GovernEE – Good Governance in Energy Efficiency

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WP 3.1.3 INTERNATIONAL SURVEY ON INNOVATIVE ALTERNATIVE ENERGY SOURCES IN DISTRICT HEATING

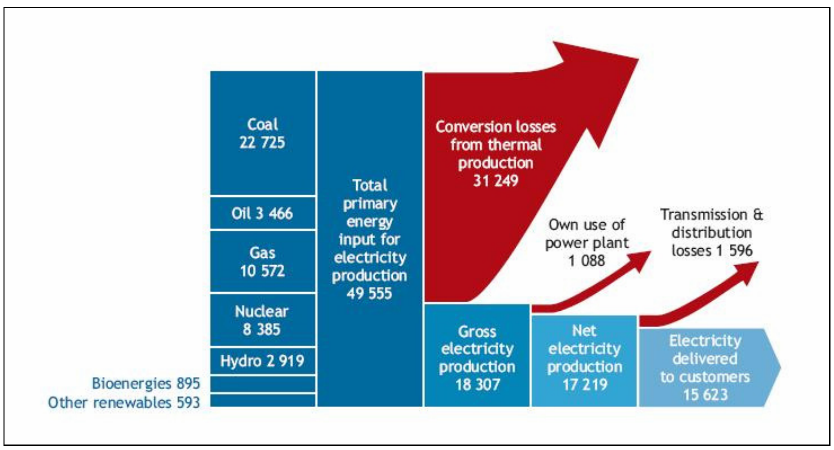
CENTRO DI ECOLOGIA TEORICA ED APPLICATA

Preface

Despite important steps taken by government and industry to mitigate air pollutant and greenhouse gas (GHG) emissions, carbon dioxide (CO2) emissions have increased by over 20% in the past decade. Without further action, the carbon intensity will increase, due in part to greater reliance on coal for power generation (IEA, 2008).

In addition, the average global efficiency of traditional fossil-fuelled power generation has remained stagnant for decades at 35-37%. About two-thirds of the primary energy that is converted to produce electricity is lost as "waste" heat (IPCC, 2007) that can, in part, be used to satisfy the demand for heat in industries, buildings, towns and cities. Further, the transmission and distribution (T&D) of this electricity from large central power stations contributes further losses of around 9% of net generation, so that only about one-third is delivered to the end customer. The following figure shows these losses for the global power system, demonstrating that 68% of total energy input is lost in energy each year before it reaches the end consumer.

Figure 1: Energy flows in the global electricity system (TWh)



Source: IEA, 2008

However, there are relevant efficiency gains that can be realised by pursuing energy efficiency in the heat and electricity sectors simultaneously through greater use of district heating and cooling (DHC) systems and combined heat and power plants (CHP).

The EU Commission highlights that: "*Thermal power generation often leads to conversion losses while at the same time natural resources are consumed nearby to produce heating or cooling in separate systems. This is both inefficient and costly. Similarly, natural sources, such as sea- or groundwater, are seldom used for cooling despite the cost savings involved. The development and modernisation of district heating and cooling networks should therefore be promoted as a matter of priority in all larger agglomerations where local or regional conditions can justify it in terms of, notably heating or cooling needs, existing or planned infrastructures and generation mix etc*[1]".

[1] (COM(2010) 677 final: Energy infrastructure priorities for 2020 and beyond - A Blueprint for an integrated European energy network).

The environmental, economic and social benefits of harnessing surplus heat and using local renewable energy sources make district heating and cooling the sensible choice for communities seeking to promote economic growth while minimizing the environmental consequences.

1 District heating and cooling system

1.1 What is district heating

1.1.1 District heating and cooling

District heating and cooling (DHC) system main function is to supply customers with energy for heating and cooling, and production of domestic warm water.
The fundamental idea behind modern DHC is to use local heat and fuel sources that under normal circumstances would be lost or remain unused (upgraded waste heat from CHP plants, industrial processes –electricity generation, waste burning, high temperature industrial manufacture, fuel- and biofuel refinery and nuclear processes– and waste incineration) and to organize the heat production in a way that is more efficient than individual production (Euroheat & Power, 2011; IEA, 2008). District heating system would serve as a heat energy broker, collecting it where there is an excess and supplying it where there is a deficit.
DHC systems are also increasingly being used as a way to introduce renewable energy resources into heat and electricity sectors.
The heat serves to warm up water which is transported via a well-insulated network of pipes to the customer premises.
It can cover heat demands in residential (Eu level the final energy consumption by households and services rose up to 37% in 2006[2]), public, and commercial buildings as well as low-temperature industrial heat demands. A heat exchanger serves as interface between the district heating network and the building radiator and hot tap water system. District cooling takes advantage of natural cooling from deep water resources as well as the conversion of waste heat via absorption chillers.
Countries with the largest number of heating degree days tend to have the greatest penetration of district heating. Moreover, due to the highly capital-intensive nature of these systems, DHC supports a greater level of local government involvement in providing services. As a result, DHC systems may be communally owned, but funded by public and/or municipal authorities.
District cooling is being increasingly pursued as an alternative to conventional electricity- or gas-driven air conditioning systems. Due to the use of resources that would otherwise be wasted or difficult to use, district cooling systems reach efficiencies that are between 5 and 10 times higher than with traditional electricity driven equipment[3].

1.1.2 Combining DHC with CHP

Based on the fundamental idea of using surplus, recycled or recovered heat (i.e. heat generated as inevitable by-product of other processes that otherwise would be wasted) as a valuable energy resource, district heating and district cooling reduce primary energy demand. At present around

[2] http://www.eea.europa.eu/data-and-maps/figures/final-energy-consumption-by-sector-in-the-eu-27-1990-2006.
[3] Euroheat and Power, http://www.euroheat.org/.

