Large-scale climate neutral Energy Geostructures in District Heating & Cooling systems/networks

LEG-DHC

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Section 01

LEG-DHC

LEG-DHC: Project Description

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- As the carbon footprint of electricity is falling, electrification of heating and cooling using high-efficiency ground source heat pumps is key to decrease non-renewable energy usage.
- Despite huge potential, geothermal systems are installed at a lower rate than other renewables.
- Codema will deliver a report outlining the role and potential of energy geostructures in district heating in Dublin, including a comparative analysis setting energy geostructures in context with other heat sources compatible with district heating.

"The LEG-DHC project aims to boost the development of Energy GeoStructure (EGS) technology and to evaluate its integration into district heating and cooling systems. The upscaled geothermal energy technology will be integrated with other renewable energy resources, green buildings and greenhouse gas reduction strategies to create next generation zero emission thermal networks."

Barriers Identified by Project Partners

- There is a lack of visibility on positive thermal and mechanical feedback from stakeholders.
- Challenges in the integration of Energy Geostructures (EGS) into DH systems at a regional level.
- The complexity of managing and balancing multiple energy sources such as geothermal, solar, and other local energy sources for a climate-neutral regional community.

LEG-DHC: Geothermal Distribution

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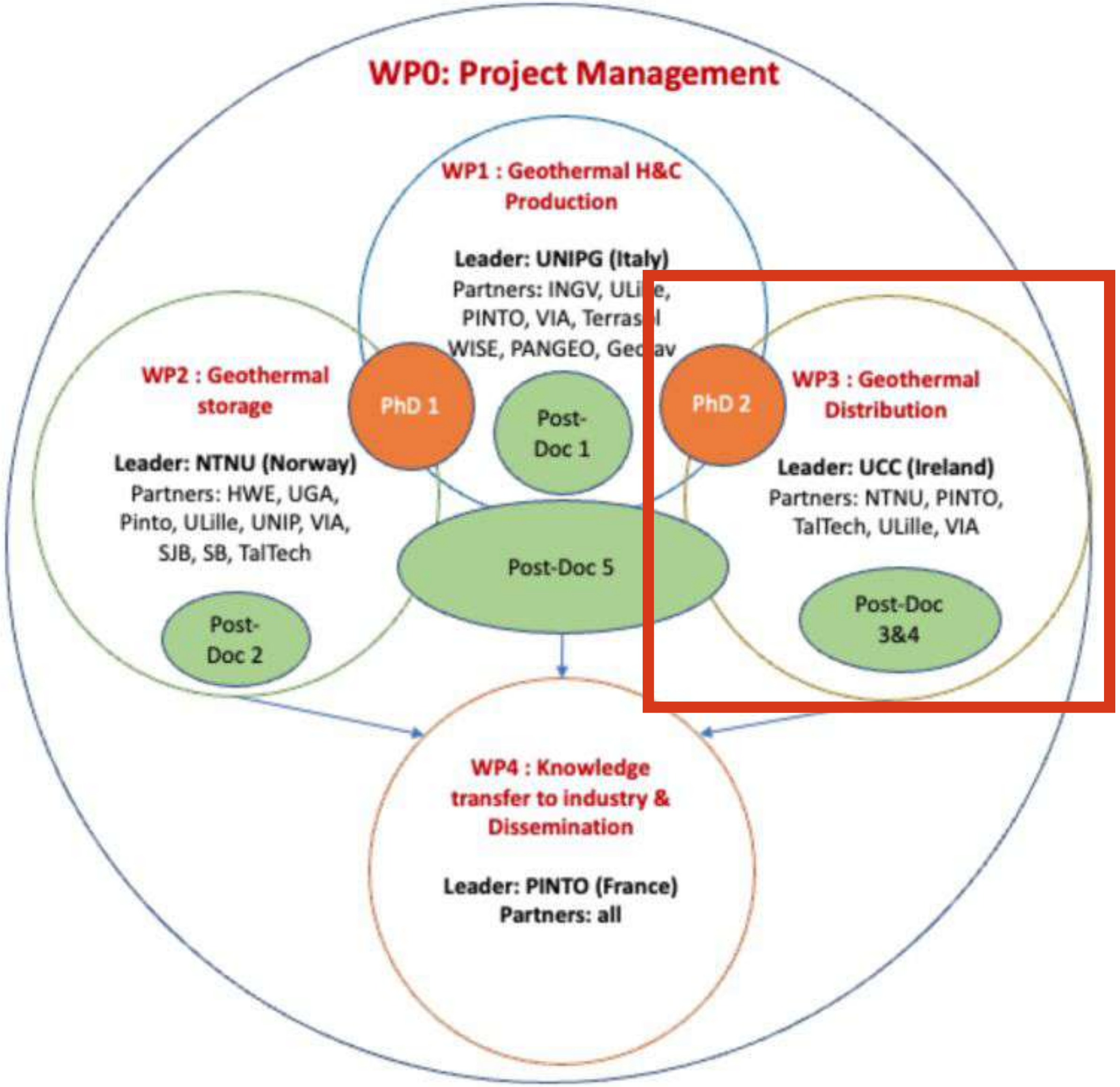

- **PhD 1** – Hired by NTNU, with co-supervision of UNIPG
- **PhD 2** – Hired by UNIPG, with co-supervision of ULille
- **Post-Doc 1** – Supervised by UNIPG, with collaboration of WISE and INGV
- **Post-Doc 2** – Supervised by UGA, with collaboration of UNIPG and NTNU
- **Post-Doc 3** – Supervised by UCC, with collaboration UGA and ULille
- **Post-Doc 4** – Supervised by TalTech, with collaboration of UNIPG, UCC and NTNU
- **Post-Doc 5** – Supervised by ULille, with collaboration of UNIPG, Pinto and NTNU

WP3 – Geothermal Distribution

- University College Cork
- Taltech
- Norwegian University of Science and Technology (NTNU)
- Universita degu studi di Perugia (unipg)
- VIA University College

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Section 02

Codema's Role

Codema: Scope of Work

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- ✔ Incorporate the geothermal heat resource identified into heat source mapping work and relate it to the overall potential for District heating in the Dublin area based on figures from Codema's Dublin Region Energy Masterplan.
- ✔ Compare this geothermal resource with other potential resources in relation to quality (temperature), availability, heating system efficiency, etc.
- ✔ Perform a high-level evaluation of key considerations in the use of the tunnel system to facilitate the installation of district heating distribution pipes.

