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D2.7

EeB technologies for synergy between building and neighbourhood energy systems

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D2.7

EeB technologies for synergy between building and neighbourhood energy systems: analysis of energy optimisation possibilities at inter-building level

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Colophon

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Publishable executive summary

This report is the outcome of an analysis of energy optimization possibilities at inter-building level by considering the interaction of buildings within a healthcare district and in relation with the surrounding neighbourhoods.

Energy is vital for the operational core-business of hospitals: delivering healthcare. Besides, in the long run, focusing on *sustainable* energy is a form of healthcare as well.

After the first step of energy reducing on each individual building, the next step in a logical approach for sustainability energy is energy exchange on the inter-building level. From the point of view of energy efficiency, a healthcare campus, with many different building typologies and typically high-energy consumers, is perfect suitable for neighbourhood energy systems.

To optimise the design process of energy exchange systems at inter-building level, interconnectivity between BIM and GIS system is necessary. This because a BIM model can help to get an accurate energy and power demand profile of a building.

A GIS system is necessary to provide with an accurate source profile, for example to locate a Power Plant. However, not only the location, but even the capacity and energy profile and the distance to the campus, including determinate complexity factors like rivers and railway. In addition, even for demand mapping of all buildings on the healthcare campus or in a district area a GIS system is required.

It takes a few steps to identify the synergy between building and neighbourhood energy systems.

The first step in this task is to analyse the possibilities of energy optimization at inter-building level. It is therefore required to analyse and determine the energy profiles of hospital buildings and a complete hospital district. This first analysis will give a better understanding of the energy flows and temperature levels within the hospital building. This knowledge is required to filter and select the appropriate NES technologies to achieve synergy with the neighbourhood.

The second step is the categorizing and description of the Neighbourhood Energy Systems technologies in factsheets as library.

Neighbourhood Energy Systems are subdivided into the following categories.

1. Energy carrier
2. Energy generation and production
3. Energy distribution
4. Energy exchange
5. Energy storage
6. Other technologies

The factsheet of the Neighbourhood Energy Systems will contain a description of the technology, the characteristic parameters, the benefits and drawbacks and an indication when and where to apply the technology.

In the third step, the first and second step will be combined to indicate in which situation which NES technology can be applied.

Hereby a matching of power and energy both demand and source supplemented with a configurator could support a decision maker.
We have therefore developed a logical selection process to exclude or include technologies by ranking on different KPI's. For example to consider geothermal, the suitability of the ground is a conditional criteria. Furthermore, a certain scale level of energy demand fits to the optimal size of the geothermal source.

The workflow for the decision making process is as follows.

1. Is to identify the local energy source which is considered for a specific location. For example availability of biomass or underground conditions.
2. Is to identify the supply potential of the supply matches required demand of power and energy and technical connection conditions.
3. Is to estimate the net fossil fuel consumption and CO_2 emission.
4. Is to check legal conditions and technical requirements of the connection.
5. Is to suggest if a storage system is needed.
6. Is to suggest if a smart grid is needed or advised.

In this way, the decision maker in a design process is provided with relevant information about suitability of the state of the art technologies. Doing this to achieve net zero energy buildings as foreseen by EPBD 2010, through the optimisation of building and neighbourhood interactions.

List of acronyms and abbreviations

- ATES : Aquifer Thermal Energy Storage systems
- BTES : Borehole Thermal Energy Storage systems
- BIM : Building Information Modelling
- CHP : Cogeneration or combined Heat and Power
- GIS : Geographic Information System
- GJ : Giga Joules
- HVAC : Heating, Ventilation and Air Conditioning
- IFC : Industry Foundation Classes
- KPI : Key Performance Indicator
- LOD : Level Of Detail
- NES : Neighbourhood Energy System
- REAP : Rotterdam Energy Approach and Planning
- SOTA : State of the Art Technology
- TWh : Terawatt Hour(s)
- UPS : Uninterruptible Power Supply

Definitions

Building heating system - heating system provides heat for one building.

District heating - a system for distributing heat, generated in a centralized location for several residential and/or commercial heating requirements such as space heating and water heating.

Grid - infrastructure or distribution system for energy exchange. For steam, hot water, cooling water or electricity. In this context, waste is material as input for generation.

Campus level - on healthcare inter-building level at the campus.

District level - on the healthcare campus. Consists of several (third part) (non) healthcare buildings on the same site.

Energy storage - temporary storage of energy, like electricity or heating, for example seasonal or day/night.

Power plant - also referred to as a generating station, power plant, powerhouse or generating plant. It is mostly an industrial facility for the generation of electric power.

Contents

1. Method and definitions

1.1 Introduction

The main goal of this report is a description of the analysis of energy optimization possibilities at inter-building level by considering the interaction of buildings within a healthcare district and in relation with the surrounding neighbourhoods. Doing this to achieve net zero energy buildings as foreseen by EPBD 2010, through the optimisation of building and neighbourhood interactions.

The focus of this report is on inter-building level on the campus site. The neighbourhood part is the subject of D2.8, and will follow in the next months. D2.8:' Description of solutions for energy systems for healthcare districts (at neighbourhood scale), including solutions for smart grid; energy generation and storage; logistic, resource and waste management.'

Some topics are described in general terms, as they are not directly relevant for the purpose of the report. Some of them, they will be investigated further in the following deliverables.

The main activities in this report are:

- composing and presenting different energy solutions kits;
- comparing and evaluating different energy solutions
- compared and evaluated at building and neighbourhood level;
- investigating the most effective solutions based on smart grids, distributed generation plants, tri-generation plants, district heating/cooling and thermal storage, especially considering cost-effective buildings/districts.

The activities, which are not included in this report, but will be done in report D2.8 are the following.

- Investigating the degree of decentralisation of energy solutions that is optimal for different parts of the district area.
- Investigating the scale needed in order to achieve highest energy-efficiency and cost-effectiveness for different energy solutions.
- Defining the optimal combination of energy carriers as basis for a district energy system - water, gas, hydrogen and/or electricity.

The report is a description of the methodology and is not a description of the decision support tool.

The report is organized in three main parts.

1. The method of designing a district EeB NES in Chapter 1.
2. In chapter 2, 3, 4 characterising both energy and power profile for supply and demand.
3. Matching the demand and supply profile in chapter 5.

1.2 Framework and focus

This report has a strong focus on technical aspects of the NES system. Of course, non-technical parameters will have an impact on the design process.

The whole process from the idea to build a district heating system to the construction could easily take a few years, sometimes up to 20 years. That is strongly depending on organizational and managerial parameters. The importance of succeed is highly depending on the stakeholders. However, these influences are not easily manageable in the design process. In most realised cases, an external party (with sufficient expertise) is responsible for energy supply, management and maintenance, but for the security and reliability. However, this company could be owner of the grid too. In terms of organisation, that is a (even manageable) risk.

The business plan for a district heating system in a healthcare district is depending on local laws. For example, it is regulated if a hospital can be an energy producer or not. However, this could change during the time of designing.
Moreover, there are strongly countries depending on specific local circumstances (for example energy prices and tax).

All these non-technical parameters are very relevant, but out of control of energy focused design process optimisation in this document. The decision maker will provide with this information in the description of the NES systems.

1.3 Strategy model

The strategy to obtain the analysis of the energy optimisations possibilities at inter-building level is the following.

Step 1: energy demand

The first step in this task is to analyse the possibilities of energy optimization at inter-building level. It is therefore required to analyse and determine the energy profiles of hospital buildings and a complete hospital district. This first analysis will give a better understanding of the energy flows and temperature levels within the hospital building. This knowledge is required to filter and select the appropriate NES technologies to achieve synergy with the neighbourhood.

Step 2: supply options

The second step is the description of the NES technologies in factsheets as library. This step is executed parallel to the first step, the basis of this step is the list of established NES technologies. The factsheet will contain a description of the technology, the characteristic parameters, the benefits and drawbacks and an indication when and where to apply the technology.

Step 3: matching demand and supply

In the third step, the first and second step will be combined to indicate in which situation which NES technology can be applied.

Result

The result of this strategy model is this report that will document the analysis of alternatives to optimize energy systems at inter-building level on the campus site and the applicable NES technologies.

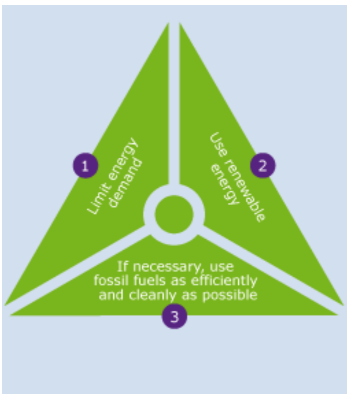

figure 1.1 Trias Energetica

1.4 Method approach REAP

On building level, there is a simple and logical approach for maximising energy efficient design: ‘Trias Energetica’. See figure 1.1.

1. Reduce demand.

2. Reuse waste streams.
3. Produce sustainably.

The knowledge of harvesting energy on-site is limited, but there are several methods that can support this endeavour. One of these is energy potential mapping, charting the local availability and quantity of renewable energy sources in the neighbourhood. But the question is 'What is a logical approach'? And what is the fourth step?

This question can be answered by using the Rotterdam Energy Approach and Planning (REAP) method. REAP was developed to support energy-neutral urban planning in a structured, incremental way. See figure 1.2. This combines both the elements of the 'Trias Energetica', and the inter-building level. Step 4 could be exchange of energy at inter-building level. The playing field of synergy between building and neighbourhood energy systems is marked by the green circle. The only possibility of energy exchange is at inter-building level.

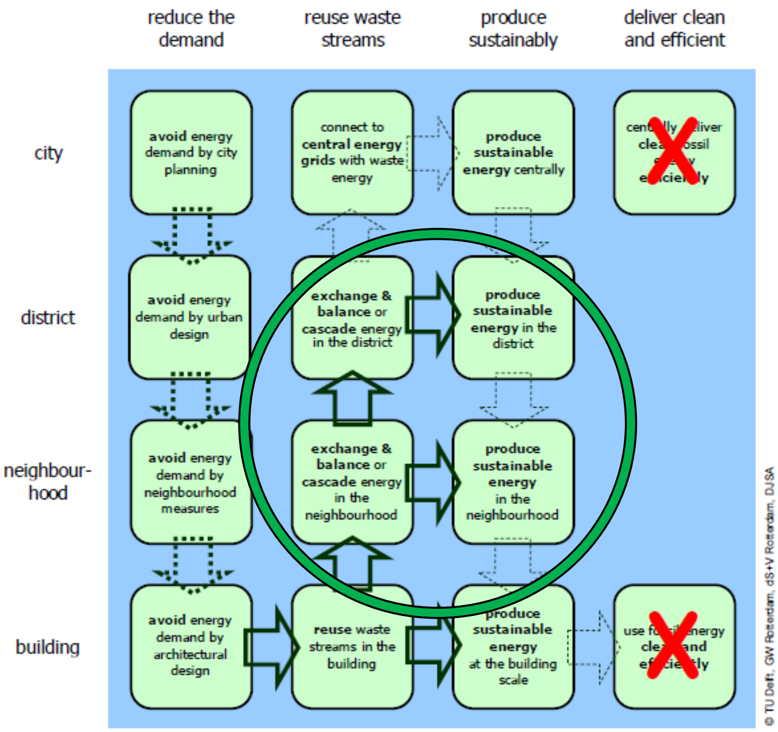

figure 1.2 REAP visualization

1.5 Technical components

What kind of technical components contains a neighbourhood energy system? Beside the energy users, we distinguish six different technical components in a neighbourhood energy system.

1. Energy carrier/medium
2. Generation/production
3. Distribution
4. Exchange
5. Storage
6. Other

These components will be characterised in the next chapters. The generation/production components are described in the appendix.

1.6 Scale level

The REAP method is talking about different scale level, at building, district or campus level, which can be defined as follows.

Building level: this level includes the buildings that have (in most cases) their own energy conversion plants, such as boilers and chillers, and that only serve the cooling and the heating needs of the building itself.

To clarify on inter-building level we distinguish different scale size.

Campus level: we can define a campus level as energy exchange systems that are composed of a (centralised or decentralised) energy exchange plant and a distribution system. All the buildings, and the plants, are included inside the boundaries of the healthcare campus. In the following figure 1.3, we can see that the red box includes the buildings and the generation and storage thermal plant inside a healthcare campus. This could be decentralised plant too. The other non-healthcare (third party) buildings outside the red box could be connected optionally.

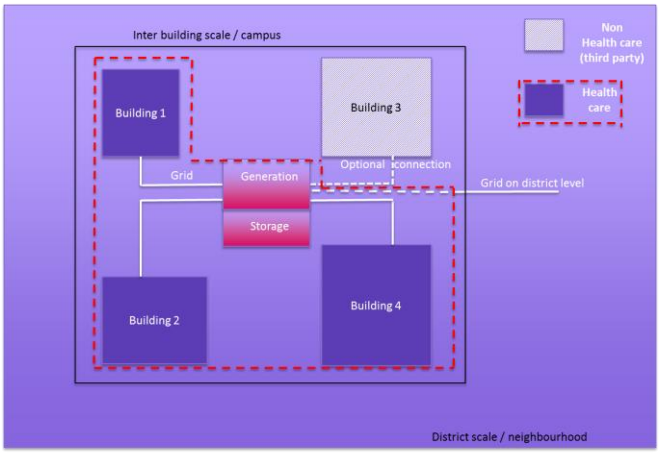

figure 1.3 Visualization campus level

District level: it includes energy exchange system that satisfies energy requirements for both residential and healthcare campuses. In this case, energy exchange on inter-building level in the campus and buildings outside the campus, connected by grid. In the following figure 1.4 we can see how the grid connects (non) healthcare buildings from inside the campus and buildings from outside of the campus.

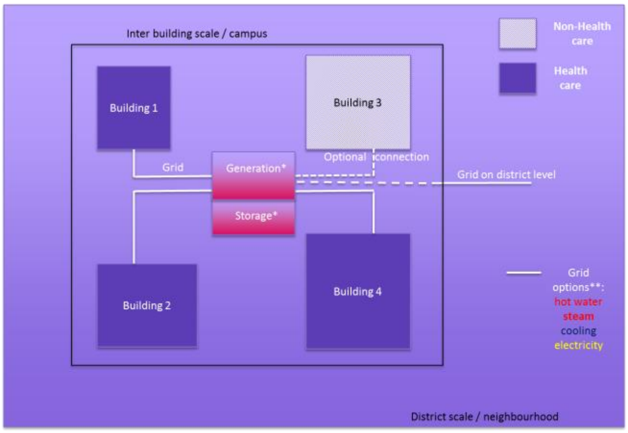

figure 1.4 Visualizing district level

City level: one or more plants outside the campus, connected by grid. In this case the source of the plant is out of scope. On the border of the campus the grid is just a grid.

2. Demand profile mapping

The first step of the analysis of the energy optimisation at inter-building level is to analyse and determine the energy and power profile of the building. But how to acquire this profile in different situations?
In figure 2.1 is schematically visualized for the energy carriers. Depending on the available data, we differentiate simulation and measurements resources.

In general, there are three possibilities.

- The maximum LOD: hourly energy and power demand profile by using a BIM model.
- Minimum LOD: energy calculations based on rules of thumbs.
- The maximum LOD: real time data records of the energy carriers.

