DT 1.4.1

DETAILED DESCRIPTION OF THE METHODOLOGY AND CRITERIA FOR LOCATION SUITABILITY

30/06/2018

*“**Methodology**, based on **criteria** related to the urban context (e.g. transport network) and on environmental and social aspects, **valuating the location for the REEF 2W platforms** (tested in WP3 and used in WP4 for identification of replication sites).”*

Contents

1. Introduction

In this deliverable, the methodology and criteria required for the Urban Compatibility Assessment (UCA) is described. From the Waste Water Treatment Plant (WWTP) surplus energy in terms of (i) electricity, (ii) natural gas and (iii) thermal energy is provided.

(i) Surplus electricity can be fed into the electricity grid. Electricity can also be transported across large distances and therefore doesn't require a detailed assessment of the WWTP surroundings, since potential electricity consumers are spread regionally or even further. Since the WWTP also requires electricity, the plant has to be connected to the electricity grid and the question concerning the distance to the electricity grid does not arise.

(ii) The natural gas substitute from the WWTP has to be treated similarly. After the purification process, the gas can be fed into a gas grid, and does not require a detailed assessment of the urban context. Gas itself can be stored and can also be transported across large distances. However, if the WWTP is not already connected to a gas grid network, it is essential to know, if there is a grid available and how far the next gas-grid connection point is located.

(iii) For the surplus thermal energy that can be provided at the WWTP a detailed urban compatibility assessment is necessary. The spatial context is essential, since thermal energy cannot be transported across large distances and potential consumers have to be identified in the vicinity of the WWTP.

The following methodology and criteria description is therefore tailored to check the compatibility of supplying the WWTP surroundings with thermal energy. However, the analysis of the WWTP surrounding, as described in this deliverable, is inevitable to get detailed knowledge about potential heat consumers and therefore necessary whenever surplus energy can be provided by a WWTP.

2. Methodology & Criteria

The methodology used to describe the urban compatibility assessment is illustrated in the following graph (Figure 1). Also, the chapters of this deliverable are split according to the methodology presented below.

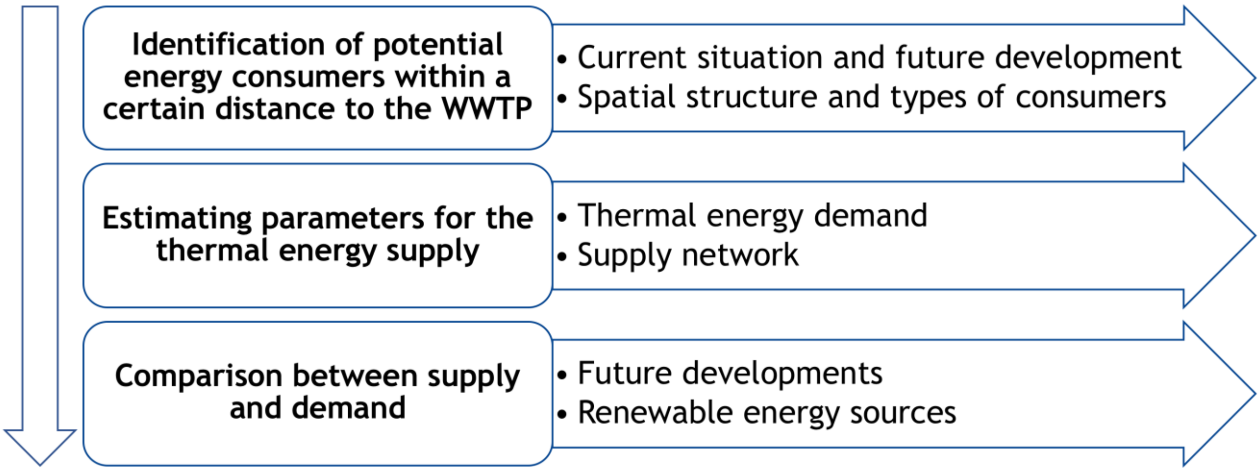


Figure 1: Methodology of the Urban compatibility assessment (UCA) (own illustration).

