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Energy, Sustainability and Society (2023) 13:46
https://doi.org/10.1186/s13705-023-00425-0

Energy, Sustainability and Society

RESEARCH

Open Access

Sustainability performance of rural municipalities in Germany

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Abstract

Background Sustainable rural development entails efforts to enhance the well-being of rural communities while safeguarding natural resources for future generations. The thorough examination of sustainable rural development is still scarce but nevertheless crucial, as it enables to reveal the various challenges and remaining potentials in rural areas, to identify key stakeholders and their respective roles in promoting sustainable rural development, and to determine the best practices for attaining set goals along the various sustainability dimensions considered. Germany has implemented a range of policies, initiatives, and programs to foster sustainable development, extending its efforts to also encompass rural areas. This study assesses the sustainability performance of rural municipalities in Germany, proposing a novel and comprehensive sustainability benchmarking system. For this purpose, the performance of selected rural municipalities along the ecological, social, economic, and technological dimensions is examined.

Results Based on the systematic implementation of methodological stages, a rigorous literature review process, a systematic indicator selection, and stringent filtering criteria, the selected indicators of our study cover environmental, energy, quality of life, economic, and technological aspects. These indicators enable to efficiently and effectively measure, compare, and evaluate the sustainability performance of rural municipalities. After normalization, weighting, and aggregation of the considered indicators, the performance is visualized in radar charts. Radar charts are handy for comparing a larger number of variables and displaying them in compact and comprehensible form in a single chart. Finally, the overall relative sustainability performance of the selected rural municipalities in Germany is compared based on an aggregated single score. The adopted methodology of aggregating indicators enables us to assess the sustainability performance of municipalities as well as to highlight variations among them.

Conclusion Most databases and sustainable development reports are updated only every couple of years and often do not report the performance of small rural municipalities but only larger (more urban) ones. By conducting a detailed analysis of these specific cases, we can identify key challenges and opportunities unique to rural communities and develop targeted strategies for a more sustainable development. Adding digitalization as a technological value indicator makes our approach more comprehensive than comparable others, and accounts for the important new sustainability dimension of societal transition. This study contributes to the existing literature by proposing a novel sustainability benchmarking system specifically tailored for rural areas. From a practical standpoint, the developed sustainability benchmarking system offers a practical tool for rural municipalities to assess and monitor their sustainability performance and to reflect on variations among them. The identified dimensions and indicators can guide the development of targeted strategies and interventions aimed at enhancing sustainability in rural

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communities. Finally, policymakers can utilize the benchmarking results to design policies, (incentive) programs, and initiatives that address the specific sustainability challenges faced by rural municipalities and account for limitations in the local potentials.

Keywords Sustainability benchmarking, Key performance indicators, Rural municipalities, Value creation

Background

Sustainable development has been a subject of ongoing debate since its inception and continues to generate discussions today. Communities and sub-national regions worldwide have endeavored to customize sustainable development according to their local contexts, taking inspiration from a variety of frameworks. Notably, over the last years the 17 sustainable development goals (SDGs) and 169 indicators, adopted by 193 countries in 2015 under the United Nations [1], have served as a reference point. Nevertheless, there is still considerable controversy surrounding the interpretation of sustainable development in local contexts and the appropriate approaches for its implementation [2].

Sustainable rural development encompasses efforts to enhance the well-being of rural communities while safeguarding natural resources for future generations. Its objective is to achieve a harmonious and enduring development along the lines of the goals of the rural communities by tackling social, economic, and environmental issues. Analyzing sustainable rural development is crucial as it provides a holistic framework for addressing various challenges prevalent in rural areas, including poverty, unemployment, and environmental degradation. Such analysis also helps in identifying key stakeholders and their respective roles in promoting sustainable rural development, as well as determining best practices for attaining this objective. To formulate policy proposals and action plans that foster sustainable rural development, it is essential to recognize the specific factors and obstacles present in rural communities. These may include inadequate infrastructure, limited access to resources, and weak governance structures [3–6].

Moreover, rural areas hold significant importance for the European Union, as they are a priority within the funding measures offered to the EU Member States. The EU Rural Development Policy 2014–2020, also referred to as the second pillar of the Common Agricultural Policy, plays a crucial role in assisting rural areas within the European Union to address the diverse range of environmental, economic, and social challenges and opportunities that emerge in the 21st century. This policy framework aims to support and empower rural communities in navigating the dynamic landscape of the modern era [7].

Among the European countries, Germany's prominent role in sustainability is widely acknowledged, regarding its high environmental standards, strong dedication to renewable energy and sustainable practices, and its urbanization [8]. According to [9, 10], Germany has implemented a range of policies, initiatives, and programs to foster sustainable development, extending its efforts also to encompass rural areas. Germany boosts diverse rural landscapes, encompassing agricultural regions, nature reserves, and villages. Studying the sustainability performance of rural municipalities within a country renowned for its sustainability endeavors offers invaluable insights that can be relevant to other regions confronting similar challenges.

Germany's comprehensive data collection and reporting systems are noteworthy, providing a wealth of information for assessing sustainability performance. Germany's robust data infrastructure surpasses that of many other nations, making it an apt choice for conducting this study. The transferability of findings is another advantage of examining sustainability performance in German rural municipalities. Germany's experiences and practices in sustainable development can serve as a valuable reference for other countries and regions aspiring to enhance sustainability in their own rural areas.

Some related literature focusing on Germany exists. Yang [8] investigated the role of urban expansion within the 'Energiewende' in addressing challenges to the sustainable energy transition in Germany. His study aimed at exploring the academic and historical foundations of the energy transition, analyze relevant events showcasing urban expansion, and identify potential solutions. Drexler et al. [11] employed the Multi-Level Perspective and an interdisciplinary framing approach to examine how incumbent actors in the automotive industry in Germany framed the topic of "transition of mobility and transport" in their public communication during the year 2020. The study aimed to provide insights into the framing strategies used by these actors and their implications for socio-technical transitions in the mobility sector. Meister et al. [12] focused on examining the support provided by municipalities to energy cooperatives at the local level, as well as the relationship between this support and national context conditions. The analysis reveals that municipal support can be advantageous for energy cooperatives by addressing key limitations they face in

Germany. Klemm and Wiese [13] proposed the utilization of multi-criteria optimization methodologies that incorporate key indicators such as absolute greenhouse gas (GHG) emissions, absolute energy costs, and absolute energy demand. They emphasized the importance of employing specific indicators that are relevant to the final energy demand or the number of inhabitants for effective benchmarking and comparative analysis. Their example scenarios are used to demonstrate the viability of modeling strategies to optimize the sustainability of urban energy systems in Germany.