District Heating Project Development

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District Heating Project Development Phases

Pre-Feasibility
- Heat Mapping
- Energy Master planning
- Demand Assessment
- Identification of Key Anchor Loads
- Identification of Heat Supply Options
- Identification of Key Stakeholders (Supply, Demand, Anchor Loads, Developer)
- Begin Data Acquisition from Key Stakeholders

Feasibility
- Background
- Regulatory Context
- Pre-Feasibility Work Validation
- Stakeholder & Community Identification & Engagement (including Data Acquisition)
- Operating Temperature Analysis
- Heat Demand Analysis
- Assessment of Network and Supply Options
- Financial and Sensitivity Analysis
- Risk Assessment & Recommendations

Post Feasibility Preparatory Steps
- Initial Business Model Appraisal
- Establishing the Case for Change
- Initial Procurement Options Appraisal
- Alignment Feasibility Study with Infrastructure Guidelines/Public Spending Code

Detailed Project
- Detailed Business Model Development
- Detailed Financial Analysis and Plan
- Detailed Procurement Strategy and Plan
- Contract Development (with Key Stakeholders)
- Define the Design Requirements for Procurement Process & Legal Assurance
- Public Spending Compliance Code
- Local Planning Considerations
- Update Business Case
- Depending on Procurement Methods chosen, detailed design may take place at this development stage or next stage.

Procurement & Contracting
- Implement Procurement Strategy
- Finalise Contracts
- Depending on the Method Chosen, the Detailed Design may take place in this Development Stage or the Previous Stage

Construction
- Construction & Commissioning
- Handover

Operation
- Operation & Maintenance
- Expansion Planning
- Metering & Billing
- Customer Service

Tem Involved

Research, Development and Innovation

Energy Management

Public and Stakeholder Engagement

Project Implementation

Project Funding and Facilitation

Section 03

Briefing Paper

Briefing Paper: Contents

- Alignment with the goals of the UCC team
- Literature review
- Case study comparison
- Analysis of stakeholder interviews
- Technical feasibility analysis

