SUPPORT DHC

District heating network separation to transition towards low-temperature systems

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1 Executive summary

This report presents a MATLAB-based tool for identifying candidate areas of existing district heating (DH) systems that could be separated and supplied primarily by a new low-temperature heat source. Instead of requiring a detailed pipe-network model for initial screening, the algorithm uses spatial DH cells and prioritises them according to proximity to the heat source, annual heat demand, and a Construction Modernity Index representing building age.

A region-growing procedure identifies a candidate area for separation, while additional processing addresses spatial gaps and disconnected islands. An iterative calibration procedure adjusts the selected area to achieve a design heat load consistent with the available heat source capacity and an assumed backup contribution from the remaining DH network.

The tool is intended for DH planners, utilities, engineers, and researchers investigating stepwise transitions towards lower supply temperatures. It generates datasets containing selected DH cells and calculated priority indices, together with spatial visualisations of the results. The tool supports preliminary assessment and planning but does not replace detailed hydraulic, temperature-feasibility, or economic assessments.

2 Introduction

District heating systems play an important role in the decarbonisation of the heating sector by enabling the utilisation of renewable and recovered heat sources. In the transition towards lower greenhouse gas (GHG) emissions and reduced reliance on fossil fuels, there is increasing interest in integrating locally available waste heat into existing DH systems. However, many urban waste heat sources are available only at relatively low temperature levels and therefore cannot be directly integrated into conventional DH networks, which typically operate with supply temperatures above 80 °C.

One promising solution is to reduce the DH supply temperature. Lower supply temperatures improve the overall energy efficiency of the system through reducing distribution heat losses, increasing the efficiency of heat pumps, and enabling the utilisation of a wider range of low-temperature heat sources. Nevertheless, integrating low-temperature heat sources into existing high-temperature DH networks presents several technical challenges. Most importantly, the minimum supply temperature required by building heating systems must still be maintained to satisfy the heat demand of consumers. Although decentralised heat pumps can be installed in buildings with the high temperature requirements to locally boost the supply temperature, a substantial reduction in the network supply temperature generally requires a detailed assessment of all connected buildings and, where necessary, measures such as radiator replacement, substation upgrades, or building energy retrofits. Consequently, the simultaneous integration of new low-temperature heat sources and reduction of DH supply temperatures can become an extensive process, particularly for large DH systems (Reguis et al., 2021, Østergaard et al., 2022, Guelpa et al., 2023, Lund et al., 2018).

An alternative approach is to separate a suitable part of the existing DH network and operate it as a relatively independent low-temperature DH subsystem supplied by the new heat source. Compared with transforming the entire network, this approach limits the number of buildings and network components that require investigation and modification. Furthermore, the separated subsystem can be designed specifically according to the characteristics of the available heat source and the thermal requirements of the connected buildings, while avoiding many of the hydraulic and operational challenges associated with introducing decentralised heat sources into the extensive high-temperature network. This enables a more targeted and stepwise transition towards low-temperature DH with reduced implementation effort and investment costs (Stock et al., 2024).

A key challenge, however, is determining which part of the DH network should be separated. The selected area should be geographically coherent, compatible with the available heat source capacity and location, and include buildings that are suited for low-temperature operation. Manual identification of such areas is impractical for large DH systems and may not produce an optimal solution. Therefore, an automated and computationally efficient method is required to identify suitable network areas for separation while considering the characteristics of both the heat source and the supplied buildings. This report presents an algorithm for identifying a coherent DH network area that can be separated from the existing system and supplied by a low-temperature heat source.

3 Algorithm overview

The algorithm aims to identify and separate a suitable part of a heat demand density map for supply by a new low-temperature waste heat source. The underlying motivation is that fully integrating a low-temperature heat source into an existing DH system—typically operating at

temperature levels associated with 3rd-generation DH—may hinder the transition towards 4th- and 5th-generation DH systems, which are characterised by lower supply temperatures.

Unlike existing approaches that rely on detailed DH network data, the proposed algorithm is based on heat demand density, building age, and the distance between the heat source and the supplied area. Heat demand density and building age data are more accessible than detailed network topology, making the algorithm more flexible and applicable to a wider range of DH systems. Furthermore, datasets containing such information have already been developed for large parts of Europe, enabling the proposed approach to be applied without the need of detailed network maps.