82% of district heat in the European Union is derived from sources of surplus heat. By far the largest proportion of this heat originates from Combined Heat and Power (CHP) installations, corresponding to more than three quarters of total district heat energy supply. The result is a reduction in European primary energy demand of at least 250 TWh per year (DHC, 2009).
The rest is based on the direct use of renewable energy sources, such as geothermal heat or biomass and fossil fuels, mainly for peak demand. The combined share of biomass, geothermal, solar and waste in the energy source mix in Europe is currently around 14%.
DHC system reaches the highest efficiency level in case of combined system which produces heat and power. The combination of cogeneration and district heating is very energy efficient.
Cogeneration heating plants (CHP) systems are attractive because they can deliver a variety of energy, environmental and economic benefits. These benefits stem from the fact that these applications produce energy where it is needed, avoid wasted heat, and reduce transmission and distribution network and other energy losses (IEA, 2008).
Other benefits cited include:

- Lower CO2 emissions;
- Reduced reliance on imported fossil fuels;
- Reduced investment in energy system infrastructure;
- Enhanced electricity network stability through reduction in congestion and peak-shaving; and
- Beneficial use of local and surplus energy resources (particularly through the use of waste, biomass, and geothermal resources in district heating/cooling systems).

CHP can take on many forms and encompass a range of technologies, but will always be based upon an efficient, integrated system that combines electricity production and a heat recovery system. CHP plants generally convert 75-80% of the fuel source into useful energy, while the most modern CHP plants reach efficiencies of 90% or more (IPCC, 2007).

1.1.3 Advantages

Considering that DHC system is mainly based on CHP, many CHP benefits became DHC benefits. There is a considerable number of solid “pro’s”, like the ease of use, the unlimited amount of domestic warm water available constantly, the desired temperature at all times, and reduction in space required by the heating system, as mentioned below. On the other hand the main “con” when applying DHC in an existing building is the conversion from individual heating which, depending on the type of system used previously, can be rather complicated and needs careful planning. However, seen over the full lifetime of such a system, this investment can be depreciated very reasonably.
In general environmental advantages and user’s benefits can be distinguished and some synthetic table are available in the Annex 1.

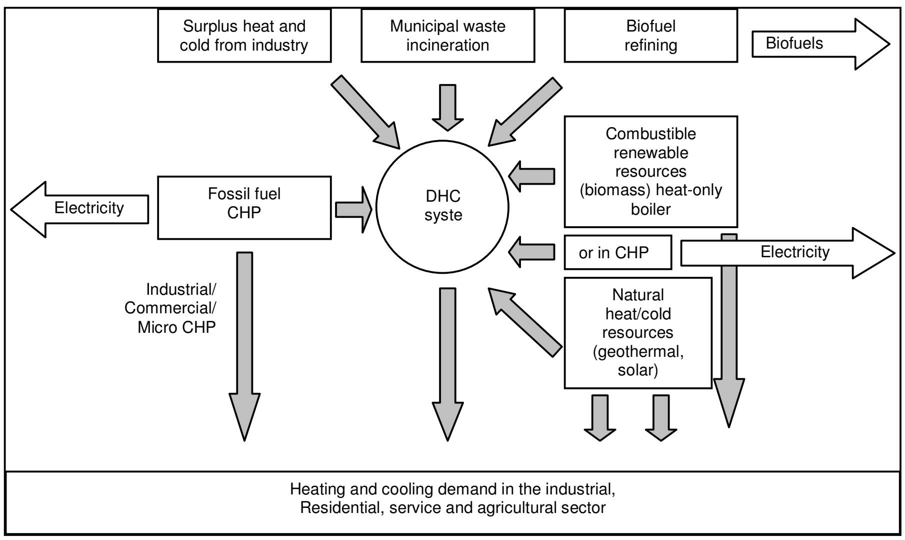
Environmental advantages (social benefits)

Even if DHC requires initial and substantial investment, it enables the transition to a low-carbon energy system and it depends on (DHC, 2009):

- The main advantage depends on the fact that DHC systems use different kind of fuels integrating them in an efficient and economic manner. In fact the plant may use waste heat, which includes for example heat from refuse incineration, refineries and other industry, electricity production and wastewater, renewable sources, such as biomass (by-products, industry waste, etc.), geothermal sources and renewable electricity, and finally fossil source, such as oil, fossil electricity and natural gas. In addition in the case of surplus heat from industries, district heating systems do not use additional fuel because they use heat (termed heat recovery) which would be dispersed to the environment (Figure 2). In addition DHC uses a wide variety of local energy sources, including those that are impossible or difficult (less efficiently and cost-effectively) to handle in individual applications. In particular, DHC integrates combustible renewables that are difficult to manage in small boilers, which is the case with most renewable sources, for example wood waste, straw and olive residues as well as the biogenic fractions of municipal waste and sewage sludge.

- District heating reduces 517 million tonnes of CO2 emissions per year that means more than 9,3% of all carbon emissions in Europe. District cooling achieves a further 40 to 50 million tonnes of CO2 emission reductions per year.

Figure 2: Resources used by DHC systems



Source: IEA, 2008 and 2009

- DHC reduces local pollutants as particle emissions, sulphur dioxide and nitrogen oxides by relocating exhausts from individual boilers to centralised chimneys. Due to economies of scale, far more effective pollution prevention and control measures can be implemented in central production facilities.

<u>User's benefits (private benefits)</u>

From the users' point of view DHC systems are typically easy to use, safe and economic:

- Safe and easy to use depending on the fact that heat water is distributed and the final user have no need for fuel storage facilities, have no boiler or burner and do not require a chimney flue;
- Users avoid maintenance and replacement costs of the localised plant, building heating equipment and save place. No maintenance is necessary for the user, the DHC utility can take care of energy and service 24/7[4], typically without ever entering the house;
- DHC guaranties an unlimited amount of heating and domestic warm water 24/7;

[4] Meaning 24 hours a day/7 days a week.

