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 can not 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.**

Objectives

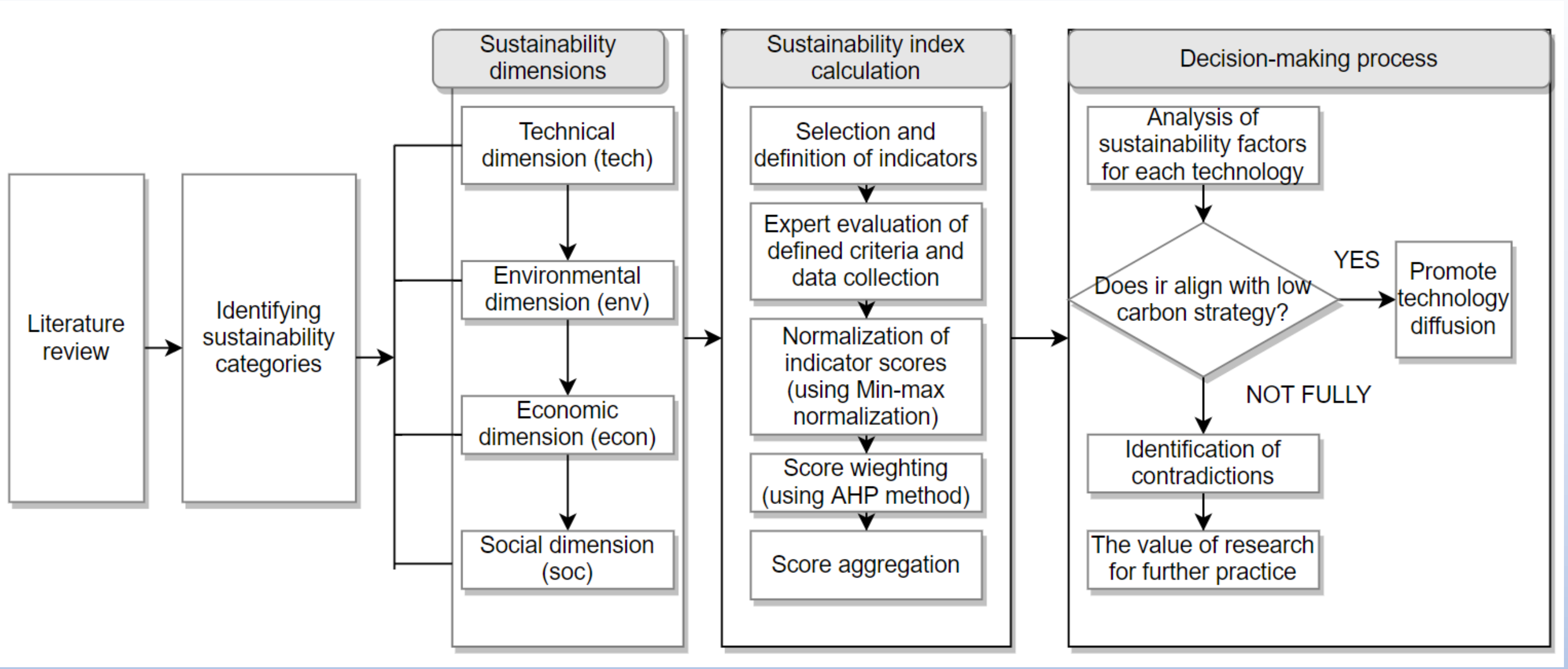
The aim of this study is to design a methodology to analyze contradictions and validate the methodology by revealing some of the controversies of the energy sector.

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.