The objective of the algorithm is to determine which part of the heat demand density map, within the boundaries of an existing DH system, can be separated and supplied by the new low-temperature heat source. By creating a DH subsystem, the transition towards low-temperature operation can be focused on a limited number of buildings and substations.

4 Data requirements

The primary input to the separation algorithm is a DH heat demand density map. The map consists of spatial cells, each representing a specific geographical area. In the current implementation, and in accordance with the available data source, each cell represents an area of 1 ha (100 m × 100 m).

The following input data are required:

- Latitude and longitude of each DH area cell
- Annual heat demand associated with each cell (ie., heat demand density)
- Latitude and longitude of the new heat source
- Thermal capacity of the new heat source
- Building age associated with each cell

4.1 Design heat loads

The annual heat demand associated with each cell must be converted into design heat loads, representing the DH load under extreme outdoor temperature conditions. This conversion is required because the separated network is designed to be supplied primarily by the new waste heat source during peak heating demand.

As heating demand decreases during warmer periods, the available waste heat may exceed the demand within the separated network. In such situations, the surplus heat can be supplied to the main DH network through the existing hydraulic connection between the separated and main networks. This hydraulic connection also enables the main network to support the separated network during periods when the design heat load exceeds the capacity of the new waste heat source. The objective of the proposed separation is not to maximise the utilisation of the waste heat source throughout the year. Rather, it is to facilitate the transition towards a low-temperature district heating subsystem while maintaining operational flexibility through the hydraulic connection to the main network. Consequently, the separation algorithm requires the design heat load of each cell.

A detailed procedure for estimating design heat loads from annual heat demand is presented in (Atabaki et al., 2026), which requires the following input data:

- Shares of space heating, domestic hot water (DHW), and distribution losses in the annual district heating load

- Effective indoor temperature (°C)
- Extreme outdoor temperature (°C)
- Annual heating degree days (°C·day)
- Capacity factors for DHW and distribution losses

As an alternative, design heat loads can be estimated using less data-intensive approaches. One such approach uses an assumed share of domestic hot water (DHW) in the annual district heating demand. First, the average hourly DHW demand for each cell is calculated by multiplying the corresponding annual heat demand by the DHW share and dividing the result by 8,760 hours. The total design heat load of each cell is then approximated as ten times its average hourly DHW demand.

5 Algorithm principles

There are three principles on which the algorithm is based:

- Distance to the heat source: Cells located closer to the new heat source are considered more favourable for separation. Prioritising nearby areas helps minimise the length of the separated network. Consequently, cells with a shorter distance to the new heat source are assigned a higher priority during the separation process.
- Heat demand density: Cells with a higher heat demand density are considered more favourable for separation. The underlying principle is that separating high-density areas allows a greater proportion of the heat demand to be supplied while involving fewer buildings and substations. Consequently, higher heat demand density is assigned a higher priority during the separation process.
- Building Age: More recently constructed buildings are generally considered more suitable for operation with lower DH supply temperatures. Although previous studies have shown that older buildings can also be supplied by low-temperature DH systems, they often require additional modifications, such as radiator replacement, resulting in higher costs. Consequently, cells containing newer buildings are assigned a higher priority for separation.

6 Priority index

To enable the separation algorithm to rank cells consistently, the three selection criteria—distance to the heat source, heat demand density, and building age—are combined into a single priority index. Since these parameters have different units and ranges, they are first normalised to values between 0 and 1 before being combined.

6.1 Distance to heat source

The distance of each cell from the new heat source is normalised with respect to the maximum distance between the heat source and any cell within the considered area. The resulting normalised value is then subtracted from one so that cells closer to the heat source receive higher values and, consequently, a higher priority. In the current implementation, the maximum distance is therefore defined by the location of the farthest cell rather than the technical characteristics of the heat source. A more physically oriented approach could instead determine the maximum service radius from the thermal capacity and supply temperature of the heat source, thereby restricting the candidate area to cells that can realistically be supplied.

