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CASE STUDY OF THE HEERLEN EXPERIENCE - BASELINE REPORT ON OPPORTUNITIES AND BARRIERS

FINAL DRAFT

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Report authors: Adam Ben-Hamo, Olivier Delpon de Vaux

Editing:

Drawings:

Data sources:

Report done by:

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A. Executive summary

The objective of this case study is to identify and assess the financial risk and reward characteristics of Fifth Generation District Heating and Cooling (5GDHC) through detailed analysis of the Mijnwater project that has been deployed in the municipality of Heerlen since 2005.

5GDHC is an emergent technology that builds on the established district heating concepts seen across Europe with the goal to create low-temperature, closed-loop district heating and cooling systems which use distributed heat pumps to step-up temperatures at the point of consumption. Low-temperature networks allow for higher efficiencies, use of low-grade sources (shallow geothermal, waste datacentre heat, heat-pump hot/cold source etc.), long-term storage of heat and reduced dependency on incineration fuel. Mijnwater was founded in 2005 by the Municipality of Heerlen (NL) and a local housing developer to help regenerate the city following the fall of the coal mining industry in the region. The project uses the coal mines beneath the city – initially as source of heat, and subsequently as a storage vessel.

In 2013 the Limburg Energy Fund (LEF), a provincial public investment body, acquired 100% of the project from the municipality and continued to fund the company and growth of the network. Mijnwater currently has 27 FTEs across operations, engineering and business development. The project currently services 330 connections and c. 50,000GJ of heating and cooling each year. The asset level EBITDA for 2019 was c. €800k, however company overheads lead to an overall negative EBITDA of -€850k; most of these overheads fund staff salaries and advisory fees. Grants are available on capex, however there are no subsidies on revenue or generation. The project falls within the scope of the Dutch Heat Law and so revenues are regulated and currently linked to gas prices. To date, c. €30m has been invested into the project funded through grants, equity investment by Heerlen and LEF and debt from LEF and the housing developer. Being a proof-of-concept project, and the first of its kind; a material portion of these costs were written-down between 2005-15.

Mijnwater have a pipeline of c. 1,000,000 GJ over the next decade with a capital requirement for c. €350m of which €160m has been identified as local demand that is feasibly connectable and €45m is already under LOI or contracted to connect in the next 2 years. If the project reaches full scale, levered buy & hold returns of 8-9% are forecast at current capex levels. Large scale roll-out and standardisation and modularisation of components and skills (as driven by this D2Grids project) can believably reduce costs leading to prospective IRRs of 10-12%. The core characteristics of the wider investment case identified in this report have been summarised below:

- Exposure to power markets instead of fuel dependency – reduces availability risk and price volatility when compared to conventional heating. A smaller percentage of total heat is sourced from energy outside the system and so there is less dependency altogether.
- More elongated capex profile: material portion of capex is invested only when customers are physically connected (to buy and install heat pumps). No upfront capex on large biomass boilers etc. resulting in slower pace of investment but volume build-up risk mitigated in part. Additional capex for connections means incremental connections are relatively less lucrative than conventional heating however no limit to connections if system is balanced (i.e. no maximum boiler power).
- Benefits of scale are substantial: not just driven by dilution of fixed costs. More connections allow for efficient balancing of the system, with less dependency on heat pumps and higher efficiencies across the network.
- Revenues are long-term contracted: c. 15 years B2C and up to 30 years B2B.
- Optionality baked-in: network can respond to shift in demand/supply profile by leveraging large scale storage, even on a seasonal time scale. Network can selectively use heat pumps to raise/lower system and storage temperatures – taking advantage of low pricing or providing electrical system services. Sale of cooling can provide additional source of revenue or act as an incentive for large customers to connect (i.e. cheap cooling) – still benefiting the network because cooling at cost price generates excess heat which can be stored or sold to another customer.

B. Introduction

District heating networks in Europe are an asset class which has been increasingly sought after by financial investors. Over the past 5 years, several large transactions have taken place mainly across the Nordics where sophisticated international financial investors have acquired large portfolios of operating district heating assets (see Figure 1).

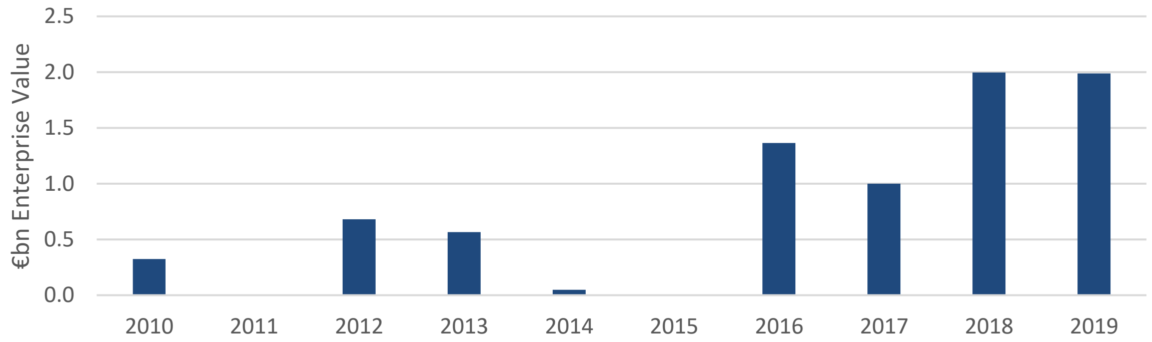


Figure 1: Annual district heating transactions (estimated Enterprise Value) in Europe by financial investors - 2010-2019 - € millions
Source: Asper Investment Management market research.

