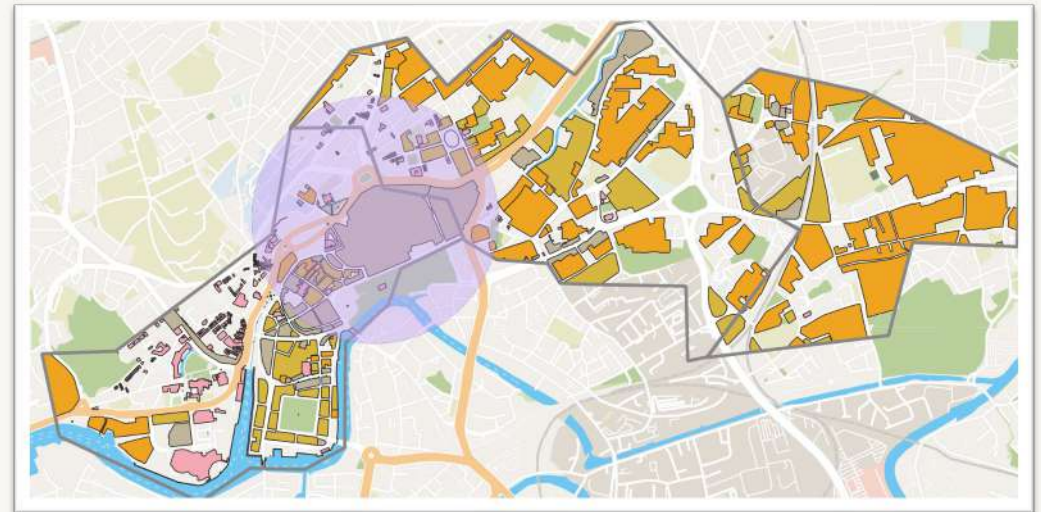
The Bristol Shopping Quarter already contains a high concentration of retail and commercial buildings with significant cooling requirements, creating an immediate case for district cooling.

Development momentum

Two major mixed-use redevelopment projects, The Galleries and St Mary Le Port, will introduce new commercial, residential and public spaces, increasing future cooling demand while creating a rare opportunity to embed cooling infrastructure before construction is completed.

Strategic position

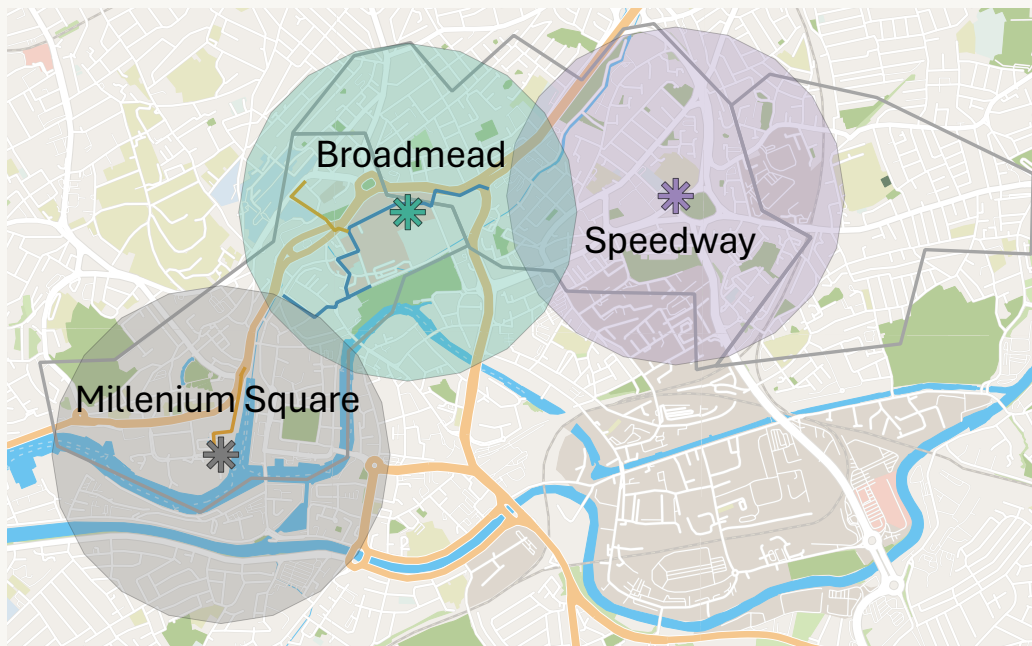
Located between Bristol Royal Infirmary, the University of Bristol and eastern residential neighbourhoods, Broadmead provides the most effective starting point for phased expansion as demand evolves.



In this project, Broadmead therefore becomes the city's first cooling energy hub, demonstrating how today's commercial demand can establish the foundations for tomorrow's wider thermal network.

Regional Planning Logic

Frome contains two planned thermal centres: **Speedwell Energy Centre** to the east and **Millennium Square Energy Centre** to the west. Together with the proposed Broadmead cooling hub, these nodes divide the district into three distinct thermal planning regions.



Each region exhibits different urban characteristics, cooling demand profiles and development trajectories. Consequently, applying the same cooling strategy across the district would lead to unnecessary investment in some areas and missed opportunities in others. Instead, interventions are tailored to local conditions and implemented through region-specific investment pathways.

The objective is to deliver low-regret, high-impact interventions that remain beneficial across multiple future demand scenarios.

Adaptive Intervention Framework

Intervention Triggers

1. Heat network expansion:

Triggers *cooling preservation*, embedding future cooling opportunities into infrastructure already being constructed to avoid costly retrofit.

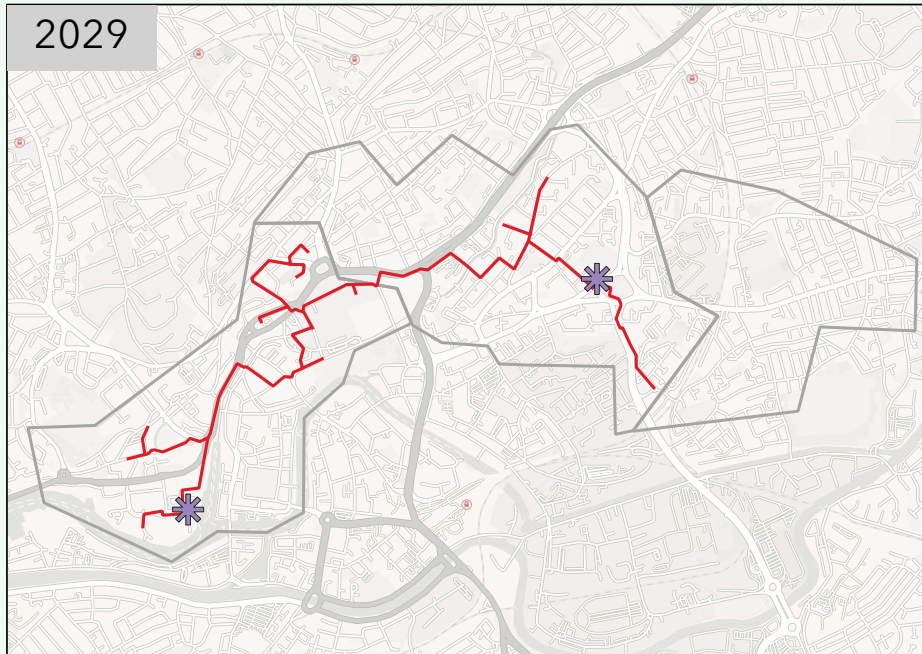
2. Cooling demand:

Triggers *cooling expansion*, introducing active cooling infrastructure only where demand is sufficient to justify investment.