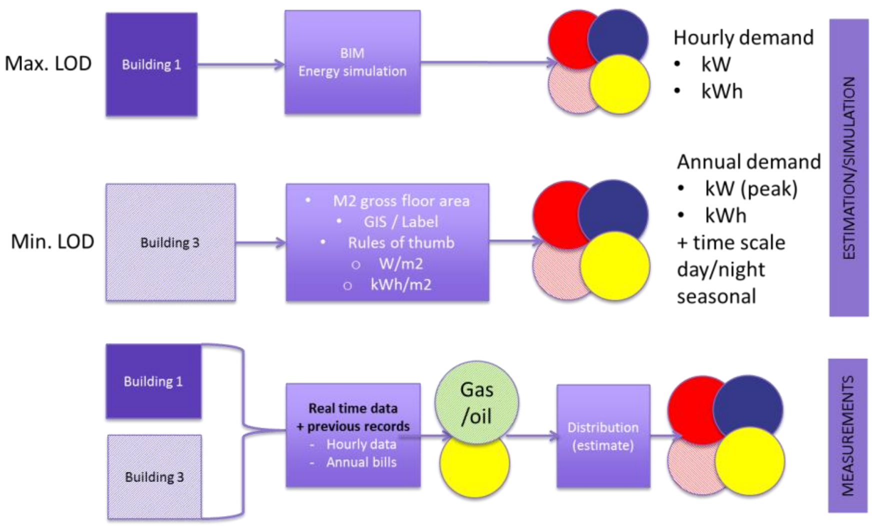

figure 2.1 Acquire energy requirement of a building on different level of detail

In the next paragraph, the situation getting an energy and power demand profile by using a design model is further elaborated.

2.1 Energy demand profile of a building

In a district, the global energy balances results from the sum of the demand coming from the various buildings. Every building in fact acts as a basic element of the system concurring with its requirement to the instantaneous energy demand that shall be satisfied by on site systems or by centralized plants.
At least for thermal needs (heating and cooling), it can be assumed that all the buildings follow instantaneously the same major trend having the same the boundary conditions (i.e. outdoor temperatures, human activities within the departments et cetera). We need that input to get a demand profile of a building.
Thus, the knowledge of buildings behaviour through a BIM model has the potential to help finding unique solutions for demand managing.
There are many ways to calculate the energy demand profile of a building. However, in generally the next approaches are to provide the designer.

Two approaches are available in the assessment of the energy demand at building levels.
i) The first one focuses on the highest instantaneous power request that can occur during the year. According to this value, the thermal plants, the distribution networks and the terminals are designed. This approach, even though it was adequate to guarantee high standard of comfort in the indoor spaces, was the standard as long as the end of the eighties when the environmental issues. This approach is related to the necessity of lowering the pollutant impact associated to HVAC.
This leads to a more conscious design that, rather than focusing on the instantaneous power, focuses on the energy requirements of the whole heating season.
ii) Another method considers not just the instantaneous power flowing through the buildings envelopes but rather implement the energy balance throughout the typical day of each month. The last balance is hence focused more on energy than on power.
The development of the calculations requires both the indoor temperature in each thermal controlled zone and of the outdoor climate (e.g. temperature and air humidity).
If the indoor temperature is rather predictable, depending mainly from the human activities that take place in a certain room, the outdoor temperature requires first the definition of a thermal model.
According to the easiest methodology, the indoor temperature is considered to be constant within 24 one hour-intervals every day in accordance to a quasi-steady state model: the curve that describe the instantaneous variation of outdoor temperature is modelled as a 24 steps histogram, normally with a satisfactory degree of approximation.
The second way, instead, still takes the continuous variation of outdoor temperature, also considering transient phenomena following hence a transient state model. The last methodology however can be implemented using estimation and simulation software like TRNSYS, EnergyPlus, DOE-2, ESP-r/ESRU, VA114 et cetera since the complexity of the transfer function method equation that governs the energy model.

The *Steady-state model* procedure instead implies the necessity to define all the parameters that are necessary to build the energy balance for each room involved in heat transfer with the external environment.
The governing equation giving the thermal requirements (heating and cooling) associated with heat transmission through the envelope during a typical day of each month, is:

$$Q_D = c_{AVG.EXP} c_{SAF} \sum_k \sum_i \sum_j k_{jik} S_{jik} o_k (T_{AVG.OUTDOOR-BAD} - T_{ikAVG.INDOOR})$$

These parameters are summarized as follows.

- $T_{AVG.Outdoor\text{-}Bad}$ the indoor dry bulb temperature and relative humidity. This parameter, being related to the desired temperature associated to the activities that take place in a certain room, normally is taken to vary from 20 °C, during the heating period, to 25 °C, during the cooling period.
- $T_{ikAVG.Indoor}$ the outdoor dry bulb temperature and relative humidity, taken from the typical climatic files of the hospital location.
- k_{jik} the U-values of each architectural element j, belonging to the envelope, located in the i room of the k department (W/m^2°C).
- S_{jik} the area of the architectural element j located in the i room of the k department (m^2).
- *o* the thermal treatment hours/day (meaning the time intervals of 'environmental contributions' when the difference of temperature indoor-outdoor generates a heat flow, other times are discarded).
- C_{AVGEXP} the average coefficient of exposure (varying from southward 1 to northward 1,2).
- C_{SAF} the safety coefficient (1.1).

In the energy balance, one should hence add the contribution for mechanical ventilation, considering an outdoor air infiltration rate in the areas not served by air handler units.

Once the thermal requirements for each single building is available, it is possible to extend the same balance at district level simply considering that the generation of heating/cooling respectively from the energy transformation of a certain fuel in boilers and/or through the operation of chillers fed by electricity, take place in a centralized place.

BIM has a huge potential in modelling and optimization of the building energy demands, but shows many limitations in the simulation of complex systems such as thermodynamic plants (CHP or district facilities and infrastructures). In these cases, an effective assistance comes from a full metering control of their operation that allows real time intervention to keep the processes efficiencies always at the highest levels.

We need that input to design a district energy system.

2.2 Energy potential mapping campus and district

Geographical information systems (GIS) may be used to map the local conditions that affect the potential of a district energy system on district or campus level. Since there are different energy demands within the campus, energy mapping is needed separately for each of the demands. GIS mapping can be done to identify or estimate the density of the various energy demands. For instance, heat density can be defined as the sum of the heat demands in a given land area divided by the land area (kWh/m^2). This information could be included in the GIS system in the future. Since this information is not included in the GIS system today, other parameters such as building typology or population density could be used to estimate the heat density together with the assumption of energy use for different buildings or per capita.

In The Netherlands, energy labels are included as information in the GIS system, as visualised below figure 2.2 for the surrounding of Rijnstate hospital. The energy labels do not only include the specific heat demand but also the electricity demand. Visualisation of energy mapping can also be helpful in the design process of an energy exchange system on the campus or district level.

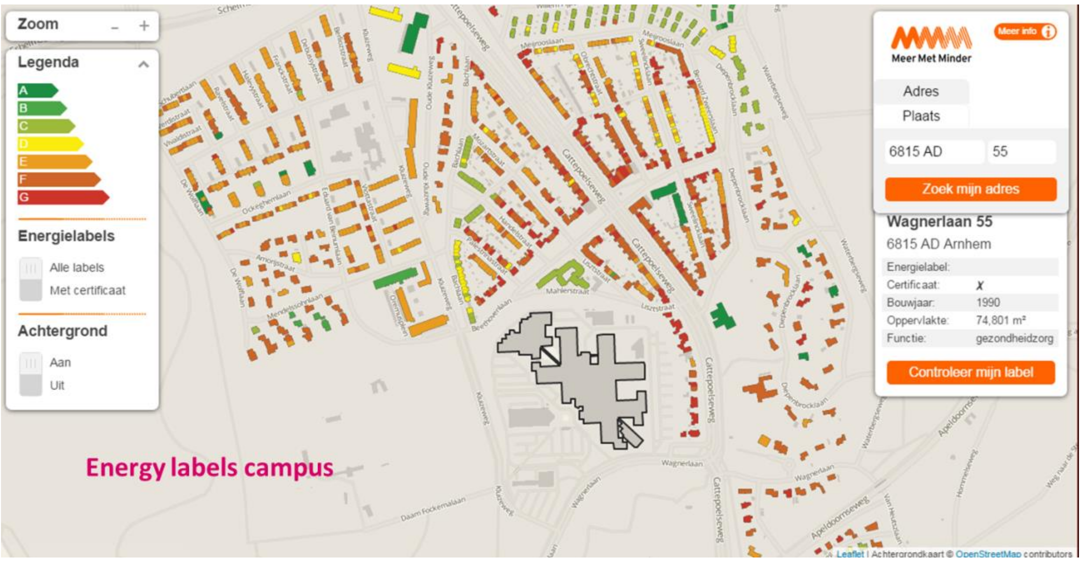

figure 2.2 Energy label district level

Figure 2.2 shows the energy labels (energy consuming) in the district around Rijnstate hospital (grey-coloured buildings). Energy label ‘A’ (green colour) means that the building has a low energy use and energy label G (red colour) means that the building has a high energy use.

3. Distribution

3.1 Energy carriers

While having the demand of energy and power is calculated, the next step is to verify what kind of distribution is possible. This connection is doing by energy carriers in a grid.
As medium for energy carrier is steam, hot water, cooling water and electricity determinate. See also figure 3.1. In this scope, waste is regarded as a source for energy generation.

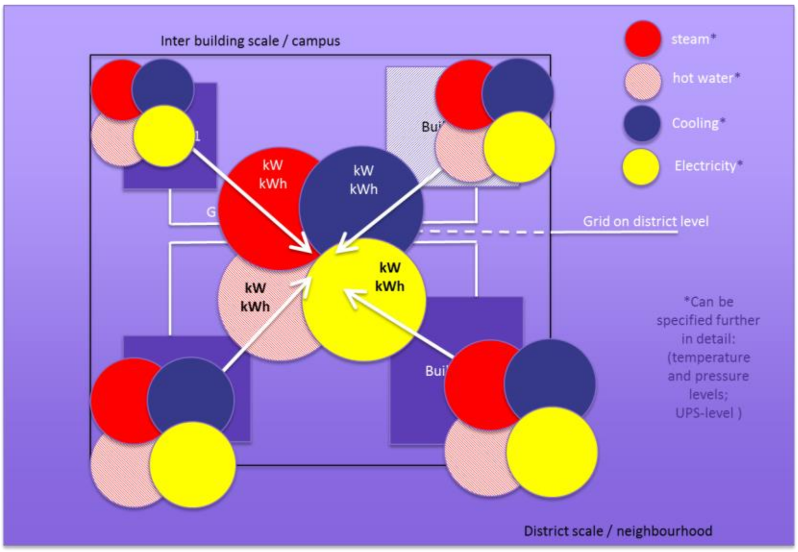

figure 3.1 Different types of energy carriers

Parameters, which should be checked by matching, are presented in table below:.

table 1 Parameters of the energy carriers

Grid type	Parameters
Electricity grids	Voltage [V]
	Available Power [kW]
	Available Electric current [A]
District heating	Available Power [kW]
	Available pressure [kPa]
	Pipeline dimension [mm]
	Water Temperature curve [^{o}C]
District cooling	Available Power [kW]
	Available pressure [kPa]
	Pipeline dimension [mm]
	Water Temperature curve [^{o}C]
Gas	Network capacity [m^3/h]
	Amount of ordered gas [m^3/month], [kWh/month]
Steam	Steam temperature [^{o}C]
	Steam pressure [kPa]
	Network capacity [m^3/h]

3.2 Characterising distribution systems

There are many typologies of distribution systems available and commonly used. In this approximation,

figure 3.2 Example of insulated pipes of district heating

we will focus on the route and connection of the distribution system both regarding with building(s) and NES technology. In figure 3.2 is showed.

There will be no characterising of the distribution system in terms of a serial or parallel system, or back-up connections and so on. That is in this global approach not relevant.

Energy mapping is necessary when investigating which are the most effective energy system solutions for the campus. In generally there are 3 types of a distribution system:

- a central district energy system or;
- a decentralised energy system based on several distributed local plants or;

- a combination of a centralised and decentralised energy systems.

These are visualised in the figures below.

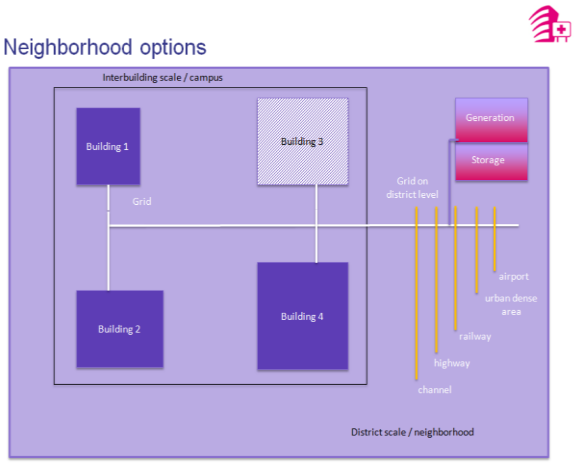

figure 3.5 Local production and storage

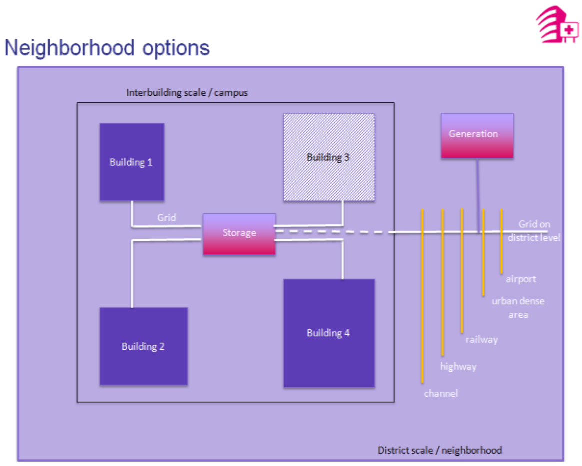

figure 3.5 Connection to the district grid with local storage

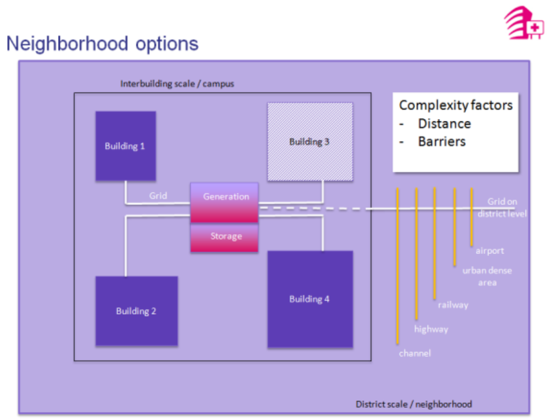

figure 3.5 Local grid on campus connect to city heating grid

3.3 Characterising complexity factors of the grid

In a typical district heating/cooling plants, there are some issues that need to be considered pivotal in order to achieve real energy savings and emission reductions, avoiding terrible misfortune. That is because district heating systems are so large, the effects of failing to design an efficient system are magnified. We characterising this issues as complexity factors. See figure 3.6.

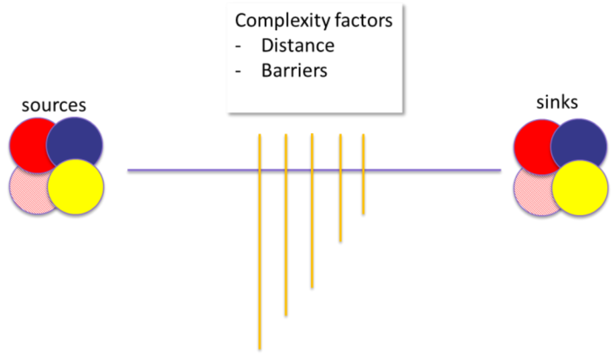

figure 3.6 Complexity factors

In figure 3.7 is presented below, could be helpful for stakeholders in the design process since it visualises possible complexity factors such as rivers, bridges, railway, different altitude et cetera.