- Users take no risk of fires, avoid explosions and carbon monoxide poisoning;
- DHC can contribute to avoid electricity peak loads during cooling season, offering cost savings and reliability benefits;
- DHC enables a highly flexible energy mix. New fuels and energy sources can be integrated with minimal need for restructuring by the operator. For users no adaptation measures at all are required when a switch of energy source is made;
- DHC network ensures more stable and cheaper prices for users. One reason for this is that in a DHC a variety of heat sources can be utilized, enabling the operator to choose the most economical one at any given time. DHC is one of the cheapest heat sources on the market.

1.1.4 Diffusion

Even if DHC system in combination of CHP is very energy efficient and cheap, DHC are highly capital-intensive nature systems. Today's liberalized markets are focused on short-term return on capital. Therefore, investors do not necessarily consider long-term commitments such as district heating as attractive options. Furthermore, to ensure an adequate return on investment in the district heating infrastructure, legislation must provide for fair allocation of the economic value of the benefits to all parties including to the investor and operator. These benefits- including avoiding energy imports, price stability and environmental savings - are indeed huge for the local community and the national economy as a whole. Developments in the DHC sector are driven to a large extent by European legislation[5].
There are more than 5.000 district heating systems in Europe, currently supplying more than 9% of total European heat demands with an annual turnover of €19,5 billion and 556 TWh heat sales. Market penetration of district heating is unevenly distributed, being close to zero in some countries while reaching as high as 70% of the heat market in others (DHC, 2009).
It is mainly the northern, central and eastern European countries that have high penetration of district heating, while Poland and Germany have the largest total amount of district heat delivery. Highest growth rates for district heating are achieved in Austria and Italy. In cities like Copenhagen, Helsinki, Warsaw, Vilnius, Riga as much as 90% of residential heat demands are satisfied by district heat.
Commercial and public buildings show high connection rates in district heated cities. The European share of district heating in industry is around 3,5%. Higher market shares (10 to 15%) appear in individual countries including Hungary, Poland, Finland, Netherlands, and Czech Republic. It is generally accepted that most state-of-the-art district heating systems are situated in western parts of Europe, Scandinavia in particular. These networks score high in terms of energy efficiency, renewable energies integration, economic performance, reliability and customer confidence.
Sweden for instance is expected to reach a 25% district cooling market share for commercial and institutional buildings in two to three years time. Cities that have reached or are on the way towards reaching 50% district cooling shares include Paris, Helsinki, Stockholm, Amsterdam, Vienna, Barcelona, Copenhagen.

Focusing on District cooling in Europe today has a market share of about 2% of the total cooling market, corresponding to approximately 3 TWh cooling. The market penetration of district cooling shows great diversity. Overall, this market has emerged quite recently and is consequently less developed than the district heating market. It is, however, growing fast with the last decade seeing a

[5] Euroheat and Power, http://www.euroheat.org/.

tenfold growth in installed capacity. Table 1 Errore. L'origine riferimento non è stata trovata. **reports some statistics about DHC and CHP diffusion.**

1.2 Production

District energy systems have three basic components: a source of thermal energy, a piping network to distribute that energy, and a mechanism for utilizing that energy in buildings (Wilson, 2007).

1.2.1 Producing heat

DHC systems use different kind of fuels integrating waste heat, electricity production and wastewater, renewable sources, and finally fossil source. The choice depends on the cost, availability and environmental impact.

<u>Fossil Fuel Combustion</u>

Fossil fuel combustion uses coal, natural gas, or oil. Steam or hot water can be produced in large boilers as the sole output, or this thermal energy can be a byproduct of electric power generation, mentioned above as combined heat and power (CHP) or cogeneration.

When chilled water is needed for district cooling systems, it can be produced at power plants or at satellite cooling plants that serve clusters of buildings. Electricity can be used to chill the water using large electric chillers (ideally operating at night with chilled water stored for daytime use), or a heat source can chill the water (typically using absorption cooling) so there is a wide range of options for the chilled water production.

While chilled water can be distributed directly through district cooling systems, another option is to distribute only heat and then to use that heat within buildings for cooling using thermally activated absorption chillers, adsorption chillers, or desiccant dehumidification systems. This practice can avoid the need to run dual piping loops.

<u>Fossil Fuel CHP</u>

Combined heat and power is an attractive option for district heating because it allows for the use of thermal energy that would otherwise be lost. In a typical coal-fired power plant today, about two-thirds of the primary energy content of the coal is lost as waste heat. Exactly how much heat is wasted depends greatly on the combustion technology used.

Conventional coal plants pulverize the coal and inject it into a furnace that produces pressurized steam; 33%-35% power generation efficiency is typical with these plants, though the latest technologies can achieve efficiencies as high as 45%. More advanced integrated gasification combined cycle (IGCC) coal-fired power plants first gasify the coal by heating it to a very high temperature (1.000°C) at high pressure in the presence of pure oxygen. The resultant gases (primarily hydrogen) are burned in a gas turbine at generation efficiencies of 42%-48%.

Natural gas is most efficiently burned in natural gas combined cycle power plants that can achieve efficiencies of 50%-60%. Such systems are typically 25 megawatts (MW) or larger. Microturbine gas generators operate at significantly lower efficiency (25%-29%), but their smaller size enables them to be used in buildings where the waste heat can be easily captured and used within the building.

Fuel oil is generally used in power plants of a few megawatts and smaller using reciprocating engines-essentially large diesel engines similar to those used in heavy equipment. Electrical efficiency ranges from about 33% at 100-kilowatt (kW) capacity up to 41% at 5-MW capacity.