6.2 Heat demand density

The maximum heat demand density among all cells within the considered area is identified. The heat demand density of each cell is then normalised with respect to this maximum value, resulting in values between 0 and 1. Cells with higher heat demand densities therefore receive higher normalised values and, consequently, a higher priority.

6.3 Building Age

In the Citiwatts database, each cell is characterised according to the distribution of building floor area across four construction periods. To represent the overall building age using a single value, the Construction Modernity Index (CMI) is calculated by assigning a relative age position to each construction period, as shown in Table 1.

Table 1. Relative age positions assigned to construction periods for calculating the Construction Modernity Index (CMI).

Construction period	Relative age position
Before 1975	0
Between 1975 and 1990	0.33
Between 1990 and 2000	0.66
Between 2000 and 2014	1

The CMI is calculated as:

$$CMI = 0\,S1 + 0.33\,S2 + 0.66\,S3 + 1S4$$

where S1 to S4 are the fractions of the total building floor area belonging to each construction period. A value of CMI = 0 represents entirely old building stock, whereas CMI = 1 represents entirely new building stock. Higher CMI values therefore indicate greater suitability for separation.

6.4 Priority index formulation

The priority index of each cell is calculated as the arithmetic mean of the three normalised parameters:

- Distance to the heat source (D_{norm})
- Heat demand density (HD_{norm})
- Construction Modernity Index (CMI)

Accordingly, the priority index is given by:

$$Priority\ Index = \frac{D_{norm} + HD_{norm} + CMI}{3}$$

Cells with higher priority index values are considered more suitable for separation.

7 Algorithm steps

7.1 Data extraction

Heat demand density and building age data are extracted for all cells within the DH area. Heat demand density and building age data are obtained from the Hotmaps (Citiwatts) database, while the DH area is obtained from the Pan-European Thermal Atlas.

7.2 Maximum supply distance calculation

A maximum distance from the new heat source (R) is defined as the working boundary of the separation algorithm. In the current implementation, R is equal to the distance between the new heat source and the farthest DH cell within the study area.

Alternatively, R could be determined from the thermal capacity and supply temperature of the new heat source, thereby representing the maximum service distance over which heat can be supplied effectively.

7.3 Design heat load estimation

The design heat load of each cell is estimated from its annual heat demand. Although a detailed procedure based on the DH capacity factor as described in Section 3.1 can be followed, the current implementation employs the simplified approach. It is assumed that 30% of the annual heat demand is used for DHW production. The average hourly DHW demand is obtained by dividing the annual DHW demand by 8760, and the design heat load is estimated as ten times this hourly value.

7.4 Priority index calculation

The Euclidean distance (centre-to-centre) between each DH cell and the new heat source is first calculated. The distances are then normalised with respect to the maximum distance R and subtracted from one, so that cells closer to the heat source receive higher values.

Next, the maximum heat demand density among all cells within the DH area is identified, and the heat demand density of each cell is normalised with respect to this value.

The CMI is then calculated for each cell based on the distribution of building floor area across the different construction periods.

Finally, the three normalised parameters—distance, heat demand density, and CMI—are combined with equal weighting to calculate the priority index of each cell. The priority index is subsequently used to rank the candidate cells for separation.

7.5 Initial cell selection

The separation process begins with the DH cell located closest to the new heat source. Selecting the nearest cell minimises the initial connection distance and associated piping costs.

7.6 Region-growing expansion

The separated area is expanded iteratively using a region-growing procedure.

A frontier set is constructed containing all cells adjacent to the already selected cells but not yet included in the separated area. Two cells are considered adjacent if they share either a complete or partial edge.

At each iteration, the frontier cell with the highest priority index is added to the separated area.

7.7 Capacity constraint

After each iteration, the cumulative design heat load of the separated area is compared with the maximum allowable capacity.

The algorithm terminates once the cumulative load exceeds the allowable limit, which is determined from the capacity of the new heat source and the permitted contribution from the remaining DH network. The margin is defined based on the assumption that a limited portion

of the peak load can be supplied from the remaining DH network. Accordingly, if the capacity of the new heat source is Q_{new}, the maximum load that can be covered is given by $\frac{Q_{new}}{1-\epsilon_{peak}}$, where ϵ_{peak} is the maximum allowable fraction of the total heat that can be supplied by the peak (backup) source. In the current implementation, a value of $\epsilon_{peak} = 0.2$ is adopted from the literature (Stock et al., 2024) and reflects the assumption that the separated DH system should remain largely independent, with only a limited share of heat supplied by the remaining network.