Typically, these investors are attracted by these assets because of their core infrastructure features, including:

1. Long term, capital intensive assets providing an essential service to its users
2. Stable, often inflation-linked cash flows thanks to a diversified customer base with high switching costs
3. Opportunities for organic growth through network expansions and continuous operational improvements

Most assets transacted up until now pertain to the 3rd or 4th generation of district heating and cooling. 5th Generation District Heat and Cooling technology ("5GDHC") has the potential to further improve the attractiveness of this asset class.

5GDHC is a decentralised, bi-directional, near-ground temperature district heating and cooling solution, based on the principle of maximising closed energy loops and bridging a supply deficit using decentralised renewable sources. The key features are:

1. **Demand-Driven and bidirectional at the points of delivery**
   The ability to simultaneously deliver energy at different temperatures to different customers, exactly as demanded, when demanded. This extends to the delivery of cooling. This is achieved through distributed heat pumps as near as feasible to the points of demand: active substations instead of passive heat exchangers. Distributed bi-directional water pumps feed the heat pumps with the necessary flow of water, warm or cool thermal energy from the grid. This decouples transport of energy from the need to guarantee the right temperatures.
2. **Closing energy loops: a grid configured to exchange energy**
   The ability to exchange demands for heat and cold among customers, thereby creating a new way to collectively reduce the needs for thermal energy. Heat pumps always create both heat and cold, the one is delivered locally, the other is returned to the grid. Exchange of energy is supported between different places, but also between different times, by exploiting thermal storage. Both waterflow and temperature may fluctuate as needed. Net flows are balanced from thermal storage and low grade thermal sources.
3. **Maximize use of low-grade thermal energy sources. Ultimately, eliminate high grade heat sources.**
   The ability to efficiently and robustly handle all short- and long-term demand peaks by employing appropriate thermal storage volumes. This allows the system to eliminate high grade heat sources and regenerate its thermal energy from low grade thermal energy sources. When this is achieved, a side benefit is that variable renewable electricity can be used when it is available. It also enables efficient management over time of demands for external electricity.
4. **Facilitate transition-proof and no-regret sustainable long-term investments**
   The ability to facilitate refurbishments of buildings for low-temperature heating and lower thermal needs. If a district heating system can temporarily cope with a fraction of inefficient buildings, this may provide flexibility for older and more difficult buildings to adapt over time.
5. **Operate efficiently at both small and large scale, merge when beneficial**
   The ability for small or large grids to be designed, built and operated to provide value to clusters of buildings at any scale. These can grow organically or merge into larger networks, when beneficial.

The concept of 5GDHC emerged throughout the development by Mijnwater of the Heerlen project since 2005. The core concepts, full definitions and technical specifications are well documented by other D2Grids partners and are not covered in depth in this case study. Instead, this paper analyses the Heerlen project with the objective to provide a concrete example of the impact 5GDHC can have on the risk/return characteristics of the asset class from an investor perspective.

First, we will briefly describe the Mijnwater project in Heerlen, looking at its background, its status today and its business plan for the next 5-10 years. Next, we will look at the financial characteristics of the project in Heerlen, zooming in on the most relevant components of its investment case. We will then bring the whole picture together, analysing the risk-return profile of the project from an investor perspective. Finally, we will discuss the lessons that can be learned from the project in Heerlen in the view of transnational roll-out of the technology at large scale.

1. Mijnwater History

Mijnwater is a district heating and cooling project that has been developed in the municipality of Heerlen since 2005, originally as a result of the drive to reenergise the area's economy and leverage the region's extensive coal mining history. The details about the project history and background have been documented elsewhere and will not be a major focus of this paper.

Heerlen is the 3rd largest city in the Limburg province in the very south of the Netherlands which until the mid-1970s was a major coal mining region. The Mijnwater project was first initiated by the municipality of Heerlen together with Weller Social Housing in 2005 in an effort to revitalise the local economy following the closure of the last coal mines and press ahead with increasingly ambitious energy transition targets in the Netherlands.

Heerlen sits over the Oranje Nassau mines, which following their closure were filled with water that warmed to c. 35°C. The first phase of the project (Mijnwater 1.0, 2005-14) aimed to use the energy contained in this water as a source of heat to be delivered to buildings above ground. It became quickly clear that such a strategy was not sustainable as the energy reserves in the mines would quickly be depleted. The second phase of the project (Mijnwater 2.0) begun in 2015, and turned the mine waters from an energy source, to an energy storage capacity. It uses shallow cavities at 250m depth for storing cool water at c. 17°C. and the deeper cavities at up to 825m to store warmer water at 35°C.

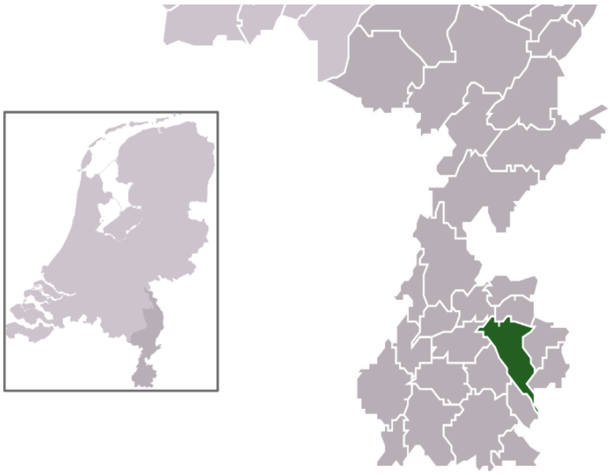


Figure 2: The Limburg Province with Heerlen shown in green (in mini-map: The Netherlands with Limburg shown in darker grey.

In 2013, Mijnwater was incorporated as a standalone entity, owned fully by the Municipality of Heerlen. 100% of the equity was in turn purchased by Limburg Energie Fonds (LEF), which continued to fund the company. Since the acquisition, Mijnwater has received a total investment of €13.0m, from LEF which has in turn gone on to fund expansion of the core network infrastructure (backbone, network heat pumps, primary piping) and to cover Mijnwater operational losses. The high-level sources and uses of funds over the period 2013 to 2019 are shown below in **Table 1**.

