TECHNICAL NOTE Nº 15

DISTRICT ENERGY, ADVANCES IN CHILE AND COLOMBIA

This document was prepared under the direction of the **Latin American and Caribbean Energy Organization (OLACDE**)

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January 2026

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Clarification

The concept of District Energy comes from the literal translation of the English term District Energy. According to the international literature, District Energy encompasses the concepts of District Heating and District Cooling, which in Spanish correspond to district heating and district cooling (or district refrigeration).

For a better understanding of the subject matter addressed in this technical note, the following section clarifies how this concept has been handled, applied, and evolved in Chile and Colombia.

In Chile's case, the main motivation for promoting district energy lies in improving the heating sector, which is why the concept of “district heating” was introduced. In fact, in some public policy and regulatory documents, district heating was explicitly defined, and it was only over the years that the term district energy began to be introduced, alongside the creation of the Geothermal and District Energy Unit within the Ministry of Energy. With this semantic introduction of the concept of District Energy in Chile, efforts continued to strongly promote district energy as an alternative for improving the heating sector, while also beginning to include cooling or refrigeration, thereby covering the full range of benefits associated with the provision of heat or cold. It should also be clarified that, as this refers to the infrastructure necessary for the application of district energy in cities, in Chile the concept of District Energy System is commonly used.

In Colombia's case, the strategy to promote energy districts stems from the need to provide outsourced cooling services for buildings with high energy consumption, as well as a measure to promote the elimination of ozone-depleting substances (ODS) in cooling systems. As a result, the concept of ‘thermal districts’ was quickly introduced into Colombian regulations as the infrastructure for the production and distribution of thermal energy for end use, establishing an innovative business model involving an energy service provider and at least one customer. The growth of the district heating market in Colombia, with six systems currently in operation, has led to the term evolving into “energy districts,” understood as infrastructures that supply multiple energy services (e.g., steam, electricity, industrial process gases) in addition to cooling and heating. Currently, Colombia have energy districts in operation, and the construction of new projects is planned in the medium term. Therefore, in Colombia the concept used at the commercial and institutional level is "energy districts".

Thus, throughout the document the terms District Energy, Energy Districts and Thermal Districts will be named, to refer to the subject of the technical note, while, to refer to the specific infrastructure or developments, they will be named as projects or systems.

1. Introduction

In 2013, UN Environment initiated research and surveys in low-carbon cities around the world to identify the key factors that explain their success in expanding energy efficiency and the use of renewable energies, as well as in meeting zero or low greenhouse gas emissions targets. This is how district energy systems were positioned as one of the best practices to provide a local, affordable and low-carbon energy supply, and unlike individual systems, district heating and cooling allowed a more efficient use of energy by reducing losses and taking advantage of local thermal resources that would otherwise be wasted.

The development of modern district and affordable energy systems in cities is one of the most cost-effective and efficient solutions to mitigate greenhouse gas emissions and reduce primary energy demand globally. A transition to these systems, combined with energy efficiency measures, could contribute up to 58% to reductions in carbon dioxide (CO_2) emissions in the energy sector by 2050, to keep the increase in global temperature within the range of 2 to 3 °C.

Despite the enormous potential that is evident in the thousands of projects in operation in the world, the Latin America and Caribbean region have an incipient development, however, the development potential of district energy could start an interesting market in countries in the region that share common energy, environmental, social and cultural challenges. With this objective, Chile and Colombia have developed a structured work, of more than a decade, to advance the implementation of district energy in their cities, addressing issues such as regulation, institutionality, demonstration projects, dissemination and training, which can be taken as an example by neighboring countries in the process of sharing experiences and enhancing development.

In Chile since 2010, the feasibility for the development of projects has been evaluated while generating the enabling conditions for development. Chile's main work has focused on district heating, a product of the energy and environmental challenges faced by the heating sector in cities. This work has been led by the Ministry of Energy of Chile and the Energy Sustainability Agency, where it has been possible to generate promoting public policies, technical studies, regulatory analysis, strengthening of institutional capacities and regulatory frameworks have been designed and implemented to promote the implementation of projects.

Since 2020, this work has been reinforced with the implementation of the Program "Accelerating investment in efficient and renewable district energy systems", financed by the Global Environment Facility, under which the National District Energy Office was established, as a way to improve governance and position this office as a technical reference for project advice. Today, important advances have been made in regulation, improvement of the technical capacity of institutions, citizen awareness and demonstration of project viability, to the point of being in the investment phases of the first pilot project for the country promoted by the State, necessary to demonstrate the technical, regulatory and economic viability of the projects for Chile, which has ambitious goals of creating a market and massifying the connection of citizens to efficient and sustainable district energy networks.

Colombia has been implementing the "Energy Districts of Colombia" strategy since 2013, which has been supported by the cooperation of the Swiss Government and the United Nations Industrial Development Organization UNIDO. This strategy, led by the Ministry of Environment and Sustainable Development and the Ministry of Mines and Energy of Colombia, has led to the construction of a first pilot cooling district in the city of Medellín operated by Empresas Públicas de Medellín - EPM, since 2016. This experience has contributed to the development of five other cooling district projects currently in operation. The strategy has focused its efforts on establishing a favorable regulatory and regulatory context for the development of these infrastructures, which has contributed to the generation of human capacities both at the academic, business and institutional levels, and has managed to constitute a new business model for the cooling and heating sector in at least 10 cities in Colombia.

Although there is substantial progress in the development of projects in both countries, there are still important gaps for scaling, so you have to take advantage of emerging opportunities. Therefore, it is necessary to show the potential attractiveness of the region as an investment pole in terms of the growing demands for heating and cooling; and in terms of the needs, also growing, for technological spare parts to advance global energy and environmental goals.

2. District Energy: Concepts and Considerations

District energy worldwide is not a new concept, in fact, the first vestiges of its development date back several centuries, when the Romans developed collective heating systems such as *hypocaustum,* in which they used piping systems to heat public bathrooms and greenhouses, thus laying the foundations of the concept of district heating. Centuries later, in 14th-century France, the city of Chaudes-Aigues became a pioneer by using natural hot springs to heat some 30 homes through a geothermal distribution system. This experience is considered the first real antecedent of a district heating system in the world. In the United States, this concept took industrial form in the 19th century. In 1853, the Naval Academy at Annapolis, Maryland, implemented a district steam heating system, reflecting a growing need for centralized solutions for large installations. Subsequently, MIT adopted a similar solution in 1916, using coal-generated steam when moving to Cambridge, Massachusetts.

However, it was in 1877 that modern district heating was born, thanks to the engineer Birdsill Holly, who launched the first commercially successful system in Lockport, New York. This model consolidated the idea of a centralized district heating network as a service. In parallel with district heating, the development of district cooling began with the first system in the United States in the late 19th century.

Modern district energy is an alternative that allows energy diversification that, although projects can be designed with conventional energy, has the advantage of being able to feed on residual energy from other processes, temperature gradients from natural resources and, of course, the renewable energy available in each territory.

The definitions of district heating and cooling from the most modern concepts are presented below.

2.1. District heating

District heating corresponds to a centralized system that generates heat in a thermal plant and distributes it in the form of hot water through a network of underground and insulated pipes, which supply heating or domestic hot water service to multiple buildings that require it. This heat can be generated from various sources, including industrial waste heat, geothermal energy, biomass, CHP heat, or even waste incineration. Unlike individual systems, district heating allows a more efficient use of energy by reducing losses and taking advantage of local thermal resources that would otherwise be wasted. According to the UN Environment report *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy*, this type of energy infrastructure is key to achieving more sustainable and resilient cities, since it improves energy efficiency, allows the integration of renewable energies, reduces polluting emissions, and offers an effective solution to face energy stress, local pollution and the challenges of climate change in urban environments. According to the International District Energy Association (IDEA), its implementation also offers more stable prices to consumers, and since thermal energy is delivered as a service, users avoid installing expensive boilers and save costs associated with operation, maintenance, repair and replacement. The key advantage is that connecting multiple buildings to a district system generates economies of scale.

Success story of Chile: Condominium Frankfurt

In the city of Temuco, Araucanía Region, approximately 670 kilometers from Santiago, there are more than 90,000 homes that use firewood as heating fuel and most of these houses have a very high energy demand due to their poor thermal envelope, causing polluting emissions to the air. The Frankfurt Condominium has a geothermal district power plant consisting of two water-water heat pumps of 70kW thermal each and a COP of 5, to generate heating and domestic hot water for 34 homes. This condominium has a hot water network for heating, which distributes it at a temperature of 38 to 40°C, and another domestic hot water network whose distribution temperature is 45°C and sanitary disinfection temperature at 65°C, every 7 days, which is done with the support of electrical resistances. According to studies carried out for the project, for the evaluation of the energy demand of a house in the Frankfurt condominium in comparison with a reference house, the first has a demand of 27 kWh/^{m2} per year while the reference house that meets the Chilean Thermal Regulations 2007 has a demand of 206 kWh/^{m2} per year, which has a saving of 87%. Compared to a house built before 2007, whose thermal demand is estimated at 300 kWh/^{m2} per year, the savings are even greater. This reveals the importance of having adequate thermal insulation in the energy consumption of buildings, where in this case, state-of-the-art technology for the supply of heating and domestic hot water could be incorporated.