2.1. Identification of potential energy consumers within a certain distance to the WWTP

In the initial step it is important to identify the exact location of the WWTP. The WWTP is either (i) located close to a potential heat sinks (short radius) like residential buildings, agricultural use or industrial areas or the WWTP is (ii) located far from any settlement or potential heat consumer (large radius).

Another approach was already presented in DT_1_2_3, where three different types of WWTPs were distinguished:

(1) WWTP located within a settlement

(2) WWTP located close to a settlement and

(3) WWTP located far from a settlement (after Neugebauer et al. 2015).

If the WWTP is located within or close to a potential heat sink, a detailed analysis of the associated thermal energy demand can be followed. As a rule of thumb, customers worth considering, comprise approximately 100 kW thermal capacity (this capacity corresponds to around 30 dwelling units). Table 1 shows a first overview of minimum criteria required in order to use surplus thermal energy from a WWTP. In order to optimally use surplus thermal energy from a WWTP, rather low temperature levels (required by the potential heat sinks) and constant temporal heat demands are required. By increasing thermal insulation of existing buildings, results in a decrease of thermal energy demand, which must also be considered for the long-term suitability of a heat supply system.

Minimum requirements for using surplus thermal energy from WWTPs	Rule of thumb
Building related:	
- Minimum heat capacity	- 100 kW
- New buildings or existing buildings	- Both
- Inlet temperature	- Common temperature (below 70 °C), up to 95 °C with special heat pumps
Distance between heat sink and source:	
- Undeveloped areas without any barriers	- For 0.5 MW up to 0.5 km, for 2 MW up to 2 km
- Developed areas (e.g. existing settlements)	- Individual assessment

Table 1: Minimum requirements for using surplus thermal energy from a Waste Water Treatment Plant (after Abwasserenergie 2017).

In the case, a WWTP is located far from any thermal energy consumer, it is recommended to consider additional potential customers that can be located close to the WWTP in future scenarios. For instance, green houses for drying purposes (agricultural use) or industrial areas that require thermal heat or cooling could be situated close to the WWTP.

Before starting to estimate the thermal energy demand, it is essential to identify potential key customers in a first step. Scattered areas comprising for example mostly single-family houses are not ideal heat consumers, since this kind of spatial structure comprises rather low heat densities. To get a first idea about key customers with rather high heat demand, the following sample selection is presented:

- Multi-storey buildings
- Industrial areas
- High density areas (e.g. city centre)
- Special use: Agriculture or forestry (e.g. drying purposes)

In general, appropriate areas comprising consumers with high thermal energy demand densities should be considered as priority areas. Also, short distance to the heat source are essential, in order to increase the energetic and economic efficiency of the heat supply system.

2.2. Estimating parameters for the thermal energy supply

This chapter is divided into two parts. The first part addresses the estimated thermal energy demand (heating and cooling) in the WWTP surrounding. The second part describes the supply network that is required in order to connect the heat source (WWTP) and potential heat consumers (sink).

2.2.1. Thermal energy demand

In the first section, the methodology of settlement related thermal energy demand estimation is presented. Moreover two additional methods are presented: (i) building related thermal energy demand estimation and (ii) thermal energy demand estimation concerning special thermal energy consumers like industries or agriculture.

Settlement related

For each settlement a certain thermal energy demand can be estimated. In order to do so, it is necessary to confine homogeneous settlement areas. Homogeneous areas comprise similar building arrangements, that again depend on density and positioning of preferably similar building types. To get a first idea about different settlement types, some examples are presented:

- Rural town centres (rather high densities with residential and non-residential use)
- Historical city centres (even higher densities with again both residential and non-residential use)
- Scattered settlements (mostly comprising single family houses or terraced houses with mostly residential-use)
- Industrial areas (non-residential areas with possibly high thermal energy demands)

Figure 3 shows how a differentiation into different settlement typologies could look like. Besides building types, the already mentioned density of a settlement is essential to determine thermal energy demand. The more energy is used within a certain area (MWh/a.ha), the better the energy efficiency. If the density is high, also thermal energy demand is high, which again has an impact on the energetic and economic feasibility of a district heating system.