The limited literature on benchmarking for rural development highlights the need for further research in this area. Our study presented here seeks to fill the research gap to some extent and enhance the understanding of the sustainability performance of rural municipalities in Germany, to set benchmarks for improving their performance, and to guide policymakers in their sustainable development policy actions. Accordingly, the five methodological stages of our study can be defined as follows:

(1) To systematically select sustainability performance indicators for comparing rural municipalities for benchmarking.
(2) To decide on the preferred method and process of sustainability benchmarking in terms of quantifiable economic, social, ecological, and technological aspects.
(3) To efficiently and effectively measure, compare, and evaluate the sustainability performance of rural municipalities.
(4) To visualize the outcome graphically in an appealing and transparent form.
(5) To validate the results obtained in terms of plausibility and consistency for a limited set of indicators.

Given the outlined research stages, the primary objective of this study is to identify the most effective approach for illustrating and evaluating the sustainable performance of rural municipalities. Our exploratory study is dedicated to two main research questions: (RQ1) Which KPIs can be used to evaluate rural municipalities' performance (and changes thereof over time) to enable these municipalities to compare their performance with others? (RQ2) How can Germany's rural municipalities improve their sustainability performance in the fields of energy, environment, economy, society, and digital infrastructure? The outcome of the study will be a set of both KPIs and an assessment framework that is applicable to the German situation.

The original contribution of the present study to the existing literature is threefold. First, our study contributes to the sustainability literature by systematically reviewing and filtering the most general sustainability policies, indicators, and rating systems relevant to the rural municipalities through a sequential top-down approach. This is original since most of the existing studies focus on medium-sized or large cities. Second, our methodological novelty employs "multiple methods" by evaluating and rating the performance of rural municipalities in terms of economic, social, ecological, as well as technological aspects, by employing and implementing a large range of selected indicators for the first time in Germany. Third, we have employed radar charts as a visualization tool to effectively communicate the performance of the selected rural municipalities. This allows for a concise and informative representation of multiple variables in a single chart and facilitates the identification of gaps between actual and target values, highlighted areas requiring improvement, and offered a comparative analysis among different municipalities or benchmark references. We believe that the results will also be of interest for municipalities planning new municipal projects, especially as they seek to learn from each other and need to justify investments more and more also in terms of sustainable development goals.

The remainder of this paper is organized as follows. Section "Literature review" presents the literature review and the theoretical frameworks related to the research question. The proposed methodology is outlined in Sect. "Methodology". The results of the analysis are presented in Sect. "Results". The discussion follows in Sect. "Discussion". Finally, a conclusion and some policy implications and recommendations are offered in Sect. "Conclusion and policy implications".

Literature review

Measuring sustainability performance is a very critical step in sustainable development planning and progress. Indeed, sustainability performance indicators have attracted considerable attention around the world because they are expected to provide a reliable, long-term, and easy-to-understand proxy for broader areas of concern for a sustainable development [14]. While key performance indicators (KPIs) for sustainability are often developed to quantify (and often benchmark) the sustainability of municipalities, it is essential to compare them from the perspective of overall sustainability performance. However, sustainability indicators are typically considered from different domains, for example, energy, water resources, air pollution and transportation, and civil infrastructure, and the indicator categories are typically presented using different units of measurement [15].

Sustainability KPIs have been widely addressed in the literature [16–18]. These indicators are also in line with the need for transitioning the municipalities to more resilient and sustainable alternatives that will work towards reaching, or maintaining, a sustainable development of local communities [19–22]. Therefore, determining an overall sustainability performance assessment becomes a challenging task that requires appropriate scientific approaches that can quantify the sustainability also of diverse municipalities. Sustainability benchmarking is a crucial step to realize the sustainable development goals of different municipalities simultaneously. However, problems and debates naturally arise about the types of indicators to be included in sustainability benchmarking projects and the extent to which some sort of standardization is needed [19, 23]. For the German federal government, promoting sustainable development is a fundamental goal and benchmark for government actions taken across the entire nation (and even beyond). Germany's federal government is committed to an ambitious implementation of the 2030 Agenda through a Sustainable Development Strategy which aims at implementing 17 Sustainable Development Goals (SDGs) derived from the 17 SDGs of the United Nations at three levels—i.e. the federal, state, and municipal level [9, 10].

Initially, big companies have taken the benchmarking process into account by comparing their performance with the best existing practices [24, 25]. Since the 1990s, a number of articles has been published on the benchmarking process concept. Camp [26], for instance, defined benchmarking as a tool that enables to identify industry's best practices and that will lead to superior performances. According to Spendolini [27], benchmarking has two main characteristics: it can be used to learn from any organization, whether or not it is a competitor, and it should integrate the efforts taken to measure processes. Several scholars reviewed the incremental development process towards enhanced performance of some sort in different fields such as manufacturing industries, urban area planning, management firms, and construction projects to enhance performance practices and techniques [28–32].

Benchmarking is also widely used to improve the performance and competitiveness of municipalities [33–35]. Luque and Muñoz [36] studied the benchmarking concept effectively for municipality planning, and provided a systematic and continuously applicable method that identifies, learns, and implements the most effective practices and capacities from other municipalities in order to improve one's municipality's performance. Local authorities are more likely to be the first candidates for a new generation of governance benchmarking in local levels since they have always been much closer to citizens than regional, national, or international levels of government. [37]. In this regard, Ammons [34] concentrated on providing a framework for evaluating and enhancing the performance of local communities. He argues that by establishing benchmarks and tracking progress towards them, local governments can better identify areas of strength and weakness, and take actions to improve their performance. Ammons emphasized the importance of using unbiased data and metrics to evaluate municipal performance. He suggests that by measuring performance in a standardized and transparent way, local communities can better understand their strengths and weaknesses, needs and preferences, and make informed decisions about distributing their resources [34].

López-Penabad et al. [38] introduced a benchmarking system for assessing rural sustainable development in Galician municipalities in Spain. They identify crucial factors linked to the rural sustainable development index and utilize the Benefit of the Doubt, common weights, super-efficiency, and logistic-geometric methodologies to construct a composite index. This comprehensive index encompasses four dimensions: economic, demographic, social, and environmental. Benedek et al. [39] conducted a study in Romania with the objective of assessing progress towards achieving the Sustainable Development Goals (SDGs) at the local and regional levels. They introduced the SDG Index as a measurement tool for this purpose. To calculate the SDG Index at the local level, the authors propose an integrated territorial approach that involves the use of 90 indicators. These indicators were stored and processed in a PostgreSQL object-relational database, allowing for a comprehensive and indicator-based assessment of the SDGs.