Literature review

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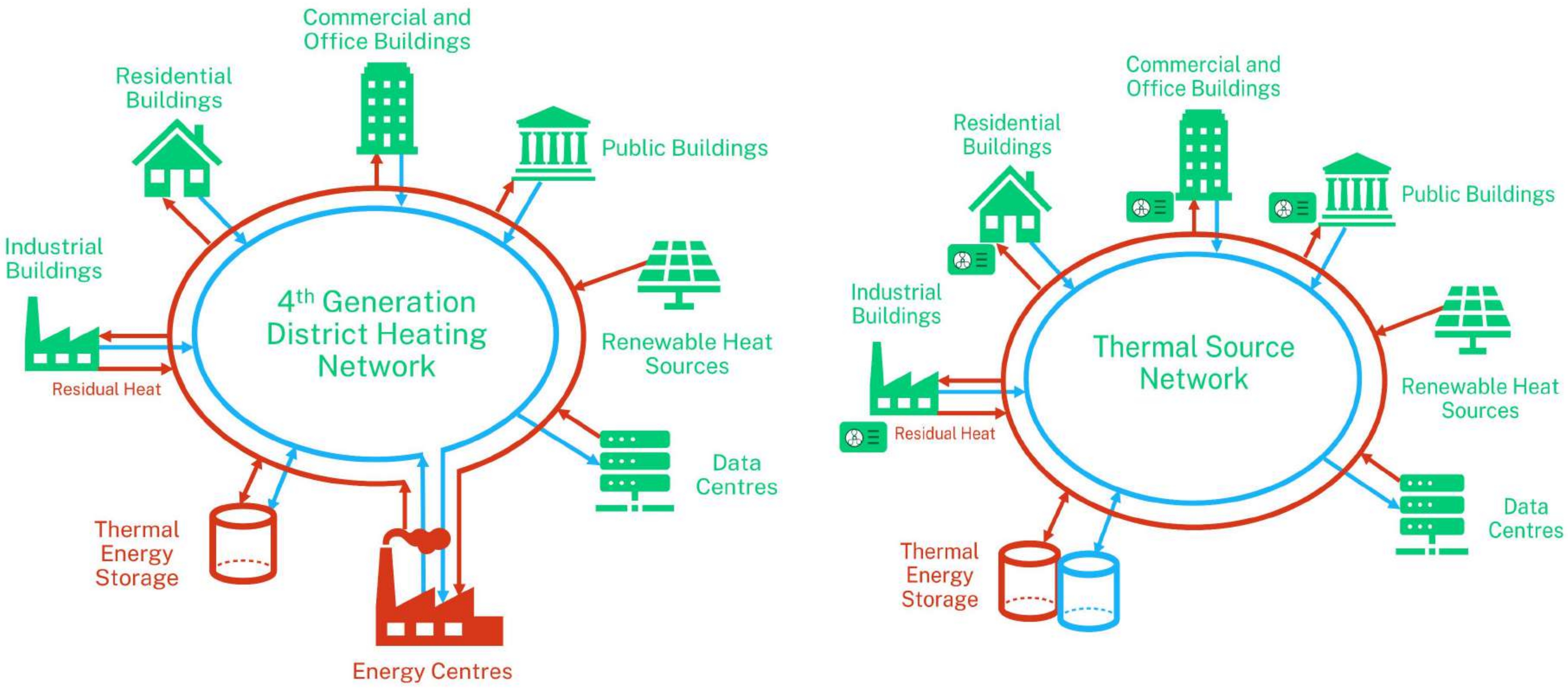
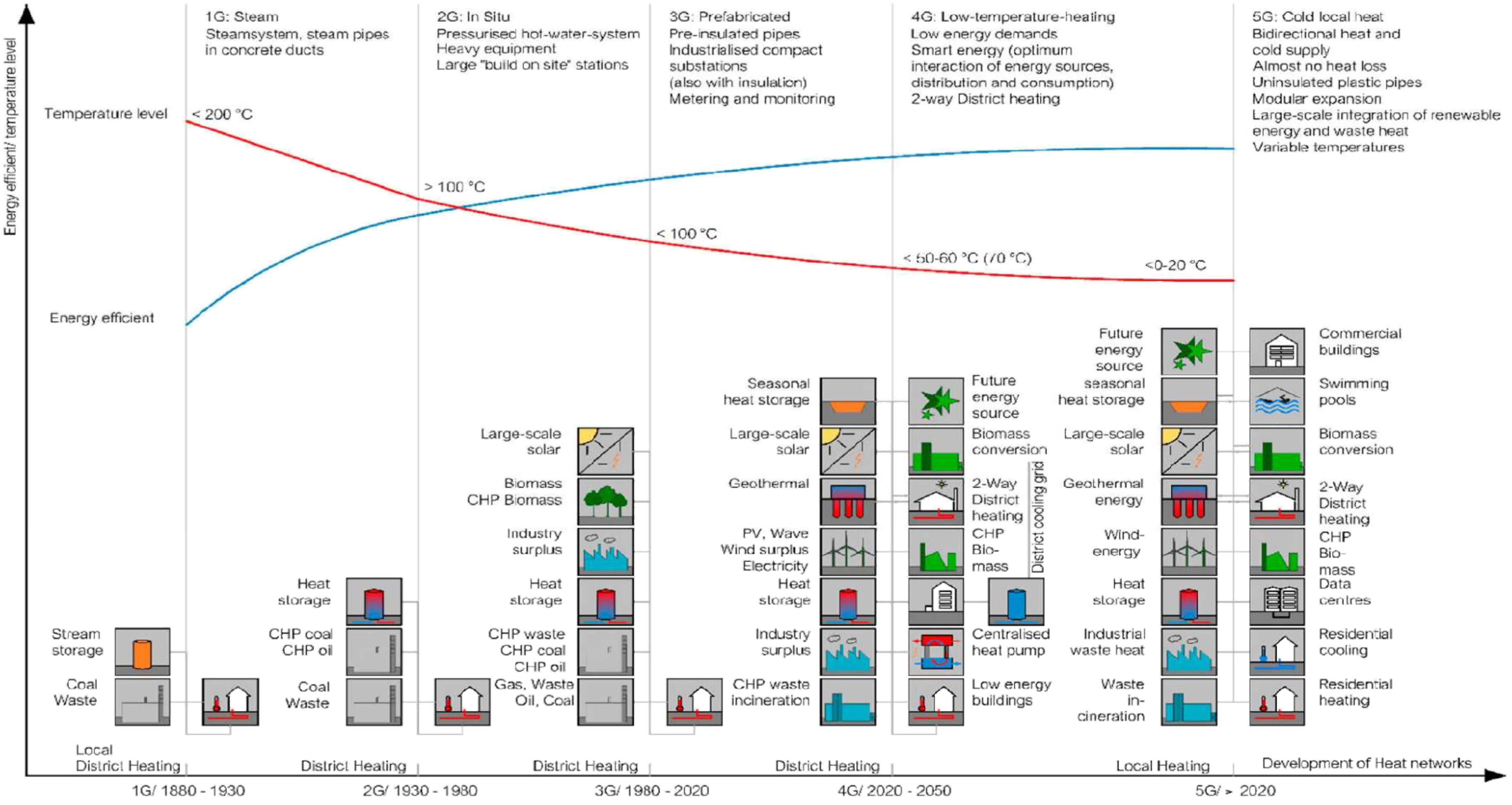
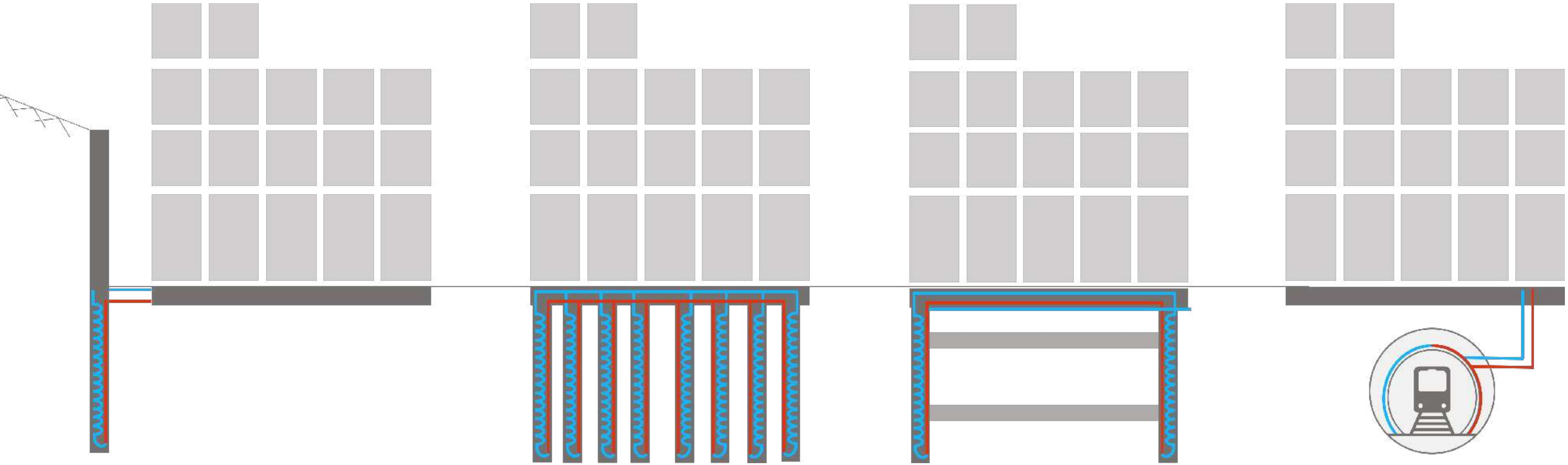
Literature + Documentation + Interviews

