



## WASTE FOR HEATING AND COOLING: HOW DISTRICT ENERGY TRANSFORMS LOSSES INTO GAINS

2017

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## I.I MAIN INFORMATION

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## I.II. OBJECTIVES

To develop six case studies of District Energy Systems in Cities in different countries, and analyse their business models.

To identify replication strategies and explore opportunities for promotion of the Eco Energy Town approach internationally.

## II. INTRODUCTION

### DISTRICT ENERGY TO ADVANCE ON THE ECO-ENERGY TOWN APPROACH

Cities account for more than 70 per cent of global energy use and for 40 to 50 per cent of greenhouse gas emissions worldwide (Seto et al., 2014). Systemic inefficiencies in the energy consumption of cities have economic and social costs for both cities and countries and are a major barrier to universal access to modern energy. Cities and towns around the world are searching for alternative energy sources to fulfil their energy needs while being respectful with the environment. They are leading the energy transition by adopting policies and supporting projects that set the path towards a cleaner future.

In this context the Korean Ministry of Environment and the Korea Energy Economics Institute are working to expand the concept of eco-energy town. Korea's approach to Eco-energy towns aims to maximize the use of local resources to decrease energy dependence from fossil fuels, cut greenhouse gas emissions and contribute to a local circular economy. The concept is based on the new paradigm of using unwanted public facilities including sewage treatment plants to generate energy, and returning the benefits to local residents. The country has already implemented the eco-energy town concept in the cities of Cheongju, Asan, Gyeongju, Yeongcheon and Yansan, and is exploring the possibility of replicating the concept internationally.

Modern district energy has been identified by UN Environment as one of the most effective technologies for many cities to transition to

sustainable heating and cooling, by improving energy efficiency and enabling the use of waste energy and renewable resources. Through the development of district energy, cities are reducing greenhouse gas emissions and air pollution, improving energy efficiency, reducing dependence from fossil fuels, using more local and renewable resources, and contributing to the transition to a green economy. Countries such as Denmark have made modern district energy the cornerstone of their energy policy to reach their goal of 100 per cent renewable energy.

Modern district energy systems supply heating and cooling services using technologies and approaches such as waste heat recovery, combined heat and power (CHP), thermal storage, heat pumps and decentralized energy. District energy creates synergies between the production and supply of heat, cooling, domestic hot water and electricity and can be integrated with municipal systems such as power, sanitation, sewage treatment, transport and waste.

One of the main benefits of district energy is that it enables to maximise the potential of waste heat or cold by providing the means to distribute this energy to the final consumers in forms of heating or cooling. For many cities, district energy is the only technology that enables the recovery and distribution to end-users of surplus, waste heat and cooling (e.g. waste heat from industry or power stations; heat from sewage, heat from incineration

processes, or waste cold from LNG regasification processes).

Based on the experience of UN Environment's District Energy in Cities Initiative, this report focuses on how cities around the world are using waste in its different forms (e.g solid municipal waste, waste heat from urban infrastructure or industrial process, combined heat and power

generation) to provide space heating, hot water, cooling and electricity to its citizens. Best practices on applied technologies, policy frameworks and business models from six case studies will be analysed to identify replication strategies and explore opportunities to advance on the promotion of Korea's Eco-Energy Town approach internationally.

### Harnessing waste as energy source

As cities set the path for their transition to a more sustainable future they search for alternative, cleaner, local, low-cost energy sources. Waste, in its different forms, whether solid municipal waste, sewage, waste heat from industrial processes, data centres or transport stations, combined heat and power generation, or waste cold from LNG terminals; is an abundant energy source in any urban environment with a key role to play in the energy transition.

District energy systems are the only way to utilize these wide variety of low-exergy, low-grade

waste energy sources that unless recovered would be lost, and transform it into heating, hot water and cooling for buildings.

Many cities around the world are already harnessing the full potential of the existing waste energy sources within its city's boundaries to improve air quality, reduce greenhouse gas emissions, offer affordable prices for space heating and cooling, or reduce import dependency on fossil fuels.

### EXAMPLE : TOKYO

Tokyo is maximizing efficiency in its district energy systems through the use of waste incineration, waste heat from buildings and metro stations, heat pumps connected to local water sources and solar thermal. To foster the development of district energy networks, the city implemented land-use planning policies that require developers of new areas to assess the opportunities for cost-effective modern district energy or to identify a cheaper next-available sustainable heat or cooling option.

### Urban waste energy sources

#### Municipal solid waste incineration plants

Waste incineration used to be utilized by cities as a mean to reduce the amount of waste in landfills. Nowadays, as a result of municipal waste management plans, many incineration plants are required to utilize the waste heat produced during the incineration process of non-recyclable waste to

generate steam, making these facilities critical to district energy systems. The heat generated during the incineration process is transferred to the water running through the district heating system and/or used by absorption chillers to produce the cold water that will be distributed to the clients through a district cooling network. Some larger waste

incinerators also have a steam turbine to produce electricity in addition to heat.

Waste-to energy plants used to be located far from the city due to potential local air pollution and bad smells. However, modern waste incinerators follow strict emissions controls to minimize their impact on local air pollution and can be easily

integrated into the urban environment (see case study of Issy-les-Moulineaux, France).

As a result instead of sending non-recyclable municipal solid waste to landfills, cities have found the way to use this waste as a low-cost fuel for the supply of hot water, space heating and cooling (see case study of Barcelona, Spain).

#### EXAMPLE : COPENHAGEN

In Copenhagen recycling waste heat results in 655,000 tons of CO<sub>2</sub> emissions reductions and displaces 1.4 million barrels of oil annually (Thornton, 2009).

#### Combined Heat and Power plants (CHP)

Combined Heat and Power plants recover the excess heat from exhaust gases of the turbine resulting in the generation of two products, electricity and heat. The fuel source for this plants can be gas, biomass, coal, biogas, etc. The heat recovered is generally used by a district heating network. Combined cool, heat and power plants are those who have an absorption chiller installed than can use the excess heat recovered from the turbine to produce cooling for a district cooling network (See case study of Zhuhai, China).

Cogeneration in modern CHP plants is typically 80–90 per cent efficient, meaning that almost all of the primary energy burned is converted to useful final energy. In contrast, conventional thermal power plants typically are only 30–50 per cent efficient and release huge amounts of waste heat to the local environment (IEA, 2014a).

Local electricity utilities can benefit from the distributed cogeneration that district energy often provides. In Bergen, electricity companies, facing capacity concerns and network strains, supported the development of district heating because it reduced reinforcement costs and provided additional revenues.

#### Waste heat from the industry

Industrial process mostly require of large amount of cooling which is covered by installing cooling appliances or using free cooling from rivers. Instead of liberating all this large amounts of excess heat to the air or water, this heat could be recovered to be used as heat source for a district energy network.

Waste heat from industry can be converted to cooling using an absorption chiller. These differ from the more prevalent electric chillers in that the cooling effect is driven by heat energy, rather than by mechanical energy. The coefficient of performance of the chiller depends on the number of absorption cycles but is typically 0.65 to 1.2.

#### Waste heat from urban infrastructure

- **Waste heat recovery from transport stations:**

Railway stations and underground stations are not only heavy energy consumers but also sources of considerable amount of waste heat. The trains breaking system, the high density of passengers, the equipment and control rooms, are the main waste heat sources of the transport stations. Some cities like London, Tokyo or Stockholm are recovering this heat that would otherwise be wasted to transfer it to their district heating networks.

## EXAMPLE : LONDON

In summer London's underground stations can reach temperatures of up to 30°C, mainly due to the trains braking system. Large fan systems are installed to extract the hot air and cool the tunnels of the underground system.

Instead of wasting this energy the city decided to recover the heat by installing heat exchangers in the vents used to extract the hot air and transfer it to a district heating network. Heat pumps are used to increase the temperature of the water up to an adequate temperature for the district heating network (usually above 60°C).

- **Data centres**

Computers and servers need a high quality environment within an optimal temperature and humidity range to function properly. To achieve a satisfactory environment, systems that ventilate, cool, humidify and dehumidify are necessary. These systems require high amounts of energy, and data centres usually have a very high energy density. Data centres can consume up to 100 or even 200 times as much electricity as standard office spaces. It has been estimated that they used about 350 TWh electricity globally in 2010, just over 1 % of the world's total electricity use and the use is constantly growing (Celsius technical toolbox). Increasing the energy efficiency of data centres can be achieved by, among other methods, recovering the waste heat in a district heating system.

In cities like Paris , research institutes like Efficacy, are exploring the potential of connecting the data centres to the cities district energy network ( see case study on data centres from Paris).

- **Sewage**

Sewage has high energy potential mostly due to the fact that the temperature of the waste water is relatively high, usually above 10 °C, which makes it a good source of heating for district energy networks if combined with heat pumps.

Cities like Vancouver or Zhengzhou (see case study) recover waste heat from sewage to provide heating or cooling to buildings. The heat can be recovered with a heat exchanger which will remove the heat before the sewage before it is processed. The system would usually require of heat pumps to increase the low-temperature waste heat up to the level required by the district heating system (usually above 60°C). With these systems cities are able reduce CO<sub>2</sub> emissions and primary energy consumption as fossil fuels are substituted by a waste heat source.

## EXAMPLE : VANCOUVER

Vancouver's South East False Creek Neighbourhood Energy utility Demonstration Project provides district heating for some 7,000 residential units, with 70 per cent of the heating energy obtained from raw wastewater. The network currently captures waste heat from a relocated and expanded sewer pump station that is co-located with the Neighborhood Energy Utility (NEU) Energy Centre. The system has been design to accept heat energy from future new connections of waste heat and renewable energy sources. The system saves 10,000 of CO<sub>2</sub> emissions every year.

### **Free cooling and waste cold recovery**

As well as heat, cold can also be recovered from multiple sources freely available in an urban environment such as seas, lakes, rivers. Other sources of waste cold include LNG terminals, where the liquefied gas follows a regasification process to be distributed through the gas network. The regasification process consists in increasing the

temperature of the LNG from -190°C up to +4°C. The waste cold resulted from the regasification process was usually delivered to the sea. Cities like Barcelona have decided to harness all this waste cold potential are using it as a source for its district cooling network.( See example of Eco-Energies Barcelona)

## EXAMPLE: BARCELONA

Barcelona initiated in 2009 a district energy network covering the district of La Marina and L'Hospitalet to supply sustainable heating, hot water and cooling to the residential, industrial and tertiary buildings covering an area of 15'000'000 m<sup>2</sup>. The network uses heat from the incineration of plant based waste from parks and gardens of the city and forest biomass, solar panels, and waste cold from the regasification process at the LNG terminal situated at the port (up to 30MW).

Key factors:

- 3.7 times more efficient than conventional solutions
- Reduces fossil fuel consumption equivalent to the generation of 67.000MWh every year.
- Saves 13.412 tons CO<sub>2</sub> emissions every year.

The first and second phase of the project including the biomass plant and the waste cold recovery from the LNG terminal have been finished. The expansion of the network is on-going.

### III. OVERVIEW OF CASE STUDIES

#### III. 1. OVERVIEW OF CASE STUDY IN ZHUHAI, CHINA

##### III. 1.1. DESCRIPTION OF ZHUHAI CITY

Located in the Pearl River Delta, Zhuhai is a prefecture-level city on the southern coast of Guangdong province in China. In the North and West Zhuhai borders the Macau Special Administrative Region and its territory includes 146 islands and a coastline of 690 kilometres (429 miles). Zhuhai was designated as one of the first Special Economic Zones of China (SEZ) in the year of 1980, due to its strategic position facing Macau, an important trading centre.

The establishment of Zhuhai as an SEZ allowed the Chinese Central Government and economy to have easier access to the Macau and global market. The implementation of SEZ intended for the city to become a city of key port, scenic and tourism city, and regional hub for transportation. The outstanding geographic location, a wide range of supporting infrastructure and a deep-water port serve as a major attraction for foreign capital. Among the top 500 enterprises worldwide, 19 of them have investment projects in Zhuhai such as ExxonMobil, BP, Siemens, Carrefour and Matsushita.

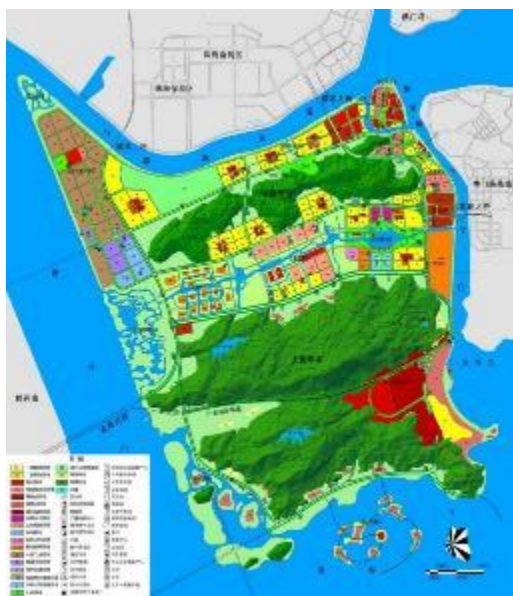
in between, and is connected to Macau's Cotai via the Lotus Bridge. The island is the largest among the 146 islands of Zhuhai with land area of 106 km<sup>2</sup>, being roughly three times the size of Macau. The whole island is designated as one of the three national-level special economic districts by the central government of China in 2009, as Hengqin New Area (the New Area). The island is made up of 1 town, 3 communities and 11 villages, and home to more than 7'000 people among whom 4'203 have been permanent residents since 2009. According to the regional urban planning in 2009, the New Area is divided into 6 sub-districts for different development purposes:

- 1) Northwestern Zone - reserved for environmentally friendly development projects;
- 2) Northern Zone - A Bridge and main entrance between Central Zhuhai and Hengqin New Area;
- 3) Northeastern Exhibition Zone - development of an exhibition center and hotels;
- 4) Central Channel - develop as a leisure and recreational theme park;
- 5) Eastern Residential and Commercial Zone - codevelopment of China and Macau projects such as University of Macau's new campus;
- 6) Southern Tourist Zone - Chime-Long International Ocean Resort (opened in 2011).



*Pic. Zhuhai is a prefecture-level city on the southern coast of Guangdong province in China.*

Hengqin Island, sometimes known as Ilha de Montanha in Portuguese, is adjacent to Taipa and Coloane of Macau with the Shisanmen Waterway



Pic. New Area is divided into 6 sub-districts for different development purposes.

According to Hengqin Administrative Committee, the area's investment on provincial-level key projects totalled 6 billion RMB (922 million USD) in 2015, whereas investment on municipal-level key projects reached 12,8 billion RMB (1,97 billion USD).



Pic. New Area development.

### III. 1.1.1. SOCIO ECONOMIC AND POLICY BACKGROUNDS

According to the "Urban Planning and Development regulation", which was authorized by the Central government in 2009, the New Area is defined as an eco-friendly region. The major goals include:

1) Primary energy efficiency. The total primary energy efficiency in the New Area, including electricity, heating/cooling and domestic hot water, should be over 75%.

2) Green building. All the commercial and public buildings in the New Area should be at least one-star (certified level) of Chinese green building rating system.

3) Green House Gas (GHG) emission. The energy consumption per Gross Domestic Product (GDP) should be 20% lower than the average level of Zhuhai city in 2025 and the CO<sub>2</sub> emission per GDP in the New Area should be 30% less than the average level of Zhuhai City in 2025.

4) Heat island effect. The heat island effect in central business district should not exceed 1° C.

Before 2008, the major economic income in the New Area is farming and fishing. However, because of the development planning and decisions from the central government in 2009, it has become the most dynamic power engine that drives local development, marked by the average annual growth rate of 81%, 89% and 123% in fixed asset

investment, local GDP and the public fiscal budgetary income, respectively. Hengqin and Macao are stepping up efforts in the construction of a World Tourism and Recreation Center and a Platform for Economic and Trade Cooperation with Portuguese-Speaking Countries. Hengqin Island is the first one in China that pilots the two-tier management system for border-crossing and customs for cargos and travelers.

The New Area has strong policy support in below described ways:

1) **Urban planning level.** In the very beginning stage of urban planning in the New Area, the local government has defined district energy system as a public service for all the buildings in the region. It is clearly defined in the urban planning documentation that district cooling is a municipal service like electricity and water supply. In the planning, the lands for district cooling plants as well as the LNG power plant, are reserved and mapped. Meanwhile, the spaces for main pipelines of chilled water and domestic hot water are also reserved. For better management and maintenance in the future, a multi-use pipeline corridor was planned and constructed together with the main

roads in the island. The corridor is of 33,4 km length and 3,4 meters height with pipes of water supply, sewage disposal, waste disposal, communications cables, heating/cooling and gas.

2) **Secure the end-user connection.** When the land is sold by the government, it is clearly stated in the contract to developers that the connection to the district cooling system is mandatory for all the public and commercial buildings in the area, unless special cooling requirements for specific functions of the buildings (like data centres). Before the Bureau of Planning and Land submits permissions for construction, end-users should sign the contract or at least achieve an agreement with the district cooling supplier.

3) **Design guidelines and management guides.** In order to coordinate all the engineering design and constructions in the New Area, the local government published several guides to help the developers, building owners, designers, construction companies and operation and management people of the end-user side to

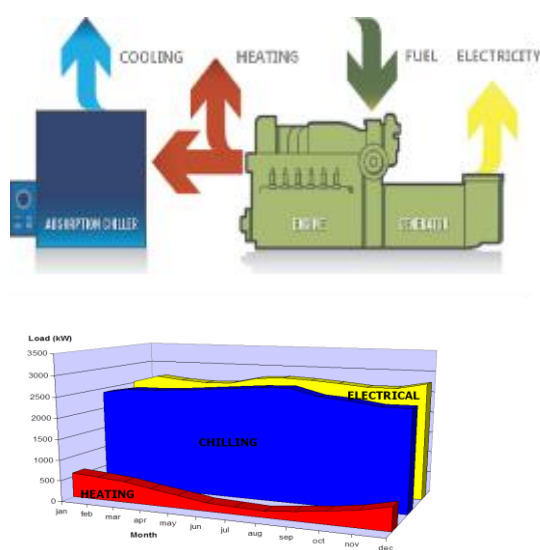
understand how to design, construct, control and manage their own HVAC system inside the buildings.

4) **Hearing meeting on cooling and hot water price and adjustment method.** Before the service supplier finalize the price, the local government (Hengqin Administrative Committee) invited all of the end-users, developers for a hearing meeting. The supplier presented all the calculations and answered questions from different parties. After that, the Administrative Committee sent out a documentation for the hearing meeting to confirm the pricing structure and conditions to adjust the price. This documentation is also shared with any future end-users.

5) **Regular meetings between district cooling supplier and end-users.** These meetings are held each quarter under the coordination of local government. The aim is to set up a regular communication channel for both sides to discuss engineering problems, project procedures and any other problems.

### III. 1.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

As part of the smart city plan in the New Area, the tri-generation system (also known as Combined Cooling, Heating and Power "CCHP") is considered to be a cost-effective solution to enhance the sustainability and efficiency in the region. The absorption chillers are using all the waste heat from power generator for cooling, and the condensed heat from absorption chillers is used for domestic hot water. Due to the unbalance demand for heating and cooling, other kinds of cooling technologies are integrated in the system in addition to absorption chillers.



Pic. Combined Cooling, Heating and Power.

The CCHP system in the New Area includes a 390 MW power plant with LNG input and nine energy centres in different areas of the island. It can supply chilled water for HVAC cooling in a total built-up area of 15 million m<sup>2</sup> of commercial/public buildings, including shopping malls, office buildings, luxurious residential apartments, high-level hotels and city complex etc..

Based on the development plan of the New Area, the CCHP system is also divided into different phases. The power plant has finished construction and been in operation since 2015. For the energy stations of phase 1, station 3# is

operating since 2016, while the other stations are under construction and planned to operate from 2018 and 2019.



Pic. New Area development.

### III. 1.2. PERFORMANCE AND OUTCOME OF THE CASE STUDY PROJECT

#### III. 1.2.1. ANALYSIS OF PERFORMANCE

Until June of 2017, the district cooling system is providing chilled water for 11 buildings clusters with a total cooling capacity of 700'000 kW

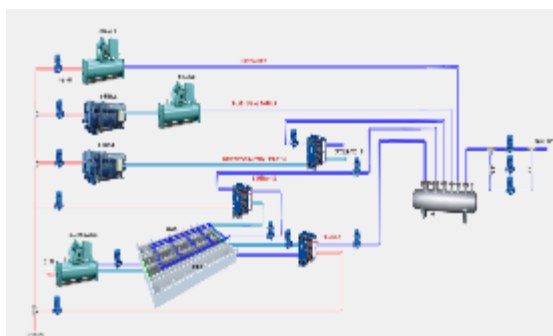
(~200'000 Refrigeration Tons). The service provider has signed cooling/heating contracts with 11 end-users for 76 building clusters.

Table. Phase 1 and Phase 2 for energy stations 1#-10#.

No.	Description	Phase 1	Phase 2
		Energy stations of 1#, 3#, 7#, 11#	Energy stations of 2#, 4#, 5#, 6#, 8#, 9#, 10#
1	Annual cooling supply (kWh)	4,67×10 <sup>8</sup>	9,51×10 <sup>8</sup>
2	Cooling capacity (RT)	85'700	174'000
3	Annual steam consumption (tons)	398'000	890'000
4	Annual electricity consumption (kWh)	4,7×10 <sup>7</sup>	8,4×10 <sup>7</sup>
5	Annual water consumption (tons)	792'000	1'680'000
6	Investment (RMB)	9,1×10 <sup>8</sup>	18,5×10 <sup>8</sup>

The price of energy supply, especially cooling and domestic hot water, has a ceiling limit, which is the price the end-users pay for their standalone systems. The aim of the technical solutions as district energy system is to provide high-quality energy with lower or similar price but also bring extra benefits to them, like saving of initial investment and mechanic rooms etc.. Thus, the selection of technical plan should consider not only efficiency and reliability but also cost-effectiveness.

In order to be flexible and economic viable for different cooling load, the cooling system has integrated various cooling source, including electrical chillers, absorption chillers, dual-evaporator chillers, ice storage and chilled/hot-water storage, as shown below. The operator can decide to run the system in different kinds of cooling modes based on the system efficiency under various loads, peak/off-peak price of electricity and steam amount etc..



Pic. Cooling system has integrated various cooling source.

The centralized CCHP system replaces traditional split HVAC system. It can benefit the

environment as well as all the end-users as following aspects:

- 1) Save electricity for cooling at 400 million kWh per year.
- 2) Save water for cooling tower at 1,15 million tons per year.
- 3) Reduce CO<sub>2</sub> emission of 1,8 million tons per year.
- 4) Reduce SO<sub>2</sub> emission of 1'500 ton per year.
- 5) Save mechanical rooms in the end-user side of 144'000 m<sup>2</sup>.
- 6) Save investments in the end-user side on the HVAC and electrical transformer equipment of 2 billion RMB.

### III. 1.2.2. ANALYSIS OF KEY SUCCESS FACTORS AND CHALLENGES OF PROJECT

#### Key success factors

1) **District energy planning** is very important, especially in the beginning stage of a green-field project. It should be done in parallel with urban planning. All the design, construction activities later on should be align with the district energy planning and make sure to satisfy it's requirements.

2) **Policy support.** The role of local government in this case only is an active supporter, not a regular. It helps to coordinate the district energy system under market rules by publishing design guidelines, assuring the urban planning and communicating between the supplier and end-users.

3) **Communication channel between district cooling supplier and end-users.** The construction plans of end-users, including development time, building functions and even built-up areas, are frequently changeable due to various reasons. These changes in turn affect the investment and construction plans of the district cooling supplier. Thus, it is very important to set up a communication channel or strategy to exchange information on a regular basis. In the case of the New Area, the district cooling service supplier is hosting a meeting with all the end-users or

potential users quarterly under the coordination of local government.

#### Challenges

1) **Lower carbon footprint.** Even though the district energy system has a relatively high primary energy efficiency, it is still relied mainly on natural gas, which generates high carbon footprint. In the future, there will be higher requirements for the energy system for even lower CO<sub>2</sub> emission while maintaining the same efficiency. It is necessary to consider alternative primary energy resources, like wind, solar etc..

2) **Balance of reliability and efficiency of energy system.** There are some data centre projects ongoing in the area. Due to the special requirements on energy reliability, these projects are excluded in connection to the district cooling systems. However, there are a lot of successful practice for the connection of data centres to district heating/cooling system in other places in the world. The challenge of this application is how to integrate the efficient district cooling system in data centres while maintaining the same or even higher reliability in energy supply.