Figure 2: Three different types of spatial developments: Purple – Multi-storey buildings (dwelling); Red: Single-family houses; Blue: Commercial area (own illustration).

Figure 3 illustrates the main principle on how to calculate the total thermal energy demand of a settlement. Based on building arrangements and building types, certain settlement typologies can be developed. For each settlement typology a specific thermal energy demand is allocated. After that, the energy related area expressed in hectares is multiplied with the specific thermal energy demand, resulting in the total thermal energy demand of a settlement.

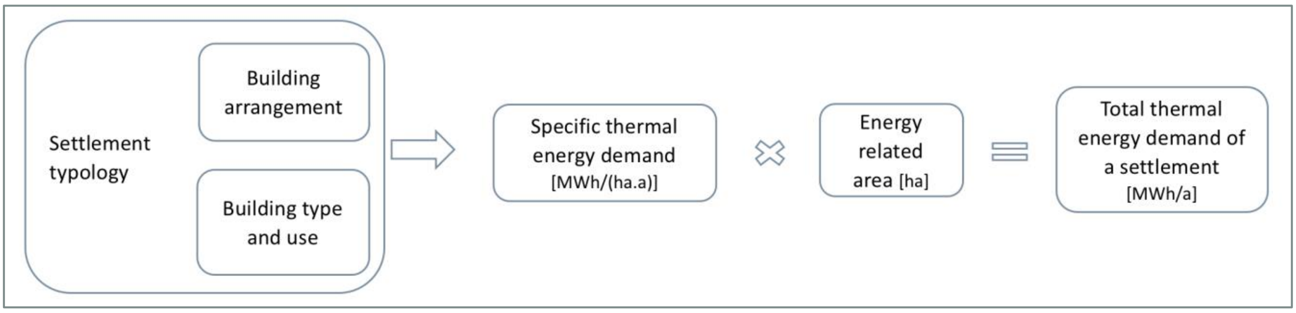


Figure 3: Principle of estimating the total thermal energy demand for a settlement in MWh/a (illustration after StMUG 2010).

The specific thermal energy demand of a settlement type can be found in various literature and present a default value in MWh/ha. Finally, after specifying the thermal energy demand of a settlement which usually presents one subarea, the total thermal energy demand can be calculated, by simply summarising heat demands of each subarea, as illustrated in Figure 4.

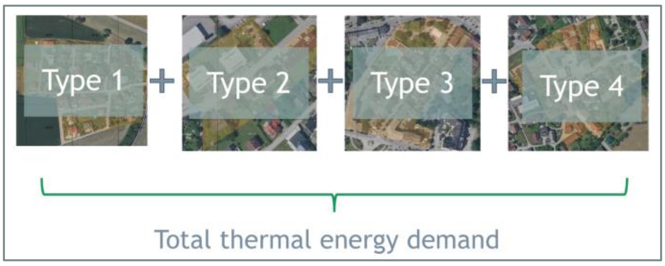


Figure 4: Illustration of combining different subareas to asess the overall heat demand (own illustration).

Building related

The following subsection is split into two parts: (i) building related thermal energy demand estimation concerning residential buildings and (ii) building related thermal energy demand estimation concerning non-residential buildings.

Residential

If a building related thermal energy demand estimation is carried out, a very detailed assessment of each building is necessary. Figure 5 shows multi-storey buildings in red. In total four buildings are highlighted. Each building consists of multiple storeys. In order to estimate the thermal energy demand of each building, detailed information about the total amount of m^2 (energy related area or gross floor area) for each building has to be gathered. Besides the building types (e.g. single-family houses, terraced houses, multi-storey buildings or apartment blocks, etc.), also the construction period is an essential parameter. Construction periods have a huge impact on the overall heat demand of buildings. For example, older buildings tend to consume more energy than buildings with a more recent building standard. By simple multiplying the amount of m^2 (energy related area) of each building with the corresponding thermal energy demand per square meter (depending on the building typology) the thermal energy demand of a single building can be calculated. The principle is illustrated in Figure 6.

Figure 5: Illustration of multi-storey buildings.