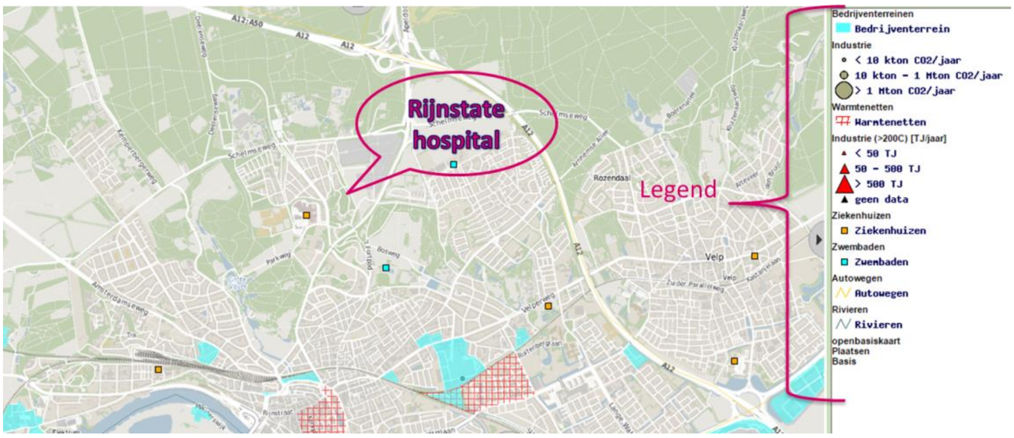

figure 3.7 GIS map of the district around the Rijnstate hospital

Passing then to two main questions.

i) Starting point 1: given is a grid. Is it possible to add one building to the grid, to state the capacity and complexity factors?

ii) Starting point 2: given is a campus with several buildings (e.g. hospital campus). Is it possible to replace all heating systems by one centralized heating plant?

The answer to the first question should consider not only the complexity factors summarized above. But also the location of the plant, insulation of tubes, insulation of junctions. And there is the need also to take into account of other parameters, at the same time such as the maximum distance from the new end user candidate and the network and the minimum volume that lead to a cost effective connection.

A typical parameter for the first issue is that the ideal distance without customers should be maintained below 1-2 km in order to suffer from considerable losses.

The second question, instead, is strongly dependent from the network extension and from the energy policy of the network manager.

In case of hospitals this possibility never occurs, since the pavilions are normally so energy intensive and their volume so considerable that is always cost effective to collect a new user.

Of course, it is possible to replace heating systems with a centralize plant (please see question 2 above) if fed by biomasses or other renewables.

In that case, one should compute that kind of environmental final benefits from the retrofit/building of a new plant.

However, the main error that characterizes many existing district heating networks is often a direct result of the choice of minimal compliance levels under a design-and-build arrangement, where the focus is to deliver a system for a low capital cost.

The choice of a wrong place for the CHP location can cause serious inefficiencies to the whole system. In the ideal solution, the cogenerate plant is placed in proximity of the 'thermal barycentre' of the district, in order to lower as possible the heat losses.

This solution however cannot be applied wherever: in hospitals, for instance, some other variables shall be considered in the design of the correct position of the central plant. The loudness of the plant, together with the emissions at the chimney are parameters that can limit the installation possibilities.

Although in literature, there are few references to insulation thickness for a given operating temperature, it can be assumed that typically, the allowable losses amount to 10-20W/m in distribution pipework, where the average pipework temperature is equal or higher than the assumed standard temperature of 95°C.

To reply at the question: which are the limits to connect a new building to the network, one should hence considers at first the data above, to understand if the distribution losses are too considerable to link the new user as well.

Another weakness that should be considered is related to the Heat Interface Units (HIUs); normally to limit liabilities between landlord, tenant or resident, it is common to provide hydraulic separation at property boundaries; this results in significant losses every time the insulation is not consistent from plant through to pipework and HIUs. Though it is becoming more common to see insulated heat exchangers in HIUs, pipework is often left exposed. The supply terms of contract can contemplate such a specification, but with often at additional cost that risk to be hardly bearable if not adding extra tariff to the final users. Of course, the last issue is less felt in hospital district heating since the uniqueness of the property. However, the problem related to the insulations in the network junctions remains central.

Finally a frequent element that should be considered in the overall complexity factor of a district heating network is related to poor pumping and flow control: *e.g.* the installation of cheap bypasses cause the systems to be always 'on', at a certain rated power, regardless of the requirement for heat.

The same return temperature risks to be higher and higher, causing a general increase in distribution losses as well. Pressure sensors installed across pumps restrict turndown, increase electrical use and the circulation of water at high temperatures.

4. Supply mapping

4.1 Characterising NES technology

NES technologies can be divided regarding various aspects. We can distinguish renewable and non-renewable technologies. In power plants heat or/and electrical energy can be produced. If hot water or steam is produced together with electricity, it is called cogeneration power plant.

In Europe coal, gas and nuclear energy are the most common non-renewable energy sources. During the last years some solar power plants were built as well. In case of electrical energy production, water power plants are irreplaceable together with wind power plants. Of course, we are focusing on renewable technologies. And of course optimisation of the technology by increasing efficiency or combine different source as a CHP. See figure 4.1.

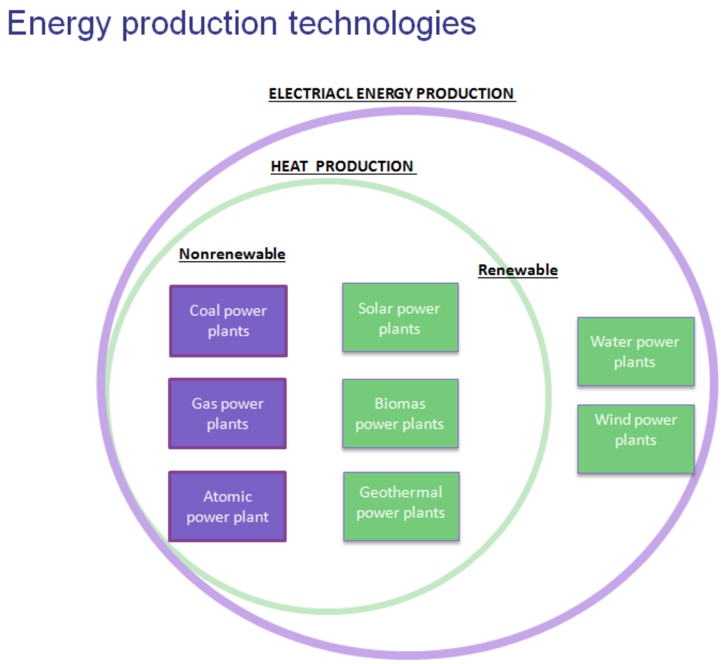

figure 4.1 Visualisation of different NES technologies

The second step of the strategy model is the description of the NES technologies in factsheets as library. The basis of this step is the list of established NES technologies. The factsheet contain a description of the technology, the characteristic parameters, the benefits and drawbacks and an indication when and where to apply the technology. See appendix.

table 2 Parameters of the energy carriers

Grid type	Parameters
Main parameters	Available Power [kW] - (possibility of connection)
	Availability of certain fuel/energy (depends on neighbourhood infrastructure)
Electricity	Voltage [V]
	Available Electric current [A]
	Available Power [kW]
	Current DC/AC
	Quality and emergency power
Water systems	Available Power [kW]
	Available pressure [kPa]
	Water Temperature curve [^{o}C]
	Available energy [GJ]

The appendix is a list of factsheets of SOTA NES technologies. They are categorised and characterised. We made it to incorporate it later into a database. This database is a library of technologies from which a designer can choose.

4.2 NES mapping

GIS mapping can also be used to identify various kinds of energy resources, such as renewable energy sources, as well as heat sources from existing energy utilities and from industrial processes and, in the future, possibly also excess heat from energy-intense medical equipment. Similarly as for energy mapping, this kind of mapping of thermal sources is needed separately for the demand of heat, steam, cooling and electricity.

When are centralised energy systems, such as district-heating and district-cooling systems, economically feasible solutions? To be competitive a district energy system needs to be able to deliver heat, steam and cooling to the end customers at total cost levels below that of decentralised heat, steam and cooling solutions. The generation costs are constant regardless of energy density, whereas the distribution costs decreases rapidly as the energy density of the area increases.

Of course, the energy supply and the energy demand should match, not only on an annual basis, but also momentously. Otherwise, storage is necessary. Therefore, energy profiles are necessary for constructing an infrastructure for the exchange of energy. For heat, steam and cooling sources, the temperature of the sources available and the temperature requirements are also necessary information in order to match the energy demands and sources.

4.3 Characterising supporting technologies

The most important supporting technology is storage. There are many possibilities to store thermal energy on district or building level. Parameters, which describe storage technology, are presented below.

Storage technologies parameters

For storage tanks:

- Volume [m^3]
- Storage capacity [GJ]
- Space availability [m^2]
- Energy loss [GJ]
- Temperature level [°C]

Smart systems

Smart electric and thermal grids allow for adapting to changing power or energy supply and demand in the short, medium and long term, and facilitate participation of end-users. For instance by supplying heating or cooling back to the network. To do so, they need to be spatially integrated in the whole energy system and interact with other infrastructure, such as networks for electricity, sewage, waste, ICT et cetera. Optimising the combination of technologies and enable a maximum exploitation of available local energy resources through cascade usage, smart thermal or electric grids can contribute to improving the efficiency of heating and cooling, while increasing the cost efficiency and increasing the security of supply at a local level by using local sources of energy. The scale of smart thermal grids can range from campus-level systems to city-wide applications.

Technical elements of smart thermal or electric grids cover thermal generation like small-scale low-carbon heating and cooling systems, electric generator like CHP. Beside that also, thermal storage technologies and innovative network improvements (network-integrated sensors and smart heat meters) allow for more effective and efficient use of the separate components, supported by overarching energy management.

5. Matching NES technology with demand side

5.1 Approach of matching

If the requested energy and power of the buildings on the campus is known, a matching of the state of the art NES technologies for synergies between buildings is ahead. This is the last step of the strategy model.

The question is how to combine energy and power, both supply and demand. In this chapter, we will explain this match to determinate the feasibility of an energy system.

We distinguish many different situations and want of course a tool who could handle all types' situations.

During the NES design process, well-based recognition of available energy sources is important and has to be done during the very first stage of the project. At this stage, designers have to decide which source is available in the surrounding. To do so knowledge about existing underground and surrounding infrastructure has to be available. Within this deliverable, it is proposed to follow an easy path to recognize the most appropriate energy source design model.

The matching process is determining feasibility of options. That process is in figure 5.1 visualised.

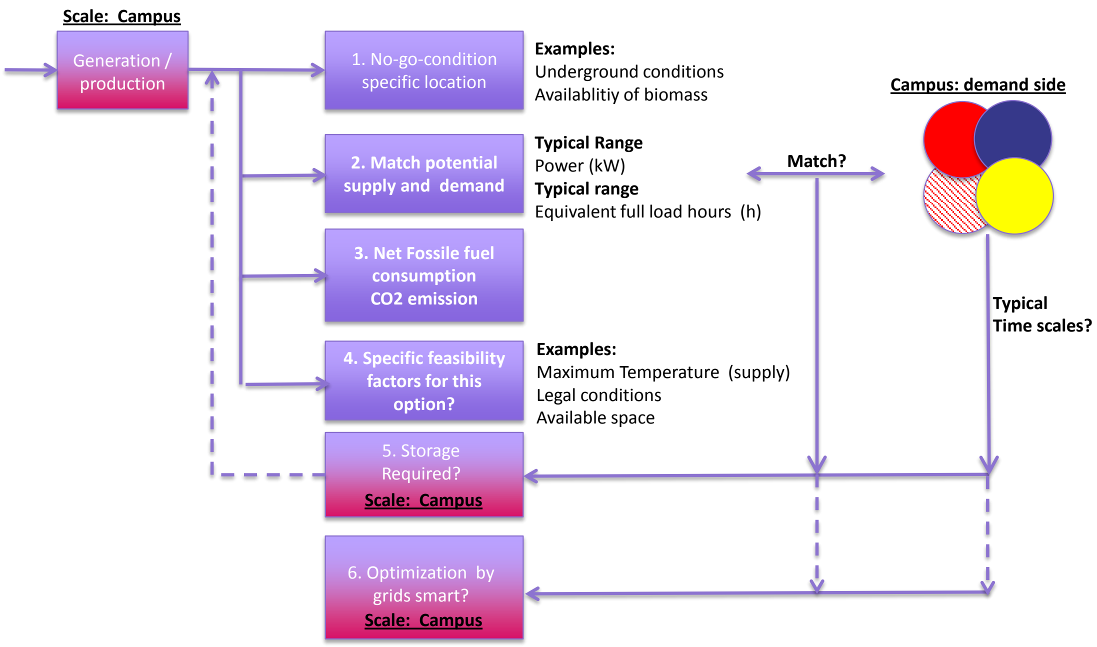

figure 5.1 Schematic process of matching NES technologies with demand side

This figure is a schematic process of matching supply NES technologies with the demand side. The demand input is extract from a BIM or a GIS module. The NES technology is characterized in a library including specified parameters for each technology. Now, every technology is uniquely determined.

The energy profile of the demand side will be compared with each characterized parameter of the NES technology to find a match, or mismatch. This comparison is based on relevant KPI's, visualized in the boxes in the middle of the figure. This comparison process with the demand side will be repeated for every technology. The outcome of this design and comparison process is a ranked list of technologies.

The workflow for the decision making process is as follows.

1. Is to identify the local energy sources which is considered for a specific location. For example availability of biomass or underground conditions.
2. Is to identify the supply potential of the supply matches required demand of power and energy and technical connection conditions.
3. Is to estimate the net fossil fuel consumption and CO_2 emission.
4. Is to check legal conditions and technical requirements of the connection.
5. Is to suggest if a storage system is needed.
6. Is to suggest if a smart grid is needed or advised.

Steps 2, 3 and 4 should be done at the same time.

When assessing the potential for a district-heating system, the linear heat density is an important parameter. Linear heat density can be defined as the heat annually sold in a district-heating system divided by the total length of the pipe network. If data of measured heat use is available, of course, this can be used instead of heat annually sold. If there is not yet an existing district-heating system, it may be difficult to calculate the linear heat density. In that case, the linear heat density must be estimated in some way, for instance, based on the different buildings in the area and assumption of the energy used in different types of buildings with different activities. The same principle presented here for heating system also applies to assessments of cooling-system, i.e. that the linear cooling density is an important parameter.

5.2 Ranking

The result is a ranking of high potential options of inter-building energy exchange and connections to the neighbourhood. The ranking will help to interpret the results. This ranking is based on different KPI's like suitable, energy potential, CO_2- emission reduction.

From the end user point of view, the outcome of the decision support tool could be a ranking the NES technologies. O is excellent choice and 7 is ignorable option.

table 5.1 Theoretical example of ranking NES technology

NES Technology	Suitable	Energy potential
Biomass boilers/CHP	0	7
Aquifer thermal energy storage/Borehole thermal energy system (ATES/BTES)	1	6
Energy Recycling System Using Chemical Heat Pump Container (CHPC)	2	5
Biogas power plant	3	4
Integrated gasification combined cycle (IGCC)	4	3
Wind turbines	5	2
Hydropower systems	6	1
Geothermal energy (deep underground)	7	0

Of course, each item is enriched with notes and recommendations. For example: the suitability of geothermic sources is depending on a certain energy scale. If the potential energy users in the campus are not enough, it is recommended to search for other energy users in the surrounding of the campus.

6. Summary and conclusion

In chapter 1 the logical and simple optimization possibilities at inter-building level are:

1. reduce demand;
2. reuse waste streams;
3. produce sustainably;
4. exchange energy.

Also in chapter 1 Neighbourhood Energy Systems are subdivided into the following categories.

1. Energy carrier

2. Energy generation and production
3. Energy distribution
4. Energy exchange
5. Energy storage
6. Other technologies

Chapter 2 evaluates the energy demand at building level and campus level on different situating by simulation and measurements.

Chapter 3 described the characterising of the energy carrier, distribution systems and the complexity factors.