Since the new heat source operates at a low temperature level, heat pumps might be required to raise the temperature. This introduces additional electrical energy input to the system. In the model proposed by (Stock et al., 2024), the combined contribution of the utilised heat source and the electricity input to heat pumps is constrained by the capacity of the new heat source, i.e. $Q_{utilised} + P_{HP} \leq Q_{new}$, where P_{HP} is electricity input to heat pumps, in order to prevent excessive reliance on heat pumps as an additional energy source.

Similarly in this algorithm, the electricity input to heat pumps is not treated as an explicit supply term but is implicitly accounted for within the source-capacity constraint. Consequently, the effective usable capacity on the new-source side is bounded by Q_{new}, and the contribution of heat pumps does not need to be explicitly considered in the load allocation step.

8 Algorithm Implementation

The previous section introduced the principles and workflow of the proposed algorithm. This section describes its MATLAB implementation, highlighting the main implementation decisions and practical considerations adopted during algorithm development.

8.1 Coordinate transformation and distance calculation

The distance between cells is calculated using the Euclidean distance. To enable this, the geographical coordinates (latitude and longitude) are converted into local Cartesian coordinates. In the conversion, one degree of latitude is assumed to correspond to 111,000 m. Although this value varies slightly with geographical location, the variation is small and therefore a constant value is assumed throughout the algorithm.

The conversion of longitude to distance depends on latitude and is calculated as the product of 111,000 m and the cosine of the reference latitude. The resulting Cartesian coordinates are then used for all distance calculations within the algorithm.

8.2 Artificial cell generation

The input DH heat density map may not always be fully connected. Therefore, one of the initial steps of the algorithm is to introduce artificial cells to ensure a connected and topologically consistent DH area. These artificial cells do not represent actual heat demand and are assigned zero heat demand and peak load values. They are used solely to support the separation process.

Two types of artificial cells are introduced:

- Bridge cells: These cells are added to connect disconnected parts of the DH area. If two groups of cells are separated by a small gap, bridge cells are inserted to create a continuous connection between them.
- DH-area hole filling cells: These cells are added to fill enclosed holes within the DH area. The procedure first uses an alpha shape to define the boundary of the selected area.

An alpha shape is a method for drawing a boundary around a group of cells while following the overall shape of the area, including concave regions and indentations. The shape is controlled by an alpha parameter, which was set to 150 m in the current implementation (equivalent to 1.5 times the cell size). Larger alpha values produce a smoother and less detailed boundary, whereas smaller values allow the boundary to follow the cell distribution more closely. Once the boundary has been identified, enclosed holes within it are detected and filled. Cells located within these holes are added to create a more continuous and connected district heating area.

Artificial cells are used only during the execution of the algorithm to maintain connectivity and support area selection. They are excluded from the final separated area and are not considered in the calculation of heat demand or design heat load.

8.3 Region-growing post-processing

8.3.1 Separated-area hole filling

The algorithm starts with the cell closest to the heat source and iteratively expands the separated area by selecting neighbouring cells with the highest priority. As a result of this region-growing procedure, some cells may remain unselected despite being completely surrounded by separated cells. To address this issue, an alpha shape is used to define the boundary of the separated area. Any enclosed holes identified within this boundary are then filled by adding the corresponding cells to the separated area. This step improves the spatial continuity and consistency of the final separated district heating area.

8.3.2 Remaining-island absorption

Ideally, both the separated area and the remaining DH area should form connected regions. However, after the region-growing procedure, the remaining area may consist of disconnected islands. One possible approach would be to check the connectivity of the remaining area every time a new cell is selected for separation. In practice, this approach is too restrictive because it may prevent the separation of cells that temporarily create a disconnected island, even though the entire island could later become part of the separated area.

Instead, the algorithm evaluates the connectivity of the remaining area only after the region-growing procedure has been completed. The largest connected component is considered the main remaining area, while smaller disconnected islands are identified. Islands that are adjacent to the separated area and satisfy predefined size criteria are absorbed into the separated area. This procedure improves the connectivity of the remaining DH area while avoiding unnecessary restrictions during region growing.

