Streamer
European research on energy-efficient healthcare districts

Deliverable 2.8: Set of EeB solutions at district level

Description of solutions for energy systems for healthcare districts (at neighbourhood scale)

Deliverable Report: D2.8 Final version

Streamer - Optimised design methodologies for energy-efficient buildings integrated in the neighbourhood energy systems.
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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.

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Colophon

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Publishable Executive Summary

Buildings, especially buildings that belong to healthcare facilities are in most cases part of a larger cluster, surrounded by other buildings. Thus, when assessing options for Energy Efficient Buildings, it is necessary to upgrade the standard energy balances considering the Neighbourhood Energy Systems (NES) as well.

Three basic steps when assessing the possibilities of NES: Supply, demand and their matching. The energy exchange between buildings is primarily addressing heating/cooling, and electricity.

This deliverable builds on the findings of the D2.7 (Description of technologies for synergy between buildings and NES), by presenting again the set of Energy-efficient Buildings EeB solutions, adds some more “layers” to their descriptions, “including solutions for smart grid: energy generation and storage, logistic, resource and waste management”.

These last items are sometimes neglected in the analyses even though they should be considered relevant in order “to achieve net zero energy buildings as foreseen by EPBD (Energy Performance of Buildings Directive) 2010 through the optimisation of building and neighbourhood interactions” that is exactly the goal of Task 2.3.

The investigations, by seeking the most effective solutions based on smart grids (e.g. distributed generation plants, tri-generation plants, district heating/cooling and thermal storage, analyse schemes that are directly related to logistic, such as, again from DoW, i) “the degree of decentralisation of energy solutions that are optimal for different parts of the district area”, ii) “the scale needed in order to achieve the highest energy-efficiency and cost-effectiveness for different energy solutions (i.e. the ones of the kits presented in D2.7)”; iii) “the optimal combination of energy carriers as basis for a district energy systems”, the last with a clear and specific focus on storage, logistic, and, in general, the management of the available resources and of their energy processes waste.

Geographical Information Systems (GIS) help to display relevant data regarding energy supply or demand, but the usefulness depends largely on the availability of data. Some data may be available from public or closed sources, other data may have to be calculated by the designer. One source of data that gives insight in energy demand is the usage of energy simulation tools (explicitly addressed in a number of other deliverables within STREAMER).

The focus of the designer will be on the building level, the inter-building level (campus), and district level. Data availability differs on each level. Energy simulation/calculation tools are available for this. The deliverable outlines a number of EeB solutions (energy systems) that are relevant at the neighbourhood level.
Other issues, related to storage; logistic, resource and waste management may be sometimes relevant in the optimization of the energy district networks and, thus, are investigated in this deliverable coherently to the general framework used in the other previous deliverables of Work package 2.

Whether or not these systems can be included in explicit simulations relating to the STREAMER design process is largely depending on the availability of relevant supporting data for those technologies.

Apart from the pure energy-related design questions, other aspects have to be taken into consideration by designers and decision makers as well. Indirect energy use is addressed by the Circular Economy concept that seeks to reduce energy consumption by considering re-use of materials, in order to save on energy needed for production and transport of products. Another set of considerations includes stakeholder interests, financial characteristics, visibility/public relations, and the like.

One conclusion is that even though some software tools (and data) are available for some design questions, for some technologies and for some geographical areas at the moment, there is no integrated design and decision support tool for evaluating NES that is suitable for the STREAMER context. In a broader sense, when incorporating logistics, resources and waste management, the same conclusion holds. Best practices specifically for hospitals have been identified however and can be designed and implemented using case-specific approaches.

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
- EDC : Early Design configurator
- EeB : Energy-efficient Buildings
- gbXML : The Green Building XML
- GIS : Geographic Information System
- GML : Geography Mark-up Language
- GJ : Giga Joules
- HVAC : Heating, Ventilation and Air Conditioning
- HCD : Hospital Campus District
- IFC : Industry Foundation Classes
- KPI : Key Performance Indicator
- LOD : Level Of Detail
- NES : Neighbourhood Energy System
- ORC : Organic rankine cycle
- REAP : Rotterdam Energy Approach and Planning
- SOTA : State of the Art Technology
- TWh : Terawatt Hour(s)
- UPS : Uninterruptible Power Supply

Definitions

Technical building system - technical equipment for heating, cooling, ventilation, humidification, dehumidification, domestic hot water, lighting and electricity production. technical building system can refer to one or to several building services

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

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

Grid – An underground piped infrastructure or distribution system for energy exchange. For steam, hot water, cooling water or electricity. In this context, waste and gas is material as input for generation.

Neighbourhood Energy System – Neighbourhood energy systems produce steam, hot water or chilled water at a central plant. The steam, hot water or chilled water is then piped underground to individual buildings for space heating, domestic hot water heating and air conditioning. It is also called District Energy System

Power plant - also referred to as a central plant, generating station, power plant, and powerhouse or generating plant. It is mostly an industrial facility for the generation of electric power, but could also generate steam, heat or cooling.

Smart Grid – An underground piped system grid, which includes a variety of operational and energy measures including smart meters, smart appliances, renewable energy recourses and energy efficiency resources.

Circular Economy – In a circular economy the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value.

Contents

1. Introduction

1.1 Objectives D2.8

The objective of this deliverable is to describe a set of EeB solutions at district level relevant for the STREAMER project. It consists of the 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.

This objective has a strong relation with deliverable D2.7: "a description of technologies for synergy between building and neighbourhood energy systems". This includes an analysis of energy optimisation possibilities at inter-building level (by considering the interaction of buildings within a healthcare district and in relation with the surrounding neighbourhoods).

The description of available software and the interoperability of data itself are described in D6.3 and D6.4. This deliverable is covering the matching process of the Neighbourhood Energy System solution itself, by using the GIS databases, GIS viewers and other tools and software.

The scope of this deliverable consists of both direct energy and indirect energy. Direct energy on the level of a Neighbourhood Energy System (NES) is described in chapter 1 to chapter 3. Indirect energy, related to logistics, resources and waste management is described in chapter 4.

1.2 Problem Statement NES

A Neighbourhood Energy System (NES) contains a plant, a grid and several buildings. Mainly the ownership (public/private) of each element is different. That makes the design process more complex. The question is whether there is sufficient (public) data from each of these three elements in order to answer design questions.

Usually energy data of the NES is only available from the administration of the network owners as they are private, for example hospitals. Data from public power supply are usually not available in such a detail, which is necessary for performing simulations. In both cases, internal private and public data, the information is mostly limited to drawings without any network topology, all properties are simple texts and sometimes without any geographic reference. The only exception is the internal use of software of network owners, which is not publicly available.

Energy consumption of buildings is also non-public information. But if we could calculate the energy demand, based on public data, we could make an early design of a NES. To be able to do that, there is detailed information like floorplan, outline, usage, needed of the buildings. The question is if a GIS environment could provide us with these data, in order to calculate an energy demand.

It is expected that there is not a single tool to provide the decision maker with all the relevant data and calculation, simulation and visualisation tools of a Neighbourhood Energy System. Thus several tools are needed to provide us with the accurate data.

1.3 Challenge

The challenge of this deliverable is to determine a model to support the decision maker in an early design stage in the consideration for further investigation in a neighbourhood energy system, using BIM and GIS. We distinguish direct energy. (The indirect energy related chain collaboration and circular economy aspects will be described in chapter 4.)

In general, a healthcare district can be considered as a thermodynamic open system with input and output of mass (*e.g.* fuels, wastes, combustion gases etc.) and energy (e.g. solar heat gains, exchanges between indoor thermal controlled environment and the outdoor, etc.) through specific vectors (*e.g.* electricity, heated and cooled water, hydrogen, etc.).

This general scheme is not really different to the one normally considered by the providers in the study of energy networks of quartiers except of the considerable extent of the demand that in hospitals is always remarkable.

Figure 1, below, describing the energy networks of a healthcare district dedicated to elderly people, might help in the understanding of how a similar open system works: plants, networks and grids are not simply serving a certain building, but interconnect facilities continuously in real time with a very high degree of complexity in the general management of the whole “system”.

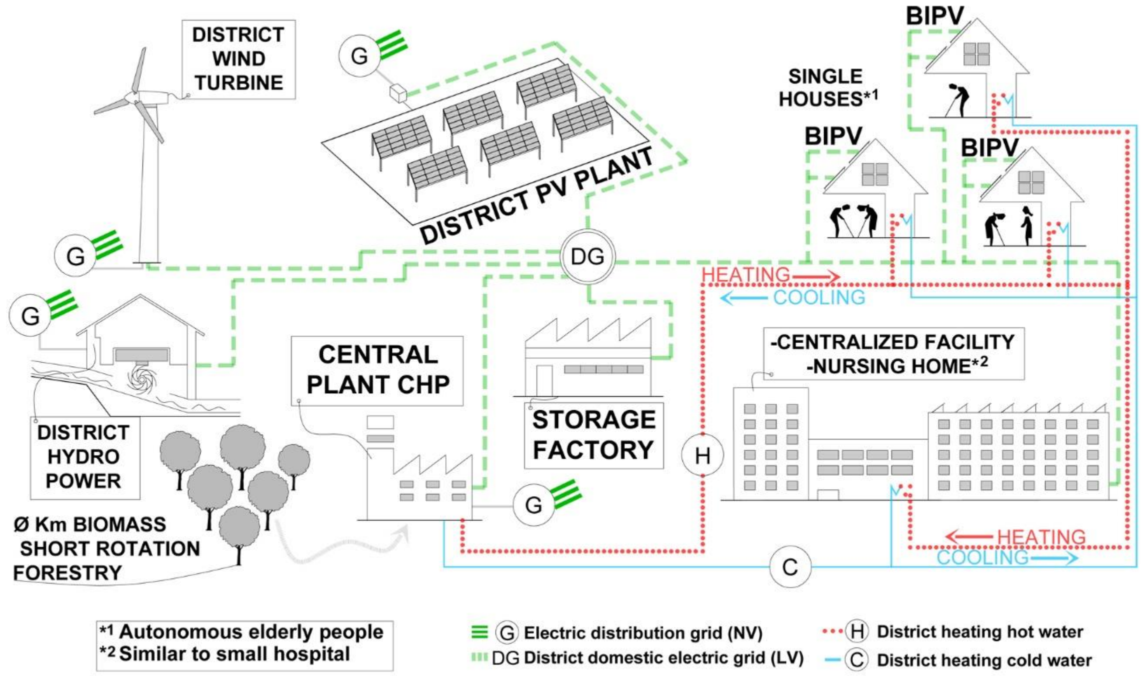


Figure 1 Example of energy networks

The same systems for the production of electricity and/or thermal energy from renewable sources, if not examined at district level, would lose a part of their positive potential in the moment of a mismatching between production and demand.

The issues related to the transport and distribution of energy are very important and can be clearly felt as pivotal by examining the thermodynamic open system model: where to locate the mass and energy input in the network should not be neglected, for instance in order to minimize the energy losses through the distribution pipes. At the same time, it is absolutely clear that a good logistic in the supply of the primary energy carrier help in the general optimisation of the whole district. The interface sections of the open system are not just the delivery points of natural gas, in general of fuels, and of electricity, but they also coincide with the input section of biomass and/or of other sources. If the biomass is produced by a short rotation forestry program, especially if carried out nearby, there is an indisputable and clear benefit for the whole district. This may be different for other energy policies, such as energy production out of waste that might be not ideal for healthcare areas, despite the general sustainability of this option.

Space itself becomes hence a variable that should be considered in the energy analyses of smart grids at district level.