Based on these two triggers, the project applies the **intervention toolkit**.

Intervention	Description	Value Created	Relative Cost
Cooling Preservation			
Energy centre space reservation	Reserve plant space for future cooling equipment	Enables future technology without rebuilding the energy centre	Low
Corridor reservation	Excavate and reserve utility corridor for future cooling mains	Avoids repeated excavation of strategic routes	Medium
Junction reservation	Oversize chambers to accommodate future cooling connections	Simplifies future expansion	Low
Cooling Expansion			
Cooling mains	Install distribution pipework where demand exists	Delivers cooling water to connected buildings	High
Tee installation	Install branch connections during cooling expansion	Allows future connections with minimal disruption	Medium
Cooling technology	Chillers, heat recovery chillers or reversible heat pumps depending on regional strategy	Provides active cooling generation	High

Planned Heat Network Expansion



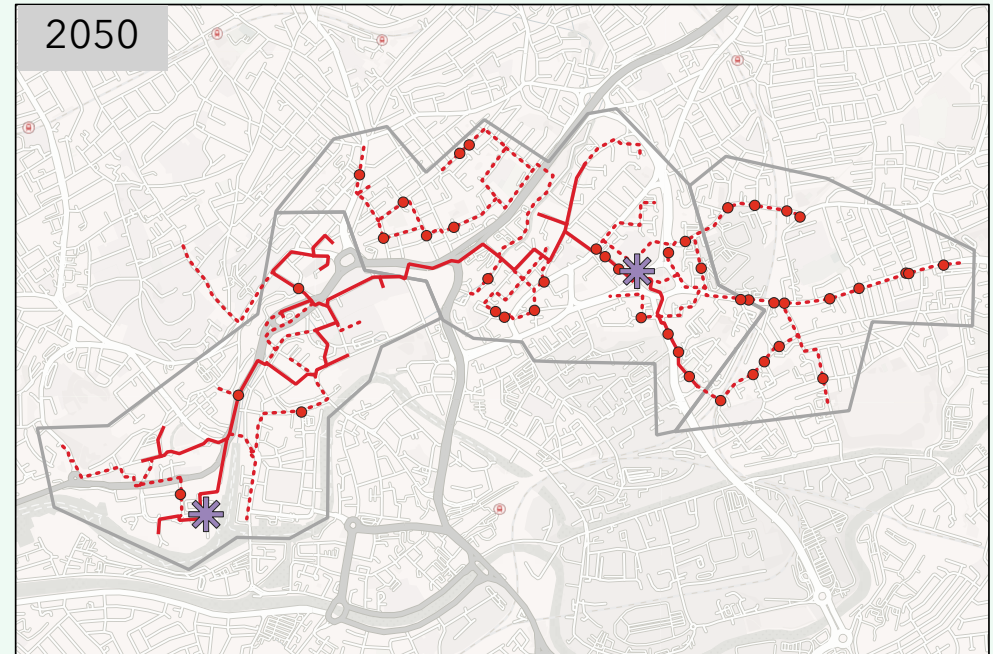
Phase 1: Core network delivery (2026-2029)

Speedway Energy Centre *

Millennium Square Energy Centre *

Primary network spine —

Initial secondary distribution network —



Phase 2: Progressive network expansion (to 2050)

Extension of secondary distribution mains - - -

Additional branches ●

Broadmead: Region Strategy



1. Character

Retail core with existing high cooling demand
Many anchor loads
Mixed-use area
High density
Few green spaces

2. Demand Opportunity

Retail and office cooling loads
Upcoming redevelopments
University and Hospital
St Paul's residential area

3. Demand Uncertainty

Redevelopments occurrence
Timing of connections
Residential cooling demand

4. Design Philosophy: Pilot and Production Hub

Deliver cooling where demand already exists while creating the city's first expandable district cooling hub.

5. Regional Role

Serve today's retail and commercial cooling demand
Recover and return waste heat to the district heating network
Act as the primary cooling hub for future expansion towards surrounding redevelopments, the University, Bristol Royal Infirmary and St Paul's
Support phased network growth as cooling demand emerges

Broadmead: Energy Centre Vision

Context

Broadmead is assumed to become Bristol's first district cooling energy hub, primarily serving existing commercial anchor loads. The proposed location occupies the existing Bristol Shopping Quarter service car park. Heat is supplied through the planned district heating network from the Speedway and Millennium Square Energy Centres.