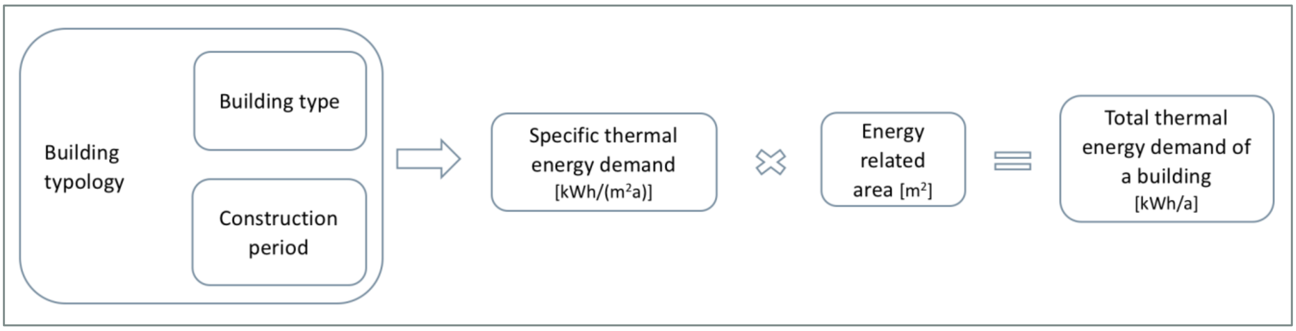


Figure 6: Principle of calculating the thermal energy demand of a single building (illustration after StMUG 2010).

For the building related thermal energy demand estimation, it is also important to consider different utilisations within one building. For instance, within multi-storey buildings apartments, as well as offices or small shops can be found. Figure 7 illustrates this phenomenon that is crucial to consider, when calculating the thermal energy demand for individual buildings.

Figure 7: Mixed types of use within one building (own illustration).

Non-residential

Besides residential buildings, also non-residential buildings constitute potential thermal energy consumers. The same methodology as presented in Figure 6 can be applied for non-residential buildings, if specific thermal energy demands [in kWh/m^2.a] are available. Examples for non-residential buildings are:

- City halls
- Building yards
- Municipal offices
- Police stations
- Schools and Kindergartens etc.
- Service buildings etc.

An alternative methodology to the previously described thermal energy demand estimations, would be the assessment of actual thermal energy demands for each individual building in the study area. From an energy suppliers point of view, public buildings constitute an interesting heat sink. In this case, most buildings are owned by municipalities. Therefore, the exact thermal energy demand can be gathered directly from local authorities. However, for residential buildings, the exact amount of thermal energy is mostly not available, or simply too expensive to assess in detail.

Special use: Operations (Commercial and industrial use)

Depending on the local situation and depending on each branch, various specific thermal energy demands for different kinds of operations are available. For instance, steel producing industry might require higher temperature levels and overall more heat than branches like software development. For a general overview on how to assess thermal energy of operations Figure 8 is presented:

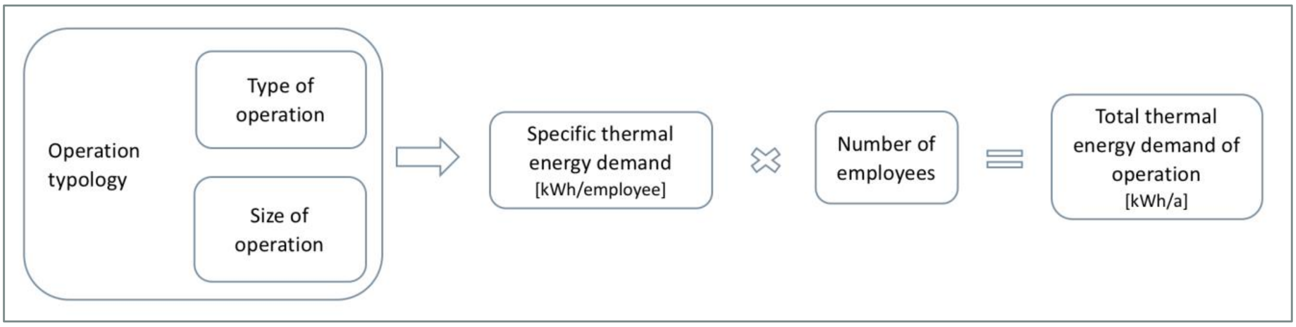


Figure 8: Principle of calculating thermal energy demand of operations (illustration after StMUG 2010).