Some tools, with the certain potential in the management of large scale energy facilities are already in the market, associating geodetic information to energy data and they will be described in the next chapters. Unfortunately, these tools, not being created from the scope of STREAMER, are still far from being a reliable instrument for the assessment of such complex energy networks.

In the next chapter 2.3, an extended library of technologies is provided. The same energy solutions kits presented in D2.7, are listed again, adding three more layers on energy generation and storage, logistic, resource and waste management. A short description of these items is summarized in table 1, whereas a specific focus on them is provided technology by technology in the text considering in particular:

i) *logistic – e.g.* how centralised/decentralised is a certain solution compared with the “different parts of the district area”;

ii) *energy generation and storage – e.g.* which is the ideal “scale needed in order to achieve the highest energy-efficiency and cost-effectiveness” -

iii) *resource and waste management – e.g.* which is “the optimal combination of energy carriers as basis for a district energy system”.

Energy systems

In the neighbourhood energy systems 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. Others, like energy efficiency

In this deliverable we are focussing on energy systems with energy carrier/medium heating/cooling with or without electricity. The distribution system of gas and other systems are out of scope. It is seen as input for generation/production, for creating energy carriers.

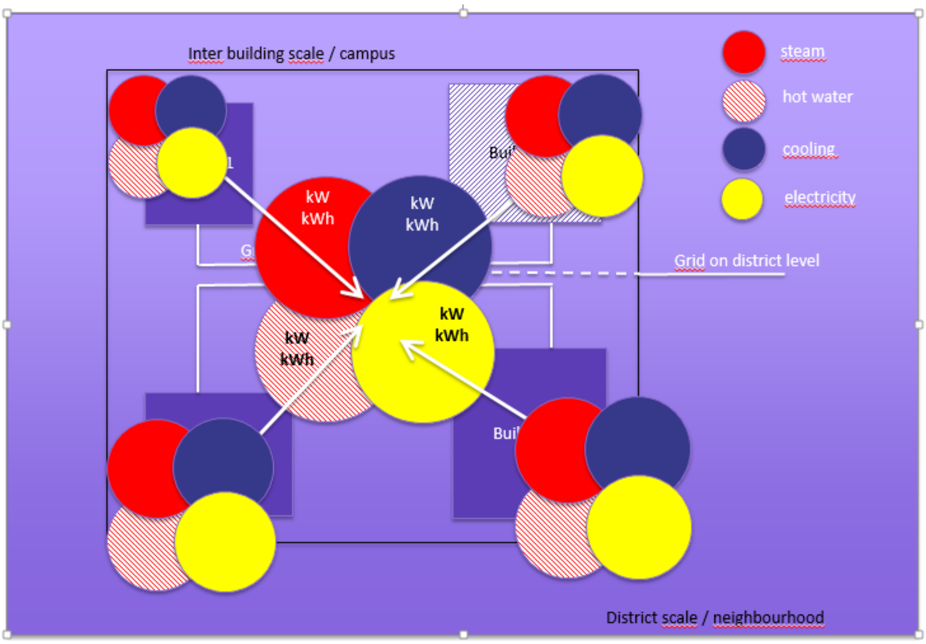


Figure 1.2 Matching process of energy carriers

The figure above shows the thermal energy exchange between buildings.

The strategy to obtain the analysis of the energy optimisations possibilities at inter-building level is already described in D2.7; in summary the approach is as follows.

The matching process of EeB solutions at district level on neighbourhood scale level is visualised below.

Figure 1.3 schematic 3-step approach of matching EeB solution on district level

Step 1: energy demand

The first step 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. The factsheet contains a description of the technology, the characteristic parameters, the benefits and drawbacks and an indication when and where to apply the technology. This library is required to combine the demand with the supply options.

Step 3: matching demand and supply

Tthe third step is to match the demand and supply to indicate in which situation which NES technology can or cannot be applied.

The challenge is to determine a workable model to match these demand with the supply in an early design stage. Generally there are three models.

- Deterministic model;
- Semantic model
- Multi Criteria analysis model

1.3.1 Deterministic model

A deterministic model is a model where:

- All the material properties are well known, and none of them is random;
- The applied load is also deterministic.

To use this deterministic model, every detailed information about the energy demand (temperature, flow and timescale) and energy supply (typology, capacity and soil-suitability) should be known. And not only has the technical detailed, but also information about the stakeholders, business models and profit. But this information is not available (in public data) at the start of the design process. And besides that, this information changes is very time and location specific. That makes the model uncontrollable and required long term support.

Because of the available information, a deterministic model could not help us to select a NES system in an early design stage.

1.3.2 Semantic model

A semantic model is a conceptual data model that includes the capability to express information that enables parties to the information exchange to interpret meaning (semantics) from the instances, without the need to know the meta-model. In the STREAMER context, a semantic model will help by assist in the application of different rooms in the building. One problem is that relevant meanings vary for each technology. For example, the expressed information ‘is located in’. That is relevant information for selecting a heating and cooling plant, but not for an electrical power plant. The current actual location of a power plant is more relevant than the area.

The semantic model is a little bit helpful for comparing NES systems with energy demands, but the model has no added value to the matching process.

1.3.3 Multi criteria analysis model

A multi criteria analysis (MCA) model is a sub discipline of operations research that explicitly considers multiple criteria in decision-making environments. Structuring complex problems well and considering multiple criteria explicitly leads to more informed and better decisions. Only knowing the relevant parameters is enough for making decisions. Determining one or several most significant criteria of each NES systems is necessary. And determining one or several of the significant criteria of the energy demand too. And it seems that public data could foresee in these requested information. MCA could be applied on two levels, in first step filter out the relevant NES technologies (based on technical/factual characteristics) and subsequently rank the various options according to user preferences (weighing factors per criteria to be specified by the user in advance). That will be further researched in this deliverable.

1.4 Scope

The scope of this deliverable is a description of solutions for neighbourhood energy systems (NES) for healthcare district. Additionally, a brief description is given of a decision support tool supporting multi criteria analysis of NES in a healthcare district, by using GIS, BIM and a Library of NES. This decision support tool can contain multiple programs and/or viewers.

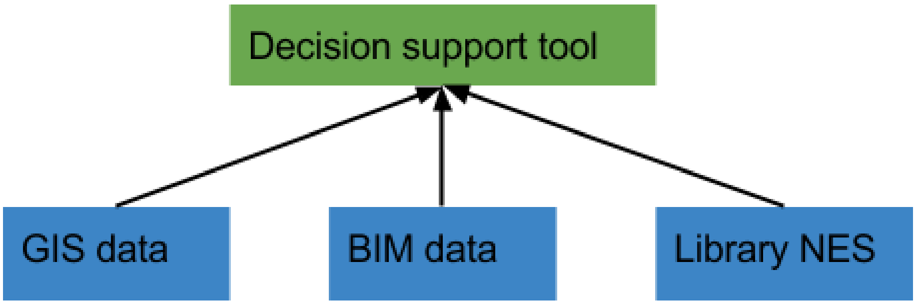


Figure 1.4 Decision support tool

Within STREAMER BIM models are used to analyse building energy efficiency, but they are also projected in a geographic information system (GIS) environment, so that relevant influencing parameters from the location could be added. The question is thus what does GIS (Geographic Information System) software has to offer.

1.5 The idea of GIS software

A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. With GIS software or viewers, geographical data can be visualized on a map. For example, if you have data on the population in cities, you could have the software plot circles of relative sizes at the geographical location of these cities. GIS software thus combines the merits of spreadsheets and data with the merits of visualization software. In consequence, it is not particularly good at either: to edit and clean up data, spreadsheet software like Excel usually works better; to make maps that really look good, one would use dedicated designer software.

However, GIS systems are particularly good in helping the user understand and process the geographical data. Imagine you have a list of cities with their population and surface area in a normal spreadsheet program. To find out which cities are the largest in terms of population, you could sort the list by population. To find out which cities are the largest in terms of surface area, one could sort the list by surface area. Population densities can be calculated and then sorted by that attribute. However, this does not say much about the combined attributes of these cities, and it is especially hard to find out which densely populated cities are near to each other, for example.

This is where GIS software is extremely useful. One could for example plot the cities as circles on a map, with a relative size according to population numbers, and could simultaneously give these circles a more intense colour according to population density. This visualization of the data gives the user a good view of the data instantly.

GIS software can filter data according to different criteria. Cities with a smaller population than a certain benchmark number can be left out; other geographical data can be used to filter for example cities in a certain country of province. With more advanced techniques, cities can be filtered that are not within an x-kilometre distance of other cities, or other cities with certain characteristics.

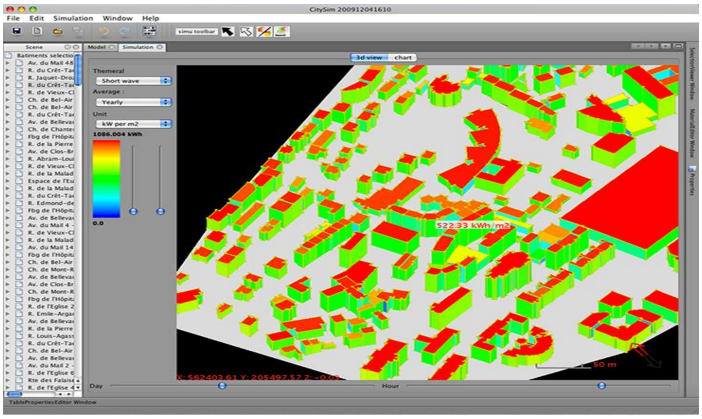
Using GIS software is thus one of the best tools a user can have to interpret geographical data in an instant. Because it can handle data and visualize it at the same time, the user can distinguish different characteristics of the data easily and quickly.

1.6 Use of GIS in STREAMER

Within STREAMER, GIS software could be very useful in helping the designer to take into account the characteristics of the location where the building will be built.

For example, when a designer would want to implement Aquifer Thermal Energy Storage (ATES), it will be very useful to know whether the earth layers at that specific location are suitable for this kind of energy system. Also, it would be useful to know whether there is a (sustainable) district heating network nearby. Another useful fact can be what the yearly average solar irradiation is on that location.

Particularly when the question is whether the building is nearby something else, GIS software is indispensable. The user can specify how "nearby" that something should be for it to show up in the data and you can see it instantly on a map. This is especially useful when the datasets are very large and the answer to the question is not instantly clear just by looking at the data.



Themeral: Short wave
Average : Yearly
Unit: kW per m2

Figure 1.5 Example of solar irradiation on buildings on district level

Nevertheless, not all geographical data relevant for STREAMER needs a geographical representation to be useful. For example, the solar irradiation on a specific location is just a single parameter that does not vary significantly within a city. While in theory it could be useful to project the different amounts of solar irradiation in a certain area, to determine where to build the building, in practice the difference would be so small that this would never be a determining factor in the decision about location. Data on solar irradiation can just be collected from a database as is already done by simple building calculation software, where you just specify the country and sometimes the city as the location. This is specific enough in the case of solar irradiation.

In this case GIS can help the decision maker to choose the appliance of solar panels. The picture below show the solar radiation on the roof of Rijnstate Hospital in Arnhem. The picture shows that despite the different level in height of the roofs, generally spoken, solar panels are suitable on the roof, without knowing any detailed information like max roof load.

Figure 1.6 Solar radiation on the roof of Rijnstate Hospital in Arnhem

As described in D2.7 we will be focussing on energy, both the demand and supply for heating and cooling.

2. Matching process

In this chapter the strategy of matching both the demand and supply of NES for heating and/or cooling will be described on a more detailed level.