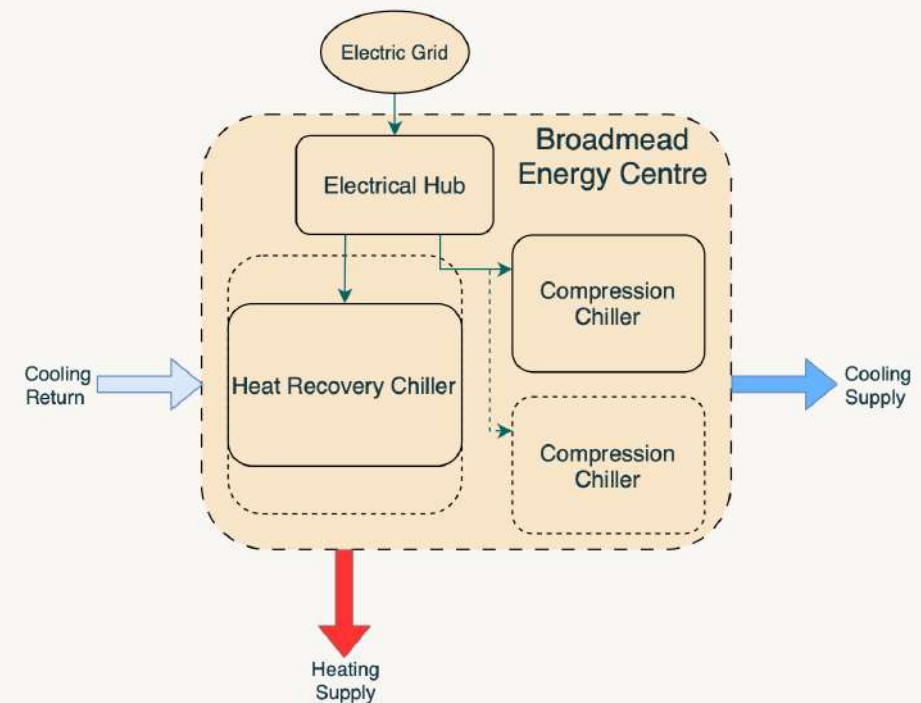
Expected Demand Patterns

Season	Heat demand	Cooling demand
Summer	Moderate	High
Winter	Moderate	Moderate

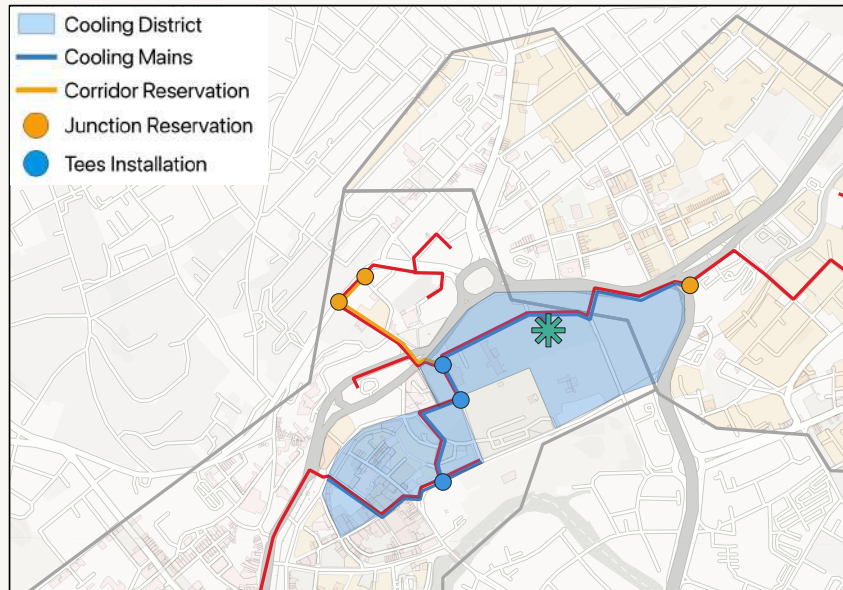
Commercial cooling demand is expected to increase over time, while district heating demand remains available through the wider heat network, creating opportunities for simultaneous heat recovery.

Design Proposition

1. **Heat recovery chiller:** Captures waste heat from cooling, providing low-carbon heating whenever simultaneous demand exists.
2. **Compression chiller for peak demand:** Covers cooling demand when recovered heat alone is insufficient, guaranteeing reliable cooling during summer peaks.
3. **Reserved plant space:** Allows installation of additional chillers as cooling demand grows without requiring major rebuilding of the energy centre.

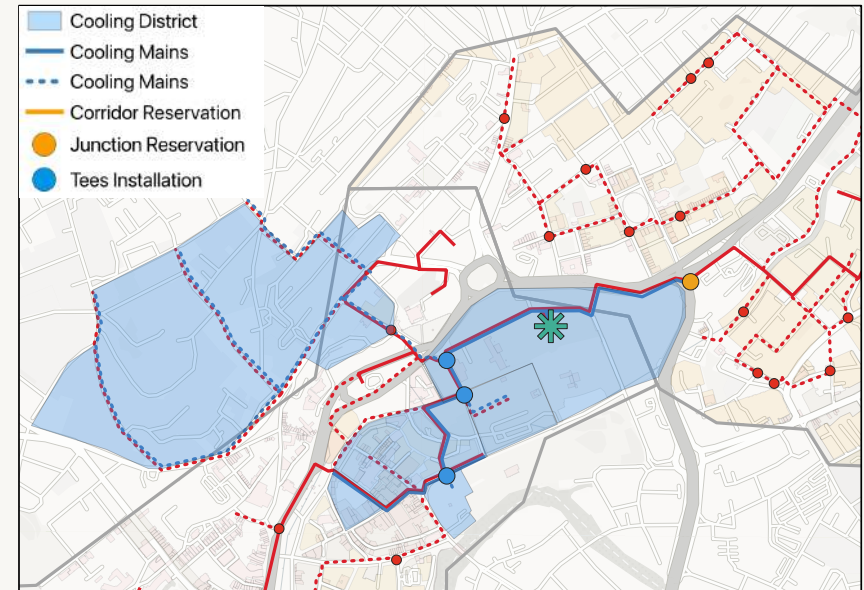


Broadmead: Network



Phase 1 (Initial heat network expansion):

1. Install cooling mains alongside planned heat network construction within the Broadmead commercial district
2. Install tees for future expansion towards surrounding redevelopments
3. Reserve corridor and junctions towards the University and Hospital
4. Reserve junction towards residential areas



Phase 2 (Further heat network expansion) :

1. Extend cooling mains towards the University and Hospital using the preserved corridors and junctions.
2. Connect new redevelopment areas as they become operational through the pre-installed tees.

Broadmead: Validation

The proposed Broadmead expansion strategy was evaluated in NPro software to assess how future network expansion influences a long-term system value.

Network expansion

Connected buildings: 247 → 533

Cooling demand: 3.0 → 6.3 GWh/year

System performance

Heat recovery: 1.1 → 2.9 GWh/year (+157%)

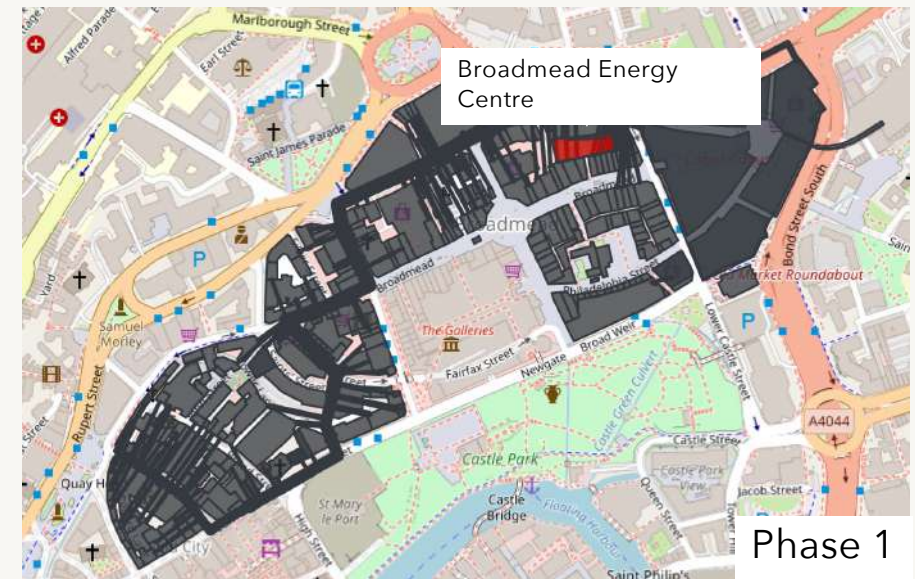
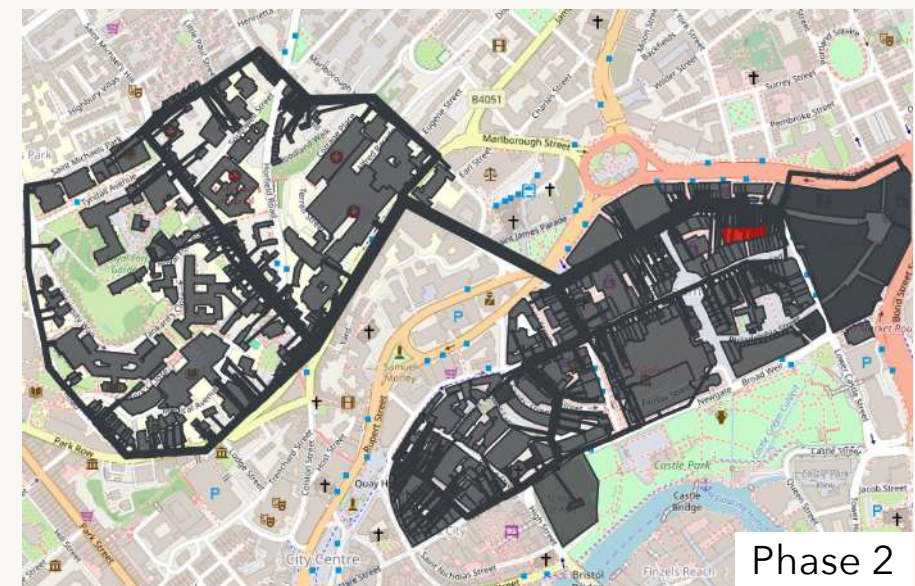
Electricity demand: 5.93 → 6.33 GWh/year (+7% only)