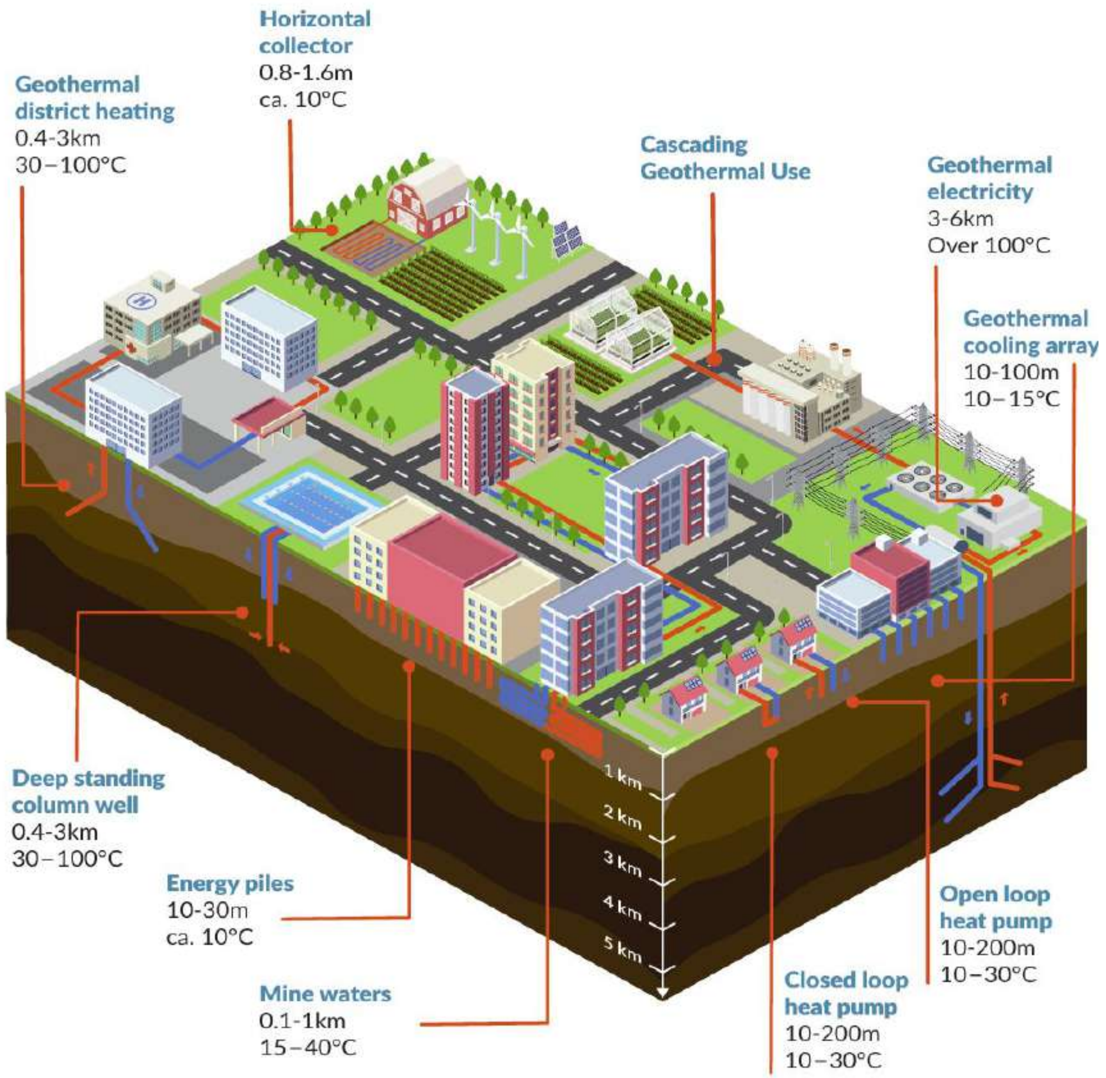
Literature review




Energy efficient/ temperature level
1G: Steam
Steamsystem, steam pipes in concrete ducts
2G: In Situ
Pressurised hot-water-system
Heavy equipment
Large "build on site" stations
3G: Prefabricated
Pre-insulated pipes
Industrialised compact substations
(also with insulation)
Metering and monitoring
4G: Low-temperature-heating
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way District heating
5G: Cold local heat
Bidirectional heat and cold supply
Almost no heat loss
Uninsulated plastic pipes
Modular expansion
Large-scale integration of renewable energy and waste heat
Variable temperatures
Temperature level
< 200 °C
> 100 °C
< 100 °C
< 50-60 °C (70 °C)
<0-20 °C
Energy efficient
Stream storage
Coal Waste
Heat storage
CHP coal CHP oil
Coal Waste
Large-scale solar
Biomass CHP Biomass
Industry surplus
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
Seasonal heat storage
Large-scale solar
Geothermal
PV, Wave Wind surplus Electricity
Heat storage
Industry surplus
CHP waste incineration
Future energy source
Biomass conversion
2-Way District heating
CHP Bio-mass
District cooling grid
Centralised heat pump
Low energy buildings
Future energy source
seasonal heat storage
Large-scale solar
Geothermal energy
Wind-energy
Heat storage
Industrial waste heat
Waste in-cineration
Commercial buildings
Swimming pools
Biomass conversion
2-Way District heating
CHP Bio-mass
Data centres
Residential cooling
Residential heating
Local District Heating
District Heating
District Heating
District Heating
Local Heating
Development of Heat networks
1G/ 1880 - 1930
2G/ 1930 - 1980
3G/ 1980 - 2020
4G/ 2020 - 2050
5G/ > 2020