Within the context of STREAMER several software tools have been identified that can already help to determine an EeB solution, including several (commercial) tools. The description of the interoperability of data is described in D6.3 and D6.4. The set of EeB solutions is described in Chapter 3. This chapter is covering the matching process itself.

2.1 Step 1 Energy demand mapping

The strategy to obtain the analysis of the energy optimisations possibilities at inter-building level is already described in D2.7.

The first step 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.

A typical design question could be: ‘What is the energy demand of the healthcare building and campus?’

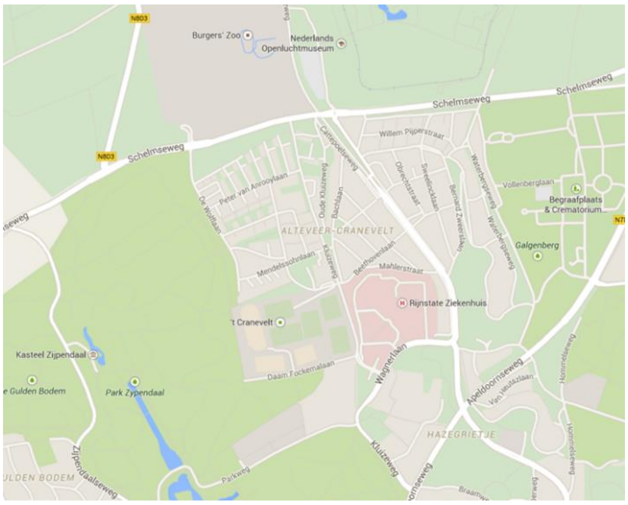


Figure 2.1 neighbourhood of hospital Rijnstate Arnhem

The picture above shows the map (EduGis viewer) of the neighbourhood for Hospital Rijnstate in Arnhem. This shows only the typology of the areas like roads, building area and forests and so on.

A picture of the buildings in the neighbourhood is shown below. This is extracted from a GIS database by the GIS viewer QGIS.

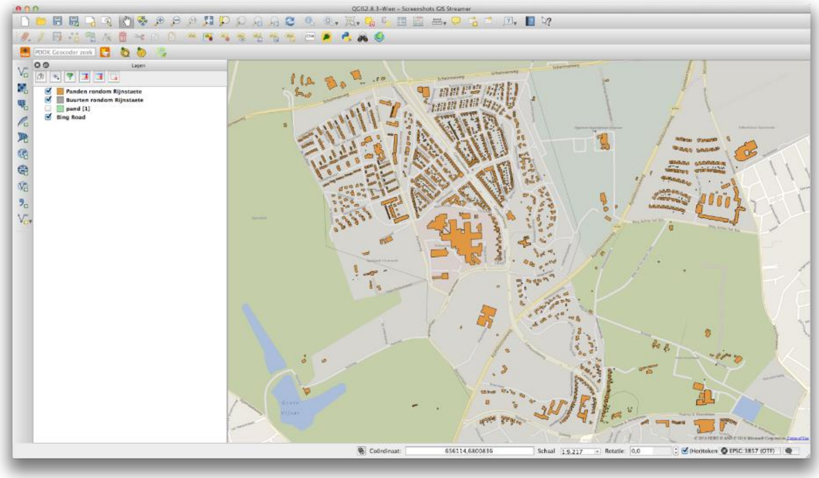


Figure 2.2 Footprint of buildings in the neighbourhood of Rijnstate Arnhem

Scale level

As described in D2.7, depending on the available data, a calculation of the demand energy and power is more or less accurate. This is visualized in the picture below.

For a single building, a BIM model gives the most accurate energy demand calculation, because all relevant needed information is available. Only knowing geometry and function could give a rough energy demand calculation which is accurate enough for an early design stage.

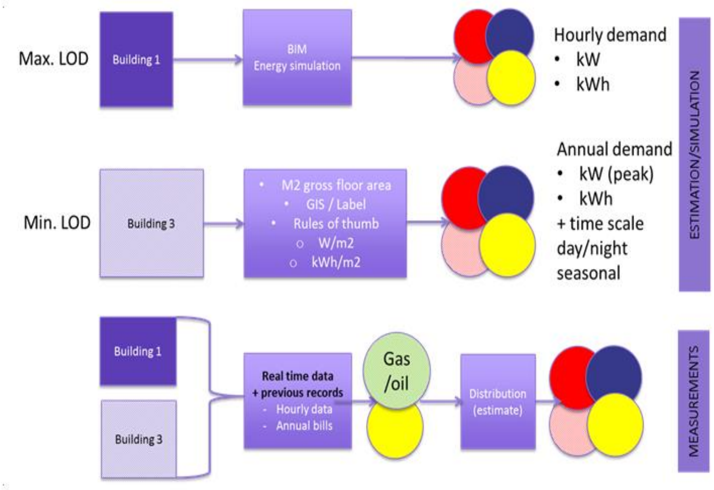


Figure 2.3 Accuracy of energy calculation

Most NES technologies are only applicable at a specific scale. This can be at the scale of individual buildings (e.g. small-scale gas fired boilers and dry cooling systems), others are applied on an inter-building or campus-level (e.g. collective ground source heat pump systems) and some can only be applied on a neighbourhood, district, city or even regional level due to large supply capacities and investment volumes (e.g. geothermal wells). In order to be able to assess the applicability of all NES technologies addressed, it is therefore necessary to gather data on energy demand on each of these levels. Three levels/scales (visualized in a map depicted on the following picture) are proposed:

Figure 2.4 Different scale level of neighbourhood

The picture above shows the map of the neighbourhood for Hospital Rijnstate in Arnhem, including the different scale levels.

The key question is: how can we get the relevant data of one or more buildings, to calculate an accurate energy demand. And how can GIS data help the decision maker. That design question will be answered for the different scenarios (retrofit or existing situation) and the different scale level (inter)building, campus level and neighbourhood level.

Assessment of energy demand at the building-level in retrofit scenario

All the necessary data on the volume and profile of the energy demand of the building under study is made available to the model via the interface from the BIM model. Calculation will be done in energy simulation tools like VABI Elements, Sefaira, e.g. it is typically usable in new build scenarios. It gives the most accurate energy simulation and calculation. Therefore we need also information about usage, typology of the building energy system, occupancy of a building, etcetera.

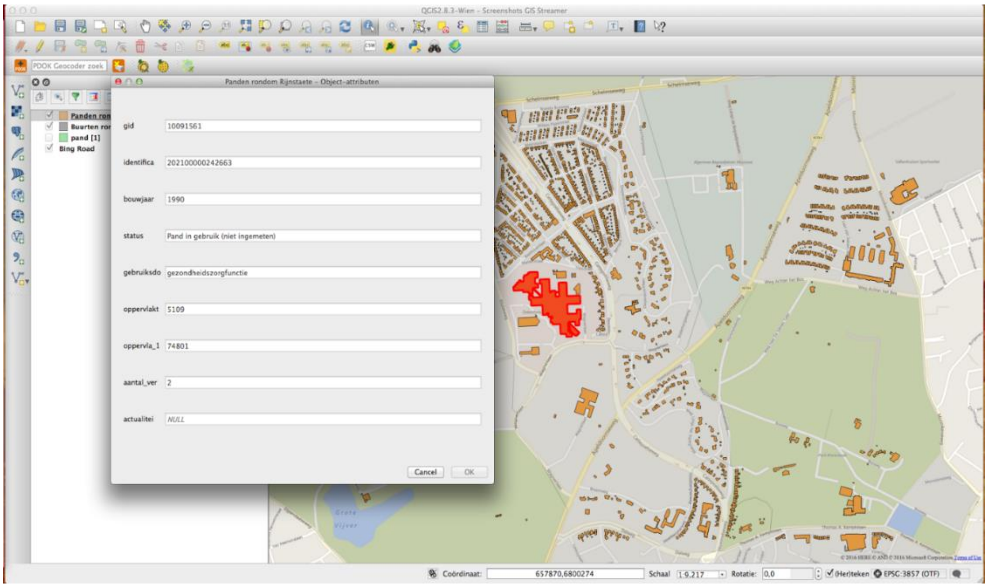


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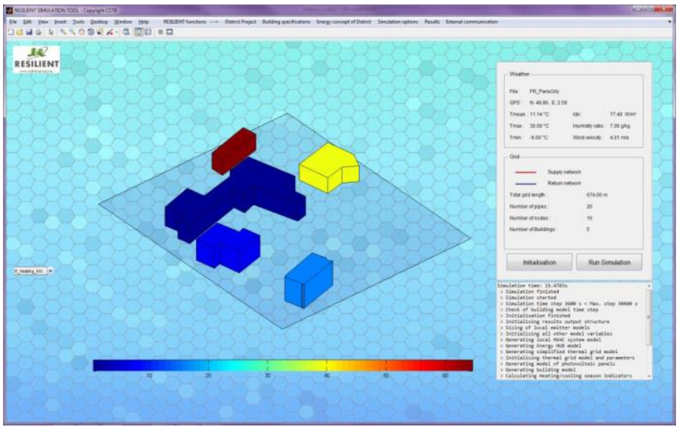
Figure 2.5 Footprint of the Hospital Rijnstate Source cadastral data

In the case of a retrofit scenario, we could use GIS data to assist in gathering the needed data. It is also possible to calculate the energy demand in GIS environment too. An example is the tool DIMOSIM, which is developed by CSTB in the EU project RESILIENT (see the References); it calculates the energy consumption based on simple building models.



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Tmin: -6.00 °C
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Number of nodes: 15
Number of Buildings: 6