Economic impact

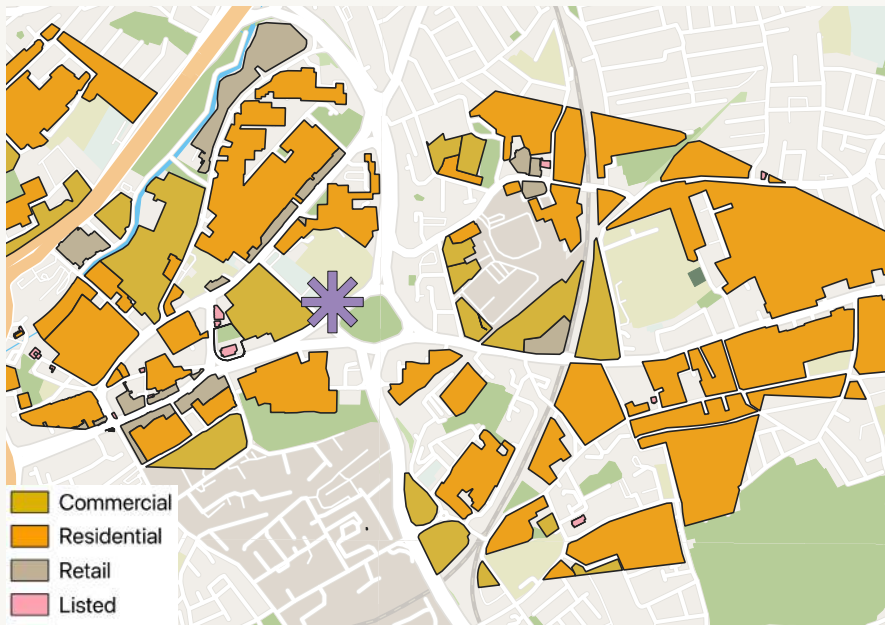
Total investment: 31 → 72 M€

Total cost after revenue: -45 → -68 M€

The simulations demonstrate that preserving expansion opportunities allows the same energy centre to accommodate substantially greater demand while improving energy efficiency and long-term economic performance.



Speedway: Region Strategy



1. Character

Predominantly residential
Limited current cooling demand
Highest long-term overheating risk
Predominantly old, terraced neighbourhoods
Many green spaces

2. Demand Opportunity

Eastern vulnerable residential neighbourhoods

3. Demand Uncertainty

Residential AC adoption
Effectiveness of passive retrofit and green infrastructure
The exact neighbourhoods where cooling demand will emerge

4. Design Philosophy: Future Residential Expansion Hub

Prioritise preparedness over construction by preserving the infrastructure required for future residential cooling.

5. Regional Role

Provide low-carbon heating today
Support future residential cooling demand as it emerges
Preserve strategic connections to enable phased expansion without major retrofit

Speedway: Energy Centre Vision

Context

Speedway is assumed to follow the planned Bath Road Energy Centre in Avon and Temple districts. It uses a centralised air-to-water heat pump as the primary heat source for the district heating network.

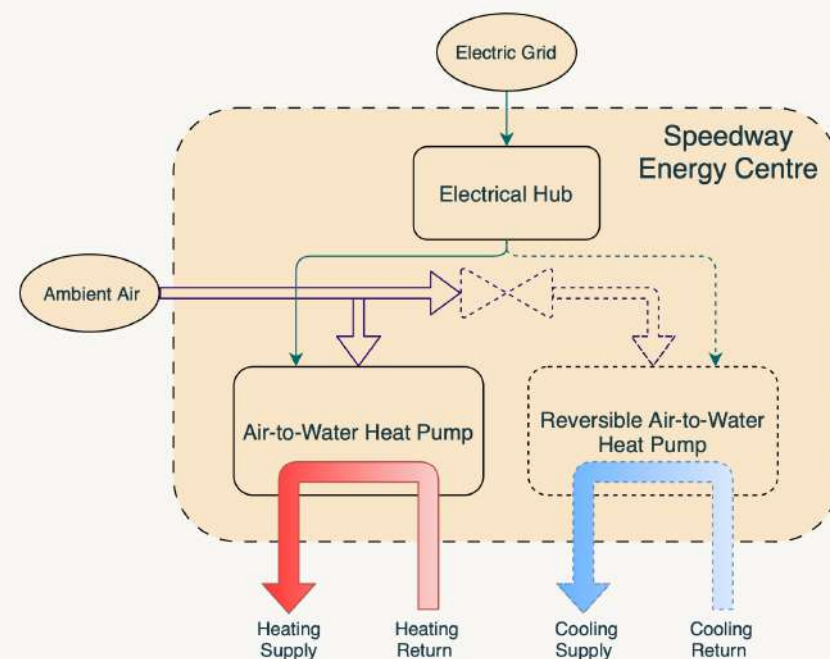
Expected Demand Patterns

Season	Heat demand	Cooling demand
Summer	Moderate	Moderate (if residential demand develops)
Winter	High	Low