2.2. District cooling

Similar to district heating, it consists of a centralized system that distributes cold water to multiple buildings through a network of underground pipes, which is used to air-condition indoor spaces efficiently. This technology makes it possible to replace numerous individual air conditioning systems, which are generally less efficient and highly demanding of electricity.

According to the UN Environment report, district cooling can use refrigerants with less environmental impact, even being able to use various sustainable sources of cold, such as absorption systems from waste heat, sea water, lakes, or thermal storage (ice banks) at night. Its implementation is key in adapting to climate change, especially in cities that face increasingly intense heat waves, so it represents a viable solution for densely populated urban areas in hot climates. In addition, it contributes significantly to the reduction of electricity consumption during peak demand hours, reducing the risk of overloads in the network. Due to its energy efficiency, ability to integrate with renewable energies and environmental benefits, district cooling is considered a fundamental tool for sustainable urban development.

Grouping the cold demand of a network of buildings, district cooling generates an economy of scale that improves efficiency, balances electrical loads and reduces fuel costs. Centralized plants avoid the costs of oversized individual systems (such as cooling plants in each building) and eliminate the need to install chillers and cooling towers, thus freeing up valuable space on roofs and buildings.

Success story of Colombia: La Alpujarra Thermal District

Name	Success story: La Alpujarra Thermal District
Location	Medellin, Colombia
Investment (capital expenditure)	$13,000
Installed capacity (TR)	3600
Technical Specifications	3 electric chillers with NH3; 1 absorption chiller with BrLi.
Energy sources	Cogeneration with natural gas and heat recovery. It is complemented by electricity supply from the interconnected grid.
Designer	BT Consultants
Constructor	Servipáramo SAS
Operator	Empresas Públicas de Medellín EPM
Entities that have supported the project	Ministry of Environment and Sustainable Development, State Secretariat for Economic Affairs of the Swiss Embassy in Colombia - SECO
Clients	Mayor's Office of Medellín Municipal Council Government of Antioquia Departmental Assembly Directorate of National Taxes and Customs - DIANAmacén Éxito de San Antonio Urban Development Company -EDUEdificio Inteligente de EPM Centre of conventions and exhibitions Plaza Mayor
Start of operations	December 2016
Benefits	Electricity consumption savings in buildings are between 15% and 20% 100% reduction in the use of Ozone Depleting Substances - ODS CO2 Emissions

Table 1. *Key data from the La Alpujarra cooling thermal district. Source: Thermal districts: Methodological guide, 2019*

2.3. Technological evolution

District energy has evolved significantly over almost 150 years since the introduction of modern district heating, adapting to technological advances, best practices and environmental needs. It is possible to recognize today the existence of four generations.

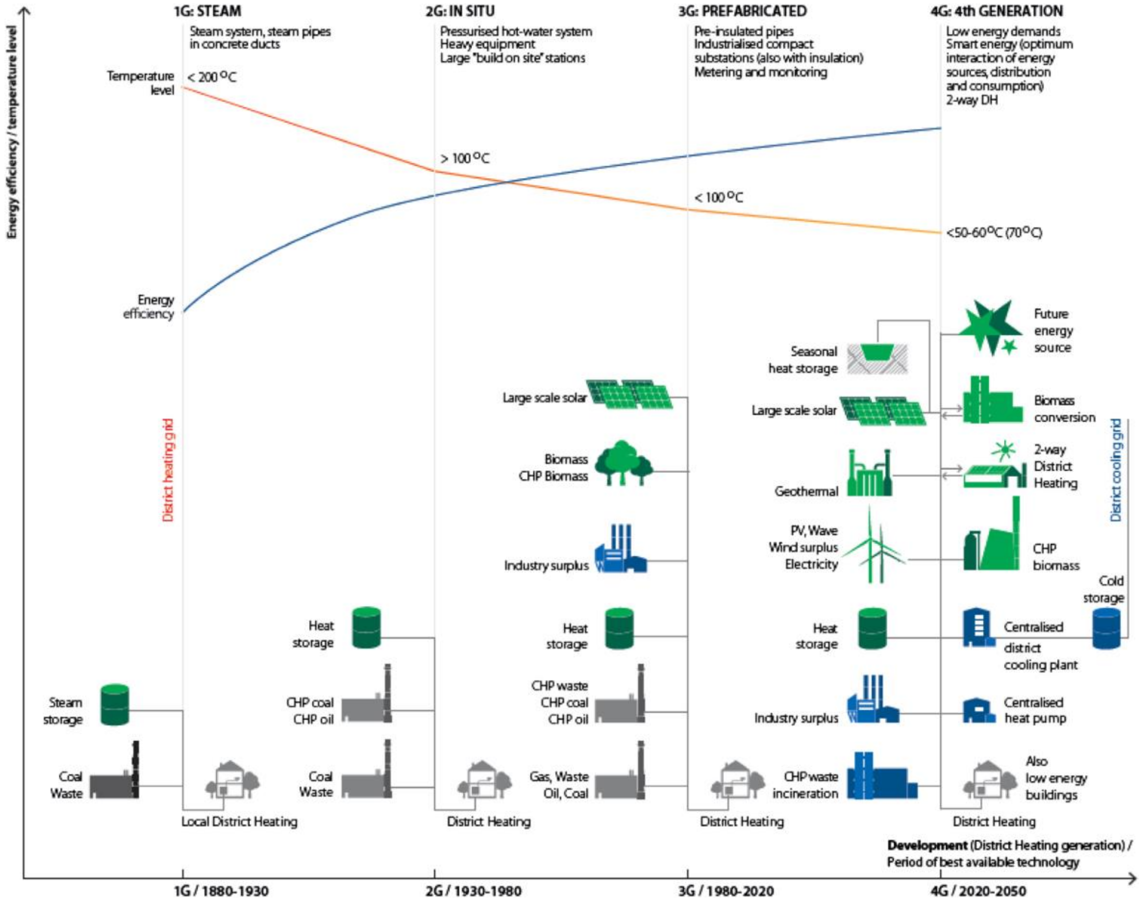

***Figure 1**. Comparison between the different generations of district energy. Source: 4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems.*

2.3.1. District heating

First Generation: These systems were introduced in the United States in the 1880s, they are characterized by using steam as a heat transfer fluid. Although they represented a significant advance for their time, today it is an obsolete technology, since high steam temperatures generate substantial heat losses, in addition to the risk of serious accidents, such as steam explosions. Although systems like those in New York and Paris still use steam, aftermarket programs have been successful in cities like Salzburg, Hamburg, and Munich.

Second Generation: Starting in the 1930s, this generation is characterized by using pressurized hot water as a heat carrier, with temperatures above 100 °C. The main motivation behind its implementation was the saving of fuel and improvement of comfort using an adequate expansion of cogeneration in urban areas. Systems such as those in the former Soviet Union made use of this technology, and traces of it can still be found in other parts of the world, particularly in the older sections of today's water-based district heating systems.

Third Generation: Introduced in the 70s and dominating system extensions since the 80s, this generation has established itself as the standard. It continues to use pressurized water as a heat transfer fluid, but with supply temperatures below 100°C. It is known as "Scandinavian district heating technology" because many component manufacturers are Scandinavian. A typical feature is the use of prefabricated and preinsulated pipes buried directly in the ground, compact substations and components that require less material. This technology has been widely adopted in system retrofits across Central and Eastern Europe, the former Soviet Union, and in all expansions and new systems in China, Korea, Europe, and the United States. USA and Canada. These systems offered security of supply, especially after the two oil crises, which boosted energy efficiency through cogeneration and the replacement of oil with local or cheaper fuels such as coal, biomass, waste and even solar and geothermal heat as a complement in some places.

Fourth Generation: This generation is characterized by working with even lower temperatures, between 30 − 70 °C for the supply and 20 °C for the return, which drastically reduces the heat losses of the network. It focuses on the ability to supply low-temperature domestic heating and hot water, distribute with minimal heat losses, recycle heat from low-temperature sources, and integrate renewable sources such as solar and geothermal. Furthermore, it has the capacity to be integrated into smart energy systems (electricity, gas, and thermal networks), to use predictive control, and it requires a robust institutional framework to ensure proper planning, cost structures, and incentives for the transition toward sustainable energy systems.

Fifth Generation It is characterized by a low-quality power source, mainly at room temperature, where each end user operates their own heat pump to adjust the supply temperature to their specific needs, unlike its predecessors that rely on a centralized heat plant. In this way, the distribution heat losses are negligible, making the pipe insulation irrelevant, thus reducing the investment. End-user heat pumps can be adapted to individual temperature requirements, and cooling can be integrated into the same network.