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 > Simulation started
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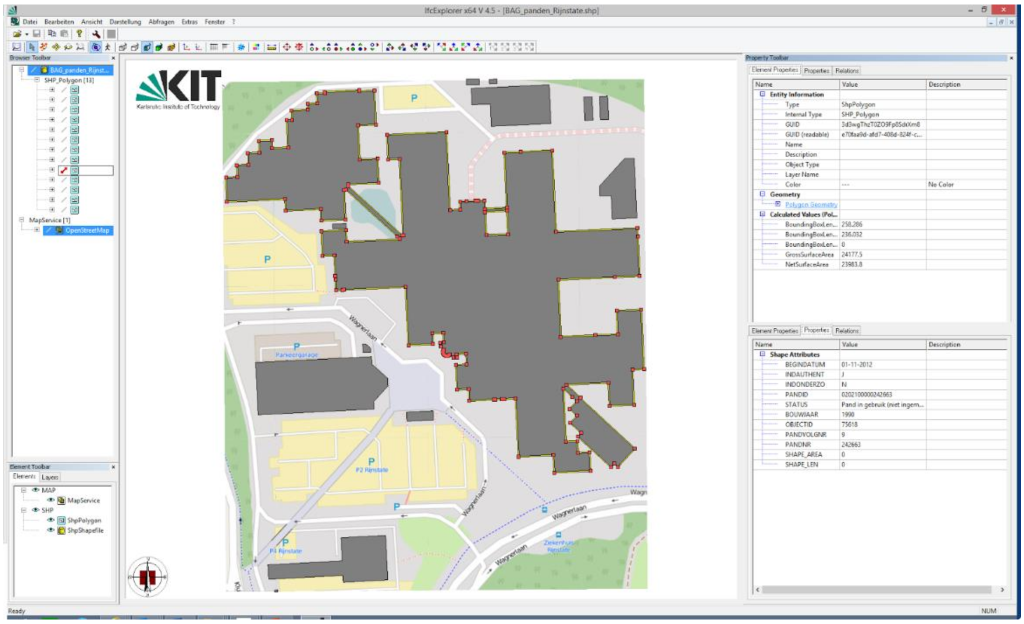
 > Initialising results output structure
 > Sizing of local emitter models
 > Initialising all other model variables
 > Generating local HVAC system model
 > Generating Energy HUB model
 > Generating simplified thermal grid model
 > Initialising thermal grid model and parameters
 > Generating model of photovoltaic panels
 > Generating building model
 > Calculating Heating/cooling season indicators
```

Figure 2.6 Dimosim energy calculation in Citygml

In that case we also need to know several parameters (about usage, typology of the building energy system, and occupancy of a building) for accurate energy calculations that are not available in GIS. If we know this, it is possible to calculate in the most accurate way the energy and power demand. Otherwise, if that detailed information is unavailable, we could make a raw calculation based on rule of thumbs.

In retrofit or existing situation Open Stream Map could provide the decision maker with raw data and properties of the building.



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BEGINDATUM	01-11-2012	
INDAUTHENT	J	
INDONDERZO	N	
PANDID	0202100000242663	
STATUS	Pand in gebruik (niet ingem...	
BOUWJAAR	1990	
OBJECTID	75618	
PANDVOLGNR	9	
PANDNR	242663	
SHAPE_AREA	0	
SHAPE_LEN	0	

Figure 2.7 Footprint of the Hospital Rijnstate source: OpenStreetMap

The picture shows the footprint of the existing building of hospital Rijnstate in Arnhem. Properties of the existing building are extracted from OpenStreetMap. It gives the geometrical properties and relevant parametric information. By extracting it into an IFC file, it is usable in other programs for example energy calculation software or in the EDC. For the four demonstration hospitals see Deliverable 6.5.

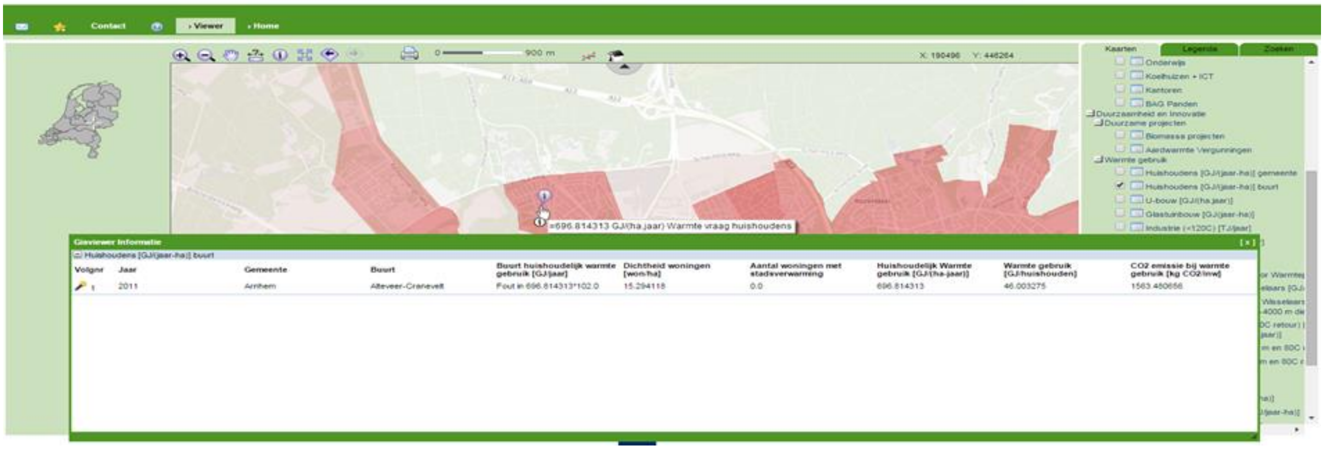
The energy demand can be calculated (in tools like DIMOSIM) and based on simplified hourly based energy demand calculation.

Assessment of energy demand at the inter-building / campus level

In order to be able to determine whether it is possible to implement NES technologies that apply to a group of buildings that are adjacent or closely situated to each other, the energy demand of the buildings adjacent to the building under study is assessed. For a generic approach, the GIS model could search for all buildings located within a certain radius around the building under study. Depending on data availability the following characteristics of the buildings involved could be sourced from GIS databases. Based on these characteristics, it is possible to derive figures and make estimates on the volume, density and type of energy demand of the buildings involved.

- Year of construction
- Type of use (e.g. office, education, store, industrial, etc.)
- Floor area
- Building height
- …

The energy demand for several buildings can be calculated simultaneously (in tools like DIMOSIM).



=696.814313 GJ/(ha.jaar) Warmte vraag huishoudens

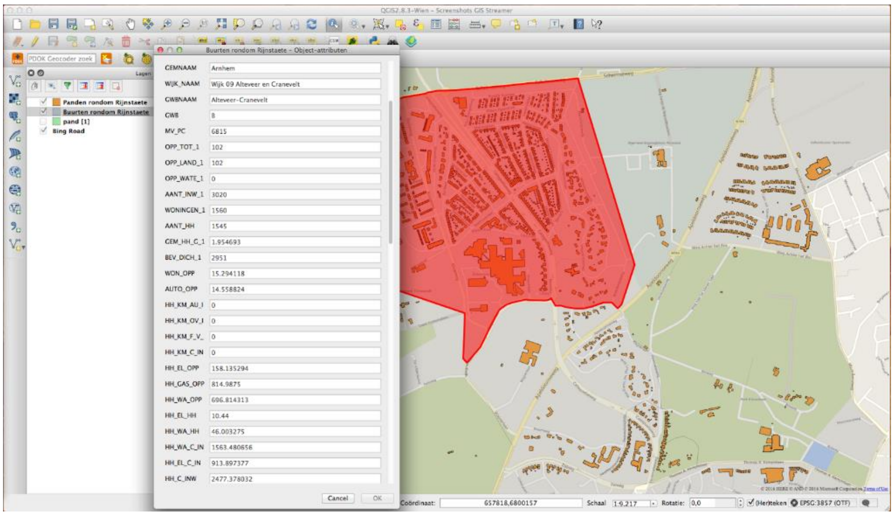
Gisviewer Informatie

Huishoudens [GJ/(jaar-ha)] buurt

Volgnr	Jaar	Gemeente	Buurt	Buurt huishoudelijk warmte gebruik [GJ/jaar]	Dichtheid woningen [won/ha]	Aantal woningen met stadsverwarming	Huishoudelijk Warmte gebruik [GJ/(ha-jaar)]	Warmte gebruik [GJ/huishouden]	CO2 emissie bij warmte gebruik [kg CO2/inw]
1	2011	Arnhem	Alteveer-Cranevelt	Fout in 696.814313*102.0	15.294118	0.0	696.814313	46.003275	1563.480656

Figure 2.8 Energy demand dwellings in neighbourhood

The picture shows the energy demand on neighbourhood or district level. Hospital Rijnstate in Arnhem adjacent neighbourhoods consist mainly dwellings. This is extracted from a cadastral GIS database, like PDOK. See also the reference EduGIS maps, or QGIS viewer as shown below.



Buurten rondom Rijnstaete - Object-attributen

CEMNAAM	Arnhem
WIJK_NAAM	Wijk 09 Alteveer en Cranevelt
GWBNAAM	Alteveer-Cranevelt
GWB	8
MV_PC	6815
OPP_TOT_1	102
OPP_LAND_1	102
OPP_WATE_1	0
AANT_INW_1	3020
WONINGEN_1	1560
AANT_HH	1545
GEM_HH_G_1	1.954693
BEV_DICH_1	2951
WON_OPP	15.294118
AUTO_OPP	14.558824
HH_KM_AU_I	0
HH_KM_OV_I	0
HH_KM_F_V_	0
HH_KM_C_IN	0
HH_EL_OPP	158.135294
HH_GAS_OPP	814.9875
HH_WA_OPP	696.814313
HH_EL_HH	10.44
HH_WA_HH	46.003275
HH_WA_C_IN	1563.480656
HH_EL_C_IN	913.897377
HH_C_INW	2477.378032

Figure 2.9 Number and typologies of buildings in neighbourhood

Number and typologies of buildings (like dwellings) can be counted for calculation of energy and power demand by the rule of thumb methodology.

In the picture below all buildings in the neighbourhood of Rijnstate hospital (In the middle in blue) in Arnhem, are colourized by year of construction. But calculation of energy demand based on year of built give the lowest accuracy.

Assessment of energy demand at the neighbourhood or district level

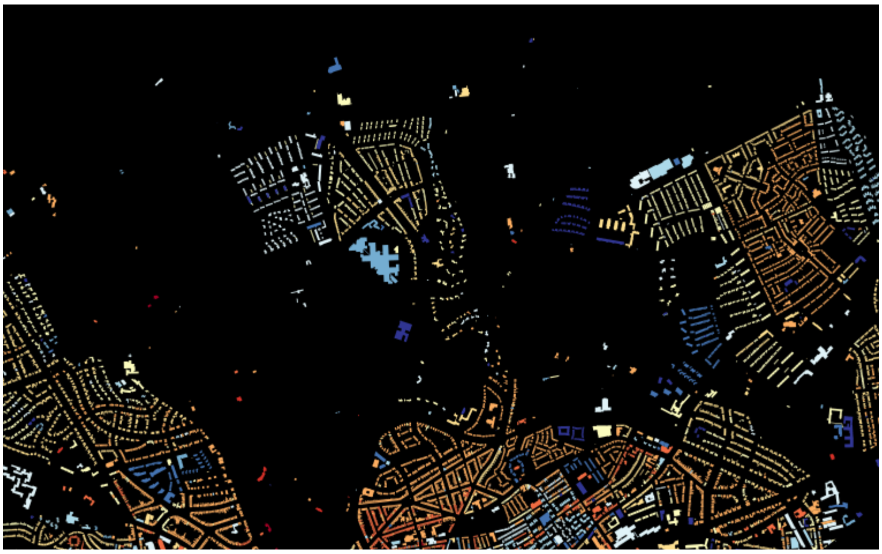


Figure 2.10 Buildings colorized sorted by age

Highly energy-intensive buildings are more relevant for feasibility of an NES system. The question is: ’are there highly energy-intensive buildings in the neighbourhood?’ GIS data like “function of a building” as hospital or dwellings could help us by ranking buildings from high to low intensive energy consumers.

Some NES technologies require a relatively large volume of energy demand to be economically feasible. Construction of a geothermal well is an example. These types of technologies cannot be scaled to the relatively small demand volumes that are typical for individual buildings or campuses. These type of technologies should however not be excluded from the analyses, as in some cases involving the surrounding area (district or neighbourhood) in the development of a shared energy supply system can provide interesting possibilities for large scale renewables deployment at the municipal level.

The energy demand profile on the district/neighbourhood level can be derived in the same manner as described previously on campus level; the only difference is the larger radius in scanning the surrounding area. This information is usually derived from a cadastral database.

In the picture below (SGIS viewer) the buildings on the campus and the neighbourhood are colorized by typology. Typology is an indication of energy intensive consumption. Thus makes it easy for calculating the energy and power demand of an area.

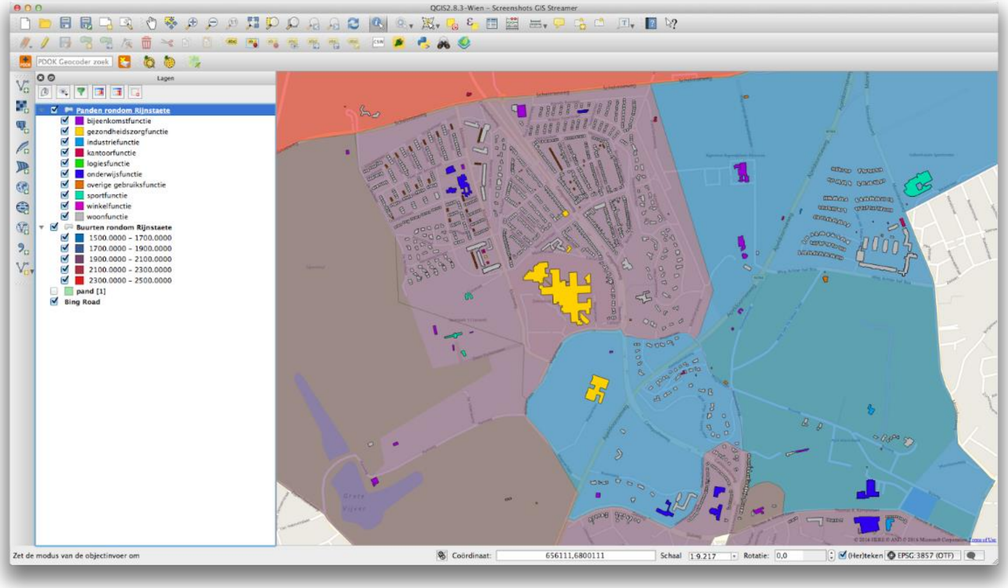


Figure 2.11 Buildings sorted by typology and energy request

2.2 Step 2: Supply mapping

The strategy to obtain the analysis of the energy optimisations possibilities at inter-building level is already described in D2.7. If the energy demand of the district level is known, the next step is to analyse the supply options. We are now focussing on the technical aspects of generation/production for heating/cooling. The question is: “How can we determine supply options?”

The second step is the description of the NES technologies in factsheets as library. The factsheet contains a description of the technology, the characteristic parameters, the benefits and drawbacks and an indication when and where to apply the technology. This library is required to combine the demand with the supply options. This library is already created in D2.7, however, it only addresses direct energy. Therefore the indirect energy aspects are added to the library as described in the Appendix.

In this second step, the model can scan the surrounding area on already existing supply (NES technologies) in the area. The applicable scanning radius depends on the type of technology that is being assessed. The approach is similar as described for mapping the demand discussed under 1 but works the other way around. If, for example, there already are ground source heat pump systems installed in the vicinity of the building under study, this could provide an opportunity (some of the capacity of the existing system might be unaddressed) or threat (if multiple of these types of systems are located too closely to each other, interference might pose a problem).

In this step, we want to know the applicability of NES, including uncertainty and certainty. And doing by a coarse-to-fine approach for fast applicability detection, we want to exclude technologies from a long shortlist/library, to narrow the number of suitable technologies for the decision maker.

We distinguish several state of the art technical generation/production in a neighbourhood energy system in a library[1]. See also D2.7 for Legal conditions and restrictions, operational, financial and managerial conditions and/or consequences, applicable for hospitals, available and reliability of the system and scale level. All this parameters are not captured in a GIS database. The technologies described in Table 1 below.

In an early design stage we want to know what the boundary conditions for suitability of a certain technology is on a healthcare campus. We want to know if a technology is applicable for hospitals or not. To analyse the availability of these technologies in the neighbourhood, we need a leading criteria of each technology, like, for example soil suitability, or distance to nearest hydro plant. Therefore we add a design go/no-go parameter, which can assist to exclude technologies from the longlist. Energy Efficiency is then used to rank the technologies.

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[1] See D2.7 for more explanation

Table 1 Energy systems

Name Energy system	Short description	Producing	Energy efficiency	Source	Logistics	Waste management	Applicable for hospital	Data extractable in GIS?
Biomass boilers/ Cogeneration or combined heat and power (CHP)	Biomass fired boilers both for domestic hot water and CIP	Hot water, steam, electricity and sometimes cooling too	Boiler: heat 90%. CHP: heat 30%-60%, electrical 10% - 30%., cooling 30$	Mainly wood and its derivatives	Ashes must be removed and fuel must be delivered	Ash from combustion process	Owned electricity generation? Availability Biomass	No Yes
Free cooling	Nearby lake or cooling tower as cold source	Cooling	Cooling 90%	Cold water from ocean and lakes	A proper infrastructure must be designed	No significant waste is produced	Capacity > ±10 MWth	Yes
