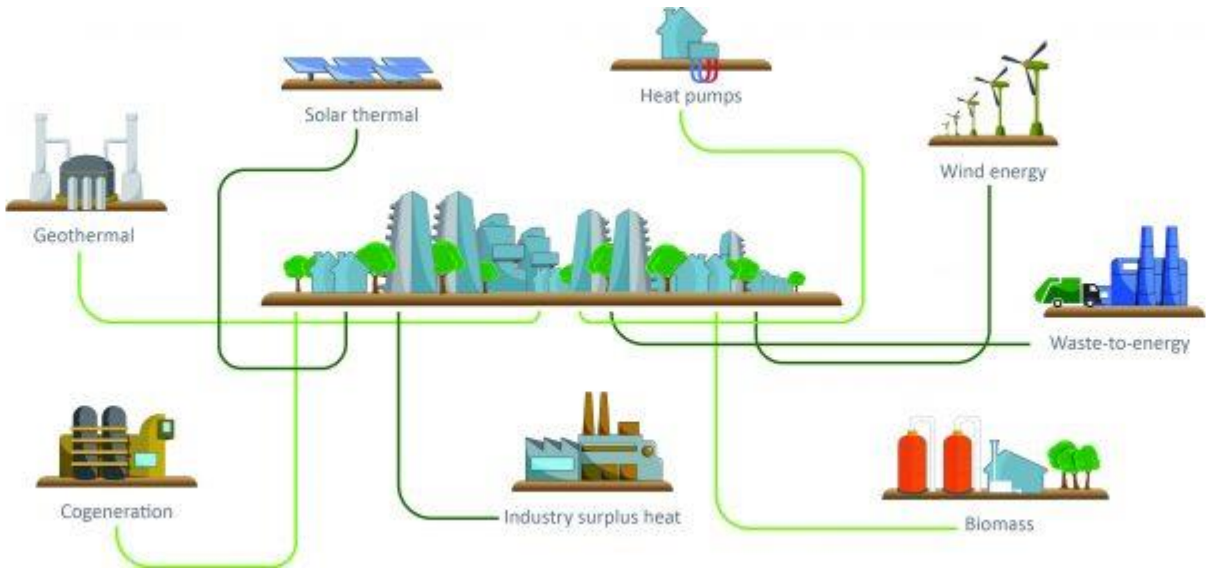

District Heating

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Overview

District heating is a flexible network of highly insulated pipes that delivers heat from a central energy source and provides space heating and hot water to multiple buildings connected to the grid. It is heavily motivated per the need of securing the energy supply by improving the energy efficiency. Therefore, in this report we will approach this concept deeper while focusing on the following goals:

1. Technology and range
2. Cost (€/kWh) and losses

Technology and range

The district energy can be divided into district heating and district cooling. These networks are inherently diverse and variable in terms of size and load, even though both employ similar operating principles, each network develops according to specific local circumstances and adapts to continuous innovation. Due to its structure, they are suitable to receive from locally available, renewable, and low-carbon energy sources, such as: solar thermal, geothermal heat, heat from combined heat and power plants (CHP) and waste heat from industry, transport, commercial and services facilities. Meaning it can also recycle waste heat expelled from activities such as electricity generation or industrial processes, which would have otherwise been lost to the atmosphere or waterways, resulting in a better pollution control than localized boilers. The ability to integrate multiple energy sources means customers are not dependent upon a single source of supply to satisfy their needs.

District heating (also known as heat networks) is an advanced system built to distribute the heat generated in a centralized location through a network of highly insulated pipes for residential and commercial heating requirements such as space heating and water heating. Five generations of district heating can be distinguished: **First generation** (technologically outdated) - steam-based system fueled by coal, used concrete ducts, operated with very high temperatures and was therefore not very efficient. **Second generation** - burned coal and oil, was transmitted through pressurized hot water as a heat carrier using water pipes in concrete ducts and heavy equipment. **Third generation** (also called the "Scandinavian district heating technology") - usually used coal, biomass and waste (instead of oil) as energy sources and, in some systems, geothermal energy and solar energy as well; uses prefabricated, pre-insulated pipes, buried into the ground and operate with temperatures below the boiling point. **Fourth generation** (currently being developed) - designed to combat climate change and integrate high shares of variable renewable energy by providing high flexibility to the electricity system. Potential heat sources are biomass, central solar energy (geothermal and solar), waste heat from industry and cooling processes, CHP plants and other sustainable energy sources. The mix of these energy sources with the large scale thermal energy storage, allow fourth generation district heating systems to provide flexibility for balancing wind and solar power generation. **Fifth generation** (or cold district heating) -

distributes heat at near ambient ground temperature, thus minimizing heat losses to the ground and reducing the need for extensive insulation. By using a heat pump in its own plant room, each building can choose to remove heat from the circuit when it needs heat or (in reverse) reject heat when it needs cooling - hence the name for this generation. The ability to choose between heating and cooling, permits waste heat from cooling to be recycled to the nearby buildings in need of heating on a "heat sharing network”. It is important to note that grid piping for ambient ground temperature networks is cheaper to install than earlier generations as it does not require heavy insulation and minimizes heat losses to the ground. However, all infrastructures on the network are obligated to install and maintain individual heat pump systems to meet each heating and cooling needs, with capacity to satisfy their own peak demand, respectively.