Nuclear power

With an average generation efficiency of 30%, the large amount of waste heat generated by nuclear power plants makes them well suited to district energy systems. However, the typical isolation of nuclear power plants and concern about radioactivity has resulted in almost no district energy being derived from these plants.

Geothermal Heat and Deep-Lake Cooling

Where there is a convenient source of high-temperature geothermal energy, distributing this heat through district energy systems is an obvious choice. Roughly 95% of all space and water heating in Iceland is provided by geothermal district energy systems from the country's tremendous geothermal resources. The oldest continually operating district energy system in the world (in France) relies on a natural hot spring.
In most geothermal district energy systems, water is pumped underground, where it is heated, then pumped back out for distribution. In some systems, high-pressure steam is used for power generation, and the waste heat is distributed as district heat.
In addition to capturing underground geothermal heat, some district energy systems provide district cooling using water from deep lakes. The City of Toronto is pumping 4°C water from a depth of 80 m in Lake Ontario to cool portions of the downtown; when completed, that system is expected to provide 183 MW (52.000 tons) of cooling to the city.

Renewable Energy Sources

Several renewable energy sources are being used as heat sources for district heat systems. Wood-chip boilers and CHP systems are growing in popularity. The Finnish company Wärtsilä Corporation is a world leader in wood-chip-fired CHP plants. The company produces modular CHP plants delivering from two to five megawatts of electricity (MWe) and up to 20 MWth of hot water.
Methane can also be captured from landfills or derived from livestock manure using anaerobic biodigesters. The University of California - Los Angeles (UCLA) pipes methane from a landfill three miles (5 km) to the campus, where it is burned in a 20-MWe CHP plant that provides the campus with district energy.
Even sewer and water lines can offer a district heat source if coupled with heat pumps to raise the temperature of that heat source.

Seasonal underground storage of thermal energy

Integrating district heating and cooling and electricity generation with the use of onsite RES introduces the issue of seasonal underground storage of summer heat and winter coldness (Harvey, 2010)
Seasonal thermal storage requires larger storage volumes and/or greater storage temperatures than diurnal storage. A greater volume of storage containers such as water tanks entails greater cost, while a greater storage temperature will lead to greater heat loss. However, the ground itself provides a natural, large-scale medium for storing heat and coldness between summer and winter.
Underground thermal energy storage can occur as aquifer, borehole or as cavern.

Heat can be stored either as low-temperature (< 50°) or as high-temperature heat (>50°). Low-temperature storage requires advanced heating systems with a low distribution temperature so that the stored heat can be used, or requires heat pumps (and additional energy input) in order to upgrade the stored heat to higher temperature. High-temperature storage is already stored at a warm enough temperature to be usable in a district heating system.
In general terms seasonal thermal energy storage is less expenses at he scale of a small DH system than at the scale of individual buildings or houses[6].

Solar-assisted district heating

The pioneering work on solar-assisted DH was carried out in Sweden during 1970s and 1980s. the largest of these systems are in Hamburg (serving 124 single-family homes), Friedrichshafen (serving 570 apartments) and in Neckarsulm (serving 6 blocks of flats, a school and a commercial centre).
Solar-assisted district heating is primarily considered in planning for new development areas (Milles, 2004).
Significant technological advancement is expected with the low-temperature heating systems currently put into operation. Large solar systems with collectors areas greater than 100 m2 and solar district heating systems with short and long-term heat storage are the most efficient approach to thermal use of solar energy.
Solar-assisted DH system with short-term heat storage can supply between 10-20% of the total thermal energy required to heat rooms and hot water. The goal of solar-assisted DH with long-term heat storage is the use of solar heat stored in summer to heat rooms in winter.
The basic elements of a solar-assisted DH system consist of solar collectors, a short-term storage unit (buffer tank), seasonal underground heat storage in boreholes, a supplemental boiler and the DH network (Harvey, 2010).
Solar-assisted DH systems with storage can be designed such that 30-95% of total annual heating and hot water requirements are provided under German conditions.

Hybrid biomass/solar district heating systems

As noted above biomass energy is being increasingly used as a fuel for DHC systems in some countries. Because the heat load is relatively small during the summer and transitional seasons, the boilers would operate with frequent on/off operation, which is inefficient. However, this is the time when the solar energy is available, so the boilers could be shut down. Thus, solar energy complements biomass energy well. Thermal storage tank are usually construct (Harvey, 2010).

Wind-energy buffer

Wind energy has already become competitive with fossil fuel electricity in regions with good winds. However, due to the fluctuating nature of wind energy, it will not be practical to supply more than 20% of total energy demand with wind energy without some mechanism for storing wind energy. One way to do this is through integration with a DHC system.
Therefore, if the wind energy component of a local power system is sized such that it sometimes provides more energy than needed, the excess power can be used with heat pumps to supply hot

[6] As the scale of seasonal energy storage reservoirs increases, the surface-to-volume ratio decreases. This will decrease the fractional loss of stored thermal energy and the capita cost per unit of storage capacity, which largely depend on the surface area.

or chilled water in place of fossil fuel or biomass energy or to charge thermal storage reservoirs (Harvey, 2010).

Hydrogen fuel

Where RES can not be directly used, hydrogen fuel can replace fossil fuel. Hydrogen can be produced from a variety of RES (primarily wind and solar energy) and transported largely by pipeline to where it is needed, stored and used when needed (Harvey, 2010).
Switching from fossil to hydrogen fuel is easier and less expensive in those communities that are served by DH systems.
In buildings heated with natural gas a whole new pipeline infrastructure is needed. In buildings served by DH systems the only infrastructure that would need to be rebuild are the pipelines supplying the central power plant. If boilers need to be modified to use hydrogen fuel, this will be easier and less expensive if done in the centralised plant.