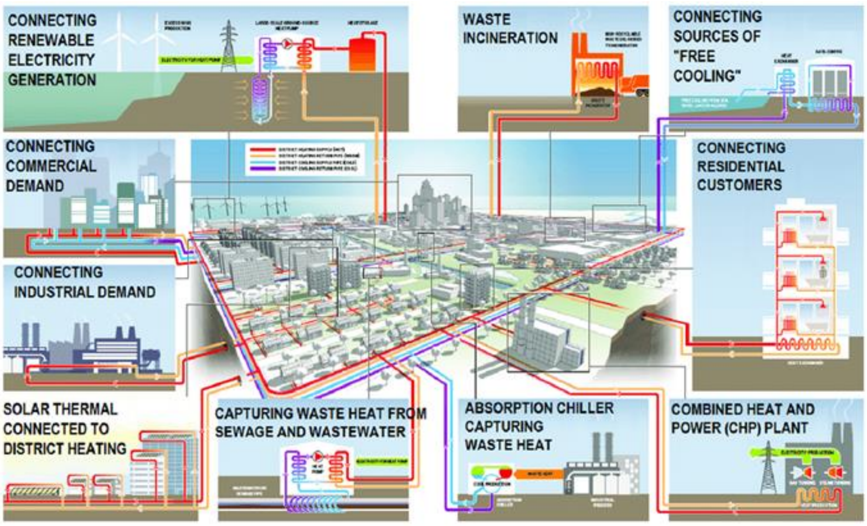

Figure 2. *Whole district energy system showing various end-users and the feeding in of heat and cooling souces (incluiding renewables) Riahi,L. (2015).*

Source: *District Energy in Cities: Unlocking the Potential of Energy Efficiency and Renewable Energy.*

2.3.2. District cooling

On the other hand, district cooling has evolved in parallel with heating.

First Generation: It emerged in the late 19th century and was based on the use of refrigerants distributed from centralized condensers to decentralized evaporators.

Second Generation: Later, in the 1960s, cold water was introduced as a distribution fluid, driven by large centralized mechanical coolers.

Third Generation: it became popular in the 90s, diversified the cold supply through the integration of absorption chillers, mechanical chillers and the use of natural sources and cold storage.

Fourth Generation: it is conceived as intelligent systems that interact dynamically with the electricity, district heating and gas networks.

2.4. Applicable business models

As with regulation, a wide range of business models are used worldwide in district energy systems, largely shaped by each country's regulatory framework and economic model. It also involves non-minor aspects such as the technical capacity, administrative powers and financial capacity of local public institutions, such as municipalities, which in many places exercise a model of public ownership fully developed by them, since they possess and have been reinforced with the capacities for this.

2.4.1. Fully public model

In general terms, it is possible to identify a fully public business model, in which the public sector (municipalities, regional governments, or national entities) undertakes the system's investment, owns and operates the assets, and receives the revenues, thereby assuming the full risk.

For macroeconomic and institutional structures such as those existing in Chile at the local level, this model is complex due to a series of factors that would have to be improved, such as the technical capacity of the professionals who make up the work teams, the financial credibility and credit capacity to face loans from banking institutions and the available own budgets. Even so, this model is not completely ruled out since there could be small district energy systems that connect, for example, only municipal buildings, which simplifies development.

In Colombia, contracts or commercial acts of companies owned by the State have their own contracting regime, subject to the rules contained in Law 80 of 1993. For the thermal energy service sales contract in public and fully private models, it is recommended to use the supply contract model. As for the selection of an investor for a public project, the ideal entity will depend on which is the public entity promoting the project. In international experiences, when the municipality or mayor's office finances the project, it does so with public funds. In Colombia, the selection of a developer for a totally public project must meet criteria of financial strength, good credibility and, above all, technical capacity to design and execute a large-scale infrastructure project. The municipalities normally lack an entity with these characteristics, so, in general, in Colombia, the mixed model for the development of large infrastructure works is given priority. Although there is no history of public administrations in the country leading this type of avant-garde initiatives and urban articulation among several actors, their participation can be especially decisive in the promotion and support of these projects.

2.4.2. Fully private model

In a fully private model, a private company or group of companies' finances develops and operates the thermal district. End users can be public or private sector buildings, which does not affect the nature of the business model.

In this model, the public sector plays an auxiliary role but does not intervene directly in the development of the project. Public entities can participate as promoters, facilitators and entities of regulation and control of the public welfare and ensure the best interests of the city or the development center.

Although this business model is not the most expanded, in district heating, nor in other network distribution services (gas, water, electricity), due to the high investment and transaction costs, in Chile there are private real estate developments, usually of high capital gain, which have exercised this business model in their developments, having the disadvantage of the impossibility of expanding outside the property of real estate development.

In Colombia, on the other hand, the totally private scheme has been the model that has been implemented in the current projects of energy districts in operation. Within the possible contractual schemes, the figure of the supply contract fits appropriately for private energy districts, in which case the thermal energy service provider undertakes to supply the user or end customer with a certain agreed amount of heat or cold, within a defined period and continuously or periodically. The project investor is selected under the criteria that apply for any investment project, the project, its cash flow estimates, its risks and returns, and the capital structure are presented to the investor, after which the investor applies a financial model to determine if the project is compatible with their expectations of internal profitability and risk aversion.

The developer of a private project is ideally a utility company or an energy service company, which has easy access to potential customers, possesses the financial capacity to drive projects and are robust enough to take on the risk of long-term projects and have credibility with users.

2.4.3. Mixed or public - private model

In a public-private model, as its name implies, companies from both areas intervene in the financing, construction and operation phases of the project.

Regarding mixed models, three modalities are common:

- The company that develops the project and operates it is a mixed company with public-private capital, which turns the project into a hybrid.
- Form a Joint-Venture in which both parties invest in the constitution of a district energy company or in which the public and private sectors finance different assets of the system.
- A concession model, in which the public entity normally develops a feasibility study of the project and then bids its construction and operation by a private party, thus turning the public entity into an owner and the private party into an operator. The operation is granted to the private party for a fixed period.

When the companies that build and operate the projects are constituted as mixed economy, in which the State has a participation of less than 50%, the contractual regime would be framed within private law and would be equal to that of a purely private project. If, on the other hand, the companies have a public participation of more than 50%, the applicable framework would be that described in the law.

In Chile, the concession-type public-private model is the one that has been explored for the promotion of pilot projects currently under development.

In Colombia, the "Distrito Térmico La Alpujarra" project in Medellín is an example of a mixed society scheme since the Empresas Públicas de Medellín (EPM) have such a public-private composition. The concession model has been proposed in the feasibility of some identified projects but has not been implemented.

2.4.4. Cooperative model

There is an emerging model in the world in the form of cooperatives, which represents an innovative form of decentralized financing based on citizen capital. These organizations allow residents to participate in the ownership and management of heating networks, generating trust, reducing costs and promoting sustainable local solutions. Their experience shows that partnerships with local governments and developers can be key to accelerating the implementation of sustainable district energy systems. This model combines citizen participation, social inclusion and technical efficiency.

The challenges for Chile lie in better promoting business models that are better adapted to the current socio-economic and regulatory reality, considering that the high investments that district energy systems have require financial structures that support the recovery of capital in the long term, as well as recognizing the technical and financial deficiencies that the public sector has. The precise mix of interests is key to achieving the social benefits sought by the public sector and the profitability sought by the private sector.

In Colombia, the private model has been the promoter of the infrastructures of energy districts, mainly for cooling and air conditioning. This has been possible due to the familiarity of energy service companies with the financial and investment schemes required for large-scale infrastructure projects. The challenge in Colombia will be to continue promoting projects at different market scales and expand the participation of other types of investors who continue to materialize new projects in the country.

2.5. Considerations for the implementation of a District Energy project.

The implementation of a district energy project and infrastructure or energy district can have various ways of approaching it, since each case will have specific characteristics depending on its application, type of users, urban or industrial use, climatic and geographical conditions and many other commercial and financial considerations.

Within the experience acquired in Colombia and Chile, and from other examples in other parts of the world, some general steps can be identified that allow a methodological approach to be taken to bring a project to implementation, the main ones being the following:

2.5.1. Identification of the potential development area of the project

During the planning phase of an energy district, the selection of the development area or location must obey a systematic process that allows establishing and quantifying the relationship between the supply of primary energy and the demand for thermal energy.

In general, an area must meet the following characteristics to be considered attractive for implementing an energy district:

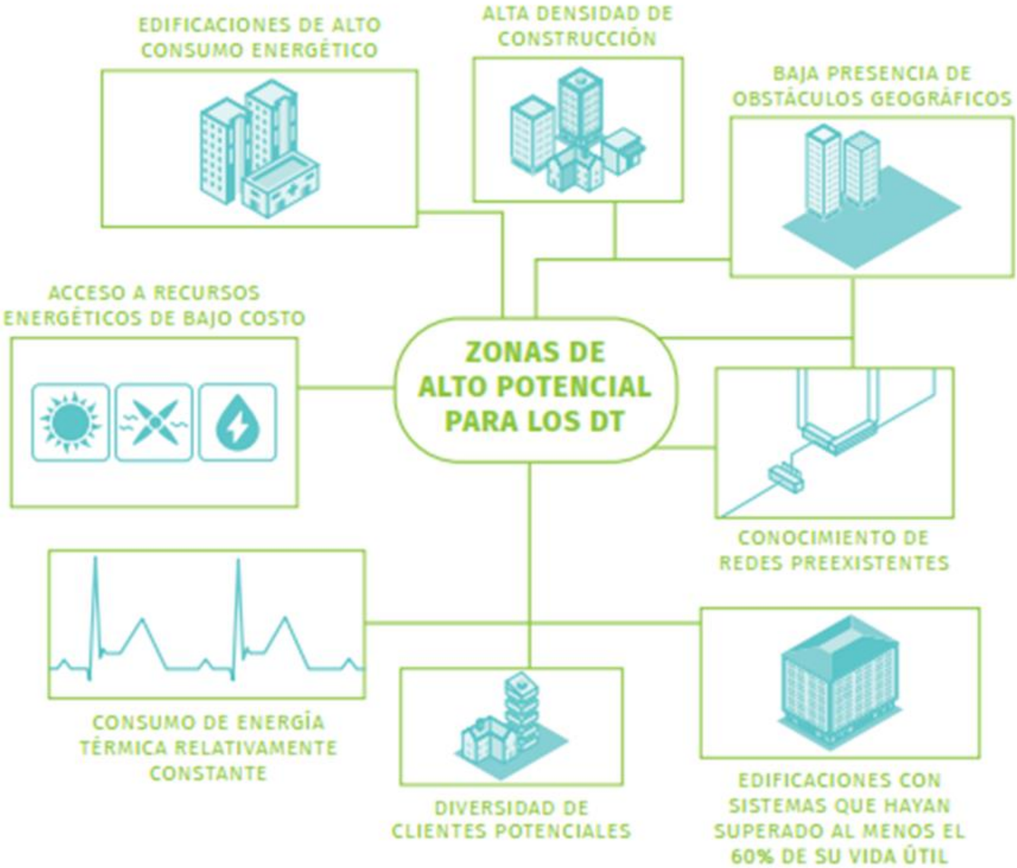

Figure 3. *Characteristics of a high potential area for energy district*

Source: *Methodological Guide "Colombia Thermal Districts Project"*

The urban expansion areas are important for the development of an energy district, since they are usually long-term projects that combine mixed land uses and where it would be easy to develop a system during its planning phase. Likewise, new industrial areas, industrial parks or ports are examples of projects where energy districts are an efficient and sustainable design alternative.

An important tool is the energy maps or heat maps of urban and industrial areas, since they can incorporate information on energy demand and at the same time the georeferenced energy sources in specific areas to be studied. This tool is very useful for city planners, planning industrial areas and for companies or consortia developing projects.

2.5.2. Conceptual engineering and preliminary feasibility

The development of conceptual engineering, pre-feasibility and technical and commercial feasibility study allows us to identify if the project will be interesting for investors, technical developers, commercial operators and end users. This conceptual engineering must address and evaluate aspects such as the place of implementation of the energy production plant, distribution pipeline routes, capacity to be installed and capacity demanded by potential end users. It must also establish a preliminary business structure and general financial model that identifies the benefits for each project actor. Ideally, this process should be carried out with the identification and commitment of the key actors of the project, involving anchor clients, developer/operator, investors and, if possible, local government entities where the energy district is expected to be implemented.

2.5.3. Identification of energy sources

Depending on the place where the development of a district energy system is planned, it is important to identify the energy supply for the operation of the thermal plant and the production of heat or cold, in order to select technologies that use local and low price resources, which will result in obtaining final service prices that are competitive with their substitutes.

It is recommended that the project developer carry out a process of rapid quantitative assessments of the possibility of accessing renewable or residual energy resources, which when integrated into an energy district represent savings in operational costs. In this regard, according to the geographical and topographical characteristics, access to renewable sources such as biomass, geothermal energy, solar energy, freshwater reservoirs, rivers, the sea and groundwater, among others, may be evaluated. It is possible to evaluate the use of energy from municipal solid waste incineration plants.

- Biomass: Through its different formats, such as chips, pellets or pruning residues, pits or others, it can be used as an energy source in specialized boilers. Chile is recognized for its industry associated with the forestry field, which can result in an advantage when it comes to proposing projects that are close to this energy source.
- Geothermal Energy: Refers to geothermal energy for direct use, in its various forms of use through surface water, groundwater or soil, which, by means of heat pumps, take advantage of the heat of these natural sources.
- Solar energy: It can be used as a source of electrical energy through photovoltaic systems, or the possibility of using solar thermal power plants for the use of direct heat can be identified either for heating or for absorption cooling systems.
- Free cooling with water bodies: It is possible to use the temperature differentials of the water bodies as direct cooling, or the soil temperature using groundwater. Although they may not be sufficient to cover the total demand of an energy district, they can be used to improve the efficiency of condensing systems or as precooling or preheating systems in the thermal energy production process.
- Seawater Cooling (SWAC): Deep seawater cooling consists of the use of this resource directly for the cooling of spaces without an intermediate cooling production. This represents high efficiency for the project, however, investment costs to reach the required depth at sea depend on geography and may not be easily affordable.
- Waste heat use: for projects located near industrial plants or datacenters, the waste heat resource from these processes can be identified as a primary source for the energy district. This residual energy can be translated into a low-cost source that improves the environmental and economic performance of the project.

- Municipal solid waste: Municipal solid waste is often an excellent source of unused energy, which can be obtained from processes such as aerobic bio digestion, anaerobic bio digestion or incineration. The projects for the energy use of municipal solid waste are highly complex, not only due to the technical aspect (waste characterization studies and system engineering), but also in terms of environmental permits and community awareness.
- Cogeneration and trigeneration: Cogeneration is a component that has multiple purposes in an energy district. When electric power is generated, it can be sold to the grid or consumed directly in electric chillers within a plant. Heat can be used to generate steam, hot or cold water through an absorption chiller. The mechanisms commonly used in cogeneration systems that are part of energy districts work from turbines or internal combustion engines that consume some type of fossil fuel to generate electricity. These feed the electric coolers, and the exhaust gases are used thermally. Trigeneration systems use the same components as cogeneration and cold production systems, but the plant is designed in such a way that its provision is simultaneous.

2.5.4. Characterization of anchor customers or key customers

Once the area where the district energy feasibility study will be carried out has been selected, it is necessary to quantify the thermal demand of potential customers, as well as to identify the highest-consuming users, who are considered critical to the project's viability (anchor customers). For an optimal demand estimate, it is ideal to collect the information described above for all anchor customers and for as many potential users as possible. The processing of the information is a task that is recommended to be carried out by an engineering team with experience in the sizing of thermal systems.

Figure 4. *Characteristics of key end users*

Source: *Methodological Guide "Colombia Thermal Districts Project"*

2.5.5. Feasibility Assessment and Impacts

In this phase of the process, it is expected to have consistent involvement of the project actors, and an evaluation of social and environmental impacts is required to identify the benefits of the project and deepen the additional benefits for the entire value chain. In Chile, there is the Environmental Impact Assessment System, a formal stage of investment projects that quantifies the environmental impacts of a project, however, this is required in advanced stages of the project, so the reference in this more general stage seeks to preliminarily identify this type of environmental impacts.

For the constructive aspects, the identification of possible physical/geographical barriers in the implementation of the distribution network and the energy production plant will be essential to determine locations and the definitive network layouts of the project. The identification of energy sources and therefore the use of available resources can contribute to improving the environmental and financial savings of conceptual engineering. Adjusting user demand calculations by identifying energy consumption profiles contributes to energy savings in the final technical design. And a relevant point that must be evaluated at each step of the process is the interest and commitment of end users to be part of the development and future connection to the energy district project.

2.5.6. Financial model and business proposal

From conceptual engineering, it is necessary to constantly evaluate and adjust the variables that define the financial model, to identify the financial viability of the project at each step of the process. At the end of this methodology, what is sought is that all the actors involved know their benefits when part of the project and the willingness to establish a commercial relationship is confirmed. Once the technical model and this financial analysis have been established, the project can begin to materialize by establishing contracts for the operation and supply of the energy service to users.

2.5.7. Financial model and business proposal

There are multiple models of regulation that countries with extensive development of district energy follow, ranging from detailed regulation of all technical and operational aspects of the networks, to simplified models that establish general guidelines that leave the establishment of construction and operating conditions in the hands of the private developer. For example, in the European Union district energy is predominantly a matter of regulation at the national level, that is, systems are not regulated uniformly among EU member countries, since there is a wide variety of national, economic, cultural and historical factors that have led to a very diverse spectrum between countries, where it has even migrated from one model to another within the same country. This is the case in Denmark and Sweden, where the former has a highly regulated district heating industry, while the latter has taken a light approach to legislation. Or the case of the United Kingdom where there is no specific legal structure for district heating and it has been developed based on a regulatory framework of general laws.

Matters such as the ownership of facilities, the category of public service, easements for the deployment of networks, compatibility with other activities, land use of the territory, pricing, bodies with competence, exploitation of energy sources, control, technical standards, incentives, subsidiary structure and operational requirements, are some of the most relevant aspects of this type of systems in order to facilitate the implementation of district energy projects in the countries, where depending on the legislative characteristics, the parliamentary regime and the socio-cultural framework of each country, these matters are addressed to a greater or lesser extent. Although the central and essential point for the correct development of district energy is the establishment of clear rules to facilitate insertion in cities.

3. Evolution of District Energy in Chile

As a result of the environmental problems of poor air quality in several cities in the central-southern area of Chile, which is directly associated with a highly polluting and inefficient heating sector, the main reason for the development of district energy in this country is to generate transformational changes in the heating matrix through the provision of this type of systems for the inhabitants of these cities. However, with the rapid changes that have occurred worldwide associated with climate change, also visible in Chile, the variable of mitigation of greenhouse gases promoted by these systems has been incorporated, allowing today with its promotion not only to attack objectives of reduction of local pollutants but also of mitigation of global pollutants and implementation of energy efficiency.