3) **Extra support of green finance in the beginning stage.** According to the economic

feasibility study of the project, it can be economic viable for the life cycle of 20 years with reasonable benefits. However, the predicted cooling demand may be different with the real condition, especially at the very beginning stage. In the case of the New Area, some buildings are constructed faster or slower than expected. As a result, new energy stations are required in some areas while existed energy stations only have 30%-50% of cooling load and the whole investment plan has to change

accordingly. The cooling system efficiency can not be kept high as designed if the cooling system keeps operating at a low part load, which in turn will increase the operation fee. All these uncontrollable factors affect the financial condition of the district energy supplier in the first 3-5 years of the very beginning stage.

### III. 1.3. IMPLICATION FROM THE CASE: IDENTIFICATION OF KEY LESSONS AND FUTURE PROSPECT

#### Key lessons.

1) **The role of local government** is very important to the success of eco-energy system in a district level. The local government should play a role to develop the business and regulate the market. As a lot of coordination work are required among district energy operator, developers, building owners and other end-users in a long-term period, it is critical for local government to organize regular update meetings among them.

2) **Technical solutions and economic viabilities.** The balance between efficiency and viability should be carefully considered when selecting different technical solutions for the district energy system. As a result, it can create a triple win situation to benefit end-users, operators and local environment.

#### Future prospect.

1) Application of renewable energy. Due to the location of Hengqin, it is possible to integrate wind energy from the ocean into the district energy system. The local government is planning to

explore the potential of that application to even reduce the input amount of primary energy.

2) Application of smart energy technologies. As an important part of smart city, smart energy should play an active role to reduce the regional energy consumption. New smart technologies, like cloud computing, big data etc., can be widely used on optimize the operation efficiency. The system supplies energy to all the commercial buildings in the region and it is able to meter hourly energy consumption with high accuracy for those buildings. Under the help of big data and cloud computing with all these recorded data, it is possible to predict the demand in the coming few days. As a result, most cost-effective operation modes can be calculated, including which kinds of technical solutions should be taken for lower operation cost and how much ice to be used or generated for cooling in certain time of the day.

### III. 1.4. REVIEW OF THE BUSINESS MODEL

The shareholders of the district energy service company are two: municipality and private

company. In Zhuhai city case municipality did not invested any money in the district energy utility for

energy/cool production nor the district heating/cooling network. The private company is responsible for the operation and management of district energy systems. All district heating/cooling networks are installed underground in corridors together with other communication networks (water supply, sewage disposal, waste disposal, communications cables, gas) and private partner pays for the rent of underground corridor as part of its operation fee. The land above pipe network corridor can be used for public facilities as parks

and etc local government leases the lands under the district energy plants for a long period of time. Meanwhile, the profitability from the district energy service company goes to the municipality funding to support the constructions of other facilities in the island, like main roads, bridges and power distribution cables etc..

The price of energy supply, especially cooling and domestic hot water, has a ceiling limit, which is the price the end-users pay for their standalone systems..

## III. 2. OVERVIEW OF CASE STUDY IN ZHENGZHOU, CHINA

### III. 2.1. DESCRIPTION OF ZHENGZHOU CITY

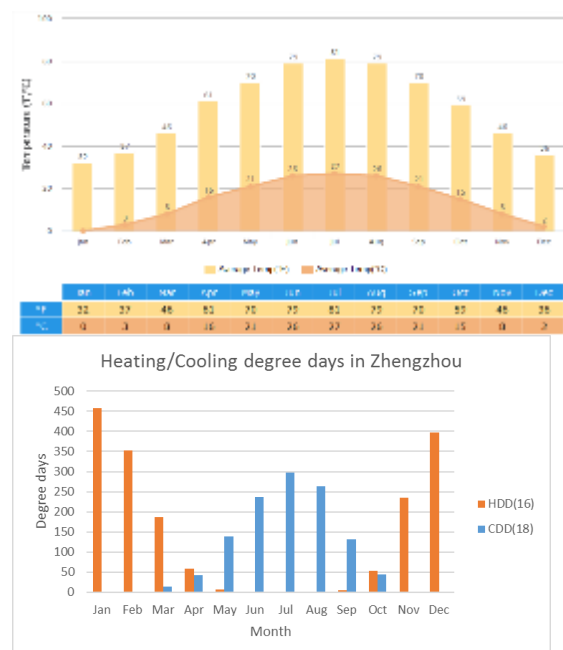
This city case is located in Zhengdong new district of Zhengzhou City in the middle of China, namely Longhu Financial Centre. The city of Zhengzhou is the capital of Henan province. Located just north of the province's centre and south of the Yellow River, Zhengzhou is situated at the transitional zone between the North China Plain to the east and the Song Mountains and Xionger Mountains to the west, which are part of the greater Qinling range. The city has a population of 9'378'000 inhabitants with an urban population of 6'406'000, the city is one of the main built up areas of Henan region.

Zhengzhou experiences a monsoon-influenced, four-season humid subtropical climate with cool, dry winters and hot, humid summers. Spring and autumn are dry and somewhat abbreviated transition periods. The city has an annual mean temperature of 14,35 °C (57,8 °F), with the monthly average temperature ranging from 0,1 °C (32,2 °F) in January to 27,0 °C (80.6 °F) in July.

it's importance, the local government invited best-of-the-world level teams for urban planning and architectural design. The team of Kisho Kurokawa from Japan were invited to be in charge of regional urban planning, while the team of Arata Isozaki from Japan as well were invited to be in charge of the architectural plan for all the buildings in the region.

According to the urban planning, the region of Longhu has planned to high-level office buildings for international financing companies, like banks, insurance companies etc.. The region is surrounded by the lake of Longhu. The total area of building land is estimated as 500'000 m<sup>2</sup>, while the built-up area is 3,1 million m<sup>2</sup>. The population working in the region is estimated to reach 150'000 with residents of 25'000. The buildings are arranged in two rings with different height control for each ring respectively of 18 m, 24 m, 35 m and 60 m.

During the urban planning stage, several public service utilities, including transportation, water and electricity supply, internet cable, waste water and heating/cooling were coupled as an over-all urban planning documentation. All the transportation should go underground, on top of a pipe corridor. Meanwhile, there are chapters of green buildings, building energy efficiency, district energy system and waste water reuse etc..



The Longhu Financial centre is planned to be the regional headquarters of financial companies or organizations in the middle part of China. Due to

### III. 2.1.1. SOCIO ECONOMIC AND POLICY BACKGROUNDS

From the most polluted cities in China Zhengzhou takes the fourth place with PM 2,5 concentration of 134,7  $\mu\text{g}/\text{m}^3$  (more than 13 times comparing to the safe limit established by the WHO) during the first quarter of 2015. By the consequence the government of the city has set a target to reduce the air pollution during heating season to WHO's defined safety limit. In Zhengzhou district heating system covers major parts of the city centre taking 60 % of buildings areas and covers 100 % in newly-developed regions. The sources for heating in the past mainly are coal thermal power plants with power and heating supply boilers, so the air pollution during heating season is much bigger.

The government of the city has set the following objectives for the 5-year plan, which started in 2015:

- 1) Replace all coal fuel to clean energy, like LNG etc..
- 2) Increase building energy efficiency by 15%.
- 3) Re-use waste water heat and water to develop heat pump or any other water-reuse technologies.

- 4) Reduce the air pollution level.

The municipality of Zhengzhou helps to develop projects by regulations of urban planning and building design. At early urban planning stage the district energy system was taken into consideration and district energy planning was a part of the urban planning documentations. The final urban planning defines the locations of district energy plants, pipeline routines ect. Another way of encouraging the development of district heating systems in newly-developed regions is setting a connection policy that obliges new buildings to connect to the network. In this case end-users or building owners would avoid building individual heating systems. The combination of district heating and cooling makes the district energy concept even easier to accept. When the local government sells the land, heating and cooling supply is considered as part of the public service to secure the human health in the buildings.



### III. 2.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

According to the urban planning, there are three district energy power plants on the island, reserved land as shown in the following figure. The pipelines of treated waste water are constructed together with the metro line beneath the lake. The heating/cooling pipelines on the island are connected among all the three power plants to make a circle. All the main pipes on the island are constructed inside of underground pipeline corridor. Heating/Cooling supply distance is no more than 650 m.



No.	Building type	Built-up area (m <sup>2</sup> )	Percentage (%)
1	Commercial office	2'171'104	69,25
2	Entertainment/shopping mall	210'945	6,73
3	Public Service	27'598	0,88
4	Hotel	725'744	23,15
5	Sum	3'135'391	100,00

#### Supplied area and system capacity

According to the urban planning and architectural plan of buildings, the district energy system covers 3,1 million m<sup>2</sup> of built-up area. The total installed capacity for cooling reaches 234 MW, while heating capacity is 101 MW.

#### Heating/Cooling supply season and operation mode

Heating supply in Zhengzhou is mandatory, while cooling supply is to increase indoor thermal comfort. The heating season is from 15th November to 31st March, which is also regulated by the local government. The cooling season in this project is more flexible, normally from 15th May to 30th September. According to the climate in Zhengzhou, the swing season mainly lies on the months of April and October. In the swing season, the demand from end-users should be heating or cooling. And it may differ day by day. Due to the unbalanced heating

and cooling demand, the distribution system share the same 4-pipe network. In winter, two of the pipelines supply heating, while another works as stand-by or cooling supply. In summer all the pipes supply cooling. The employment of waste water heat reuse gives the district energy system more flexible in providing heating or cooling or both at the same time to the end-users.

The waste water is used to replace cooling towers for cooling in summer and operate as heat pumps for heating in winter.

Main settings of heating/cooling:

- Heating water temperature: 41/51 °C;
- Cooling water temperature: 4,5/12,5 °C;

Due to all the supply temperature values are different with the standard conditions of HVAC equipment, a further calibration of actual heating/cooling supply ability is carried out. The results shows that fan coils can supply sufficient heating.

### Waste water heat reuse

According to the positions of different water treatment factories around the Longhu area, Matougang is the closest one, within 4 km. Parameters of hourly output flow rate, temperature and quality of treated waste water in that factory were measured for the whole year of 2015, as listed below. Based on these data, how much water to be distributed to the plants can be calculated, as listed below.



Month	Days	Monthly water volume (10 <sup>4</sup> m <sup>3</sup> )	Daily water volume (10 <sup>4</sup> m <sup>3</sup> )	Daily average water temperature, °C
1	31	1'489,23	48,04	15,9
2	31	1'319,46	42,56	15,3
3	28	1'246,67	44,52	16,76
4	31	1'496,89	48,29	19,01
5	30	1'468,82	48,96	22,7
6	31	1'498,71	48,35	25,3
7	30	1'518,00	50,60	26,6
8	31	1'586,10	51,16	28,1
9	31	1'495,09	48,23	26,3
10	30	1'281,86	42,73	24,1
11	31	1'435,11	46,29	19,7
12	30	1'366,00	45,53	16,3
SUM	365	17'201,96	47,13	21,36

District energy plant	Cooling		Heating	
	Hourly max waste water usage (m <sup>3</sup> /h)	Daily waste water volume (m <sup>3</sup> /d)	Hourly max waste water usage (m <sup>3</sup> /h)	Daily waste water volume (m <sup>3</sup> /d)
1#	5'209	96'276	4'799	73'347
2#	5'209	96'231	4'824	73'615
3#	5'209	99'986	4'086	69'888

### Technical characteristics of case study

#### 1) System reliability

Most of the buildings in the Longhu island are headquarters of financial companies, which require to set up server rooms or small-scale data centers inside their buildings. These server rooms or small-

scale data centers, ranked as Tier 4, have special requirements for cooling supply:

- High reliability. The cooling source has sufficient back-up, as 2N+1, and is able to on-line maintenance.
- Whole-year-round steady cooling demand.
- High cooling density.

Based on above requirements, the district energy systems have been designed accordingly. Firstly, the distribution network is set as 4-pipe system and able to supply cooling all the year around, even in winter. Secondly, all of the three district energy plants are connected through circle pipelines, even though they are operated as branched ones. Thus, the plants can be back-up to each other. Thirdly, separate tanks of chilled water storage for these high reliable requests of end-users are set up in each plant to cover 30 minutes of usage for cooling in any emergency conditions. At the end, cooling towers are installed as a back-up of waste water for cooling.

## 2) Thermal energy storage and waste water supply pattern

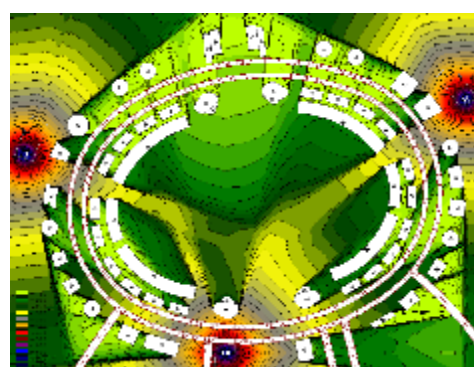
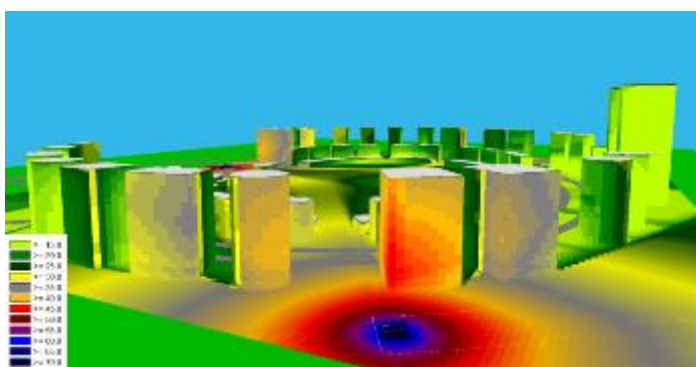
According to the monitor of hourly waste water amount from Matougang water treatment factory, the supply of waste water has daily peak and off-peak periods. The peak period of waste water supply covers the period of 7:00 am - 9:00 am, 12:00 pm - 2:00 pm and 5:00 pm - 9:00 pm for week days, and more steady for week-ends. However, the cooling/heating demand have different pattern with that. In order to fill the gap, chilled/hot water storage tanks are set to store approximately 3-hour of peak load in each plant (22'700 m<sup>3</sup> totally in all three plants).

## 3) District energy plant architecture

Usually, district energy plants look like industrial buildings and people don't like to have them around in their leisure time. However, the three district energy plants of this project are located in the core area of the island. The local government specially requested that the plants were built like gardens or parks to attract citizens, as part of the landscaping in the region. Starting in the stage of urban planning, the architects were working together with the district energy expert team to assure that this approach was being considered. As shown above, through the combination of industrial architectural design and landscaping design, the plants are successfully integrated into the urban environment and have become part of the local attractions.

## 4) Environmental impacts of district energy system

- Evaluation of noise level. The district energy design team worked closely with urban planning consulting team during urban planning stage to choose locations that would minimize the noise generated by the cooling towers. Through noise simulations the team identified the places in which the acoustic impact would be minimal. According to the simulation results, the noise level on the facade of surrounding buildings is less than 55 dBA in day time and 45 dBA in night time.

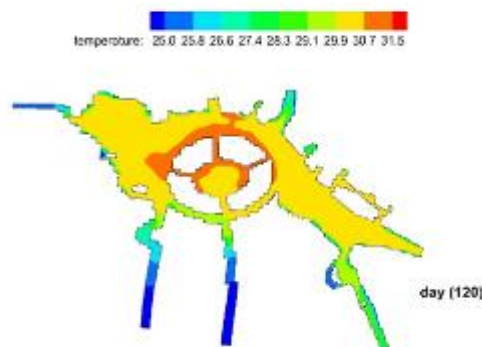
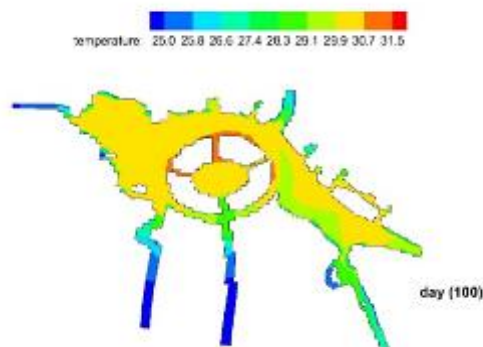


- Evaluation of using lake water for cooling. The region is surrounded by Longhu Lake, which contains over 50'000 m<sup>2</sup> of water surface with

average depth of 5 m. The discussion of using lake water for cooling began since very early stage of urban planning. Through a long-term (120 days)

Computation Fluid Dynamic (CFD) simulation, the results shows that the heat from cooling system into the lake increases the water temperature to 1,2° C

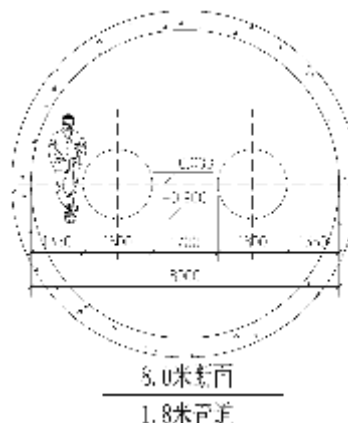
and it is harmful to the bio systems. Based on the result, the district energy system gives up the plan of using lake water for cooling.



### 5) Waste water pipes under lake

During the stage of urban planning, there were several options of how waste water pipes could

cross the lake from outside. The final plan was to construct the pipes together with the metro lines to go across the banks of the lake.



### Estimated enviornmental impact

Compared with traditional standalone cooling systems of 3,1 million m<sup>2</sup> of buildings, the district energy system in Longhu region benefit the environment and end-users in the following aspects:

- 1) it saves 126 million kWh per year of electricity for cooling .
- 2) it saves 1,2 million tons per year of water for the cooling tower.

3) it reduces CO<sub>2</sub> emission in 0,14 million tons per year.

4) it reduces SO<sub>2</sub> emission in 871 ton per year.

5) it saves 40'000 m<sup>2</sup> in mechanical rooms for the end user<sup>2</sup>.

6) it saves 0,25 billion RMB investments at the end-user side on the HVAC and electrical transformer equipment.

### III. 2.2. PERFORMANCE AND OUTCOME OF THE CASE STUDY PROJECT

#### III. 2.2.1. ANALYSIS OF PERFORMANCE

Based on the urban planning, all the buildings in the island were constructed phase by phase and accordingly to the construction plan of the three district energy plants. Meanwhile, each of the

plants were assigned to supply heating and cooling to certain buildings. The capabilities of each plant are listed below.

Table. Capabilities of each plant.

District energy plant	Built-up area m <sup>2</sup>	Cooling Capacity		Heating Capacity
		kW	RT	kW
No. 1	1'035'469	79'025	22'469	34'666
No. 2	1'082'110	79'083	22'486	34'716
No. 3	981'162	76'747	21'822	31'884
<b>Sum</b>	<b>3'098'741</b>	<b>234'854</b>	<b>66'777</b>	<b>101'266</b>

#### III. 2.2.2. ANALYSIS OF KEY SUCCESS FACTORS AND CHALLENGES OF PROJECT

##### Key success factors

**1) Guidance of local government.** The local government plays an important role in integrating the district energy system into the urban planning. However, after the urban planning is completed, the local government handed the project to the market changing its role from leading entity to adviser. The local government helped in coordinating all the necessary regulations, design guidelines and policies to support the project development.

**2) Technical solutions for affordable heating and cooling.** In the area of Zhengzhou, heating and cooling season only cover 4 months respectively. Due to a relative low demand for heating and cooling, it is very expensive if district energy system only supplies one of them. However, by using the heat from waste water, it is possible to combine both of them to make the whole system cost-effective.

##### Challenges

##### 1) Off-peak tariff for thermal energy storage.

Even though thermal energy storage is applied to large amount of projects as one of the energy efficient solutions, the tariff of electricity in Zhengzhou is relative expensive. It does not consider lower price during the off-peak period. As a result, thermal energy storage is not cost-effective.

**2) Broad reuse of waste water.** Even though the quality of treated waste water can achieve level 1, meaning it can be used widely as washing, cleaning etc., except drinking, the district energy system only use the heat from it. Actually, it can be used as sewage water, landscaping water ect. after the heat exchanges to district energy system. Thus, it will reduce somehow the price of waste water.

### III. 2.3. IMPLICATION FROM THE CASE: IDENTIFICATION OF KEY LESSONS AND FUTURE PROSPECT

#### Key lessons

1) Integrated district energy system in the early stage of urban planning can assure the implementation of eco-energy. The planning and design of district energy system can be align with the project development so that the integration of networking. The use of waste water can be designed and constructed at the same time as other utilities in the region.

2) Economic analysis is very important in deciding which technical solutions to apply in a district. The final technical solution should not only be high energy efficient and totally eco-friendly, but also affordable to all the end-users.

#### Future prospect

1) Systematic planning of reusing waste water at the city level. Through this project, it appeals that it's cost-effective to reuse the heat from waste water for district energy systems. In order to better understand the areas in the city with higher

potential for waste water reuse, it is suggested to map all waste water resources and the zones where district energy could be implemented with the help of GIS. Then, a detailed planning of waste water reuse at the city level should be done on the basis of this mapping. As a result, the local government and potential investors could understand which parts of the city may have higher potential for district energy with waste water reuse.

2) Integration of renewable energy in waste water treatment procedure. This procedure requires to maintain the temperature of water to 15-25 °C so that the chemical process should continue. However, extra energy is needed to heat the water, especially in winter. Most of the water treatment factories in Zhengzhou are using LNG for that. It is possible to introduce renewable energy, like solar heating system, so that the amount of primary energy supply to the district energy system as a whole can be reduced.

### III. 2.4. REVIEW OF BUSINESS MODELS

#### Investment and operation body

There are three commercial/governmental bodies collaborating for the Public-Private Partnership in this district energy system. First, the municipality, representing the local government, who contributes providing the land for the district energy plant and pipeline. They also finish construction and other engineering work for the district energy system (Turn-key or Engineering Procurement Construction (EPC)). Second, the owner of the waste water treatment plant who distributes the treated waste water from its plant to the island. Finally, the operator of the district energy system, who makes sure that the system operate at a high efficiency and reliability.

All these three partners share holdings in the company and make sure the system works in a cost-effective way.

The municipality, as one of the three share holders in this case, contributes with the land for the district energy plant and pipeline, and covers 100% of constructions/installations costs of all the district energy systems. The district heating/cooling plant and pipeline are installed underground, so above ground there are public parks and recreation area.

There is a public endowment under local government for all the development or refurbishments of district energy system, including waste water treatment plants, district heating/cooling systems and networks etc.. The

municipality can get the funding from this foundation to invest in the engineering work at different stages of the project. After the buildings of end-users are fully developed and connected, one-time connection fee is charged before the supply of heating/cooling. This connection fee will go directly back to the endowment. Meanwhile, the

rents of the land for district energy plants and pipelines go to the endowment on a monthly basis as well. So that the municipality can use all these money for the future development or investment of other similar projects.

### III. 3. OVERVIEW OF CASE STUDY IN BARCELONA, SPAIN

#### III. 3.1. DESCRIPTION OF BARCELONA CITY

Located on the coast of the Mediterranean Sea, Barcelona is in the Northeast part of Spain. The city has a metropolitan population of approximately 5,3 millions of inhabitants, making Barcelona the sixth most populous urban area in Europe. The coastal location favoured the development of local economics, also thanks to the presence of two rivers – Llobregat and Besòs. Therefore, Barcelona has a variegated trading network because of the connection to other coastal cities of the Mediterranean Sea, as well as to Iberian cities. In fact, the port of Barcelona is one of the most important ones in Europe, branding Barcelona as “transport hub”.

Situated on the seacoast, Barcelona is located on a plain and has an average of 12 meters above sea level. A semicircle of mountains, Collserola, surrounds the city, as well as national parks, such as Serra de Collserola and Parc de la Serralada de Marina. The climate is humid subtropical climate

with little temperature fluctuations. January is the coldest month and August the hottest. Spring and autumn are the seasons with more frequent rainy precipitations, while snow is rare. The presence of mountains protects the city from wind.

Based on the historical administrative divisions, in 1987 the city was officially divided in 10 districts, which are still nowadays valid. Each of the districts has an elected council and a city councilor. In particular, the districts are:

- Ciutat Vella;
- Eixample;
- Sants-Montjuïc;
- Les Corts;
- Sarrià-Sant Gervasi;
- Gràcia;
- Horta-Guinardó;
- Nou Barris;
- Sant Andreu;
- Sant Martí.