Frare et al. [40] proposed a comprehensive system of sustainability indicators specifically designed to support rural municipalities in Brazil. The study employed a rigorous four-stage methodology to select the indicators. Firstly, the Delphi technique was utilized. Subsequently, 64 indicators were evaluated by 19 mayors from cities in southern Brazil. Their resulting subset of sustainability indicators covers nature and social well-being, sustainable public management, historical and cultural management, sustainability education, new savings for sustainability, and urban planning and accessibility. In the third stage, a fuzzy expert system was employed to establish a decision tree and create a general index for a pilot municipality. This practical application demonstrates the culmination of the study, highlighting the importance of the sample in the final (fourth) step.

Rodrigues and Franco [41] conducted a study with the objective of organizing indicators and indices that enable the assessment of sustainable development in 308 cities and towns, considering economic, social, and environmental aspects. Their findings enabled the development of a Composite Index for Sustainability, which was established through the application of multivariate statistical techniques such as Exploratory Factor Analysis and Principal Component Analysis. This approach confirmed the scientific rigor and robustness of the index, representing the primary contribution of their research. Furthermore, the results revealed that the dimension of urban sustainability in Portuguese municipalities manifests itself in a threefold manner.

Hatakeyama [42] developed conceptual frameworks for sustainable development indicators (SDIs) using Japanese municipal governments as case studies. His findings reveal five SDIs and allow to identify four approaches, emphasizing the most practical and optimal frameworks. The first approach, favored by a majority of local governments, displays a strong inclination towards socioeconomic policies while neglecting environmental aspects, despite the overarching goal of holistic sustainability. This trend reflects the current sustainability landscape at the local level in Japan. In contrast, the alternative approach aims to achieve a balanced integration of three dimensions of sustainable development, with a primary focus on well-being. This framework addresses the lack of environmental orientation, potentially contributing to the coherence of public policy implementation.

Methodology

The literature search for our study was conducted using Google Scholar, and the following keywords were utilized: sustainability, sustainable development, rural, benchmarking, indicator, measure, and dimension. These keywords were selected to specifically target relevant literature on sustainability performance in rural municipalities.

The search criteria included articles published in peer-reviewed journals, conference proceedings, international organizations, and reputable reports related to the sustainability performance of rural municipalities in Germany. The focus was on obtaining recent and relevant publications to ensure the inclusion of up-to-date information and insights. The initial search yielded a significant number of results, which were further refined based on relevance and alignment with the study's objectives. The refinement process involved screening the titles, abstracts, and keywords of the retrieved articles to identify those that specifically addressed the sustainable performance of rural municipalities. The selected articles were then thoroughly reviewed, and their references were examined to identify additional relevant sources that may have been missed during the initial search. This step helped to analyze and characterize rural municipalities and to ensure a comprehensive coverage of the literature, thus minimizing the possibility of overlooking key studies or concepts.

Regarding the KPIs sought, the specific types and criteria used in the search were not explicitly mentioned in the provided information. However, the intention was to identify a set of indicators that could effectively measure the sustainability performance of rural municipalities. These indicators may include dimensions such as the economic, social, ecological, and technological ones, as mentioned in the abstract and the background section. The search aimed to find studies that utilized and discussed such indicators in the context of rural sustainability benchmarking.

Indicator selection for the benchmarking system

In our study, we first conducted an extensive literature review based on a sequential top-down approach to find the appropriate metrics for our research. In order to identify standard KPIs that are widely acknowledged and corroborated by scientific publications and international organizations, we reviewed the 17 global SDG goals set by the United Nations [1], the World Health Organization (WHO) [43], The World Bank [44] and, additionally, Germany's sustainable development strategy [9, 10]. After that step, we compiled more than two hundred different measures and indicators. These indicators, in general, all allow to measure and communicate sustainable development progress in an effective and meaningful way. However, many of them were found to be either irrelevant or unreasonable to be directly used for the evaluation of rural municipalities' development in our study.

The UN SDG indicator framework - with its 17 main goals and 169 targets - primarily focuses on the challenges faced by developing countries. However, with its extensive list of indicators that are often only vaguely defined, this framework can become overwhelming and difficult to manage. The United Nations Economic and Social Council (UN ECOSOC) [45], in contrast, recognizes smart sustainable cities as a significant catalyst for growth, productivity, and employment. According to UN ECOSOC, a smart sustainable city is an innovative urban area that utilizes information and communication technologies and other tools to enhance the quality of life, operational efficiency, service delivery, and competitiveness. It also ensures the fulfillment of economic, social, environmental, and cultural needs for both present and future generations. The UN Smart Sustainable Cities Indicators framework offers a well-balanced approach to sustainability across various dimensions. It is characterized by clear definitions and a forward-looking strategic vision. Thus, the set of indicators was filtered in terms of economic, social, ecological, and technological aspects according to the UN Smart Sustainable Cities Indicators framework. At this stage, a subset of 83 indicators was chosen (see Fig. 1 and Table 5 in Appendix 1).

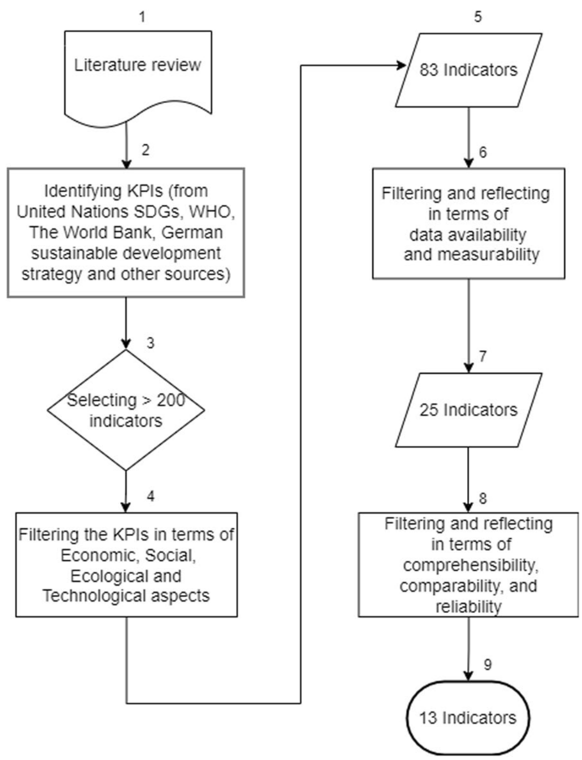

Fig. 1 Procedure adopted in the indicator selection for the rural municipality benchmarking system

In a next step, we selected KPIs that can be used to evaluate the rural municipalities' performance and enable these municipalities a comparison with each other. These KPIs can also be operationalized to balance the economic (ECO), social (SOC), ecological (ENV), and technological (TEC) dimensions covered.