3.1. Heating and Cooling Sector in Chile

Chile has about 4,300 kilometers in length and a varied geography, so there are various types of climate and consequently different thermal demands to meet the needs of heat and cold. More than 70% of energy consumption in buildings in Chile corresponds to thermal uses (heating, hot water and food cooking). As latitude increases towards the extreme south regions, there are high demands for thermal energy for heating. Otherwise, it occurs towards the north of the country, where it is possible to find the driest desert in the world, so high demands for cooling are experienced. These geographical and climatic conditions have meant that, in energy terms, there is a close relationship between the construction conditions of buildings, the demand for thermal energy, the air conditioning devices and the energy used to provide heating or cooling.

The main sources of energy used to meet heating demands in Chile are firewood, kerosene, liquefied petroleum gas and natural gas (in cities that have networks). Firewood is predominant in its use and is consumed in poor quality conditions, generally wet, and used in combustion devices with low energy efficiency and zero emission control.

The problem then, caused by the massive use of wet firewood, a high demand for this energy product of poor thermal insulation and the use of inefficient and polluting individual devices, was a high air pollution by particulate matter (MP2.5 and MP10) emitted by the heating sector, specifically the residential sector, which was evidenced in the main and highly populated cities of the southern regions of the country, such as Temuco, Osorno and Coyhaique, which constantly appear in the first places of the most polluted cities in Latin America.

In 2000, a major change in the construction of homes in Chile in terms of energy performance began through the Thermal Regulation of the Ministry of Housing and Urbanism (MINVU), which is the regulatory instrument that establishes the minimum requirements for thermal insulation for roofs, walls, floors and windows of homes in Chile.

In 2000, the first stage of the thermal regulation was enacted, which required energy performance characteristics, mainly insulation, to the roofs of new homes. As of 2007, the second stage of the thermal regulation came into force, which extended the thermal insulation requirements for new housing to walls, ventilated floors and windows. In the year 2025, the third stage of thermal regulation was enacted in Chile, which will came into force in November 2025. This modification constitutes a significant advance to improve the energy efficiency of homes and achieve conditions of indoor comfort and healthiness in homes. The change in the regulations is aimed at buildings for residential use and includes, for the first time, minimum thermal behavior requirements for education and health establishments, which represents a qualitative advance for these sectors. Despite these efforts, the liability of the entire park built before the year 2000 is massive and constitutes more than 65% of the park built, therefore, there are important gaps in thermal insulation in homes.

Related to technological changes, from 2010 onwards, public programs have been implemented to replace wood-burning heaters with cleaner systems, as a way to reduce polluting emissions from the residential sector and thereby restore air quality levels to protect the health of the population.

For their part, non-residential buildings, such as hospitals or commercial or administrative buildings, mainly use centralized systems with fossil fuels, such as liquefied petroleum gas or natural gas, and even coal for their operation.

On the other hand, as a result of the growing needs for air conditioning or cooling, Chile in recent years has experienced a boom in the use of air conditioning equipment, which has increased fivefold between 2018 and 2023, due to greater accessibility, lower prices, increased supply and greater performance that make them more competitive compared to other options.

3.2. Regulatory context of District Energy in Chile

In Chile, there is no specific regulatory framework for district energy. Despite the above, there is a general regulatory treatment that regulates all the parts or components of this type of projects separately, in matters such as territorial planning, real estate construction, energy and the environment, so, if this is considered as a whole, it can be argued that, although in a fragmented way, there is applicable regulation.

In fact, the Atmospheric Decontamination Plans of the Ministry of the Environment, which contain promotional measures for the implementation of district energy projects, among others, being a regulatory document promulgated by the President of the Republic, the definition established there for district heating becomes official, which is ratified by a clarification made in 2021 by the Ministry of Housing and Urbanism (DDU 459) in relation to the compatibility of district energy projects with territorial planning. The definition is: *"District Heating: centralized heat generation and distribution system, through which heating and domestic hot water service are provided to a set of networked buildings."* In the same clarification issued by the Ministry of Housing and Urbanism, the permitted land uses for installing the thermal plant required for this type of system are specified. This was further expanded through a regulatory amendment to the General Ordinance on Urban Planning and Construction issued by the same Ministry in 2023, thereby facilitating the installation of thermal plants across a wider range of land uses and removing a major barrier that had constrained the viability of projects in cities.

On the other hand, appealing to structured legal vehicles for the development of public works, it has been possible to interpret the compatibility of public and urban works concessional systems for the development of these systems, which although they were designed for other purposes fit with the development of district energy projects when analyzed as an intervention of public space with infrastructure works, thus allowing the possibility of establishing public-private partnerships for their implementation.

As far as public policies are concerned, Chile has a National Energy Policy in which there is an ambitious goal of connecting 500,000 users to district heating systems by 2050, thus contributing to the country's goal of achieving carbon neutrality in that year. In addition, other policies such as the National Energy Efficiency Plan, Air Decontamination Plans and the Long-term Climate Strategy, including some Community Energy Strategies, promote district heating as a technology that allows progress in improving air quality, reducing GHG and black carbon, which is certainly aligned with the country's goals to achieve the National Determined Contribution.

3.3. Evolution of District Energy in Chile

In Chile there are two emblematic, long-range projects, which since the 1970s continue to operate to this day. One of them is located in the Metropolitan Region and supplies district heating (heating and domestic hot water) to more than 1,500 apartments in residential towers in the heart of the city of Santiago. The other project in operation since this time is that of the University of Concepción, which supplies district heating to much of the university campus of the city of Concepción in the Biobío Region, approximately 500 kilometers south of Santiago.

Interestingly, after these developments, no further projects of that scale and scope emerged. It was until 2009 when district heating reappeared with a project that was built and continues to operate to date in the private condominium "Frankfurt" in the city of Temuco, Araucanía Region.

There are other projects currently in operation, smaller in scale and limited to private residential complexes; however, they were designed as centralized heating systems and therefore lack the expansion potential that is characteristic of this type of project.

It is because of these isolated cases, which did not have a greater replication in other areas or cities, that the State of Chile has been promoting district energy since 2010. Through the performance of different technical and economic analyses, at that time the focus was on promoting district heating to decontaminate cities that had air quality problems due to emissions from the residential heating sector. Thus, between 2010 and 2018, a dozen studies were carried out with this objective, without having reached the implementation stage.

It was until 2018 that the focus of work expanded with the creation of the Geothermal and District Energy Unit within the Ministry of Energy of Chile, where the concept of district energy began to be established as a way to amplify the analysis of projects and the promotion of this issue towards energy efficiency and renewable energies, and not only for heating, in a broader spectrum than that visualized in the first years of work.

In 2020, Chile was awarded a program from the Global Environment Facility (GEF) called "Accelerating investment in district and renewable energy systems in Chile" (hereinafter

GEF7 District Energy Program), which was the successor of the global initiative of District Energy in Cities of UN Environment, in which Chile participated from 2017 to that date.

With the start of the GEF7 District Energy Program in Chile, the National Office of District Energy – ONED – was founded in the Energy Sustainability Agency of Chile, which in addition to being responsible for the execution of the various activities of the program, quickly positioned itself as a technical entity of advice and linkage with the private and public sector. Through these efforts, the Program succeeded in strengthening the institutional framework dedicated to promoting district energy, as well as sparking interest from both the public and private sectors in advancing investment projects in cities, with a broad-based rollout of capacity-building and dissemination of this technological alternative. To this day this program is still in force in Chile and ends in January 2027.

Thanks to this overarching framework of work, the State is now coordinating the implementation of two pilot projects, with the aim of replicating and scaling these experiences toward the creation of a market. A project is located in the city of Santiago, Metropolitan Region, in the communes of Recoleta and Independencia, and seeks to supply district energy, that is, heat and cold, to health and educational buildings in these communes, with a significant territorial deployment and investments that border on 35 million dollars, which is soon to be tendered. The other project is located in the city of Talca, Maule Region, about 250 kilometers south of Santiago, and seeks to build a new housing complex contemplating the district heating system from the beginning, which would allow it to expand over time with the construction of 4 future stages of housing construction, reaching a total of more than 2,000 homes.

With what has been done to date and considering the most recent studies and reports in Chile, a district energy market potential of 850 MW has been analyzed (based on pre-feasibility studies and master plans developed in 5 cities of the country), with the consequent potential of reducing greenhouse gases of 193,000 t CO_2e/year.

These advances suggest that the deployment of district energy in Chile will be substantial in the coming years, where the Ministry of Energy of Chile and the Energy Sustainability Agency are working to meet these goals and thereby achieve the creation, in the medium term, of a market for district energy.

For more information on progress in Chile, it is suggested to visit the website www.energiadistrital.cl where it will be possible to find technical studies, news, dissemination material, thematic guides, among others.

4. Evolution of Energy Districts in Colombia

The development of Energy Districts responds to the urgent need for cities to migrate to a sustainable urban development model, in an increasingly challenging context. In this regard, Colombia is a pioneer in the region in promoting this technology and business model, with the conviction that it will be a key component in shaping sustainable cities.