The heat used to pump hot water to the end-user in the network, is not used directly by the customer and, instead, is used to heat each customer's own water supply via a **heat exchanger**. The connection of buildings to a district heating network is not complicated. In cases where the building has an existing boiler, this would simply be replaced by a heat exchanger, as they are less expensive than boilers and require less maintenance (due to less moving parts).

The renovation, construction and expansion of district heating and cooling (district energy network) with the integration and balance of a large share of renewable power (serving as thermal storage) are the fundamental basis for the smart energy systems of the future. These types of networks are based on scale since the production of heat in one large plant can often be more efficient than the production in multiple smaller ones. For this reason, large scale heat pumps are regarded as keys for technology involving smart energy systems with high shares of renewable energy.

The heat density, related to the population density (characterized by the necessity of more buildings), is particularly important to the system’s economic viability, as it becomes cheaper to implement when buildings are closer, resulting in lower up-front investment costs and increased cost-effectiveness when compared to individual heating systems. The closeness of buildings means shorter pipelines resulting in lower heat losses and reduced pumping, minimizing the operational costs of the grid. Overall, district heating has many benefits like: More renewable energy; Increased comfort; Hot water on demand; Better energy rating; Carbon reduction; Revenue flow-back; Flexible system; Recycle waste heat; Reduced maintenance cost; Improved air quality.

Cost and Losses

The estimated values for the cost of installation and maintenance and for the losses associated with this type of system, were obtained by comparing the values of previously done projects.

We started by assuming that only 40% of the total houses in the island would have district heating, this means that only 8 000 houses would have this system. Since there are 50 000 inhabitants on the island, the percentage studied represents 20 000 inhabitants.

From the report of waste, we concluded that the daily incineration energy usage per person (DIEUPP) is **1,81 kWh**. Multiplying this value by the number of inhabitants using DH, we conclude that the daily incineration energy use is **36,2 MWh**.

For the yearly value we considered that the population would use heat only to heat water or cook, and that on average, they would use this system for about 4 hours a day. Possibly they would use more in the winter and less in the summer. For these reasons we estimated 1460 hours of usage per year so by multiplying the daily amount by these hours we get the annual amount of incineration energy use per person and repeating the same process but multiplying the energy use for all people we obtain the amount of energy use for all people yearly.

Using the value of the daily incineration energy use per person and multiplying with the total number of inhabitants we get the daily resource for all inhabitants of the island.

Knowing that the **total efficiency** for the CHP is **85%,** being that for the **generation of heat** the efficiency is about **60%** and for the generation of **electricity** is about **25%**, it is possible to determinate the **daily heat consumption/produced heat** of **54,3 MWh** and the **daily electricity consumption/produced electricity** of **22,6 MWh. Was considered 15% of losses.** To obtain the kWh/year we multiply the daily heat/electricity consumption for 365 (days in a year).

Out of the dissertation of João Abrantes, we removed the cost of the investment for a CHP plant (we used the value for VALORSUL). And assuming a lifetime of 10 years, we calculated the annual cost (AC) of the investment in its lifespan. To discover the price of heat (€Heat) or kWh thermal, which is 0,629€/kWh, we used the following expression:

$$AC = €Heat\ [€/kWh] \times Nr\ of\ kWh - Heat[kWh/year] + €Electricity\ [€/kWh] \times Nr\ of\ kWh\ electricity[kWh/year]$$

In the year zero (t=0), the consumer will have an additional cost due to the investment of the necessary materials for DH (1 400€). To this value it will add the maintenance cost of 150€/year plus 2% of losses, the heat price yearly depending on the usage of energy and the distribution fee surplus its 10% of losses. The cost for distribution (8,05€/MWh) was acquired from the EuroHeat report "The competitiveness of district heating compared to individual heating.". For the following years (t=n com $n \in [1,10[$), the initial investment cost will no longer be considered. The values of the costs for every year of usage can be consulted below in the tables (1), (2), (3) and (4).

Tables 1 and 2 - Yearly and daily costs per customer in the initial year or year zero.

(1) Yearly cost per consumer (t=0)		Losses
Maintenance	153,00 €	0,02
Distribution	23,40 €	0,10
Investment	560,00 €	
Heat price	1 661,74 €	
Total cost	2 398,14 €	

(2) Daily cost per consumer (t=0)	
Maintenance	0,42 €
Distribution	0,06 €
Investment	1,53 €
Heat price	4,55 €
Total cost	6,57 €

(3) Yearly cost per consumer (t=n; n[1,10[)	
Maintenance	153,00 €
Distribution	23,40 €
Investment	- €
Heat price	1 661,74 €
Total cost	1 838,14 €

(4) Daily cost per consumer (t=n ; n[1,10[)	
Maintenance	0,42 €
Distribution	0,06 €
Investment	- €
Heat price	4,55 €
Total cost	5,04 €

Tables 3 and 4 - Yearly and daily costs per customer from year 1 and the following years.

Conclusion

A lower heat demand by the consumer results in a higher heat price due to bigger heat losses in the pipelines since the heat demand is directly proportional to the heat density.

District heating is a good solution for locations with high heat density and cold climates which is not the case of our island. In view of these conditions, this heat transmission system is expensive and not appropriate for our project.

To summon, more efficiency, more renewables and more flexibility lead to a better energy system.

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