*Pic. Barcelona location in Spain.*

### III. 3.1.1. SOCIO ECONOMIC AND POLICY BACKGROUNDS

Barcelona has initiated the transition towards a more sustainable energy model, working to maximise renewable energy generation and reducing final energy consumption by applying energy efficiency measures. In this context the city aims to be a pioneer in energy policies prioritizing and promoting a set of measures and actions to change the city's energy model and set the path towards the energy transition.

With this purpose the Municipality created an entity called Energy Operator to develop local energy policies in an efficient and coordinated way to materialize the energy transition. The main goal of the Energy Operator is to implement the activities and projects included in the local energy plan, now the Energy, Climate Change and Air Quality Plan 2011 to 2020 ("PECQ").

The PECQ is a local strategic plan drafted by Barcelona's Energy Agency to set the path of local measures to be put in place in the period 2011-2020 on energy efficiency, management of energy demand or energy generation with alternative funds of the city. The aim of the PECQ is to:

- reduce the city's energy consumption;
- reduce GHG emissions associated;
- improve air quality, mainly NO<sub>x</sub>;
- improve the quality of energy supply;
- set specific environmental goals<sup>1</sup>: i) reduce 9,9% the city's total energy consumption, ii) double the rate of local renewable energy generation, iii) reduce GHG emission in 17,5%, iv) reduce NO<sub>x</sub> emissions in 26%, v) reduce emissions of PM10 in 39%, vi) accomplish the limits of EU on NO<sub>2</sub> and PM10 emissions.

The plan includes two separate but complementary programmes:

- the programme "City": including all aspects related to energy demand and consumption of the different sectors – residential, transport, industry, tertiary;

- the programme "Municipality": including areas that depend directly from the Municipality, such as public buildings, lighting, water, urban services.

#### District Energy as key technology of the Energy, Climate Change and Air Quality Plan (2011-2020)

Barcelona identified district heating and cooling in the PECQ as an innovative technology to be launched with a significant impact on the energy efficiency sector. In this context the plan makes reference to the need of integrating the "energy, climate change and air quality vector into urban planning as strategy to facilitate the development of district energy in the city.

To encourage and promote the development of district energy, the PECQ includes the following projects and actions:

- Improve energy efficiency in the industry sector and increase distributed electricity generation by encouraging the installation of cogeneration plants to provide waste heat to different industrial processes.
- Develop a district energy network in Zona Franca-Gran Via L'Hospitalet using waste incineration, biomass and waste cold from LNG regasification process at the LNG terminal situated at port. The project will decrease CO<sub>2</sub> emissions and reduce dependency on fossil fuels.
- Extend the Forum-22@ DHC network to the district of St Andreu in the context of improvement of energy efficiency and reduction of primary energy consumption. Maximise the use of heat generated in the waste incineration plant of TERSA.
- Incentivise the connection of residential buildings to DHC. Encourage connection of multi-residential buildings as DHC has been proved to be the most efficient way of covering the buildings thermal demands.
- Buildings connected to the DHC network are exempted of installing solar thermal panels for

<sup>1</sup> Baseline 2008

water heating. Due to the lack of proper maintenance, which costs about 1'500 € per year, this exemption encourages building owners from hotels, etc to choose district energy.

- In public buildings: once the heating and cooling systems currently installed come to the end of their life, explore alternative as efficient as possible. Systems that could be studied are: cogeneration, connection to the existing district energy networks. Do an inventory of existing equipment in existing public buildings and

explore whether to renovate equipment or externalise the supply of heat or cold in case there is a DHC network nearby. In the buildings of new construction, buildings should be built according to the norms and requirements of energy efficiency based on the norm of energy certification of buildings of new construction.

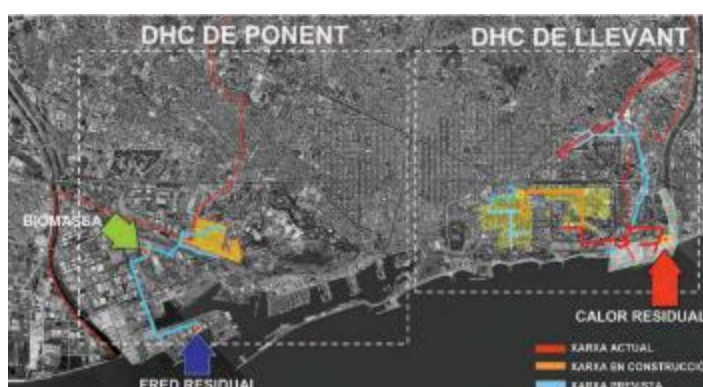
- New buildings in the district 22@ are obliged to first study if it is feasible to connect to the District Heating Network.

### III. 3.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

#### Barcelona's district energy network

Barcelona has lately encouraged the development of district energy systems to reach the goals of improvement in energy efficiency set by the city's energy and climate change plan.

So far the city has two district energy networks: the "Forum-22@" network located at the East, and the "Zona Franca - la Marina" network located at the West.



*Pic. Distric heating location in Barcelona.*

#### The "Forum-22@" district heating and cooling network

The Forum-22@ district heating and cooling network is situated in the area of the Forum and the district 22@, a very dynamic district with a mix of residential buildings, hotels and innovation companies. The network is managed by the company Districlima. Districlima is a public-private partnership conformed by the private company Engie and the municipality of Barcelona. Districlima started its activity in 2002 to develop

Spain's first district heating and cooling network to supply heating, air conditioning and sanitary hot water. The project was initiated in an urbanistic remodelled area of Barcelona that includes the Cultures Forum 2004 (Besòs seafront), and it encompassed the design, construction and further use of the Forum's production station and energy distribution network per 25 year concession contract.

In 2005, Districlima was awarded with a 27 years concession contract for the extension of the

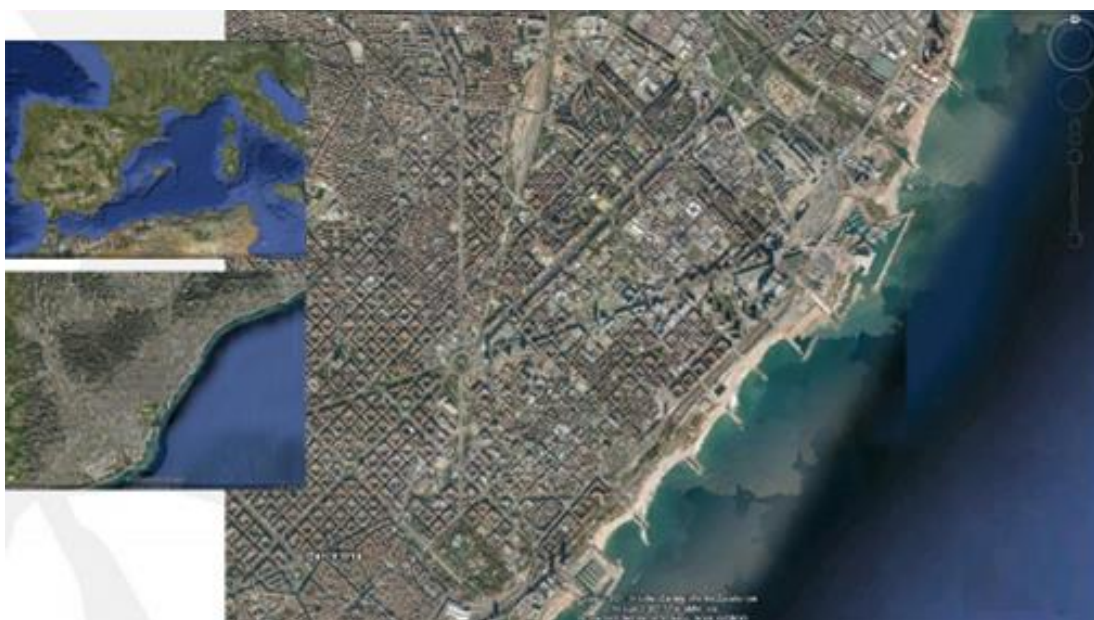
network to the 22@ technology district, in line with the area's urban development and new users' connection requirements

The plant operates using waste heat from the waste incineration plant of Besos, operated by TERSA – the municipal company for waste management.

The district energy system of the Forum was the first network to be implemented in Barcelona and it continues nowadays with its process of expansion. Most of the buildings connected to the network are tertiary buildings or social housing.

To supply heat and cold the plant uses high efficiency equipment that guarantees constant

supply to the users of the system. The energy balance of the district energy system represented in 2009 34'895 MWh of waste heat from TERSA incineration plant, a 940 MWh produced from gas for the auxiliary system and an electricity production of 9'927 MWh. This way 95% of the heat and 19% of the supplied cold comes from waste heat from TERSA incineration plant. Savings in primary energy consumption were 39'403 MWh/year and savings in CO<sub>2</sub> emissions were 7'076 t/year (a 51% and a 58% compared to conventional systems). In 2016 the system saved 18'900 tones of CO<sub>2</sub>, compared to 4'600 tones CO<sub>2</sub> saved in 2008.



*Pic. Geographical location (satellite view).*

### Technical characteristics of the Fòrum-22@ DHC Plant and Network

The network has two production plants: The Forum plant and the Tanger plant.

#### Forum Plant

Almost all the heat and a part of the cold are produced making good use of the steam produced by the incineration of urban waste in the nearby treatment plant (TERSA). The rest of the cold is produced through industrial electric chillers that are seawater cooled. In this way, high performance

is achieved and the installation of cooling towers is avoided. The system is completed with a cold water storage tank of 5'000 m<sup>3</sup>, 2 absorption equipments of 4,5 MW each one, 2 electric coolers of 4 MW each one, 2 electric coolers of 7 MW one, refrigeration system of 3 exchangers of seawater/cooling water, machines of 12,5 MW each, 1 seawater collection station of 5'000 m<sup>3</sup>/h. Heat production is ensured by 4 steam/water heat exchangers of 5 MW each one, 1 gas boiler of 20 MW capacity.



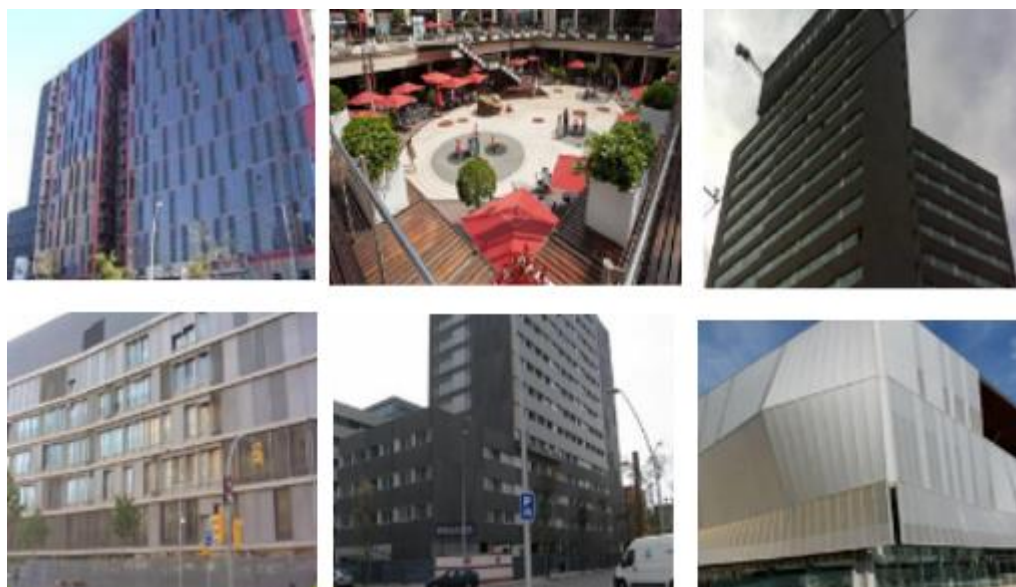
*Pic. District heating and cooling Plant and network.*

### Tanger plant

Initially conceived as a peak plant, the goal of the Tanger plant is to guarantee the energy supply in periods of high demand or in case of any contingency. It has an advanced ice storage system that allows producing energy in periods of low demand and store it until it is needed. The combustion gas from the boilers is exhausted by the historical chimney of the ancient textile factory “Ca l’ Aranyó” (1872). The Tanger plant started to operate from April 2012 with one compression chiller of 6,7 MW for the production of glycoled water and two gas boilers of 13,4 MW each one for

production of heat. In a second phase there will be installed one compression chiller of 6,7 MW for production of glycoled water and one natural gas boiler of 13,4 MW for heat production. Today the network has 95 large buildings connected. The network climatizes a roof surface of 970'000 m<sup>2</sup>, has contracted 62 MW heating power and 93 MW cooling power with 16,8 km network and an installed cooling power of 45,4 + 40 MWh water storage tank + 120 MWh ice storage tank, and 46,8 MW heating power.

The total project investment is over 63 M€, CO<sub>2</sub> emission savings makes 18'903 tones.



*Pic. over 90 large buildings are connected to Tanger plant.*



*Pic. From 2003 to 2016 cooling power from 0 MW increased to 93 MW, heating power from 0 MW to 62 MW respectively. District Heating Network from 3,3 km increased to 16,8 km.*

### An overview of the “Zona Franca-La Marina” district heating and cooling network

The “Zona Franca- La Marina” district heating and cooling network which is situated in the Zona Franca and La Marina del Prat Vermell district. This network is being built by the company Ecoenergies. Ecoenergies is also a public-private partnership conformed by the private company Veolia and the municipality of Barcelona. The network will use plant based waste from the maintenance of parks and gardens and forest biomass for the heating network and waste cold from the regasification process at the LNG terminal for the cooling network. The LNG arrives to the port at a very low temperature (approx. -190°C) and goes through a regasification process to bring the gas up to +4°C. Instead of wasting the cold by transferring it to the sea, the district cooling network utilizes it to supply space cooling to an entire neighbourhood.

Once the the projected network reaches its full extention, district energy will be the main heating and cooling supply system for the whole distric of la Marina, connecting residential and tertiary buildings. The installation of 13'000 m2 solar thermal panels will complete the source energy mix of this eco-neighbourhood still under construction. Once the project is completed there weill be savings of 67'060 MWh/year of primary energy consumption and 13'412 t/year of CO2 compared to conventional systems

### III. 3.2. PERFORMANCE AND OUTCOME OF THE CASE STUDY PROJECT

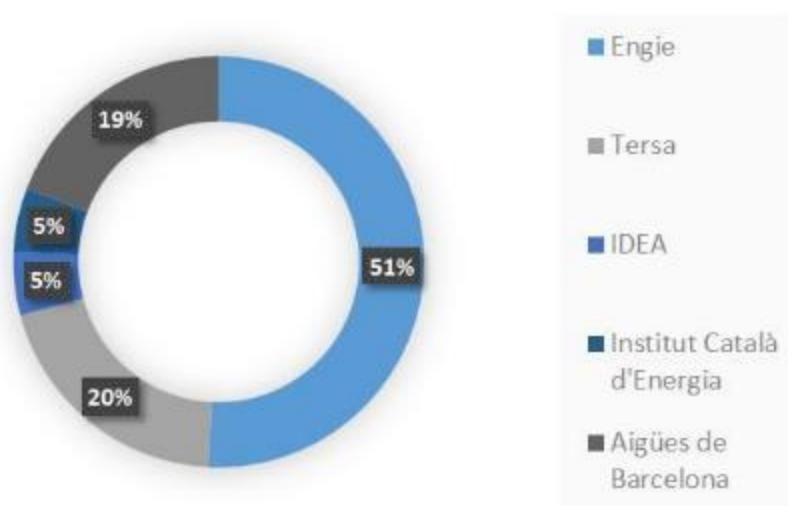
#### III. 3.2.1. ANALYSIS OF PERFORMANCE

##### Main project figures

Since 2004 Districlima, S.A. develops the heating and cooling urban distribution network in the districts of Forum and 22@.

Districtlima is a public-private partnership formed by the private company Engie and several local public entities such as TERA (the public local waste management company), IDEA (a national institute

for energy efficiency), the Catalan Energy Institute, and Aigües de Barcelona (the local water utility). The company started making profit in 2010. Up to that point, the municipality had been supporting the company by promoting the connection of public buildings and even paying higher tariffs to compensate some losses..



Pic. Founder partners according to Districlima.

##### Economic performance

- Notable reduction of contracted electrical power.
- Savings in users energy bills.
- Reduction in maintenance costs and fewer technical specialisation requirements.
- No need to purchase or replace own production equipment.
- Aids energy expenditure forecasting.
- More space available for business or other uses.
- Cutting-edge buildings with a high added value.

##### Security performance

- Guarantee of safety and continuity of supply.
- Elimination of risk of legionella in buildings as there are no refrigeration towers.
- Permanent supervision of facilities by specialists, including substations
- No inflammable gases inside the building.

##### User performance

- Flexibility: service is guaranteed at all times, avoiding the need to plan and adapt to different

user requirements. Power can therefore be increased easily with minimum investment

- **Reliability:** the equipment is redundant, high quality, automated and constantly supervised by highly qualified technicians to ensure unfailing service.

- **Simplicity:** less complex facilities with low cost maintenance. Greater operative simplicity of facilities as energy production does not belong to the building

- **Space saving** unobstructed roofs and small technical rooms.

- **No vibrations, noise or negative visual impact:** due to the elimination of air conditioning equipment and chimneys.

#### **Environmental performance:**

- Waste energy sources (urban solid waste) are used in high performance energy equipment, thus minimising fossil origin primary energy consumption.

- Reduction of greenhouse effect gas emission as it is a more efficient energy solution. 18,903 ton of CO<sub>2</sub> saved in 2016, equivalent to planting 945,000 trees.

- Significant reduction of refrigerant losses into the atmosphere compared to conventional systems.

- Noise and vibration reduction in buildings connected to the system.

- Null visual impact as the system ensures that roofs and facades remain completely unobstructed.

### **III. 3.2.2. ANALYSIS OF KEY SUCCESS FACTORS AND CHALLENGES OF PROJECT**

#### **Key success factors:**

- Buildings connected to the network benefit from higher ratings in energy efficiency certification, they gain space that can be used for commercial purposes such as swimming pools on roof tops or other architectural solutions.

- Buildings have lower maintenance costs, noise and vibrations.

- The system facilitates an increase in power capacity with almost no additional investment.

- The system increases security of supply by connecting to multiple energy sources.

- Clients always get the most efficient and cheaper energy as they automatically benefit from any improvement and technological upgrade made in the plants.

- The city and the community benefits from lower external energy dependence and a decrease in the global electricity consumption, which

translates in a minimization of the electrical and gas infrastructures.

#### **Challenges of the Project**

- To have an accurate estimation of the demand, in terms of time, quantity and location.

- To connect buildings outside the area covered by the concession contract. The concession contract allows connection of the buildings that fall under a specific area. This means that if a building outside of this area demands connection to the network Districlima can not extend the network to connect this building.

- Clients might be dispersed at the beginning of the project, and the district energy company will have to evaluate if the investment required to connect these buildings would be profitable on a long term basis or not.

### **III. 3.3. IMPLICATION FROM THE CASE: IDENTIFICATION OF KEY LESSONS AND FUTURE PROSPECT**

#### **Key lessons**

- **Integrate district energy in urban development processes.** The development of this type of projects embedded in the urban planning need to be linked to building development and the transformation of the urban environment. These

projects need to be part of the urban planning from the very beginning.

- **Partner with a private company with high investment capacity and technical expertise.** It is important to have a high investment capacity as it is a long term investment.

- **Engage with all stakeholders.** Involve all the different stakeholders from the very beginning (municipality, building developers, investors, community).

- **Offer long concession contracts.** The long concession approach turned out to be very positive and attractive for the private sector. It reassures the private sector that the business is stable and allows them to get their return on investment even if there are changes at the political level.

#### Future prospect

The future prospects for Districlima are very positive. The company has recently gained the

concession to extend and operate the network required to connect one of the main hospitals in Barcelona (Hospital del Mar). Building owners demand the most and most their services and the provisions for growth and network extension are very positive. The Municipality sees Districlima as one of the pillars to provide the city with sustainable cooling and is willing to keep on signing long concession contracts to attract private investment.

### III. 3.4. REVIEW OF BUSINESS MODEL

Districtlima is a public-private partnership (50,8% private and 49,2% public) created in 2002 to operate Barcelona's first district heating and cooling network under a concession contract.

Hybrid public and private business model are very common in those cases in which the local authority is willing to carry some risk and has a desire to exercise some control, but it also wants private sector participation to bring in expertise and/or private capital. A challenge with this projects is ensuring that all parties have a clear, agreed vision of what the objectives are and how they will be achieved.

Under the hybrid approach the local authority has a wider range of options for business models. The most common options found in the district energy sector are the public and private joint venture, the concession contract, and the community owned not-for-profit or cooperative.

Barcelona's local authority opted for the concession contract model to attract investment and the expertise of the private sector. The network is regulated through two different concession contracts that apply to two different zones, the 22@ Zone and the Besós Zone, as presented in the following figure

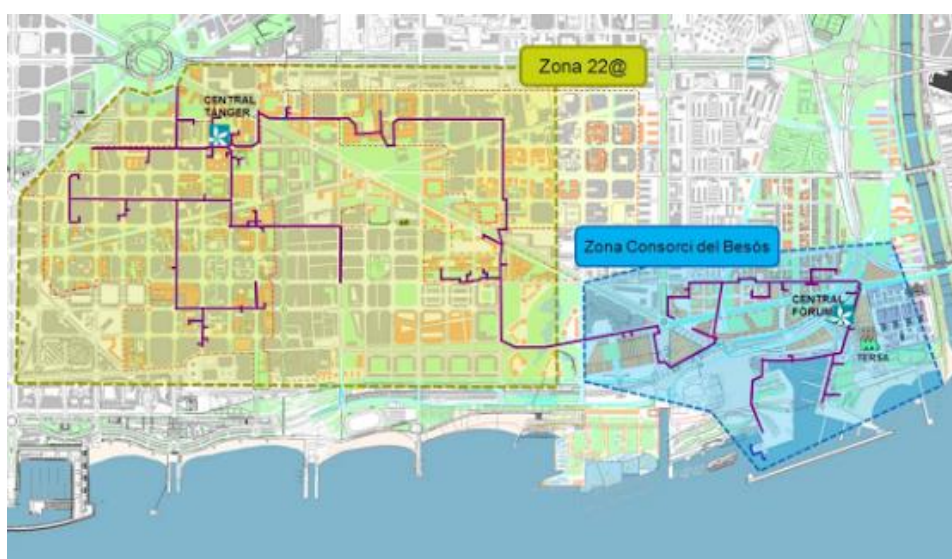


Figure 2: The network is regulated through two different concession contracts that apply to two different zones, the 22@ Zone and the Besós Zone.

The first concession contract started in 2004 and it was to design, develop and operate the Forum's district heating and cooling network for 25 years. In 2005 a second concession contract was signed to extend and operate the network through the 22@ district for another 27 years. Once the concession contracts are finished the installations will go back to the Municipality, who will issue a new concession contract.

Each zone is regulated by the corresponding representative of the public authority in each district. The Besós zone is regulated by the Consortium Besós and the 22@ zone is regulated by the entity 22@BCN.

The role of the regulators is:

- Define the limits of the territory under which the concession contract is valid.
- Supervise the correct execution of the contracts between operator and client.
- Supervise and approve the tariffs for heating and cooling applied by the operator.
- Guarantee the rights of the customers.

The heating and cooling tariffs are therefore agreed every year with the regulator who makes sure that consumer rights are respected.

Tariffs are also set in a way that allow Districlima to recover the investment made. The

main income source for Districlima is the sale of heating and cooling. The company recently incorporated the substations maintenance service in their range of services to ensure that substations follow adequate maintenance procedure and to avoid deficiencies in the supply due to lack of maintenance work. Substations are installed in the customer's building and its maintenance is responsibility of the client.

One of the main objectives of Districlima is offering its client a 10% of savings in their heating and cooling bill compared to the business as usual scenario.

With its regulated tariff system it hasn't been till 2010 that Districlima started making profit after starting operating in 2004.

One of the main advantages of this model is that the presence of the local authority as designer of the concession contract and also as part of the public-private partnership of the company developing and operating the network is that it mitigates many of the risks associated with gaining project approvals. The fact that the local authority ultimately may own the system, as well as the contracting/financing complexities associated with a concession model, means that the local authority still takes on significant risk.