Economic aspects: Economic aspects encompass indicators related to the financial and economic performance of rural municipalities. This may include metrics such as GDP per capita, employment rates, income distribution, poverty levels, investment in local businesses, and economic diversification. The selected indicators should be available, measurable, easy to understand, comparable across municipalities, and reliable in terms of data sources and accuracy.

Social aspects: Social aspects refer to indicators that capture the well-being, quality of life, and social dynamics within rural communities. These may include metrics such as access to healthcare and education, crime rates, community engagement, social cohesion, cultural preservation, and social equity.

Ecological aspects: Ecological aspects refer to the environmental considerations and impacts of human activities. When evaluating indicators in relation to the ecological dimension, the focus is on assessing the sustainability performance in terms of environmental conservation, resource management, and minimization of negative ecological effects. Indicators related to the ecological aspect may include measurements of GHG emissions, energy consumption, waste generation, water usage, biodiversity conservation, and land and habitat preservation.

Technological aspects: Technological aspects focus on indicators that assess the level of digitalization, technological adoption, and innovation within rural municipalities. These may include metrics such as broadband connectivity, digital infrastructure, e-governance services, technology access and utilization, and innovativeon capacity.

The selected indicators should satisfy the criteria of data availability (sufficient availability specifically for rural municipalities), measurability (quantifiable and objective measurements), comprehensibility (clear and understandable to stakeholders), comparability (allowing for meaningful comparisons across municipalities), and reliability (reliable data sources and methods).

Therefore, additional filtering regarding data availability and data measurability were applied to the selected 83 indicators. For instance, data for specific indicators are often not available for comparing and setting up targets for performance improvement. Also, sustainable development benchmarking at a local level should account for the fact that simple quantitative and measurable indicators do not always entirely reflect the system's complexity into which a local entity is embedded. In many cases, meaningful benchmarks cannot be derived at all with such indicators. Therefore, in the present study, performance indicators are selected subject to the constraint of availability of reliable data sources to better understand benchmarking. This stage narrowed down the number of KPIs and eventually resulted in 25 acceptable indicators. In a final step, selection criteria such as comparability, reliability and comprehensibility of the indicators were applied as well. This reduced the number of indicators further to 13.

Case study selection

In order to achieve a reliable benchmarking system, a comparison of rural municipalities can be carried out by grouping either municipalities with similar characteristics, e.g., in terms of area and population, or municipalities with varying characteristics, thus allowing for the benchmarking also of very heterogeneous municipalities. The first approach of comparing cities with similar characteristics is adopted in the current study. Therefore, we applied the 13 indicators presented in Table 3 to ten rural municipalities in Germany which were selected based on the following three main criteria: (1) the case studies can be considered as rural areas since their population

Table 1 10 selected rural communities in Germany

Municipality	Source	Population (2020)	Federal state	Area (km^2)
Finnentrop	www.finnentrop.de/	16,854	North Rhine-Westphalia	104.42
Roetgen	www.roetgen.de/	8650	North Rhine-Westphalia	39.03
Weeze	www.weeze.de/	11,228	North Rhine-Westphalia	79.49
Aulendorf	www.aulendorf.de/	10,177	Baden-Wuerttemberg	52.36
Limbach	www.limbach.de/	4506	Baden-Wuerttemberg	43.61
Ebersberg	www.lra-ebe.de/	12,213	Bavaria	40.83
Alsfeld	www.alsfeld.de/	15,941	Hesse	129.71
Rehfelde	www.gemeinde-rehfelde.de/	5221	Brandenburg	46.51
Eppelborn	www.eppelborn.de/	16,569	Saarland	47.04
Remagen	www.remagen.de/	17,156	Rhineland-Palatinate	33.16

is below twenty thousand inhabitants (according to the Federal Office for Building and Regional Planning [46]). (2) Their area is less than 150 km^2 and, most importantly, (3) they have regularly published the most favorable data for our investigation in contrast to other German rural municipalities. After reviewing the profile and the database of more than hundred different rural municipalities in Germany overall, the ten selected rural municipalities with the mentioned criteria for our study are Finnentrop, Weeze, Rehfelde, Eppelborn, Remagen, Wiesmoor, Aulendorf, Limbach, and Roetgen (Table 1), located in seven federal states and ranging from 4,506–17,156 in population and 33.16–129.71 km^2 in area size.

Data collection and analysis

For the empirical analysis (benchmarking), we collected data from statistical offices of the federal and state governments and local publications. We also relied on analysis of publicly available documents, including municipality websites and publications, media articles and press releases, and the review of academic and grey literature. However, it should be noted that the availability of relevant, quantitative, precise, comparable, and authentic data collected from real-life phenomena is essential in selecting indicators and performing benchmarking successfully. For our benchmarking system, the availability of statistical data was a bottleneck, particularly at the rural municipalities level. Data of specific indicators are often not available for comparing and setting up targets for performance improvement. Because the data collection process had its limitations, we moved from a longer, desirable list to a somewhat shorten but operable one. Thus, we eventually benchmark the rural municipalities considered by using the most recently released data from the databases reported in Table 2.

According to Table 2, (1) the WiFi map database provides around 30,000 locations marked on the map for WLAN hot spots in Germany, based on the latest available data. This results in a detailed overview of the Germany-wide spread of public access. (2) The map of noise exposure for five different selected states—such as North Rhine-Westphalia (NRW), Bavaria, Hesse, Baden-Wuerttemberg, and Brandenburg—illustrates the close connection between residential location, environmental pollution, and health every couple of years. (3) The air quality database presents the recently measured and calculated concentrations of three pollutants (PM_{10}, NO_2, and ozone), with the health-criticality of the three measured concentrations, and determines the overall result across the country. (4) The broadband atlas as the central information medium for broadband coverage presents the initial results of data collection for broadband availability in Germany as of June 2021. The results are based on voluntary data submissions by broadband Internet providers. (5) General data from all German federal states encompass sources such as statistical reports, municipal profiles, and joint publications. (6) Maps related to the installed capacity of variable renewable energy sources can be found in energy atlas databases.