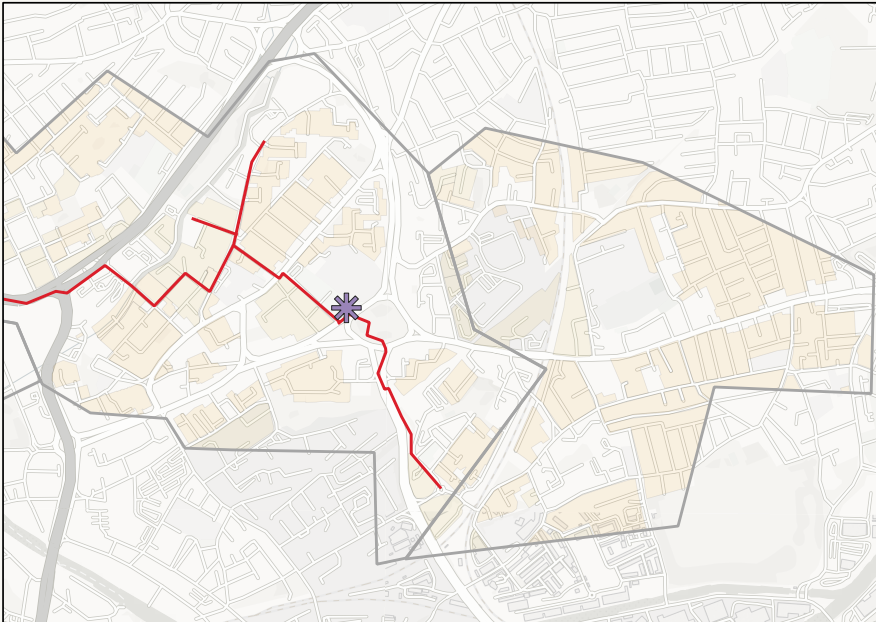
Future expansion should prioritise a technology capable of providing cooling when required while remaining useful during the winter heating season.

Design Proposition

1. **Air-to-water heat pump (planned)**: Primary heat source for the district heating network.
2. **Reserved plant space for an additional reversible air-to-water heat pump**: Provides cooling during summer and switches to heating during winter, maximising asset utilisation while supporting increasing heating demand as the network expands.

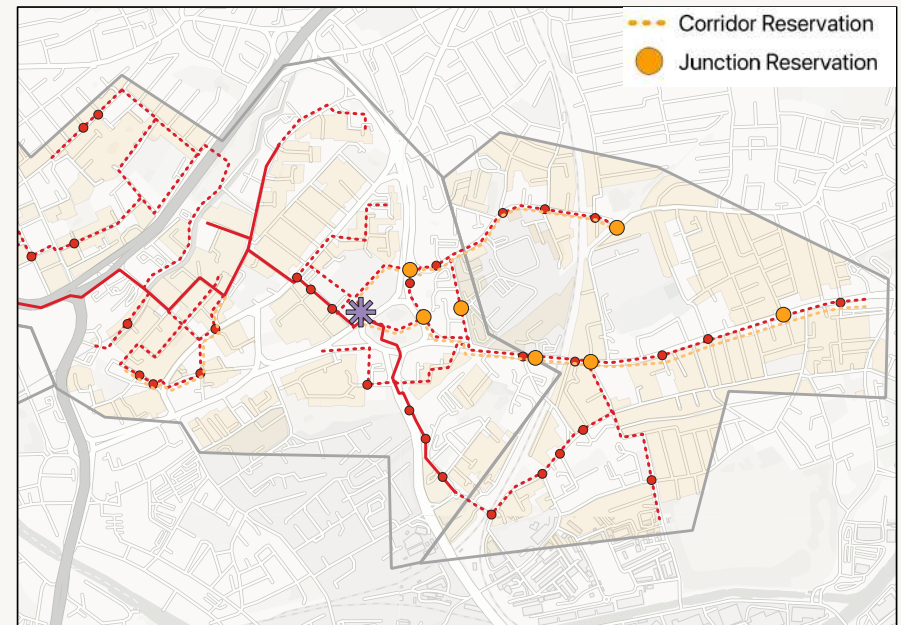


Speedway: Network



Phase 1 (Initial heat network expansion):

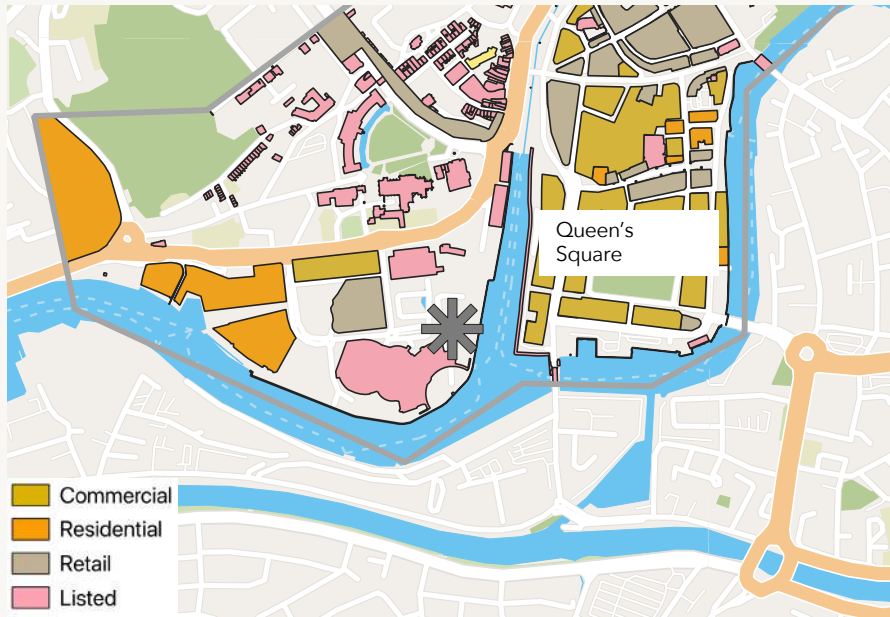
- No cooling expansion required
- Preserve ground access and expansion space around the energy centre
- Monitor the evolution of residential cooling demand



Phase 2 (Further heat network expansion):

- Reserve corridors towards dense and heat-vulnerable residential neighbourhoods
- Reserve junctions where future demand clusters are expected
- Where demand is already evident, replace preservation with immediate cooling expansion during construction

Millenium Square: Region Strategy



1. Character

Mixed-use modern area, mostly commercial
Largest amount of historical and listed buildings
River-influenced
No immediate climate vulnerability

2. Demand Opportunity

Historical buildings
Queen's Square
commercial area

3. Demand Uncertainty

Passive retrofit success for
historical buildings
Mixed-use redevelopments
and dynamic nature of the
city centre may significantly
change local cooling profiles

4. Design Philosophy: Flexible Thermal Exchange Hub

Exploit the River Avon as a seasonal thermal asset while
remaining adaptable to uncertain future demand.

5. Regional Role

Provide low-carbon heating today through river-source
thermal exchange
Enable future heating and cooling flexibility
Adapt to evolving demand patterns without major retrofit
constraints

Millenium Square: Energy Centre Vision

Context

There is limited information on the energy centre design. However, its riverside location indicates potential for a water-source heat pump system, similar to the Castle Park Energy Centre in Old Market district.