4.1. Heating and Cooling Sector in Colombia

The use of air conditioning systems in Colombia is immersed and characterized by the residential, tertiary and industrial sectors. According to estimates from the Analysis of cooling demand and its potential for flexibility in Colombia UK Impact (2023), it was determined that for the residential and tertiary sector, cooling systems consume a total of 33% of energy. Likewise, it is estimated that electricity demand for 2030 will grow by up to 42.8%, reaching 117.72 PJ (32.7 TWh) of energy.

Regarding the ownership of air conditioning systems in the residential sector, according to the data reported in the UPME demand projection for electrical energy, maximum power and natural gas 2023-2037, 4.18% of households in Colombia by 2022 had air conditioning equipment. As a result of the use of these systems, a total demand of 45.7 PJ UK Impact (2023) is considered for air conditioning and refrigeration systems with a growth in demand of 2.76% per year for the period 2022-2030.

For the tertiary sector (commercial and public), total energy demand for cooling systems in 2018 is estimated at 27.8 PJ, with the main consuming sectors being offices, hotels, hospitals, shopping centers, among others. For this sector, an annual growth of 2.52% in demand for air conditioning systems is estimated.

In the industrial sector, it was determined that cooling systems demand 9 PJ of energy for cooling systems for use in the production of food, beverages and tobacco products, production of non-metallic minerals and the production of substances and chemicals. In this sector, a 2.17% growth in demand for air conditioning systems is estimated.

However, the conditions of each city are different with respect to the uses of the systems, in the following graph you can identify the characteristics of use by sector:

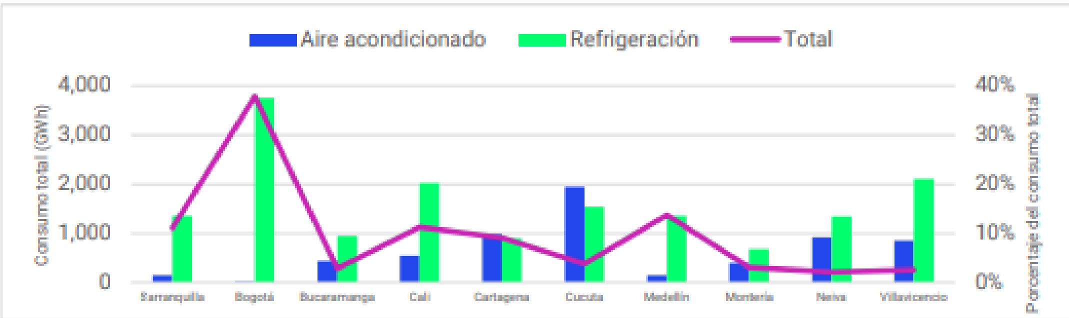

Figure 5. *Energy consumption in GWh for the residential sector. Source: Analysis of cooling demand and its potential for flexibility in Colombia UK Pact (2023)*

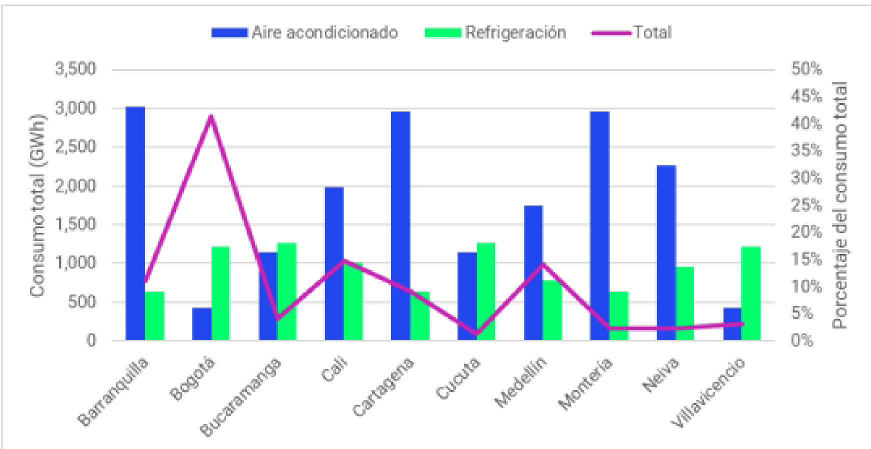

Figure 6. *Energy consumption in GWh for the tertiary sector. Source: Analysis of cooling demand and its potential for flexibility in Colombia UK Pact (2023)*

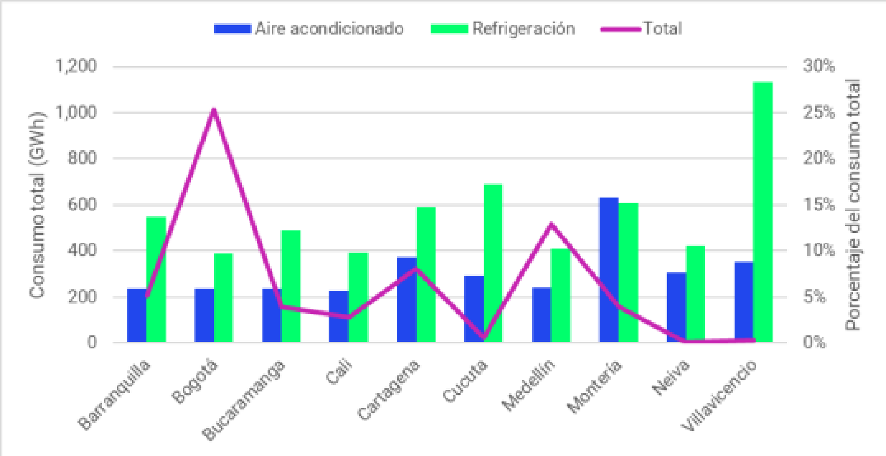

Figure 7*. Energy consumption in GWh for the industrial sector. Source: Analysis of cooling demand and its potential for flexibility in Colombia UK Pact (2023)*

There is therefore a direct relationship between heating and cooling demand and climatic conditions; however, in cities such as Bogotá, where the use of air conditioning is not common, this may change due to climate change.

4.2. Regulatory context of Energy Districts in Colombia

The implementation of Energy Districts in Colombia is part of the mitigation measures for nationally determined contributions – NDC by the Ministry of Environment and Sustainable Development. Likewise, they are an energy efficiency measure identified in the Rational Energy Use Program of the Mining and Energy Planning Unit (UPME) and are covered by a dedicated chapter in the Technical Regulation for Thermal Installations (RETSIT), issued by the Ministry of Mines and Energy in December 2023.

To strengthen the approach to efficient energy management and climate change, Law 2169 of 2021 defines the need to incorporate actions to consolidate various measures into sectoral planning instruments, including for the massification and promotion of energy districts as a centralized source of energy. Furthermore, there are other key regulations that promote the rational and efficient use of energy and related incentives, including those associated with electricity self-generation and the sale of surplus energy, as well as cogeneration, which is defined as the simultaneous production of thermal and electric energy.

The promotion of energy districts has been included in territorial planning and climate change plans in some Colombian cities.

However, no regulations have been developed for the construction of distribution networks from energy heat or cold districts.

Below, we present a summary of the regulatory framework in Colombia related to district energy:

NORMA	PURPOSE
Resolution 40773 of 2023 Ministry of Mines and Energy	By which the Technical Regulation for Thermal Installations - RETSIT is issued.
Law 2099 of 2021	By means of which provisions are dictated for the energy transition, the dynamization of the energy market, the

	economic reactivation of the country and other provisions are dictated
Resolution 030 of 2018 CREG: Energy and Gas Regulation Commission.	Operational and commercial aspects are regulated to allow the integration of small-scale self-generation and distributed generation into the National Interconnected System
Resolution 585 of 2017 Mining and Energy Planning Unit	Establish the procedure to evaluate and issue concepts on evaluated projects and certify the environmental benefit for energy efficiency projects and access the tax benefit established in Decree 1625 of 2016 of Min Environment.
Single Environmental Decree 1076 of 2015 Min Environment	In chapter 3, Environmental Licenses, section 1, articles 2.2.2.3.2.2 and 2.2.2.3.2.3 indicate the activities subject to licensing. Thermal District projects are not subject to environmental licensing processes, although design characteristics must be considered.
Resolution 5 of 2010: Energy and Gas Regulation Commission.	By which the technical requirements and conditions that cogeneration processes must meet are determined and this activity is regulated.
Law 697 of 2001	Through which the rational and efficient use of energy is encouraged, the use of alternative energy is promoted and other provisions are dictated.
Law 1715 of 2014	Through which the integration of non-conventional renewable energy sources into the national energy system is regulated.

Table 2. *Regulations in Colombia related to district energy*

Moreover, Colombia has a regulatory framework governing the import and export of refrigerant gases, mainly aimed at implementing the Montreal Protocol for the phase-out of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), as well as the Kigali Amendment for the reduction of hydrofluorocarbons (HFCs).Other regulatory parts identified are related to equipment containing refrigerant gases and the disposal of these as hazardous waste.

Some Colombian cities have a regulatory framework focused on the promotion of energy districts. Among the regulatory instruments are the Territorial Planning Plans, the Management Plans to face climate change and the Local Environmental Management Plans[1].