### III. 4. OVERVIEW OF CASE STUDY IN MILAN, ITALY

#### III. 4.1. DESCRIPTION OF MILAN CITY

With more than 1,3 million people, the city of Milan is the capital of Lombardy and the second-largest city of Italy. Located in the North-West of Italy, precisely in the Po Valley the metropolis is halfway between the Mediterranean Sea, the Alps and Apennines mountains. The total area of the city is more than 180 km<sup>2</sup> at a 120 m of altitude. The local climate is temperate with some continental characteristics due to the distance to the coast of approximately 150 km. Thus, cold winters and hot summers are the distinctive climate patterns of Milan. With high humidity – especially in the summer – and yearly average precipitation of 950 mm, the vegetation is typical of humid subtropical areas (according to the Köppen climate classification).

The geographical characteristics led to the development of Milan as the biggest industrial city of Italy, which further accelerated its economy. In particular, the proximity to Genoa and Turin allowed for the creation of the so-called industrial triangle by the end of the XIX century. Today Milan

is the third largest among European cities by GDP and it has some of the most important Italian educational, cultural and financial centres.

The metropolitan area of Milan is divided in 9 municipalities and each of them has a municipal council in charge for a variety of administrative functions. In particular:

- Personal, educational, cultural, and recreational services;
- Management and maintenance of the local patrimony;
- Private constructions;
- Green areas and urban development;
- Urban safety and district driveability;
- Trade and artisanal activities;
- Relations with citizens on finance and fight against fiscal evasion.

The municipalities are organised on a sunburst planning, numbered from 1 to 9 on a clockwise order (see picture below). Each of them is divided in districts (quartieri) which have no institutional, nor administrative power.



*Pic. The metropolitan area of Milan is divided in 9 municipalities (municipio).*

### III. 4.1.1. SOCIO ECONOMIC AND POLICY BACKGROUNDS

#### Energy policy objectives, strategy and targets

Milan's energy strategy links the benefits of district energy with broad policy targets on CO<sub>2</sub> and greenhouse gas emissions, energy intensity, fossil fuel consumption, energy efficiency and renewable energy. District energy related targets include future share of district heat/cooling/power, share of district energy in specific buildings (e.g., public buildings) or share or absolute numbers of buildings connected.

As a member of the European Union (EU), Italy must contribute to the EU's objectives concerning energy and climate change to be achieved by 2020: 20% reduction in EU greenhouse gas emissions from 1990 levels; renewable energy share in energy consumption of 20%; a 20% improvement in the EU's energy efficiency.

Such national and international targets prompted Milan to become a signatory of the Covenant of Mayors, a voluntary agreement launched by the European Commission. Covenant signatories are committed to reduce their CO<sub>2</sub> emissions by at least 20% by 2020 (Milan chose 2005 as a reference year). Milan officially adhered to the Covenant of Mayors with a local government decision in 2009. This means Milan's CO<sub>2</sub> target is in-line with the EU's 20% reduction in EU greenhouse gas emissions from 1990 levels.

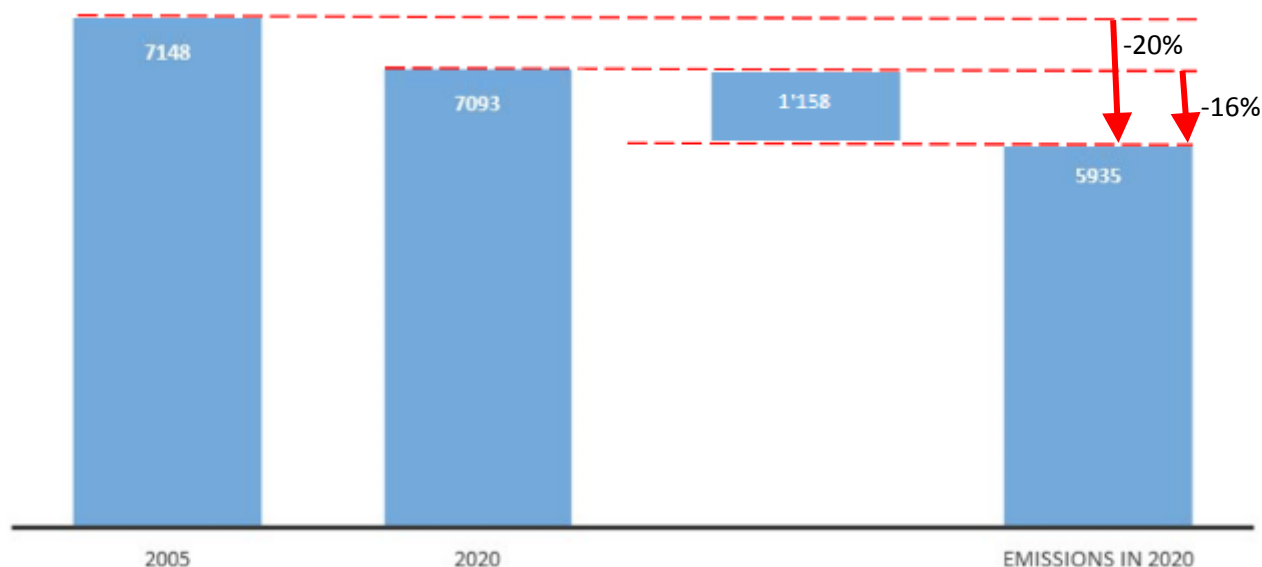
Milan released a Sustainable Energy and Climate Action Plan in 2009 that detailed the pathway to reducing emissions by 20% by 2020. This is being further elaborated into a Sustainable Energy Action Plan (SEAP) which will include specific actions that Milan's local authority will implement in order to achieve the emissions reduction target and will include an in-depth analysis of Milan's energy system including building efficiency, waste-to-energy plants and district heating. By specifically analysing the

heating and cooling sectors within its overall energy strategy, Milan has identified that district heating alone could contribute almost 10% of the city's 2020 target of 20% less CO<sub>2</sub> emissions.

Milan's energy strategy provides long-term benefits to the city by providing investor confidence and the analysis being developed in the SEAP will provide the validation and direction needed for district energy development. Every action of the municipality administration, be it a plan, a single project, a regulation or a policy, is designed in coherence with the EU objectives concerning energy and climate change and the city's own CO<sub>2</sub> emissions target. In addition, Milan is planning and developing district heating to be coherent with European and national legislation requiring development towards high efficient district heating. As such, Milan will be investigating new energy sources such as waste heat from industrial sites that can increase the efficiency of the system.

#### The sustainable energy action plan

Milan's Sustainable Energy Action Plan will detail a pathway to reducing emissions to 20% below 2005 levels by 2020 by analysing potential contributions from different sectors in Milan. The Plan only considers CO<sub>2</sub>, as it constitutes the majority of city emissions (92%) and the reduction of other GHGs is dealt with in regional and national policies. In 2005 overall emissions were 7'418 kt CO<sub>2</sub> and by 2020 these will have been reduced to 5'935 kt CO<sub>2</sub> as shown in picture below. In the Plan, future improvements to Milan's extensive district heating network are expected to contribute 139 kt CO<sub>2</sub> in emission reductions. The improvements to the district heating network were expected to be an enlargement, with an increase of heat distributed from the current 642 GWh/year to the expected 1'180 GWh/year.



Pic. Emission reductions relative to Business as Usual scenario (BAU) – overall emissions (direct and indirect) (ktCO<sub>2</sub>/year).

#### Energy mapping and holistic energy planning.

Milan uses various mapping tools and studies to direct district energy development to optimal demand areas, to help to understand energy use, infrastructure, emissions as well available resources, to identify interconnection routes and where potential heat sources could be connected. For example, Milan has developed several studies and plans to evaluate the potential utilization of groundwater for heating. Also Milan uses a holistic energy plan for integration of district energy in land-use and infrastructure planning, develops guidelines for urban development plans to contain energy vision and required energy assessments for new developments.

**Connection policies.** Milan applies a connection policies that encourage connection where it is economically and technically feasible and minimizes load risk. Zoning by laws is performed to encourage district energy developments.

Milan has used its planning authority to implement a building code that actively promotes district energy by requiring higher levels of energy efficiency performance than national standards and incorporating district heating into energy efficiency assessments of buildings.

Milan does not have a mandatory connection policy requiring buildings to connect to district energy networks however legislation exists in a new building code approved in 2014 that effectively promotes connection to district heating system. The building codes stipulates specific minimum energy efficiency requirements for new and retrofitted buildings. In practice this means any new building being constructed and any existing building undergoing a significant retrofit. These energy efficiency requirements do not only look at the building but also the supply of heat and hot water and so can be met by connecting to the district heating network in combination with other building efficiency measures. As such, buildings are being encouraged through the city's building code to connect to district heating. Furthermore the new building code allows new buildings to exceed standard building size requirements in planning conditions if higher energy efficiency levels than the minimum are met.

This is effectively a density bonus for developers in the city that are developing high efficiency buildings, and further encourages connection to district heating. A pre-requisite to meeting the standards of the building code is for a building to not have a diesel boiler, eliminating this

carbon intensive and expensive heating technology from all new and retrofitted buildings.

This building code has a higher threshold for energy efficiency than national standards and this is because in Italy cities are able to adopt climate and energy related measures into their planning instruments. This can include the introduction of higher standards at the local level, such as energy performance standards in local building codes, that exceed national legislation.

**Interconnection policies and incentives.** Local governments can direct the expansion and integration of district energy networks through network connection plans that often rely on a degree of municipal ownership to progress. Milan has an ambitious plan for connecting its segregated nodal networks into one large network with a transmission ring around the city. It is unlikely that without the strong support of the city, and the partial ownership of A2A Spa by Milan that such an ambitious interconnection plan would be achievable.

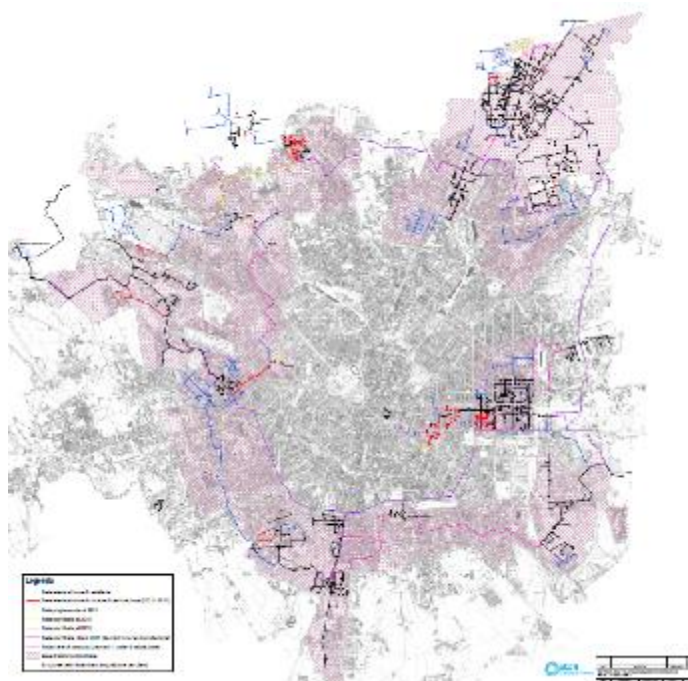
In 2012 there were five main networks in Milan and they are called Milano Sud, Gallarate/San Siro, Città Studi/Tribunale, Santa Giulia Mecenat and Bicocca. The heat delivered by the district heating network within the city of Milan will almost double from 2014 to 2020 to be over 1 TWh

per year and the heat demand on the whole network including neighbouring municipalities will increase by approximately 60 % by 2020. Such increases in heat demand will be made possible by the interconnection of networks which the city of Milan supports through its partial ownership of A2A Spa.

The network will be slowly interconnected to create three large networks from five: the first interconnecting Milano Sud and Gallarate/San Siro to produce Milano Ovest (completed in 2015), the second covering the eastern part of the territory, connecting Santa Giulia and Città Studi and the third extending Bicococcaca in the north of the city.

This interconnection has allowed the city to use the most efficient plants more (CHP and waste to energy) and renewable energy sources and waste heat where available and to use boilers only to cover peak loads and as a backup in case of breakdown.

The vision in the long term is to create a large single network by interconnecting the three large networks into a ring structure around the city's centre. Picture below illustrates the planned expansion of the network as envisaged in 2012 from five individual networks, to three networks, and finally to one large network.



*Pic. Red, black and blue lines show network development up to 2014. Yellow lines show development in 2015. Orange and purple lines show future development.*



*Pic. A portion of Milan's district heating network, connected to the Canavese CHP plant. Milan's segregated networks are undergoing interconnection and expansion to form three large heat networks by 2016, which will then be interconnected via a ring around the city.*



Pic. Milan's district heating system representation. In the image the three current networks, the different plants and service areas can be seeing. A2A district heating Design for Sustainability, 2017.

Having completed the first stage of development of the 3 inter-connected macro operating systems in the West, East and North of the city of Milan, the development of district heating of A2A is going to continue with the second phase involving the planning of a backbone to transport the heat produced by the thermoelectric plant of Cassano d'Adda.

With a view to develop a regional district heating network on July 2015 the regional authorities of Lombardy, Milan City Council and

A2A stipulated a memorandum of understanding with an aim to analyse the possibility of development of 35 km network from the Cassano plant to the metropolitan area. Preliminary studies suggest the connection with the East area of the city as there are connections with the current macro systems.

The project has some important environmental advantages, as well as a positive impact on the economy and territory due to the investments made in development of the infrastructures.



Pic. A part of Milan's district heating network, connecting the Canavese CHP plant to the Cassano d'Adda. Milan's thermoelectric plant.

### III. 4.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

Milan has a large district heating system providing up to 10% of the city's heating demand in buildings. The city is using district energy to switch the heat consumption of the city from predominantly gas boilers and oil boilers to renewable heat and cool consumption of the city from inefficient air conditioners to waste heat from

power plants and ground water sources through absorption chillers. Thanks to waste to energy and cogeneration plants, in 2016 year 320'312 tonnes of CO<sub>2</sub> were saved. This case study references to one of the best practices defined in the District Energy in Cities.

No	MW thermal of heat production connected to a DES	MW Electric of electricity production from DES connected CHP	MW of Cool Production connected to a DES	MWh of Heat production per year on DES	MWh of Cool production per year on DES	Kilometres of heat network	Kilometres of cool network
1.	622 MW <sub>th</sub>	113 MW <sub>e</sub>	17,5 MW	642'023 MWh	7'492 MWh	136 km	11 km

#### The District Heating Network.

Milan has a large district heating system which serves both Milan and neighbouring municipalities. The network has operated since 1997 and has been developed in segregated networks that will be interconnected in the future.

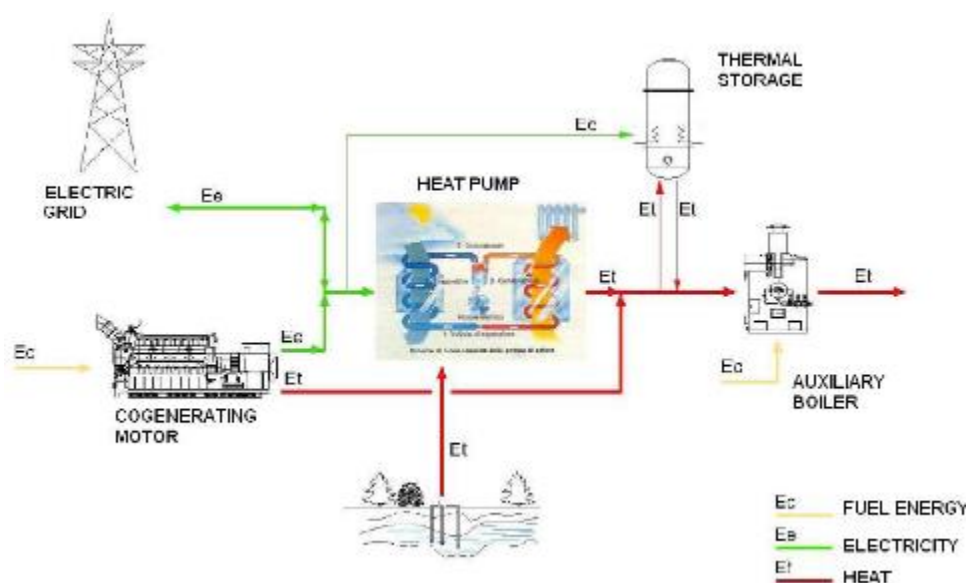
The network connects more than 8-10 % of existing buildings volume within the City of Milan. In 2016, the system delivered 734 GWh of heat to consumers in the city from waste-to-energy plants, gas CHPs, heat pumps, and gas boilers. The total network including connections to neighbouring municipalities is approximately 299 km length and serves approximately 195'800 flats equivalent (1 flat = 80 m<sup>2</sup>). The network, consisting from five main distribution networks and 6 minor networks creating individual "nodes" of district heating, is going to connect to one big system. Some of the main distribution networks cover part of the territory of neighboring municipalities which may in addition have their own network.

The development of Milan's district heating system has been nodal with multiple small networks developed in the city as described above. The first large plants built in Milan were 'Tecnocity' on the Bicocca network in the north of Milan and 'Famagosta' on the Milano Sud network in the

south of Milan, both gas CHP plants (in Famagosta a groundwater heat pump was installed later). Later 'Silla 2' was added in the west of Milan in the Gallarate area, this is a waste-to-energy plant, which incinerates municipal solid waste from Milan and the surrounding region. The district heating in the east of Milan was then powered by the 'Canavese' plant, a progressive CHP to heat-pump plant.

99,6 % of the urban waste is being recovered to other material or produced energy. Thanks to the maintenance in "Silla2" waste-to-energy plant, which will provide a renewable heat input to district heating networks, 305'000 tonnes of CO<sub>2</sub> were avoided in 2016 (+28% compared to 2015).

"Canavese" is a CHP plant in the east of Milan which uses natural gas to produce electricity and heat. Dependent on the relative demands for heat and electricity, the electricity from Canavese can be used to power heat pumps connected to an aquifer under Milan. In combination with on-site heat storage and auxiliary gas-fired boilers, the "Canavese" plant is capable of meeting peak load demand for the network in the east of Milan. The "Canavese" plant was awarded a Certificate of Merit by the International Energy Agency and Euroheat and Power in 2011.



*Pic. Diagram showing electricity and heat production at Canavese plant. The Canavese DH system has been designed specifically to enhance the use the geothermal energy from ground water, a renewable energy resource which is plentiful in the area of Milan.*

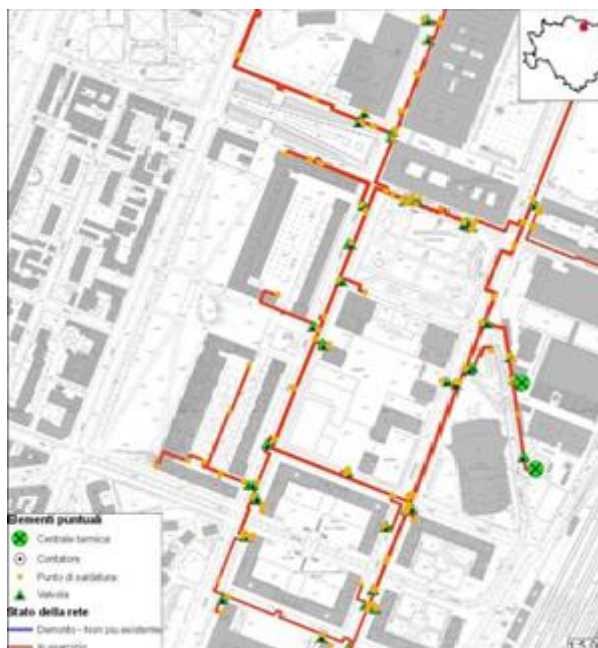
### Using groundwater for heating.

Milan has a large thermal resource in the form of a deep aquifer that can be exploited for heating uses in the city through the use of heat pumps connected to extraction wells. Milan is currently investigating how to connect this groundwater resource into the district heating system and individual buildings. Previously, a publicly funded study was developed to identify the potential use of groundwater heat pumps for public buildings. This study is being built on today as the city assesses the potential utilisation of groundwater heat by evaluating the proximity between existing wells extracting water from the aquifer and demand. These existing wells permanently extract water from the aquifer in order to control the level of the water table and would be ideal to connect heat pumps to. Mapping exercises identifying the spatial relationship between supply and demand could lead to district heating and/or cooling development to connect existing wells, or to the development of new wells that would be better placed to heat areas of high demand.

As the operator and developer of district heating in Milan, A2A Spa works in coordination with urban planning instruments such as the urban

master plan. A2A Spa shares its plans for district heating with the City Administration and the result is that future developments are outlined in the PUGGS (the Plan for Underground Services). This is essentially a holistic energy plan specifically for network development, that sets out the future development of underground networks including district energy and other energy networks such as gas and electricity. Whilst the city is a minority shareholder in A2A Spa it does not dictate exact district heating expansion plans to A2A Spa but will help the operator ensure that development is line with broader urban planning and the city's CO<sub>2</sub> target.

PUGGS was developed as a result of regional legislation requiring municipalities to develop plans for underground network development. The plan accounts for changes in population distribution and coordinates different infrastructure developments to minimize disruptions in the city. The vision of the district heating network is described in PUGGS and in the long term the multiple networks will be interconnected to create a large single network forming a ring around the city center.



Pic. Extract from PUGGS showing existing network and valve points in a neighbourhood of Milan.

### The District Cooling Network.

Currently there is only one district cooling network in Milan and it is based around the Tecnocity CHP in the Bicocca area of Milan. The district cooling network uses absorption chillers and electric chillers with a total power of 17,5 MW. Typically, residential buildings in Milan do not have

centralised cooling systems, limiting the expansion of the network to existing residential developments. However, future development of the district cooling network will focus on connecting existing tertiary buildings such as offices and new developments which could include centrally cooled residential buildings.

## III. 4.2. PERFORMANCE AND OUTCOME OF THE CASE STUDY PROJECT

### III. 4.2.1. ANALYSIS OF PERFORMANCE

#### Resilience-related performance

Through the use of waste heat and renewables, district heating in Milan is far more resilient to external price shocks on fossil fuel markets.

By reducing the number of diesel oil fired and natural gas boilers in Milan district heating has improved the safety of heat delivery in the city.

Milan is in a region that is a net-importer of electricity from more southern regions which can lead to grid constraints on the national electricity transmission system. By increasing local production of electricity from CHP and waste-to-energy plants Milan has helped reduce electricity grid constraints and can reduce the peak electricity

demand in Milan through the use of thermal storage.

#### Economic performance.

District heating is far less expensive than diesel oil heating and has comparable prices to heating through individual gas boilers saving residents, businesses and the city money on heating costs.

In 2011, district heating saved Milan 20'000 tons of oil equivalent in energy expenses.

Milan's partial ownership of its district heating system provides share dividends and concession payments every year to the city.