The basic methodology to identify thermal energy demand for operations is to use the number of employees. For each employee, depending on the operation typology, a specific thermal energy demand is estimated. In a subsequent step, the thermal energy demand can be calculated by multiplying the number of employees with the specific thermal energy demand for each operation typology.

The following sample list shows potential commercial and industrial thermal energy customers:

- Iron & steel production
- Machinery or car production
- Telecommunication industry
- Software development
- Agricultural machinery production
- Breweries or beverage production, etc.

Special use: Agriculture and forestry

This special non-residential thermal energy sink should always be given consideration. Especially for future developments. In most cases, the immediate vicinity of a WWTP comprises agricultural areas. Therefore, the agricultural sector is an obvious thermal energy consumer. The following list shows potential fields of application in the agricultural and forestry sector (after Gaderer et al. 2007, Schulz et al. 2007, Loibl et al. 2008):

- Drying of products in agriculture and forestry like:
    - Wood chips (whole year; required drying temperature 65 °C)
    - Crop (July – August; required drying temperature 50 °C)
    - Medical and spice plants (June – October; required drying temperature 55 °C)

- Heating and cooling of barns (depending on season)
- Heating of greenhouses (October to March; e.g. vegetables and fruits – required air temperature between 20 and 30 °C)
- Use for aquaculture (whole year; water temperature between 15 and 35 °C)

2.2.2. Supply network

In order to transport thermal energy, an appropriate supply network in the form of a district heating network has to be established. An important parameter concerning the supply network is the total lengths of the network in [m]. In terms of heat transportation, the distance between source and sink can vary, depending on the type of district heating system. Basically, there is a differentiation between "warm" district heating and "cold" district heating (also illustrated in Figure 9):

(1) Warm district heating up to 80° C

Shorter distances can be covered with a central heat transfer station close to the WWTP.

(2) Cold district heating 7 – 17 °C

Longer distances can be covered with heat transfer station at the customer site

Neugebauer & Stoeglehner 2015 described the benefits and challenges concerning cold and warm district heating systems. For example, warm district heating requires better thermal insulation. This is because with high temperatures, also greater amounts of heat losses are possible. Cold district heating offers the possibility for multiple heat customers to "consume" the required heat on different temperature levels, since the heating centres including heat pumps are located at the customer location.

