HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #3

ENERGY EFFICIENT BUILDING SERVICE ENGINEERING

Co-funded by the Erasmus+ Programme of the European Union

1 DISTRICT HEATING SYSTEMS AND WASTE HEAT RECOVERY

1.1 BASIC IDEA OF DISTRICT HEATING

District heating is a modern public service used to meet the heat needs of residential, institutional and industrial consumers. The district heating system supplies thermal energy to larger groups of buildings and districts through equipment connected to a central heat producer. Thus, the heat energy required for the heating of buildings and the supply of domestic hot water is covered by the central heat production plant of the district heating system, and the required heating capacity is delivered to the consumers through the district heating network. [1]

District heating is a weather-dependent heat providing service. In industrial district heating, the withdrawal of heat depends on the industrial production process. The heating of public buildings, public institutions and industrial buildings is connected to the district heating network through substations. [1]

District heating has the following advantages of economy, comfort and convenience.

1. It unites several individual combustion plants, the centralized heat generation is under constant, professional supervision and the heat production is controlled in a more careful operation.
2. Fuel consumption is reduced compared to individual use.
3. Flue gases from central combustion are less harmful to the environment, due to professional, large scale filtering.
4. The maintenance required per building is low or minimal.
5. Space savings in buildings can be achieved. The risk of fire is eliminated in the supplied buildings.
6. There is a favourable possibility of interconnection in the production plants (cogeneration of heat and electricity) in the structure of the consumer area and between the different production plants.
7. A favourable service schedule can be developed.
8. The total capacity to be installed can be reduced (application of heat storage, heat storage capacity of a large network water volume, use of building structures as heat storage, as a result of design solutions consciously resulting from the effect of reducing concurrency).

The temperature of the heat transfer medium used for district heating is usually set in parallel with that of the ambient, based on the meteorological forecast and outdoor temperature measurement. Thus, primary temperature is pre-regulated in the heat production plant, then each consumer has its individual local post-regulation.

Regardless of the legal relationship and ownership, facilities delivering heat to a district heating network are considered to be district heat producers. District heating producers are companies, plants, works that manage, control or operate such facilities, regardless of whether this heat service is provided as a main or ancillary activity or whether this activity is included in the name or description of the company. A district heating plant is a closed thermal energy system consisting of one or more heat generating plants, a heat supply network and heat consumers, in which the effect of each plant is extended to both other members and the whole system.

District heating systems significantly improve the air quality of cities through proper installation of the heat producing plants. During the choice of location for a heating plant meteorological conditions (e.g. wind regime) are taken into account too. This way the plant will emit flue gases at high altitudes and therefore the harmful gases will be well diluted until they reach populated areas. In densely populated areas, even modern gas-fired individual and central heating systems increase air pollution because their emission strategy is not in accordance with meteorological conditions, and the flue gases settle in populated districts contributing to air pollution. [2]

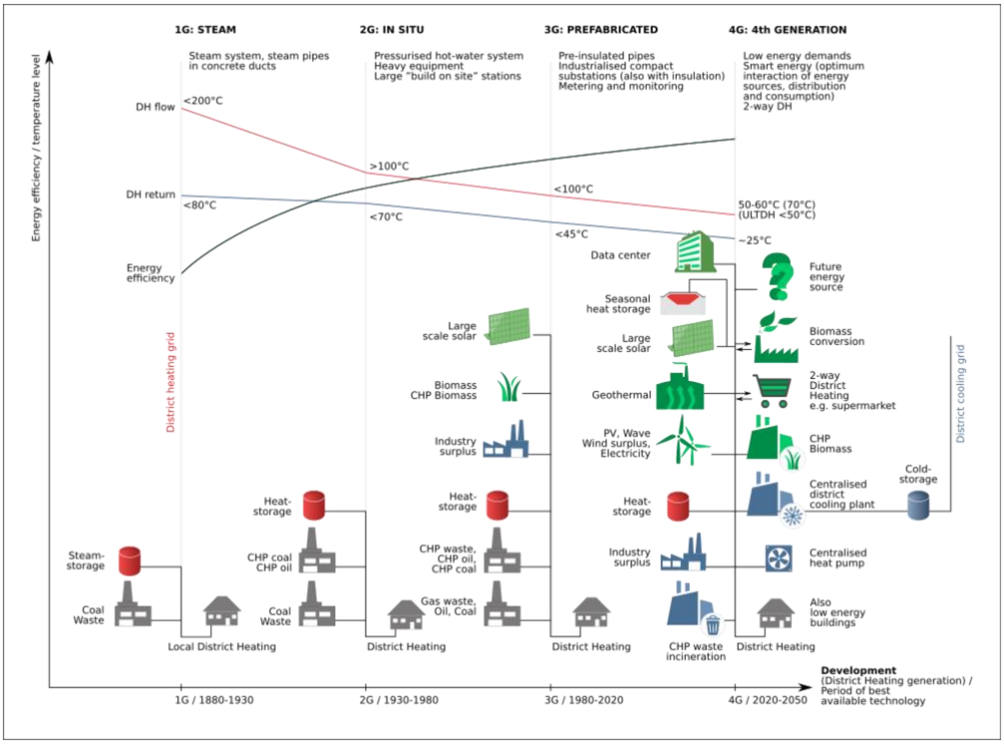

Figure 1: The development of district heating over generations [4]