4.3. Evolution of Energy Districts in Colombia

The implementation of energy districts in Colombia has been led by the Ministry of Mines and Energy and the Ministry of Environment and Sustainable Development of Colombia, with the support of the Embassy of Switzerland - Secretariat for Economic Cooperation and Development (SECO) and the United Nations Industrial Development Organization (UNIDO), through the Energy Districts Program in Colombia.

In its first phase (2013-2019), the construction of the La Alpujarra thermal district, located in the administrative center of Medellín, was achieved as a demonstration pilot and the first energy district in Colombia and Latin America. During this period, work began with the national government and the governments of 7 cities to improve the conditions of the

[1] More information on the regulatory framework related to Energy Districts in Colombia at https://www.distritoenergetico.com/prueba/normatividad/

national and local regulatory framework and provide technical assistance for the development of energy districts.

The second phase of the project (2019-2024) allowed strengthening the institutional, knowledge and market conditions to accelerate the dissemination of Energy Districts as an innovative and efficient urban infrastructure model, especially as regards the air conditioning service in urban environments, and heat distribution for industrial applications. Three main components were worked on: Institutional, sustainability of knowledge and market development.

In this period, the development of an institutional and regulatory framework was achieved that allowed the inclusion of the Energy Districts as a solution in public policies of 10 cities and the issuance of the Technical Regulation for Thermal Installations – RETSIT by the Ministry of Mines and Energy. Likewise, more than 20 technical and economic feasibility studies were prepared, which allowed the selection of at least 12 potential projects for the implementation of district energy solutions or outsourced cooling services.

Colombia has a catalog of Qualifications for the refrigeration, air conditioning and energy districts sector in the process of approval and Sectoral Labor Competence Standards for the certification of operators of energy districts and RETSIT inspectors.

Currently, Colombia has 6 cooling/industrial Energy Districts in operation, and it is expected to have at least 8 systems operating by 2030.

For the period 2025 to 2027, in Colombia it is expected to promote a greater implementation and deployment of Energy Districts projects, promoting the inclusion of renewable energies for their operation.

These advances suggest that the deployment of Energy Districts in Colombia and District Energy in Chile will be substantial in the coming years, where different organizations in both countries are working to meet these goals and thereby achieve the creation, in the medium term, of a solid market.

5. Main Barriers in Chile and Colombia

5.1. Regulatory

Despite the advances that Chile has in relation to interpretations, creations or regulatory modifications, the regulatory dispersion presented by the fragmented legal bodies and originally designed for other purposes is still insufficient, due to the particular and multisectoral nature of this type of projects. Therefore, the creation of a specific regulatory framework for the development of district energy in Chile is presented as an important challenge to facilitate and deliver clear rules for the massive implementation of this type of systems. A specific regulatory framework would centralize the powers of promotion, financing and supervision of projects, among other powers and rights, which today falls on organizations that do not necessarily present the same motivation, challenges or institutional goals of those who promote the projects, or, they are not familiar with the energy field, therefore it costs them to align with the same objective of the Ministry of Energy.

In Colombia, the Energy Districts strategy has been successful and has made significant progress in the creation and consolidation of a favorable framework for energy districts. A relevant milestone is the construction and adoption of the Technical Regulation for Thermal Installations by the Ministry of Mines and Energy, which is a national and international reference for the regulation of thermal energy as a service and as an end use. This regulation establishes energy efficiency and sustainability criteria for energy districts as well as for individual facilities to promote that the new facilities are sustainable and conducive to future connections to urban thermal energy distribution networks. The strategy also contributed to the establishment of favorable conditions at the institutional and market levels and achieved important initial results in promoting this infrastructure in Colombian cities through local regulations.

While energy districts have been strategically included in different regulatory instruments, Colombia still lacks a solid and harmonized institutional and regulatory framework for energy districts. Therefore, there is still work to be done for the adoption of a regulatory instrument that defines energy districts as energy service infrastructure, their technical, operational and market conditions, among other aspects.

5.2. Financial

Energy districts in Colombia are a growing reality, with great benefits for their users and a significant potential for economic success for their developers and operators. However, due to the novelty of the solution, its implementation still faces some barriers, one of which is financing. Energy districts are not easy to finance through direct investment or commercial credit from the financial sector. This situation is due, on the one hand, to the rigidity and conservative profile of the Colombian financial sector; but it is also a consequence of other circumstances that have not been adequately managed by government entities, local governments, development banks, insurers, managers, users and other stakeholders in energy districts. Particularly in Colombia, developers of energy efficiency and energy projects are not interested in undertaking projects with a long recovery period and high capital expenditure, even if the project generates a high profitability. While this is inherent to the business and project cycle of energy districts, stronger communication tools can be generated to convey value to end users in terms of long-term savings, co-benefits and the quantification of operational risks in the investment decision and thus reduce the focus of developers on short-term benefits. Working with the financial sector to develop and test customized solutions for energy districts could send a strong signal to the market, particularly the private sector.

In the case of Chile, although it is not yet possible to draw conclusions regarding project financing, it can be noted that the financial barriers faced by project developers are likely to be similar to those in Colombia.

5.3. Technical

In Chile and Colombia there are leading engineering companies with the technical capacity to design and execute energy district projects, and in Colombia there is extensive experience in the development of large heat or cold distribution projects. Similarly, well-known district energy project developers and operators worldwide, as well as component and equipment manufacturers, have maintained a local presence for years and are familiar with the specific features of the markets in both countries. In Colombia there is a group of designers and consultants with technical competence and even international certifications, and a consolidated market of installers and integrators of thermal engineering technology, which have been developed in conjunction with the mining and oil industry. However, this group is still small for the rapid promotion of energy districts that is expected and needed in Colombia. For its part, Chile envisions the inclusion of foreign companies in the development of projects, which would also reinforce the eventual lack of a market for companies specialized in the technical design, installation, maintenance and operation of district energy systems.

Regarding information on thermal energy demand, which is key to project design, in the case of Colombia this data is unclear and, in many cases, measurements and consumption characterization are lacking. This lack of information from official sources on the consumption and end use of energy makes it difficult to identify opportunities for the development of Energy Districts, as well as the adequate sizing of their systems. Strengthening local and regional tools and capacities to map, assess and disseminate the potential of renewable energy sources for energy districts is also a key priority. Chile in this sense, has advanced with the realization of various studies to characterize energy consumption in different sectors and the realization of heat maps, which show the demand and supply of georeferenced thermal energy in the territory, to indicate the most favorable places for the implementation of projects.

5.4. Institutional

In Chile, a barrier that has become evident in recent years is the lack of institutional authority to promote projects, particularly within the Ministry of Energy. This is related to the country’s regulatory framework, and it places a heavy burden on inter-institutional coordination with other public bodies to align efforts, manage expectations, and leverage each institution’s powers to facilitate project implementation.

This situation is further exacerbated by the lack of technical capacity in other public institutions, particularly at the municipal level in some cases, where they do not have the technical staff needed to understand and structure projects in their territories.

6. Opportunities for Chile and Colombia

As the next natural step in the technological transition of the heating and cooling sector in both countries, the need to accelerate the implementation of district energy projects has become evident.

That is why, together with the public policies designed, regulatory changes implemented, country capacities created to date, greater investment is required, availability of public resources for subsidies, political will and public-private coordination to massify the development of projects. It is also necessary to continue refining and updating public policies and regulations to adapt to the dynamic global challenges in terms of energy and climate change.

All these aspects are presented as enormous opportunities in both Chile and Colombia mainly due to factors such as:

- Policies to promote and boost district energy and energy districts.
- Alignment with other public policies on energy efficiency, renewable energy, air quality, and climate change.
- Existence and improvement of the enabling regulation for district energy.
- Establishment of country goals that require the advancement of different technological alternatives.
- Accession to international agreements
- The possibility of getting experiences from other countries that have more years of development.
- The possibility of establishing cooperation ties with international organizations specialized in the field.
- Presence in countries and the region of companies with extensive experience.
- Public and private technical capacity to promote projects.

The following are 2 interesting points to show, following the progress of both countries in these areas:

6.1. Integration with energy efficiency in buildings

The energy efficiency in buildings constitutes a synergistic condition with the implementation of district energy systems. Reducing and stabilizing the thermal demand, through passive measures (bioclimatic designs, improvement of envelope, airtightness, solar control, efficient ventilation, etc.), allows to size better systems that can work at adequate temperatures, decreasing the power required in equipment and networks, as well as lower temperatures (in the case of heating), as well as the use of more efficient and sustainable technologies, such as centralized heat pumps, waste heat recovery, control and automation systems and lower capacity biomass boilers, including integration with non-conventional energy sources. This translates into lower investment, operation and maintenance costs, and ultimately a lower rate for end users, making the district energy system more technically and economically viable.

6.1.1. Opportunities in Chile

In this context, the updating of the Thermal Regulation and the guidelines of the National Energy Efficiency Plan 2022 - 2026 (PNEE) of Chile are essential to ensure buildings compatible with collective energy solutions such as district energy, promoting an orderly, efficient and sustainable energy transition.

The PNEE establishes the need to improve the thermal performance of new and existing buildings as one of its lines of action. For this purpose, it proposes: ‘Updating energy efficiency standards for buildings in order to reduce their energy demand, especially thermal demand.’ Therefore, the Thermal Regulation is positioned as the main instrument for reducing thermal demand in housing. In addition, this update is part of the regulatory package enabling the implementation of the Energy Efficiency Law, enacted in 2021.

