Strategies for decreasing peak loads and energy use

This page describes the main techniques adopted for decreasing peak loads and manage the demand side of a district heating or cooling system.

Introduction

District heating (DH) is a consolidated technology, which has reached a consistent diffusion in Europe, mainly in the Northern and Eastern areas; on the other hand, **district cooling** (DC) is a relatively new concept, whose development mainly depends on the features of the district. The recent trends regarding heat production in DH networks is an **increasing exploitation of waste heat sources and renewables**. This means that in most cases, the temporal production profile of these sources is more rigid than the use of conventional fuels: more or less constant in case of industrial waste heat or completely different from typical demand profiles for most renewable sources.

On the other hand, the tendency on the heat distribution side is to increase the heat storage capacity, both in the short term and in the long term, up to the seasonal level. The evolution of district heating from the demand side has been a little slower; the main tendency is related to the **improvement of metering systems**, with a gradual shift from old-style heating bills based on the size of the heated surfaces to billing systems based on the amount of provided heat. In addition to metering, the main techniques for demand side management regarding heat demand peaks are:

- demand-side **heat storage systems**, such as hot water storages at buildings or groups of buildings level;
- **use of heat capacity of buildings** or other heated users (i.e. swimming pools) for shifting, broadening and flattening demand peaks;
- active involvement of users through **economic incentives**, providing heat at different prices in different moments, depending on the waste heat availability compared to the demand;
- **increase of users' awareness** towards energy efficiency;
- **connection of new consumers** with different heat demand profiles that balance other loads.

The possibility and convenience of implementing all or part of these strategies on existing or new DH/DC systems is mainly dependent on climate, size of the network and used heat sources. In general, **daily heat demand** is more constant in colder climates and larger grids, whereas warm climates, smaller networks and district cooling systems show sharper variations, and thus a larger need for thermal storage or peak capacity.

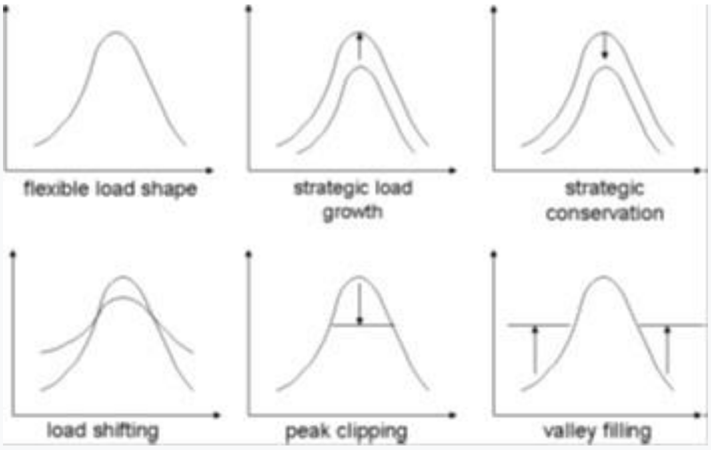
The reduction of **annual variations** is quite complicated: for district heating, it could be obtained through a better insulation of buildings, allowing the relative reduction of space heating demand with respect to hot water production, and by the implementation of absorption cooling in the summer. In district cooling, a flattening of the yearly curve can be achieved through a better screening of sunlight or by using different chill sources (adsorption cooling, cooling by river or underground water in cold climates).

In any case, seasonal heat storage is probably the best way to allow a sharp reduction in the annual demand peaks from other sources, although its implementation through the already available technologies (geological storage) is strongly limited by the geological conditions of sites and by the possibility of finding a fruitful balancing among cooling and heating needs along the year. Most of DH/DC systems adopt the following **prioritization scheme** as regards heat production:

- first priority is given to the cheapest and, usually, best environmentally performing heat sources (e.g.: industrial waste heat, CHP), typically providing heat constantly along the year and the day, but whose heat production patterns are normally not synchronized with those of heat demand;

- when additional heat is required, better tunable and programmable plants are used (e.g.: solid biomass boilers, heat pumps), which have high installation but low operating costs due to the large number of hours per year and the low cost of fuel (for biomass) or the high efficiency (for heat pumps);
- the residual production, following peak demand, is commonly provided by gas or oil fired peak boilers, whose use is normally limited as much as possible.