Model for sustainability index construction and decision-making algorithm



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 CO_2 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 CO_2 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:

$$I_{S,j} = \sum_{i}^{n} W_{ji} \text{ x } I_{N,ji}^{\pm} \text{ , } W_{ji} = \frac{1}{n_{ji}}$$

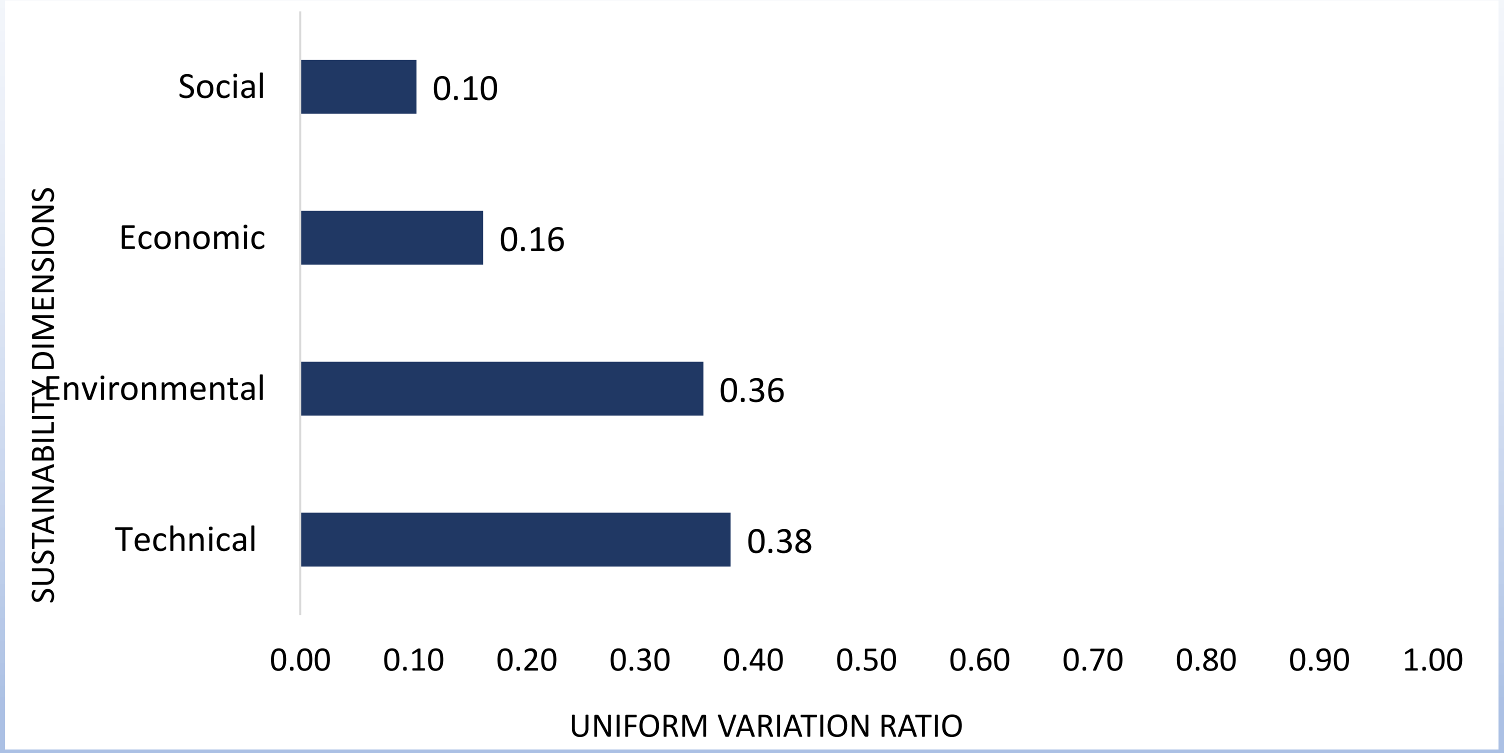
$I_{S,j}$ is dimension's sub-index value, W_{ji} is impact weight of indicators on dimension sub-index (application of equal weighting) n_{ji} is number of indicators in dimension.