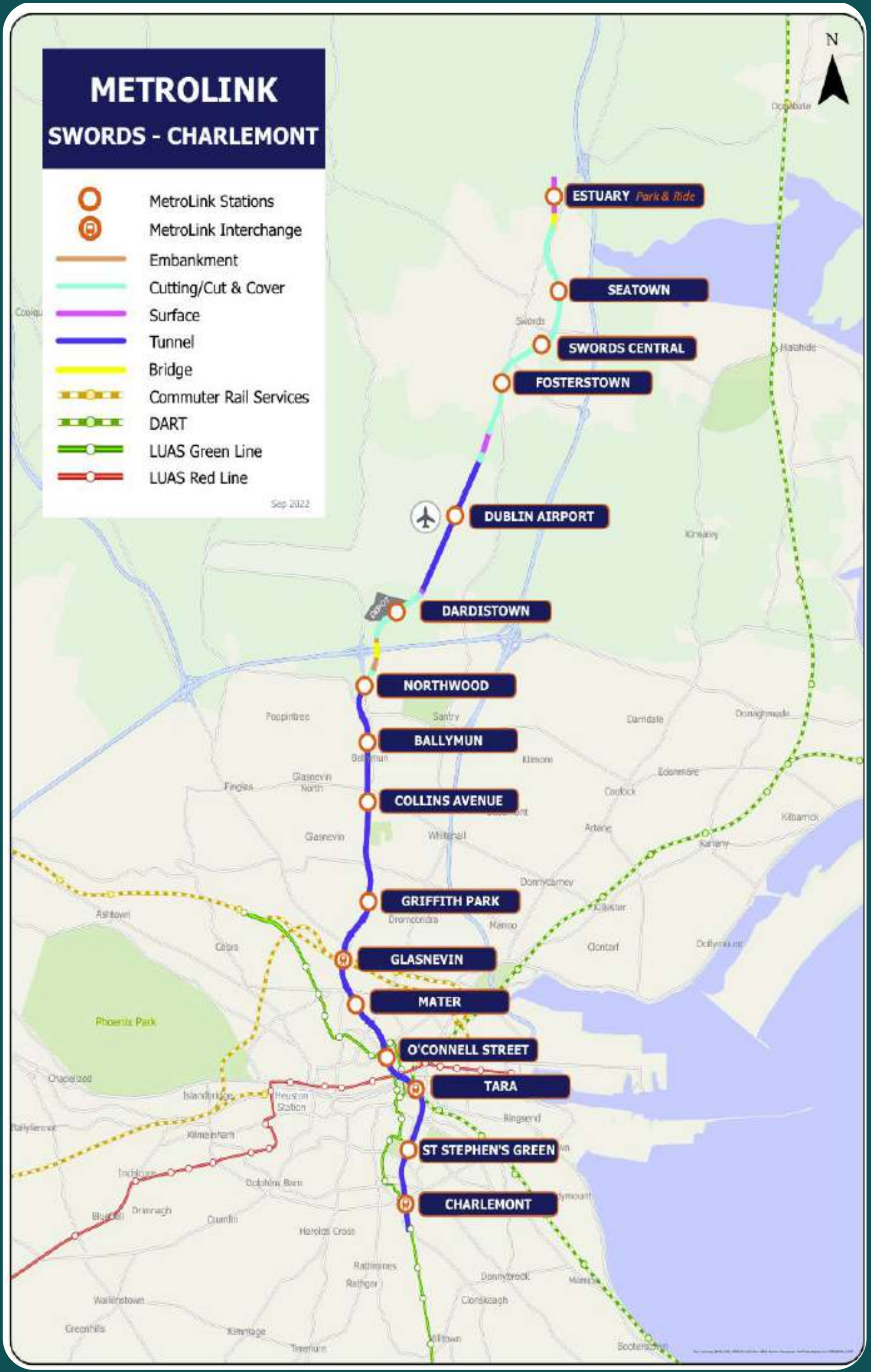
Energy Geostructures




Horizontal collector
0.8-1.6m
ca. 10°C
Geothermal district heating
0.4-3km
30–100°C
Cascading Geothermal Use
Geothermal electricity
3-6km
Over 100°C
Geothermal cooling array
10-100m
10–15°C
1 km
2 km
3 km
4 km
5 km
Deep standing column well
0.4-3km
30–100°C
Energy piles
10-30m
ca. 10°C
Mine waters
0.1-1km
15–40°C
Open loop heat pump
10-200m
10–30°C
Closed loop heat pump
10-200m
10–30°C

Dubin MetroLink

Dubin MetroLink



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Dublin Port Tunnel

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- Assuming 300m^3/day flow rate.
- Source temperature of 14°C being cooled to 3°C (open-loop heat pump system i.e. cooling below 3°C degrees would cause issues with frosting).
- Annual average heat abstraction of 159kW (~1,394MWh/annum)
- Assuming a COP of 3 for the heat pump, the heat output would be 50% greater than the heat abstracted from the drainage water (i.e. heat abstracted multiplied by 3/2 to give the heat output from the heat pump).
- This results in a heat production capacity of 239kW and annual heat production capacity 2,091MWh (~2.1GWh) from the heat pump.

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Section 04

Stakeholder Interviews

Dubin District Heating Scheme

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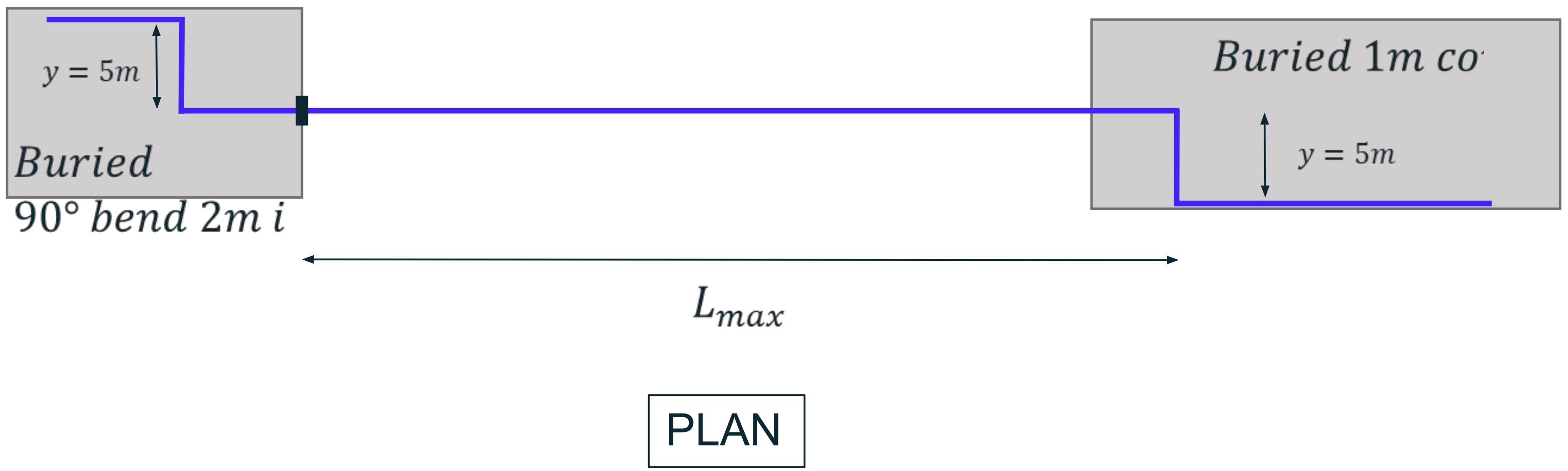
Building Specialist

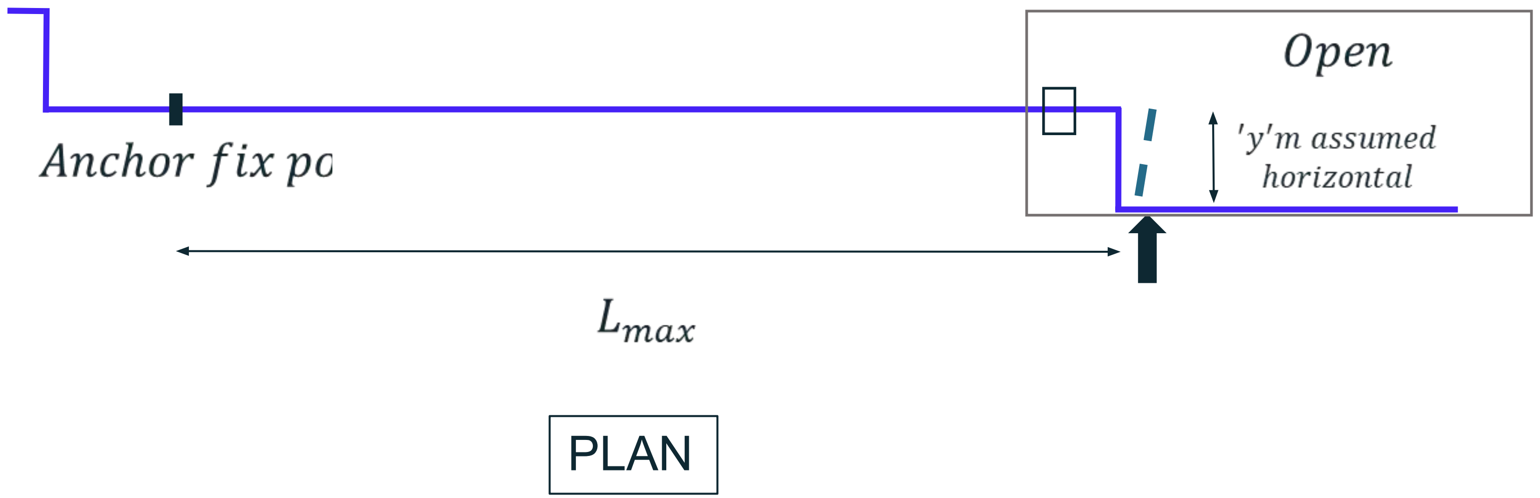
Codema reached out to **District Heating structural design specialists** operating in the Irish architecture, engineering, and construction (AEC) sector for valuable insights on integrating DH into underground structures.

