Evaluation of contradictions in the energy sector towards green deal targets
The Contradictions Between District and Individual Heating Towards Green Deal Targets

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Introduction

Over the last decade, numerous strategies, regulations, and policies have been enforced to drive decarbonization.

The policies pursued and the enforcement mechanisms used are not always highly effective and often fall short of the necessary climate targets set by policymakers.

There are situations when the government cannot overlook existing blind spots in policy-making. The blind spot can be defined as the area around the vehicle where the driver cannot see through the mirrors without turning their head or taking their eyes off the road. Similar blind spots occur in energy policy.

Heat supply is the most carbon and energy-intensive sector in the European Union, accounting for about 50% of total demand European Union.

Most studies comparing district heating and individual heating focus on one perspective, analysing either the cost-effectiveness, technical performance, or environmental impact of the different heating technologies. Looking at only one dimension and neglecting other sustainability dimensions can create unexpected blind spots in energy policy.

It is necessary to develop a comprehensive methodology that allows for a full-fledged sustainability assessment that includes a unified consideration of all aspects together.
The aim of this study is to design a methodology to analyze contradictions and validate the methodology by revealing some of the controversies of the energy sector.

This study's main objective is to compare the sustainability of district heating with different individual heating solutions.

The subject of the study is not individual heating and district heating solutions in a particular country, but the study aimed to highlight the existing trends in the sustainability of heating solutions.

Sustainability is assessed in terms of the compatibility of the technology with the goals of a low-carbon economy.
The core element for sustainability assessment is the construction of the composite sustainability index. In this study composite sustainability index is calculated for district heating (based on the natural gas) and four different technological solutions of decentralized (individual) heating wood pellet boiler; natural gas boiler; solar collectors; and (4); heat pump.

The selection of individual heat supply solutions was based 1) on a Danish study on individual heat supply solutions 2) on the availability of data to create a complex index 3) on the sustainability of the heat supply solution.
• **Determination of Sustainability Dimensions and selection of Indicators**

Model includes four main dimensions – technical, environmental, economic, and social. Each dimension is composed of various descriptive indicators.

In total, 19 indicators were selected and grouped into representative dimensions.

• **Data collection and expert evaluation**

Quantitative indicator values for each technology were determined based on two main approaches – quantitative and qualitative assessment. For the indicators where the specific values could be found from publicly available databases, scientific papers, researches and reports, legislation, and technology data sheets.

Technology efficiency (tech1), specific CO₂ emissions (env1), specific capital investments (econ1), specific service and maintenance costs (econ2), technology lifetime (econ3), specific energy costs (econ4).
Data and assumptions for district heating and individual heating technologies

| Indicator                   | Notation | Unit   | District heating | Wood pellet boiler | Natural gas boiler | Solar collectors | Heat pump |
|-----------------------------|----------|--------|------------------|--------------------|--------------------|------------------|-----------|
| Efficiency                  | tech1    | %      | 100              | 80                 | 92                 | 82               | 257       |
| Specific CO₂ emissions      | env1     | g/kWh  | 202              | 0                  | 202                | 0                | 42        |
| Capital investments         | econ1    | EUR    | 6175             | 10740              | 6440               | 23980            | 16243     |
| Service and maintenance costs| econ2    | EUR/year| 0                | 605                | 255                | 300              | 360       |
| Technology lifetime         | econ3    | years  | 25               | 20                 | 19                 | 30               | 20        |
| Specific energy costs       | econ4    | EUR/kWh| 0.036            | 0.038              | 0.04               | 0                | 0.058     |
Methods

Composite sustainability index which consist of:

**Data normalization:** Results were normalized using min-max normalization technique. The min-max normalization standardizes indicator values in the range [0;1]

**Weighting and indicator aggregation into sustainability index**

Weighting is performed in order to proceed with indicator aggregation into representative sub-indices and final composite sustainability index. After data normalization, weights are assessed by a two-step procedure. At first, equal weighting is applied to calculate sustainability dimension sub-index scores using:

\[ I_{S,j} = \sum_{i}^{n} W_{ji} \times \frac{I_{N,ji}^+}{n_{ji}}, \quad W_{ji} = \frac{1}{n_{ji}} \]

\( I_{S,j} \) is dimension’s sub-index value, \( W_{ji} \) is impact weight of indicators on dimension sub-index (application of equal weighting) \( n_{ji} \) is number of indicators in dimension.

Then AHP method is utilized to account for different impact scales of each dimension to the overall sustainability index: \( I_{CSI} = \sum_{j}^{n} W_{j} \times I_{S,j} \) \( I_{CSI} \) is composite sustainability index, \( W_{j} \) is impact weight of dimension sub-index on composite sustainability index (determined from AHP).