Sources	€m	Uses	€m
Municipality of Heerlen	16.3	Energy Installations	7.6
LEF Senior Loan	5.0	Cluster Net	8.2
LEF Equity	8.0	H/C Sources	2.0
Weller Junior Loan	1.4	Backbone	1.5
		Solar PV	0.2
		Work in Progress	4.4
		Accrued Losses	6.8
TOTAL	**30.7**		**30.7**

Table 1: Mijnwater Capital Sources and Uses 2013-2019. Note these do not include grants received and client contributions. Source: Mijnwater

2. Mijnwater - Today and Future

Today Mijnwater has grown into a fully staffed energy company, employing 27 FTEs across three departments; Infrastructure, Energy, and Operations. The Mijnwater network has grown substantially, and today services 330 connection across 3 clusters, delivering c. 50,000GJ of heating and cooling per year.

Beyond its role as a developer and operator of a district heating & cooling network, Mijnwater has always put a lot of emphasis on research & development, where a team of 3 FTEs are focusing on the continuous development of the 5GDHC concept, including the sharing of knowledge with other stakeholders through their involvement in several EU Interreg-funded projects.

Key statistics of the project include:

- 3 regional clusters
- 2 wells for energy storage in the mine tunnels
- 330 connections consuming 23,000 GJ of heat and 24,000 GJ of cooling

Going forward, Mijnwater has ambitious plans to grow the network organically, having identified 6,500 new connections and 400,000GJ of heat/cooling demand that could reasonably be expected to connect over the next 5 years. Moreover, the Mijnwater team is working on implementing additional 5GDHC features to improve the system's efficiency further (e.g. adding a seasonal storage 'ecovat').

Mijnwater's business plan consists of three phases (each of which also includes the prior):

1. Phase I - 2020: Investing €45m of gross capex to add 23 new offtakers and a total of 65,000 GJ of heat/cooling demand to the system by 2021.
    - All offtakers have signed Letters of Intent, and a substantial portion are fully contracted to connect.
2. Phase II - 2025: Further investment of €130m (total €175m), adding a further 45 large offtakers and 300,000 GJ of heat/cooling demand by 2027.
    - Based on demand already identified and assessed by MW to be feasibly connectable in the next 5 years.
3. Phase II – 2030: Invest up to €185m (total of €360m), taking the network to 1,000,000 GJ of heating and cooling demand.
    - Reaching 1m GJ is a driving ambition of the Mijnwater team. It would require additional demand from significant network growth and encompassing of more of Heerlen / neighbouring towns.

For the purposes of this case study, we focus on the Phase II plan of investment through to 2025, a gross capex of €175m and a total of 350,000 GJ of heat and cooling connecting to the system. Of this, customer contributions and subsidies will contribute c. €55m, for a net capex of €120m over the next 5 years. Further investment will also be required throughout the lifetime of the assets (particularly heat pumps) with a total capital cost for replacement of €40m, allowing for a lifetime of the network and assets of 50 years.

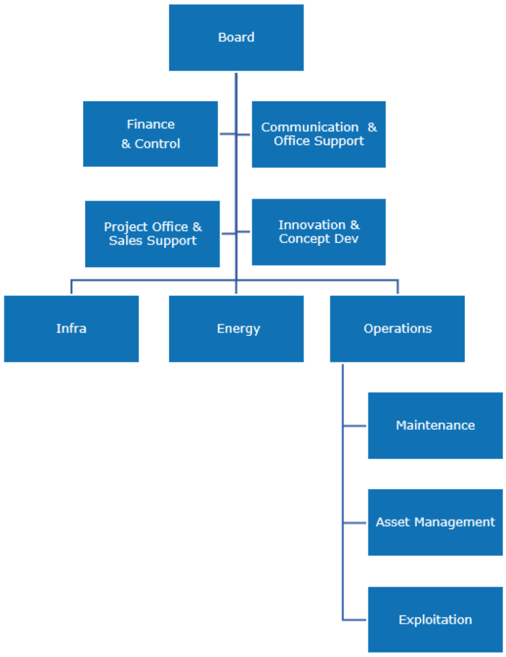


Figure 3: Mijnwater Organisation Chart

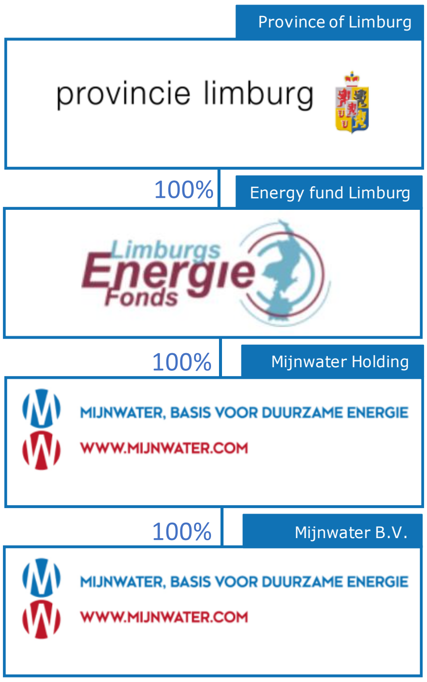


Figure 4: Mijnwater ownership structure

C. 5GDHC – Investment Case

Analysing the Mijnwater project financial characteristics provides useful insights into the risk/return profile of the 5GDHC concept. In particular, the difference between its current financial profile vs. that of its business plan to 2025 allows us to identify the benefits of scale and impact of rolling out of the full 5G concept. Table 2 below outlines the forecast cash flows for the project between 2020-27.