Aquifer thermal energy storage / Borehole thermal energy system	Ground source heat pump with seasonal storage (ATES/BTES)	Heating and cooling	COP heating: 4 COP cooling: 8	Heat and Cooling from the ground	Energy produced when and where needed. No logistic issues.	No waste during activity. Reuse of parts when uninstalled	Local circumstances: Underground suitability	No Yes
Waste to energy	Burning medical wastes to produce energy	Electricity and heating	electrical 30%, heat 40%	Waste from industry and urban collection	Waste must be transported to the plant	Not combustible and organic material cannot be processed	Local legalisation	No
(Solar) Organic Rankine cycle (ORC) system	(Solar driven) ORC for electricity and heat production or hot water production	Electricity and heating	Energy: 22%	Solar energy	It has many applications due to its versatility	No significant waste is produced	Owned electricity generation	No

Name Energy system	Short description	Producing	Energy efficiency	Source	Logistics	Waste management	Applicable for hospital	Data extractable in GIS?
Biogas power plant	Organic waste from neighbourhood can be used as a fuel.	Electricity and heating	Boiler: heat 90%. electrical 10% - 30%.	Natural raw material	Transportation issues	Waste material as fertilizer	Owned electricity generation? Availability Biomass	No Yes
Integrated gasification combined cycle (IGCC)	Gasification for achieving higher electrical efficiencies in combined cycle plants	Hot water, steam, electricity and sometimes cooling too	Boiler: heat 90%. CHP: heat 30%-60%, electrical 10% - 30%., cooling 30$	Clean coal gas called Syngas	Local resources and heat sink capacity must be balanced		Owned electricity generation?	No
Hydropower systems	Hydropower from a nearby river or tidal power from a nearby sea	Electricity	electrical 53%	Potential energy from rivers or dams	A connection to the electrical grid must be created	Waste issues in end-of-life disposal	local availability Capacity > ±5 MWth	Yes yes
Wind turbines	Generation of electricity by wind turbines	Electricity	electrical 40%	Energy from wind	Generation of power near consumption point. No logistic issues	No waste during activity. Components can be re-use when uninstalled	local availability	Yes

Name Energy system	Short description	Producing	Energy efficiency	Source	Logistics	Waste management	Applicable for hospital	Data extractable in GIS?
Geothermal energy (deep underground)	Use of a heat exchanger which extracts heat from a geothermal source	Electricity and heating	COP 20	Heat in the subsoil; Available all year	Applicable on large scale; No transportation issues.	No waste during activity.	Soil suitability Capacity > ±4 MWth	Yes Yes

Figure 2.12 Searching for availability of Generation/production

The picture above shows the map of the neighbourhood for Hospital Rijnstate in Arnhem. Including specified GIS information like soil suitability and potential for geothermal (green) and hotspots and potential for industrial waste heat (*). This information is extracted from a cadastral (GIS) chart visualised in a GIS viewer.

In OpenStreetMap it is possible so search for free text fields, such as “Power Plants”, so search for power plants in the neighbourhood. But this gives electrical power plants only. And, only the public power plants and not the commercialized or semi-private plants are listed. Besides that, the required data is inaccurate. For example because of security reasons information is not visible, or it is just not available because Open Street Map information is not subject to a rigorous and formal process to ensure completeness.

Matching

The strategy to obtain the analysis of the energy optimisations possibilities at inter-building level is already described in D2.7. When the energy demand and supply is known, the next step is to match them.

2.3 Step 3: Matching demand and supply

The third step is to match the demand and supply to indicate in which situation which NES technology can be applied. We are now focussing on the technical part of distribution and exchange.

The question is: “How can we determine matching options? And what are the complexity factors like passing a railway, river or highway? Can GIS data provide information for that?

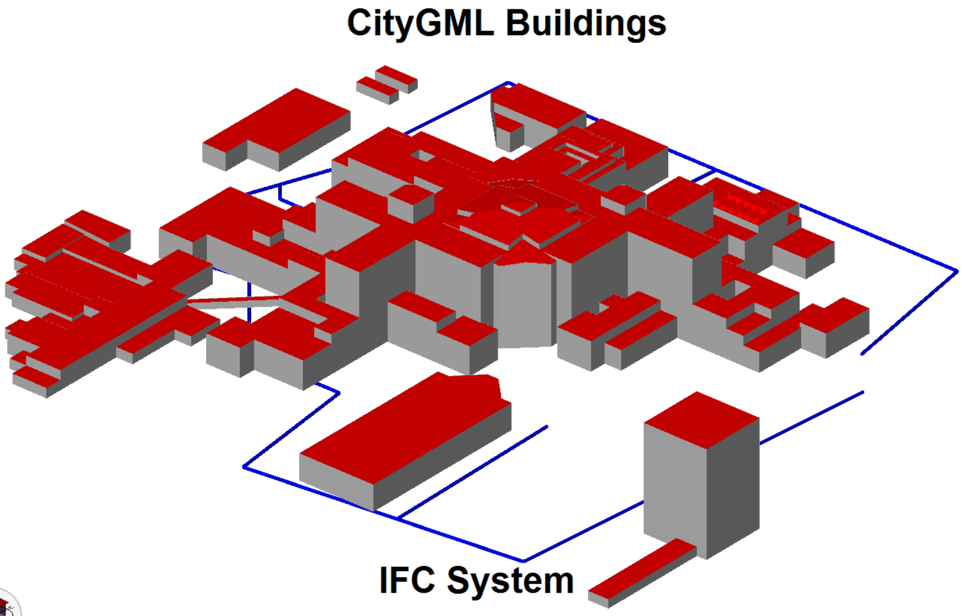

Figure 2.13 Building outlines with distribution system

The picture shows an example (though not according to the actual situation) of a district heating system in Rijnstate Hospital. The question is: ’Could the power plant supply the energy demand?’

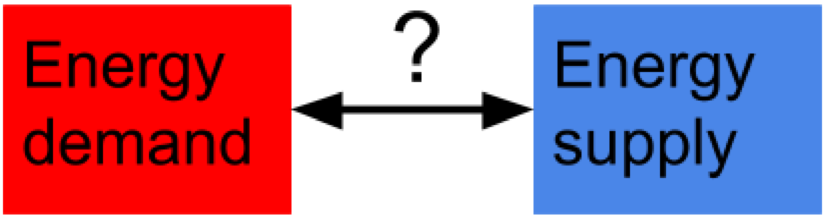

Figure 2.14 Matching Energy demand and supply

The question as to what extent supply and demand can be matched can be answered on two levels: Technical and user Preferences level (see Chapter 3.4). We are now focussing on the technical level. Mapping the supply and demand will have yielded a number of parameters based on which the technical and economic feasibility can be estimated. Examples of such parameters are:

- Temperature levels
- Types of energy demand (heating, cooling, electricity)
- Energy demand per square metre
- Distance to existing supply
- Subterranean conditions

In cadastral databases, an area with a district heating system is recognisable. See picture below, the red crossed lines indicate this.

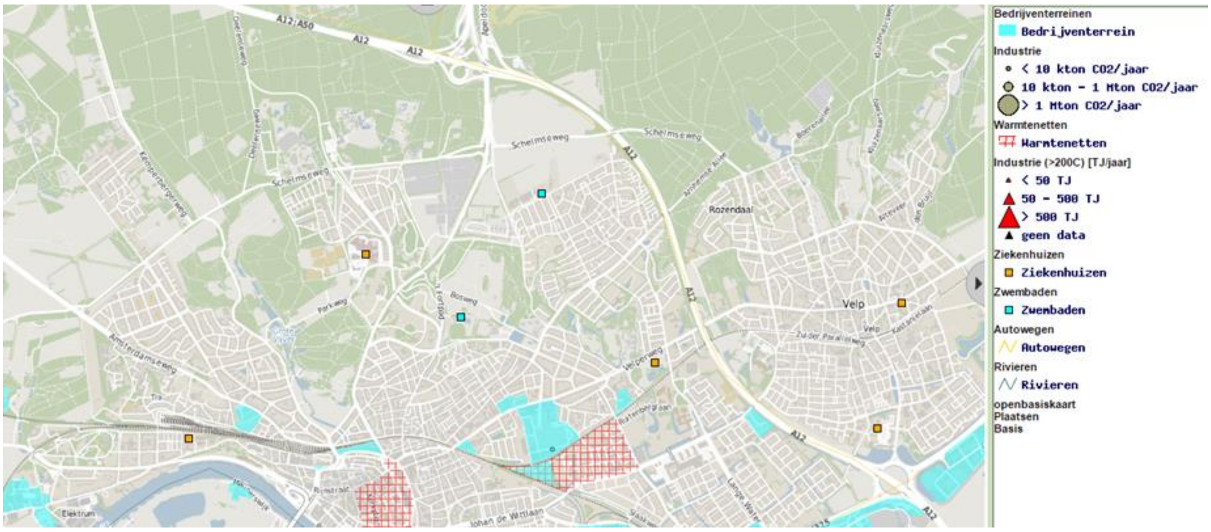

Figure 2.15 locating heating network

Parametric information, like typology, and building year is not available. That need to be investigated further.

In the QGIS viewer it is possible to combine different layers and GIS databases. And with queries, more detailed questions can be answered. For example, the conceptual energy design question: If the soil is suitable for ASES systems, visualise the potential amount of buildings (with a certain energy and power demand per building) to match an ATES system. This is shown in the picture below.

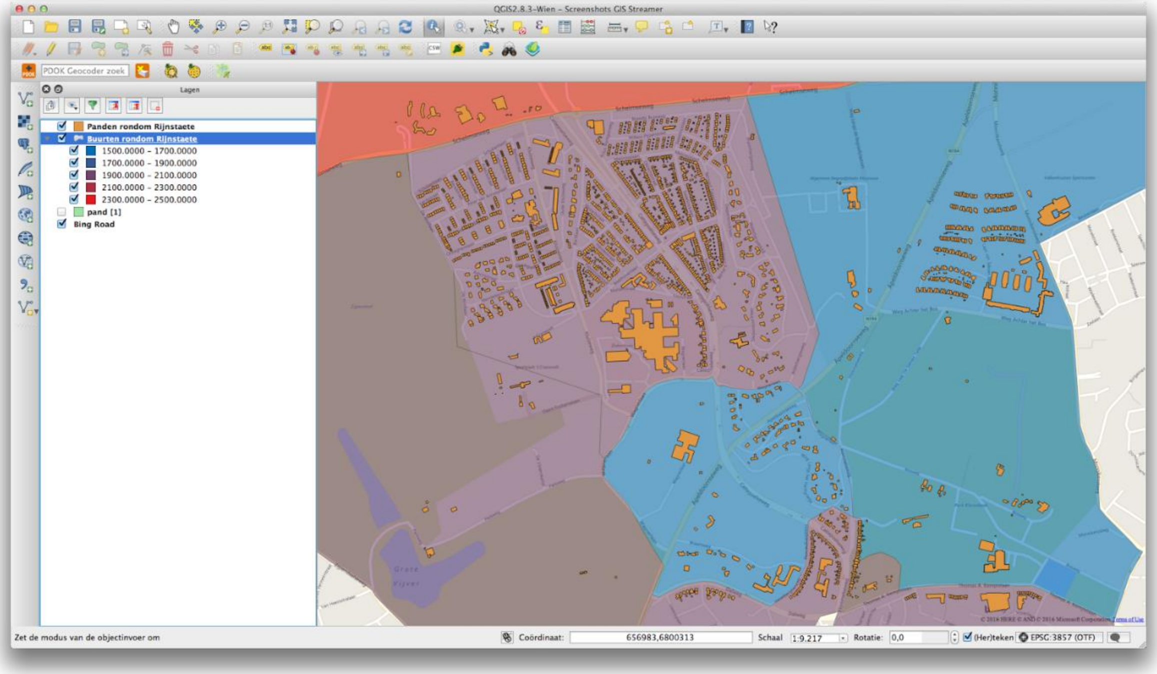

Figure 2.16 Combine supply and demand

Grid

Software tools in a GIS database for designing a grid itself are not available yet. They are almost all in development stage (for example DIMOSIM, a tool based on Matlab). See the screenshot below with a grid example.

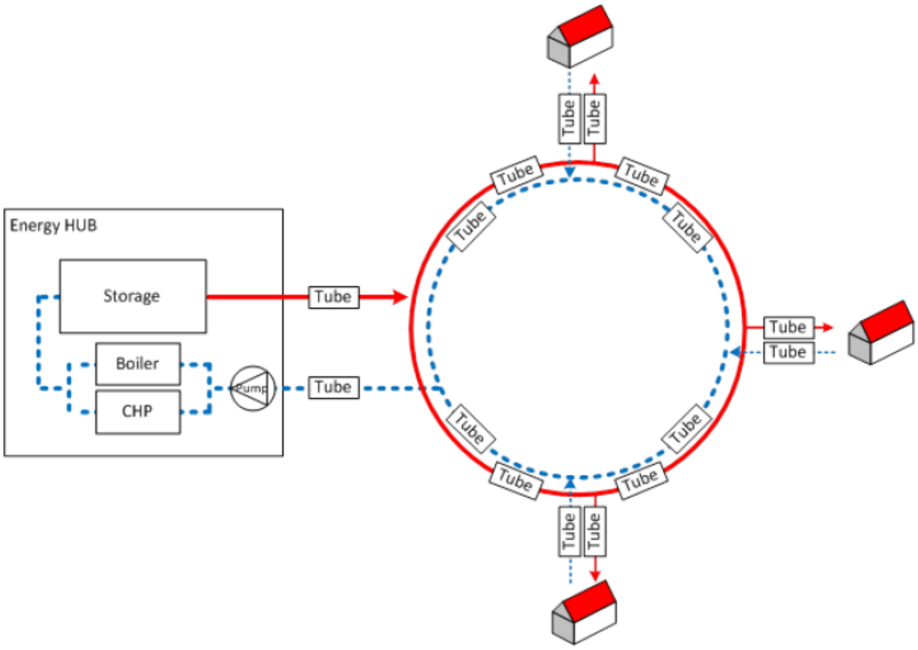

Figure 2.17 Grid design

At the moment it is not possible to visualize any obstacles or complexity factors automatically. For example: because of some small hills, the altitude of Hospital Rijnstate is different from the dwellings in the direct surrounding. That will give a physical challenge for the design of a district system, but is not automatically visually apparent for the decision maker.

The amount of relevant GIS databases usable for energy related design questions, and designing of a grid is growing. At the moment these grid design tools are more usable for cables, water and traffic. When these tools are suitable for energy, it mainly is about electricity.

A survey shows there are tools to simulate smart grids. These tools focus on the optimization of matching supply to demand and appear to neglect the consequence this will have on energy consumption of the network. All these tools are categorised, described and evaluated for usability in the STREAMER context in D6.3 and D6.4.

2.4 Business Case of District heating system

Although we are now focussing on energy, it is not the only parameter in the business case of an EeB District heating system. There are several, mainly non-technical parameters.

User preferences

Using Multi Criteria Analysis (MCA) introduces the possibility to rate the various NES technologies based on a standard set of characteristics, to which the user can indicate its preferences by applying weighting factors. Examples of relevant characteristics to be addressed are:

- Dependency on other parties in (developing the) energy supply
- Environmental benefits, sustainability
- Financial characteristics (ability or necessity to invest more money upfront to lower the energy bill, dependency on fossil fuel (prices))
- PR value

These are the parameters which influence the business case of an EeB district heating system the most.
But these parameters are not in any GIS database and thus usually not easily presentable for the decision maker. There are exceptions in some cases by owners of a district systems. For example, the Dutch network Alliander have developed (for internal use only) a tool to help the different decision makers, each with their own (often conflicting) interests. This system is called HEAT (see the references for a link to a small clip).

2.5 Output

The output of the matching process can be presented to the user in the form of a list of technically/economically promising options, ranked based on the user's specific preferences through applying MCA. The level of detail and methods by which the model assesses the feasibility of each NES technology should be carefully balanced with the amount of necessary input data that is to be sourced from GIS databases. The availability of such data is expected to be limited and differ widely on a country by country basis. For this reason, we propose to develop a model that is able to (apart from generating a map) provide the user with a list of potentially interesting NES technologies for further study rather than developing a model that is able to produce a full-fledged feasibility analysis of each applicable technology. This limits the amount of input data necessary for the model to work and thereby makes it more widely applicable within the EU. The NES factsheets can include a standard section with the most important questions to be addressed by qualified experts in order to make more detailed assessments on the feasibility of NES technologies.

3. Software and available data

3.1 State of the art

What can be done with the software and whether it is useful to implement GIS in STREAMER, is largely dependent on the available data. The GIS software is just a tool to process data; if there is no relevant data available, the added value is small.

In the Netherlands, a lot of useful data has been released for public use, albeit that some of the data (for example "existing district heating systems") is only relevant in certain locations, simply because the number of district heating systems in the Netherlands is still rather small. Of course, this could change in future.

Data at a European scale is not so readily available. A short search has shown that the data is fragmented and incomplete. For example, there is data available for geothermal energy storage for a small part of a district in Germany. However, for GIS to be useful for STREAMER, ideally this type of information should be available in one, uniform, dataset for the whole of Europe, or at least a number of neighbouring European countries.