This is in line with the objective of the PNEE to achieve that new homes reduce their thermal demand by 30% by 2026 compared to the base conditions of 2019.

The planning of buildings and urban spaces must be incorporated from the initial stages of design, energy efficiency criteria and forecasting for the connection to district energy systems. Considering orientations, compact urban forms, adequate densities, spatial continuity and thermal installations not only improve the energy performance of buildings, but also facilitates the future implementation of collective solutions, without requiring investment in subsequent adaptations. This anticipatory view, based on the integrated planning of the built environment, allows reducing technical and economic barriers, promoting a more resilient, efficient and connected urban infrastructure.

Success story of Chile: Urban Housing Project with District Energy

In the city of Talca, Maule region, 250 kilometers south of Santiago, the Ministry of Housing and Urbanism is promoting the development of a macro-urbanization project, which seeks the creation of neighborhoods with identity, green areas and safe public spaces that incorporate diversity, where district energy is incorporated as an innovation from the beginning of the project.

The objective is the construction of a socially integrated housing complex, sustainable and of high urban quality, which considers high standards of energy efficiency, such as thermal insulation and sun protection. Within the project, the implementation of a district domestic heating and hot water system that adjusts to the needs of users is added.

Figure 8. *LAN of macrourbanization of Talca. Source: Seremi de Vivienda y Urbanismo Región del7Maule - SERVIU Maule.*

6.1.2. Opportunities in Colombia

Through the Resolution of the Ministry of Mines and Energy 40156 of 2022, Colombia adopts the Indicative Action Plan of the Program for the Rational Use and Efficiency of Energy - PROURE, in which it establishes the actions and measures that the country must adopt for the reduction of consumption and emissions resulting from the use of energy. This document defines the potential savings goals for each sector, considering thermal districts as a transversal strategy that allows compliance with the country's energy savings goals as a result of national and international commitments.

Sector	Ahorro potencial PJ	Emisiones Evitadas MTonCO2	Relación PJ/MTonCO2
Residencial	523.07	8.23	63.48
Transporte	673.33	50.33	13.38
Terciario	131.71	6.25	21.07
Industrial	256.36	14.12	18.17
Termoeléctrico	25.46	1.89	13.46
Hidrocarburos	27.67	1.66	16.67
Minería	11.46	0.77	14.86
Edificaciones	38.08	1.75	21.68
Almacenamiento	1.05	0.003	377.80
Distritos térmicos	0.35	0.008	45.17

Figure 9. *PAI-PROURE 2022-2030 goals. UPME Source*

In this case, for Colombia the reduction goal resulting from the implementation of the energy districts strategy is a potential of 0.35 PJ of energy, its main uses being in the tertiary sector.

The Energy Districts have become so relevant that within the national roadmap of net-zero carbon buildings it was included as an essential strategy to achieve carbon neutrality in buildings by 2050.

6.2. Market potential

In Chile and Colombia, it is possible to estimate an interesting market growth around district energy, which can be replicated by any country in Latin America and the Caribbean (LAC), which would allow in the medium and long term to have a LAC region as an attractive pole of investment and development.

From a project investment point of view, the most relevant factors for scalability are the attraction of private investment and the availability of public funds for project support. Instances such as the promotion of countries' project portfolios, as well as the clarification of the regulatory framework and the declaration of interests and political will at the country level, could attract investors and developers who today build and operate mega-systems around the world.

6.2.1. Opportunities in Chile

Chile has spent more than a decade creating the enabling conditions to scale up the implementation of projects in cities and thereby achieve the desired benefits in terms of air quality and GHG mitigation. This work has already delivered tangible results, including nearly 20 pre-feasibility studies, five city-scale master plans, and two projects on the verge of being piloted, among other significant advances. These efforts are complemented by isolated projects that have been operating since the 1970s, at both smaller and larger scales, which likewise serve as reference points for long-term development, continuity, and adaptation.

Currently, a market potential in Chile of about 1.2 billion dollars has been estimated, which would represent an installed capacity of heat and cold of 853MW of power and mitigation of GHG emissions of 193,000tCO2eq/year. This is reflected in the project pipeline, which includes 16 smaller-scale areas, five city-level or large-scale master plans, and two pilot projects that are about to be tendered in the Metropolitan Region and the Maule Region.

At the same time, through its national energy policy, Chile has set the ambitious target of connecting at least 500,000 users to district energy networks by 2050, reinforcing its commitment to creating a market that contributes to the country's carbon neutrality and energy transition goals.

On the other hand, to complement private investment, as well as to maximize the social benefits of this type of solution, governments should be able to mobilize public resources to deliver those projects that have a significant potential for social benefits. In this regard, Chile has been making progress in establishing a methodology for the social evaluation of district energy projects, which will allow it to better identify and value the social benefits of this solution, allowing it to access regional public funds to support investment.

6.2.2. Opportunities in Colombia

In Colombia, energy districts are a developing market for the conception of urban energy systems, aligned with new criteria of environmental responsibility that are imposed among entrepreneurs, investors, academia, the public sector and ordinary citizens. They are a key strategy for the circular economy model promoted by the national government, in response to the increasingly intense demands of global warming.

Today it is widely understood that cities have their own 'urban metabolism,' in which district energy systems make it possible to reuse and optimize resources and energy that are crucial for a sustainable urban future. By allowing the grouping of multiple users under the same distribution network, with intelligent monitoring sensors that reduce operation and maintenance costs, they represent the most efficient way to replace old highly polluting air conditioning equipment. The growth potential and opportunities for transformation that Colombia has are enormous. The key to making this paradigm shift is in the conscious decisions of each one when it comes to consuming or undertaking investment projects. The true impact of energy districts is directly linked to the level of penetration they have in Colombian cities, for which the involvement of all actors is necessary.

The strategy in Colombia has led the country to have a context that promotes and encourages energy districts as a new urban and industrial sustainability infrastructure.

The Colombian market for energy districts currently has:

- Technical Regulation for Thermal Systems and Installations adopted by the Ministry of Mines and Energy, which establishes efficiency and environmental sustainability criteria for energy districts.
- National regulations that establish energy districts as an environmental and energy efficiency measure.
- Local regulations in ten cities establish energy districts as urban sustainability measures.
- Colombian engineering companies with experience in the design, construction and operation of infrastructures of energy districts.
- Six energy district projects are currently in operation, five for cooling and air conditioning in the commercial, institutional, hospital and residential sectors; one in the industrial sector that supplies more than four energy services from the same power plant.
- More than twenty high potential projects with technical and financial feasibility studies.

7. Conclusions

In Chile, there is a vast market for heating and cooling in the building sector, as more than 70% of energy consumption in buildings corresponds to thermal uses (space heating, hot water, and cooking). Across its 4,300 kilometers of length and diverse climate zones, the country faces not only heating demand in buildings but also a growing demand for cooling as a result of climate change.

Chile's strategic decision to focus its efforts on integrating district energy into existing policies and regulations, rather than developing new ones, has proven highly effective in advancing enabling conditions. The institutionality and leadership of the Ministry of Energy of Chile and the Energy Sustainability Agency are relevant to channel development and seek synergies between initiatives.

Currently, a district energy market potential of 850 MW of installed capacity for heating and cooling has been identified, with a corresponding potential reduction in greenhouse gas emissions of 193,000 tCO_2e per year.

The pilot project that is for tender in Santiago de Chile is expected to mobilize the private sector and the market, demonstrating adequate legal and administrative channels for its implementation and with high potential for scalability. However, while substantial progress has been made in project analysis, significant gaps still remain for scaling up. Therefore, it is necessary to take advantage of emerging opportunities and to reinforce the overarching public policy objectives related to decarbonization, energy transition, and pollution reduction.

Meanwhile, Colombia, through its effective and well-structured strategy for implementing district energy, has achieved rapid progress and the realization of initiatives in several cities, resulting in six district energy projects in operation and around twenty additional studies and analyses that could move into the implementation stage. This effort has been led by Colombia's Ministry of Mines and Energy and the Ministry of Environment and Sustainable Development, together with the District Energy Program in Colombia.

As a result of the development of projects, the technical capacity of Colombian companies for the design, construction and operation of infrastructures of energy districts has grown and has been consolidated, which allows us to assert that Colombia has capacity within the country for the development of large heat or cold distribution projects.

With regard to regulation, the Ministry of Mines and Energy of Colombia has generated national regulations and technical regulations that protect and guide the execution of projects, as well as local regulations in the cities that take on the particularities of the territory.

International cooperation has also been a key factor in Colombia, as organizations such as the Swiss Embassy – State Secretariat for Economic Affairs (SECO) and the United Nations Industrial Development Organization (UNIDO) have supported the Ministry of Mines and Energy and the Ministry of Environment and Sustainable Development in the successful implementation of the District Energy Program in Colombia.

Finally, it is worth noting that the experiences of Chile and Colombia in implementing district energy in their cities are transferable to other countries in Latin America and the Caribbean that share common energy, environmental, and social challenges. Therefore, it is necessary to show the potential attractiveness of the region as an investment pole in terms of the growing demands for heating and cooling; and in terms of the needs, also growing, for technological spare parts to advance global energy and environmental goals.

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