After completion of our data collection process according to Fig. 2, we used the published data from the above-mentioned databases, including municipality websites and publications. It should be noted that we aimed at using the latest published data for our selected indicators

Table 2 Data used for the rural municipality benchmarking

No.	Database	Description and references used
1.	WiFi map	Map of available public hot spots [47]
2.	Noise map	Map of noise exposure [48–52]
3.	Air quality	Air quality measuring stations [53, 54]
4.	Broadband atlas	High speed Internet coverage [55]
5.	General statistics	List of rural municipal publications [56–60]
6.	Energy atlas	Map of renewable energy resources [61–65]

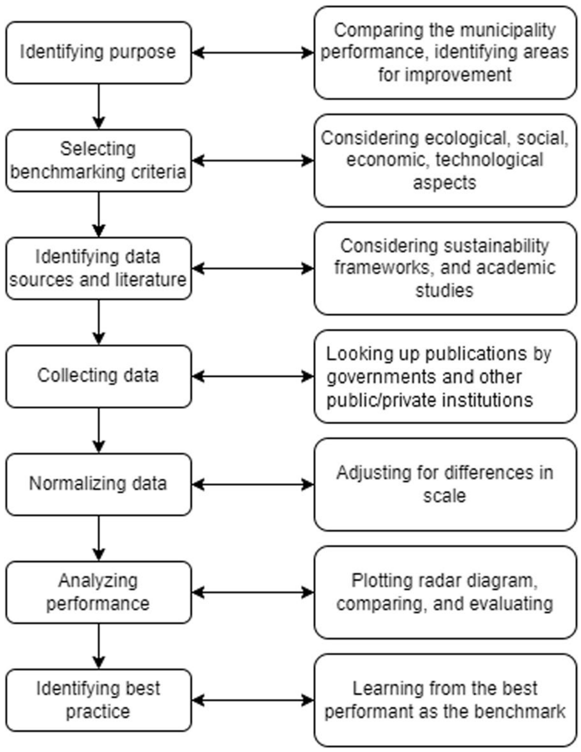

Fig. 2 Benchmarking process for the selected rural municipalities

and, also, to provide a dynamic benchmarking system over time that measures the progress over time. However, the latter was not possible, generally, due to the unavailability of historical data that makes the performance measurement of rural municipalities much more difficult. This allowed us to provide a snapshot of their sustainability performance at a specific point in time. Therefore, in the end, we are only able to provide a static benchmarking system that illustrates the sustainable development of the selected rural municipalities based on the latest achievement they could record in their recent publications. Finally, we implement a simple and easy-to-understand aggregation method to derive a single value for each municipality, addressing the concern regarding the merging of different units of measurement.

Results

Based on the systematic implementation of methodological stages, the rigorous literature review process, meticulous indicator selection, and stringent filtering criteria, the study's findings are summarized in Table 3 and explained in some detail in the following.

Ecological (ENV)

Local governments play a critical role in protecting the environment for enabling a sustainable development. An excellent example is the role of municipalities in combating problems arising due to climate change by taking preventive measures and mitigating the causes of climate change, including GHG emissions [75]. As climate change is a global problem that requires a global solution, the contribution of a local municipality is pro rata, and typically derived and downscaled from the GHG mitigation goal/s set by the state or federal government.

ENV1. Emission of greenhouse gases: The German federal government aims to reduce GHG emissions in Germany by at least 55 percent in 2030 compared to 1990 levels [66]. This indicator measures generated emissions of the so-called "Kyoto basket" of GHG, integrated into

Table 3 Indicators used to assess the sustainability performance of municipalities in Germany

SDG category	Code	Indicator	Source	Unit
Environmental	ENV1	Emission of greenhouse gases	Federal Statistical Office [66]	Tons per capita
Environmental	ENV2	Territorial protection	BMUV [67]	Percentage
Environmental	ENV3	Total phosphorus input in flowing waters	Federal Environment Agency [66]	mg per liter
Energy	ENV4	Promotion of renewable energy sources	Federal Statistical Office [68]	Percentage
Energy	ENV5	Economic and efficient use of energy sources	Federal Statistical Office [66]	Percentage
Quality of life	ENV6	Ambient air quality improvement	WHO [69]	µg per cubic meter
Quality of life	ENV7	Reduction of noise pollution	WHO [70]	dB (A)
Economic	ECO1	New business registrations	The World Bank [44, 71]	No. of registered companies
Economic	ECO2	Reduction in income inequality	Federal Statistical Office [66]	Thousand Euros
Social	SOC1	Civic engagement	The Federal Government [72]	No. of hours
Social	SOC2	Access to public transport	United Nations [73]	Percentage
Technological	TEC1	Access to public free WiFi	European Commission [74]	No. of access points available
Technological	TEC2	Access to high-speed Internet	BMDV [66]	Percentage

Coding used: ENV ecological, ECO economic, SOC social, and TEC technological a single indicator expressed in units of CO_2 equivalents, using the global warming potential of each gas. The GHG intensity of energy consumption is the ratio between energy-related GHG emissions and gross inland energy consumption. It expresses, for instance, how many tons of CO_2 equivalent from energy-related GHGs are emitted per unit of energy consumed in a specific economy but could also include land use change.

ENV2. Territorial protection: This indicator provides information about the extent of strictly protected areas, including nature reserves, national parks, and designated zones within biosphere reserves, as a proportion of the available land area. A higher indicator value indicates a larger proportion of the land area covered by these protected areas. This indicator reflects efforts to preserve and conserve natural habitats and biodiversity, contributing to the overall conservation and sustainability goals in Germany [67].

ENV3. Total phosphorus input in floating waters: The indicator shows the proportion of those monitoring sites where the guideline values for phosphorus (PO_4) per liter in watercourses for good ecological status are met in specific types of watercourses. This indicator measures the concentration of phosphate in the dissolved phase from water samples from river stations and aggregates to annual average values. At high concentrations, phosphate can cause water quality problems by triggering the growth of macrophytes and algae [66].

ENV4. Promotion of using renewable energy sources (RES): This indicator reflects the share of electricity in gross electricity consumption from RES. The gross final energy consumption is the energy utilized by end consumers (final energy consumption) plus grid losses and self-consumption of power plants. According to the German government's energy concept, the share of electricity from RES, measured in gross electricity consumption, should increase to at least 65 percent by 2030 and at least 80 percent by 2050 [68].