#### Environmental performance.

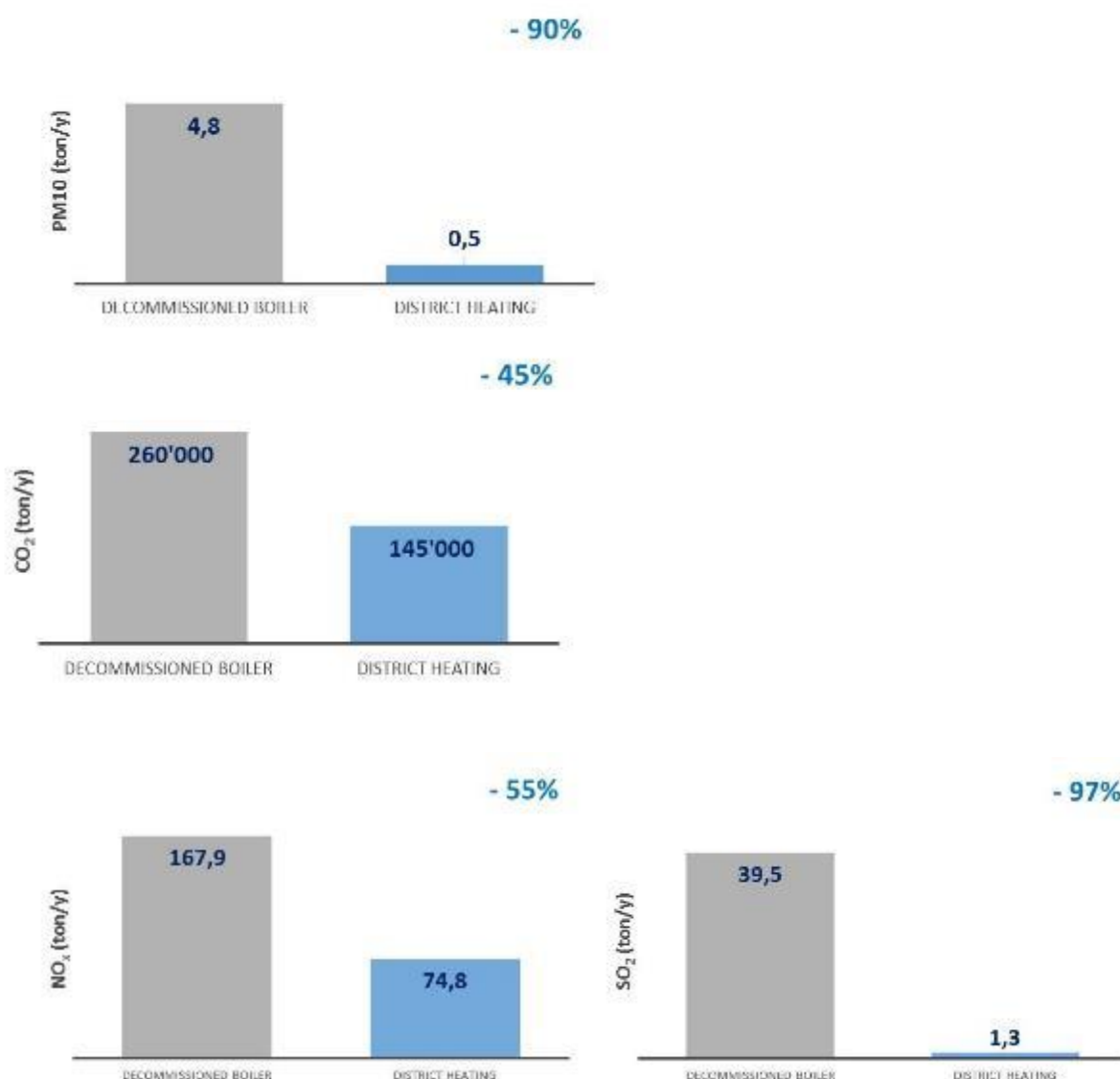
Milan's use of CHP, thermal storage, heat pumps, boilers and waste energy contributes to the balancing of the national electricity system. Such balancing increases Italy's ability to incorporate higher shares of renewable electricity now and in the future, for example higher levels of solar PV and wind.

District heating is enabling an acceleration of the substitution of diesel oil boilers which are still

present in the city, and more polluting than gas boilers.

District heating is enabling the use of renewables and waste heat in heating which would otherwise not be available to buildings.

By being more efficient and renewable, Milan's district heating network in 2016 avoided the emission of 2,5 tons of particulates, 70'000 tonnes of CO<sub>2</sub>, 50 tons of NO<sub>x</sub> and 25 tons of SO<sub>2</sub>.



*Pic. Data of avoided emissions in the District Heating System of Milan.*

**Contribution to the decarbonisation goals.** According to the sustainability report of A2A SpA for 2016, the contribution to the achievement of the

national and Community targets for reducing greenhouse gas emissions of the heating-cooling district energy system are 50% of heat resulting

from non-fossil fuels and waste heat recovery in the high efficiency mix used for the production of heat for district heating and cooling. Thanks to the maintenance of the Silla2 waste-to-energy plant, which will provide a renewable heat input to district heating networks, 305'000 tonnes of CO<sub>2</sub> have been avoided (+28% compared to 2015).

#### **Contribution to a circular economy.**

In 2016, almost the total (99,6%) of the collected waste was started to be recovered to material or energy. Thanks to new investments on the Silla 2 plant, the heat recovery from the energy recovery of waste will increase, which in 2020 will exceed 40% of the total disbursed in the network

### **III. 4.3. IMPLICATION FROM THE CASE: IDENTIFICATION OF KEY LESSONS AND FUTURE PROSPECT**

In order to meet the huge growth in demand for district heating in Milan described above large increases in heat capacity will be required. By 2020 at least 70 % of heat will be produced by waste-to-energy, gas CHPs, renewables and third party waste heat and the remaining 30 % by gas fired boilers. Milan has a significant potential for using its groundwater resources for district heating. Already extraction wells draw water from an aquifer to prevent the water table being too high in the city. The city is studying how to combine these existing wells with heat pumps to capture the thermal energy of the groundwater. Spatial maps

are used to understand the spatial relationship between supply and demand and could lead to district heating and/or cooling connections for groundwater or just to the exploitation of the existing wells for the heating of buildings located nearby.

Future development of the district cooling network will focus on connecting existing tertiary buildings such as offices and new developments which could include centrally cooled residential buildings.

### **III. 4.4. REVIEW OF BUSINESS MODEL**

Utilities in Milan operate under a concession contract from the city including gas, electricity, district heating and district cooling networks.

The construction and operation of Milan's district heating and cooling systems, which include five main distribution networks and 6 minor networks, is carried out by A2A Calore e Servizi, a subsidiary of A2A Spa. A2A Spa is a public-private, multiutility company responsible for distribution of electricity and gas in Milan and other nearby cities, laying district heating and cooling. A2A Spa is the largest company in the Italian district heating sector. Milan owns 25 % of the company A2A Spa which provides district heating and cooling in the city as well as distributing gas and electricity. Whilst A2A Spa operates independently of the city, Milan is able to use its ownership to help direct the company's strategy to be in line with the city's carbon reduction target and efforts to improve efficiency and renewables levels.

The city of Milan maintains control of the district heating and cooling development through the concession contract for district heating and local planning and approval policies. The gas distribution network will be put to public tender for a concession contract soon and the concession regarding district heating will be updated to be in coherence with the PUGSS.

#### **Facilitating Business by Financing and fiscal incentives.**

City authorities have an important role to play in financially supporting the development of district energy. Milan's district heating network is extensive and is partially owned by Milan through the multi-utility company A2A Spa. The large balance sheet of A2A Spa means direct loans and grants are not required from the city of Milan for development of district energy, however the city provides specific financial incentives that support

the business model of district energy in Milan directly or indirectly.

In 2008, Milan allowed a reduction in infrastructure charges for new and retrofitted buildings that respect fixed standards concerning energy efficiency and/or renewable energy sources, including connection to district heating. District heating does not represent a compulsory requirement for the reduced infrastructure charge, but can represent one of the elements that allow the achievement of the fixed standards. The absence of diesel oil as a fuel in heating is a pre-condition in order to benefit from the incentives provided by the infrastructure charge reduction measure and as such switching from diesel oil boilers to other sources such as district heating is indirectly subsidized.

Furthermore, Milan previously provided incentives for district heating in the form of a direct subsidy to buildings to switch from diesel oil boilers to district heating to overcome initial capital costs. However, the payback period of this switch is today so low at 4-5 years that the city no longer incentivises this as building owners will switch anyway.

Financing and fiscal incentives from the municipality includes: debt provision and bond financing, loan guarantees and underwriting, City-financed revolving fund, grants, low-cost financing/loans, rebates, subsidies, tax credits and exemptions within tax systems: for example, sales, property taxes, permitting fees, and carbon taxes.

Facilitation by the municipality can be made by the help of City assets. Using local government land/property/buildings for district energy installations or connections or anchor loads (leasing/selling/permitting).

Facilitation by the municipality can be made by the help of Demonstration projects. Pilots, testing emerging technologies – often hybrid, such as: lowgrade waste-heat recovery from sewage or metro, renewable energy integration and storage, also pilot new policies for district energy systems.

#### **Facilitating Business by the local government acting as provider and consumer.**

**City as supplier** Milan is facilitating investment in groundwater heat pumps by allowing A2A Spa the free use of the Province of Milan's extraction wells which are currently used to keep the level of the aquifer at a level that will avoid flooding.

Optimizing district energy systems to ensure efficient use of resources and to realize the diverse benefits requires working with various actors outside of the standard heating/cooling utility and end-user model. Milan's ownership of A2A Spa, which is also responsible for electricity, gas and telecommunication installations, allows the business model of district energy to benefit from multiple synergies with these utilities. In particular, the development of the network in the city is coordinated with the other utilities within the A2A Spa group to minimise disruption from earthworks and reducing costs of network delivery by developing networks at the same time. Also, A2A Spa is able to strategically optimise the development of the gas and district heating networks, which would otherwise be competing, to lower costs for end-users by not increasing gas network capacity in new district heating areas, for example.

**City as consumer.** The city is also using its own building stock to accelerate expansion of the network and in 2013 the City Administration approved the decision to connect about the 10% of its buildings to the district heating network. The works, operation and management were entrusted to A2A, in coherence with the contents of the Concession.

#### **Facilitating Business by the Local Government acting as a Coordinator and Advocate.**

Raising awareness of the working principles and benefits of district energy is often a largely "invisible" solution among society at large. Cities and community organizations are essential to catalyzing discussions of district energy systems and for advocating for their incorporation into city strategies. Milan, has a municipality-run Energy Help Desk that promotes fuel switching, provide technical and financial information on energy efficiency and renewables, and strongly promote district heating to consumers.

In Milan, many existing buildings already have a centralized heating system. In these cases, besides substituting the existing boiler with a heat exchanger and the connection to the network, no other significant infrastructural works are needed.

Energy suppliers offer retrofitting through energy service contracts. However, communication is a key ingredient to obtaining the energy service agreements. The current building owners need to be educated on the benefits and reliability of being a customer of a district energy system. This is strongly promoted by the municipality through its Energy Help Desks (EHDs), as fuel switching from diesel oil boilers is one of the priorities of the municipality, due in large part to the resulting local air quality improvements.

EHDs are run by the municipality and provide an information service regarding energy issues to end-users and residents. Energy experts are available according to a fixed schedule in the institutional offices of the city's districts, to address any questions and to provide information on potential interventions, available incentives and financing instruments on district heating, energy efficiency and renewable energy. A new central

office was launched in September 2014. Since its conception, district heating has been promoted through information campaigns relating to its environmental benefits.

In addition to EHDs, Milan's Environment Policies Department, Energy and Sustainable Development Service, is in charge of developing energy policies and coordinates with other city units engaged in topics related to energy generally to advance an integrated policy approach. The Municipality of Milan created the "Mobility" Environment and Territory Agency (AMAT) as a public company which supports local planning activities concerning climate change mitigation, energy efficiency and renewable energy as well as to undertake environmental assessments, data collection and indicator development.

Taking into consideration the profit structure of business model Milan's partial ownership of its district heating system provides share dividends and concession payments every year to the city.

A2A's shareholding structure by the end of 2016 reveals that the 25% of the shares belong to the municipality of Milan. Among the retail market (41% of the total), investors residing in the provinces of Milan hold 26,3% of the shares. This demonstrates local commitment and common interests.

The owners of the company A2A group are distributed in Public+Private sector in the following proportion:

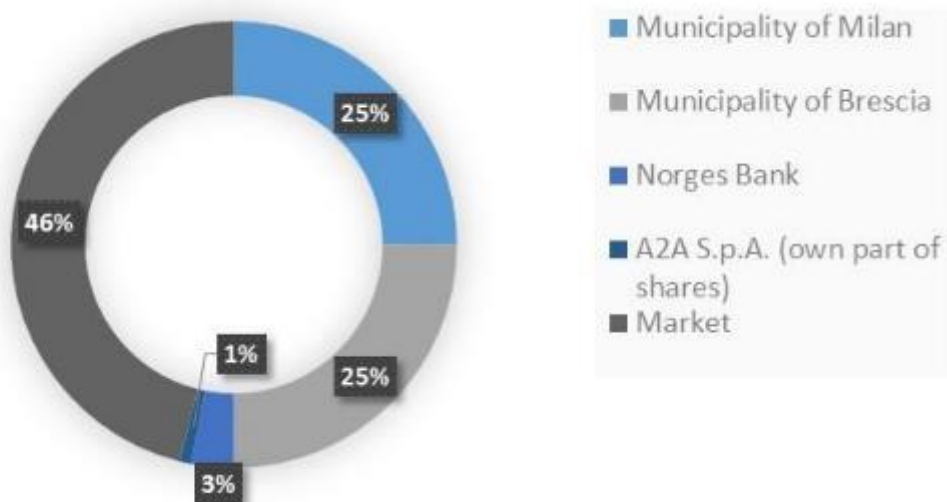
- 25 % municipality of Milan;
- 25 % municipality of Brescia;
- 3,1 % Norges Bank;
- 0,8 % A2A S.p.A. (own part of shares);
- 46,1 % other shareholders market.

The parent company A2A S.p.A. is listed on the Milan stock exchange market. The A2A shares are

traded on the electronic stock market and belongs to the FTSE-MIB segment and falls within the "Public Utilities - Electricity" sector.

A2A has 82'504 shareholders, divided between institutional investors and retail investors. Institutional investors hold approximately 33,8% of the share capital. Retail investors total approximately 81'000 and together hold 12,9% of share capital (16,2% of 2015). 99,8 % of the retail shareholding is resident in Italy and in particular 57,8% in Lombardy. Investors residing in the provinces of Milan and Brescia hold 26,3 % and 12,9% respectively of the total retail.

A2A S.p.A operates the production, distribution and sales of heat through A2A Calore & Servizi. A2A Calore & Servizi is a company of the A2A Group and is the leader in Italy in the field of urban heating, which has been planning and managing for more than 40 years in the areas of Milan, Brescia and Bergamo.



*Pic. Distribution of stakeholders.*

### III. 5. OVERVIEW OF CASE STUDY IN ISSY-LES-MOULINEAUX, FRANCE

#### III. 5.1. DESCRIPTION OF PARISIAN SUBURBAN AREA OF ISSY-LES-MOULINEAUX

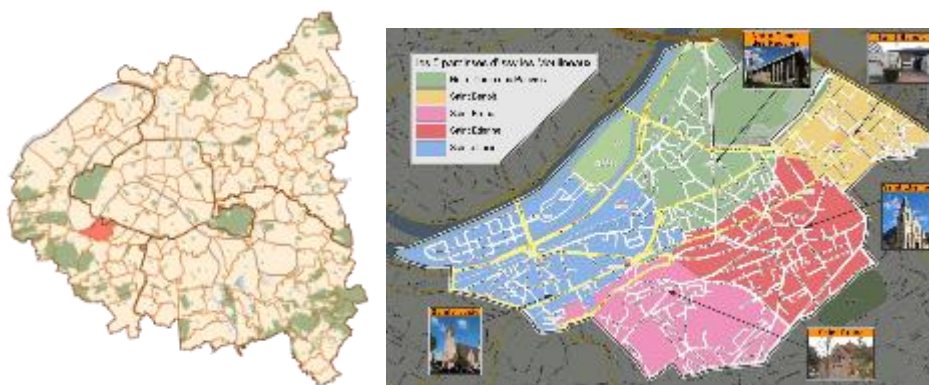
Paris is a densely populated, energy intensive city that is making real progress and commitments to reduce its impact on the environment. In 2004 the territory emitted 25 million tCO<sub>2</sub>eq and in 2014 a reduction by 9.2% has been noted. The city is now looking to increase efforts to bring emissions down to 18.8 million tCO<sub>2</sub>eq by 2020, a targeted reduction of 25% on 2004 levels. District energy has played an important role in Paris historically in reducing coal consumption and today is expanding to connect social housing, improve energy efficiency and increase the renewables share. From now and into the future, district energy will play an important role in carbon reduction commitments, through the reduction of primary energy use and as an enabler of large scale renewable energy systems inputting into district energy networks.

Issy-les-Moulineaux is a commune in the southwestern suburban area of Paris and it is located in Northern France. Situated on the Western side of the river Seine, it is part of the départements of Hauts-de-Seine, in the region of

Île-de-France. Densely populated, with 66'166 inhabitants over an area of 4,25 km<sup>2</sup>, Issy-les-Moulineaux has been part of the Métropole du Grand Paris since 2016.

Due to its location, the climate is Western European, is oceanic, in particular because of the presence of the North Atlantic Current. Overall, throughout the year, the temperatures do not reach extreme peaks of cold and/or heat and the level of humidity is moderate.

Despite its dimensions, Issy-les-Moulineaux hosts the major French telecommunication and media businesses. Moreover, it is considered the heart of the business district of Val de Seine. In fact, in the recent years, the city shifted from general industry to production of services as well as industries for electrical equipment, chemicals, and printing and publishing. Defined as “the most innovative city in France”, Issy-les-Moulineaux is developing towards the usage of environmental-friendly technologies.



Pic. Location of Issy-les-Moulineaux.

### III. 5.1.1. SOCIO ECONOMIC AND POLICY BACKGROUND

The city of Paris currently produces only 3% of its own energy requirements, while the surrounding region of Ile de France produces 11%. The City of Paris is the granting authority for the public distribution of energy in the Paris area and grants concession contracts for electricity, gas, heating and cooling supply. Cities in France legally own all the underground networks that run through them (including electricity, water, telecommunications, heat, cool). Cities can manage and maintain these pipes, as the City of Paris does for the water network, or instead they can grant concessions to public or private parties to manage and maintain these networks. Electricity, gas, heating and cooling distribution networks are granted concessions by the city of Paris and controlled through concession contracts. The city is obligated to provide concessions to ErDF (French Electricity Distribution Networks) and GrDF (French Gas Distribution Networks) for electricity and gas network management and maintenance. For heating and cooling networks no such obligation exists. The Paris Urban Heating Company (CPCU) is 33% owned by the City of Paris and under a concession contract both distributes hot water or steam and maintains and manages the district heating pipes throughout the city. There are no other district heating companies that operate under concession in Paris but CPCU does have many competitors heating buildings not connected to CPCU's network (e.g. gas boilers, electric heaters, heat pumps etc.). CPCU is responsible for approximately one third of the total heating supply in the city, making CPCU the largest district heating network in France. Cooling supply and district cooling network maintenance is provided in a similar concession model by Climespace, a subsidiary of GDF Suez.

#### Paris District Energy Strategy

The current main district energy objective written into the concession contract of CPCU and in

the city's Climate Action Plans is to increase renewables and recovered heat in the energy mix and to develop the district energy networks to new areas. These actions will be vital for Paris to meet its commitment to be carbon neutral by 2050.

Paris has produced three Climate Action Plans in 2007, 2012 and 2017. These Plans set out the city's energy and environmental strategy including specific targets and the pathways towards achieving these targets. Between the two first Climate Action Plans the broad strategy and targets of Paris did not change although the pathways to achieving these targets were updated. The city recognised that in order to catalyse city-wide development towards these targets the city authority would need to be more ambitious and fast-acting in reducing its own greenhouse gas emissions, and consequently developed more ambitious targets for the city authority to achieve in its buildings and operations. The broad energy and environmental targets in Paris are:

- 25%<sup>2</sup> reduction of GCG emissions
- 25% reduced energy consumption
- 25% renewable or recovered waste heat in the energy mix

The 2012 Paris Climate Action Plan took stock of what had been achieved since the 2007 Paris Climate Action Plan and reiterated Paris' commitments to the majority of the targets set out in the 2007 Paris Climate Action Plan. In 2017 the city has reviewed the Climate Action Plan of 2012 to adapt the city targets to the Paris Agreement reached at COP 21. The new revision of the Climate Action Plan is called Climate Air and Energy Plan and sets the path for carbon neutral Paris in 2050. This new Plan has been presented to the City Council in November 2017 and it is expected to come into force in March 2018.

CPCU sets its environmental targets based on the targets established in the Climate Action Plan. The development of the CPCU heat network to be

<sup>2</sup> Compared to 2004

heated by 60% renewable or recovered energy by 2012 was not realised and so the ambition of this target was reduced. The CPCU are now targeting heat networks having 50% renewables or recovered energy by 2015 and 60% renewable or recovered energy by 2020.

The new Climate Action Plan sets the following targets for 2050:

- Zero GCH emission
- 80% reduction of the city's carbon footprint compared to 2004
- 50% reduction of energy consumption compared to 2004
- 100% energy consumption met with renewable energy and waste energy recovery, from which 20% generated locally.

#### Urban development zones

The urban development zones are being used to test technologies and policies that will help the city meet long-term energy and environmental targets. A best practice that could also be used to expand the eco-energy town concept. These development zones have special regulations and are required to try to connect to district heating if possible. Occasionally, the city of Paris pays for the extension of the district heating network to a new zone in order to ensure connections. This is achieved by the city providing a direct, low-interest loan to CPCU

for the development of this extension. The city creates specific clauses in building developers' planning permission that requires connection to district heating or cooling. Paris is now studying the possibility to have new zones with mandatory connections when the energy mix of the district heating is more than 50% renewable or recovered energy. This mandatory connection will be written in a coming city planning document and will also focus studies on the potential for local energy production within these new zones, as well as connection to the CPCU district heating and Climespace district cooling networks. Two urban development zones are described below: Bruneseau Urban Development Zone and Paris Nord Est.

### III. 5.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

#### Overview of Syctom, Parisian agency for domestic waste treatment and waste heat supplier to the Paris district heating network.

Syctom is the Parisian metropolitan agency for domestic waste and former Intercommunal Association for the treatment of domestic waste of the Parisian region. It is a public entity of intercommunal cooperation in charge of domestic waste treatment.

It was created in 1984 and regroups 84 communes from 5 departments of Île-de-France

(Paris, Yvelines, Hauts-de-Seine, Seine-Saint-Denis et Val-de-Marne). Every community is represented in the Association committee. Each commune has the authority over its waste.

For more than 30 years, Syctom has been a major actor in waste treatment in France and Europe. In the context of its mission as public service, it aligns the communities of its territory under a common project, for an exemplary waste management in favour of the circular economy. Syctom is the biggest European association for waste treatment

and recycling. It gives service to approx. 6 million people, 10% of the French population, and treats every year 2,3 million tons of domestic waste.

It assures the treatment and recycling of the waste collected by the member communities, including:

- Paper and packages from selective collection (except glass);
- Residual domestic waste;
- Bulky goods and waste provided by rubbish dumps;
- biowaste;

In a world where raw materials are scarce and fossil fuels are about to disappear, waste is a valuable resource. With its waste-to-energy plants, Syctom forms part of a new economy, greener and more sustainable, with the goal of "Zero waste".

To guarantee an optimal recycling of waste, Syctom counts with 10 treatment units or plants, situated as close as possible to the place where waste is generated: 3 units of incineration including waste to energy systems, 6 waste sorting centres, 1 centre of transfer of domestic waste and 5 dumps.

Syctom is planning the construction of new treatment centres that will allow the recycling of organic waste. To complete its treatment capacities, Syctom uses the service provided by external centres, in particular storage centres and incineration units.

### The waste to energy centre of Isséan at Issy les Moulineaux

The multidisciplinary centre of Isséane at Issy-les-Moulineaux includes a recycling centre with selective sorting of waste and an incineration unit including a waste to energy system for domestic waste.

The plant has been designed following the highest environmental standards and it is considered to be a model of urban integration. That includes a lot of on the characteristics of the building and the area: no chimney visible, green facades, looks like an office building, neighbours didn't want the plant at the beginning but accepted the project in the end, no smell, trucks carrying waste is the only thing you see.



*Pic. The plant has been designed following the highest environmental standards and it is considered to be a model of urban integration.*

The whole waste treatment process is divided in the two main steps :

1. Recycling;
2. Waste incineration and energy production;

### Recycling

Since 2008, Isséane recycling centre receives selective waste from 15 communes under the domain of Sycotm. Waste is sorted and divided by type of material before joining the recycling branch. Isséane was built in the middle of the city and on a limited surface, that is why it was decided to use the space underground, which has led to a particular ergonomic design with compact and high automated processes. Its architecture has been carefully designed and its garden that gets over the facade facilitates its integration in the heart of the city.

The sorting plant of Isséane has a sorting line treating 5 tons of waste per hour using a highly automated process.

The recycling process can be summarised in the following steps:

- Unloading of trucks: after having been weighted, dump trucks descend the access ramp of

the unloading platform to discharge the recyclable waste obtained from the selective collection. After going through a quality control process, waste are stored and then loaded into a food belt to be transferred to a pre-sorting line.

- Pre-selection: a first manual sorting allows to remove the non-recyclable material and big cartons from the selective collection.

- Mechanical and optical selection: a trommel screen separates first the materials by size and a disk separator separates hollow bodies (packages) from flat bodies (papers). A magnetic separator attracts right afterwards steel packages. Two optical sorting machines allow to separate plastics per type and colour.

- Mechanical selection: a manual sorting of waste in a cabine is made on the flow of papers and at the end on the flow of packages sorted mechanically to control and refine the selection of recyclable materials par categories.

- Baler: the material sorted arrive to a baler, where they are immediately compacted by category plastics, paper, carton, aluminium, steel and food cartons. They are stored to be sent to specialised companies where they will be recycled.