The fundamental investment case behind 5GDHC is not dissimilar to conventional district heating and cooling: high upfront investment at low IRRs, with attractive upside from network expansion. However, the Heerlen case study points to some interesting additional risk/return characteristics that diverge from this conventional case:

1. Capital investment: 5GDHC appears to require a smaller critical volume of customers to make a working investment case.
   - In the conventional case, a large % of the total capex is invested upfront and customers can be added at a low incremental cost. A significant number of customers are required to connect to ensure the fixed cost is recovered, but beyond that, additional customers are highly lucrative
   - For 5GDHC, a much smaller % of the total capex is required to be invested upfront (no centralised boilers), however significant incremental capex is required as customers are connected. The net effect is still positive – fewer customers are required to make back cost – however beyond that, additional customers far less lucrative
   - Whilst the potential upside from network expansion is somewhat reduced, there is a significant risk mitigation in the fact that a majority of capex is deployed only once additional volumes are contracted
   - In some cases, further investment into renovation is required to connect poorly insulated buildings to low-temperature networks. Whilst these may reduce the capacity to retrofit 5GDHC, it is unlikely to pose an issue to newbuild customers who typically make up the majority of the customer profile.
2. Profit and Loss: 5GDHC networks benefit from sale of both heat and cooling to generate revenue, and the future balance of these will aid the reduction of costs.
   - Like conventional networks, 5GDHC charges customers a fixed annual rate plus a usage charge. Unlike conventional networks, 5GDHC is designed to sell cooling efficiently as well
   - High asset level gross margins, electricity is the largest cost item -> no supply risk / fuel price exposure.
   - Electricity costs can be reduced through system efficiency
   - As with conventional network dilution of fixed overheads at the group level is crucial for a robust investment case
3. Subsidies on capex investment, no subsidy on generation or revenue

In the following section we develop some of the key features of the Mijnwater project and the 5GDHC concept, and contrast with conventional heating where possible. There are a few important caveats worth noting:

1. The Mijnwater project may be considered a “first of a kind” project, and as such its current cost base and setup may not be reflective of actual costs achievable should this be replicated using lessons learned from the past.
2. Mijnwater has benefited from various grants over the past 10 years which have financed the development of the project. This analysis aims at adjusting the returns for such grants to the extent possible
3. The Mijnwater project is subject to various characteristics which are driven by its location and background that may not be directly applicable to other projects seeking to replicate the concept. This paper aims at identifying such characteristics.

Revenue		2020	2021	2022	2023	2024	2025	2026
Standing charge - Heat supply	*29%*	567,000	1,033,000	1,401,000	1,702,000	1,894,000	2,450,000	3,233,000
Standing charge - Cooling supply	*13%*	138,000	323,000	542,000	814,000	931,000	1,200,000	1,594,000
Standing charge - Tap water	*1%*	9,000	37,000	56,000	77,000	97,000	150,000	194,000
Usage - Heat supply	*33%*	356,000	848,000	1,189,000	1,961,000	2,274,000	3,286,000	4,033,000
Usage - Cooling supply	*7%*	56,000	251,000	325,000	502,000	554,000	587,000	599,000
Usage - Tap water	*7%*	76,000	210,000	290,000	348,000	403,000	665,000	977,000
Other Revenue	*9%*	373,000	403,000	439,000	494,000	574,000	804,000	861,000
TOTAL REVENUE	***100%***	**1,574,000**	**3,105,000**	**4,242,000**	**5,898,000**	**6,726,000**	**9,142,000**	**11,491,000**
Operational costs								
Energy costs	*41%*	(401,000)	(714,000)	(994,000)	(1,364,000)	(1,615,000)	(2,218,000)	(2,645,000)
Maintenance	*29%*	(285,000)	(550,000)	(733,000)	(953,000)	(1,077,000)	(1,473,000)	(1,916,000)
Measurement & administration costs	*3%*	(31,000)	(62,000)	(85,000)	(103,000)	(120,000)	(165,000)	(235,000)
Other costs	*0%*	(13,000)	(14,000)	(14,000)	(14,000)	(15,000)	(15,000)	(15,000)
Other operating expenses	*26%*	(858,000)	(875,000)	(892,000)	(910,000)	(928,000)	(947,000)	(966,000)
TOTAL OPEX	***100%***	**(1,588,000)**	**(2,215,000)**	**(2,718,000)**	**(3,345,000)**	**(3,754,000)**	**(4,818,000)**	**(5,777,000)**
Asset EBITDA		**844,000**	**1,765,000**	**2,416,000**	**3,464,000**	**3,899,000**	**5,271,000**	**6,680,000**
Company EBITDA		**(14,000)**	**890,000**	**1,524,000**	**2,553,000**	**2,972,000**	**4,324,000**	**5,714,000**
Asset EBITDA Margin		*54%*	*57%*	*57%*	*59%*	*58%*	*58%*	*58%*
Company EBITDA Margin		*-1%*	*29%*	*36%*	*43%*	*44%*	*47%*	*50%*
GJ Delivered		*62,690*	*113,688*	*146,697*	*203,986*	*232,380*	*324,189*	*379,846*
Capital Expenditure								
Energy Installations		(15,434,000)	(14,083,000)	(20,708,000)	(20,493,000)	(22,547,000)	(15,949,000)	(5,033,000)
Sector Net		(5,006,000)	(2,365,000)	(2,300,000)	(2,696,000)	(3,334,000)	(1,927,000)	(1,490,000)
Clustor Net		(7,131,000)	(5,691,000)	(4,984,000)	(3,033,000)	(1,163,000)	(4,140,000)	-
H/C Sources		(2,138,000)	(4,047,000)	-	(188,000)	-	-	-
Backbone		(2,733,000)	(5,285,000)	-	-	-	-	-
GROSS CAPEX		**(32,441,000)**	**(31,471,000)**	**(27,993,000)**	**(26,410,000)**	**(27,044,000)**	**(22,016,000)**	**(6,523,000)**
Subsidies		2,792,000	6,506,000	2,533,000	2,737,000	2,930,000	3,465,000	1,883,000
Customer Contributions		3,557,000	8,912,000	5,363,000	4,680,000	3,117,000	4,491,000	3,205,000
NET CAPEX		**(26,092,000)**	**(16,053,000)**	**(20,097,000)**	**(18,993,000)**	**(20,997,000)**	**(14,060,000)**	**(1,435,000)**
Cumulative Capex			*(42,145,000)*	*(62,242,000)*	*(81,235,000)*	*(102,232,000)*	*(116,292,000)*	*(117,727,000)*
Cumulative Capex/EBITDA			*47.4*	*40.8*	*31.8*	*34.4*	*26.9*	*20.6*

Table 2: Forecast cash flow between 2020-26 showing the investment of capex and growth of revenue and EBITDA.