ENV5. Economic and efficient use of energy sources: This indicator shows the development of value added per unit of final energy input. The term "final energy" refers to the energy used in the form of thermal or electrical energy in the production sectors to manufacture goods or by private households for satisfying their end-use energy needs. Primary energy consumption, on the one hand, indicates how much energy was consumed in a country in the energy sectors for conversion purposes and, on the other hand, how much energy is needed for production activities, transport, and private households. According to the German federal government's energy concept, final energy productivity is to be increased by 2.1 percent annually between 2008 and 2050. At the same time, primary energy consumption is to be reduced by 50 percent by 2050 (in both cases compared with 2008 levels) [9, 10].

ENV6. The sustainability indicator "Air quality in municipalities" is relevant and informative for assessing immission[1] pollution in municipalities due to the effect and general occurrence of particulate matter (PM) and NO_2. The calculation is based on data from urban background monitoring stations (according to the EU Council Decision on Information Exchange 97/101/EC). The sub-indicators PM_{10} and NO_2 are defined as arithmetic averages of the respective annual mean values. Therefore, they characterize the mean long-term background levels of the two air pollutants PM_{10} and NO_2 as follows:

ENV6.1. Ambient air quality improvement 1 (PM_{10}): The PM_{10} indicator shows the amount of particulate matter (dust particles with a diameter of smaller than 10 micrograms) per cubic meter of air. The guideline value for fine dust recommended by the World Health Organization (WHO) of an average of 20 micrograms per cubic meter of air per year should be achieved throughout Germany by 2030 [69].

ENV6.2. Ambient air quality improvement 2 (NO_2): Concerning the reduction of nitrogen dioxide (NO_2) concentrations, the WHO guideline value for NO_2 is 40 micrograms per cubic meter as an annual average. Therefore, the emission of air pollutants should be reduced by 45 percent by 2030 compared to 2005 levels [69].

ENV7. Reduction of noise pollution: In October 2018, WHO published guidelines on environmental noise for the European continent in order to reduce the average noise pollution from road traffic [70]. The indicator measures the population's percentage in noisy areas that are permanently exposed to a pre-defined noise level and is implemented by two sub-indicators:

ENV7.1. 24-hour noise immissions, 65 dB: This sub-indicator shows the proportion of people affected by environmental noise subject to mandatory mapping and has a 24-h noise index that aims to limit any values higher than 65 dB in the total population of the federal state.

ENV7.2. Nighttime noise immissions, 55 dB: This sub-indicator shows the proportion of people affected by environmental noise subject to mandatory mapping and has a nighttime noise index that aims to limit any values higher than 55 dB in the total population of the federal state.

[1] Immission is the opposite of emission, which refers to the release of pollutants or other substances into the environment. Immission is the actual exposure of individuals or the environment to the emissions or external factors.

Economic (ECO)

The selected indicators for the development of the local economies are:

ECO1. New business registrations: New businesses registered are the number of new limited liability corporations (or equivalent[2]) registered in a calendar year in the municipality concerned. Business registrations for new businesses are used as an indicator. The units of measurement are private, formal sector companies with limited liability. Note that though business registrations are initially only declarations of intent that do not necessarily lead to the actual establishment of a business, the data nevertheless give an idea of the dynamics, such as start-ups [44, 71].

ECO2. Reduction in income inequality: (Nominal) Disposable income is an indicator of the (monetary) wealth of private households. Disposable income is calculated as the annual income available to private households after income redistribution. For regional comparisons, disposable income is related to the respective number of inhabitants (per capita income) [66].

Social (SOC)

Social sustainability refers to the capacity of a society to meet the present and future needs of its members, promoting their well-being and ensuring social equity and justice. It encompasses aspects such as community engagement, access to basic services, human rights, social cohesion, and cultural diversity.

SOC1. Civic engagement: This indicator measures the number of hours spent by individuals in Germany dedicated to civic and voluntary activities. It serves as a recognized measure of social cohesion and overall well-being within the country. The significance of volunteering and civic engagement has been particularly evident in dealing with the refugees coming to Germany [72].

SOC2. Access to public transport: This indicator measures the proportion of the population that has convenient access to a public transportation stop within a reasonable walking distance. It considers a radius of 500 m for low-capacity transport modes such as buses, and 1000 m for high-capacity transport modes such as trains and ferries, along the street network [73].

Technological (TEC)

Two leading indicators were selected for the digitalization category which measure the Internet connectivity of the rural municipalities:

TEC1. Access to public free WiFi: This indicator measures the number of public free WiFi access points installed per year and the number of connections they generate within the rural municipalities. WiFi access points provide empirical proof to overcome the restricted scope of Internet geography examinations on wired infrastructure. The coverage of WiFi access points can be represented as geometrical circles surrounding specific areas in municipalities. The wireless Internet technology expands the connectivity of the fixed Internet infrastructure by delivering untethered and ubiquitous access [74, 76].

TEC2. Access to high-speed Internet: The indicator measures the percentage of households connected to fiber to the home (FTTH) with a minimum speed of 1000 Mbits per second. It ensures good connectivity of the population by providing efficient digital infrastructures and focusing on the fixed (wired) broadband subscriptions [66].

Normalization, weighting, and aggregation of indicators

In order to use a consistent benchmarking system with an identical unit of measurement, we converted and normalized all the achieved values according to Eqs. (1) and (2). The obtained values were normalized to ensure easy comparability on a scale of 0 to 1. We employed two normalization methods: the min–max (ν') and max–min (ν^*) techniques. In the normalization process, (ν) represents the value of the raw data, while min(ν) and max(ν) determine the lower and upper bounds representing the worst and best performance, respectively. The normalized values, (ν') and (ν^*), are obtained through re-scaling. For the majority of indicators, we utilized the min–max(ν') normalization method with Eq. (1). In this approach, a score of 0 indicates the worst performance, while a score of 1 represents the highest performance.

In the case of indicators such as ambient air quality improvement, total phosphorus input in flowing waters, and reduction of noise pollution, the max–min(ν^*) normalization method is applied using Eq. (2). This means that 0 indicates the worst performance and 1 the best performance.