In chapter 4 the energy generation and supporting technologies on energy demand are characterised and described in appendix.

Finally in chapter 5 Neighbourhood Energy Systems at inter building level are matched with the demand side.

Recommendations for the decision making process are given by defining the following steps.

1. Is to identify the local energy sources which is considered for a specific location. For example, availability of biomass or underground conditions.
2. Is to identify the supply potential of the supply matches required demand of power and energy and technical connection conditions.
3. Is to estimate the net fossil fuel consumption and CO_2 emission.
4. Is to check legal conditions and technical requirements of the connection.
5. Is to suggest if a storage system is needed.
6. Is to suggest if a smart grid is needed or advised.

In order to rank the technology for Neighbourhood Energy Systems a set of key performance indicators (KPI) are given. These KPIs can be used to find suitable solutions.

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APPENDIX 1 - List of State of the Art neighbourhood energy system technologies

Beside the energy users, we distinguish six different technical categories in a neighbourhood energy system.

1. Energy carrier/medium
2. Generation/production
3. Distribution
4. Exchange
5. Storage
6. Other

In Table 2 neighbourhood energy solution technologies, the state of the art technologies are categorised

Table 2 neighbourhood energy solution technologies

categories	name	Short description
2,3,4	District energy	Heat or cold is centrally produced and distributed among heat recipients by a grid.
5,6	Gas energy storage	Excess power is converted into methane.
5	Thermal storage installation	Campus wide thermal storage installation
3	Smart electrical grid	Smart electricity grid for balancing supply and demand of electricity
3	Smart Thermal grid	Smart thermal grid for balancing supply and demand of heat (and cold)
6	Building energy prediction	Techniques for building energy prediction
1,2	Biomass boilers/ Cogeneration or combined heat and power (CHP	Biomass fired boilers both for domestic hot water and CIP
2,4	Free cooling	Nearby lake or cooling tower as cold source
2,5	Aquifer thermal energy storage / Borehole thermal energy system (ATES/BTES)	Ground source heat pump with seasonal storage
4	Waste heat from neighbourhood	Exchange of heat with neighbourhood buildings or factories
2	(Solar) ORC system	(Solar driven) ORC for electricity and heat productionor hot water production
2,6	Waste to energy	Burning medical wastes to produce energy
4,5	Energy Recycling System Using Chemical Heat Pump Container (CHPC)	Waste heat is stored as chemical energy in the CHPC.

categories	name	Short description
1,2	Biogas power plant	Organic waste from neighbourhood can be used as a fuel.
2	Integrated gasification combined cycle (IGCC)	Gasification for achieving higher electrical efficiencies in combined cycle plants
5,6	Load levelling and management	Load levelling and management to combat for load variations
2	Wind turbines	Generation of electricity by wind turbines
2	Hydropower systems	Hydropower from a nearby river or tidal power from a nearby sea
2	Geothermal energy (deep underground)	Use of a heat exchanger which extracts heat from a geothermal source

Appendix 2 displayed for each state of the art technology a factsheet.

APPENDIX 2 – Factsheets

Factsheet ATES and BTES

Description

Aquifer en Borehole Thermal Energy Storage systems (ATES and BTES) are systems for large scale seasonal storage of heat and cold.

With ATES, groundwater is pumped out of the ground and injected into the ground by wells, also known as “open” systems. Such a system is composed out of a doublet: one borehole is used for water extraction and one for reinjection. The aquifer is kept in hydrological balance. BTES consists of a working fluid (water in most cases) which is pumped through a heat exchanger in the ground. This a so called “closed” system. Such a system can consist out of one to hundreds of boreholes.

The temperature of the water from these systems is generally not sufficient for heating purposes. A heat pump is needed to upgrade the temperature.

The working conditions of ATES, in combination with a heat pump is as follows:

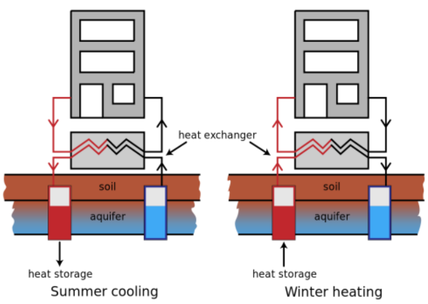
- During the summer period, water of 8-12°C is pumped from the cold well through a heat exchanger. Cooling is generated in the building. The heated groundwater is injected into the warm well.
- During the winter period the warm well acts as extraction well. The heat from the ground water is used for heating the building. The temperature of the warm well is not sufficient for direct heating purposes, so a heat pump is needed to obtain the right temperature.

BTES has the same working principle as ATES. The main difference is that the energy is stored in the bedrock underground and not in an aquifer. BTES is thereforer not limited to locations with aquifers underneath. BTES are commonly used for small scale systems (large single family houses). Larger systems are possible, but more boreholes are needed, so a more expensive system is created.

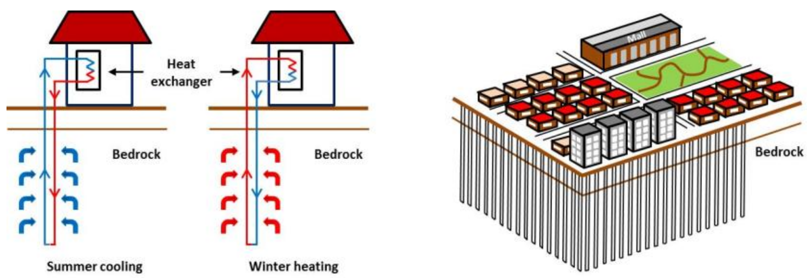
References description

- www.solar-district-heating.eu
- http://large.stanford.edu

Figure



ATES (source: http://large.stanford.edu)



BTES, small scale (left) and large scale (right) (source: httop://large.standford. edu

Technical parameters

Cooling temperature: >8°C. The temperature may fluctuate during the season.

Heating temperature: depends on injection temperature during the summer. In most cases the temperature is >12°C.

Description other parameters

Legal conditions or restrictions: In The Netherlands the law order there should be an energy balance during several years. This means that the amount of extracted energy and the amount of injected energy should be in balance. This prevents the ground to heat up or cool down. ATES and BTES are not aloud in areas where potable water is produced.

Operational, financial and managerial conditions and/or consequences: Not all ground types and conditions are suited for thermal energy storage. To apply this solution, the geological formation should be suitable storage purposes. With ATES and BTES the wells or boreholes should be separated by a large enough distance to prevent thermal breakthrough.

In the building low temperature heating system and high temperature cooling system (like floor heating/cooling) is highly recommendable.

Applicable for hospitals: the underground of the hospital should have characteristics which are suited for this application.

Available and reliability of the system: available all year for cooling or heating. The supply temperature of the water may fluctuate during the year.

Scale:

ATES: depends on number of doublets, characteristics of the underground and the dimensions of the wells. Maximum capacity per doublet is circa 2 MW_{th}.

BTES: depends on the number of boreholes, the characteristics of the underground and the dimensions of the boreholes. Maximum capacity per borehole is several 10 kW_{th} per borehole.

Practical example

Practical examples of the application of ATES are:

- Maria Hospital, Overpelt (Belgium), ATES.
- Flevo Hospital, Almere (Netherlands), ATES.
- Haga Hospital, The Hague (Netherlands), ATES.
- Academic Hospital, Utrecht (Netherlands), ATES.

Streamer
European research on energy-efficient healthcare districts

Factsheet Free Cooling

Description

Free cooling uses the cooling effect of naturally cold water. Sources of cold water can be deep lakes, rivers or oceans.

Free cooling has several advantages: the energy consumption can be reduced with maximum 90%, no (ozone depleting) refrigerants are needed and noise production by chillers is eliminated.

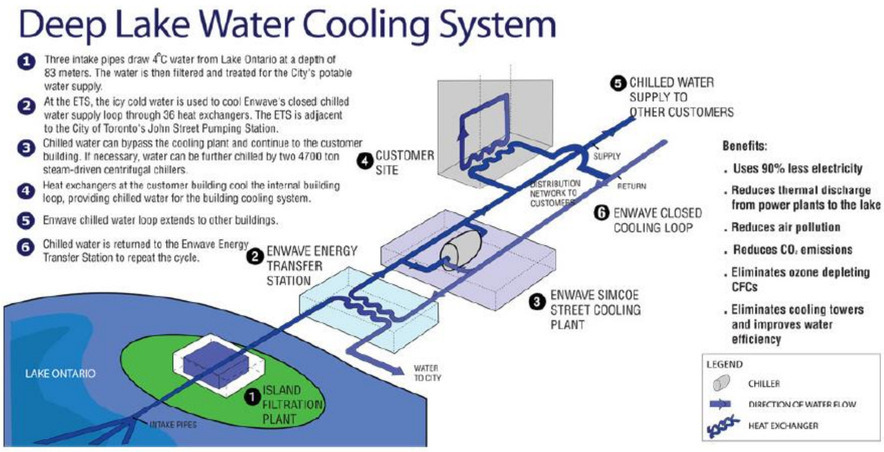
A system of free cooling consists of several elements. Intake pipes are used to pump the water out of the deepest (and coldest) part of the lake, river or ocean. This naturally cold water is pumped first through a filter section, to prevent blockages in the system. The water then passbees a heat exchanger, so cold water is produced in a closed cooling system. The naturally cold water is pumped back into the lake, river or ocean. To prevent a rise of the temperature of the cold well, the distance between the intake pipe and the return pipes should be large enough. This prevents the mixing of the warm return water with the cold intake water. Water chillers can be used to secure a year-round cooling temperature.

The temperature of the cold well depends on several factors. The volume and the depth of the lake, river of ocean are very important. These parameters determine the maximum cooling power of the system. If a lake is used as cold source, it should be large enough to provide a constant cooling temperature. Lakes are regenerated during the winter period, when the surface of the lake cools down. Because cold water has a higher density, the water sinks to the bottom of the lake, so a new cold well is generated.

References description

- http://www.districtenergy.org/assets/CDEA/Case-Studies/Enwave-case-history-Toronto7-19-07.pdf
- http://www.kwhpipe.ca

Figure



Schematic overview of the deep lake water cooling system in Toronto (Canada)
(Source: www.NYC.gov)

Technical parameters

Medium: cold water

Cooling capacity: from ±10 MW_{th}

Temperature: >4°C

Description other parameters

Legal conditions or restrictions: if a lake is used as cold source, the temperature rise of the lake is an important factor to be considered. Thereby a problem may be the phosphorous rich water from the bottom of the lake, which is brought to the surface of the lake. This may lead to the growth of algae.
Operational, financial and managerial conditions and/or consequences: The costs of the infrastructure of free cooling are high. This means the system should fulfil a significant part of the capacity and operating hours per year to be profitable. To obtain the minimum required capacity, a district cooling network can be set up..
Applicable for hospitals: the hospital should be located next to a deep lake, river or ocean.
Available and reliability of the system: available all year. The temperature of the naturally cold water may fluctuate during the year.
Scale: large (from 10 MW_{th}).

Practical example

Examples of free cooling by naturally cold water are:

- Gothenburg (Sweden): district cooling network by using a river as cold well. The capacity is 100 MW.
- Amsterdam (The Netherlands): district cooling network by using a lake as cold well. The capacity is 60 MW.
- Toronto (Canada): district cooling network by using a lake as cold well. The capacity is 180 MW.

Factsheet Biomass boilers / CHP

Description

Biomass includes all kinds of materials that were directly or indirectly derived from vegetal matter and its derivate, such as wood fuel , wood-derived fuels, (fuel) crops, agricultural and agro-industrial by-products and animal by-products.

Biomass is a renewable fuel and considered to be CO_2-neutral with respect to the greenhouse gas balance. The energy derived from the biomass is called bio-energy. Biomass combustion is the main technology route for bioenergy.

A biomass combustion system consists of several elements: fuel storage, fuel feeding, combustion boiler, ash removal system, flue gas cleaning and exhaust system. The selection and design of these elements is mainly determined by the characteristics of the fuel to be used and the capacity needed. Two important characteristics are the moisture content of the biomass and the dimensions of the fuel. The combustion technology is mainly interesting for biomass with a low moisture content (<50%). As a result, wood is often used as fuel for combustion systems.

Biomass boilers are available in a wide power range. The smallest systems are wood stoves with a capacity of several kW's. These can be used for individual room heating. The capacity of the largest systems can be up to several 100 MW_{th}'s. These systems can operate fully automatically.

If electricity as well as heat is generated by the biomass combustion installation, it is called a biomass CHP (combined heat and power). A part of the produced heat is converted into electricity by an ORC (organic Rankine Cycle) or steam turbine. ORC's are mainly used for smaller systems (up to several 100 kW_e's) and steam turbines for larger systems (from several 100 kW_e's up to several 100 MW_e's). The design of a CHP determines whether the plant is heat-controlled or electricity controlled. The first option results in a high heat efficiency and a low electric efficiency (the second option vica versa). Most CHP's can change the heat/power ratio, so the production can be adapted to the consumption.

References description

The handbook of Biomass Combustion & Co-firing, edited by Van Loo and Koppejan, 2008.

Figure

Wood boiler at the University Hospital of South ManchesterSource:AcronAPS)

Wood chips

Technical parameters

Medium: Hot water or steam. A biomass CHP generates also electricity.

Energy efficiency: Boiler: heat efficiency 90%. CHP: heat efficiency 30%-60%, electrical efficiency 10% - 30%.

Temperature level: 30 – 1.000 °C

Thermal Capacity: 5 kW_{th} up to several 100 MW_{th}'s

Electric capacity: 100 kW_e up to several 100 MW_e's

Description other parameters

Legal conditions or restrictions: Several pollutants are emitted to the atmosphere as a result of combustion. The main pollutants are dust particles, nitrogen oxides (NO_x) and sulphur oxides (SO_x). The emission of these components is limited by legislation. To be able to meet these limitations, flue gas cleaning systems are required. A biomass installation requires transports for the supply of fuel and for the removal of ash.

Operational, financial and managerial conditions and/or consequences: the price of biomass depends on several aspects, such as the quality and the heating value of the biomass and the local availability.

Applicable for hospitals: An important aspect is the emission of flue gasses. The entry of flue gasses into the ventilation system of the hospital should be avoided. This can be prevented by a proper distance between the ventilation system and the biomass system.

Available and reliability of the system: Biomass boilers and to a more limited extent biomass CHP, are commonly used techniques and therefor proven in practice.

Scale: large (from several 100 kW_{th} up to several MW_{th}'s)

Practical example

There are several examples of the application of biomass systems in hospitals in several countries in Europe:

- University Hospital of South Manchester, United Kingdom (4 MW_{th} biomass boiler)
- Hospital Freistadt, Austria
- Albert Kenessy Hospital, Hungary
- Hospital Kirchberg, Luxembourg
- Addenbrooke and Rosies Hospitals in Cambrige, United Kingdom
- Antrim Area Hospital, United Kingdom
- Crosshouse hospital, Kilmarnock, United Kingdom

Factsheet Electric Smart Grid

Description

Current electric grids are the result of rapid urbanization and infrastructure development. They generally use a hierarchical structure in which power plants are at the top of the chain, whereas customers are at the bottom of the chain. This hierarchy has made more difficult obtaining real-time information about the service. The high and dynamically changing demand and the problems of the old electricity grids have led to modernise the distribution network by introducing technologies that can help with demand-side management and revenue protection; Electric Smart Grids are introduced by integrating renewable energy sources, smart transmission and distribution.

Smarts Grids are public electric grids that integrate added functionalities from the new information and communication technologies, which link all components of the power grid (including generating stations, distribution facilities, transformers, businesses, and households), in order to integrate the behaviours of both consumers and suppliers. According to the EU, Smart Grids are intended to ensure an economically efficiency, and to provide a sustainable power system with low losses and high levels of quality and security of supply and safety.