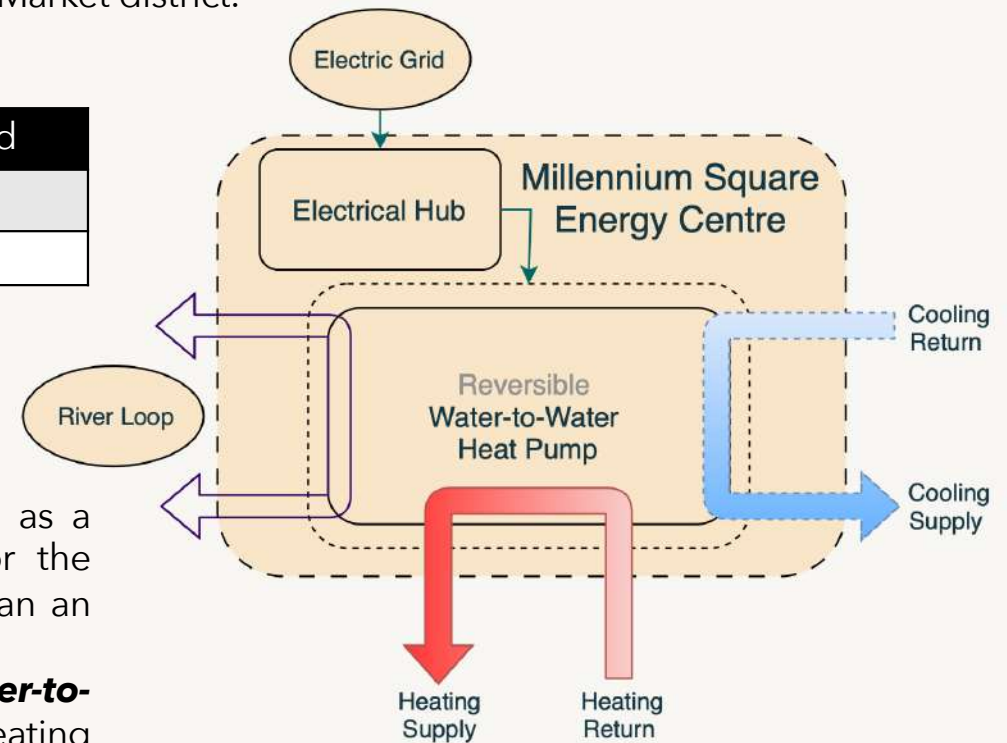
Expected Demand Patterns

Season	Heat demand	Cooling demand
Summer	Low-Moderate	Moderate
Winter	Moderate	Low-Moderate

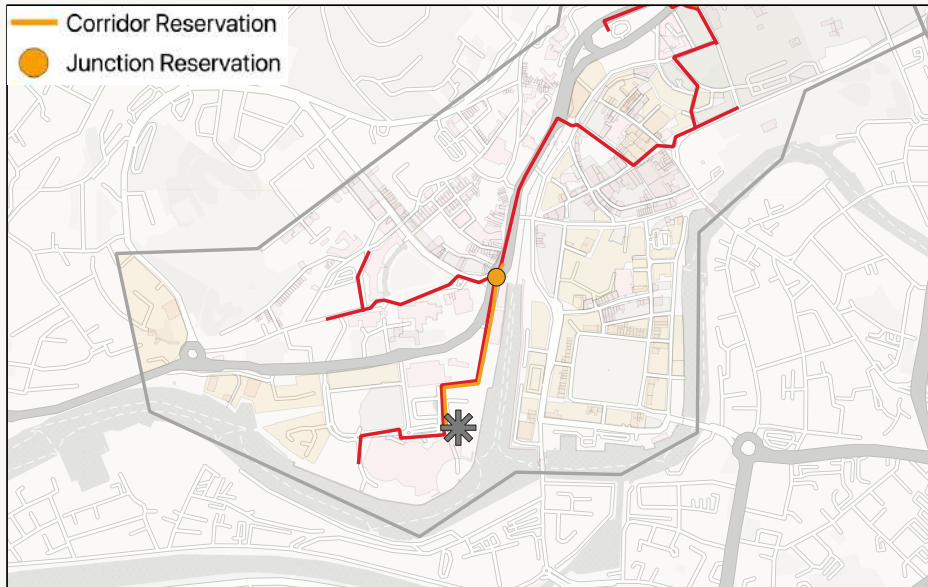
Design the energy centre as a flexible thermal exchange hub, prioritising low-carbon heat today while preserving the capacity to transition towards cooling as urban demand evolves.

Design Proposition

- Water-to-water heat pump (planned):** Uses the River Avon as a stable heat source to provide efficient low-carbon heating for the district network, offering more consistent winter performance than an air-source system.
- Reserved plant space for an upgrade to a reversible water-to-water heat pump:** Enables the same system to switch between heating and cooling operation, using the River Avon as a heat source in winter and a thermal sink in summer to accommodate uncertain future demand without additional cooling infrastructure.

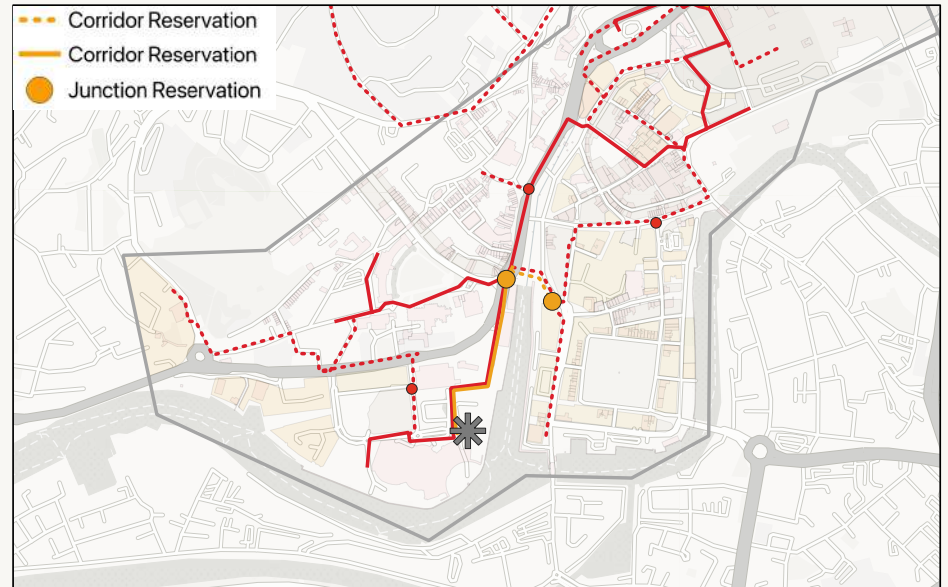


Millenium Square: Network



Phase 1 (Initial heat network expansion):

- Reserve a northern expansion corridor from the energy centre to approach key commercial and heritage areas with concentrated energy demand
- Reserve a junction near the secondary main towards Bristol City Hall to enable future network branching



Phase 2 (Future heat network expansion):

- Reserve a corridor through the channel to enable future connection towards Queen Square while avoiding costly retrofit constraints in a challenging area
- Reserve an expansion junction at the corridor end to enable future branching towards northern retail and southern commercial areas

Stakeholders, Incentives, and Policy

Stakeholder	Interest	Incentive
Vattenfall	Future-proof district heat network	Lower retrofit costs and access to future cooling customers
Bristol City Council	Climate resilience and regeneration	Delivers adaptation alongside decarbonisation objectives
Developers	Efficient redevelopment delivery	Future-ready thermal infrastructure increases asset value
University and Hospital	Reliable thermal supply	Lower operating costs and improved resilience
Residents and Businesses	Thermal comfort	Access to district cooling without widespread individual AC

Policy Requirements

1. Cooling-ready requirements for heat network construction

Require new district heat network projects to assess and preserve space for future cooling integration during construction.