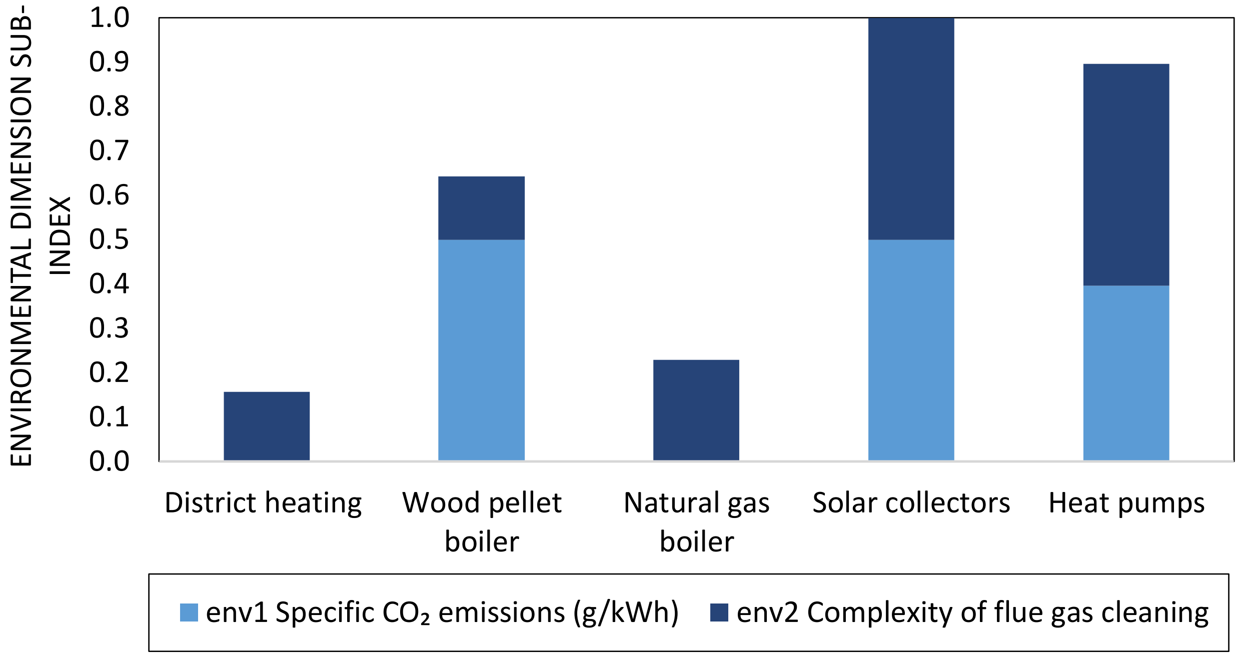
Then AHP method is utilized to account for different impact scales of each dimension to the overall sustainability index: $I_{CSI} = \sum_{j}^{n} W_j \text{ x } I_{S,j}$ I_{CSI} is composite sustainability index, W_j is impact weight of dimension sub-index on composite sustainability index (determined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