- Retrofitting and installation of geostructures pipes is not a novel concept. Work has been done before, notably in the Nordic countries such as Sweden.
- Installing DH pipes in underground structures requires a *“multi-utility approach”* dependent on if the tunnel caters for multiple utilities such as the Liffey Tunnel.
- There are multiple methods to approach installing pipes in concrete ducts.
- Construction tolerances must be considered.
- The specifics of the pipe layout, diameter, and other parameters should be known prior to approaching a specialist.
- There is a limit to the length of pipe – anchored pipes will only allow a shorter run pipes. Maximum length varies with depth and diameter. The expansion of the DH pipes should also be taken into consideration.
- Tunnelling costs are high in comparison to traditional open cut trenching methods so the project commercial viability should include these costs.
- Room will be required for the tunnel shaft construction along with sufficient length to lower the push sections of the DH pipe.
- Repairs can be expensive so rigorous weld Non-Destructive Testing (NDT) and double casing joints should be considered.
- An active leak detection system should be employed (with potentially four wires rather than the usual two).

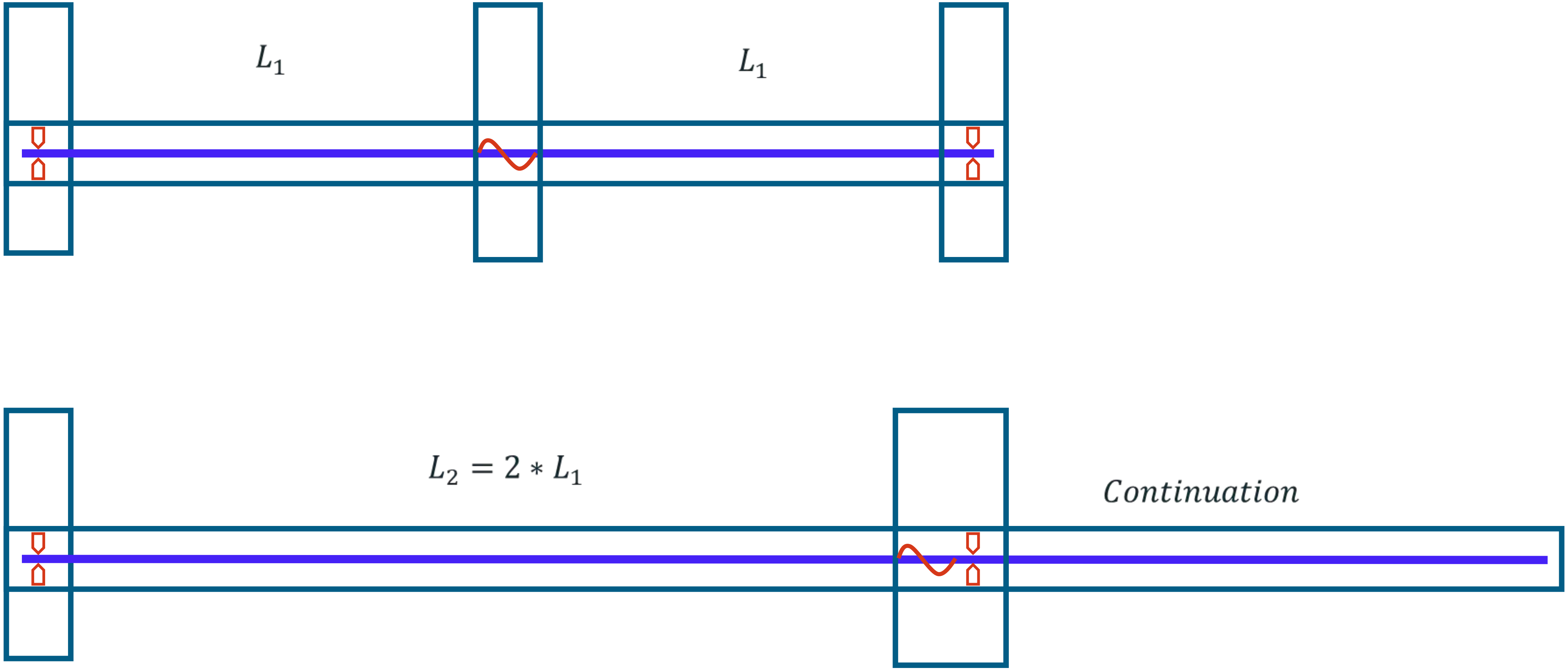
Scenario 1-A: Buried Z bends in ground at either end



Option 1-B: Anchored at one end, freely suspended at the other end



Option 2: Axial Compensator PN 16, 1 Compensator



Local Authority

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Using existing connections with the Dublin Local Authorities (DLAs), Codema contacted one of its **local authority** clients to discuss the barriers to the implementation of energy geostructures in Dublin.

- Using waste heat from the underground for heat networks should be considered in the initial application.
- Shallow open-cut excavations are easier. The key issue with trenchless excavations is *"that you don't know what the ground conditions are like."*
- Trench boxes or tunnel access are essential for any excavation beyond 2m in depth.
- Underground structures are expensive: For any project, one must consider the capacity to install geostructures in the first place.
- Existing tunnels, such as the Dublin Port Tunnel, have not been designed for geostructures.
- *"While tunnelling can be expensive, deep shafts [for pipes / services] can increase the project costs."* It is only considered if no other options are available.
- One must ensure the longevity and maintenance of any underground heating system is sound as the consequences of a malfunction / damage by 3rd party would have an impact on its operation and surrounding environment.
- The magnitude of costs are more uncertain with underground structures.
- A tunnel is supposed to be dry – appropriate measures must be put in place in case of flooding.
- If there is no set standard in Ireland and it is common practice to use the relevant British standards.
- Actively monitoring the entire process with monitoring devices will be mandatory.