1. Capital investment

Capital expenditure on district heating can be broadly broken down into four categories;

1. Heat / cold sources
2. Primary network
3. Secondary network
4. Customer installations (network, heat pumps and heat exchangers)

Table 3: Capex categories for 5GDHC and Conventional DH projects of similar size (c. 400 TJ).
Source: Asper Investment Management NL market research

Capex Item	5th Generation DH	Conventional DH
Customer Installations	75%	5%
Primary Network	5%	10%
Secondary Network	15%	20%
H/C Sources	5%	65%
Upfront	**25%**	**75%**
Variable	**75%**	**25%**

Conventional district heating involves a large upfront cost to install centralised heat sources (boilers, geothermal wells etc.) and the core primary network. Investment is typically secured by a portion of long-term contracted offtake prior to reaching financial close (and beginning major construction work) – this critical mass of demand, typically 70%, is required for minimum feasible project economics and the use of leverage for large projects. Following the establishment of the core network and heat sources, additional, smaller customers can be connected through a much smaller investment into secondary network and installation of low-cost, standardised heat exchangers at customer sites. As a result, these incremental connections are typically highly lucrative and drive the profitability of the project.

5G district heating, by virtue of its independence from large and centralised heat generation units, has a smaller proportion of fixed, up-front capex, with c. 25% of capex invested into H/C sources, storage and primary network, but with higher incremental capex for network growth, driven by the need for expensive heat pumps at customer locations to step-up temperatures. The result is that projects are feasible with a lower starting connection volume, and a slower build-up as additional investment is deployed. This profile mitigates in part the volume build-up and critical mass risks that conventional networks face.

The result of the shift towards primarily variable, or connection-dependant, capital costs results in a longer investment timeframe, to match the time required to connect customers into the network. This can be seen clearly in the charts below – 5GDHC requires more time to build volumes, however capex is only invested as volumes grow – reducing the overall capital at risk in the early stage of development.

Figure 5 shows the capital investment profile and build up of volumes for conventional and 5GDHC, in both cases for projects delivering c. 400 TJ of heating and/or cooling supply. Annual capital investment is shown by the blue bars, with total annual energy supply shown by the yellow line. Note the key difference in the investment period (longer for 5GDHC) and build up of volumes (slower ramp up correlated with capital investment).

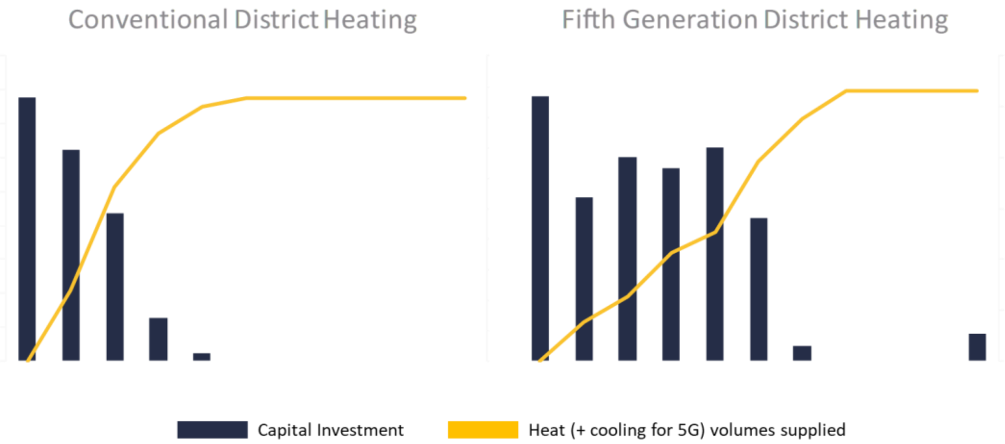


Figure 5: Capex requirements and volume build-up for conventional and 5GDHC networks. Source: Asper Investment Management

For conventional district heating networks, the generation unit comprises c. 40% of the capex and so requires a large further investment after 20 years. Typically, the investment case is based on this 20-year lifetime and a remaining terminal value. Conversely, 5GDHC requires maintenance of only c. 10% of capex over the same period (primarily for replacement of heat pumps at customer installations) and as a result it is easier to get comfort with an asset life and investment case as long as 50-years.

Despite this, the total capital cost divided by the energy generated over the asset lifetime and discounted at 6% is c. €20 /GJ – compared to conventional heating at c. €10/GJ. This is in part driven by the longer investment case of 5G, which is more impacted by discounting. Clearly though a substantial capex reduction must take place for the technology to achieve large scale roll-out (covered further in section 5).

2. Customer contributions and Grants

New customers, and in particular B2B customers, will typically contribute to the installation cost when connecting to the network. The contribution is dependent on several factors including; total connection cost, cost of alternative (gas heating) and forecast savings on energy bills. For prospective customers, the commercial decision to connect to a 5G network boils down to these same factors.

- In the Netherlands, ongoing energy costs are capped at the Heat Law tariff which dictates that heating generated through alternative technologies must not exceed the price of conventional heating (i.e. decentralised gas boilers).
- Upfront costs are therefore often the primary decision-making factor.