1.2.2 Distributing heat and chilled water

After generating the steam, or hot or cold water, the next task in a district energy system is to distribute that energy. While either steam or hot water can be distributed in district heating systems, most new district heating systems are being designed for hot water, and some older steam systems are being converted to hot water.
A hot water district energy system always involves a piping loop. The supply and return pipes are installed side by side because at every branch pipe going off the supply pipe, a return line needs to feed back into the return pipe. By the time the main heating or cooling supply pipe reaches the last distribution point, its diameter has typically shrunk significantly because it's carrying less water.
When a district energy system supplies both heating and cooling, four pipes are used: supply and return for both hot water and chilled water.
Because a significant portion of the cost of a district energy system involves the trenching to lay pipes, it is wise to plan ahead and determine if a chilled-water loop is likely to be needed and, if so, install it at the same time.
District energy systems use special pre-insulated piping. Most of the piping is steel that is insulated with polyurethane and then wrapped in a protective, high-density polyethylene jacket.
Determining the optimal pipe diameters is an important part of district energy system design. The amount of thermal energy delivered is a function of water temperature and flow volume, and a given flow volume can be achieved with fast-moving water in smaller pipes or at lower velocity in larger ones.
Lowering the velocity reduces friction and therefore pumping energy, but larger pipes are more expensive to buy and bury. The required flow volume, the cost of pumping energy, and the cost of pipes determine what size pipes are used.
District energy pipes are often manufactured with embedded wires that are used to monitor for breaks and leaks.
Insulation is key to the success of district hot water systems. Five centimetres or more of high-density polyurethane (typically 65-90 kg/m^3), mineral wool, or cellular glass insulation keeps heat loss from the pipes to a minimum-usually less than 2% per mile, sometimes a lot less.
Pipes are laid in well-drained trenches. Pipe joints and connections are made according to manufacturer recommendations (welding or soldering with metal pipe). Over this, the pipe joints are protected with sections of HDPE jacketing-often cylindrical jackets that fit over the pipe joints

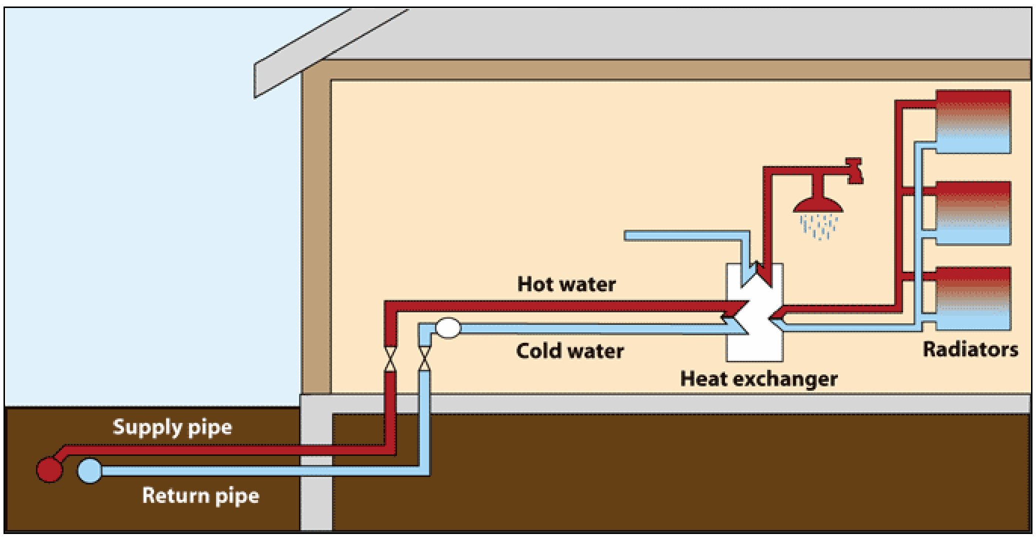
and are heat-shrunk in place. During this pipefitting, the continuity of monitoring wires (if provided) is maintained, and leads are connected to sophisticated alarm systems.

1.2.3 Using district energy

The third and final component of a district energy system is the mechanism for utilizing the heat in our buildings.

Smaller branch pipes generally bring the hot water into a building from the trunk line. In the building, rather than being distributed directly (through a baseboard hydronic heating system, for example), the hot water usually transfers heat to a hot water tank via a heat exchanger (Figure 3). Hot water from this tank is usually used directly for heating; a separate heat exchanger may be used to heat domestic hot water. While hydronic heating is most commonly used with district heat, the heat can alternatively be used in forced-warm-air heating systems using a fan coil (a hydronic coil in the air handler).

Figure 3: Using district energy



Source: Wilson, 2007.

Within this system is one or more meters to measure how much heat from the district heating system the building is using. This key component allows the district energy utility to charge for energy use. The meters measure both incoming and outgoing water temperature and flow rate.

European manufacturers offer preplumbed modules that include the heat-exchange tank, all the valves and connections to the heat loads in the building, and meters. A single module replaces the individual boiler and water heater in a house.

If the temperature of the water being distributed is not high enough to satisfy heating loads, it can be boosted using small water-source heat pumps that use electricity to concentrate low-temperature heat.

District cooling systems that deliver chilled water are used primarily in large commercial buildings, but a few new housing projects in Europe are utilizing such systems for air conditioning. As noted, in addition to distributing chilled water from a central source, it is also possible to cool a building with distributed hot water using adsorption chillers or desiccant dehumidification. In either case,

within the buildings, the cooling can be delivered via forced-air ducts or hydronic radiant cooling panels.
If demand for air conditioning increases in Europe, due to either global warming or changing comfort standards, it will be interesting to see how these thermal needs are served by district energy systems.