The main differences between the current electric grids and the smart electric grids can be summarized as follows:

Features of current grids	Features of smart grids
Analogue/Electromechanical	Digital
Unidirectional	Bidirectional
Centralized production	Distributed production
Communication on partial sections of the grids (Hierarchical)	Communication on the whole grid (Network)
Electric system balance management through the offer / production	Electric system balance management through the demand / consumption
Consumer	Conscious consumer
Manual restoration	Self-healing
Manual check and test	Remote check and test
Few sensors	Sensors throughout
Limited control	Pervasive control

The architecture of a smart grid is generally composed of 3 levels:

- The first level consists of transporting electricity via a classical electrical infrastructure (cables, transformers, etc.)
- The second level encloses the communication architecture, which is based on different communication technologies (Fibre optics, General Packet Radio Service, power-line communication, etc.). It enables system components to exchange information and commands securely and reliably.
- The last level is considered as the intelligent core and it is composed of applications and services such as remote trouble shooting fixing system or automated programmes that use real time information to answer the electricity demand.

Consequently, using Smart Grids allows managing the electrical system in a more flexible way to limit the constraints such as irregularities of renewable energies or the development of new uses (e.g. electrical cars). The final objective is to constantly ensure a balance between supply and demand and to provide safe, sustainable and economically efficient electrical power while increasing energy efficiency, reducing peak demand and being able to integrate low carbon energy sources into the grid.

Finally, it is important to mention that the development of Electric Smart Grids needs the consensus on some standards that allow the communication and data exchange between the different components of the SmartGrid. Some standards have already been approved for this purpose by NIST (United States National Institute of Standards and Technology) and the European Commission, which is working on Europe's AMI standard for Smart Grids.

References description

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- http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/2014_dpia_smart_grids_forces.pdf
- https://www.smartgrid.gov/the_smart_grid
- http://www.renesas.eu/ecology/eco_society/smart_grid/
- http://www2.schneider-electric.com/sites/corporate/en/group/energy-challenge/smart-grid.page
- http://www.hitachi.com/environment/showcase/solution/energy/smartgrid.html
- http://www.smartgrids-cre.fr/index.php?p=definition-smart-grids (in French)
- http://www.dalkia.ie/media/energy_bulletins/smart-grids.htm
- http://ec.europa.eu/energy/gas_electricity/smartgrids/doc/expert_group1.pdf
- http://new.abb.com/smartgrids/what-is-a-smart-grid
- http://www.silverspringnet.com/pdfs/whitepapers/SilverSpring-Whitepaper-SmartGridStandards.pdf

Figure

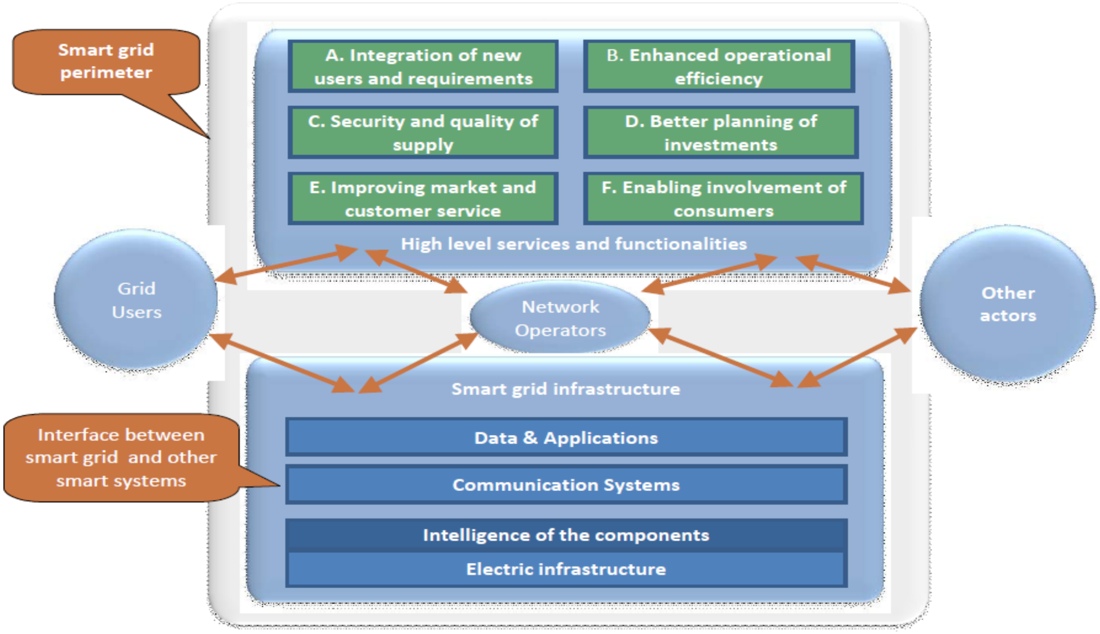
Figure	
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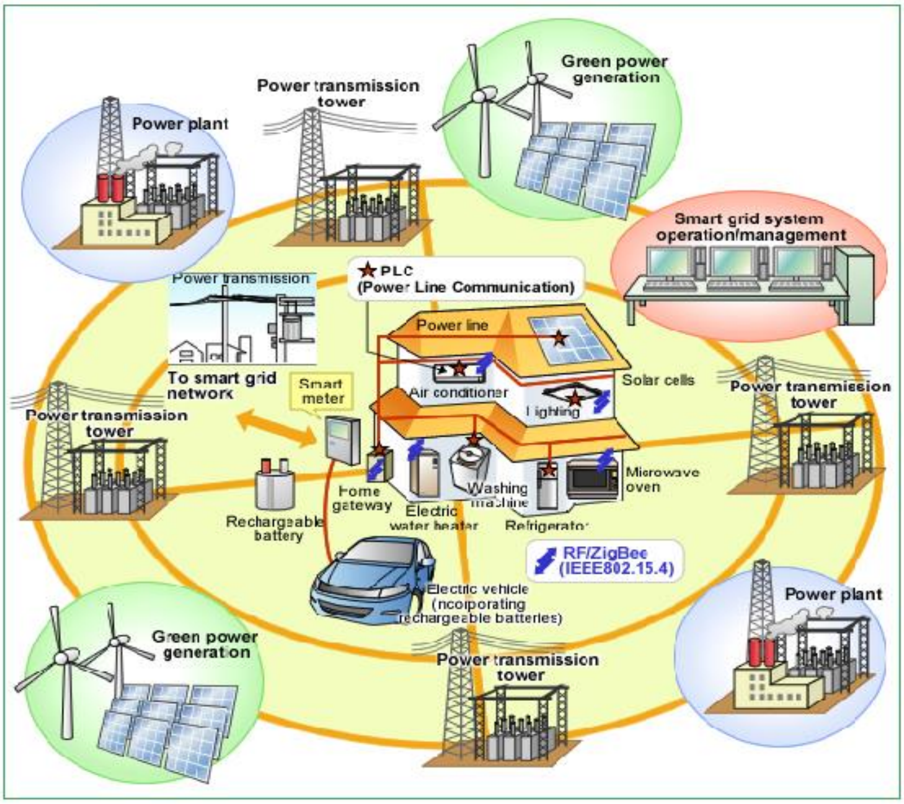
Figure	
Source	http://www.renesas.eu/ecology/eco_society/smart_grid/

Technical parameters

Medium: Electricity / IT

Energy efficiency : More efficient and more reliable than the currently used electric grids

Temperature level: N/A

Thermal Capacity: N/A

Electric capacity : According to the context

Description other parameters

Legal conditions or restrictions: Data security and privacy.

Operational, financial and managerial conditions and/or consequences: Total investment cost is important but subsidies can be obtained and it has a high return on investment (ROI).

Applicable for hospitals: Yes. Smart Electric grids can be implemented either on a building scale or on the healthcare district scale.

Available and reliability of the system: the Smart Electrical Grid will make it possible to better manage peak demands while being more efficient.

Scale: Building/District/City.

Practical example

There exist many Smart Electrical Grids pilot projects and real cases. Below you can find a small description and a reference for threre of them:

- **IssyGrid®:** It is the first French pilot project for district level energy usage optimisation, created by an Issy-les-Moulineaux city and Bouygues Immobilier initiative. https://www.issy.com/en/home/issy-a-smart-city/issygrid
- **National Grid:** It is a Smart Grid that involves about 15000 customers, community and stakeholders from across Worcester, MA, USA. http://www.worcesterma.gov/announcements/national-grid-and-city-of-worcester-bring-the-future-of-energy-to-ma-with-largest-smart-grid-pilot-in-the-state
- **TSECL:** A Smart Grid pilot project at Agartala, India, which covers about 46000 customers. http://indiasmartgrid.org/en/Pages/Projects.aspx?ID=6

Factsheet Smart Thermal Grid

Description

Smart Thermal Grids can be defined as the district cooling and heating network, in which all urban energy systems are connected to the other urban infrastructures, such as electricity network, sewage, and waste. It ensures reliable and affordable heating and cooling supply by the participation of end-users; i.e., they can supply heating or cooling back to the network. It aims at lowering costs and heat grid losses by improving the components and creating synergy by decreasing the buildings' heat or cooling demands. The final goal is to realise to very flexible, distributed and fully carbon neutral energy solutions.

A Smart Thermal Grids is a network of pipes connecting the buildings in a neighbourhood, town centre or whole city, so that they can be served from centralised plants as well as from a number of distributed heating or cooling production units including individual contributions from the connected buildings. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.

It is intended to avoid the usage of peak load production sources (which often uses fossil fuel) and to reduce energy consumption. The aim of Smart Thermal Grids is to ensure a safe, sustainable and economically efficient thermal power (heating and cooling supply).

Relevant elements and features of a smart thermal grid are:

- Low temperature network.
- Smaller pipe dimensions.
- District heating pipes with improved insulation.
- Supply and return pipes in a loop layout to establish circulation of supply pipe during summer.
- Intelligent control and metering of the network performance.

Smart Thermal Grids are flexible in the short, medium and long terms, able to adapt depending on the circumstances in supply and demand, integrate the end users' actions and behaviours while increasing energy efficiency, reducing peak demand and being able to integrate low carbon energy and local sources into the grid (e.g. such as solar thermal, biomass and geothermal energy). The integration of these grids in a specific district needs be carefully planned, of ensuring they can interact with the whole district energy system and infrastructure.

Similarly to smart electrical grids, adaptations of current technologies structures are necessary to develop such grids especially through storage systems, smarts sensors/substations, connections with IT systems, etc.

Smart thermal grids are an active research area; currently, researchers are working on the fourth generation for district heating (4GDH) that shall be applied during the next few years.

References description

- Henrik Lund, Sven Werner, Robin Wiltshire, Svend Svendsen, Jan Eric Thorsen, Frede Hvelplund, Brian Vad Mathiesen, 4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems, Energy, Volume 68, 15 April 2014, Pages 1-11, ISSN 0360-5442, http://dx.doi.org/10.1016/j.energy.2014.02.089.
- Fredrik Wernstedt, Paul Davidsson, and Christian Johansson, 'Demand side management in district heating systems', in Proceedings of the 6th international joint conference on Autonomous agents and multiagent systems, AAMAS '07, pp. 272:1–272:7, New York, NY, USA, (2007). ACM.
- Christian Johansson, Fredrik Wernstedt, and Paul Davidsson, 'Deployment of agent based loadcontrol in district heating systems', in Proceedings of the First Agent Technology for Energy Systems Workshop, Ninth International Conference on Autonomous Agents and Multiagent Systems, (2010).
- http://www.rhc-platform.org/fileadmin/2013_RHC_Conference/Presentations/Tuesday_23rd_April/Session_G/1/Philippe_Dumas_Smart_cities_-_Solution_Proposal_Smart_thermal_grid.pdf
- http://eu-smartcities.eu/sites/all/files/Smart%20Thermal%20Grids%20-

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- http://ec.europa.eu/energy/publications/doc/2011_energy2020_en.pdf
- http://vbn.aau.dk/files/78422810/Smart_Energy_Systems_Aalborg_University.pdf

Figure

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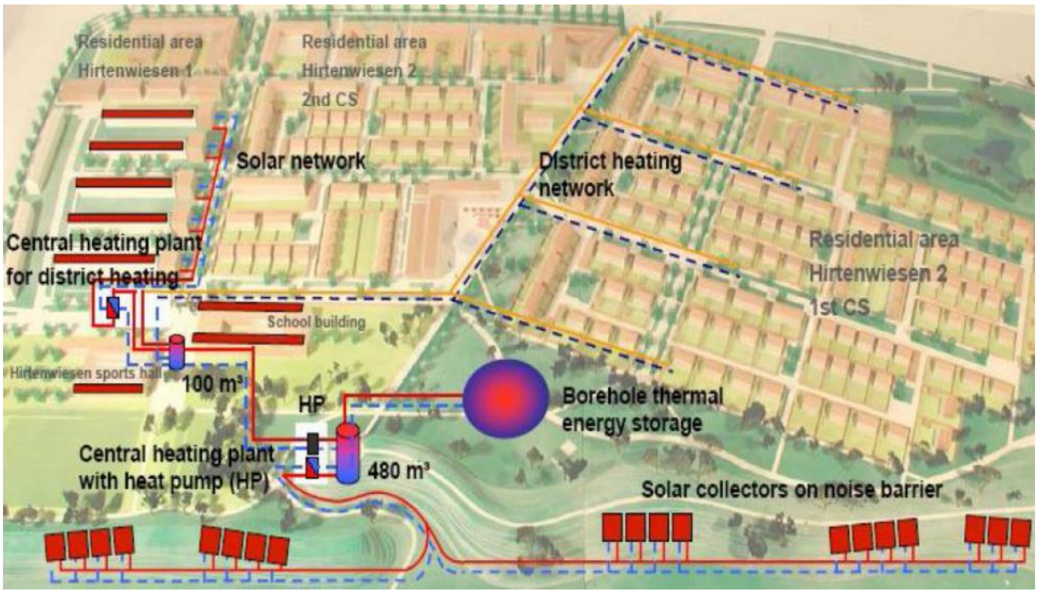

Source http://eu-smartcities.eu/sites/all/files/Smart%20Thermal%20Grids%20-%20Smart%20Cities%20Stakeholder%20Platform.pdf (page 3)

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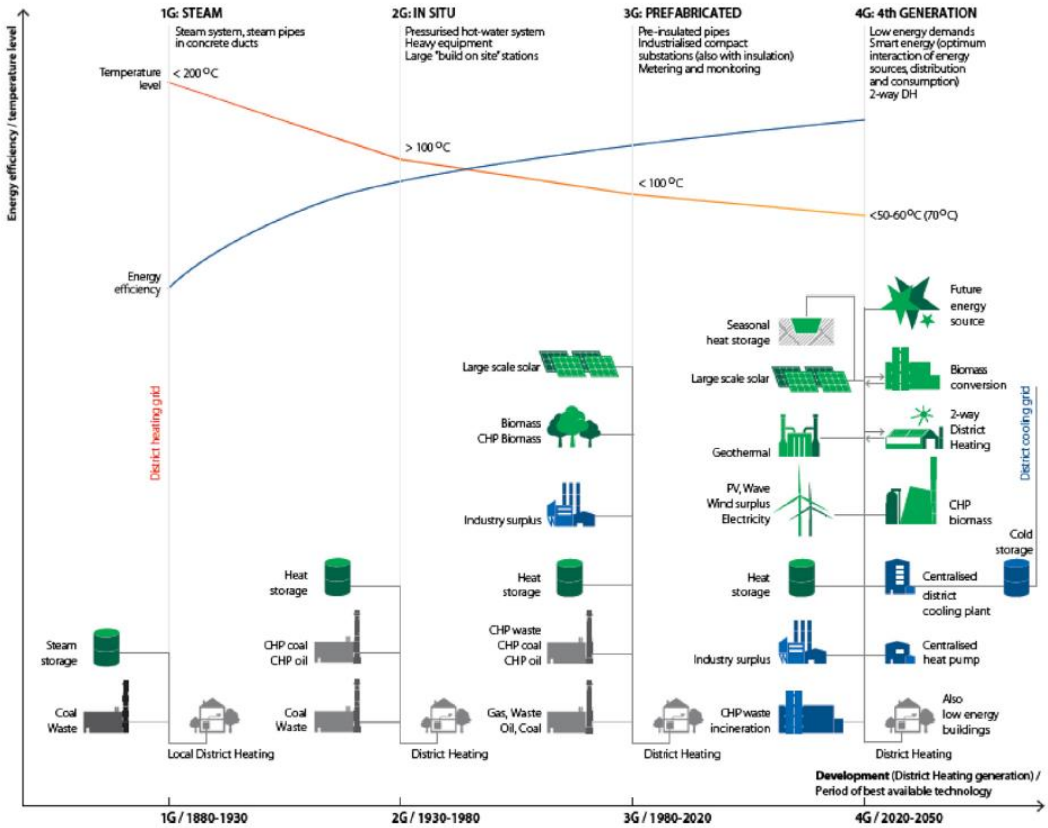

Source http://dx.doi.org/10.1016/j.energy.2014.02.089

Technical parameters

Medium: Thermal power

Energy efficiency : Better than the current grid

Temperature level: Depending on the context

Thermal Capacity: Depending on the context

Electric capacity: N/A

Description other parameters

Legal conditions or restrictions: data security and privacy.