In the case of Mijnwater, the average customer contribution will typically reduce the gross capex requirement by c. 15% - however this can vary drastically from project to project. Notably, the contribution is determined based exclusively on the cost of the energy installation on site (heat pump and exchanges) without consideration of the final stage network which is required to bring energy from the primary or secondary networks to the customer site. As such, adding smaller customers who are further from the network typically incurs a larger relative capex cost, although this network may in future prove valuable for connecting further customers, baking in some optionality value.

A series of grants are available across NW Europe to enable a larger scale roll-out of energy transition technologies. For example in France the national heat fund provides subsidies of up to 20% of capex for district heating projects with a share of renewable sources greater than 50%.

3. Revenue Generation

District heating revenue models are typically based on both a standing charge, paid annually, and a variable charge for heat, based on the total energy consumption of the customer, usually in GJ or kWh. This model is well established from gas heating, so there is little friction in converting customers. Similarly, 5G DHC operators can charge customers a fixed, annual charge and variable rate based on energy consumption and this has typically been the case for pilot networks to date. Unlike conventional networks, 5GDHC can benefit from selling both heating and cooling, and in the case of the Mijnwater project, this is responsible for c. 20% of the total revenue (see Table 4).

Table 4: Breakdown of revenue split for Mijnwater across different charging merchanisms. Source: Mijnwater

	Standing Charge	Usage
Heat supply	28%	35%
Cooling supply	15%	5%
Tap water	3%	10%
Other Revenue	4%	-
TOTAL	**50%**	**50%**

In the Netherlands, the price at which heat can be sold is regulated by the Heat Law – and specifically is limited by the NMDA principle – which dictates that suppliers of heat cannot charge more than the equivalent cost of generating that heat through a conventional home boiler, today approximately €22.5 /GJ. Currently this price is indexed based on the supply of retail gas across the Netherlands, however as the market for heat develops (driven today by mostly conventional district heating systems) it is likely a new regulated price system will emerge. Currently, cooling and low temperature heat delivery are not regulated, although this is envisaged in future. Despite being a fundamentally low temperature network, the Mijnwater project is still subject to the Heat Law tariff, as it owns and operates heat pumps and ultimately delivers high temperature water at the point of consumption.

Achieving a long term balance of heating and cooling demand opens a new possibility for the 5GDHC revenue model; charging customers by the size of their connection (e.g. this would be in kW or GJ/s) on the basis that the removal of heat from the system creates cooling, which balances elsewhere in the network (and perhaps at a different time of year, if seasonal storage is in use). There would likely be some substantial regulatory and consumer hurdles to overcome to make this a reality.

Whilst the sale of cooling is an attractive trait of the 5GDHC concept, it may not simply involve just additional revenue – but an additional service used to attract large scale customers. For example, a supermarket whose major demand is for heat, but also requires cooling for refrigeration, can pull this cooling from the network extremely cheaply substantially reducing a second and otherwise unrelated cost.

In the medium term, 5GDHC may also be able to benefit from revenues for providing system services to the electricity grid operator. During times of electrical oversupply (usually driven by peak renewables generation and low demand, e.g. a warm sunny day) heat pumps can operate to increase the temperature of the network and storage reserves, benefitting from low prices, and receiving payments for balancing the grid system. Conversely, through a reduction in demand and use of stored energy during high load times, payments can be received for reducing grid load. Further details of plans for third-party system services can be found on the TenneT website.

Looking in detail at the customer base of Mijnwater for the Phase II expansion (see Figure 6), we can see that throughout its growth, heat accounts of 75% of the total revenue, cooling 15% and other revenues (metering and administration charge) around 10%. The revenue per GJ is primarily driven by the price of heat as set by Heat Law tariff, whereas the price for cooling varies significantly depending on the offtaker.