In order to aggregate the individual indicator values into a single value for each municipality, we utilized existing frameworks as presented in Table 4. These frameworks provide a structured approach to combining the various indicators and capturing the overall sustainability performance of each municipality:

$$(\nu') = \frac{\nu - \min(\nu)}{\max(\nu) - \min(\nu)}, \tag{1}$$

[2] These include general partnership (Offene Handelsgesellschaft, OHG), limited partnership (Kommanditgesellschaft, KG), limited liability company (Gesellschaft mit beschränkter Haftung, GmbH), and entrepreneurial company at limited liability (Unternehmergesellschaft (UG)

Table 4 The reference data used to normalize the metrics according to Frare et al. [40], Rodrigues and Franco [41], Hatakeyama [42], and equal weighting

Indicator	Code	Description	[40]	[41]	[42]	Equal weight (w_i)
Environmental	ENV1	Emission of greenhouse gases	–	0.369	0.69	0.0833
Environmental	ENV3	Total phosphorus input in flowing waters	–	0.369	0.61	0.0833
Energy	ENV4	Promotion of renewable energy sources	5.94	0.369	0.64	0.0833
Energy	ENV5	Economical and efficient use of energy sources	4.36	0.369	0.57	0.0833
Life quality	ENV6	Ambient air quality improvement	–	0.369	0.72	0.0833
Life quality	ENV7	Reduction of noise pollution	–	0.245	0.60	0.0833
Economic	ECO1	New business registrations	7.89	0.386	0.64	0.0833
Economic	ECO2	Reduction in income inequality	7.15	0.386	–	0.0833
Social	SOC1	Civic engagement	–	0.245	0.59	0.0833
Social	SOC2	Access to public transport	5.73	0.245	–	0.0833
Technological	TEC1	Access to public free WiFi	–	–	–	0.0833
Technological	TEC2	Access to high-speed Internet	–	–	–	0.0833

$$(v^*) = \frac{\max(v) - v}{\max(v) - \min(v)}. \tag{2}$$

Once the indicators were normalized, we multiplied each indicator value by its respective weight. Table 4 presents three different frameworks for weighting the indicators related to sustainable development. However, upon examination, we found that none of the frameworks explicitly include weighting for social and technical indicators that we used. As a result, we decided to utilize the equal weighting method for our assessment. By using the equal weighting method, we aimed at avoiding any bias or subjective judgment that could arise from assigning different weights to different indicators. This implies that according to Eq. 3, the relative weight of each indicator is inversely proportional to the number of (in total 13) indicators:

$$w_i = \sum_{i=1}^{n} \frac{1}{n}, \tag{3}$$

whereas n is the total number of indicators and w_i is the weight assigned to indicator i. We multiplied each normalized value v_i by its corresponding weight w_i. The resulting score s_i represents the weighted score for indicator i, according to (Eq. 4):

$$s_i = w_i \cdot v_i. \tag{4}$$

After obtaining the weighted scores s_i for each indicator, we proceeded to aggregate them. The aggregation was performed by summing up the weighted scores (S), resulting in a single value that reflects the overall sustainable performance of each municipality (see Eq. 5). The aggregated score is normalized such that it ranges between 0 and 1, with higher values indicating better sustainability performance:

$$S = \sum_{i=1}^{n} s_i. \tag{5}$$

This approach provides a holistic evaluation of municipalities by considering multiple indicators and their respective weights. By aggregating the indicator values, we can effectively capture the complex nature of sustainable development and present it in a simplified manner with a single value for each municipality. This facilitates the comparison and ranking of municipalities based on their sustainability performance.

Visualizing the data

To graphically illustrate the performance of the selected rural municipalities, we make use of radar charts. Radar charts are handy for comparing a large number of variables and displaying them in compact form in one single chart. Radar charts help to identify the prevailing gap between actual and target values for selected municipalities. Furthermore, they provide insights into the dimension seriously lacking in acquiring the target values. A radar chart also enables to study the scope of sustainable improvement in every indicator subset considered. Radar charts present the data more clearly and allow to compare several different case studies with each other, or to compare them with the benchmark. Also, one can use different measurement scales in a radar chart.

After equally weighting the indicators based on Eq. (3), we multiply each indicator's normalized value v_i by its corresponding weight w_i to obtain a weighted score s_i according to Eq. (4). This multiplication reflects the importance of the indicator in the overall assessment of sustainability. The resulting weighted score provides a measure of the individual indicator's impact on the municipality's sustainability assessment. A higher weighted score s_i indicates a stronger contribution of the indicator to the overall sustainability performance, while a lower score suggests a relatively lower impact.

After testing and applying the indicators for each selected local community and comparing the results, we arrived at two different comparing scenarios as follows:

(1) Comparison of the rural municipalities considered within the same federal state: In this scenario, all rural municipalities within the state of North Rhine-Westphalia are compared with each other, and the results are shown in Fig. 3. Thus, they mostly have the same sustainability and other policy goals explicitly defined by the federal state. As can be seen, all municipalities considered have almost the same performance in terms of ecological and economic indicators, including improving ambient air quality, reducing phosphorus input in flowing waters, reducing noise pollution (during the day and at night), and registering new businesses. Regarding the digitalization aspect, all three municipalities are clearly underperforming. However, for the energy and environmental indicators, they have a quite good performance. The municipality of Weeze, with the highest share of renewable electricity generated among all the municipalities included in the sample, has the lowest GHG emissions. On the contrary, the municipality of Roetgen has the lowest share of renewable electricity generation, yet produces a higher volume of CO_2 per capita.

(2) Comparison of all municipalities across the country combined: This scenario is more comprehensive because it compares the sustainability performance of all rural municipalities considered and provides more information about the actual progress of municipalities across the country (in 7 out of the 16 German federal states overall, cf. Table 1). As shown in Fig. 4, the diverse sustainability performance of all the analyzed rural municipalities is presented using the benchmarking system. It can be seen that those rural municipalities perform strongly in terms of quality of life indicators (ENV6 and ENV7). Accordingly, for the air quality indicators ENV6.1 and ENV6.2, which refer to PM_{10} and NO_2, respectively,