Geospatial Surveyor

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Codema reached out to an international **geospatial surveyor** firm that operates within Ireland and the UK to discern the health and safety requirements of operating within a confines space.

- Understanding the dimensions of the tunnel is of the utmost importance for the installation of any geostructures system.
- The accessibility of a tunnel would demand consideration for health and safety precautions. A 0.8m tunnel is considered *'accessible'.* The majority of tunnels are smaller than one would like for manned entry.
- Cage drones or rovers equipped with LIDAR can be deployed to access tough-to-navigate areas and generate a 3D digital profile and dimensional cross-section of the underground.
- Retrofitting any geostructures system into an underground means that it is critical to know exactly where the tunnel is in terms of its dimensions.
- Consideration must be made for other services in the underground structure (pipes, cables, etc.)
- Care must be taken in the realm of occupational health, operational safety, and structural integrity.
- The Dublin MetroLink is a very unique situation as it is one tunnel instead of two bores.
- Underground structures take *"a long road"* to get approval.

Shortlist of potential heat sources

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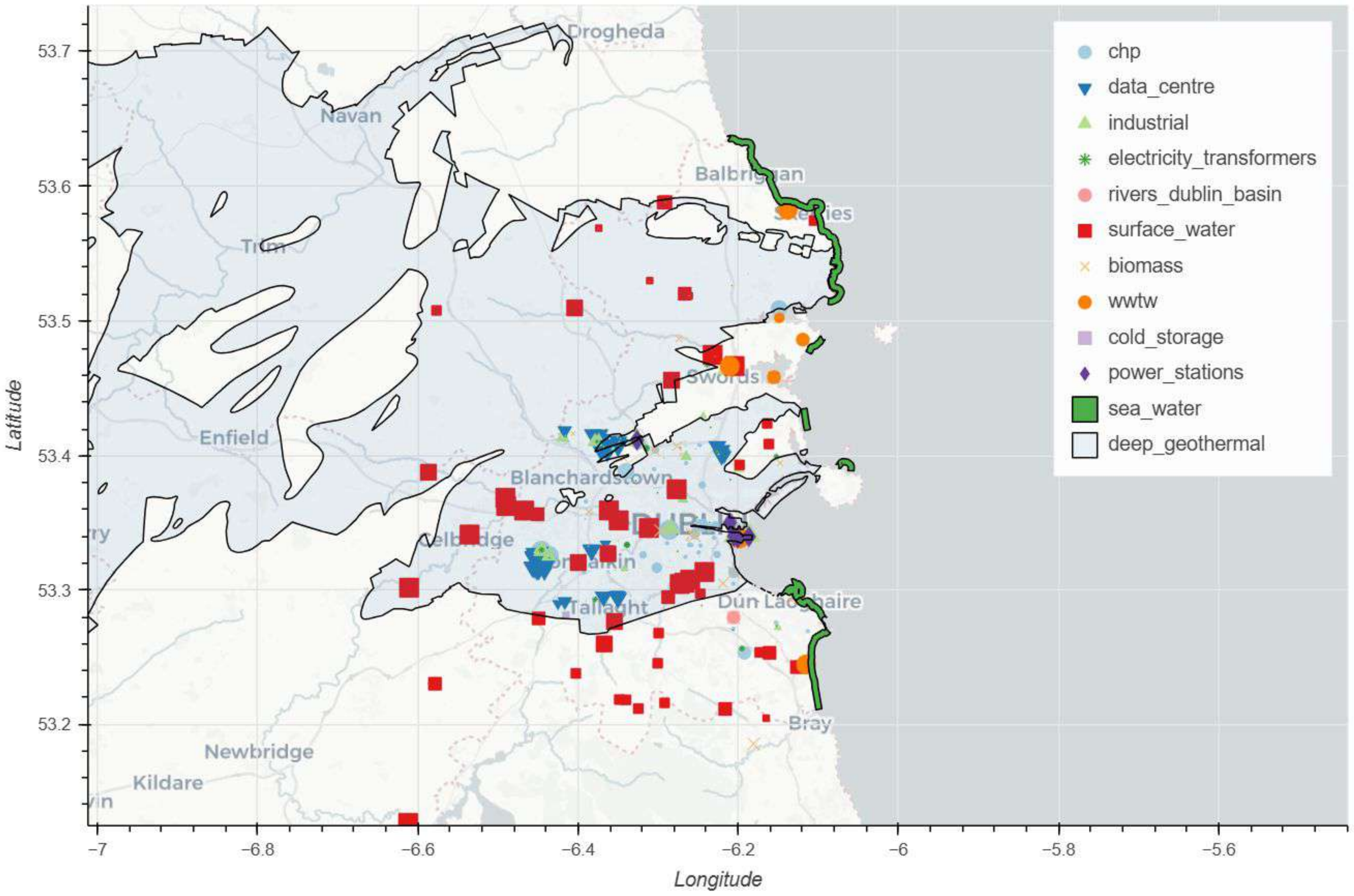