The biggest problem with dispersed datasets, is that they are not based on the same metrics. For example, some datasets could leave out the smaller district heating networks, while others would include them. Some would measure energy in kWh, others in Joule. Additionally, data formats and their definitions (the semantics) of the data will differ. Before this data can be used universally in a STREAMER/GIS program, it has to be harmonized. This is a challenge beyond the scope of the STREAMER project.

The conclusion with respect to relevant data is that it highly depends on the location of the hospital whether or not GIS will be helpful to support the design and decision making process for using NES.

3.2 STREAMER enhanced software CEN EPB software (EN 15603)

District Energy calculations can be done with CEN EPB software (EN 15603). In this tool the requested energy and power demand for a building is calculated. By reducing the district heating system with the heating plant to a number of energy efficiency (COP or efficiency), it is possible to calculate the real requested energy from the district heating system. The result is an analysis of the most energy efficient energy source. These calculations are based on an NES EeB system with an energy efficiency value.

As a part of the STREAMER Project, the CEN calculation tool has been enhanced and can thus also be used for district energy demand calculations.

4. Circular economy

Apart from the direct energy, we distinguish also indirect energy on district level.
Sustainability implies the need for a transition from a linear to a circular economy. A circular economy aims to decouple economic growth from the use of natural resources and ecosystems by using those resources more effectively. In a circular economy, the more effective use of materials enables to create more value, both by cost savings and by developing new ones.

The section briefly introduces the Circular Economy concept, indicates the implications for hospitals, and then outlines two best practice technologies that have been found to be relevant for hospitals.

4.1 Introduction

The healthcare sector cannot ignore the responsibility for long-term healthcare system sustainability on holistic level. For instance, thinking about the long-term impacts of choices today, it is necessary to take into account the growing number patients in the future. Circular economy principles, as opposed to linear economy, can help to create sustainable healthcare. The most important aspects are recycle, upcycle and re-use; this implies reallocation of products, equipment and goods. Recycle is to decompose the product into separate materials and re-use these for other products, often with a lower quality or added value; upcycle is the process where the separated materials are used in higher-value products; re-use implies an almost one-to-one renewed use of the same product.

Generally spoken, there are two types of circular economy, distinguishing on the character of the materials that are re-used/recycled:

- Biobased circular economy (bioeconomy);
- Technical circular economy.

Evaluation of designs using different types of economy (linear, biobased circular or technical circular) can be done by looking at the type and amounts of resources consumed and waste generated aligned to a productivity level. To compare these economies only considering the amounts of resources and waste, is ignoring the fact that different types of handling also have different energy consumption and impact on the environment. In a holistic approach the effects of handling the resources and waste should be considered as well, including any logistics of the resources and waste. As an example, locally burned waste might produce less energy, but this could be compensated by the decrease of energy consumed to get the waste to a public waste disposal (power plant).

An exploratory project[2] that was conducted in a large mixed-use (healthcare) district in Amsterdam South East (aimed at creating a cross-chain control centre for waste management) identified waste as one of the logistic challenges with the highest potential. The project found that the local hospital, Amsterdam Medical Center, was by far the largest contributor to the total waste production. The largest fraction was mixed waste (more than 1500 tons per year), with chemical, biodegradable and paper (recyclable) being ranked 2, 3 and 4 (250-500 tons per

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[2] See http://www.dinalog.nl/amsterdam-zuidoost-circulair-logistiek-slim-samenwerken/ (in Dutch)

year). This clearly illustrates the case for hospitals to pay attention to their waste management processes. The project additionally explored Energy Grid opportunities (energy storage) and Last Mile Logistics (shared supply processes and optimizing mobility situation in the district including e-mobility). Open Data was used to perform analyses, although a preliminary finding was that the usefulness (completeness, accuracy, relevance) of this data was problematic. This is the case even in a relatively new district in an economic important part of the national capital, so the situation in other locations may in general not be significantly better.

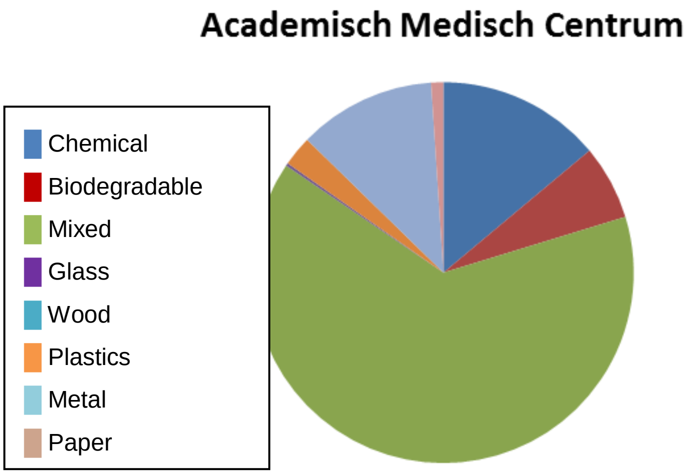

Figure 4.1 Example hospital waste mix

4.2 Circular economy for hospitals

The holistic view on energy introduced in the previous chapter will include the aspects of resources and waste and its logistics. In D6.3 (chapter 2) this is addressed at the urban level, describing the modelling/simulating energy needs. However there are no tools available yet to calculate energy consumption (let alone carbon footprint) on a holistic level (see conclusions of D6.3) or environmental impacts of waste management.
An aspect of circular economy that receives a lot of attention is waste. There are several types of waste in Hospital Campus Districts (HCD). Some of them can be easily obtained and processed, but some need to be stored and processed very carefully as they have high hazardous potential.
That is why waste disposal in HCDs is a complicated process, involving legislation and rules.

In hospitals, the following main groups of waste are distinguished:

1. Infectious waste,
2. Sharps waste,
3. Pharmaceutical waste,
4. Radioactive waste (not in every hospital),
5. Pathological and anatomical waste: Human tissues, blood, etc.,
6. Biodegradable wastes: Kitchen and food scraps, etc.,
7. Recyclable waste: Paper, plastic, metal and glass, being the most widely recycled materials.

This waste mix is specific to hospitals; in general, urban areas will distinguish other categories, as illustrated in *Figure 4.1.* Additionally, waste categories and waste treatment regulations differ in each country. In general however, hospitals can address waste in the ways outlined below.

Waste that is considered as contaminated does not bring high reuse potential. However, biodegradable and recyclable waste having low hazardous potential should be segregated, recycled and reused on site or off-site.

Kitchen waste should be composted on site if it is possible at the HCD area or off-site. Paper, plastic, metal and glass should be segregated and transported to the place of recycle.

For on-site waste burning technologies, paper materials have big potential. There are several technologies of burning wastes on site. Paper can be combusted in solid fuel stoves. Heat can be used for steam production (electricity generation) and heat production as well as for sterilization process.

PVC materials can be segregated on-site; special bins for plastic shall be placed at HCD area for that purpose. Collected materials should be later shredded on site and transported to the place of recycle. There are several technologies of PVC recycle like Vinyloop: PVC recovered in this way include the cable insulation, coated fabrics, carpets, wallpaper, automotive parts, blister pack or Feedstock recycling which serves to receive gaseous fuels, liquid and / or solid and commercial HCl salt or chlorine (NaCl, $CaCl_2$).

Medical waste has to be treated with special care. There are several regulation on how they should be stored and utilized. For medical waste treatment utilization technologies such as autoclave sterilization, microwave sterilization, steam sterilization, dry thermal disinfection, the sterilization method with mineralization, pyrolysis and combustion can be considered. Autoclaved medical tools are used again as they do not destroy in the process of sterilization. The final product of sterilization with mineralization could be used for road foundations or as an insulating layer in landfills.

Burning waste carries a risk of aromatic dioxins, hydrocarbons, furans and other organic contaminants getting out to the atmosphere. In this power plants emission has to be monitored, combustion side products have to be treated with special care as they are mostly pollutants. Additionally, the authorised air emission level of pollutants maybe unreachable due to technical and cost constraints. That is why burning wastes is not a profitable process and does not bring high circular economy potential.

4.3 Best practice technology I: Biodegradable products

Biobased circular economy or Bioeconomy is an economy based on biomass resources and life sciences, instead of fossil based. It is all about use of biomass for non-food applications. This could be: chemicals, materials, transport fuels, electricity and heat. But, healthcare waste needed to be processed carefully as they have high hazardous potential. However, what if there are biodegradable disposable objects. For example: biodegradable cutlery. These are widely available in a cost-efficient way. They are made from biodegradable materials like wood, paper or food. By using biodegradable products, the usage of energy and water for cleaning will be decreased.

Not only in the hospital, but also the needed energy for production of the product will be reduced. These energy savings resulting in lower CO^2 emissions.
The internal logistic organisation of the hospital will be changed too. Biodegradable disposable are needed as input for the pharma filter as well. See next paragraph.