Waste-to-Energy Applications

The consumer society urges citizens to consume more, while this leads to the accumulation of waste which damages the environment. At the same time, the negative impact of waste on the environment can be significantly reduced, once it is treated properly. One of the most efficient treatment methods is waste incineration in waste-to-energy applications.
Waste is a material or object, which its owner aims to get rid of or has to get rid of. The treatment, disposal or utilisation of waste is a task of high complexity, as waste of different origins cannot be treated uniformly. The five levels of waste treatment hierarchy presents the suitable technologies for the treatment of various origins of waste. [5]

The most important item of the hierarchy is *prevention* of waste production. Every individual has to minimise their waste production. The aim is to buy products with minimal package materials or to reuse these as many times as possible.
The second level is the *reuse* of products in order to lengthen their active period. Repair and cleaning can make several objects usable, or others can use them. This delays the purchase of unnecessary new products and the production of waste happens also later, in smaller extent.
The third level of the hierarchy is *recycling*, when the material of products is being used as a raw material to create new ones. One has to be aware of the fact that for several materials the recycling process is actually downcycling, so the secondary product will be of lower quality and the material degrades during the recycling process.
Waste which cannot be recycled based on its material or contamination, will be burnt in a *waste incineration* plant. The energy which comes to be during the incineration process (*waste to energy*), will be utilised in district heating and electricity systems.
The least favourable way to treat waste is disposal, which represents the fifth level of the hierarchy. In compliance with environmental regulations, waste is disposed at a site dedicated for this use. Care should be taken to dispose only that part of the communal waste, which cannot be utilised in any of the previously mentioned ways. During the controlled disposal of waste, landfill gas which comes to be at the site can be utilised for electricity production. [5]

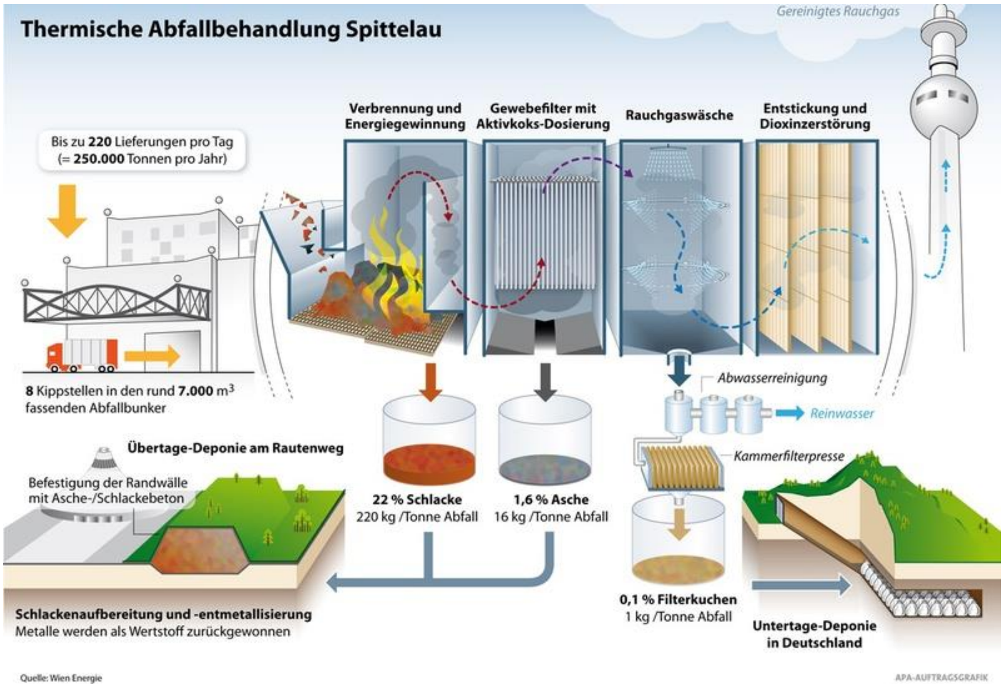

Figure 2: Waste incineration process in the Spittelau plant in Vienna, Austria [8]

In 3rd generation district heating systems the heat transfer medium is warm water with a temperature below 100 °C. The decreasing temperatures in the distribution network are leading to lower losses and increasing system efficiency. Several components including pipelines and substations are prefabricated. Pre-insulated pipelines are laid directly into the ground without concrete gutter. This technology is used in the renovation of old systems in the former Soviet Union and Eastern Europe. In some cases, the use of renewable heat generators (solar collectors, geothermal energy).