Operational, financial and managerial conditions and/or consequences: total investment cost is important but subsidies can be obtained.

Applicable for hospitals: Smart thermal grid can be implemented on the healthcare district scale.

Available and reliability of the system: the smart thermal grid will make it possible to better manage peak demands while being more efficient.

Scale: District/City – depending on the context.

Practical example

Several smart thermal grids have been already implemented in Sweden, Denmark, and Netherlands. Below we briefly explain some case studies and include a reference to each.

- **Smart Thermal Grid, TU Delft in The Netherlands** in which the district heating grid covers the majority of the heat demands at the TU.

http://repository.tudelft.nl/assets/uuid:727209bf-8f38-4914-a9d8-0dc68ee38acb/Thesis_Edwin_van_Vliet_2013_.pdf

- **Thermal network in Heerlen, The Netherlands**: Aims at developing an optimal energy system for the Heerlen campus, based on the principles of exergy planning.

http://www.rug.nl/staff/f.m.g.van.kann/postercampusheerlen.pdf

- **Sunstore4 demonstration in Marstal, Denmark**: A European Project that integrates 100% renewable energy plant, based on solar energy and biomass energy (willow wood chips from energy crops), including a compressor heat pump using CO2 as refrigerant and electricity production from biomass.

http://sunstore4.eu/

Factsheet Building energy prediction

Description

The aim of this technology is to predict the energy consumptions of a building by means of the analysis of data and of its thermal behaviour (outdoor temperature, solar radiation, heating/cooling system power etc.). It aims at improving the building performance, achieving energy conservation, and reducing environmental impact. It is also important for preparing an implementation plan convincing building owners to renovate with energy-saving, energy-generating, and energy-storing solutions.

This is a complex problem since the energy behaviour of a building is influenced by many parameters, such as weather, building material, location, occupancy, to mention a few. Modelling and predicting building energy consumption uses engineering, statistical, and artificial intelligence models, whereas the main difficulty resides in developing a flexible model, which can be easily re-used for different buildings (no matter the scale of the study, the location of the building, etc.).

The engineering methods use physical principles to calculate thermal dynamics and energy behaviour on the whole building level or for sub-level components. Statistical models simply correlate the energy consumption or energy index with the influencing variables. These empirical models are developed from historical performance data, which means that before training the statistical models, it is necessary to collect enough historical data. Neural networks are the most widely used artificial intelligence models in the application of building energy prediction. This type of models is good at solving non-linear problems and is an effective approach to this complex application. The last used model is called the grey model, which can be used to analyse building energy behaviour when there is only incomplete or uncertain data. Very little work has been done regarding this model.

References description

- Hai-xiang Zhao, Frédéric Magoulès, A review on the prediction of building energy consumption, Renewable and Sustainable Energy Reviews, Volume 16, Issue 6, August 2012, Pages 3586-3592, ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2012.02.049.
- http://www.nt.ntnu.no/users/skoge/prost/proceedings/ifac2014/media/files/1519.pdf
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- http://www.bartlett.ucl.ac.uk/iede/research/project-directory/projects/energy-consumption-office-buildings
- http://campustechnology.com/articles/2014/10/09/carnegie-mellon-manages-energy-usage-with-predictive-analytics.aspx

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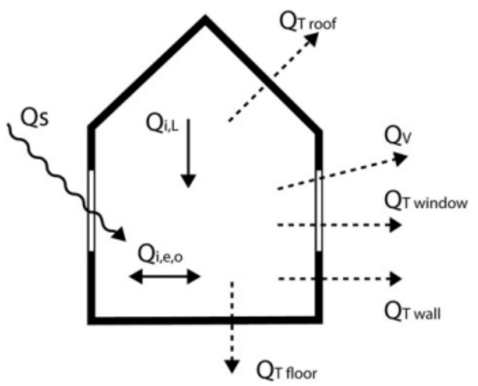


Source: An example of a energy prediction model (http://dx.doi.org/10.1016/j.autcon.2008.07.003)

Technical parameters

Medium: IT

Energy efficiency : N/A

Temperature level: N/A

Thermal Capacity: N/A

Electric capacity: N/A

Other parameters……

Description other parameters

Legal conditions or restrictions: Some estimation tools are freeware and others are commercial tools.

Operational, financial and managerial conditions and/or consequences: N/A

Applicable for hospitals: Yes

Available and reliability of the system: This technology is growing up especially through the development of the BIM. Nevertheless, the reliability of the information still has to be confirmed since it is only an estimation.

Scale: Building or group of buildings

Practical example

- **EnPROVE Project**: a European project whose objective is to develop a reliable method in predicting energy consumption of a building once appropriate energy-efficient technologies are employed.
- **CityNet project**: This project was part of the FP6 Marie-Curie Actions Research Training Network: CityNet focusing on developing a model for energy consumption in office buildings at a stock level.
- **Carnegie Mellon University**: They have a project in which they monitor nine buildings energy consumption and predict energy consumption based on this information.
- Many other tools have been developed for this purpose and for simulation, such as: DOE-2, EnergyPlus, BLAST, ESP-r, and TRNSYS.

Factsheet Geothermal energy

Description

Geothermal power consists of using the heating potential accumulated in the subsoil. The subsoil temperature depends on the depth and the geothermal gradient in the area in question. It is a very relevant energy resource. It's origin comes from the interior heat of the Earth which is fed, among other causes, by the disintegration of radioactive isotopes and the differential movements between the various layers that form the Earth.
Going into the Earth's crust, the temperature increases at a rate of 2.5 to 3°C for each 100 m over most of the planet.
The geothermal resource is the amount of heat given off by the Earth's interior which in the conditions of technological developments at each time allows its use in suitable financial conditions.
There are various types of geothermal energy sources, depending on the temperature of the geothermal fluid.

The following figure shows the working principle of a geothermal doublet. Two wells are drilled from the surface into an aquifer layer, one is for extracting hot water and the other is for reinjecting the water into the aquifer after its heat is absorbed in a heat exchanger. The source temperature depends on the depth of the source and the layer structure underground. As a rough estimate, the ground temperature close to the surface can be assumed a constant 10°C. Hot water is extracted from the aquifers using a production pump which is situated in the subsurface and it needs to be replaced every 5 years. Usually a second pump is also deployed at the reinjection side. A heat exchanger is needed to extract the heat from the underground water and use it for heating purposes.

References description

RES-HOSPITALS, Towards Zero Carbon Hospitals with Renewable Energy Systems: www.res-hospitals.eu:

- Final Technical Implementation Report Rijnstate - Arnhem (NL), N. Cankoy, A.A.L. Traversari, 20 November 2013
- RES Guide for European Hospitals Gorliz Hospital Basque Region, J.A. Arriarán, I. Minguez, November 2013

Figure

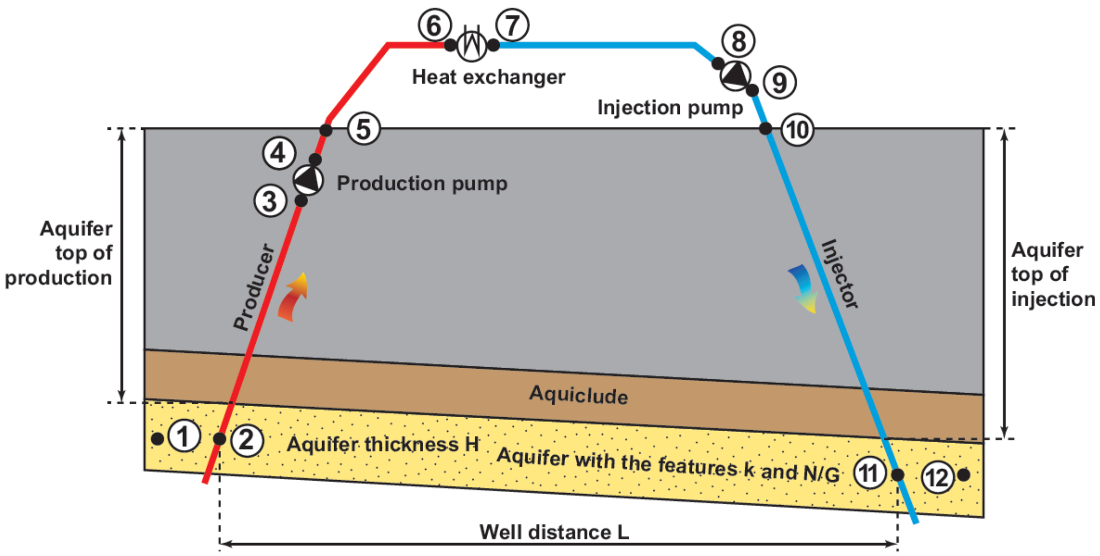


Illustration of a geothermal doublet (Source: J.D. v. Wees, „Geothermal aquifer performance assessment for direct heat production – Methodology and application to Rotliegend aquifers," Netherlands Journal of Geosciences, vol. 91, nr. 4, pp. 651-665, 2012).

Technical parameters

Medium: hot water

Outlet temperature: 80-200°C

Reinjection temperature: 40°C

Flow rate: N/A

Thermal Capacity / Heat Power: At least 4 MW

Description other parameters

Legal conditions or restrictions: In the Netherlands the new Mining Act regulates, among other issues, the detection, exploration and extraction of geothermal energy. For all these activities licenses are needed. Interviews with survey and drilling companies revealed that the mining act is no barrier.
Operational, financial and managerial conditions and/or consequences: The biggest financial limitation for an investment on geothermal energy is the required initial investment for the drilling costs. The drilling costs depend on the application type and on the required drilling depth. Yet the needed investments are at least at the level of 5 M€. This may cause difficulties to finance the project although it may prove highly profitable in the long-term. In addition, there will be yearly costs related to the electricity consumption of the pumps and the maintenance of the system.
Applicable for hospitals: Due to the year round needs, hospitals are ideal objects for the use of geothermal energy. This technique can supply year-round heating and cooling demands of the hospital and neighbour areas if needed, where the cold generation entirely can take place by absorption cooling.
Available and reliability of the system: Geothermal energy in the deep underground is available all year.
Scale: For economic reasons geothermal energy is only applicable on a relatively large scale. A direct application is only appreciated when a hospital consumes enough energy (150,000 GJ) to justify the geothermal investment alone. If the consumption is significantly less, the hospital should connect to other large consumers.

Practical example

For the RES-Hospitals project, a financial analysis of different geothermal options is made for the three participating Dutch hospitals. For these hospitals, geothermal heat is a worthwhile option as it can supply year-round heating and cooling demands of the hospital and neighbour areas if needed. The three hospitals are aware of the possibilities and willing to continue investigating geothermal heat as a renewable source:
Final Technical Implementation Report Rijnstate - Arnhem (NL), N. Cankoy, A.A.L. Traversari, 20 November 2013;
Final Technical Implementation Report TweeSteden - Tilburg (NL), N. Cankoy, A.A.L. Traversari, 20 November 2013;
Final Technical Implementation Report Gelre - Apeldoorn (NL), N. Cankoy, A.A.L. Traversari, 20 November 2013;
(www.res-hospitals.eu)

Factsheet Wind Turbines

Description

A wind turbine converts the energy of the wind into a circular motion, which by a generator is used to generate electricity.

Currently, wind power is one of the renewable sources in which technology has reached a highest degree of maturity, especially for wind farms on land. We can make a distinction between large high power wind turbines and mini low power wind turbines.

Low wind power can provide distributed renewable power through its integration in urban, semi-urban, industrial and agricultural environments (like hospital sites), especially associated with consumption points in the distribution grid.
Low power wind installations have a number of additional advantages compared to large ones, such as higher overall efficiency because of losses avoided in the transport and distribution systems and because they allow the integration of renewable generating without the need to create new electrical infrastructures.
Low power wind installations have specific advantages that are added to those of large ones:

- Generation of power near to the consumption points;
- Versatility of applications and locations, connected with self-consumption, with the possibility of integration into hybrid systems;
- Technological access to the end user, ease of transport of equipment and installation;
- Operation with moderate winds without requiring complex viability studies;
- Use of small sites;
- Supply of electricity in isolated places far from the power grid;
- Optimisation of the use of existing electrical distribution infrastructures;
- Low operating and maintenance costs and high reliability;
- Reduced environmental impact because of their smaller size and visual impact.

References description

RES-HOSPITALS, Towards Zero Carbon Hospitals with Renewable Energy Systems: www.res-hospitals.eu:

- Final Technical Implementation Report Rijnstate - Arnhem (NL), N. Cankoy, A.A.L. Traversari, 20 November 2013
- RES Guide for European Hospitals Gorliz Hospital Basque Region, J.A. Arriarán, I. Minguez, November 2013

Figure


Picture of mini low power wind turbines on a building (Source: RES Guide for European Hospitals Gorliz Hospital Basque Region, J.A. Arriarán, I. Minguez, November 2013)
Picture of a large high power wind turbine on the site of the Queen Elizabeth Hospital (Source: www.ecotricity.co.uk)

Technical parameters

Medium: electricity

Electric capacity (generator power output): from 1kW to 2.3 MW

Other parameters: wind speed (m/s) and height (m):

A wind turbine with a height of 100 meter and a rotor of 82 meter in diameter has power output of 2.3 MW. Even at less windy regions which are characterized by an average wind speed of 7 m/s at 100 m height, this turbine can produce

5,060 MWh/year (18,214 GJ/year).

Description other parameters

Legal conditions or restrictions: Building a wind turbine requires permits. The legislation regarding larger wind turbines is often seen as very restrictive and time consuming. Especially in the urban environment concerns of local residents should be considered. In the Netherlands large wind turbines can't be constructed on the hospital site, due to a compulsory minimum distance of 400m towards the nearest residential buildings (patient wards in this case).
In each country there can be a lot of laws and regulations that apply to wind turbines, such as spatial planning acts, environmental acts, tax rulings and other laws and regulations, for example in connection with aircraft and radar stations.
Operational, financial and managerial conditions and/or consequences: Wind energy is more efficient in areas with high wind speeds. The wind speed reduces landwards. Besides the geographical situation wind speed is also determined by local obstacles (nearby housing, industry and forests). On shore windmills are also dealing with an increasing public and political resistance, mainly concerning the noise, appearance and the effects on the lives of birds.
Applicable for hospitals: Given the interest due to the short return of interest time of low power wind turbines.
Available and reliability of the system: reliable of wind speed.
Scale: from mini low power wind turbines (1 kW) to large high power wind turbines (2,300 kW)

Practical example

Wind turbines have been installed in a number of hospital sites in North West Europe including England, Denmark, Northern Ireland and Scotland. For example, the Queen Elizabeth Hospital in King's Lynn, England has installed an 800kW wind turbine supplying 18% of electricity demand. This is the first public sector organisation in the UK to be powered by green energy from their own, on site, large scale wind turbine provided in a merchant scheme. The electricity generated will be fed directly to the hospital, reducing its import of conventional polluting electricity, in the process reducing the hospital's carbon emissions and its annual electricity bill.