*Pic. Location of Sycotm in a Paris district.*

**Key data of recycling plant**

- The plant serves 700'000 habitants;
- 71% of waste is recycled;
- in 2016 year 23'099 tones of waste received;
- 23'025 tones of waste sorted;
- 16'174 tones converted into energy.

**Incineration and energy production**

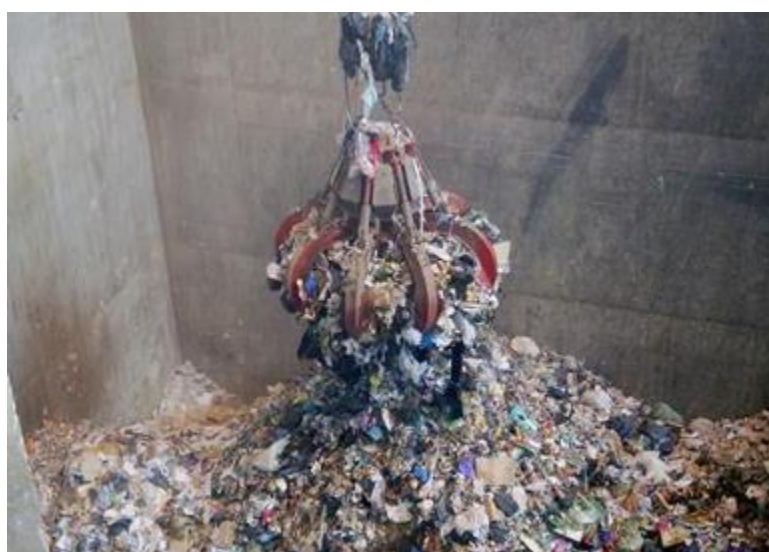
The incineration centre with energy production plant of Isséane receives domestic waste from 22 communes of the territory managed by Sycotm.

The heat generated with waste combustion allows the production of steam that feeds Paris district heating network CPCU, as well as the generation of electricity that it is used for the own consumption of the plant and the surplus sold to EDF company.

**Technical characteristics**

The incineration plant of Isséane assures the combustion of 61 tons/hour of waste, with :

- A reception pit of 23'000 m<sup>3</sup>, equipped with a bridge crane and a grappeling hook;



*Pic. Bridge crane and a grappeling hook.*

- Two groups of boilers with a capacity 30,5 t/hour each, and in which waste is incinerated at a temperature of more than 1000 °C;
- A steam turbine that allows electricity generation.

The incineration and energy production process can be summarised in the following steps :

- unloading of the trucks: after having been weighted, dump trucks descend the access ramp of the unloading platform where they discharge the domestic waste in a pit.
- The pit: the pit has a capacity of approximately of 23'000 m<sup>3</sup> and it is equipped with a bridge crane and a grappeling hook. It can receive approximately

9'000 tons of waste, equivalent in volume to 7 Olympic swimming pools.

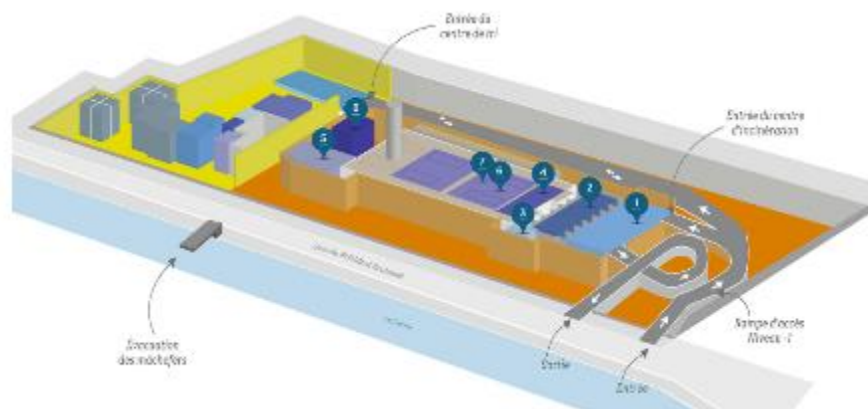
- Control room: in the control room, technicians manage the two big grappeling hooks to mix and transfer the waste to the two boilers. They also control the operation of the centre and the quality of the emissions to the atmosphere.

- Boiler and steam turbine: two boilers with unitary capacity of 30,5 tons/hour incinerate the domestic waste at a temperature above 1000°C. Water from the boiler is transformed in steam that will be sold to CPCU to heat the buildings of Paris connected to the district heating network.

- Smoke treatment: the smoke is extracted by an electro filter. It is then treated by a bag filter and a catalytic reactor that captures and treats the

different pollutants. Before these pollutants are rejected to the atmosphere, the smoke is continuously analysed and thanks to analysers placed in the chimney.

- Storage of waste incineration: the slag, solid waste obtained from the incineration, is stored and then evacuated through the river towards the centre of treatment where they will be treated and then reused for roadway backfill.



Pic. Principle working scheme.

Table. Description data of plant.

No.	Description	Amount
1.	Served scope	1,45 million habitants
2.	Heat generated for households	80'000 households
3.	Tones incinerated	482'134 t
4.	Steam sold	678'925 MWh
5.	Electricity sold	35'793 MWh
6.	Ferrous materials	7'216 t
7.	Non ferrous materials	653 t

### Environmental balance

The smoke treatment (by a dry procedure) made at Isséane, guaranties that the emissions are well below the European norms. The atmospheric emissions are constantly controlled by the operator thanks to the analysers placed at the chimney. In parallel Sycotom performs regular controls of emissions and measures the atmospheric impact using an Owen gauge and with video surveillance.

On the other hand, the slag produced during the combustion is transported by the river to be recycled and reused in the public works:

- 82'280 tons of slag have been evacuated by the river;
- 3'000 trucks avoided using an alternative way of transport different to the road.

### III. 5.2.2. ANALYSIS OF KEY SUCCESS FACTORS AND CHALLENGES OF PROJECT

#### Key success factors

**Combining municipal waste treatment with energy generation.** By applying an holistic approach Paris found the way to turn non-recyclable urban waste into an energy source for the district heating system. The waste generated by 1.45 million habitants turned into space heating for 80,000 households, contributing to GHG emissions reductions and reduced imports from fossil fuels.

**Guaranteed clients group.** The plant has a guaranteed client which is CPCU (Paris district heating network) and EDF (the national electricity network). All the steam produced by I Isséan is sold to CPCU and the electricity generated to EDF. CPCU needs of the steam produced by Isséan to reach the environmental goals requested

by the city of Paris, which demand 60% renewable or recovered waste energy for 2020.

#### Challenges of the project

##### **Integrating the plant in the urban environment:**

The waste treatment and incineration plant had to be designed to be integrated in the middle of a dense urban environment following the highest environmental standards. The final design included putting two thirds of the plant underground, installing a dry smoke treatment in the chimney, building green facades by covering the main buildings facades with plants, giving the appearance of an office building rather than a waste treatment plant, and controlling bad smells. The only visible activity is the coming in and out of trucks carrying waste.

### III. 5.4. REVIEW OF BUSINESS MODEL

Syctom treats domestic waste collected from the habitants of the member communities, which pay Syctom through:

- a "population part", the price is the number of habitants registered in that community multiplied by the unitary amount "population part", which is voted and approved by the association committee, in which every commune is represented.

- A cost per ton of waste treated. This price is also voted and approved by the association committee.

Another source of income for Syctom is steam generated in the boiler through waste combustion,

which is sold to CPCU, the Parisian district heating company. Tariffs per ton of steam are negotiated every year between Syctom and CPCU. Syctom engaged to supply a minimum annual amount of renewable energy or waste energy to CPCU to consolidate its objectives of energy mix.

Furthermore Syctom transforms the heat from the incineration into electricity with a steam turbine. The electricity generated is partly used for the own consumption of the plant and the rest is sold to EDF, serving as third source of income for the Association.

## III. 6. OVERVIEW OF CASE STUDY ON WASTE ENERGY IN DATA CENTRES

### III. 6.1. DESCRIPTION OF DATA CENTRE CITY

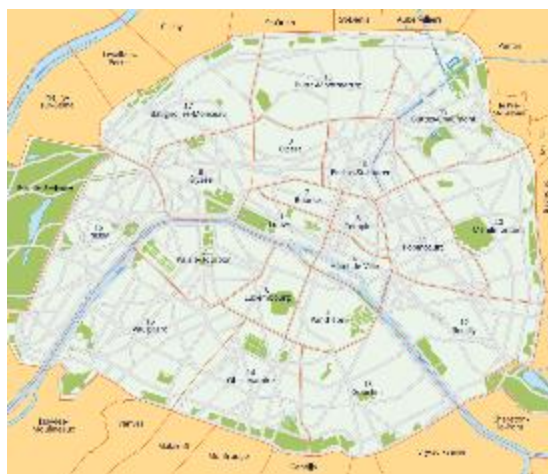
The city of Paris, capital of France, is located in Northern part of the country, in the Île-de-France region and in its own department. Crossed by the river Seine, Paris has a limited city area of 105,4 km<sup>2</sup> and its elevation varies between 26 and 130 metres above sealevel; thus, the city is mostly plain. The relative proximity to the English Channel and to other European cities, such as Brussels, make Paris a metropolis with deep trading networks as well as developed internal infrastructures. In fact, the city subway (Paris Métro) is the second busiest in Europe and the train station (Paris' Gare du Nord) is one of the most hectic worldwide.

The climate of Paris is Western European oceanic, with influences from the North Atlantic Current. Overall, throughout the year, the temperatures do not reach extreme peaks of cold and/or heat and the level of humidity is moderate. The surrounding oak and beech forests create a buffer from the highly industrialised areas outside the city. Moreover, the city has implemented

policies to face the air pollution and to purify the water.

The administrative division of Paris follows the shape of a spiral, numbering each of the arrondissement with increasing numbers (from 1 to 20) from the centre to the outer part. The river Seine divides the city in two major parts, Right Bank and Left Bank. Each of the arrondissement is further divided into quartiers, with a total of 80.

Paris is the economic and financial lead of France with a urban GDP ranked as second highest in Europe and several headquarters of companies and high-tech manufacturies. While the economic activities of the city have shifted towards high-tech and IT services, the environmental friendly industries of France are settled in Paris. Moreover, the city is located within the business triangle of France, between Opéra Garnier, La Défense and the Val de Seine. Furthermore, Paris is considered as one of the cultural centres of France and Europe.



*Pic. Location of Paris region in France.*

### III. 6.1.2. PROJECT OUTLINE, PURPOSE, MAIN CONTENTS, CHARACTERISTICS (INCLUDING BUSINESS AND ENVIRONMENTAL ACTIVITIES), AND EXPECTED EFFECTS

#### Data centre definition

A "Data center" is a building or part of it that houses information technology (IT) equipment for data storage. Usually the installed equipment are servers, storage bays, network and telecommunications systems. This equipment is used to process and store data, irrespective of its personal or corporate origin and does not depend on provenance (country of origin or global).

In these IT services are involved a large number of agents and they can be divided into four groups: hosting providers, telecoms operators, digital services firms and cloud computing services.

3'885 colocation data centers were identified in 117 countries (June 2016) with 182 data centers in France (26 data centres under construction are included) and this list covers only one category of players - the colocation providers.

Data centers have high concentration of servers, so they are famously energy-intensive, quoting power density requirements of 250 to 1'500 W/m<sup>2</sup>IT and in some cases even as much as 3'000 W/m<sup>2</sup>IT.

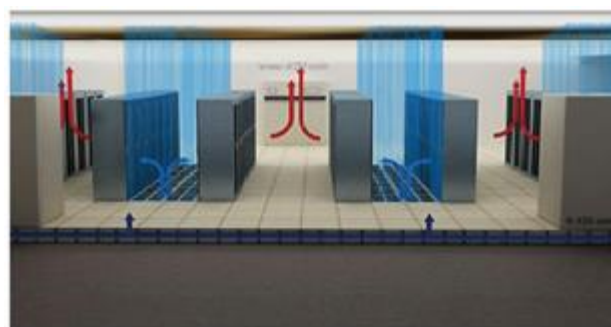
According to France's national grid operator RTE presented data, power consumption in 2014 by French data centers covers 1,4 TWh that is equivalent to 1% of the tertiary sector or 0,3% of total power consumption in France.

One of the issues is that RTE is currently aware of 42 data centers, which are connected to the power grid in the Paris region of France and all with high power consumption with a requirement for power

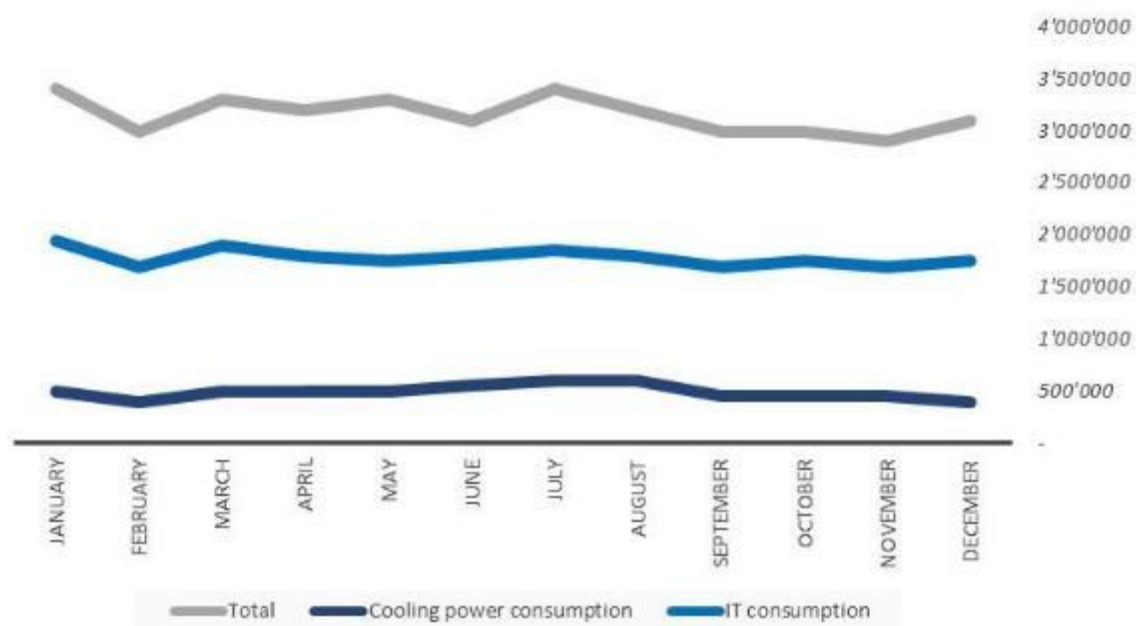
of 210 MW. This demand corresponds to an average power of 5 MW per data center that is equivalent to an IT surface area of around 5'000 m<sup>2</sup>. Looking forward to 2025 year France's national grid operator RTE expects to see a further 36 data centers in the Paris region and an increase of +86%.

Cooling systems used to cool IT rooms in data centers essentially are run on electrical power. The main cooling systems encountered rely on cooling by the help of:

- water-cooled chiller;
- air-cooled chiller;
- direct expansion;
- free cooling systems.



*Pic. The general cooling principle in the IT rooms visited involved blowing cold air under a raised floor, between two rows of server racks.*



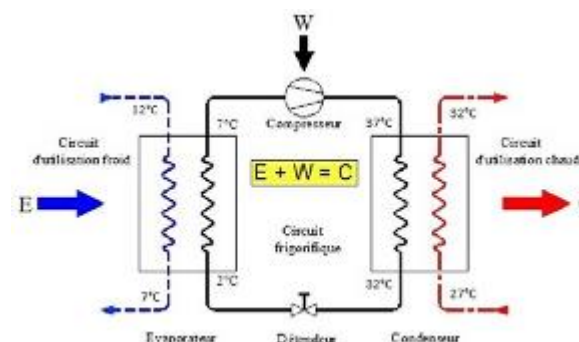
Pic. Picture represents total data center power consumption, IT power consumption and cooling power consumption for 2015. These are monthly consumption figures.

Taking into consideration the waste energy recovery potential of data centres, the key figures to consider are:

- Surface areas, distinguishing between total surface area and the IT surface area;
- Electrical power used, IT power;
- The cooling system, feasibility of recovery.

Availability and quantity are key factors in the characterization of waste heat recovery but the temperature level is also very important factor.

Data centres represent low-temperature waste heat at a maximum temperature of 60°C: cooling water (air and cold compressor, etc.). These low temperatures are well suited for new-generation district energy systems, which include renewable and recovered energy sources.



Pic. Schematic of a cooling system cooling circuit.

Taking into consideration 501 district heating systems in 350 cities in France, 80% of district heating systems operate at high water temperatures  $\leq 110^\circ\text{C}$ .

New "low-temperature" system can be described as having water temperature  $\leq 60^\circ\text{C}$ . In low-temperature district heating systems, the temperature of the waste energy can be raised by modifying the cooling system operating setpoints - increasing the temperature of condensation. This process leads to lower energy efficiency and higher cooling system operating costs.

Existing system mainly have water temperature  $\leq 110^\circ\text{C}$ , so in the case of existing systems, which

operate at higher temperatures, the technical solution to raising recoverable energy temperature would be to add one or more high-temperature heat pumps between the data center and the district heating system. Recovering energy at a higher temperature levels enables this waste energy to be used as part of low-temperature district heating (when a new system is being created), increases the recovery potential and provides good coverage of end-user heating needs.

This technical solution was implemented by Dalkia company for the construction of a low-temperature (48°C/38°C) district heating system in Bailly-Romainvilliers in the Seine-et-Marne department, under contract with the data center (and taking into account the higher compressor consumption). In France only one operator has actually used this energy to create a district heating system which is now located in the Bailly-Romainvilliers where low-temperature network

recovering waste energy from the Natixis data centre.

The Bailly-Romainvilliers data centre has four IT rooms each of 750 m<sup>2</sup>. The data center occupies a total premises area of 12'000 m<sup>2</sup> and IT rooms make up 25% of this area. The equipment installed is of Tier IV equivalency.

Estimating recoverable energy usage at 35°C gives annual recoverable energy of 16,4 GWh, equivalent to 1'369 MWh/month.

Within the Natixis data centre, energy is recovered from two of the six cooling systems installed in the building. The data centre supplies heat to the boiler-house via a district heating pipe network of 900 m. The boiler-house transfers this recovered waste energy via a second network for 2 km to the heat substations of end-user. In the heat substations to provide domestic hot water and heating of proper temperature the gas is used to raise the temperature sufficiently.



Pic. Aerial view of the ZAC du Prieuré business park.

The district heating system for the ZAC du Prieuré business park was initially scaled for the recoverable energy from the Natixis data center

and was supposed to be capable of heating up to 600'000 m<sup>2</sup> of buildings area. At the present moment only the aquatic complex and the business

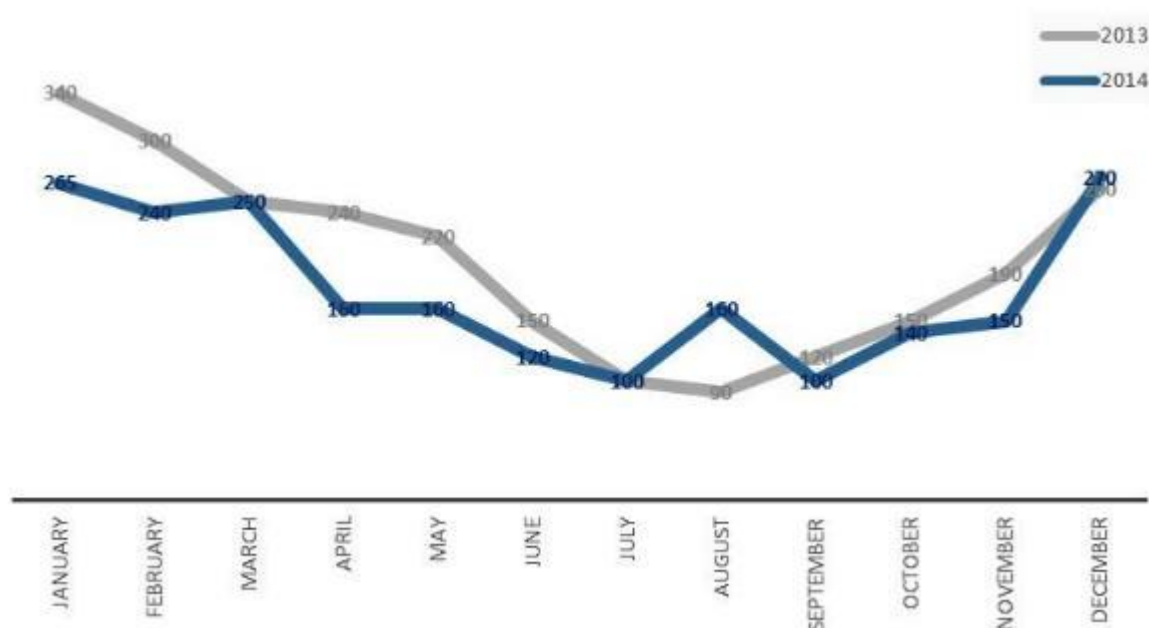
start-up incubator are connected to the system, together representing 6'000 m<sup>2</sup>.

### III. 6.2. PERFORMANCE AND OUTCOME OF THE CASE STUDY PROJECT

#### III. 6.2.1. ANALYSIS OF PERFORMANCE

Waste energy from data centres can be successfully recovered, so the chart below shows

the quantity of energy recovered from the data center for the years of 2013 and 2014.



*Pic. Quantity of energy recovered from the data center (2013 and 2014).*

In 2013 the quantity of heat recovered from the data centre was 2,4 GWh and in 2014 was 2,2 GWh. Dalkia buys this waste energy recovery under the terms of a contract with the Natixis data center.

The chart above about waste recovered heat shows the seasonal variation in end-user demand - the peaks are in winter at 330 MWh/month and falls to it's lowest value during the summer time period at 80 MWh/month. The energy not used in the district heating system is evacuated from the data center.

Over these two years, the backup system was not run out as 100% of the energy produced from the boiler-house was sourced from the data center.

For the month of January, a 3,5 MW heat exchanger represents a maximum consumption of 2'604 MWh: a data center operates continuously 24 hours per day 7 days per week. The chart above shows a quantity of the highest consumption over the year 330 MWh in January 2014. This makes only 13% of the maximum energy available at the heat exchanger.

### III. 6.2.2. ANALYSIS OF KEY SUCCESS FACTORS AND CHALLENGES OF PROJECT

#### Challenges

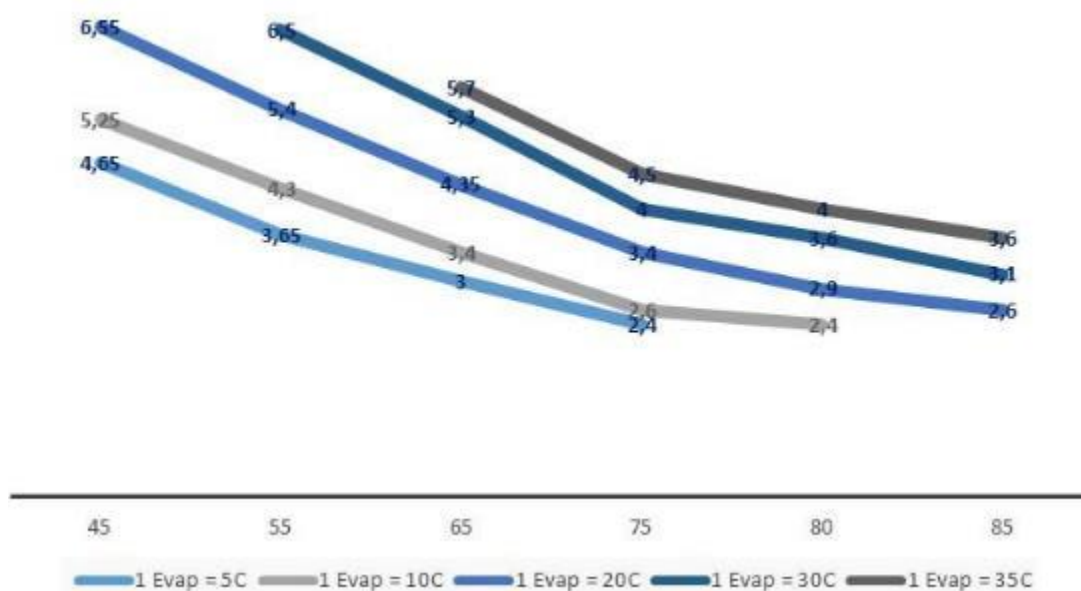
**Managing differences in temperature levels:** the data center has a recoverable energy at 36°C and the district heating working temperatures are 80 to 110°C. If the district heating system is used to transport recoverable energy in the existing district heating system, the temperature of that energy will have to be increased.