The development of **thermal energy storage** systems was born as a cost-optimization strategy that allowed to maximize the exploitation of low-cost heat sources and minimize the use of dedicated peak boilers. However, these systems are useful also in a demand management perspective. The main actions that could be implemented in a DH/DC system as regards demand management are grouped under the name of **load shaping** and are schematized in the following figure: strategic load growth or conservation, load shifting, peak clipping, valley filling.



Load Shaping Techniques

Thermal energy storage (TES) can be applied as a mechanism for peak shaving or load shifting and integrated with the electricity network. For example, TES in combination with electrical devices such as electric resistances, heat pumps, air conditioning systems or chillers can cover heat/cooling demands in off-peak hours (when prices are lower, typically during the night) and store thermal energy to use it later during on-peak hours (typically during the day), in order to flatten end-users electrical load profile.

Demand Management Techniques

The features of the most important demand management techniques are presented in the following table and described in the paragraphs of this section.

Strategy	Description	Thermal Peak Shaving	Thermal Energy Saving Potential	Electric Peak Shaving	Electric energy saving potential	Celsius Demo	Applicability	Cost Effectiveness
Demand side heat storage in the buildings' thermal mass	This technique exploits the thermal capacity of massive buildings to deliver heat to	Very high	High (high time constant mean	High if heat is produced throug	Fair in case of electric resistance, high in case of heat pump	GO1 (theoretically possible within	High on new buildings specifically designed, fair on existing buildings	Very high

	the building in moments when the overall heat demand is low. This strategy is best effective (with minimal negative effect for the internal comfort) when implemented on buildings with high thermal mass enclosed in a thick external thermal coating (in order to achieve very high time constants), and with radiant emission systems having a large exchange surface between the space heating thermal vector (heating water circuit) and the building's mass.		s high capacity and high insulation)	h electric systems		London demos), CO1	with radiant heating	
Demand side heat storage though heat tanks	This technique consists in storing heat at the user's side through any heat storage system. Technologically, such a storage system is very often an insulated water vessel. This technique allows receiving heat at a constant rate using it discontinuously. Thus, peaks are shaved at the demand side, allowing a smoother heat production and flow rate on the DH main	Very high	Low (indirectly savings are obtained by the smoother demand)	High if heat is produced through electric systems	Fair in case of electric resistance, high in case of heat pump and DHW electric production	RO1 (the heat hub is a large heat storage at the side of the demand), CO1 (at building scale)	High potential for displacing peak boilers in the user areas	Low to very high (high effectiveness for RO1 replicas and for DHW electric heaters)

	lines. If heat is provided by electric heat pumps or electric heaters, this can enable electric peak shaving and shifting. In general this allows being able to supply a thermal power higher than the maximum output of the thermal generator.							
Supply side heat storage through heat tanks	This technique consists in storing heat at the production side through any heat storage system. Technologically, such storage system is very often an insulated water vessel. This technique allows to receive heat at a constant rate using it discontinuously. Thus peaks are shaved at the demand side, allowing a smoother heat production and flow rate on the DH main lines. Heat storage is particularly important in small DH systems. Within a network like the Goteborg one, with 1200 km extension, such capacity is already	Very high	Low (indirectly savings are obtained by the smoother demand)	High if heat/cold is produced through heat pumps	Theoretically high, still not applied	LO2	High where needed (small and medium DH/ DC systems)	High