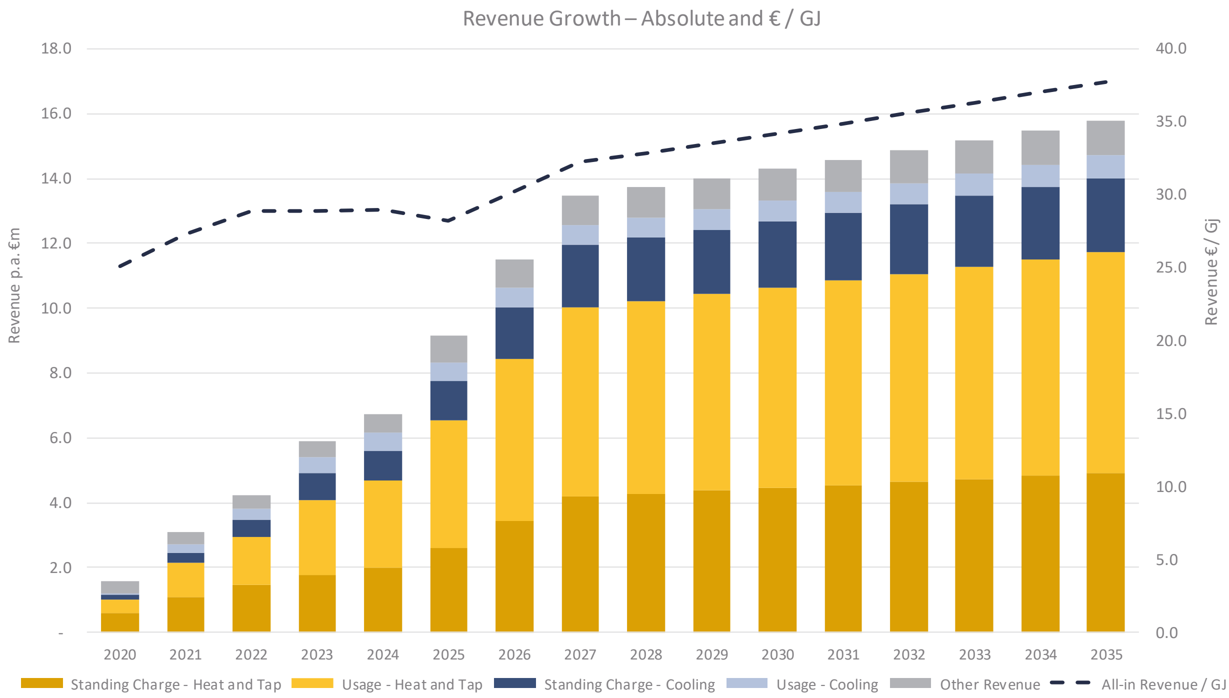


Figure 6: Revenue growth by category and total revenue per GJ: Source: Mijnwater

4. Operating Costs

District heating operators have several operating costs that need to be covered, at a high level:

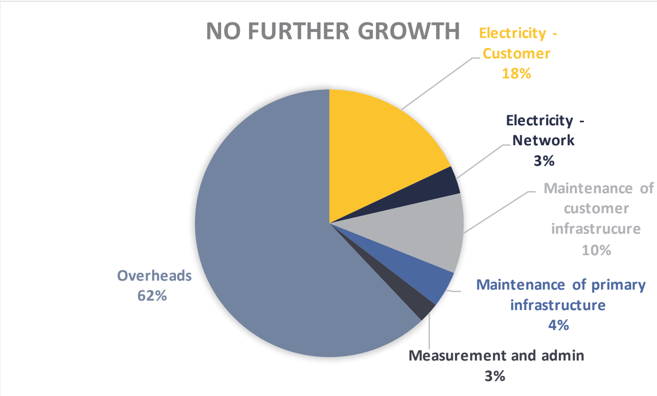
1. Asset-level costs:
   a. Electricity costs for heat pumps at both customer installations and on primary network (step-up heat from storage)
   b. Maintenance of secondary network connecting customers
   c. Maintenance of primary network and infrastructure (storage, renewable sources etc.)
2. Operating expenses:
   a. Staff including engineering, sales, development, customer service, legal
   b. Marketing and business development
   c. Office rents, third party service providers, measurement, project administration

Whilst conventional district heating plants are exposed to the price and supply of fuel for incineration (e.g. gas, biomass or waste), 5GDHC is instead dependant on electricity as an energy input. Figure 7 demonstrates that over the long term, electricity is the largest ongoing expense. This exposure to electricity prices is in many ways beneficial vs. fuel; there is high liquidity and security of supply, prices are more predictable over the long term and energy provided is of a much lower carbon intensity than incineration fuels. Still, exposure to power prices over a 50-year basis is an important factor to consider when building an investment case.

In several ways, 5GDHC offers mitigants to power price exposure;

- Short term storage at distributed substations can enable the system to 'charge' at times of low power prices, increasing system temperatures that in turn reduce the amount by which heat pumps are required to step-up the temperature.
- Due to the increased efficiency of a balanced heat/cooling system, operators may offer price incentives depending on whether the system overall is 'long' or 'short' of heat. A balanced system allows for minimal use of heat pumps reducing the overall cost and resulting in a net economic gain for project, despite reducing revenue.

Today, Mijnwater's most significant cost is company overheads, which includes primarily external advisory services, but also administration, insurance, legal, marketing and others. During the development phase, Mijnwater salaries are paid through a margin on the total capex i.e. through capital investment – however over the long term as the business becomes more stable, personnel costs will be covered by project revenues.



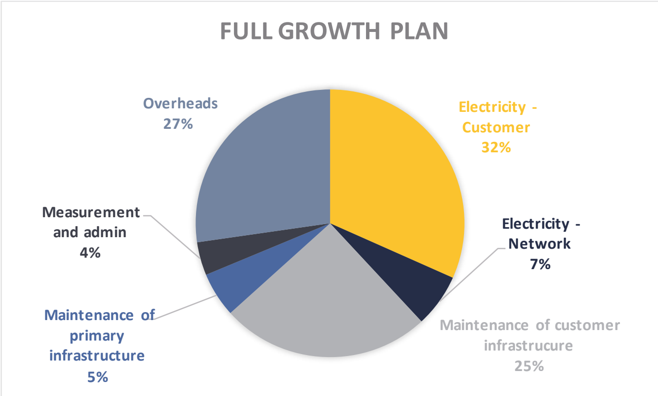


Figure 7: Split of Operating Costs for Mijnwater - Today and 2027. Source: Mijnwater

When compared to conventional district heating, the asset level gross margins of c. 60% are very attractive and reflect a middle ground between conventional fuel-based generation (gross margins 25%-35%) and no-fuel generation such as wind (gross margins 70%-80%).

When comparing with conventional district heating, we can look at operating costs on a levelised cost basis (taking the present value of cost divided by GJ delivery and discounted at 6%). Here the effect of a smaller relative operating cost for 5GDHC are clear – the levelised cost is c. €5 /GJ, compared with c. €10 for conventional fuel-based heating. To understand the full investment case and contrast it with conventional heating, we must consider the levelised cost of both the capex and opex – and this is discussed in the section below.

5. Core returns & upsides

This case study has focused on the Phase II expansion plan of Mijnwater, and here we examine the unlevered returns in this case, and also for the Phase I and Phase III plans – these are outlined at a high level in Table 5. Clearly, the connection of additional volume to the system is crucial to the investment case over the long term – however even with a Phase II build out, these returns are unlikely to attract large scale institutional investment.