8.4 Iterative growth calibration

Both the separated-area hole-filling procedure and the remaining-island absorption procedure may add cells to the separated area after the region-growing step has been completed. Consequently, the final separated demand may exceed the target demand used during region growing. To account for this effect, the algorithm does not grow the separated area directly to the target supply capacity. Instead, region growing is stopped at a reduced level defined by a calibration coefficient. The hole-filling and island-absorption procedures are then applied, and the final separated design heat load is recalculated. An iterative calibration procedure adjusts the growth coefficient until the final total separated design heat load falls within an acceptable range of the target value, ($\frac{Q_{new}}{1-\epsilon_{peak}}$).

9 Algorithm parameters and limitations

The proposed algorithm aims to produce a separated DH area while preserving the connectivity of both the separated area and the remaining DH network. However, enforcing connectivity after every cell selection during the region-growing procedure would be computationally demanding and overly restrictive, since a temporarily disconnected island may later become incorporated into the separated area. Therefore, the connectivity of the remaining DH area is evaluated only after completion of the region-growing procedure.

The largest connected component is regarded as the main remaining DH area, while smaller connected components are classified as remaining islands. Although this post-processing approach substantially improves connectivity, it does not guarantee that the remaining DH area will always form a single connected component. This limitation is accepted in order to maintain computational efficiency and avoid imposing overly restrictive connectivity constraints during region growing.

The behaviour of the post-processing procedure, however, can be adjusted through two user-defined parameters controlling island absorption. A remaining island may be absorbed into the separated area if it is adjacent to the separated region and satisfies both a size criterion and a design peak load criterion.

The island-size criterion is:

$$N_{island} \leq f_{island} N_{selected}$$

where f_{island} is the island-size factor. In the current implementation, the default value is $f_{island} = 0.2$, meaning that islands containing no more than approximately 20% of the number of cells already included in the separated area are eligible for absorption.

The design peak load criterion is:

$$Q_{island} \leq Q_{island,max}$$

where $Q_{island,max}$ is the maximum allowable design peak load of an absorbed island. In the current implementation, $Q_{island,max} = \infty$, meaning that no explicit peak-load restriction is imposed.

Both parameters are user-adjustable and may be modified depending on the desired behaviour of the algorithm. Increasing the island-size factor or the maximum allowable island peak load allows larger disconnected islands to be absorbed, thereby improving the spatial connectivity of the remaining DH area. However, this also reduces adherence to the original priority-index criteria, since the absorbed cells are selected primarily to improve spatial continuity rather than because they have the highest priority values.

In addition, absorbing larger islands may increase the final separated design peak load beyond the initial growth target. Conversely, lower threshold values preserve closer adherence to the priority index and target capacity but increase the likelihood that disconnected remaining islands will persist. The parameter values therefore represent a trade-off between spatial connectivity, priority-index consistency, and compliance with the target separated heat load.

To compensate for the increase in separated demand caused by island absorption and hole-filling operations, the algorithm employs an iterative growth-calibration procedure. Rather than growing the separated area directly to the target design peak load, the region-growing process initially stops at a reduced level controlled by a growth coefficient. After post-processing, the resulting separated design peak load is compared with the target value, and

the growth coefficient is iteratively adjusted until the final demand falls within an acceptable tolerance.

In the current implementation, the region-growing process initially targets 90% of the new heat source capacity by setting the initial growth coefficient to 0.90. Following the post-processing steps (hole filling and island absorption), the resulting separated design peak load is compared with the target value. If the final load is below the acceptable range, the growth coefficient is increased by 0.01; if it exceeds the acceptable range, the coefficient is decreased by 0.001. This iterative adjustment continues until the final separated design peak load falls within ±3% of the target value, $\frac{Q_{new}}{1-\epsilon_{peak}}$. To ensure numerical stability, the growth coefficient is constrained to the range 0.10–2.00. These values were found to provide a computationally efficient calibration but may be modified by the user to suit different applications.

Guidelines for using the MATLAB implementation of the proposed algorithm are provided in Section 10.