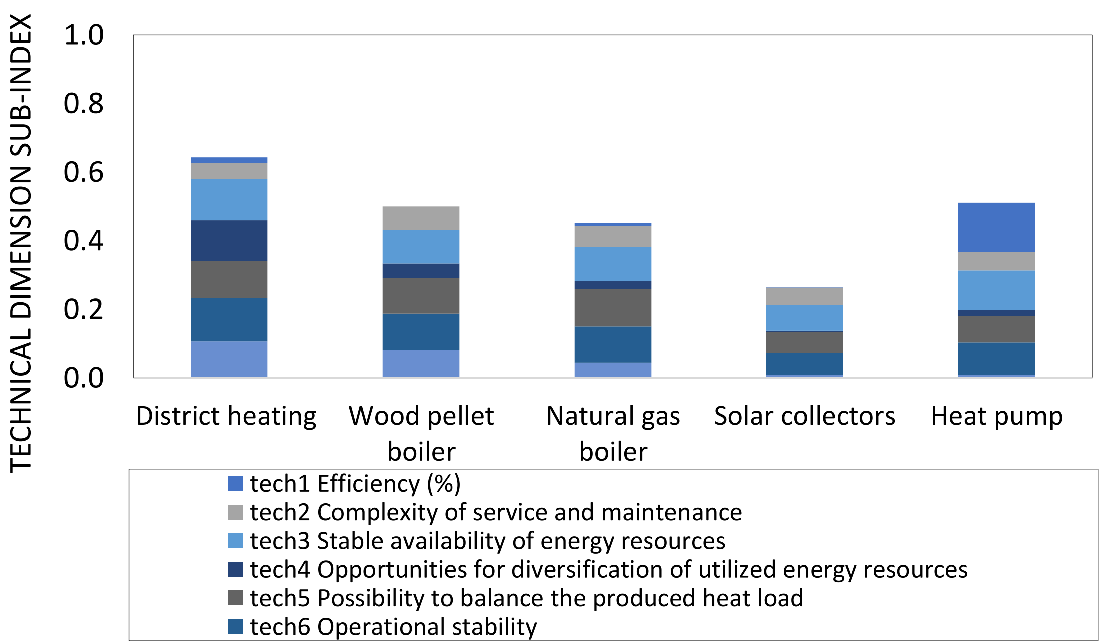
AHP method was used to collect expert opinion on each dimension's impact on the overall sustainability.

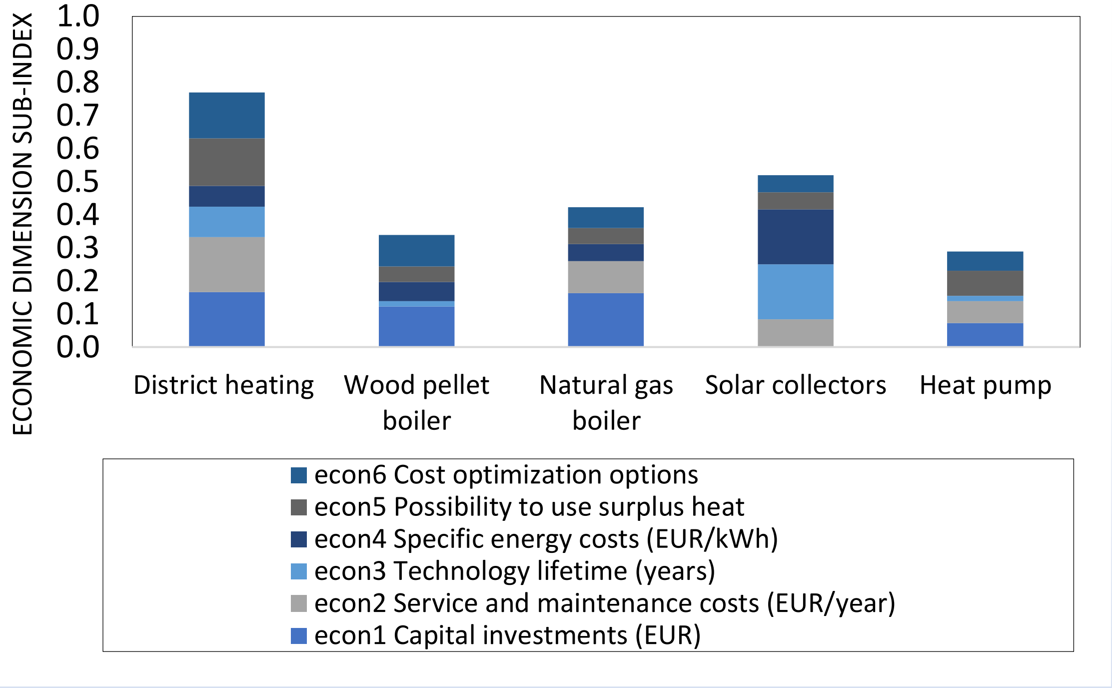
i	Indicator	Unit	Indicator value	District heating	Wood pellet boiler	Natural gas boiler	Solar collectors	Ground/air source heat pump
tech1	Efficiency	%	Data/assumptions	-	-	-	-	-
tech2	Complexity of service and maintenance (availability of specialists on site, immediate avoidance of risk situations)	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 CO_2 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