	provided by the water volume stored in the network piping itself.							
Smart heat pricing	As for electricity grids, also in DH it is possible to think to a different pricing as a function of real heat cost and availability. The consequence of this should be a shift in heat demand from peak hours, featuring higher pricing, to lower demand hours, thanks to behaviour change in users or demand-side storage development. Such a strategy can be effective in shaving daily peaks related to social causes, but not at yearly level. It is effective, therefore, in situations with high demand variations, with a real, large, measurable cost for daily peaks. This is not the case of Gothenburg, where daily peaks are largely shaved by the size of the network, but it is something important in situations with small DH syste ms, with small piping capacity	Med ium	Medi um (prici ng alwa ys prom otes savin g)	No	No	GO29e partiall y promot es saving throug h pricing	Tariff has to be consumption dependent and heat meters must be equipped with clock	High

	and large statistical variations.							
Sale of thermal comfort, not of energy	The sale of internal comfort, rather than of kilowatthours of heat, is the base concept of climate agreements in Gothenburg. This type of contract allows a company to invest in the improvement of the thermal plant and of the building envelope of the customer rather than in selling heat, when these improvements are economically/environmentally more convenient than selling extra heat (or peak heat).	Medium	Very high	No	No	GO29e	Nearly everywhere	High
Promotion of energy efficiency in buildings renovation	Promotion of buildings insulation is a primary policy for reducing energy demand in the EU. In particular, external insulation coating of buildings allows not only the reduction of energy demand but also a large increase of thermal capacity of the building. This implies a larger thermal inertia, useful for shaving demand due to	Very high	Very high	High if heat is produced through electric systems	Fair in case of electric resistance, high in case of heat pump and DHW electric production	GO1, GO29e	Applicable everywhere on new buildings and in renovation of the existing ones	Medium

	external temperature changes but also – as in case of GO1 to partly compensate fluctuations in energy demand of other buildings connected to the network.							
Promoting DH/DC development	The increase of the number of users, as well as the types of services, of DH allows the reduction of statistical fluctuations in energy demand, and the broadening of daily use patterns. This causes a broadening of peaks and, in general, a relative reduction between minimum and maximum demand.	High	Medium	No	No	GOe	Gothenburg is already covering large part of the city. High potential in London and Rotterdam	Low (DH development is always expensive)
Promotion of absorption systems for cooling	In case of large availability of waste heat and in presence of networks operating all year long at high temperature (above 90 °C at least) adsorption cooling is a cost-effective, environmentally friendly technology for producing chill. Considering that summer time peak electric	Low	High	High	High	GO14e	A high temperature network operating also in summer is needed	Low (adsorption cooling is also expensive)

	demand is largely driven, in southern Europe especially, by cooling, the advantage in the development of these systems is also in terms of shaving electric energy demand peaks.							
Development of seasonal storage	There are several possibilities being investigated for achieving seasonal storage. The only available possibilities on large scale are however limited to geological heat storage, where heat is stored by large masses of underground water or by geological layers. This technique finds its best conditions where it is possible to play with large amounts of energy with a good balance between heat demand and cold demand, with an average temperature between the two similar to the yearly temperatures. In many cases, thermal losses by conduction towards other geological	High	High (especially when fed by waste heat)	High	Medium	No	Proper geological conditions are needed	Medium (in some conditions this technique can be particularly convenient)

	layers and towards the surface may be a problem in terms of convenience of storage but also an environmental problem.							

Supply or Demand Side Heat Storage

The most widespread solution for heat storage is **inertial storage**, mainly based on large hot water tanks, which are present in several DH systems. This solution is mainly applied at the **supply side** to shave daily peaks, thus maximizing the exploitation of heat produced from cheaper sources. In addition to large dedicated tanks, also the DH network pipes are a kind of heat storage, since the heat accumulated in the volume of water occupying the pipes has a thermal capacity and have an influence on the timing of heat distribution in the whole system. Heat storage systems can be also implemented at the **demand side**, either by installing hot water tanks or by using the thermal capacity of the building itself. This technology specifically aims at load shifting and, if applied at large scales, can reduce or completely eliminate daily load variations, thus being one of the most promising solutions for demand side management. Regarding users' characteristics, demand peaks can be flattened by exploiting the difference in heat demand among different types of users. For example, residential users show peak demand around 7:00, office buildings around 8:00, swimming pools' heat demand can be easily shifted one or two hours before opening, etc. A more detailed description can be found in Thermal energy storage.