10 Demonstration of the algorithm

The proposed algorithm is demonstrated using the DH system of Reggio Emilia, Italy. Heat demand density and building age data were obtained from the Citiwatts database, while the DH area was extracted from the Pan-European Thermal Atlas. The remaining input data, including the location and thermal capacity of the new low-temperature heat source, were assumed for demonstration purposes.

In the first example, the thermal capacity of the new heat source was set to 50 MW. The resulting separated DH area is shown in Figure 1. The black cells represent the original DH area, while the red cells indicate the area selected by the algorithm for separation. The right-hand figure provides a more detailed visualisation, showing the location of the new heat source together with the artificial cells introduced during preprocessing and the remaining islands absorbed during post-processing. The figure also distinguishes between original separated cells, artificial cells, and absorbed islands.

The final design peak heat load of the separated area is 60.57 MW, which lies within the target tolerance of ±3% around the desired value of $\frac{50}{1-0.2} = 62.5$.

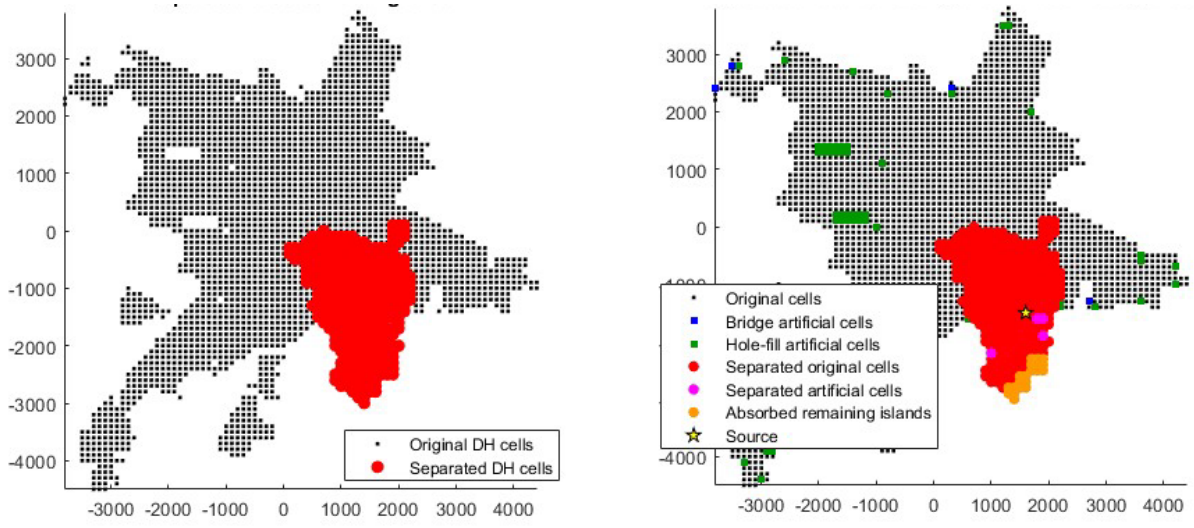


Figure 1. Example application of the proposed separation algorithm to the DH system of Reggio Emilia, Italy, with a 50 MW low-temperature heat source located at (44.6779838, 10.6453515). Left: Original

and separated DH areas. Right: Detailed view showing the heat source, artificial cells, absorbed remaining islands, and the final separated area.

Figure 2 presents the priority-index heat map for the entire DH area of Reggio Emilia corresponded to the Figure 1. Cells shown in brighter red have higher priority indices and are therefore more suitable for separation and supply by the new heat source, whereas cells closer to black have lower priority indices and are considered less suitable. It can be seen that some cells with relatively high-priority indices are located far from the new heat source. However, owing to the connectivity requirement imposed on the separated area, these cells are not included in the separated region shown in Figure 1.