Factors influencing a heat loss in a pre-insulated district heating pipe laid directly in the ground:

- thickness of thermal insulation,
- thermal conductivity of the soil,
- installation depth,
- the diameter of the wire, and
- thermal conductivity of thermal insulation.

The thermal conductivity of thermal insulation is less degraded by the harmful effects of the environment than in the case of transmission lines conducted in a protective duct, as moisture is practically unable to penetrate into thermal insulation. [9]

The 3rd generation is a step forward in terms of substation construction too with prefabricated, compact, modular substations. Plate heat exchangers are used instead of tube bundles resulting in significantly less space required.

Development direction of district heating generations:

- Lower heat transfer temperature
- Prefabrication reduces labour requirements during installation.
- Better quality, more flexible use of materials.
- Reducing losses, increasing efficiency.

The 4th generation of district heating incorporates the first and foremost objective of the technology: creating an energy community with waste heat reuse. In an energy community (city, town or medium sized settlement) certain buildings have cooling needs during the heating season due to their activities. The construction of a low temperature primary network is the main task of the transition into the 4th generation. As the waste heat of various entities is usually available on a lower temperature level, it is possible to utilise it only with a low temperature network. The lower distribution temperatures significantly increase efficiency, as the losses remain lower. The energy demand of buildings is constantly decreasing, because of the strict regulations on thermal shell development. This is why in the future buildings can also be operated with low temperature heating systems.

Densely populated settlements have advantages, in terms of district heating and waste heat utilisation, as distribution pipelines are shorter and the losses remain lower.

The ReUseHeat project [10] focuses on targets to develop district heating systems with an increased share of waste heat utilisation. Some projects examined and realised in the project are the following:

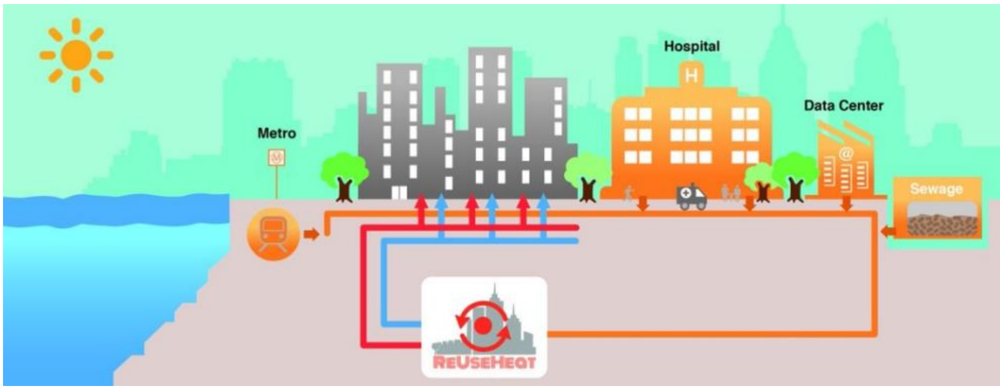

Figure 3: Waste heat utilisation in an energy community, based on the idea of the ReUseHeat project [10]

Data Centres [10]

The electricity consumption of data centres in 2010 was 350 TWh worldwide. This is more than 1% of the world's total electricity consumption in 2010. Cooling is required for safe operation of the installed IT equipment. The electricity consumption of data centres in Europe was 56 TWh/a in 2007, but by 2020 104 TWh / a was expected due to growing trends of streaming and IoT. Cooling is 40% of the total energy consumption of a data centre.

Data centre performance:

- 5 MW IT capacity (some in Europe)
- 500 kW - 5 MW (many)
- Under 500 kW (majority)

A medium-sized data centre has 1 MW IT capacity with a heat emission of 3700 MWh/a. The waste heat which could be utilised would be 0.46 MWh_{th} after 1 MWh_{el} of electricity consumption.

Underground Tunnels

Underground lines are present worldwide in 148 cities with 11,000 km line length, used by 151 million passengers day. In the European Union there are 2800 km underground lines in 50 medium and large cities, carrying 31 million passengers/day. Underground lines represent a heat source, because of the thermal dissipation of the energy of movement when braking and due to the ventilation of subway cars. The approximate amount of waste heat is 6.7-11.2 TWh/a, which comes to be in densely populated areas, in which the average distance between two stations is 1 km.

Sewage Pipe Network

Every town and city has an extended sewage network, which can be considered as a low-temperature heat source due to its annual average temperature of 10-15 °C. With the combined application of low temperature district heating systems and heat pump technology this heat can be utilised as a reliably balanced heat source for the heat pumps. In Nice, France and Cologne, Germany projects have already been completed utilising sewage networks as heat sources.

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Co-funded by the
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