4.4 Best practice technology II: Waste management - Pharma filter

Waste management purpose is to manage and reduce waste from collection to disposal while recovering valuable resources and creating clean, renewable energy. A state of the Art technology is a Pharma filter.

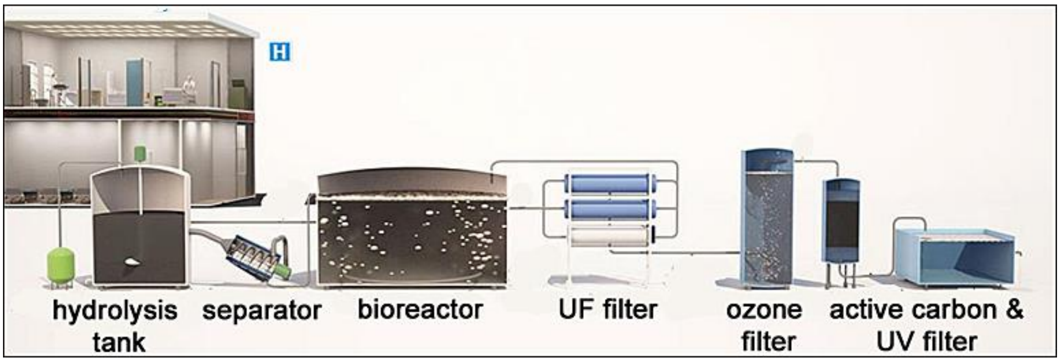

Figure 4.2 Pharma filter (source: Pharma filter Netherlands)

In fact this installation, which should be installed within the environment of the hospital, has effect on waste reduction, energy (biogas) and logistics. This figure above shows the concept of Pharma filter. The waste from a hospital department will be disposed of in a shredder, the Tonto®. This Tonto is conveniently located at the nursing department sanitization station and replaces the conventional bedpan washer. The Tonto is connected to the existing sewer system. Together with the effluent from toilets, sinks and showers, the shredded waste is transported, through the existing hospital piping infrastructure, to a purification plant on the hospital site.
Solid waste is separated from wastewater in the plant. The solid waste is reduced by anaerobic digestion, producing biogas. This gas is re-used for powering the plant. The wastewater is purified and all harmful substances are eliminated.
Evaluation of the first usage of pharma filter in Antonius Hospital, shows the system reduces the amount of solid waste containing 90% and produces green energy from biogas too. The hospital is now producer of clean sustainable energy, from waste.

STREAMER partner Rijnstate Hospital in Arnhem (NL) is partner of a Corporate Social Responsibility group of stakeholders (together with other hospitals, waste service companies university and knowledge institutes) that develops and implements this technology.

5. Conclusion

In this deliverable a set of EeB solutions at district level is researched. Descriptions of solutions for energy systems for healthcare districts (at neighbourhood scale) are described. (Note that the previous version of D2.8 is now complemented with other aspects including logistics, resource and waste management.)

This deliverable focuses on the energy part (especially heating and cooling), but the business cases are much more complicated because of the different stakeholders in the design process. The financial parameters and the stakeholders are very time and location depending. At the moment there are no tools available to cover the whole design process.

The used three step approach (Demand, Supply and Match) is helpful for categorising the different design questions for the decision maker in an early stage of the design process.

For the Demand step, the requested energy from one or more buildings can be calculated, not only for a single building, but also for a set of buildings and a campus or neighbourhood too. Data stored in GIS (mainly based on cadastral data) can then in principle provide the decision maker with relevant data. In general, it seems that at the moment the EU-wide publicly available data of NES and energy demands of sites/buildings is scarce. In specific areas, this may be different.

For the Supply step, GIS databases can help the designer to provide answers to design questions concerning supply options. For example by searching the nearest power plant, or checking the suitability of an ATES system in the soil.

At the moment it is possible to combine this supply and demand both energy [kWh/year] and power [kW], but not on a more detailed level like temperatures, pressure levels. It needs also to be investigated further how to determine additional complexity factors like different altitude level.

Creating and drawing a grid in a GIS environment is currently possible for electricity network and electrical smart grids. There is also software available to design a district heating system itself. That means that the designers and decision makers are supported by different tools and GIS viewers to answer early design questions about the suitability of an EeB NES system.

Application of Circular Economy principles can have an important impact on the total energy consumption and related Carbon Footprint of Hospital Campus Districts. The variety of techniques and aspects that come into play here is large and research is still being done to explore the potential of Circular Economy principles; consequently, design processes and supporting tools are not yet available. However, for waste management, being an important part of Circular Economy, a number of best practice technology solutions are available.

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6. Appendix - Library of Technologies

6.1 Biomass boilers / Cogeneration or combined heat and power (CHP)

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.

Logistic

A biomass installation requires transports for the supply of fuel and for the removal of ash. The fuel (mainly wood or its derivatives) has to be delivered to a size reduction equipment, once its dimensions fit the boilers, it can be stored (storage system depends on the nature of the biomass and the available space) and delivered to the combustion process when needed.

Energy generation and storage

A biomass combustion system consists of several elements: fuel storage, fuel feeding, combustion boiler, ash removal system, and 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 storage of raw material close to the system allows the system itself to work uninterruptedly, it is then more efficient.

Resources and waste material

Biomass includes all kinds of materials that were directly or indirectly derived from vegetal matter, such as wood fuel, wood-derived fuels, (fuel) crops, agricultural and agro-industrial by-products and animal by-products. 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). To be able to meet the limitations set by the legislation regarding the emission of these components, flue gas cleaning systems are required.

6.2 Free Cooling

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 is led to a heat exchanger, so cold water is produced in a closed cooling system. The naturally cold water is then pumped back into the lake, river or ocean.

A hydraulic system as opposed to Aeolic Free cooling system could also avoid or decrease large chiller system capacity.

Logistic

Cold water is pumped out of the lake and pipe system is then needed to deliver the water to the energy transfer station, the street cooling plant and the end-users building, where heat exchangers permit to cool the internal building loop, providing chilled water for the building cooling system.

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; this system is therefore applicable to hospitals if a deep lake/river/ocean is nearby.

Energy generation and storage

This system provides cold water from existing lake or ocean for building cooling systems, it is not usual or recommended to store this thermal energy; the system, indeed, does not operate when there is no need of cooling air, such as in wintertime (this also permit the lake to regenerate).

Resources and waste management

The volume and the depth of the lake, river of ocean 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. No waste material is created by water cooling system.

6.3 Aquifer thermal energy storage / Borehole thermal energy storage

Natural energy sources are, due to their nature, changeable and not predictable, conversely the energy demand is continuous; a thermal energy storage system is therefore needed to ensure energy supply throughout the year.

ATES is composed of at least two boreholes: one is used for water extraction and the other for reinjection, so the hydrological balance of the aquifer is preserved. This is the reason why ATES is also known as “open” system.

BTES are known as “closed” system because the fluid (water in most cases) is pumped through a heat exchanger in the ground with no interaction with the nearby subsoil or potential aquifer.

The key parameter for the feasibility is the balance of heating and cooling loads between winter and summer. If not reached, the gap need to be compensated by either additional heating or cooling capacity.

Logistic

This technology is very suitable for large scale infrastructures and hospitals in particular – many practical examples are listed in D 2.7 – because, once installed, it provides energy when and where is needed, without any delay due to transportation.

Energy generation and storage

Aquifier and Borehole Thermal Energy Storage system are mainly used for large scale seasonal storage for both heat and cold; this is due to their property to be expanded or reduced without additional heat losses: BTES, for instance, can be expanded by installing the new boreholes with a concentric excavation; this method allows to maintain the most of the thermal energy in the centre of the system

In order to optimise technologies and resources, the only requirement for the installation of ATES/BTES is that the underground of the hospital should have characteristics suitable for this kind of technology, appropriate analysis should be prevented.

Resources and waste management

ATES/BTES does not produce remarkable waste material during its activity but, once uninstalled and removed, it is possible to reuse single part of the system in order to minimize the waste products.

6.4 Solar organic Rankine cycle (ORC) system

(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.

Logistic

The Organic Rankine Cycle is well suited for hospital, mainly because of its ability to recover low-grade heat and the possibility to be implemented in decentralized lower-capacity power plants and because the technology has rather small impact on environment. ORC systems are very flexible and can be used in different applications like district heating systems, pellet production factories, sawmills and tri-generation systems with absorption chillers.

Energy generation and storage

The ORC unit is based on a closed Rankine cycle performed adopting a suitable organic fluid as working fluid. 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. Thanks to the ORC, so thanks to the use of a properly formulated working fluid and to the optimization of the machine design, both high efficiency and high reliability are obtained.

Resources and waste management