If there is not used a proper technology to utilise waste heat, a typical data center can drain an Olympic-sized swimming pool every two days (Evaporation and blow-down losses are by-products of a common method used to cool data centres, where hot exhaust air exiting from electronic equipment is cooled by the help of passing it through an air/liquid heat exchanger. The liquid coolant also passing through the exchanger picks up the heat on its way to cooling towers, another form of heat exchanger that uses water evaporation to remove heat from the liquid

coolant). Is that a problem? For some countries - yes as for example in USA California state data centers use 0,7 percent of California's water then agriculture uses 60,7 percent.

#### Success factors

One of possible solutions for that is to utilise waste heat in district heating system and if a district heating system is old with high temperatures use high-temperature heat pumps. A heat pump is a thermodynamic system that can be used to recover the energy contained in a low-temperature fluid and return it at a higher temperature level. So the high temperature heat pumps are available to deliver temperatures in the limits of 65-70°C. From the beginning of 2016 year some manufacturers as "Carrier" offers high temperature heat pumps with condenser-side water temperatures of 85°C temperature.



Pic. Typical Carrier High Temperature heat pump coefficient of performance (COP).

### III. 6.3. IMPLICATION FROM THE CASE: IDENTIFICATION OF KEY LESSONS AND FUTURE PROSPECT

In most cases and particularly in the case of an existing data center in an urban area, if there is a possibility that the recoverable energy can be transported, this energy source has to be connected to an existing district heating system. One of the main questions is: are there any data centers located close to district heating systems and how far?

80% of existing district heating systems operate at quite high water temperatures of  $\leq 110^{\circ}\text{C}$ . To avoid excessive investment costs and excessive heat losses, the need for a pipe line between the data centre and the district heating is assumed at maximum distance of 2 km. Another question is: what, if data centres are located more than 2 km from the district heating system network with a temperature of  $\leq 110^{\circ}\text{C}$ ?

In the above described case of the Bailly-Romainvilliers low-temperature district heating network, from the data center recovered energy is used to supply an aquatic complex which has year-

round energy demand, fluctuating in accordance with the seasons but not so much as residential, office or public buildings. The advantage of this case is that heat to aquatic complex is supplied directly via a heat exchanger without the need for a high-temperature heat pump. In the heat substation gas is used to increase temperature suitable for domestic hot water needs.

According to the GIS data it was possible to identify that 88 data centres in France are located less than 2 km from 144 pools. Decreasing the distance from data centres to pools to 500 m, the amount of pools decreased to 13 data centers and 10 pools.

Today we can find not only one implemented waste energy from data centres to district heating or swimming pool case as IBM company does but he final rhetoric question would be "Is it data center heats the swimming pool or is it swimming pool cools the data centre".



*Pic. Data centre inside premises.*

### III. 6.4. REVIEW OF BUSINESS MODEL

Usually the utilisation of waste heat from data centres are private sector projects. Data centres are usually privately owned and it is the potential client, e.g district heating utility that may approach the building owner to propose a waste heat recovery connection that might be beneficial for both. CAPEX investments in waste energy recovery from data centres are made 100 % at the beginning of the project. At a later stage only operation and maintenance (OPEX) expenditures

are required. Local government are usually very interested in this kind of projects as they may decrease the price of heat energy production, diversify fuel consumption or decrease emissions level. The local government can support this projects by establishing private-public partnerships, or supporting waste heat recovery from data centers by developing targeted waste heat connection policies.

## IV. ESTABLISHMENT OF BUSINESS MODELS FOR THE CASE STUDIES

The Eco-energy town concept combines the integration in the urban environment of eco-buildings with the local, clean energy generation. This study has presented some examples of how cities have integrated waste heat recovery into their local energy mix by developing district heating and cooling networks as mean of transport of this wasted energy. This section looks more in depth at the basics of business model definition and the models developed by all this cities to make waste heat recovery economically feasible.

### New business models to facilitate energy access in an emerging context

Taking into consideration energy access, a new definition or understanding of the Public-Private Partnership is the “pro-poor public-private partnership” model or called “5 P” model. The 5 P model targets the provision of services to poor communities, often ignored by traditional Public-Private Partnership as provision of services to the poor involve larger business risk. The 5 P model describes the poor not only as consumers receiving benefits, but also as partners in various business ventures. Each partner plays a different role in the 5 P model: participants from private sector meet their corporate social responsibility obligations, utility and energy companies can fulfill their obligations to deliver basic services, communities and members of civil society can expand their access to basic services. So the new pro-poor partnership models are needed to implement, operate, and sustain energy access projects. Case studies on energy access indicate that it is important to provide an ecosystem of innovation beyond “physical access”, standard policies and implementation guidelines that will help new partnerships to emerge and grow.

### Heat energy business model

Magretta J. in her article "Why Business Models Matter" notes that “a good business model remains

essential to every successful organisation”. Stahler, P. Heat energy business model are defined as a model for:

1. Business architecture for product/service flows, including:
  - (a) Establishing the heating plant and district heating net-work.
  - (b) Organising the wood fuel supply chains.
  - (c) Defining ownership and responsibilities between all stakeholders involved, such as sellers and buyers of the service, subcontractors and fuel producers.
2. Establishing the earning logics - strategies to generate and maintain profitable and sustainable business operations.

In practice the business model involves many stakeholders, such as entrepreneurs, subcontractors, financiers and clients. The participating parts do not always have to be interrelated chronologically and have an impact on the overall business performance. Special case of business models "Heat energy business models" differs from many other businesses models because usually there is an external actor - customer who has invested in the unit of entrepreneurship, so various ownership relations and overlapping each other responsibilities are possible.

Finland has also very strong experience of business models implementation in energy sector. On the basis of heat energy production contracts three main categories in organising municipal heat production in Finland are identified:

- a) Public companies,
- b) Public-private partnerships,
- c) Private companies or cooperatives.

In Public-private partnerships business model usually customers make the investments because they were better able to bear the investment risk. From other side governmental support decrease the risks of possible financial losses. This in PPP

contracts makes investment in new technology more attractive. In business models of the energy sector the investments determine much of the responsibilities regarding the practical operations and ownership of the heating plant and equipment. Four main options for ownership can be identified:

1. Customer (municipality or industry) owns the energy utilities (for example heating plant and network) and has the decision-making and control over the heating service.
2. Entrepreneur owns and controls the energy utilities and customer pays only for consumed energy.
3. Customer receives ownership of the energy utilities (plant and network) from an external investor with delay after investor has received the invested money back.
4. External network or concept provider has the ownership and entrepreneur will produce the heat according to contract.

### Contract

To define the responsibilities is required a detailed contracts between the owners and users of the energy utilities. The contract is a tool to improve mutual confidence and serves in negotiations and problem solving cases. Typically the main blocks of a energy production contract are: 1) the amount of heat/cold that will be produced, 2) heat/cold pricing and pricing mechanisms, 3) starting of heat/cold supply, 4) measuring of heat/cold supply, 5) ownership of the equipment, service and maintenance, 6) ensuring the heat/cold supply, 7) starting and ending of contract, 8) cancellation of contract and compensation. The contract should also cover changes in heat/cold demand, temporary problems and severe interruptions in heat/cold supply. The contract also includes the principles for calculating the heat/cold price per MWh. Good practice is to divide heat/cold price into basic and usage fees. Various pricing mechanisms are available and it is important to ensure that the selected mechanism is quite simple, transparent, cost correlative and equal for different customers. Heat/cold price can be adjusted in periods varying typically between 1 and 6 months.

It is important to carefully define the ownership of energy equipment and buildings to avoid any overlapping or mixed responsibilities. Equipment reliability, normal service and maintenance works are usually the owner's responsibility. A contract can be periodic (for example 2–10 years) if the entrepreneur invests in heating/cooling plant and equipment but usually contract period up to 15 years. The contract typically includes a paragraph regarding negotiations for continuing the cooperation after the contract period has expired. In a case if the entrepreneur cannot fulfil the obligations foreseen in the contract, it is possible that a guarantee fee defined in the contract has to be paid.

Heat/cooling energy business models can be established with various different earning logics and strategies to generate and maintain profitable and sustainable business operations.

### Description of Public utility or company

Usually municipalities have taken care of heating/cooling production as their own responsibility, as any other public service provision. The main two organization models can be used are: public utility or public company. Public utility is part of the whole municipal economy but has more independence compared to other departments. The main benefit of public utility comparing to a public company is the absence of income tax. So many of the municipalities have established public companies to make their businesses more effective. A municipality can establish a heating/cooling company under its ownership or share ownership with another partner as a local electricity company still keeping the main control. The public company is part of the municipal concern, but is still an independent legal entity. A public company is a flexible form for decision-making as it independently can decide about investments. The company is not linked directly to municipal finances, thereby reducing investment risks.

### Description Public-Private Partnership

Public-Private Partnership is a business model in which the customer (municipality or industry) invests in and owns the heating/cooling production equipment while an entrepreneur takes care of the fuel supply and heating/cooling production for a defined fee. Since the main investments are made by the customer, the entrepreneur can operate with small initial capital.

### Description of Private companies and cooperatives

Nowadays an increasing number of private companies and cooperatives are willing to invest in heating/cooling production and take the financial and technical risks. If the business is completely outsourced, the heating/cooling entrepreneur acquires a position comparable to a leading market position. This can be avoided by a detailed contract including well established heating/cooling pricing mechanisms. On a larger scale the entrepreneur can work full-time and there increasing a probability for better profit. The customer pays only for the heating/cooling service with the heat price consisting of joining fee, basic fee and usage fee. The entrepreneur purchases the heating/cooling plant and network, and also takes care of its operation and management. So the more tasks the entrepreneur is capable to handle, the higher the potential profits are expected for the company.

### Description of Network model of a large company

According to the network model, heat energy entrepreneurs cooperate with large-scale companies and gain advantage via network and scale effects.

### Description of Energy saving company (ESCO)

Energy Saving Companies (ESCO) may not only apply energy saving concept to improve energy efficiency but also can produce and utilize renewable energy. ESCO has a legal entity definition delivering energy services or energy efficiency measures for a customer, so ESCO takes financial risks with its investments. The payment for the delivered services is based on the actual

achieved energy efficiency improvements, reduced energy costs or other agreed performance criteria. In energy production ESCO invests in energy production equipment and the customer pays the same price for the heat as before the investments were applied. The produced energy is cheaper than the older system, so company can make a profit. After ESCO recoup its investment the customers get full ownership of the invested equipment and further lower energy costs. So the ESCO business model is useful for customers willing to keep the ownership of heat production equipment and do not having resources for the large investments. For the entrepreneur with ESCO experience it may be a good option. ESCO business model sometimes is difficult to apply successfully on a small scale projects as the biggest problem is the long payback periods. But from the other side ESCO have ready-made concepts and skills to run all the operations. A stable price level at the payback time reduces financial risk of the ESCO. From the customer's it is attractive as this model has a small investment risk, steady energy price for an agreed period and also ownership of the equipment.

### Description of Franchising business model

According to the definition franchising is a business model where two independent partners have a contract. The franchiser has developed a business model and gives the rights to the franchisee to use this model based on the franchise agreement. The franchisee operates according to the by franchiser defined operational instructions. The franchisee pays to the franchiser for the rights to use the developed business model. Franchising requires full-time entrepreneurship. In energy production franchising also can be organized - franchiser gives the business model and concept and operational principles. In practice the franchiser support the franchisee in planning investments, financing, maintenance, fuel supply and other issues and the franchisee pays for this support. In this business case the customer do not have to invest in the heating/cooling plant or network as the entrepreneur takes the risk of investments.

## Business model architecture

The business architectures for energy production are different in every case but have three main steps in common:

### 1) Determining the targets for business and profit.

Investing in the heating/cooling plant and the network the entrepreneur should determine business and profit targets and that relates to the following questions:

- What is the main entrepreneur's objective and what entrepreneurship is: full-time or part-time?
- What level of risks the entrepreneur is ready to accept?
- How much and for what time period is the entrepreneur ready for the capital investments?

**2) Designing the business architecture.** To design business architecture the entrepreneur should ensure the availability of resources including physical and human resources in the forms of physical capital, supply chain structure and supporting infrastructure as for transportation, storage, etc., and available business associates for different business models.

**3) Constructing the earning logics.** The earning logics strategies to generate and maintain profitable and sustainable business operations are dependent both on business and profit targets and business architecture. In cases of lack of resources, there are often many possibilities to find external financiers, complementary partnerships, networks or subcontractors for filling in the gaps, generating the economics of scale and improving both technical and economic reliability.

## Business models to develop district energy in cities

The report "District energy in cities" published by UN Environment, identified three main business models widely used when developing district energy systems. These are:

- Wholly public;
- Private;

- Hybrid – cooperation between public and private is combined.

**Wholly public** business models is the most common globally. The public sector, in its role as local authority or public supplier, through subsidiaries or directly has full ownership of the regulated services/ project, which allows it to have complete control of the services/ project and makes it possible to deliver broader socio-economic objectives, such as reduction of air pollution, tariff control etc. As stated in the Report - of the 45 champion cities, 18 have or are developing "wholly public" models as the majority district energy model. In modern democracies district energy systems (especially energy transmission systems) are treated as natural monopoly and are regulated by the state.

**Private business models** are rarely observed as a main business model when developing district energy systems. This relates to the fact that private investors are more likely to have higher financial rate of return what has direct impact of district energy tariffs. Private business model is more often observed when developing separate elements of district energy systems – for example energy production units. This model is rarely chosen because business owners are less aware about customers, it is profit driven model. As an examples of private business models can be identified ownership (private joint venture).

Hybrid business models are more widely used than private because of the combination of financially feasible rate of return, what is important for private sector, but it also lets public sector to control socially and economically grounded long-term sustainable systems. Hybrid business models can be identified not only by invested capital origin, it could also be the case when private capital is used for development of the systems and then public sector takes control over. As an examples of hybrid business models can be identified public/private joint venture, concession, ESCO or EnPC, lease etc.

## Analysis of business models of the case studies

### Isséan plant case study, Issy-les-Moulineaux (France)

Waste heat recovery from incineration plants is one of the most investment intensive projects in municipal infrastructure. This is due to high level of utilisation requirements, high environmental requirement and also to specific high-level technology investments. In the city of Issy-les-Moulineaux waste recycling and waste incineration plant projects were developed by wholly public business model. The implementation of this business model ensures:

1. Adequate tariffs for waste collection and utilisation;
2. Tariff (including return on capital) is regulated;
3. Profit from regulated activities is limited to loans payments;
4. Additional income from WtE plant electricity production;
5. Additional income from recycled materials.

The recovery of waste requires of high level of investments, which have to be covered through waste management fees. Wholly public model in this case applies as far as it can balance between waste management fee and investment risk. Additionally strict regulation for investment return and return on investment have to be set in order to control waste management, electricity production and heat production in Waste to Energy plant.

### Barcelona city case study

Barcelona is a good example of how public-private partnerships have been key for the successful development of the city's district energy network. As presented in the case study, the main energy (heat and cool) producer for Barcelona district heating system is the public company TERSA that operates the city's waste to energy plant. District energy system with all its infrastructure is managed under a 25 years concession contract. The district energy operator has two main shareholders

with near equal part of shares – a private company and the municipality company. The district energy company is managed by the management board which includes members of the municipality. The key factors of Barcelona's hybrid business model are:

1. Long concession contract with private partners with deep knowledge in operation and management of district energy supply companies;
2. Heat and cool transmission services are regulated, profitability of this regulated activity is relatively low that is why introduction of private partner have no negative impact on energy prices;
3. Hybrid business model ensures that both private (investor) financial return and public (customers) needs (also social politics) are implemented through management board;
4. Energy transmission business has low rate of return what means it is affordable for stakeholders that can take higher financial risks and these are not municipalities or its companies with limited financial and administration resources.

### Zhuhai city case study business model overview

Company owned by private entity together with municipality made green field investment into district energy systems for heat and cool supply for the new district of the city of Zhuhai. The infrastructure was created by using a hybrid business model. Municipality contributed to the company with the land property, licence for energy supply in the territory and other in kind infrastructure. After the infrastructure was built, tender was initiated and another private company took over operation and management of the district heating, cooling and hot water supply services. These are main key factors of Zhuhai hybrid business model:

1. Municipalities contribution with in kind assets and rights let municipality to have major part of shares of district energy infrastructure company;
2. For the district energy supply services private company was selected what means energy supply experience and services efficiency risk reduced to a minimum;

3. Municipality do not have to create any specific administrative units or companies in order to guarantee district customers with the energy;

4. Zhuhai city is a good example how in the same city different business models applies in order to ensure district energy supply in existing district energy systems and to create new ones;

5. Zhuhai example also shows that in some cases municipality contribution by government guarantees or money is not necessary in order to have shares also control of district energy systems;

Hybrid business model in Zhuhai city is a good example how municipality using its property and rights to the licences regulated energy supply services ensures infrastructure development also competitive district energy prices for consumers.

#### **Zhengzhou city case study business model overview**

Zhengzhou city according to the monitoring results have a high-level environmental pollution. When developing new territory – Longhu Financial Centre – a new cooperation and new business model was required to avoid additional pollution. Decision concerning energy production from treated water was made and water supply infrastructure to three plants in Longhu financial centre were built, the same as heating and cooling infrastructure inside Longhu financial centre. In Zhengzhou city example private business model was used in order to develop treated water supply infrastructure to the Longhu Financial Centre plants, and public business model was used to develop plants and infrastructure at the island. Implementation of both business models created working infrastructure for district energy supply without additional pollution. These are main key factors of Zhengzhou business model:

1. Private entity established treated waste water supply infrastructure to the Longhu Financial centre energy production plants with the guarantees for return of and on investments; city received pollution free energy source;

2. Two different business models were used in order to achieve the common result;

3. Municipality owns Longhu Financial Centre district energy system what ensures stable and competitive energy prices for consumers;

4. Local governance contribution in establishing integrated district energy system was vital when coordinating construction of treated water infrastructure (together with metro), plants on the island and planning energy production sources;

Zhengzhou city case business model is an example of great urban planning when establishing district energy systems. Most pollution free energy sources were chosen and administrative barriers for the establishment of such a uncommon energy production source were tackled.

#### **Milan city case study business model overview**

The development of the district heating system in Milano is encouraged by zoning of the territories according to heat source priority, development of building code and other tools for promotion of district heating. Milan has an ambitious plan for connecting its segregated nodal networks into one large ring based city network. Company partially owned by municipality implements interconnections between hydraulically isolated district heating systems. These interconnection as far as planned one will let increase overall city district heat demand and to use most environmental friendly, economically feasible energy sources and plant for heat production. Milano city case can be names as hybrid business model when initiative from the private/ public company lead to private business development and/ or better utilisation of present energy production capacities.

These are the main key factors of Milan business model:

1. With the advanced city district energy planning capabilities stakeholders identified that there are enough clean heat production capacities in the city area and identified biggest need to utilise them – to develop city district heating system through partly controlled company;

2. New investments into heat production units in such a cooperation avoided – most economically feasible are utilised in integrated district energy system;

3. With the integrated energy system connection of additional existing energy production capacities with the distance more than 35 km also assessed as feasible;

4. Development of integrated district energy system gives a new possibilities for existing plant owners (bigger market), for new projects, based on heat production from geothermal energy, development, better utilisation of high risk projects such as existing Waste to energy plant;

Milan city case business model is great example how district energy systems can be promoted and developed in a sustainable way, with the better utilisation of emission free, renewable energy based energy sources. Expansion of district energy system will contribute to National targets in energy efficiency, emissions reduction. This is hybrid business model when city targets are reached with the district energy infrastructure development and better utilisation of existing production plants. Development of district energy system opens new challenges

#### IV. ESTABLISHMENT OF BUSINESS MODELS OF CASE STUDIES COMPARISON

No.	Description	Zhuhai	Zhengzhou	Barcelona	Milan	Issy-Les-Moulineaux	Paris
		China	China	Spain	Italy	France	France
<b>1.</b>	<b>Project initiation and implementation reasons</b>						
1.1.	City/ state	Yes	Yes	Yes			
1.2.	Lack of generation units						
1.3.	New system development	Yes		Yes		Refurbishment of an old incineration plant.	Yes
1.4.	Environmental problems of identified area				Yes		
1.5.	Lack of capital						
1.6.	Lack of competence and knowledge						
1.7.	High business risk						
1.8.	Waste utilisation problems						
1.9.	High level of regulation		Yes				
1.10.	National needs for generation units	Yes	Yes				
<b>2.</b>	<b>Project implementation business model</b>						
2.1.	Management Agreement				Yes		
2.2.	Leasing						

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
2.3.	Concession Agreement			Yes		Syctom (owner of the plant) is fully public. Syctom is the Parisian public company for waste management. However the operation and maintenance of the plant is made by TIRU (private company from the group EDF) They signed a 13 years contract with Syctom starting in 2007 for the operation of the plant. The CPCU (Paris district heating network which is a private-public partnership) is Syctom's main client, as the steam generated by the incineration plant is fully sold to CPCU.	
2.4.	Privatization						
2.5.	Heat Entrepreneurship						
2.6.	ESCO	Yes	Yes				
2.7.	Shares capital						
2.8.	Energy market creation (f.e. heat generation)						

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
2.9.	Public private partnership contract (PPP)	YES	YES				
3.	<b>Contract duration (years)</b>						
3.1.	Duration of contract (years)	Information not available	Information not available	25 years	20 years	The contract duration between Syctom and TIRU for the operation of the plant is 13 years. The current contract will finish in 2020. On the other hand Syctom has a contract with CPCU (Paris district heating network) who buys the steam from Syctom. The price at which CPCU buys the steam from Syctom is reviewed annually and approved at the Syctom management board	No info presented by requested institution
4.	<b>Ownership of company</b>						
4.1.	Ownership of company (Private/Public)	State-owned Public	Public	Private-Public	Private-Public	Syctom is fully public, CPCU is a Public-Private partnership owned by Engie 64,39%, City of Paris 33,60%, other public sector 2,11%	Private

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
4.2.	Distribution of shares between (Private % / Public %)	Information not available	Information not available	50,8 % Private (Engie) / 49,2 % Public (TERSA, Institut Català d'Energia, IDEA, Agbar).	50 % Private / 50% Public. Renewal in the period 2017- 2019 of the shareholder agreements in place between the municipality of Milan and the municipality of Brescia in relation to the shares of the company A2A s.p.a.	Syctom receive and income from two sources: 1) Per ton of waste treated; 2) Tons of steam sold to CPCU. This income stays at Syctom for the operation of all it's plants, it is not distributed between anybody else. In the case of CPCU, the income is distributed between Engie and the city of Paris.	Private
5.	<b>Governing Public body</b>						
5.1.	The governing Public body (Municipality board/Mayor)	Municipality	Municipality	The Municipality	The governing public body in Milan is headed by the Mayor and 6 Council members, they all set policies, determine the tax rates and approve the annual budget.	Syctom is managed by a board conformed by 84 communes of 5 departments of Ile de France	Municipality

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
6.	<b>Management and Operation</b>						
6.1.	Management (Private/Public)	State-owned Public	Private	Private-Public (there is a management board with representatives of all public and private founders institutions). Although in reality the main driving force is mainly Engie company (Private partner) - the one that leads the management and operation, also the one with more expertise on district energy networks.	Private	Public	Private

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
6.2.	Operation (Private/Public)	State-owned Public	Private	The operator is Private partner (Engie)	Private	Private through concession to TIRU (Group EDF) through a contract for 13 years	Private
7.	Payment for services, primary energy resources						
7.1.	Payment for services, primary energy resources (Private/Public)	Private	Private	Districtclima has a contract with TERSA (Public company of waste management) to buy the steam that is generated by the incineration of waste at the waste incineration plant of Sant Adrià de Besós	Private. 51% of natural gas imports originate from Russia. The second most important exporter of gas is Libya with 13% of share and Algeria with 13% of share. The import of gas from Netherlands takes 8% and from Norway 5%.	CPCU buys the steam from Syctom at 17€ per ton.	Private
8.	Guaranteed purchase						