Techno-economic Analysis

Heat Source Options	Ambient Air ASHP	Water Source WSHP	Shallow Geothermal (<400m)	Deep Geothermal (>400m)	Wastewater Treatment Plant	Commercial Low-Grade Waste Heat	Bioenergy	Data Centres
Longlist Source Options								
General Description	Air Source Heat Pumps (ASHP) can be integrated into DH systems to extract ambient air heat, which is then upgraded to a higher temperature and distributed through the DH network for space heating and hot water supply in connected buildings.	A water source heat pump (WSHP) extracts energy from a nearby river by circulating a heat transfer fluid through pipes in the riverbed. This fluid absorbs heat and transfers it to the refrigerant in the heat pump, which is then compressed and heated. The resulting heat is circulated to the buildings in the DH scheme.	Shallow geothermal energy is the heat extracted from the earth's near surface, typically up to 400m deep. According to Geological Survey Ireland (GSI). Ireland has a recognised potential for low-to-medium temperature geothermal energy resources (>400m deep) suitable for large-scale or district heating and cooling in municipal, residential, and industrial areas.	Deep geothermal energy is the heat extracted from the earth's deeper subsurface, typically beyond 400m, for use in heating, cooling, and electricity generation.	Recovered heat from Wastewater Treatment Plants (WWTP) can be integrated into DH schemes by using post-treatment sewage water through heat exchange and heat pump systems.	Waste heat can be captured from supermarkets by using heat recovery systems that extract thermal energy from refrigeration and HVAC systems, which can then be transferred to a DH network or used for heating the store.	Bioenergy can be used in DH by burning biomass or biogas in boilers or Combined Heat and Power (CHP) plants to generate heat, which is then distributed through a network of pipes to provide space heating and hot water to connected buildings.	Data centres generate substantial amounts of heat as a byproduct of their operations, requiring advanced cooling systems to maintain optimal functionality.
Proximity to a Network	ASHPs can be installed in any location provided there is sufficient space and utility to house the equipment at the site.	The proximity of water sources is site dependent.	Shallow geothermal arrays can be installed at many locations, the feasibility and practicality depend on specific geological, regulatory, and site-specific factors (such as land availability).	Extensive geological surveys, engineering studies, and cost-benefit analyses are necessary to determine the suitability and viability of deep geothermal projects in a particular location.	WWTPs sparsely populate the county as can be seen in Figure 13.	There are numerous supermarkets in the Dublin region in randomised locations. It would be difficult to aggregate the waste heat to supply any one area.	Bioenergy resources may be available in rural areas. Limiting factors for utilisation include contracting complexities (double contracts for security of supply), increased traffic of large trucks into city locations, and a need for ongoing operational supply management.	Data centres are traditionally situated away from town centres in industrial parks.
Heat Capacity (MW)	The capacity of a centralised ASHP used in a district heating system is sized based on the anticipated heat demand that will be connected to the scheme.	For a river, the flow rate and assumed temperature produces heat using a heat pump.	High resolution and robust data is available in Ireland to depths of 400m. However, the capacity of a shallow geothermal array is dependent on the number of energy geostructures, and as such the system is typically sized based on anticipated heat demand of the DH system.	Capacity data not available. This will depend on factors such as available temperatures and the permeability of the subsurface.	The EU waste heat map shows the heat production of different WWTPs. This can also be estimated based on population equivalent that the WWTP is serving.	This will vary greatly for different sites. The average anticipated heat recovery per facility in Ireland is 3TJ/annum. Estimates of such figures can be found in the various heat source maps shared in this report.	While there is a potential bioenergy resource available in Ireland, the resource has scalability limits in comparison with other resources, as the lowest carbon bioenergy sources will have many competing use cases.	Server waste heat capacity is equivalent to the server electrical load
Heat Source Temperature (°C)	Ireland has a temperate maritime climate, which means it experiences relatively mild seasons (Mean daily winter temperatures vary from 4.0°C to 7.6°C. Mean daily summer temperatures vary from 12.3°C to 15.7°C.	The temperature of a river can fluctuate between ~2°C and ~24° C. The Environmental Protection Agency (EPA) provides figures on this.	Ireland has an estimated crustal geothermal gradient of 25 - 30° C/kms. The assessment of ground temperature in Ireland has identified that depths of up to 400m have estimated temperatures below 26°C. At 100m the estimated temperature is up to 22°C.	Temperature data not available but typical rule of thumb for the temperature gradient is for temperature to increase by 30°C per km depth.	Treated wastewater typically has an annual average temperature of 12°C, ranging from 8°C to 15°C, and occasionally higher in summer.	-	High temperature heat available from bioenergy combustion.	The waste heat from data centres typically has a temperature profile ranging from 25°C to 35°C if using air cooling rather than liquid cooling, which, while considered low-grade, is highly suitable for integration into a district heating system when paired with heat pumps.

Techno-economic Analysis

Criteria Categories	Sub-Criteria	Centralised Air source heat pump	Low-Grade Waste Heat	Shallow Geothermal/ Geostructures	Counterfactual (Individual ASHP)	Business as Usual
Multi-criteria analysis of heat sources						
Financial Considerations. Life Cycle Costs	Capital Expenditure	Moderate	Moderate	Moderate	High	Low
	Maintenance & Operations Expenditure (OPEX)	Moderate	Moderate	Moderate	Moderate	Low
	Energy/Fuel Cost Expenditure	Moderate	Low	Moderate	Moderate	Low
	Dependability & Flexibility	High	High	High	Medium	Medium
Implementation & Operability	Installation impact	Moderate	Moderate	Moderate	Moderate	Moderate
	Set-up time	2-4 Years	2-4 Years	2-4 years	< 1 Year	<1 Year
	Space/Footprint requirements	High	Low	Low	High	Low
Strategic/Market Vision	Scalability Potential	Moderate	Moderate	Moderate	Moderate	Moderate
	Consumer Cost Impact	Moderate	High	High	High	Moderate
Environmental	Carbon Emission Mitigation	High	High	High	High	Low
	Environmental Impact	Moderate	Low	Moderate	Moderate	Significant

Preliminary Conclusions and Recommendations

General Recommendations:

- From the techno-economic perspective, relative to the counterfactual, waste heat is the first consideration for incorporating into LEG-DHC networks due to dependability and scalability. The results of the techno-economic analysis in this report show that geostructures are preferable to the counterfactual (which is a single Air Source Heat Pump (ASHP). Interestingly, the Business-As-Usual (BAU) approach of maintaining existing gas boilers is on par with the incorporation of geostructures from a techno-economic perspective, despite no points awarded to the BAU approach for environmental considerations. A centralised ASHP followed in the rankings of this analysis and in last place from the five options considered was the counterfactual, an individual ASHP.
- Engagement with local councils in the project pre-development stage to raise awareness, share relevant data, and check alignment with planned works/highlight collaboration potential can ensure buy-in.
- Extensive understanding of the underground conditions of the site prior to construction (existing infrastructure, ground conditions, water table, etc.) is essential.
- Develop the boundary conditions of the pipe sizing before contacting a specialist to assess a scenario (expected diameters and lengths).
- In instances where horizontal directional drilling is being undertaken, a coffer dam should be dug adjacent to the network site to install piping. This will have an associated land use requirement which will need to be considered.
- 'You can't manage what you can't measure.' Best practice would be to conduct a dimensional analysis of any underground site prior to a shovel going in the ground. This should be followed by constant monitoring of the geotechnical structures from a thermal and mechanical perspective.
- The site-specific risk of flooding should be considered through relevant hydrological modelling.

Final Deliverables (October 2025)

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- LEG-DHC Presentation [.pptx]
- LEG-DHC Briefing Paper [.docx]
- LEG-DHC Requested Data [.xlsx]

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