This technology is available all year long and, due to its versatility, can be used in biomass field and in processes that are not directly tied to electricity production like sawmills, pellet factories, district heating systems, etc. optimizing the global efficiency of the plant using the waste biomass coming from these existing production processes to produce, thanks to the ORC technology, hot water for internal use (belt driers, district heating, etc) and electricity. Main condition for solar ORC is to gather enough solar energy which may be problematic in regions where solar radiation is rather small

6.5 Waste to energy

An example of a waste to energy facility is the incineration. Usually systems are design to provide heat recovery or electrical energy. 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. 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.

Additionally, heat pumps can be used to collect energy from the sanitary grey water network. In winter and in summer, large heat pump installation could recover from 30% to 90% of the heat capacity of this waste water to preheat or heat sanitary Hot water. The COP is around 4 to 7.

Logistic

Waste is delivered to the incinerator from different selection plant in the district or directly from the urban garbage collection. Main issue is waste storage and problems with germs and bacteria. Long waste storage is not recommended (mainly in hospital district); Wastes should be burn immediately, what not always is possible, they then have to be previously segregated, to avoid emission of pollutant material.

Energy generation and storage

This technology helps to solve waste storage problem, supplying neighbourhood with thermal and electrical energy at the same time. In order to minimized the emission of pollutant material, as specified in National Standards, modern incinerators are equipped in pollution mitigation systems (e.g. flue gas cleaning).

Resources and waste management

Different types of waste can be led to the incinerator (waste from industrial, healthcare, agricultural and commercial activities). Wastes can be treated, before being incinerate, to avoid not-combustible material (glass, metal) or organic material

6.6 Biogas power plant

Nowadays this system has gained such a mature and reliable level of development that makes it a key technology in the global market; a qualified know-how for planning and constructing reliable biogas power plants has been consequently developed. The process consists in two different part: the aerobic phase, in which the oxygen permits water and carbon dioxide to be produced and raw materials to be mineralised; the second phase, in which the oxygen is consumed (anaerobic phase) and carbon dioxide and methane are produced.

Logistic

Biogas power plants have been optimised during the decades; now the system is further enhanced by avoiding the electricity losses that occur in the transport, transmission and distribution processes from the point of power generation to the end-user facilities. A capillary and efficient electricity grid is therefore necessary. Raw materials have to be delivered to the power plant, and this add a consistent transportation cost; this is the reason why power plant installation close to farms/industries is preferred.

Energy generation and storage

In biogas power plant, through anaerobic digestion, electricity and thermal energy are efficiently produced on site for local consumption; with a combine heat and power plant it is possible to eliminate the inefficient process of providing electrical energy while fuel is separately burned in a boiler to produce heat. Modern biogas power plants re-use thermal energy (from combustion process) for preheating or generating steam; surplus electrical energy can be transferred to the power grid.

Resources and waste management

Biogas power plant can produce combustible gas from different type of raw materials (waste from agroindustry, green plants and animal manure), waste product from industries can then be re-use. The waste material of the process proved to have good quality as fertilizer, is therefore use instead of other chemical products. To prevent olfactory contamination, each unit (tanks and pipes) of the process must be hermetically sealed.

6.7 Integrated gasification combined cycle (IGCC)

Integrated Gasification Combined Cycle IGCC is a combination of two leading technologies. The first technology is called coal gasification, which uses coal to create a clean-burning gas (syngas). The second technology is called combined-cycle, which is the most efficient method of producing electricity commercially available today. 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.

It must be noted that the gasification process is noisy and odorous. The main waste categories are tar and ashes which are respectively hazardous and non-hazardous classified waste. In addition, the impact of biomass delivery is very heavy for large plant capacity.

Logistic

The size of district-heating systems is shown to be especially important for the integration of IGCC plants due to economies of scale and to the higher heat generation of these plants in comparison to bio transport fuel plants.

Energy generation and storage

The gasification process of the plant produces a clean coal gas, called syngas, which fuels the combustion turbine. In the gasifier coal is then combined with oxygen to produce the gaseous fuel (mainly hydrogen and carbon monoxide). After a cleaning process, the coal gas is used in the combustion turbine in order to produce electricity. The last part of the plant consists of a combustion turbine/generator, a heat recovery steam generator, and a steam turbine/generator. Steam is produced by the heat recovery steam generator from the exhaust heat from the combustion turbine. This steam then passes through a steam turbine to power another generator, which produces more electricity.

Resources and waste management

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 gasify the fuel, the overall efficiencies will be lower. The efficiency of the gasification process depends on the technology and fuel used.

6.8 Wind turbine

A wind turbine converts the energy of the wind into a circular motion, which by a generator is used to generate electricity. Wind power is one of the renewable sources in which technology has reached a highest degree of maturity; thanks to the researches made, it is now possible to use even moderate winds to generate electricity.

Logistic

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). To be optimised, windmills need to be installed far from urbanised areas; already existing electrical grid can be used to deliver the electricity to the storage factory, it is then possible to optimise the use of existing electrical distribution infrastructure.

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 many 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 turbines have been installed in many hospital sites (mainly in North West Europe), due to the facility of installation and the short return of investment (ROI) time.

Energy generation and storage

Wind turbines, and their locations, are determined on the characteristic of the wind and of the environment, it is then possible to operate with moderate winds and to use small sites, trying to reduce environmental impact.

Wind turbines allow to generate electricity in isolated place far from the power grid; it is also possible to integrate this technology with a storage system in order to optimise the produced energy.

Resources and waste management

Low power wind turbines permit generation of power near the consumption points, due to their versatility of applications and locations; it is also possible to integrate wind turbines into hybrid systems.

Wind turbine energy plant does not produce waste material during its operational activity; once reached its end-of-life disposal, it is then possible to re-use parts or single components.

6.9 Hydropower system

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. 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 higher than the type described before.

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.

Logistic

Hydroelectric power plants are usually installed where the environmental condition are optimal; often these sites are not accessible or supplied with electrical grid; it is therefore necessary to provide the technical and technological infrastructure in order to make the plant functioning and reachable for periodical maintenance of the powerhouse.

Energy generation and storage

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

Resources and waste management

The creation of dams can 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. Flowing water power plant does not cause significant modification of the environment: water is captured only if the minimum flow is guaranteed in the river.

No waste material is produced during the standard activity of the plant; End-of-life disposal should reinstate the natural condition of the environment, each component and technological element of the plant has to be removed.

6.10 Geothermal energy (deep underground)

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.

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.

<u>Logistic</u>

For economic reason 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

<u>Energy generation and storage</u>

Two wells are drilled from the surface into an aquifer layer, one is for extracting hot water and the other is for reinjection the water into the aquifer after its heat is absorbed in a heat exchanger. A heat exchanger is needed to extract the heat from the underground water and use it for heating purposes.

<u>Resources and waste management</u>

Geothermal energy in the deep underground is available all year. 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; no waste are generate during its standard producing activity.

6.11 Other technologies

Still other technologies can be considered:

- The use of heating based on heat pump connected to lakes, rivers or the sea could also regenerate the temperature of the water.
- Some new technologies including hybrid panel need to be added as it is very suitable for simultaneous energy production of electricity and hot water and also used in summer as a mean of radiative cooling. Energy efficiency can reach from 20% to 90% (for hybrid). In addition, large area are available either on roof or as carpark or walkway shading.