AHP method was used to collect expert opinion on each dimension’s impact on the overall sustainability.
| i     | Indicator                                                                 | Unit   | Indicator value | District heating | Wood pellet boiler | Natural gas boiler | Solar collectors | Ground/air source heat pump |
|-------|---------------------------------------------------------------------------|--------|-----------------|------------------|--------------------|--------------------|------------------|------------------------------|
| tech1 | Efficiency                                                               | %      | Data/assumptions | -                | -                  | -                  | -                | -                           |
| tech2 | Complexity of service and maintenance (availability of specialists on site, immediate avoidance of risk situations) | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| tech3 | Stable availability of necessary energy resources for full thermal energy production | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| tech4 | Possibilities to diversify the energy resources used (the technology is not limited to only one type of energy resource supply) | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| tech5 | Possibilities to balance the generated heat load (ability to respond to rapid seasonal and short-term changes in demand) | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| tech6 | Operational stability (stable heat supply to the grid)                      | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| tech7 | Possibilities for the use of low-grade fuel                                 | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| env1  | Specific CO2 emissions                                                      | Kg/kWh | Data/assumptions | -                | -                  | -                  | -                | -                           |
| env2  | Degree of complexity of flue gas cleaning                                   | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| econ1 | Capital investments                                                        | €/kW   | Data/assumptions | -                | -                  | -                  | -                | -                           |
| econ2 | Specific service and maintenance costs (OPEX)                               | €/kWh  | Data/assumptions | -                | -                  | -                  | -                | -                           |
| econ3 | Technology lifetime                                                        | Years  | Data/assumptions | -                | -                  | -                  | -                | -                           |
| econ4 | Specific energy costs                                                      | €/kWh  | Data/assumptions | -                | -                  | -                  | -                | -                           |
| econ5 | Possibility to use surplus heat for optimization of heat production and maximum resource efficiency | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| econ6 | Cost optimization options (choice of energy resource based on the most economically advantageous price at the moment; opportunities for economies of scale) | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| soc1  | End user comfort and satisfaction level                                     | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| soc2  | End-user safety level (reduced or no risk of fire, leakage, etc.)           | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| soc3  | Impact on the promotion of local resources (reduction of energy imports)    | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
| soc4  | Level of end-user control over heat consumption                             | Value  | Expert evaluation | -                | -                  | -                  | -                | -                           |
Dimension weight from an expert survey

| SUSTAINABILITY DIMENSIONS | UNIFORM VARIATION RATIO |
|---------------------------|-------------------------|
| Social                    | 0.10                    |
| Economic                  | 0.16                    |
| Environmental             | 0.36                    |
| Technical                 | 0.38                    |
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pumps

env1 Specific CO₂ emissions (g/kWh)
env2 Complexity of flue gas cleaning

tech1 Efficiency (%)
tech2 Complexity of service and maintenance
tech3 Stable availability of energy resources
tech4 Opportunities for diversification of utilized energy resources
tech5 Possibility to balance the produced heat load
tech6 Operational stability
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pump

- **SOCIAL DIMENSION SUB-INDEX**
  - soc4 Consumer control level over heat consumption
  - soc3 Impact on the promotion of local resources
  - soc2 Consumer safety level
  - soc1 Consumer comfort level

- **ECONOMIC DIMENSION SUB-INDEX**
  - econ6 Cost optimization options
  - econ5 Possibility to use surplus heat
  - econ4 Specific energy costs (EUR/kWh)
  - econ3 Technology lifetime (years)
  - econ2 Service and maintenance costs (EUR/year)
  - econ1 Capital investments (EUR)
Composite sustainability index

![Composite sustainability index chart](image_url)
Summary

Composite sustainability index was constructed to compare sustainability levels of district heating with four different individual heating solutions – wood pellet boiler, natural gas boilers, solar collectors, and heat pumps.

Wide range of indicators were selected including both quantitative and qualitative assessment methods. The sustainability index was composed of 19 different indicators that were grouped in four sustainability dimensions – technical, environmental, economic, and social.

Indicators were normalized using a min-max normalisation technique that scaled sub-indices and index values in a range [0;1], allowing comprehensively interpreting the obtained results.
Conclusions

According to energy experts assessment technical and environmental dimensions were evaluated as the most essential determinants of heat supply system’s sustainability.

After the model approbation process, it was concluded that it is important to carefully select indicators to obtain an objective assessment of technological solutions and consistent calculations.

The highest sustainability index was obtained by heat pumps (0.64), followed by solar collectors (0.63), wood pellet boilers (0.55), and district heating (0.50). The lowest index value was obtained by natural gas boilers (0.38).

The results indicated that district heating is highly competitive and cost-efficient compared to individual heating solutions since it obtained the highest sustainability scores for technical and economic dimension sub-indices.

A potential blind spot was identified in environmental dimension sub-index values where district heating reported poor values due to higher flue gas complexity and emission factor assumptions made during the calculation procedure.
Conclusions (II)

The results showed that higher sustainability for the district heating could be achieved by cutting the utilization of fossil energy resources such as natural gas for combustion processes and replacing it with biomass.

Policymakers should put more emphasis on finding sustainable ways to promote flue gas cleaning and air decontamination from biomass combustion processes.

The utilization of a sustainability index could improve policy makers' decision-making processes during the implementation of energy policies.

The composite sustainability index method can serve as a useful tool for determining which technologies should be promoted. Above all, it can help identify the critical aspects of each technology that need to be addressed to avoid possible blindspots in energy policy.

The sustainability index calculation outcomes could be further utilized to make more constructive and reasonable decisions related to the achievement of long-term targets to a low carbon economy.