2 Innovative DHC system: best practice

The District Heating and Cooling plus (DHC+) Technology Platform[7] sets out in global terms how district heating and cooling stakeholders see the future development of their industry. It reflects on the basic features of district heating and district cooling and on the ways the systems are expected to evolve throughout their subsequent stages of development by 2020, 2030 and beyond (DHC, 2009).
Considering the 2020 DHC sector is expected to focus on progressive technological innovation upgrading materials, equipment and processes. For example in DH renewables like (deep) geothermal and solar from large thermal plants are increasingly integrated. Even surplus wind energy can be stored as heat in district heating networks by means of electrical boilers and heat pumps. In addition steps towards modernization transferring best practices, and expansion of existing networks have to be done.
Regards 2030 vision, it is expected to shift from a classical district heating configuration using one main energy source to supply customers, to a multiple source system. Operators can feed a wide variety of sustainable heat and cold sources into the system at different places in the network, depending on availability and need, and effectively and timely match them to customer demands. In this sense district heating and cooling infrastructure acts as an intelligent energy exchange network: a smart grid.
Some cities and communities are becoming leaders in the development of innovative DHC plants. in line with the Copenhagen climate conference (2009) the Global District Energy Award 2009[8] was organised. District energy systems from all over the world were called upon to apply for the award. It aims at recognizing the achievements of cities and communities across the globe that demonstrates local district energy leadership in providing clean, sustainable energy solutions. Applications were received form 27 cities/systems.
Description of cities systems are available in Annex 2 folder.

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7 http://ww.dhcplus.eu/
8 http://www.copenhagenenergysummit.org/index.php?action=award.

Table 2: Best practice of innovative DHC systems

Location of district heating	Feeding system	District heating output	Brief description of the district heating system	Efficiency	Installed power capacity	Users number	Users typology	Website
Weißenfels (D)	/	Cogeneration	Hot water system with gas-cogeneration and gas-boilers	83%	33,2 MW (incl. 11,5 MW cogeneration)	350 buildings	private public historical buildings	www.stadtwerke-wsf.de
Vienna (A)	Biomass: Forest	Thermal energy: heating	Forest biomass power station	80%	Fuel thermal output 65,7 MW, District heating extraction max. 37 MWth, Generator output max. 24,5 MWel	48.000 households with current, 12.000 households with heating	private	www.wienenergie.at
Vienna (A)	/	Cogeneration	Gas and steam turbine	86%	/	/	private public historical buildings	www.wienenergie.at
Zürich (CH)	Geothermal	Thermal energy: heating, cooling	The water of the Zürich Lake is used as energy source for heating and cooling. In the winter the heat will be extract to heat the buildings and in summer the lake will be used for cooling the buildings	/	heating 720 kW, cooling 900 kW	120 households for cooling in the summer; 600 households for cooling	private public	www.stadt-zuerich.ch

Source: Our elaboration

3 Conclusions

Integrated energy systems involve centralised production of heat and possibly chilled water that are distributed to individual buildings through DHC networks.
DH networks can be coupled with large-scale underground storage of heat that is collected from solar thermal collectors during the summer, and used for space heating and hot water requirements during the winter.
Heat can be supplied with biomass as part of a biomass cogeneration system pr from geothermal heat sources.
If both heat and coldness are stored, then heat pumps can be used to recharge the thermal storage reservoirs, or to directly supply heat or coldness to the DHC network during times of excess wind energy. This in turn permits sizing of the wind system to meet a larger fraction of total electricity demand without having to discard.
In the long run, DHC systems with cogeneration will make it easier a possible transition to a hydrogen economy (Harvey, 2010).

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Annex1: Comparison of different heating solutions, indicating Pros and Cons[9]

	EQUIPEMENT
District Heating	+ low space requirements, the heat distribution equipment needed is very small + unlimited amount of DHW is available 24/7
Oil-fired heating	- need for a big fuel storage tank - boiler & burner - need to have a chimney

[9] Euroheat & Power (2011).

Pellets	- storage facilities for pellets necessary - need for pellet boiler with combustion chamber and pellet feeding system - need to have a chimney
Electrical heating	+ no equipment except radiators necessary for space heating - need for separate DHW tank
Gas-fired heating	- chimney - need for gas burner and boiler
Active solar heating	- solar collectors on e.g. on the roof of the building - need for heat exchanger package - heat storage tank + no need for a separate DHW tank
Heat pumps	- needs a ground heat exchanger (heat pump) as central unit - only for preheating of DHW, needs a separate DHW tank

	MAINTENANCE
District Heating	+ no maintenance necessary for the customer
Oil-fired heating	- yearly maintenance of the burner to ensure efficient use of the fuel - regular cleaning of the storage tank recommended to ensure efficiency.
Pellets	- needs regular control and maintenance + easy to handle - needs regular chimney sweeping and ash removal + regular maintenance of the burner, the boiler and the storage keeps particle emissions low
Electrical heating	+ no maintenance necessary
Gas-fired heating	- must be maintained regularly to ensure high efficiency and security - maintenance work can only be performed by accredited repair shops
Active solar heating	- requires regular supervision and maintenance
Heat pumps	+requires little maintenance as few mechanical components

	COSTS		
	Fuel costs	Maintenance costs	Investment costs
District Heating	+ no concern about fuel availability for the customer + steady pricing, public tariffs + predictable prices - local pricing differences	+ very low maintenance costs	+ moderate investment costs if the building is already using a centralized waterborne heating system as little equipment is necessary
Oil-fired heating	- uncertain fuel price development and fuel costs + long-term fuel storage possible + almost all oil heating systems can be used with gas as alternative fuel	- large maintenance costs as regular maintenance is needed	- large investment costs