	Phase I	Phase II	Phase II
Total Capex	(41,323,586)	(159,278,913)	(373,928,591)
B&H IRR	3.6%	5.3%	6.8%
Average dividend yield	2.3%	5.7%	10.4%
Payback period (years)	29	24	23
First Distributions	30-Sep-21	31-Dec-25	31-Dec-25

Table 5: Returns for each investment plan. Source: Asper Investment Management analysis

Fortunately, there are several possibilities for upside in the business case which can improve project returns. The first is sourcing long-term debt financing at a low cost of capital. Typically, banks will make non-recourse loans to projects to fund construction at interest rates between 2-5% and for tenors between 10-15 years, however specific terms can vary by geography and technology. By bringing in low cost capital, project sponsors can increase the return on equity, and reduce the overall requirement for investment. A full analysis of funding structures in The Netherlands would be required to understand the impact to returns for Mijnwater, however we would expect a positive impact to returns of c. 1-3%.

As previously discussed, a key driver of investment returns is the Levelised Cost of Energy (**LCoE**) which we have referenced in the context of either capex or opex, for which 5GDHC was respectively higher and lower. Combining the two gives us the total LCoE (using discount of 6%):

1. Conventional District Heating: Opex €10 + Capex €10 = **€20 /GJ**
2. Fifth Generation District Heating and Cooling: Opex €5 + Capex €20 = **€25 /GJ**
    a. Note this includes subsidies on capex. These are not included for conventional district heating which in the Netherlands benefits from subsidies for generation

Whilst 5GDHC still doesn't offer the long-term value per unit energy as conventional sources, it has come a long way. As the definition becomes clearer, and widespread standardisation of equipment, skills, contracts and financing become available, 5GDHC can emerge as a lower cost technology, reducing the price of heat to consumers and providing a lower carbon alternative to gas fired boilers across north-western Europe. Furthermore, an increase in fuel prices driven by greater demand will diminish the current economic advantage for conventional heating – bringing 5G into a competitive environment. Finally – the carbon intensity of conventional heating faces potential regulatory risk; as governments push to incentivise the decarbonisation of heat it is likely that the case for conventional heating may deteriorate further over the longer term (e.g. through emissions charges).

The sensitivity analysis below shows the potential upsides from reductions in the cost of 5GDHC, and how these impact the IRR. Starting from the Phase II unlevered IRR:

1. Reductions in Capex: as the largest individual capex item, heat pumps are the primary target for cost reductions. Currently, the market for heat pumps is dominated by small, specialist companies with low volumes and high overheads and there is little standardisation. A 2016 report on this subject was published by the UK government[1] which described an overall cost reduction of c. 20% - which would reflect a reduction of overall capex of c. 10-12%. Similarly, standardisation across all equipment and installation will put downward pressure on costs.
2. Reduction in Opex: there are several conceivable routes to reducing the ongoing operating costs, largely targeting electricity costs and company overheads which make up c. 65% of total opex.
    - As discussed in section 4, managing a balance of heating and cooling as well as leveraging short- and long-term storage can reduce electricity costs materially. The full impact would need to be carefully assessed.
    - As the company scales and developments complete, fixed company overheads will dilute across a much larger revenue base, however to ensure a robust business, Mijnwater will need to address new personnel costs which were previously covered by investment.
    - Further overhead reduction is plausible through either integration of key roles (such as finance, legals and engineering) or through benefits of scale and competition
3. Roll out of Phase III, as previously discussed.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf

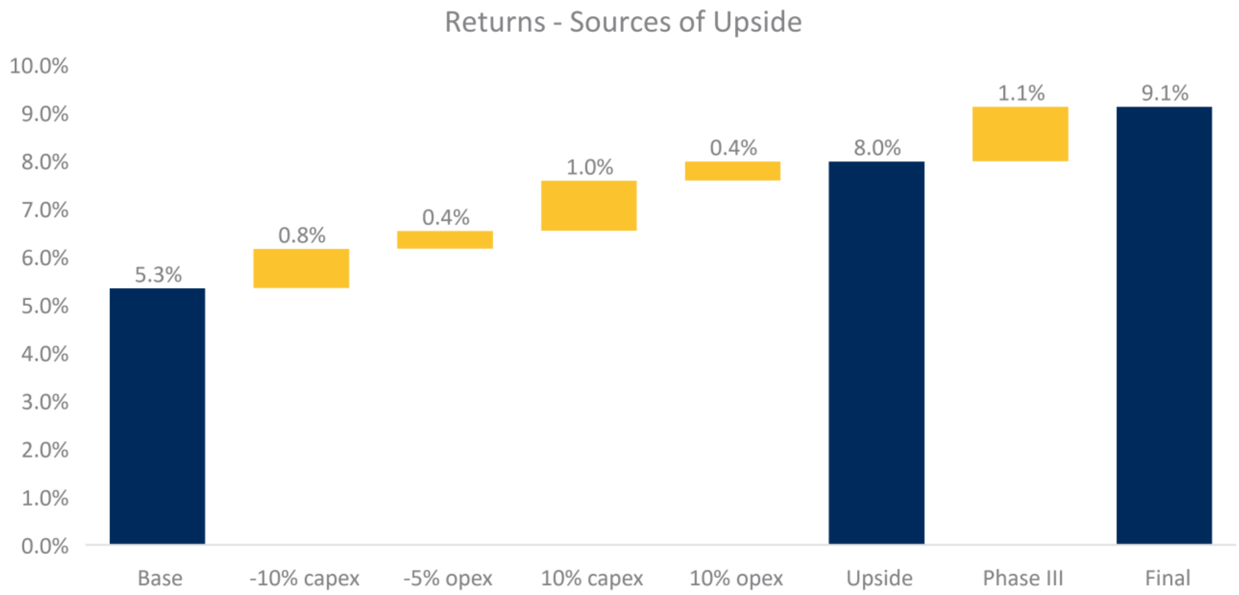


Figure 8: Chart showing the build-up of unlevered, B&H project returns following reductions in costs. Source: Asper Investment Management analysis