2. Connection requirement of major redevelopments

Large mixed-use redevelopments within designated heat network zones should connect to the district energy network where technically feasible.

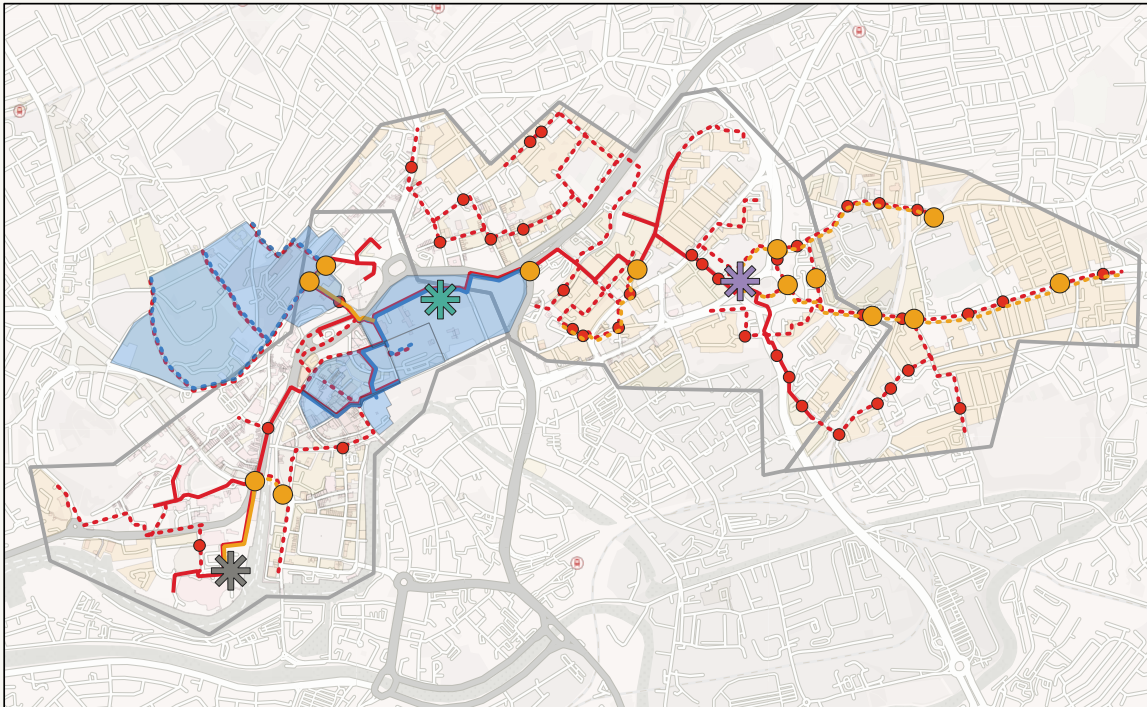
3. Cooling demand monitoring

Periodic reporting of cooling demand from neighbourhoods to identify when network expansion becomes viable.

Future A: Cooling Demand Remains Limited

This scenario could arise through one or a combination of the following futures:

- Slower-than-expected climate warming
- Successful reduction of cooling demand through passive retrofit and urban greening
- Rapid electricity decarbonisation enabling efficient decentralised cooling
- Adoption of more efficient zero-carbon building-level cooling technologies



Infrastructure Response:

No further cooling expansion is deployed

Broadmead: Continues serving existing retail and commercial anchor loads, generating long-term revenue, as demonstrated by the financial assessment.

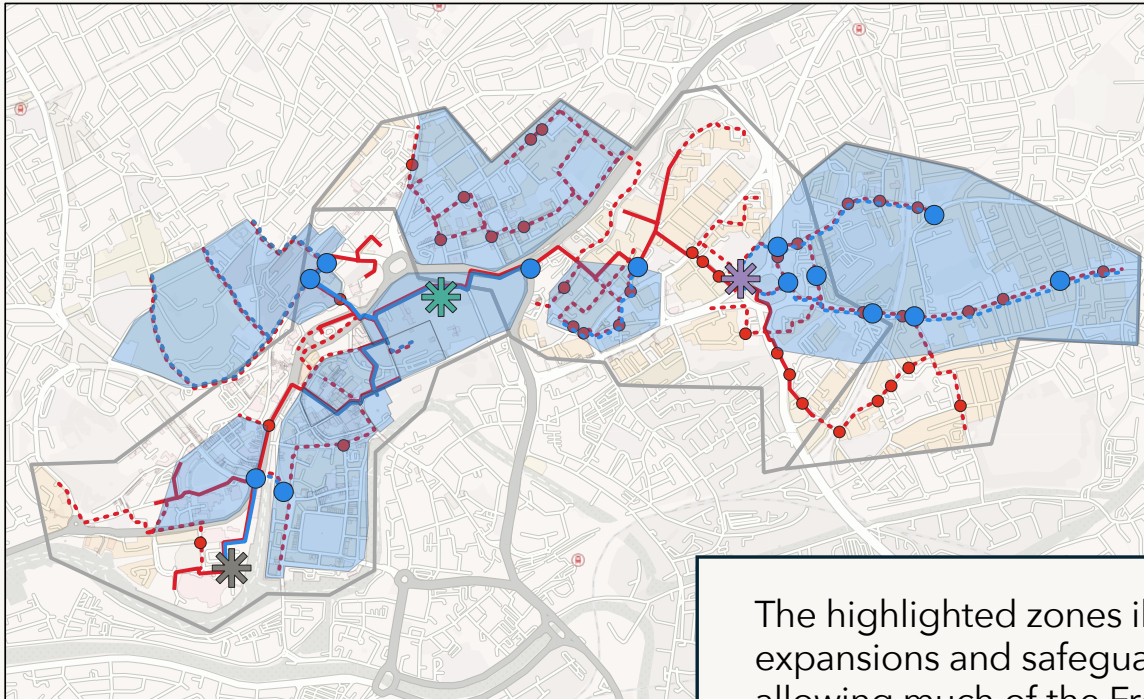
Millennium Square and Speedway: Reserved corridors and junctions enable future network expansion and reinforcement, while reserved plant space allows the integration of larger or more efficient heat generation technologies. If these provisions are ultimately not required, the reserved corridors can be repurposed for other buried utilities or future infrastructure.

If these provisions ultimately do prove unnecessary, they represent a relatively low cost should a different future emerge.

Future B: Cooling Demand Materialises

This scenario could arise through one or a combination of the following futures:

- Faster-than-expected climate warming and more frequent heatwaves
- Passive retrofit and urban greening prove insufficient to reduce cooling demand
- Electricity decarbonisation progresses more slowly, increasing the value of shared low-carbon cooling infrastructure
- Building-level cooling technologies fail to provide a sufficiently practical, efficient, or sustainable solution at scale



Infrastructure Response:

Deploy the safeguarded cooling expansion where required

Broadmead: Activate the reserved junction to extend cooling towards St Paul's.