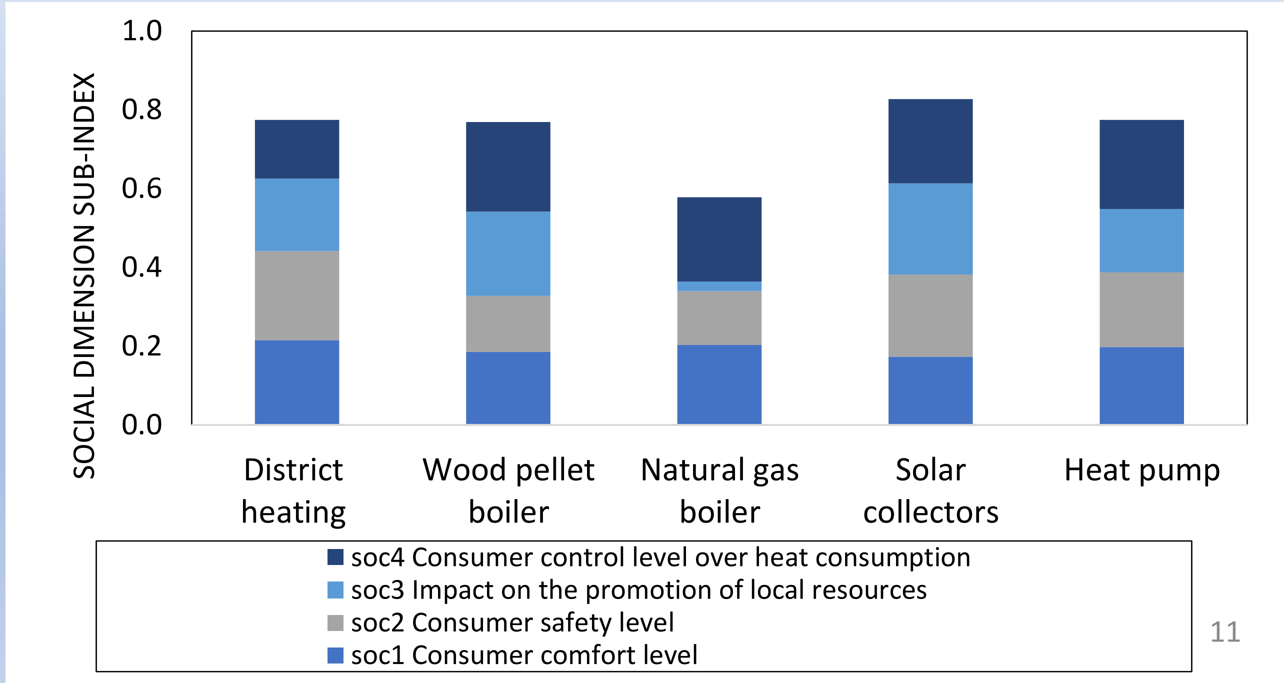



ENVIRONMENTAL DIMENSION SUB-INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pumps
env1 Specific CO_2 emissions (g/kWh)
env2 Complexity of flue gas cleaning


TECHNICAL DIMENSION SUB-INDEX
1.0
0.8
0.6
0.4
0.2
0.0
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pump
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