Versilia Hospital (Italy) and Gorliz Hospital (Spain) have already installed mini low power wind turbines.

Girvan Hospital (UK) is one of the few in the world, and the first in Scotland, to invest in a 100KW wind turbine to supply some of its electricity.

www.res-hospitals.eu
www.ecotricity.co.uk

Factsheet Hydropower system

Description

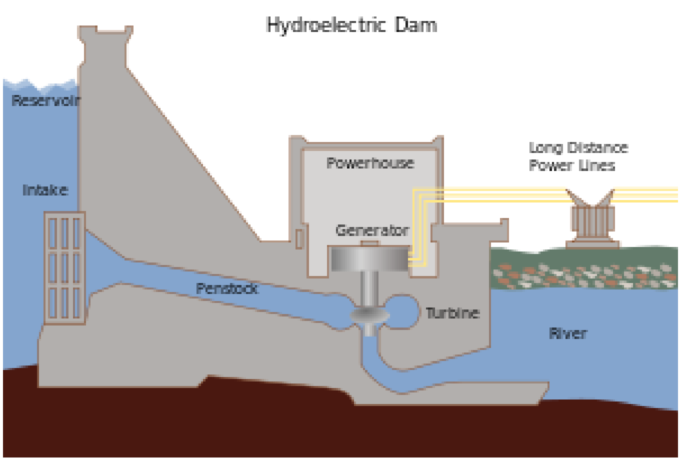
Hydroelectric power is obtained by using the potential energy of the mass of water in a river water course to convert it firstly into mechanical energy and then into electricity. A hydroelectric power station thus consists of a set of installations and equipment needed to transform the potential energy of a water course into available electricity.
There are two basic types of hydroelectric power stations, flowing water power stations and power stations at the foot of a dam.
Flowing water stations use an intake to collect part of the flow of a river for the power station turbines before returning it to the river. This power station type has low power ranges (normally less than 5 MW). This type also includes the "irrigation canal power stations” that use the difference in water level in irrigation canals to produce electricity. The power range of these power stations is between 1 and 5 MW.
Power stations at the foot of a dam consist of building a dam or using an existing one that can store supplies from a river and regulate the flows to the turbines at the precise moment. These power stations usually have power levels above 5 MW. Notable within this type, because of its future perspectives, is the "pumping or reversible power station." These are plants that function as a conventional power station, generating power (by turbines) but can raise the water to a reservoir or a tank while consuming electricity (pumping mode). There are two types, pure pumping in which the upper reservoir is a great tank wich only water supply is the pumping from the lower reservoir, and mixed pumping in which the upper reservoir has natural supplies.
Special other forms of hydropower are tidal and wave power. These, not yet widely used, forms of power generation are mainly situated offshore, and therefore always outside a hospital district.

References description

RES-HOSPITALS, Towards Zero Carbon Hospitals with Renewable Energy Systems: www.res-hospitals.eu:

- RES Guide for European Hospitals Gorliz Hospital Basque Region, J.A. Arriarán, I. Minguez, November 2013

Figure



Cross section of a conventional hydroelectric dam (Source: http://en.wikipedia.org/wiki/Hydroelectricity)

Flowing water power station (Source:www.freeimages.co.uk)

Technical parameters

Medium: electricity

Electric capacity: from 1 MW to > 5 MW

Description other parameters

Legal conditions or restrictions: because of the environmental impact there are a lot of legal conditions and restrictions for using hydropower systems.
Operational, financial and managerial conditions and/or consequences: Hydroelectric plants are very expensive to build, and must be built to a very high standard. The high cost means that plants must operate for a long time to become profitable. The creation of dams can also create flooding of land, which means the natural environment and the natural habitat of animals, and even people, may be destroyed. The building of dams for hydroelectric power can also cause a lot of water access problems. The creation of a dam in one location may mean that those down river no longer have control

of water flow. This can create controversy in places where neighboring countries share a water supply.
Applicable for hospitals: direct use of these hydropower systems is only applicable for hospitals if there's flowing water, a dam or a river with a difference in water level nearby the hospital district.
Available and reliability of the system: available all year.
Scale: large (from 1 MW up to more than 5 MW).

Practical example

Examples of hospitals that use energy (partly) generated by hydro power systems appear to be in Denmark, Luxembourg and Portugal:

- Bornholms Hospital
- Sygehus Sonderjylland
- Hôpital Kirchberg
- Hospital Amato Lusitano
- Hospital Fernando da Fonseca
- Unidade Local Saude Norte Alentejano

(Solar) ORC system

Description

(Solar driven) ORC can be used for electricity and heat production or hot water production. ORC systems are based on the vaporization of a high pressure liquid which is in turn expanded to a lower pressure thus releasing mechanical work. The cycle is closed by condensing the low pressure vapour and pumping it back to the high pressure. The working fluid is an organic compound characterized by a lower ebullition temperature than water and allowing power generation from low heat source temperatures.

References description

,,Techno-economic survey of Organic Rankin Cycle (ORC) systems''. Quoilin Sylvain, Van Den Broek Martijn, Declaye Sebastien, Lemort Vincent. July 2012

http://ac.els-cdn.com/S1364032113000592/1-s2.0-S1364032113000592-main.pdf?_tid=b3c67e84-6236-11e3-a956-00000aacb360&acdnat=1386747463_5ca493e0b38a1852ddc5772491779832

“ORGANIC RANKINE CYCLE (ORC) IN BIOMASS PLANTS: AN OVERVIEW ON DIFFERENT APPLICATIONS“, Roberto BINI Turboden Srl, Brescia, Italy ”http://www.turboden.eu/en/public/downloads/10A02943_paper_marco.pdf

Figure

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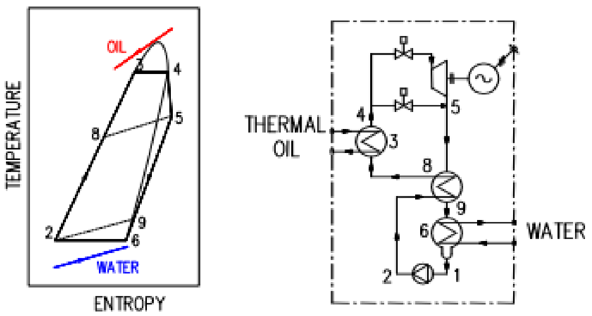


Figure 1: Thermodynamic cycle and components of an ORC unit

http://www.turboden.eu/en/public/downloads/10A02943_paper_marco.pdf

Source: http://ac.els-cdn.com/S1364032113000592/1-s2.0-S1364032113000592-main.pdf?_tid=b3c67e84-6236-11e3-a956-00000aacb360&acdnat=1386747463_5ca493e0b38a1852ddc5772491779832

Technical parameters

Medium: R245fa/ SES36

Energy efficiency : 22%

Temperature level: depends on solar collectors type 85-150 °C

Thermal Capacity: 20kW- 5MW

Electric capacity: 4kW-1MW

Description other parameters

Legal conditions or restrictions: Should be checked individually for each installation as legal conditions among the countries may differ. In this technology solar field area can be plant size limiting factor.

Operational, financial and managerial conditions and/or consequences: Investment costs will probably exceed the cost of gas burned CHP because of need of building big solar field . However later maintenance may be less expensive if efficiency of designed system will be higher than standard CHP. Main condition is to gather enough solar energy which may be problematic in regions where solar radiation is rather small.

Applicable for hospitals: There is application potential in the hospital environment as technology has rather small impact on environment.

Available and reliability of the system: Available all year long

Scale: Decentralized – micro ORC or centralized – bigger units

Practical example

Turnkey solution to the ORC plant, including the biomass ORC system, Waste heat recovery ORC system and the Geothermal energy. http://sunjianhua107979.en.ec21.com/offer_detail/Sell_ORC_BIOMASS_POWER_PLANT--10434245.html?gubun=S

Factsheet Waste to energy. Incineration plant

Description

An incineration plant is a waste to energy facility. This technology helps to solve waste storage problem, supplying neighborhood with thermal and electrical energy at the same time. This technology became popular in Denmark and Japan and is well known and tested. Nowadays, modern incinerators are equipped in pollution mitigation systems (e.g. flue gas cleaning). The main types of incinerator plants are :moving grate, rotary-kiln, fluidized bed and fix grade. Usually systems are design to provide heat recovery.

A waste to energy plant consist of a deception and waste feeding system, one Or more incineration units complete with bottom ash handling system, boiler, flue gas treatment and stack. [2]

If there is a CHP plant in the facility, the boiler is a steam boiler and produced steam is transferred to a turbine, which drives a steam generator. Heat can be recovered and used for district heating production. The flue gas generated thanks to five steps of treatment is cleaned of dust, heavy metals, acid gasses (HCl, HF and SO_2). [2]

The emission limit values are specified in National Standards and the underlying EU Waste Incineration Directive (No.2000/76). [2]

An investigation, which was taken in Krakow, Poland , to assess the environmental effect of the secondary solid waste generated during the incineration process of medical waste showed that :

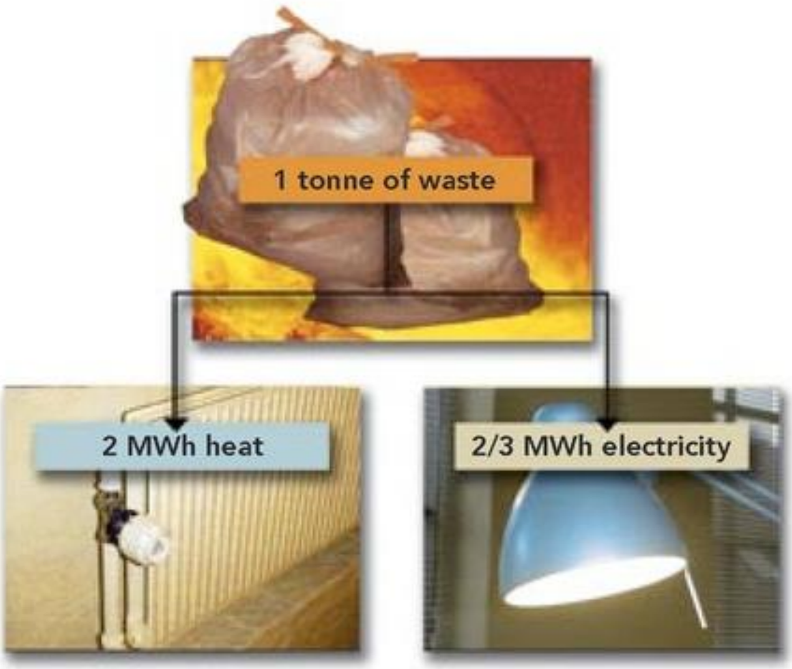
- “the hospital waste incineration plant significantly solves the problems of medical waste treatment in Krakow
- the detected contaminant concentrations were generally lower than the permissible values;
- the generated ashes and slag contained considerable concentrations of heavy metals, mainly zinc, and chloride and sulphate anions. Ashes and slag constituted 10–15% of the mass of incinerated wastes; they are more harmful for the environment when compared with untreated waste, and after solidification they can be deposited in the hazardous waste disposal.” Quotation from [1]

References description

1. [1]- Agnieszka Gielar, Department of Environment Protection, AGH University of Science and Technology, Faculty of Geology, Geophysics and Environment Protection, Al. Mickiewicza 30, Krakow, 30-059, Poland. Email: agnieszkagielar@geol.agh.edu.pl
2. Waste to energy In Denmark , http://viewer.zmags.com/showmag.php?mid=wsdps

Figure

Source: Global Environment Center Foundation , http://nett21.gec.jp/waste/data/waste_K-4.html



Source: Waste to energy In Denmark , http://viewer.zmags.com/showmag.php?mid=wsdps

Technical parameters

Medium: solid wastes

Energy efficiency : electrical energy 30%, heat energy

Temperature level: steam c.a. 450^{o}C

Pressure: 42 Bars

Thermal Capacity: up to 20 MW

Electric capacity: up to 10 MW

Description other parameters

Legal conditions or restrictions: Emission limit values have to be kept as required according to national and European law. Should be checked in every case study individually as depends on plant size and burned wastes type and environment.

Operational, financial and managerial conditions and/or consequences: Main issue is waste storage and problems with germs and bacteria. Long waste storage is not recommended in hospital district. Wastes should be burn immediately, what not always is possible. Fumes have to be tested in order to prevent air contaminations as burning wastes can cause one, chimney filters and laboratory tests may generate additional expenses. Wastes should be previously segregated what can be an additional cost.

Applicable for hospitals: Smaller Local plants can be applied.

Available and reliability of the system: All year long

Scale: centralized,

Practical example

Figure 1. Entimos power plant in Tervola, Northern Finland

http://www.wienenergie.at/media/files/2008/technik-bro-spittelau%20-%20englisch_9396.pdf

http://www.cardiff.ac.uk/archi/programmes/cost8/case/energy/tervola.html

http://www.energ-group.com/energy-from-waste/our-plants/

Factsheet Energy Recycling System Using Chemical Heat Pump Container (CHPC)

Description

This technology enables to store waste heat from various technological processes. Heat is preserved as chemical energy in CHPC unit. Chemical heat pump can store thermal energy from; technological heat, the Sun, geothermal energy etc. Energy can later be released at various temperature levels. [1]

Recover waste heat can be moved from one place to another without significant losses.

A CHPC Unit can produce temperature lifts exceeding of 100°C at output temperatures up to 250°C. This makes a lot of opportunities for application and high energy saving potential. [2]

Technology main advantages are:" long thermal storage, high energy storage density, no other energy sources, and large output temperature range." [1]

Main disadvantageous is that this technology is not easy available on the market and well tested.

References description

[1]- Energy Recycling System Using Chemical Heat Pump Container. Hironao Oguraa, Dept. of Urban Environment Systems, Chiba University, Chiba, 263-8522 , Japan

[2]- Energy ResearchCcenter of the Netherlands; Chemical heat pump for utilization of industrial waste heat

https://www.ecn.nl/fileadmin/ecn/units/eei/Onderzoeksclusters/Restwarmtebenutting/b-07-037.pdf

Figure

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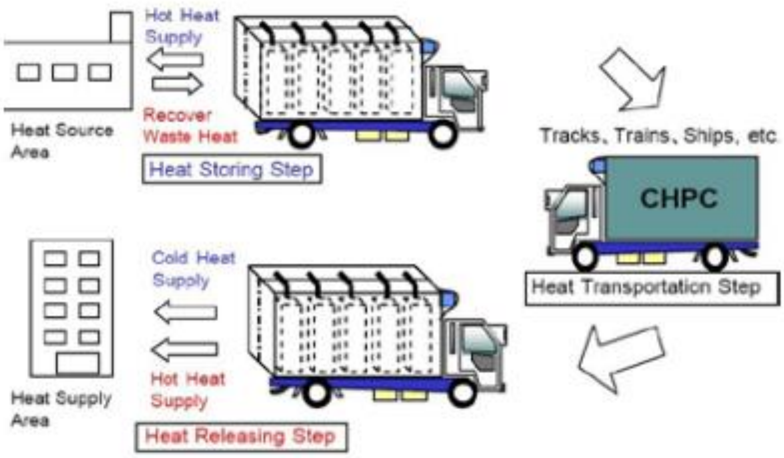


Proposed waste heat recycling system using Chemical Heat Pump Container

Source: http://ac.els-cdn.com/S1876610211046261/1-s2.0-S1876610211046261-main.pdf?_tid=89b1f276-6e5c-11e4-8e9f-00000aacb35d&acdnat=1416230625_1874846e4ff48250ddadac7066bed756

Technical parameters

Medium: chemical compounds (vapor in a salt)

Energy transformation efficiency : 30%

Temperature level: input waste heat temperatures can be between 80-150°C and the output temperatures are in the range of 150-250°C

Temperature lift : 50- 100 °C

Description other parameters

Legal conditions or restrictions: Not known

Operational, financial and managerial conditions and/or consequences: Problems with design and maintenance as technology is not well described.