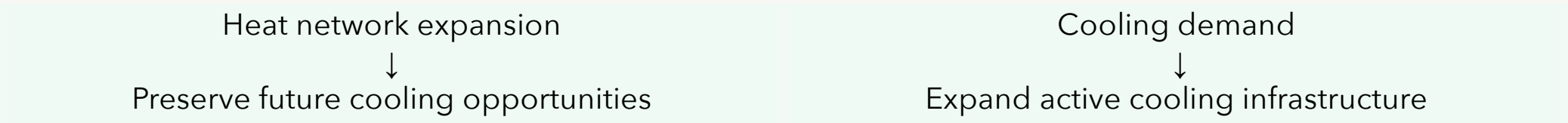
Speedway and Millennium Square: Use the reserved corridors, junctions and energy centre capacity to extend cooling towards the identified demand clusters with minimal additional construction.

The highlighted zones illustrate the strategic reach enabled by the heat network expansions and safeguarded infrastructure delivered during Phases 1 and 2, allowing much of the Frome district to be accessed with substantially less retrofit while remaining prepared for uncertain demand timing and location.

Project Takeaways

1. Across both futures, the proposed infrastructure continues to create value: immediate cooling assets generate operational and financial returns where demand exists, while safeguarded corridors and expansion-ready energy centres preserve strategic flexibility at relatively low cost where demand remains uncertain.

2. This reinforces the proposed framework of intervention triggers:



3. Applying the framework to the Frome district demonstrates how regional characterisation guides implementation. While the intervention triggers remain universal, local district characteristics determine the appropriate future-proofing strategy for both the network and the energy centre.

District	Network strategy	Energy centre strategy
Broadmead	Expand cooling now	Install dedicated cooling plant
Speedway	Preserve future expansion	Safeguard space for future cooling plant
Millennium	Preserve future expansion	Safeguard upgrade to reversible river-source operation

Transferability

The methodology is transferable to UK cities where existing or planned district heat networks coincide with uncertain future cooling demand.

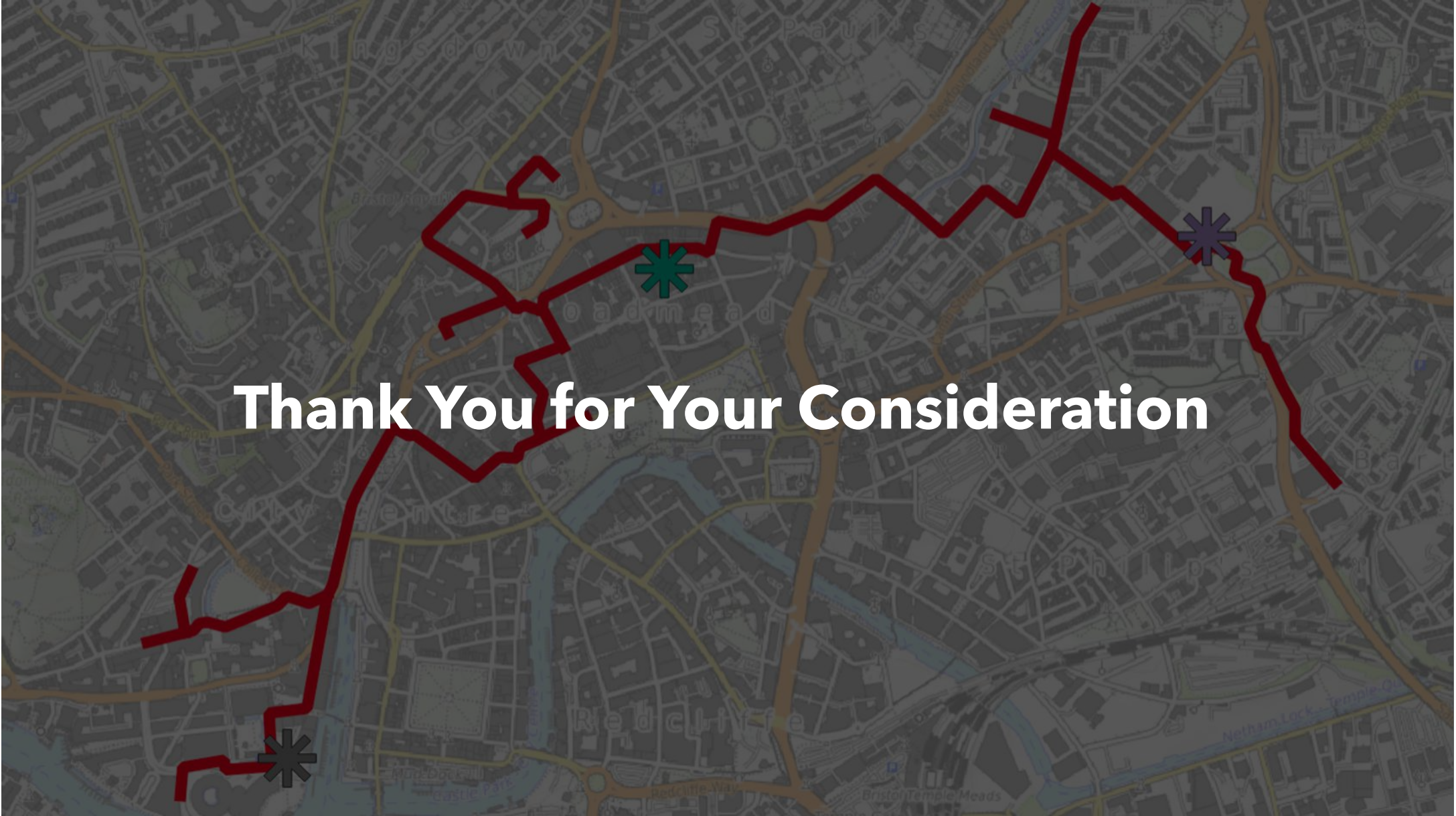
Application Pathway	
Step	Purpose
Prioritise	Where should cooling start?
Divide	What are the local planning units?
Characterise	What are the district's thermal role, resources, and future opportunities?
Trigger	When should intervention occur?
Preserve	What infrastructure should be future-proofed?
Expand	Where is cooling now justified?

Conclusion: Infrastructure as a System

Infrastructure as a System means looking beyond individual assets and identifying opportunities for them to support one another to create greater collective value.

This project demonstrates how integrating heating and cooling within a shared thermal infrastructure allows investments made for one purpose to strengthen the other, preserving future cooling opportunities while enabling the heat network to recover, exchange, and utilise thermal energy more effectively.

More broadly, it demonstrates that the transition to future cities requires infrastructure to be planned as coordinated systems, enabling cities to respond to changing, uncertain demand with greater flexibility and resilience.

A map of Bristol, England, showing the city's layout with streets, rivers, and landmarks. A thick red line is drawn across the map, forming a large, irregular shape that encompasses most of the city. Three asterisk markers are placed on the map: a green one in the upper central part, a purple one in the upper right part, and a black one in the lower left part. The text "Thank You for Your Consideration" is overlaid in the center of the map.

Thank You for Your Consideration