Seasonal Heat Storage

For long-term storage, a possibility which is being considered and implemented in several systems is **geological heat storage**. With this technology, large amounts of heat are stored for the whole season within underground aquifers or other geological layers, through indirect heat exchangers or, where possible, by directly injecting/recovering water. This technology is especially suitable for DH systems fed by large solar thermal systems collecting most of the energy during the summer, or waste heat from industrial processes producing it in excess to the demand of the DH system. This solution foresees the storage of heat in media that are necessarily not insulated with respect to the surrounding ground, so that the convenience of this system (aside many possible problems related to heating large geological volumes, i.e. to natural underground water circulation, rocks fracturing and thermal expansion problems) increases with its size, since storage volume grows cubically and thermal exchange surface increases squarely with linear dimensions. Similarly to "Supply-Demand side heat storage", a more detailed description can be found in Thermal energy storage.

Economic Instruments

Policies aimed at reducing energy demand of users of a district heating system are similar to those aimed at promoting, in general, energy efficiency in buildings. In both cases, the techniques to deal with on demand side management rely on the same instruments, which are **metering** and **billing**. In the past, heat provided by the DH network was usually not measured at the served buildings and billing was fixed, sharing the service cost not on the real measured energy but on buildings' size, sometimes corrected by some considerations on buildings' characteristics and/or use. In this situation, no incentive to save energy for users is possible. The measurement at user level gives evidence on consumptions, which are therefore directly linked to bills: this implies a **direct interest of users in saving energy**.

Metering consumptions at user level is much more efficient than metering at building level: indeed, in the latter case, the savings due to the actions of one user (e.g.: the replacement of old windows with high performance ones) are shared with the other users. It is estimated that large building blocks can achieve savings of 20-25% thanks to the installation of individual metering systems in temperate climates; in colder climates their effectiveness is lower. However, since the heat distribution network internal to buildings does not belong to the DH managing authority, such an intervention can be planned only by the buildings' owners, which frequently results in not realizing any intervention. A possible solution may be the engagement of an ESCO, which can be linked to the DH company, in the implementation of this intervention. Metering and billing at building level and at unit level have a large impact on the overall energy demand within the DH systems, but also on **peaks**.

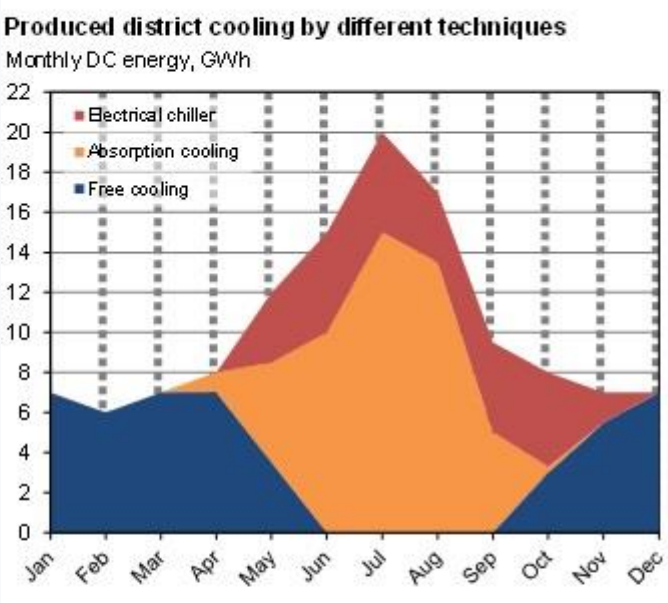
A common habit is to reduce or switch off space heating during the nights. In homes equipped with programmable thermostat, this is commonly achieved by setting two different internal temperatures, i.e. 18 and 21°C, respectively during the night and during the day. This means that, at user level, heating demand has a peak in the morning, when set-point temperature passes from 18 to 21 °C. At district level, this is translated in a peak in the first hours of the morning – which at district level is broadened and lowered, respect to the baseload, due to the different needs of the various DH users - implying the need for the DH manager to switch on peak boilers, especially when outdoor temperatures are low. Thus, night setback is unfavourable in most DH systems, and also questionable in modern, energy-efficient buildings since the indoor temperature will not drop quick enough to achieve a reduction in the average indoor temperature (which is needed to achieve energy savings).