Pellets	+ affordable and predictable fuel costs (not dependent of world events like oil/gas) + different storage ways (different size pellet bags or pellets blown into bigger storage room)	+ moderate maintenance costs	+ large investment costs
Electrical heating	- prices hard to predict - local pricing differences + no fuel availability concern for the customer	+ no maintenance costs	+ very low investment costs
Gas-fired heating	+ no fuel storage space needed, connected directly to the gas grid + cost efficient heating alternative + almost all oil heating systems can be used with gas	- moderate maintenance costs	- large investment costs
Active solar heating	+ no fuel costs	- moderate / large maintenance costs	- large investment costs
Heat pumps	- preheating of the DHW with heat pump will save 25-50% of warm water costs - costs for adjusting the radiators to the system when retrofitting +longer lifespan than conventional heating systems	+ small/very small maintenance costs	- drilling costs depending on location - large investment costs

	RELIABILITY		
	Reliability & efficiency	Risks	Durability
District Heating	+ very reliable	+ very low risks	lifetime for the substations: typically 20 to 30 years
Oil-fired heating	+ high efficiency + reliability high but subject to fuel availability	+ moderate risks	lifetime for the boiler: 20 years, burner: 10 years
Pellets	+ Consistent fuel size and energy content + Burns predictably - consistent heat output	+ small risks	+ estimated boiler life: 20 years
Electrical heating	+ very reliable	+ very low risks	+ very long lifetime
Gas-fired heating	+ efficiency ratio over 90% + very reliable	+ small risks (mainly related to fuel availability)	+ estimated boiler life: 20 years

Active solar heating	- efficiency and production subject to sunshine hours - cannot be relied upon as only heating system	- moderate risks as it is dependent of the weather	+ life length for the collectors: 10 to 20 years
Heat pumps	+ energy efficient + high reliability and durability	+ moderate risks	+ life length: 15 to 20 years

	ENVIRONMENTAL ISSUES	Primari Energy Factor, PEF[10] (typical)
District Heating	+ low environmental impact due to heat recycling and use of renewables	< 0.8 (European average)
Oil-fired heating	- Fossil fuel - emissions	1.3
Pellets	+ very low environmental impact + pellets are renewable fuel - particle emissions	0.1
Electrical heating	- subject to the energy source used for the electricity production - low conversion efficiency	2.5 (European average)
Gas-fired heating	+ 1/4 less CO2emissions compared to oil + no sulphur emissions, small particle emissions	1.3
Active solar heating	+small environmental impact - needs complementary heating system	0
Geothermal heat pumps	+ energy efficient and environmentally friendly compared direct electrical heating system	0.9

	OTHER
District Heating	+ district heat can be produced through many different production methods and is thus not dependent on a specific fuel + suitable for all kinds and sizes of buildings - only available for buildings in areas where a district heat network is available (urban areas)
Oil-fired heating	+ availability and use not subject to distribution networks + suitable for all kinds and sizes of buildings
Pellets	+ the pellet burner can be used with boiler for pellet use but can also be connected to most oil- and wood used boilers - suitable mostly only small buildings - pellets availability is not unlimited
Electrical heating	+ electricity is available almost everywhere - suitable mostly only small size of buildings

[10] PEF is a tool for comparing the efficiency of different heating systems to each other as it takes the whole energy chain and the energy market into account. The PEF is defined as the ratio between fossil energy input and the energy used in the building. The lower the PEF, the less fossil fuel is used.

Gas-fired heating	+ possible to use gas for cooking when connected to the gas grid + suitable for all kinds and sizes of buildings - only available for buildings in areas where a gas network is available (urban areas)
Active solar heating	- requires a complementary system + can use both circulating water or forced air as heat distribution system - suitable only small size of buildings
Geothermal heat pumps	- requires electricity to function → heat is produced to 2/3 from renewable geothermal heat and to 1/3 from electricity + can use both central heating and under floor heating as heat distribution system + using under floor heating increases the efficiency ratio of the system - suitable mostly only small size of buildings