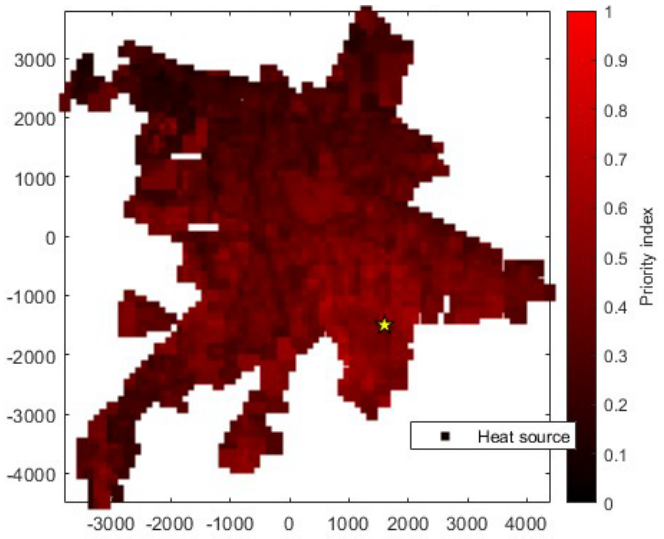


Figure 2. Spatial distribution of the priority index for the DH area of Reggio Emilia, with a 50 MW low-temperature heat source located at (44.6779838, 10.6453515).

Two additional examples demonstrating the application of the proposed algorithm are presented in Figure 3 and Figure 4.

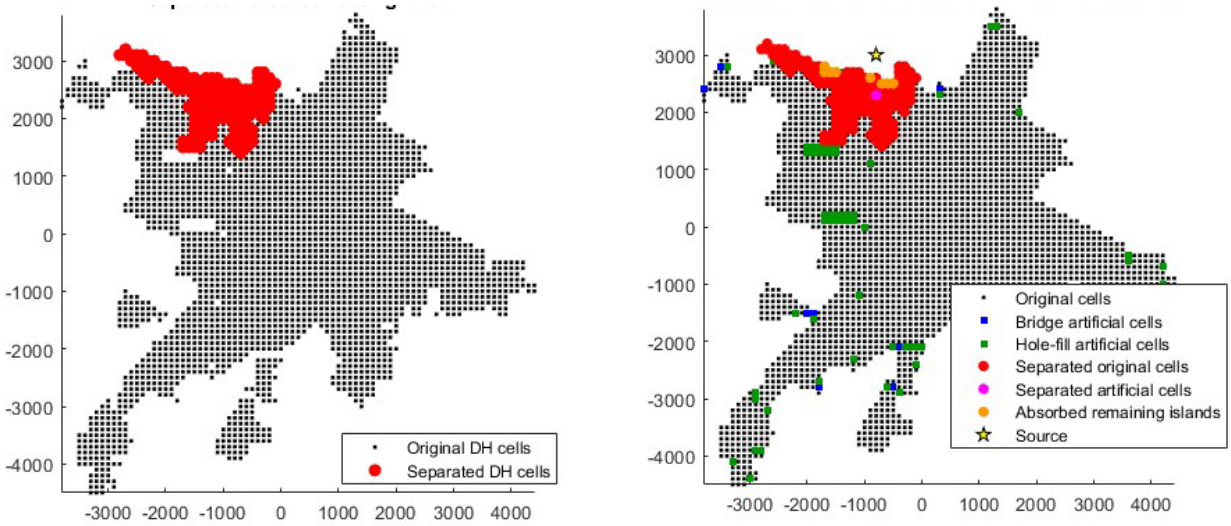


Figure 3. Example application of the proposed separation algorithm to the DH system of Reggio Emilia with a 10 MW low-temperature heat source located at (44.7179838, 10.6153515).