A possibility that is being implemented in some places is to introduce **dynamic pricing**, asking for higher tariffs during peak hours and offering lower tariffs during night and lower heat demand hours. In this way, some effort from users can be further obtained: some of them will anticipate heat demand compared to the typical morning peak, thus achieving the overall result of flattening and broadening the peak. The main obstacle for the implementation of this technique is often the need for replacing heat metering devices with systems registering data hourly.

Another economic opportunity for demand management is the **sale of internal comfort instead of energy**. This is a more evolved service and is a business model that promotes the reduction of buildings' heat demand. This has no direct effect on peaks but allows to move the incentive to make buildings more energy efficient from the building owner to the energy company. For this reason, the energy company could choose to implement measures that are also beneficial in terms of peak balancing, for example control systems that include peaks forecasting in physical (weather) or social (occupancy in homes/offices, etc.) heat loads. More information about service and climate agreements can be found both here in the Technical Toolbox and in the Socio-Economic Toolbox.

Promotion of Absorption Systems for Cooling

Absorption heat pumps can generate cooling water from heat and are therefore an interesting option for district heating companies who have access to waste heat, especially during the summer. An efficient strategy for district cooling is that implemented in Göteborg for chilled water production: **free cooling** is primarily exploited (i.e.: cold water from the river Göta Älv and outdoor air), then **absorption heat pumps** are used as a second option and **electrical chillers** are switched on only when none of the other techniques are sufficient to cover the load. The results of such a strategy are shown in the following figure.



Cooling Sources in Gothenburg

Two options are available for the implementation of absorption systems: **centralized chillers** and local cooling sites. In the former solution, large absorption chillers are installed in the central production station and are fed with hot water coming from industrial waste heat recovery and/or CHP; chilled water at about 6°C is then distributed to users through a closed system of pipes and comes back to the chiller at approximately 11°C. On the other hand, the latter solution foresees the exploitation of the existing district heating network: hot water is fed to the buildings and supplied to **local absorption heat pumps** that use it to produce chilled water. The main benefit of the use of local absorption heat pumps is to allow the cooling of the buildings where the district cooling network is not available.

In the context of **balancing peaks in the heat demands**, the use of absorption chillers decreases the seasonal variations in the district heating network, by increasing the heat demand mainly during summer. It may also affect daily variations since they "transfer" cold demand variations to the district heating network. The use of absorption heat pumps is most beneficial in systems where waste heat is available during the period when cooling is demanded; however, with currently available absorption chillers, high temperatures are necessary, which may increase the losses in the distribution system and reduce electricity production, depending on the conditions in the system. Since absorption chillers are not primarily powered by electricity, their use gives the maximum economic benefits where electricity prices are high. In addition, their use is most beneficial in systems where a significant fraction of heat is provided by industrial heat recovery systems, waste incineration or cogeneration plants that produce large amounts of heat also during the summer period. More information about heat driven cooling is found in the Roadmap and in Absorption cooling technology.