Table 3: District heating and cooling – Statistics 2009

	Unit	Austria	China	Croatia	Czech Rep.	Denmark	Estonia	Finland	France	Germany	Greece (2007)	Iceland
TOP District Heating and Cooling Indicators												
Energy supply composition for District Heat generated												
- Recycled heat	%	68,0%		71,9%	66,0%	64,4%	38,6%	75,0%	46,0%	91,3%	99,0%	20,0%
- Direct Renewables	%	14,0%			2,0%	24,8%	14,0%	5,9%	6,0%	0,2%		79,0%
- Others	%	18,0%		28,1%	32,0%	10,8%	47,4%	19,1%	48,0%	8,5%	1,0%	0,1%
Total District Heat sales in 2009	TJ	63.549	263.188.000	9.550	93.114	99.569	24.725	116.690	86.472	284.386	1.879	25.272
Total District Heat sales in 2005 (if not available 2007)	TJ	56.644	211.035.000	10.781	95.624	99.664	27.496.80	105.411	85.716			22.820
Annual District Heat sales turnover 2009	Mio. Euro	1.014		85		2.500	303	1494	1.437			66
Annual District Heat sales turnover 2005 (if not available 2007)	Mio. Euro	723				2.300	180	991	1.270			47
Share of citizens served by District Heating	%	20%		10%	38%	61%	53%	49%	8%	14%		99%
Trench length of District Heating pipeline system 2009	km	4.201	110.490	460	7.554		1.447	12.210	3.321	19.538	658	6.950
Trench length of District Heating pipeline system 2005 (if not available 2007)	km	3.563	71.338	460	7.740		1.410	10.020	2.970	18.438		4.390
Average District Heating price	Eur/GJ	15,96		8,95	17,10	25,03	12,25	12,80	16,61	19,55		2,58
Number of District Heating utilities		730		11	449		200	ca. 150	418 (systems)	228	5	18
Total installed District Heating capacity	MWth	8.200	286.106 +93.193(t/h) steam	1.800			5.586	20.790	16.460	51.506	445	2.075
Total investment in District Heating for 2009	Mio.Euro	262					600					
Estimated employment figures in District Heating sector		2.514		1.366 (2007)	14.170	10.900	6.000	1.700			141	335
District heated floor space	m2	43.000.000	3.795 Mio.		144 Mio.		30.500.000	256 Mio.		517.8 Mio	4.611.254	13.759.000
New connections to District Heating		48.000 new dwellings					1.800 new dwellings	10.000 households				898 new households
Heat sales volume for new connections to District Heating	GJ						140.000	4.200				170.000
CO2 emissions per TJ of District Heat generated	Ton CO2/TJ	23				39		56	0,19 kg CO2/kWh			0,0003
Total heat demand 2009	TJ	305.057		124.278	148.759		29.030	261.610				27.292
Total share of CHP of national electricity production	%	18,80%		19,50%	13%	55%	9,20%	35,60%	3,10%	12,50%	1,90%	24,50%
CHP heat autoproduction	TJ			14.850			23.709	144.300			4.226 TJ	
Average energy use of buildings per m2	Wh/m2							133		171		
District Cooling												
District Cooling capacity 2009	MWth	28						117	630	176		
District Cooling capacity 2005 (if not available 2007)	MWth	15						41	423			
District Cooling sales 2009	MWh	24.500						79.050	925.000	187.556 (work)		
District Cooling sales 2005 (if not available 2007)	MWh	6.751						25.990	661.000			
Trench length of District Cooling pipeline system 2009	km	6						58	131	56		
Trench length of District Cooling pipeline system 2005 (if not available 2007)	km							23	90			

	Italy	Japan	Korea	Latvia	Lithuania	Netherlands	Norway	Poland	Romania	Russia	Slovakia	Slovenia	Sweden	Switzerland	United Kingdom	USA
TOP District Heating and Cooling Indicators																
Energy supply composition for District Heat generated																
- Recycled heat				55,0%	57,5%		50,7%	63,7%	91,6%	43,9%	38,0%	86,0%	67,0%	56,1%		
- Direct Renewables				14,3%	13,9%		25,5%	1,4%	0,3%		4,0%	1,0%	24,0%	22,6%		
- Others				31,0%	28,7%		23,8%	34,9%	8,1%	56,1%	58,0%	13,0%	9,0%	21,3%		
Total District Heat sales in 2009	227 Mm3	22.997	201.389	22.042	27.900	26.708	13.300	239.000	50.600	6.891.293	57.600	7.742	181.612.000	16.600		365.818
Total District Heat sales in 2005 (if not available 2007)	156 Mm3	25.072	195.109	25.020	28.742	20.744	8.580	295.000	61.105			8.268	174.274.400	16.010		
Annual District Heat sales turnover 2009			2.444	306	491		277	2.486	710		1.115	96	3.006			5.037
Annual District Heat sales turnover 2005 (if not available 2007)			1.557	319	262		142	2.150	648			90	2.426			
Share of citizens served by District Heating	4%		12%	64%	60%		1%	50%	23%		41%	17%	42%			<1%
Trench length of District Heating pipeline system 2009	2.404	736	2.268	1.000	2,535		1.100	19.286	7000	173.100	3.471	705	21.100	1.090		3.206
Trench length of District Heating pipeline system 2005 (if not available 2007)	1.667	710	1.849	1.000	2.507		780	18.577	8.148			623	16.000	920		
Average District Heating price			12,14	13,89	17,60		20,80	10,40	14,04	4,48 for residential sector	18,08 for households/ 20,2 for others	12,44	16,56			8,64
Number of District Heating utilities	55	86	67	40	30		70	499	91		365	58	439 (systems)	41		132
Total installed District Heating capacity	2.204 only in CHP	4.250	12.956	7.308	9.621	5.552	2.305	59.790	53.200	541.028 (2007)	27.896	2.242	15.000	2.150		87.734
Total investment in District Heating for 2009					32			500	25				850			
Estimated employment figures in District Heating sector		2.295		2.500	4.700		1.100	40.565	36.450		7.871		5.000			32.000
District heated floor space		48.886.000	1.207.076.000	38.160.000	35.300.000			472.000.000	63.200.000		146.684.000	8.288.700	678.000.000		63.000.000	388.687.924
New connections to District Heating			188.000 households					64.000 households								
Heat sales volume for new connections to District Heating	1.717.000			270	530.000		1.440.000	2.100.000				23.500				
CO2 emissions per TJ of District Heat generated	61,4		58,02 (heat and el)	53	50			103 Mg/TJ	83,3							82,89
Total heat demand 2009			265.330				234.000	606.000			62.760 (residential only)		305.638			
Total share of CHP of national electricity production	9,50%		5,10%	33,60%	12,70%	33,60%	0,10%	16,30%	9,60%		2,40%	6,70%	4,00%	1,10%	6,40%	
CHP heat autoproduction												4.130				
Average energy use of buildings per m2	200		904 kJ/m2					90-110					117			4.830 BTU/m2
District Cooling																
District Cooling capacity 2009	153,4	3.916	1.123				90					1	650			14.063
District Cooling capacity 2005 (if not available 2007)							75									
District Cooling sales 2009		3,864,167					108.054	46				0,026	828.700			22.417.315
District Cooling sales 2005 (if not available 2007)							80.810						662.000			
Trench length of District Cooling pipeline system 2009			20				58	20					326			587
Trench length of District Cooling pipeline system 2005 (if not available 2007)							48						182			

Source: Euroheat & Power, http://www.euroheat.org/Statistics-69.aspx