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
8.1.	Guaranteed purchase of CHP electricity (priority in exporting to grid - feed in tariffs) (Yes/No)	No	No		YES. In Milan there are policies and incentives in the long term, the municipality owns a part of the society. But not a purchase contract explicitly guaranteed.	Not applicable	No info presented by requested institution
8.2.	Guaranteed purchase of Heat (Yes/No)	Yes	Yes	Districlima buys the steam from TERSA (the Public incineration plant). The price at which the steam is sold is agreed between both parts and reviewed periodically.	YES. In Milan there are policies and incentives in the long term, the municipality owns a part of the society. But not a purchase contract explicitly guaranteed.	Yes. All the steam generated by the Syctom plants is sold to CPCU. Syctom engaged to supply to CPCU a minimum amount of renewable energy and or waste energy to help the district energy network meet the goal of 60% Renewable Energy or recovered energy by 2020. CPCU is part of the " Climate Plan of the city of Paris ", as such it contributes to the goals	Yes

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
						set by the city of reducing 25% GHG emissions by 2020.	
8.3.	Guaranteed purchase of Cool (Yes/No)	Yes	Yes	Districtclima buys the steam from TERSA (the Public incineration plant). The price at which the steam is sold is agreed between both parts and reviewed periodically.	YES. In Milan there are policies and incentives in the long term, the municipality owns a part of the society. But not a purchase contract explicitly guaranteed.	Not applicable	No info presented by requested institution
8.4.	Licence to utilise waste (from geographical area) (Yes/No)	No	No		Yes	Yes	No info presented by requested institution
9.	<b>Consumers</b>						

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
9.1.	Heat energy consumers are obliged to connect to district heating network (Yes/No)	No	Yes	No mandatory connection policies	No	In certain zones yes	
9.2.	Consumers for cooling are obliged to connect to district cooling network (Yes/No)	Yes	Yes	No mandatory connection policies	No	Not applicable	
9.3	Are there smart heat meters installed? (Yes/No)	No	Yes	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution
9.3.1	Are there smart heat meters installed for flat level? (Yes/No)	No	Not for residential buildings, so not installed in the flat level	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution
9.3.2	Are there smart heat meters installed for building level? (Yes/No)	No	Yes	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution
9.4	Are there smart hot water meters installed? (Yes/No)	Yes	No supply of DHW	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution
9.4.1	Are there smart hot water meters installed for flat level? (Yes/No)	No, DHW is only for hotels and luxury residential house	No supply of DHW	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
9.4.2	Are there smart hot water meters installed for building level? (Yes/No)	Yes	No supply of DHW	No info presented by requested institution	Yes	No info presented by requested institution	No info presented by requested institution
9.5	Are there smart cooling meters installed? (Yes/No)	Yes	Yes	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution
9.5.1	Are there smart cooling meters installed for flat level? (Yes/No)	No	Yes	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution
9.5.2	Are there smart cooling meters installed for building level? (Yes/No)	Yes	Yes	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution	No info presented by requested institution
<b>10.</b>	<b>Investment</b>						
10.1.	Investment (Private/Public)	Private-Public	Private-Public	Private. Engie (Private body operating the network of Districlima, investing in the extensions of the network)	Private	CPCU, the district energy network, it is public-private investment, as CPCU is a public-private partnership	Private

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
10.2.	Investment Schedule (Instant, First part of contract, Constant (Flat), etc.)	Instant	First part of contract	No info presented by requested institution	First 5 years of intensive investment. 15 years of maintenance. Constant further investment	No info	Instant
10.3.	Investments and upgrades after contract termination goes to Public/Private	Public	Public	Once the concession contract is finished the network would go back to the Municipality	No info presented by requested institution	Actually CPCU has been granted with a concession contract to operate and maintain and extend the district heating network since 1949. It is very likely that their contract will be extended in the future. Anyway the owner of the network is the city, and CPCU is running it through a concession contract. Upgrades after contract termination would then go public.	No info presented by requested institution
10.4.	Possibilities for a new big investments in a Contract is Foreseen/Not Foreseen	Foreseen	Not foreseen	Yes, an extension of the network to connect the	Yes	CPCU is constantly upgrading and investing in the network.	No

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
				Hospital del Mar			
10.5.	All investments according to agreement have to be approved by Public Partner (Municipality) (Yes/No)	Yes	Yes	Yes	Yes. Corporate governance: The company is governed via a two-tier board structure, comprising a management board and an independent supervisory board. The supervisory board is composed of 15 directors, of whom 6 are appointed directly by the Brescia Municipality, 6 by the Milan Municipality and the remaining three by a vote from the list of the	The Municipality owns 33% of CPCU so any new investment is consulted and approved previously by them as part of the management board	No info presented by requested institution

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
					remaining shareholders.		
10.6.	New investments have to be approved by Public (Municipality) (Yes/No)	Yes	Yes	Yes	Yes	The Municipality owns 33% of CPCU so any new investment is consulted and approved previously by them as part of the management board	No info presented by requested institution
10.7.	Life cycle of investments is longer than agreement duration (Yes/No)	No	No	Yes	Yes	Yes	No info presented by requested institution
10.8.	Tariff for services approval by (Municipality/Regulator/Private/Other)	Local government	Local government	Tariff for selling the heat and cold is set and approved by the management board in which all Public-Private parties participate. So it is a common	Yes	Tariffs are controlled by the Municipality, who sets a maximum tariff and also sets lower prices for social housing	No info presented by requested institution

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
				decision of these two parties.			
10.9.	Community is involved in participation of tariff approval (Yes/No)	Yes	Yes	No direct involvement	Yes, by the help of Consumer Associations	No	No info presented by requested institution
10.10.	Tariff methodology is defined by Regulator/Municipality	Regulator	Regulator	Defined by the management board of Districlima in which all Public-Private parts are represented.	Regulator (Authority for Electricity, Gas and Water Systems)	Municipality	No info presented by requested institution
10.11.	Emission trading scheme is applied (one of Kyoto mechanisms)	No	No	No info presented by requested institution	Yes	No info presented by requested institution	No applicable
<b>11.</b>	<b>Profit</b>						
11.1.	Profit level is controlled by Public partner/Regulator (Yes/No)	Yes	Yes	Not controlled	Yes, profit level is regulated by specially defined price methodology	Municipality. The concession contract specifies a maximum heat tariff that the CPCU can charge. This maximum heat tariff is indexed by	No info presented by requested institution

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
						the proportion of renewable energy sources used to encourage CPCU to switch to renewables	
11.2.	Profit goes to Private/Public partner	To Public and Private	To Public and Private	Districlima	To Public and Private	To Public and Private	Private
<b>12.</b>	<b>Subsidies and Grants</b>						
12.1	Subsidies are applied (lower VAT, etc) (Yes/No)	No	No	No	No	CPCU has had access to low interest loans from the Municipality. Occasionally, the city of Paris pays for the extension of the district heating network to a new zone in order to ensure connections. This is achieved by the city providing a direct, low-interest loan to CPCU for the development of this extension	No info presented by requested institution

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
12.2.	Grants are applied (Yes/No)	No	No	No	No	CPCU has had access to low interest loans from the Municipality. Occasionally, the city of Paris pays for the extension of the district heating network to a new zone in order to ensure connections. This is achieved by the city providing a direct, low-interest loan to CPCU for the development of this extension	No info presented by requested institution
12.3.	Origin of subsidies/Grants (EU/State/Other (please describe if other))	No	No	No info presented by requested institution	No	Municipality	No info presented by requested institution
13.	Land						
13.1.	Land property for utilities is Public/Private	Public	Public	Public	No info presented by requested institution	Public	Public
13.2.	Rent for land by Private Partner is paid (Yes/No)	No	No	No	No info presented by requested institution	No info presented by requested institution	No

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
<b>14.</b>	<b>Legislation</b>						
14.1.	Legislation of Project implementation business model and Energy framework is well developed (Yes/No)	Yes	Yes	Yes (developed by the Energy Agency of the Municipality)	Yes	Yes	Yes
14.2	Legislation is attractive for Project implementation business model and Energy framework	Yes	Yes	Yes	Yes	Yes	Yes
14.3.	Regulation for energy prices is applied (please identify for which of them)	Heating/Cooling/Domestic Hot Water	Heating/Cooling	The price for selling heat is set by the management board in which Public entities are also present. The price at which Districlima buys the steam is agreed with TERSA which is a fully Public entity.	Yes. District heating prices are updated quarterly, taking into account the variations defined by specific declarations by the Authority for Electricity, Gas and Water Systems (AEEGSI).	The concession contract specifies a maximum heat tariff that the CPCU can charge. This maximum heat tariff is indexed by the proportion of renewable energy sources used to encourage CPCU to switch to renewables	
14.4.	Regulation for waste utilisation is applied	No	Yes	Yes	Yes		

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
<b>15.</b>	<b>Technical level of utilities before agreement</b>						
15.1.	Technical level before agreement (Very good/Average/Bad/No utilities were installed before contract)	No utilities were installed before contract (Greenfield project)	No utilities were installed before contract (Greenfield project)	Very good	No utilities were installed before contract	Very good	No utilities were installed before contract (Greenfield project)
<b>16.</b>	<b>Public partner debts before agreement</b>						
16.1.	Public partner debts before agreement (Yes/No)	No as it is a new developed project	No as it is a new developed project	No	No as it is a new developed project	No	No as it is a new developed project
<b>17.</b>	<b>Business model replicability</b>						
17.1.	Business model is replicable (Yes/No)	Yes	Yes	Yes. It is Public-Private partnership that is working very well and that in fact they are replicating for other projects in the city of Barcelona. It	Yes	Yes, it is replicable and working well in many other cities. Engie, private partner of CPCU encourages working under public-private partnership as they offer high stability. Even if the profits are somehow capped, the fact of having a stable	Yes

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
				could also be replicated in other locations		period for operating a network and having stable profits has been proved to be very attractive for the private sector	
<b>18.</b>	<b>Employees</b>						
18.1	After initial agreement for services signed employees are transferred to Private partner (Yes/No)	No	Yes	No info presented by requested institution. Today all the operators, engineers, managers have a contract with Engie	No, because it is a new developed project	No info. I think employees working now at the Syctom plant have a contract with TIRU and the ones working for CPCU have a contract with CPCU. If the agreement changes and other company gains the contract they would probably have to sign a new contract with the new company. They will remain anyway with private sector contracts	No
<b>19.</b>	<b>City goals to achieve pollution reduction</b>						

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
19.1.	Project (Contract) helps to achieve goals of pollution reduction for the city (Yes/No)	Yes	Yes	Yes	Yes	Yes, "Plan Climat Ville de Paris" Paris Climate Plan	Yes
<b>20.</b>	<b>Fuel</b>						
20.1.	Primary energy resources are used (Yes/No)	Yes	No	Gas for peak loads	Natural gas is the 50% , Waste to Energy 40%, Geothermal 10%.	Syctom uses just waste to generate steam. CPCU uses 50,7% renewable plus waste recovery	No
20.2.	Renewable energy sources are used (Yes/No)	No	No	No	Yes	CPCU: 8%	No
20.3.	Waste energy are used (Yes/No)	Yes	Yes	Yes	Yes, industrial waste and waste to energy 40%	CPCU 42,7%	Yes
20.4.	Fuel diversification is made (Yes/No)	No	No	Waste energy/Gas	Yes	Yes	No
<b>21.</b>	<b>Project impact</b>						
21.1.	Reduced energy prices for consumers (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes
21.2.	Higher level of security of supply (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes
21.3.	Lower price for waste utilisation (Yes/No)	No	Yes	Yes	Yes	Yes	Yes
21.4.	Implemented state strategies (Yes/No)	Yes	Yes	Yes	Yes (for example Covenant of	Yes	Yes

No.	Description	Zhuhai China	Zhengzhou China	Barcelona Spain	Milan Italy	Issy-Les-Moulineaux France	Paris France
					Mayors in 2009. At Italy level also international commitments from EU)		
21.5.	Positive impact on EU Directives Energy Efficiency implementation (Yes/No)	Not EU country	Not EU country	Yes	Yes, permits granted by Ministerial Council of the Energy Community	Yes, contributes to Horizon 2020	Yes
21.6.	Positive impact on Global Energy Efficiency implementation (Yes/No)	Yes	Yes	Yes	Yes (higher standards than average in Italy)	Yes	Yes
21.7.	Lower negative environmental impact for the city/ citizens (Yes/No)	Yes	Yes	Yes	Yes, reduced NO <sub>x</sub> , CO <sub>2</sub> and PM	Yes	Yes
21.8.	Higher level of RES in the energy production balance (Yes/No)	Yes	Yes	Yes	Yes. This new developed company does not have a lot of RES this year but they are investing to develop	Yes	Not applicable

## V. RECOMENDATIONS FOR REPLICATION AND SCALE UP OF THE ECO ENERGY TOWNS APPROACH

The concept of Eco Energy town is based on the new paradigm of using unwanted public facilities including sewage treatment plants to generate energy, and returning the benefits to local residents.

Following a similar approach at a bigger scale, cities like Milan, Barcelona, Paris, Zhuhai and Zhengzhou are using the waste heat generated in the urban environment – waste heat from solid municipal waste incineration, waste heat from data centres, waste heat from sewage, combined heating, cooling and power generation- as an energy source to supply heating, cooling and electricity to its citizens. By utilizing waste heat as energy source these cities reduce their dependence on fossil fuels, reduce CO<sub>2</sub> emissions, improve air quality and contribute to creating a local circular economy, transforming energy losses into environmental and economic gains.

To enable waste heat recovery and its successful distribution to end users in the form of heating and cooling, these cities encountered diverse barriers and challenges. The case studies selected in this report represent best practices of implementation of district energy projects using waste heat as energy source. These best practices can be extrapolated and adapted to the eco-energy towns concept, and can serve as guidance to identify key areas to expand and internationalize the eco-energy towns approach.

### Holistic Energy Plans

An energy plan is a roadmap of project developments and policies that help the city realize the articulated goals of its energy strategy. Holistic energy plans integrate energy in infrastructure and land-use planning, and they are a key best practice in the development of district energy systems. They analyse the impact of (an interaction between)

energy, land use and infrastructure – including waste, water, buildings and transport ( see case study on Barcelona)- aiming at identifying synergies and opportunities for cost-effective district energy.

Collaboration with city-owned or private wastewater or transport utilities may help to reduce costs in project development and construction. Holistic energy planning can allow a city to promote and/or designate areas or zones that have favourable conditions for district energy development or expansion, and to apply tailored policies or financial incentives on a case-by-case basis.

Holistic energy plans can also be a key tool to enable the successful implementation of the Eco-energy town's concept. The development and integration of clean energy generation facilities such as a biogas plants, a waste heat recovery from sewage, a waste to energy plant or a solar PV panels into an urban environment entails considering their technical, environmental and economic requirements. An holistic energy plan that integrates these requirements into the infrastructure and land-use planning of the town, can facilitate overcoming the technical, regulatory and financial barriers of building these facilities in the town. The energy plan can also be used to improve the business case of these clean energy generation facilities. This can be done including policy interventions such as requiring the use of locally generated energy first, and adapting the planning framework requiring for example waste-based heating or cooling systems for new developments.

Successful integrated planning required collaboration among the diverse local government organizations that are affected by land planning –

such as energy, waste, buildings, transport etc. Most of the champions cities in district energy have decided to establish an administrative structure to coordinate these various bodies, for example through an interdepartmental committee, multi-stakeholder partnership or designated agency. Local authorities aiming at implementing the eco-energy town concept either in one specific zone or in the whole town, may find helpful to create a multi-stakeholder coordination structure to facilitate an early collaboration of all relevant stakeholders and ensure that the energy plan is incorporated effectively into other planning documents. This early collaboration among stakeholders will reduce the risks that can arise from lack of permitting or lack of public awareness support.

### Energy Mapping

To identify opportunities for targeting resources and policies to meet district energy goals, municipalities often need more detailed information on the current and future geographical distribution of energy use at the neighbourhood and building levels, as well as on local heat and energy assets and distribution structures. This can be achieved through an energy mapping process that analyses the local conditions, such as sources of excess heat, renewable heat assets ( geothermal and solar), and concentrations of heat or cooling demand –often using GIS- based spatial information (Connolly et al.,2013;Person et al.,2012). Further data and layers of analysis can be added over time, depending on the policy objectives and goals.

Energy maps to develop eco-energy towns can contain, among other variables, data on:

- Existing and projected energy consumption by sector, fuel source or neighbourhood; resulting emissions and pollution; and an understanding of the load profile
- Present and future building density and use type
- Sources of waste heat recovery
- Available renewable energy sources

- Large energy consumers and buildings /facilities with potential excess heating or cooling capacity (gyms, swimming pools)
- Barriers and opportunities particular to the location related to local energy sources, distribution, transport, land use, development density and character
- Socio-economic indicators to identify fuel-poor areas that could benefit

Energy mapping can help cities identify specific projects on clean energy generation facilities that could be developed, what kind of energy source ( waste heat, manure, sewage, solar) might be used and how it should be processed to obtain energy in the desired form, either as biogas, electricity , heat or cool) . It will also help identify how the project can be expanded and connected to future developments or who will be the end-consumers. Energy maps can also identify how a town can best apply its land-use authority to encourage a certain clean energy generation project and to develop tailored incentives in a specific zone to reduce risks and attract private investment.

Energy mapping can help eco-energy towns to:

- raise public awareness by creating an effective visualization tool for communication,
- facilitate stakeholder engagement.
- Analyse the different scenario create opportunities for business models.
- set targets
- identify the most efficient projects from a techno-economic perspective
- identify and visualise opportunities for future development projects
- integrate energy usage and sources in early stage urban planning.

### Engaging the Local Government

Local governments have a privileged position to encourage the development of clean energy generation facilities in their cities and towns and implement the concept of eco-energy towns. The role of local government is key as planner and

regulator, as facilitator enabling finance, as provider and consumer, and as coordinator and advocate.

The strong support and engagement of local authorities in the case studies presented in this report has been key for the successful development of the projects. Some examples of these interventions from local governments are:

- To facilitate public land use for the construction of the district heating network (see case of Zhuhai);
- To act as coordinator between suppliers and end-users ( see cases of Zhuhai, Zhengzhou, Barcelona or Milan);
- To design guidelines and policies that support the development of the project ( see case of Zhengzhou, Barcelona, Paris and Milan);
- To cover the engineering and construction costs of the district energy system ( see case of Zhengzhou);
- To attract private investment by encouraging connection of public buildings- minimizing load risk- and offering stable long-concession contracts ( see case of Barcelona and Paris);
- To stimulate private investment and industry activity by facilitating access to low-cost finance (Paris);
- To guarantee consumer protection by regulating heating and cooling tariffs (see case of Zhengzhou, Barcelona and Paris).

Local governments interested in developing clean energy generation facilities and implementing the eco-energy town approach may find these examples useful to identify the areas on which their engagement may be required for the success of the project. Key will be the development of an enabling regulatory framework to attract investment in the projects. This would require identifying the project risks and design policies capable of alleviating them.

### Public-Private Partnerships

Cities like Barcelona, Milan or Paris, have found in public-private partnership the perfect combination

to expand their district energy networks. In Barcelona the local government launched a call for tender looking for a private partner with which to successfully develop and expand the district energy network. The municipality selected a private company with high investment capacity and technical expertise and offered a long concession contract to reassure the private partner that they would obtain an interesting IRR.

A common best practice is to align the interests of the public and private sector in developing and implementing public policies that generate sustainable value. This is achieved through constant dialogue and good practices of cooperation. In the case of Milan, the interests were aligned and have remained because of the involvement of both sectors in the business model of the district energy system. The community should also be included in the business model through providing the best quality service, local employment and privilege city shareholders.

### Setting targets: establishing decarbonisation goals

A clear environmental and energy strategy with official decarbonisation goals or renewable energy targets gives a clear guidance for investors. It can reduce opposition to projects and to any associated disturbance in development or operation and it can help mobilize support from other levels of government.

A long-term eco-energy vision can reassure investors, making possible longer-term infrastructure developments such as building a waste-to energy plant.

Promotion of long-term strategies to limit the emissions into the atmosphere and develop energy efficiency initiatives, including through the use of energy from renewable sources can reassure investors, making possible longer-term infrastructure developments such as building a waste-to energy plant. Decarbonisation targets can be adapted to every context, including the rural context, by for example setting targets for waste heat recovery, energy generated from animal waste

(manure), renewable energy targets or air quality targets (for example limiting PM2.5 emissions).

Any model for the management of aspects of the environment and health should follow strategies as described below:

- Integrating climate change mitigation strategies into the production lines;
- Increasing constant energy efficiency investment and maintenance.
- Promoting technological innovation and performance improvement, so as to guarantee an increase in energy production and generation capacity, mitigation of pollution of the soil, subsoil and water, protection of biodiversity and ecosystems, a reduction in water losses, and the continuity and reliability of infrastructures. into energy efficiency assessments of buildings

#### **Encouraging a circular economy: developing a waste management policy**

The concept of eco-energy towns is tightly bound to the concept of circular economy and a responsible use of resources. This approach can be replicated by every city adopting the appropriate policies for the management and disposal of waste and encouraging the reuse of materials. This principle must be in the core of the business plan, by launching and taking part in technical round tables and opportunities for a comparison of ideas, in line with the community's demands and expectations. The following actions can help develop a waste management strategy:

- Applying policies for the management and disposal of waste that can, where applicable, encourage the reuse of materials.
- Developing separate waste collection activities and an efficient management of the fraction of waste that cannot be recovered, through its recovery in the form of energy.
- Environmentally conscious management of landfill sites.

These recommendations are based on best practices from the implementation of district energy projects based on waste heat recovery. A more detailed analysis focused on the specific characteristics and barriers of eco-energy towns should be made to define a more precise guideline on how to replicate and scale-up the eco-energy towns approach.

## References

- E. Antonini, D. Longo, V. Gianfrante. Challenges for Public-Private partnership in improving energy efficiency of building sector. 2016
- A. Satchwell, P. Cappers, C. Goldman. Carrots and sticks: A comprehensive business model for the successful achievement of energy efficiency resource standards. 2011
- A. Chaurey, P.R. Krithika, D. Palit, New partnerships and business models for facilitating energy access. 2012.
- B. Ilan. Business model. 2015.
- G. May. Business model for energy efficiency in manufacturing. 2017.
- C. Gauthier, B. Gilomen. Business Models for Sustainability: Energy Efficiency in Urban Districts. 2016.
- S. Babino, H. Galvan. Budget-Neutral Financing to Unlock Energy Savings. Potential: An Analysis of the ESCO Model in Barcelona / Green energy and efficiency. 2014.
- Y. Li, C. Zhan. Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China. 2016.
- L. Okkonen, N. Suhonen. Business models of heat entrepreneurship in Finland. 2010.
- L. Shen, V. Tam, L. Gan. Improving Sustainability Performance for Public-Private-Partnership (PPP) Projects. 2016.
- A. Kolk, D. Buuse. In search of viable business models for development: sustainable energy in developing countries. 2012.
- Sulla città di Milano. (2017). Retrieved from About Milan: <http://www.aboutmilan.com/it/la-citta-di-milano.html>
- Municipi in Dettaglio. (2017, 09 20). Retrieved from Comune di Milano: <http://www.comune.milano.it/wps/portal/ist/it/amministrazione/governo/Municipi/Municipi+in+dettaglio>
- Rodriguez, V., & Connell, T. J. (2016, 08 12). Barcelona. Retrieved from Encyclopaedia Britannica: <https://www.britannica.com/place/Barcelona>
- Walker, A., & Porraz, B. (2003). The case of Barcelona, Spain. Barcelona, Spain: University College of London.
- [www.districtclima.com](http://www.districtclima.com)
- City of Issy-les-Moulineaux. (2017). Retrieved from Map-France: <http://www.map-france.com/Issy-les-Moulineaux-92130/>
- La ville. (2017). Retrieved from Issy: <http://www.issy.com/>
- Ardagh, J. A., Ehrlich, B., & Daul, K. (2017, 04 24). Paris. Retrieved from Encyclopaedia Britannica: <https://www.britannica.com/place/Paris>
- INSEE. (2014). L'Industrie en Île-de-France, Principaux Indicateurs Régionaux.
- Mairie de Paris. (2005). Conseils de quartier. Retrieved from [https://web.archive.org/web/20081207175020/http://www.paris.fr/portail/accueil/Portal.lut?page\\_id=4971](https://web.archive.org/web/20081207175020/http://www.paris.fr/portail/accueil/Portal.lut?page_id=4971)
- Creating sustainable value in A2A: Integrated Report (A2A, 2016)
- Bilancio di Sostenibilità Milano (Sustainability Balance A2A, 2016)
  - [http://www.a2acaloreservizi.eu/home/cms/a2a\\_caloreservizi/](http://www.a2acaloreservizi.eu/home/cms/a2a_caloreservizi/) (information retrieved on October 2017)