Applicable for hospitals: Rather small applicability in hospital district as technology is not well tested and reliability cannot be estimated.

Available and reliability of the system: Not known/ technology haven not been tested

Scale: Small to Medium power plants

Practical example

There were no application of this technology found

Integrated gasification combined cycle (IGCC)

Description

Natural gas-based combined cycle CHP plants have the potential of a higher electrical efficiency compared to conventional steam cycle CHP plants. The number of these plants has increased sharply during the last decade in Europe. Technologies for integrating gasification have the potential for achieving higher electrical efficiencies in combined cycle (IGCC) plants also for solid fuels that are difficult to handle, such as biomass and waste. However, total efficiency is lower than using conventional steam cycle CHP plants since operating conditions for gas turbines preclude condensation of flue gases. With higher prices of natural gas and CO2 allowances, a conversion of existing plants' operation into integrated biomass gasification operation (BIGCC) might be of interest as well.

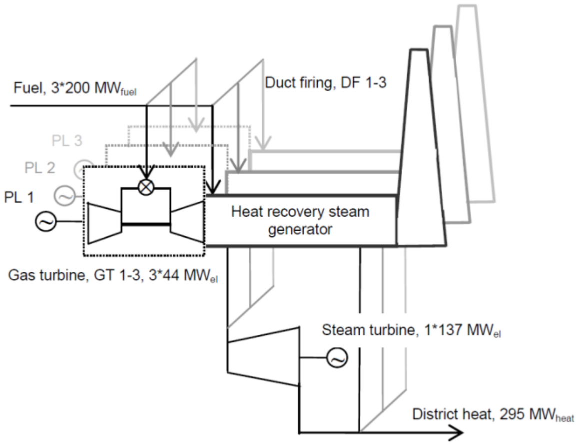
References description

The technology for biomass gasification and its technical application for heat, power and transport fuel generation have been extensively researched; for a review of recent research and demonstration projects, see Wetterlund (2012). The technical performance of different strategies for the use of low calorific biomass derived gases in combined cycle plants has been evaluated by Rodrigues et al. (2007). A feasibility analysis of co-firing of gasified biomass and natural gas in combined cycle plants has been made by Walter and Llagostera (2007). In a techno-economic study of biomass combustion and gasification technologies in CHP applications, biomass costs, the plants' annual fixed cost for equipment purchase, nominal efficiencies and load factors have been claimed as some of the most important parameters for the economic performance, Dornburg and Faaij (2001).

Börjesson and Ahlgren (2010) use an optimization model to identify cost-optimal DH solutions of biomass gasification integration on a regional scale. They find that limited local biomass resources (available at lower cost than imported biomass fuels), together with the limited heat sink capacity of district-heating systems, result in a trade-off situation between renewable power and transport fuel generation in the regional energy system. The size of district-heating systems is shown to be especially important for the integration of BIGCC plants due to economies of scale and to the higher heat generation of these plants in comparison to bio transport fuel plants.

- Wetterlund, E., 2012. System studies of forest-based biomass gasification. Dissertation No. 1429, Linköping University of Technology. Available at: http://www.diva-portal.org/smash/get/diva2:488688/FULLTEXT01.pdf (141202).
- Börjesson, M., Ahlgren, E.O., 2010. Biomass gasification in cost-optimized district heating systems - A regional modelling analysis. Energy Policy 38, 168-180.
- Rodrigues M., Walter A., Faaij A., 2007. Performance evaluation of atmospheric biomass integrated gasifier combined cycle systems under different strategies for the use of low calorific gases. Energy Conversion and Management 2007;48(4):1289-1301.
- Walter A., Llagostera J., 2007. Feasibility analysis of co-fired combined-cycles using biomass-derived gas and natural gas. Energy Conversion and Management 2007;48(11):2888-2896.
- Dornburg V., Faaij A.P.C., 2001. Efficiency and economy of wood-fired biomass energy systems in relation to scale regarding heat and power generation using combustion and gasification technologies. Biomass and Bioenergy 2001;21(2):91-108.

Figure



Source: Schematic illustration of the Rya NGCC CHP plant with its three production lines. Source: Fahlén, E. and Ahlgren, E.O., 2009. Assessment of integration of different biomass gasification alternatives in a district-heating system. Energy 34 (2009) 2184–2195.

Technical parameters

Medium: solid fuel/product gas/steam/hot water/electricity

Energy efficiency : Large-scale natural gas combined cycle (CC) power plants are reaching electrical efficiencies of 60% (based on LHV); if not only power but also heat would be generated in the natural-gas-based CC plants, total efficiency would increase to about 90% (based on LHV), whereas potential electrical efficiency would be reduced to about 50% (based on LHV). If also considering the thermal efficiency of gasifying the fuel, the overall efficiencies will be lower. The efficiency of the gasification process depends on the technology and fuel used.

Description other parameters

Legal conditions or restrictions: Same as for CHP plants in general.

Operational, financial and managerial conditions and/or consequences: Biomass costs, the plants' annual fixed cost for equipment purchase, nominal efficiencies and load factors have been claimed as some of the most important parameters for the economic performance of a BIGCC plant, as previously mentioned.

Applicable for hospitals: Same as for CHP plants in general.

Available and reliability of the system: Same as for CHP plants in general.

Scale: The size of the district-heating system or the size of the heat load is important for the integration of cost-intensive BIGCC plants due to economies of scale.Largest IGCC plant today 1.300 MW (the Nuon plant in the Netherlands).

Practical example

Example of co-location of a gasification plant with a natural gas combined cycle CHP plant in the Rya harbor in Gothenburg, Sweden.

http://www.goteborgenergi.se/Files/dok/Projekt/Rya/Rya_teknisk_eng.pdf (141202)
http://www.power-technology.com/projects/nuonmagnum-igcc/

http://www.goteborgenergi.se/English/Projects/GoBiGas__Gothenburg_Biomass_Gasification_Project (141202)

Load leveling and management

Description

Strong load variations, in district heating and cooling systems and in the power network, do not only contribute to an inefficient resource utilization; they may also constitute a hindrance for the penetration of new advanced technologies which need many operation hours to justify the higher investment costs for the more complex equipment needed. Thus, there is need for load leveling and management or other types of system strategies.

In colder countries, strong seasonal and daily load variations in district-heating systems limit the utilization of base load technologies and increase the need for part load and peak load generation associated with lower efficiencies and higher emissions and operation costs. Many larger Swedish district-heating systems are characterized by a high share of the heat supply coming from waste-fuelled plants, industries and CHP plants and, in some of these district-heating systems, heat is wasted during low demand periods.

There are possibilities for peak-shaving by demand-side measures which may be relevant for both electricity and heat consumption. So-called demand-side response occurs when the user chooses to use the energy products during low-demand (and low-cost) periods. For some applications, it may be possible to alter the time schedule for heat-demanding processes, such as drying wet fuels until periods with low heat demand. Alternatively, seasonal thermal storages may be used that have also proven to be profitable in certain district-heating systems with high dependence of oil for peak load heat generation (Zinko and Gebremedhin, 2008). However, seasonal thermal storage requires large volumes for storing considerable amounts of heated water and is associated with high heat losses unless equipped with expensive insulation.

Thermal storage of heat is more commonly used for short-term load leveling; typically, daily or weekly variations in heat demand are managed by thermal storage in pressurized or non-pressurized steel tanks. This system strategy has the potential for not only reducing the need for peak capacity and the use of expensive fuel, but also for increasing CHP generation (Henning, 1998; Wigbels et al., 2005). Moreover, thermal storage in combination with heat pumps has the potential for balancing electricity supply and demand in energy systems that are characterized by a high share of wind power and CHP plants, as in Denmark (Lund and Clark, 2002). Another system strategy for short-term load leveling would be utilizing the inherent inertia in a DH network (Wigbels et al., 2005), as well as in building mass and radiator circuit piping systems (Olsson Ingvarson and Werner, 2008).

Another interesting system strategy would be to construct regional district-heating networks by interconnecting existing district-heating networks to enable regional optimization. This may level out the variations in the load profiles between different kinds of end consumers. This also creates opportunities for connecting additional customers in less populated areas, as well as new excess heat deliverers. Such regional projects have become a reality in several regions in Sweden and may also be fruitful in other regions and in other countries as well.

Naturally, the cooling demand is highest when the heating demand is lowest. Implementation of heat-driven absorption cooling is therefore one possible way of increasing the heat load during low-demand periods (Fahlén et al. 2012). At hospital areas, where there is need for both heating and cooling, the utilization of heat-driven absorption cooling technology could be one interesting strategy for increasing the energy efficiency and for reducing the climate change contribution of a district heating and cooling system by utilizing excess heat rather than electricity for cooling.

In warmer countries, the peeks in the power demand are partly due to the use of electricity-driven cooling facilities. Within the European countries, the growing number of cooling facilities increases the already strong daily variations in electricity demand and thereby also the need for peak load power generation which is associated with high operating costs and CO_2 emissions. During summer, power demand for comfort cooling and solar power generation coincide well since both are related to the solar radiation. Therefore, electricity-driven compression chillers coupled with photovoltaics (PVs) may be an interesting solution to meet the peeks in the power demand (Fahlén et al., 2014).

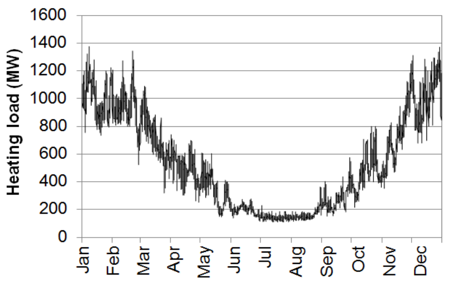
References description

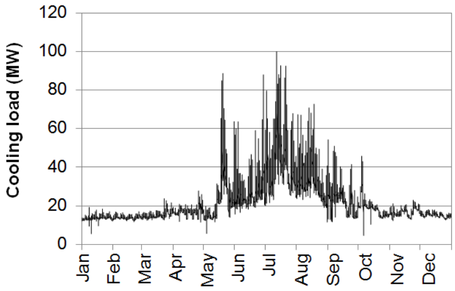
Description of references, see the text above.

- Johansson, I., Larsson, S., Wennberg, O., 2004. Drying of bio fuel utilizing waste heat (in Swedish), Thermal Engineering Research Association (www.varmeforsk.se, 2012-01-25), Report A4-312, 2004.
- Zinko, H., Gebremedhin, A., 2008. Seasonal heat storage in combined heat and power systems (Säsongsvärmelager i kraftvärmesystem, in Swedish), Swedish District Heating Association (www.svenskfjarrvarme.se, 2012-01-25), Report 2008:1.
- Henning, D., 1998. Cost minimization for a local utility through CHP, heat storage and load management. International Journal of Energy Research 22, 691-713.
- Wigbels, M., Bøhm, B., Sipilae, K., 2005. Dynamic heat storage optimisation and demand side management, Annex VII I 2005:8DHC-05.06. IEA DHC/CHP, Available from: www.svenskfjarrvarme.se (2008-11-22).
- Lund, H., Clark, W.W., 2002. Management of fluctuations in wind power and CHP comparing two possible Danish strategies. Energy 27, 471-483.

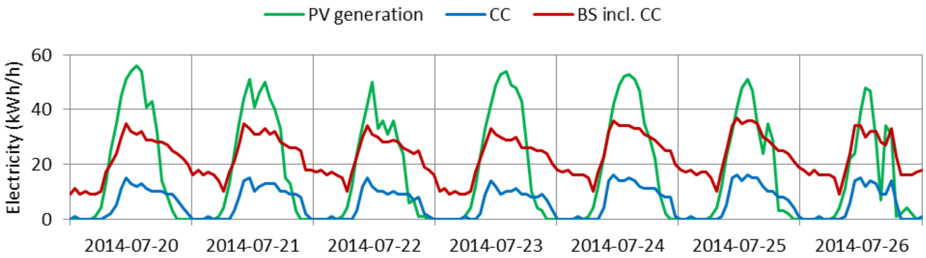
- Olsson Ingvarson, L.C., Werner, S., 2008. Building mass used as short term heat storage, in: Palsson O.A., editor, 11th International Symposium on District Heating and Cooling, University of Iceland, Reykjavik, August 31-September 2, 2008.
- Fahlén E., Trygg L., Ahlgren E.O., 2011. Potential CO2 reduction by increased integration of absorption cooling in a Swedish district energy system. In: 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy, Novi Sad, Serbia, July 4-7, 2011, pp. 3081-3094.
- Fahlén E. et al. (2014). Comfort cooling and solar power – a perfect match? To be published in Rehva Issue 6 (Innovative HVAC solutions for high performance buildings).

Figure





Seasonal and daily load variations in the district heating and cooling system of Gothenburg. Source: Fahlén E., Trygg L., Ahlgren E.O., 2011. Potential CO2 reduction by increased integration of absorption cooling in a Swedish district energy system. In: 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy, Novi Sad, Serbia, July 4-7, 2011, pp. 3081-3094.



Hourly production of solar power and hourly use of electricity for comfort cooling (CC) and of total building service electricity (including power used for cooling, BS. incl, CC) in a passive house retirement home in southwest of Sweden, one week in July 2014. Using the first passive house-certified retirement home in Sweden as a case, the figure illustrates that a comfort cooling plant combined with photovoltaics could be an interesting solution to achieve net zero or near zero in energy use for comfort cooling thanks to the high correlation in power generation and use of electricity. Source: Fahlén E. et al. (2014). Comfort cooling and solar power – a perfect match? To be published in Rehva Issue 6 (Innovative HVAC solutions for high performance buildings).

Technical parameters

Medium: hot water/cold water/electricity

Energy efficiency : N/A

Description other parameters

Legal conditions or restrictions: Same as for CHP plants in general.

Operational, financial and managerial conditions and/or consequences: Same as for CHP plants in general.

Applicable for hospitals: Same as for CHP plants in general.

Available and reliability of the system: Same as for CHP plants in general.

Scale: Same as for CHP plants in general. Steel tanks can store up to approx. 50 000 m3 water and aquifers up to as much as 1 million m3 (MWh depends on the temperature difference.

Practical example

Aquifer thermal energy storage

The largest energy storage in an aquifer in the world is found at the Arlanda airport outside Stockholm, Sweden. Annual energy savings are estimated at about 4 GWh electricity and 15 GWh of heat. It is estimated to reduce carbon dioxide emissions from energy use by 80 - 100 percent.

See: http://www.swecogroup.com/en/Sweco-group/Solutions/Energy/Thermal-storage-gives-Arlanda-eco-friendly-energy-supply-/ (15-02-05)

Steel tanks

A pressurized steel tank has been built in the district-heating system in Borås, Sweden. The tank (37 000 m3) has a four to five time larger than the volume of the district-heating network (8 000 m3). It can store 1600 MWh and will be used for short-term storage on a daily or weekly basis.

See: http://www.borasem.se/vanstermeny/ommiljo/vartmiljoarbete/miljoprojekt/ackumulatortanken.4.4f25c32411dba368edd8000304.html (15-02-05)