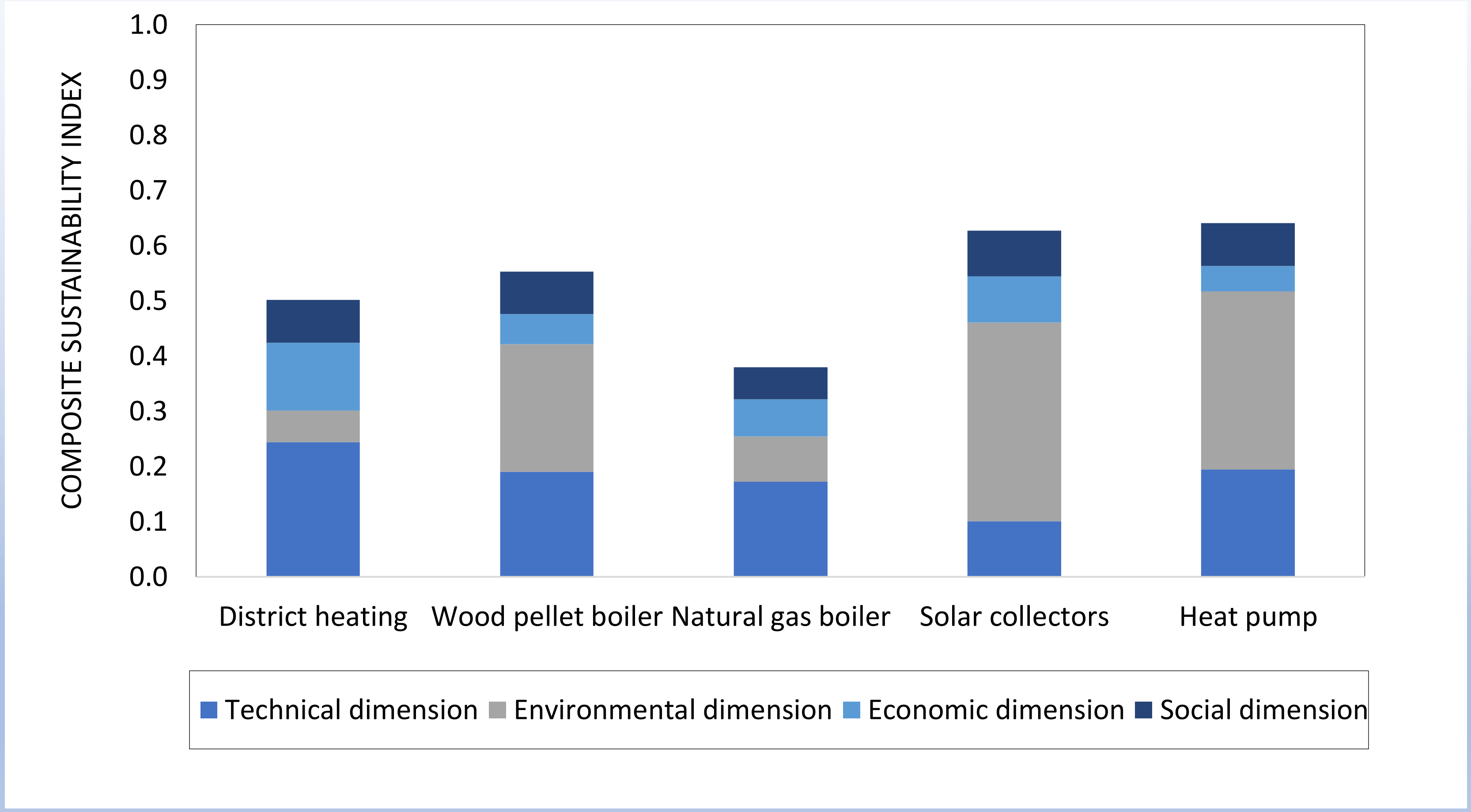


ECONOMIC DIMENSION SUB-INDEX
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pump
econ6 Cost optimization options
econ5 Possibility to use surplus heat
econ4 Specific energy costs (EUR/kWh)
econ3 Technology lifetime (years)
econ2 Service and maintenance costs (EUR/year)
econ1 Capital investments (EUR)



SOCIAL DIMENSION SUB-INDEX
1.0
0.8
0.6
0.4
0.2
0.0
District heating
Wood pellet boiler
Natural gas boiler
Solar collectors
Heat pump
soc4 Consumer control level over heat consumption
soc3 Impact on the promotion of local resources
soc2 Consumer safety level
soc1 Consumer comfort level

Composite sustainability index



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. as 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.