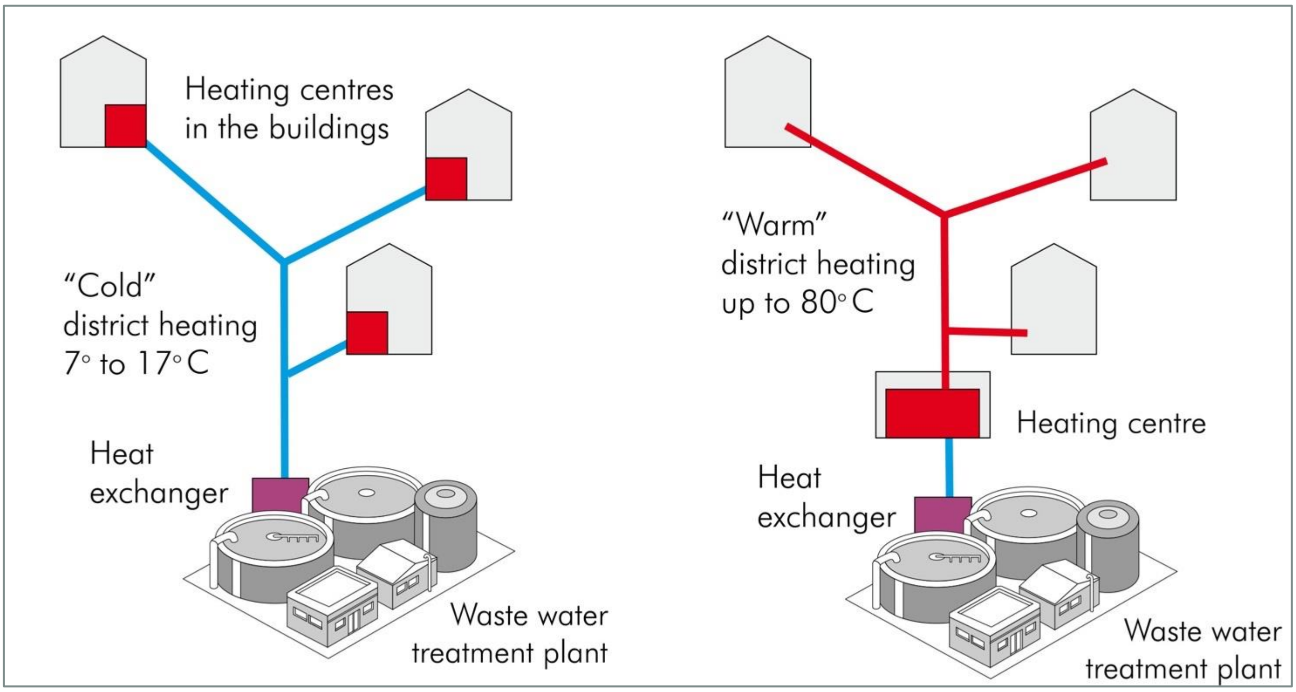
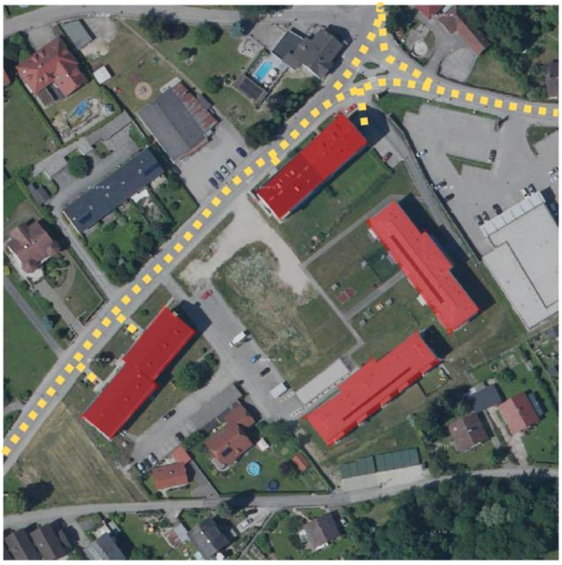


Figure 9: Differentiation of "warm" district heating system and "cold" district heating system (Neugebauer & Stöglehner 2015, DBU, BWP, IEIA 2009; Tracey Saxby, IAN Image Library (Http://ian.umces.edu/imagelibrary/)).

Within settlement

For the calculation of the length of the supply network (pipe length) within a settlement, default values from literature are available. Depending on the number of buildings within a certain area and the building type, different lengths of the supply network are available. Basically the settlement type related grid length [m] can be multiplied with the corresponding area of the settlement [ha]. The result is the total grid length of the settlement in metres. Figure 10 illustrates the required lengths of a district heating network within a settlement.



F igure 10: Illustration of the district heating network in yellow (own illustration).

Connection of source & sink

Beyond the defined settlement areas, additional metres of the district heating network are required. Figure 11 illustrates the approach of planning a potential district heating system. Within the settlement areas (yellow) default values of pipe lengths can be used. Outside the settlement area (in red) additional pipe lengths to the next potential grid connection point or the heat sink itself have to be calculated. This procedure is necessary, in order to connect the thermal energy source with the thermal energy sink.