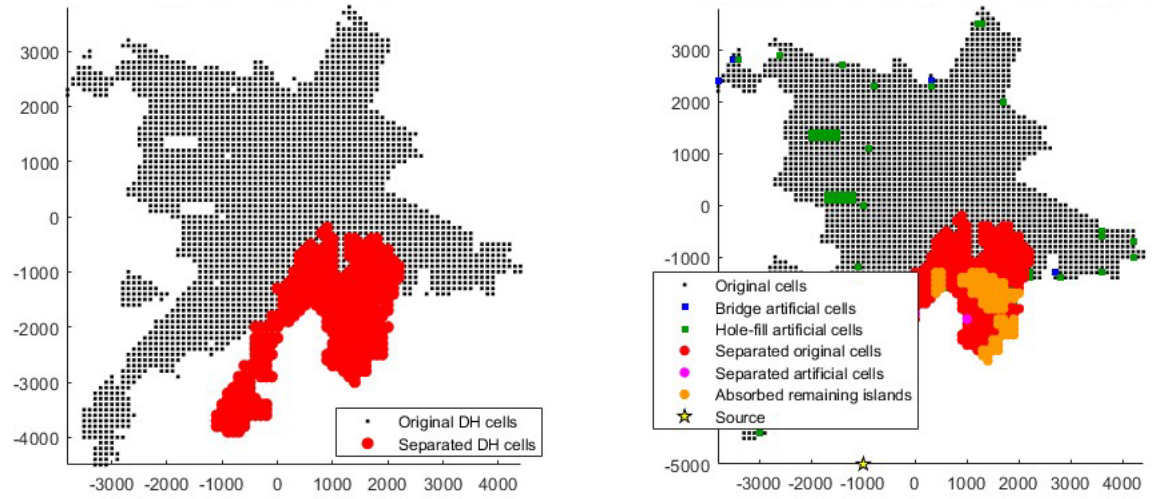


Figure 4. Example application of the proposed separation algorithm to the DH system of Reggio Emilia with a 40 MW low-temperature heat source located at 44.6464215, 10.6123116).

It can be seen from Figure 3 that the cells selected for separation are not necessarily only those located closest to the new heat source. Similarly, Figure 4 shows that, in some cases, certain cells may be selected in order to avoid creating isolated remaining areas and to maintain the connectivity of the separated region.

11 Guidelines for using the MATLAB tool

The MATLAB implementation requires an Excel input file containing one row for each DH-area cell. The required columns are pointid, Latitude, Longitude, AnnualHeatDemand_MWh, CMI, and DesignHeatLoad_MW. AnnualHeatDemand_MWh represents the annual heat demand of the cell, CMI is the Construction Modernity Index defined in Section 5.3, and DesignHeatLoad_MW is the design heat load described in Section 3.1. The six quantities are prepared before execution; the MATLAB script does not generate design heat loads or calculate the CMI from building-age categories.

Before running the code, the user should specify the input-file name, latitude and longitude of the new heat source, its thermal capacity, and, if applicable, the maximum supply distance (R) in the input section of the MATLAB script. Other algorithm parameters may also be adjusted if required. The input Excel file and MATLAB script should be placed in the same working directory.

Running the script identifies the cells selected for separation and generates two Excel output files: Separated_real_cells.xlsx, containing the selected DH cells, and DH_cells_with_priority_index.xlsx, containing the original input data together with the calculated priority index. The code also generates figures showing the separated area and the spatial distribution of the priority index. A separate User Guide accompanies this technical report and provides the detailed data preparation, parameter configuration, execution, and output-interpretation instructions.

12 Conclusions

This report presents a MATLAB-based algorithm for identifying suitable areas of existing DH systems that could be separated and operated as low-temperature subsystems supplied by new heat sources. The proposed approach combines heat demand density, building age, and

distance to the heat source to prioritise DH cells for separation. A region-growing procedure, together with spatial connectivity adjustments and iterative growth calibration, is used to identify a geographically coherent area with a design heat load compatible with the available source capacity and the permitted backup supply from the remaining DH network.

The tool provides a practical approach for preliminary assessment of DH network separation without requiring detailed information on the existing pipe network. Using spatial heat demand data and a limited number of user-defined parameters, the MATLAB implementation identifies the cells selected for separation and generates corresponding datasets and graphical visualisations. It can therefore support DH operators, planners, and researchers in investigating potential low-temperature DH subsystems and comparing scenarios involving different heat source locations and capacities.

The algorithm was demonstrated using the DH system of Reggio Emilia, Italy, considering different heat source capacities and locations. The results illustrate its ability to identify suitable areas for separation while accounting for the available heat source capacity and the spatial characteristics of the DH system.

Nevertheless, the tool is intended for preliminary spatial screening rather than detailed technical design. It does not explicitly consider the actual pipe network topology, hydraulic constraints, temperature requirements, or investment costs. Furthermore, the results depend on the quality of the input data and the selected algorithm parameters. Consequently, the identified areas should be regarded as potential candidates for separation, requiring further technical and economic assessments before implementation.

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