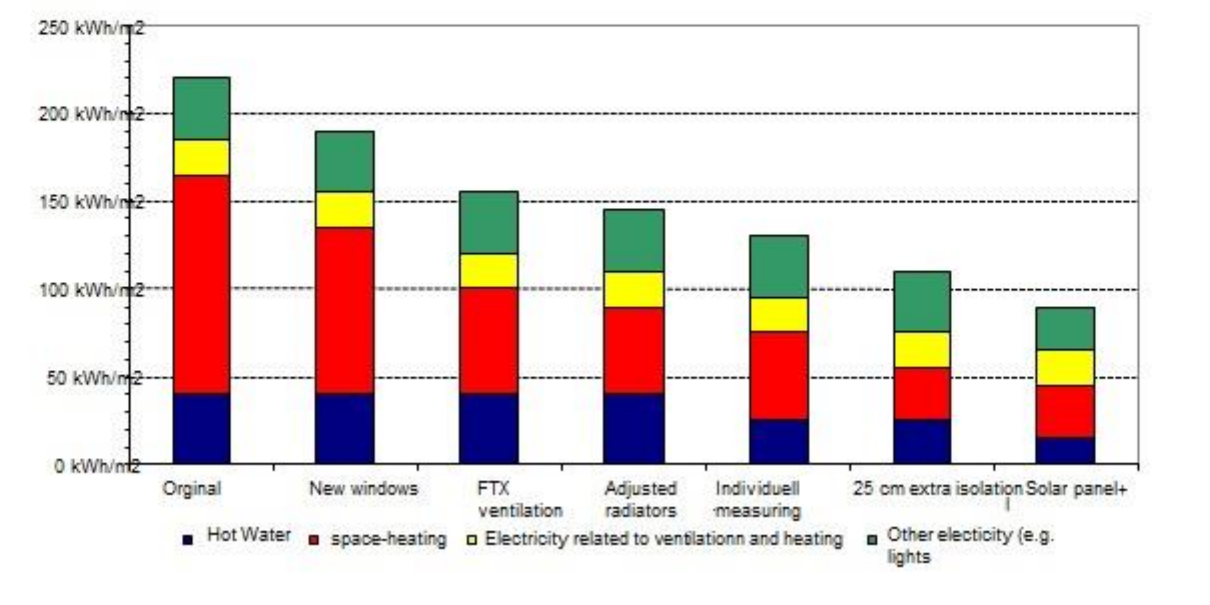
Promotion of Energy Efficiency in Buildings Renovation

It is evident that **buildings refurbishment** has a direct impact on their heat consumption. However, under a DH/DC management perspective, it is important to be able to quantify the overall impact of energy efficiency interventions, which mainly corresponds to quantifying the rate of refurbishment of the building stock. A possible way to perform this analysis would be the use of agent-based models in order to survey the emerging behavior, i.e. the collective impact of individual houses refurbishment on the overall heat load. In order to address these energy efficiency shortcomings, Swedish municipalities like Gothenburg have engaged in a holistic approach for energy reduction which in 2008 was outlined by the Swedish ventilation association (Svenk Ventilation):

1. the first measure towards improved energy efficiency naturally consists of achieving a better insulation of the building envelope;

2. the second step consists of bringing improvements to the ventilation system as energy reductions must never happen at the expense the comfort of the occupants;
3. once these measures concerning the building envelope and the ventilation system have been implemented, it is necessary to adapt the heat supply system (radiator loops) to the new heating requirements needed in every room;
4. afterwards, it is also beneficial to investigate energy savings that can be derived from the enhancement of the hot water systems;
5. eventually, some additional measures such as individual metering and the implementation of solar thermal panels can be implemented.

The reduction of energy needs achieved in Gothenburg through the implementation of energy retrofitting measures on existing buildings is shown in the following figure.



Results of Buildings Retrofitting in Gothenburg

Other measures for improved energy efficiency are handled in End User Side Optimisation.

Promoting DH/DC Development

A promotion of district heating and district cooling aimed at **increasing the number of users**, possibly characterized by different consumption patterns, shall result in a reduction of the statistical fluctuations in energy demand. This leads to the broadening of the daily loads and, more in general, to a relative reduction of the difference between minimum and maximum demand, which allows a more constant use of heat/chill generation systems. Even higher benefits can be achieved whether the new users are characterized by a completely different load pattern compared to residential and tertiary users. For example, the connection of ships to the DH network when at quay, being implemented in a Celsius demonstratorin Gothenburg, is beneficial under this perspective because the specific ferries use to stay at quay during the night.

CELSIUS contacts

CELSIUS partners contributing to this article: D'Appolonia

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