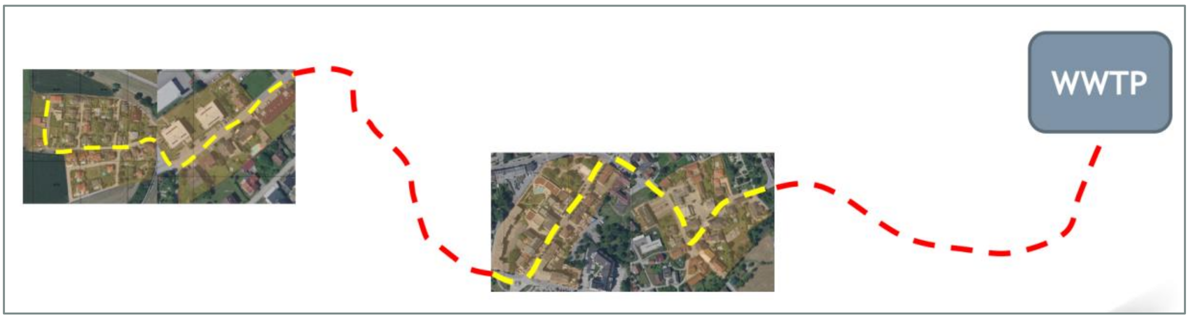


Figure 11: Connection of thermal energy sink with the thermal energy source: The WWTP (own illustration).

An important parameter to check the suitability of a district heating system is the so-called heat demand density. According to Nussbaumer et al. (2017) the heat demand density can be simply calculated by dividing the thermal energy demand of a settlement with the total grid length of a settlement. Heat demand density values below 2 (MWh/a.m) are considered as economically unsuitable. The higher the connection density, the more efficient the supply system.

2.3. Comparison between supply & demand

The thermal energy that is provided at the WWTP can now be compared with the estimated demand in the vicinity. Ideally, enough thermal energy demand is already available around the WWTP and a detailed planning process can be pursued. However, in order to check also the future feasibility of thermal energy use in the WWTP surroundings the following aspects of this chapter should be considered.

2.3.1. Future development

Concerning future developments, it is essential to reflect potential optimizations of the spatial structure. For example, by adding further buildings to the study area or to increase the thermal insulation rate. Another important aspect is to consider additional potential renewable energy sources in the spatial context that might reduce the overall heat demand in the study area.

Optimisation of spatial structures

Figure 12 shows potential space for future additional buildings (in orange). In this case an additional building could be built or additional storeys could be added to already existing buildings, increasing the total future thermal energy demand of the area. The so-called degree of development can be used to describe this phenomenon. If the degree of development is estimated to be 100 %, no additional future development is possible. If it is below 100 %, future developments should be included in the calculation.

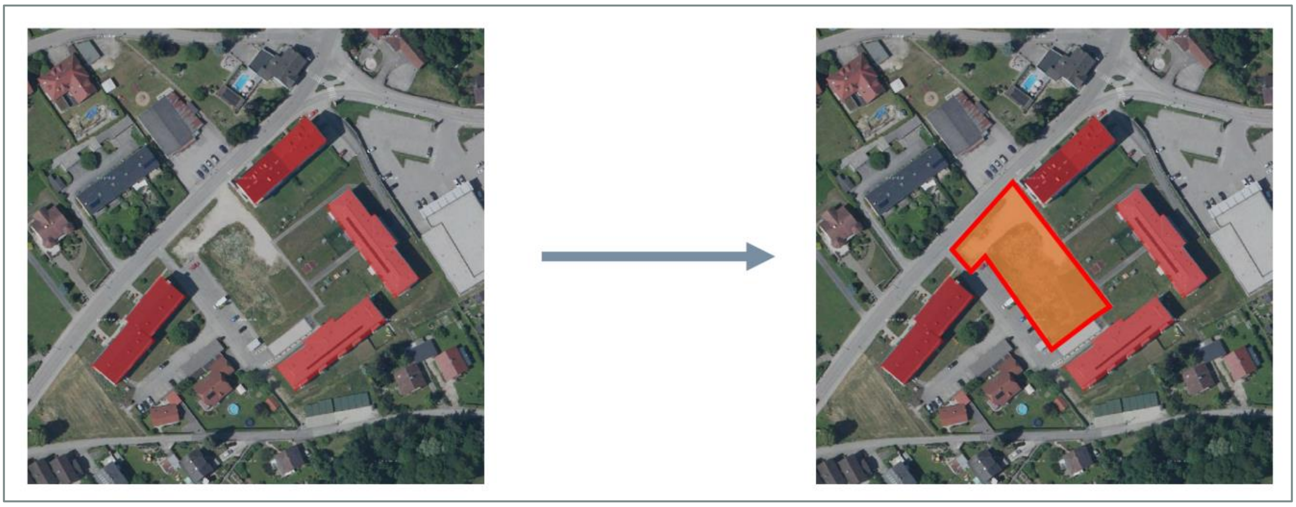


Figure 12: Space for additional buildings, increasing future thermal energy demand (own illustration).

Another important aspect is thermal insulation of buildings. Wherever insulation of existing buildings is carried out in near future, a corresponding reduction of space heating is the result. Also, the future degree of connection within a certain area can change. If additional areas are developed, more customers might connect to the district heating system. One possible future scenario for supply networks is the degree of connection. The degree of connection can change over time. For existing settlements, the degree might be rather low, whereas for recent developments the degree might be 100 %, resulting in higher efficiency of the system. Figure 13 illustrates the connection of two additional buildings within the supply area.

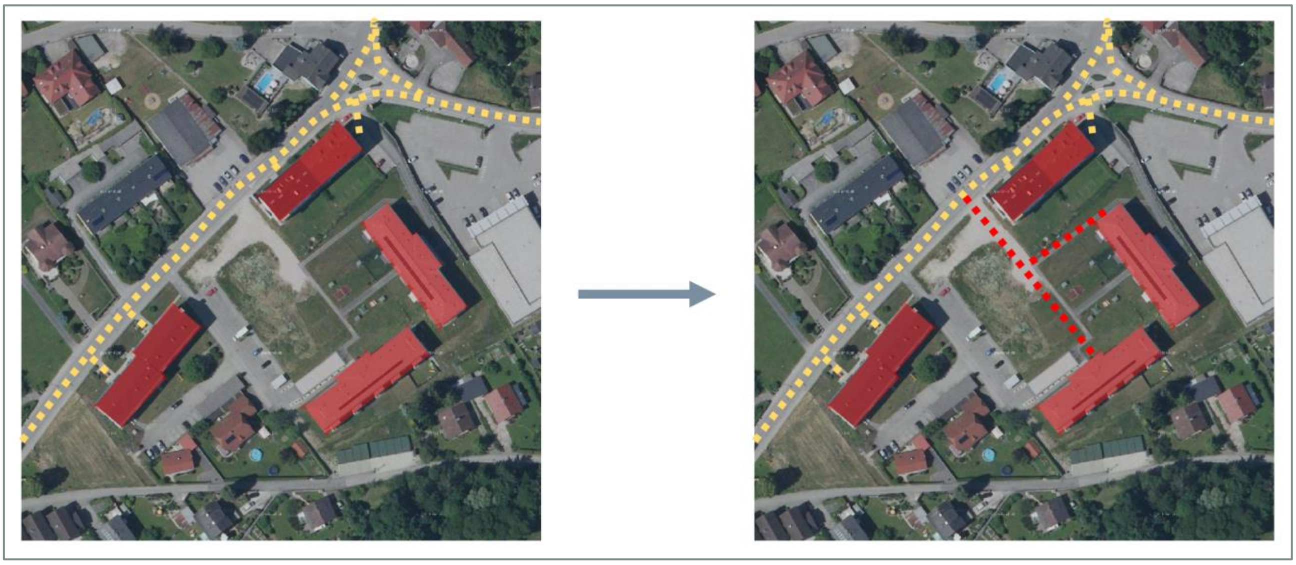


Figure 13: Illustration of additionally connected buildings. Additional grid lengths are highlighted in red, whereas already existing grid length is illustrated in yellow (own illustration).

Identification of renewable energy sources

One circumstance that might reduce the total thermal energy demand of a settlement is the construction of decentral energy sources like solar heating systems. If multiple solar heating systems are installed within a certain area, the thermal energy demand will decrease, resulting in lower efficiencies of the supply system. Therefore, it is essential to consider this fact for future scenarios and to implement this circumstance in the calculations.

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