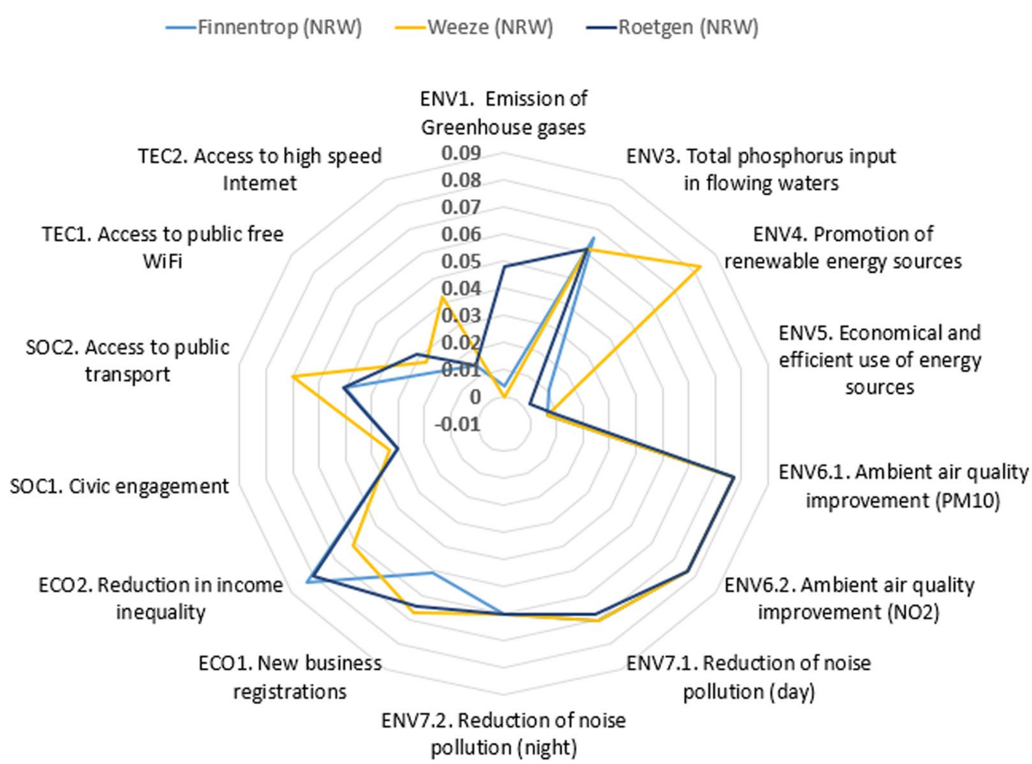

Fig. 3 Comparison of performance of the three selected municipalities within the state of North-Rhine Westphalia (NRW) based on the resulting score s_i for the selected indicators

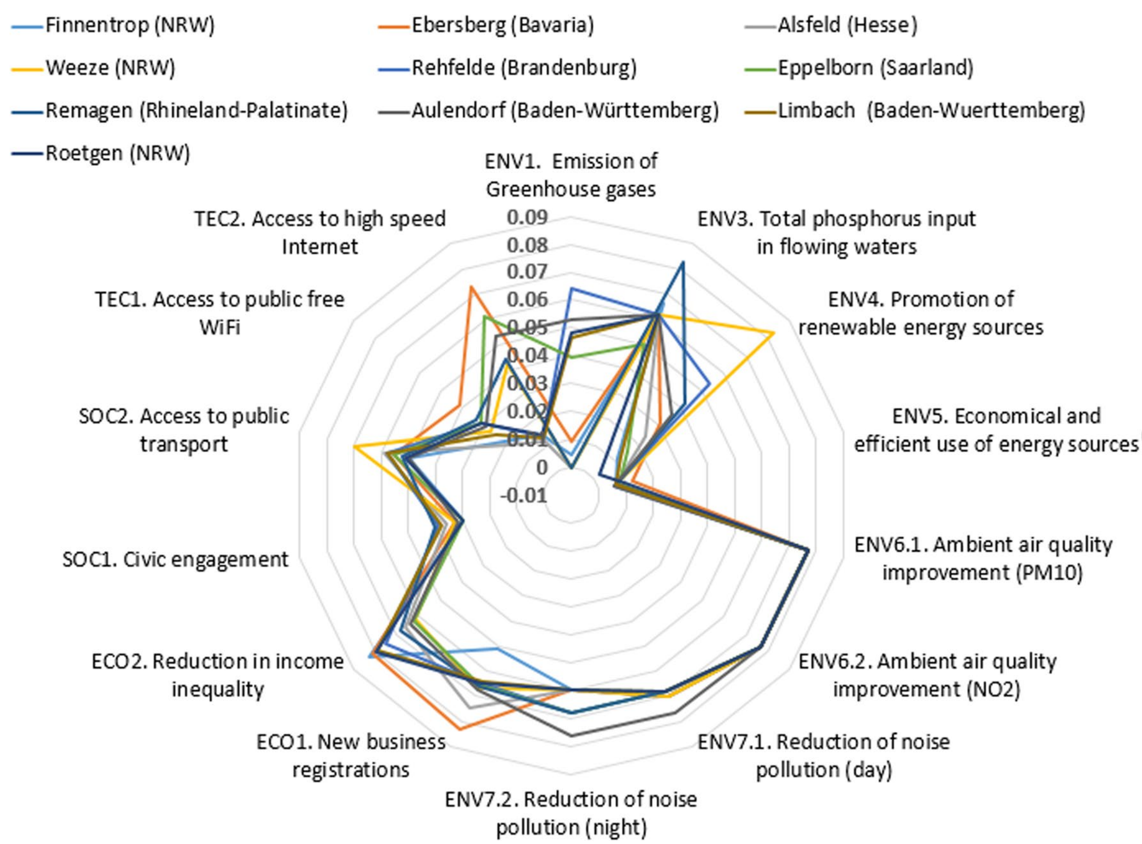

Fig. 4 Comparison of the sustainability performance of the examined rural municipalities in Germany based on the resulting score s_i for the selected indicators

all the selected municipalities have reached the target value. For indicators such as noise pollution reduction, the hope is that the target values will be reached earlier if the rural municipalities measure the existing noise regularly and reduce the noise pollution accordingly. Based on the achieved data, the overall performance of the two municipalities Ebersberg and Roetgen are more sustainable than the others because their scores are shown to be closer to the benchmark.

Figure 5 depicts a visual comparison of the sustainability performance of the selected municipalities in Germany using a bar chart. The comparison is based on the final score (S), which is derived by aggregating the resulting score s_i for multiple indicators (cf. Eq. 5) assessing the sustainability of each municipality. Therefore, S is a single value that summarizes the overall sustainability performance of a rural municipality across economic, social, ecological, and technological dimensions.

Discussion

The radar charts in the previous figures summarize and compare the sustainability performance of the individual municipalities. The measurement scales of the indicators range from 0 to 1, and 1 indicates the optimal target value. Comparing the two scenarios with each other shows that the most helpful approach is to compare the sustainability performance of the municipalities within each state against the defined benchmark. This is because each state has a different benchmark, and these state-defined benchmarks for some indicators may also differ compared to the state's sustainability strategies.

The evaluation and assessment of the sustainability performance of rural municipalities open a discussion on several issues. First and most importantly, the data available to measure and evaluate the performance of rural municipalities in Germany is relatively poor. Most databases and sustainability reports considered are updated only every five years and do not capture the performance of rural municipalities in particular too well. This limitation is not unique to our study but is a common challenge encountered in similar research on rural municipalities, indicating that this is a widespread challenge within the field [38–42].

Second, the results obtained from different scenarios compare the performance of the selected municipalities with the best practice. This can encourage regulatory

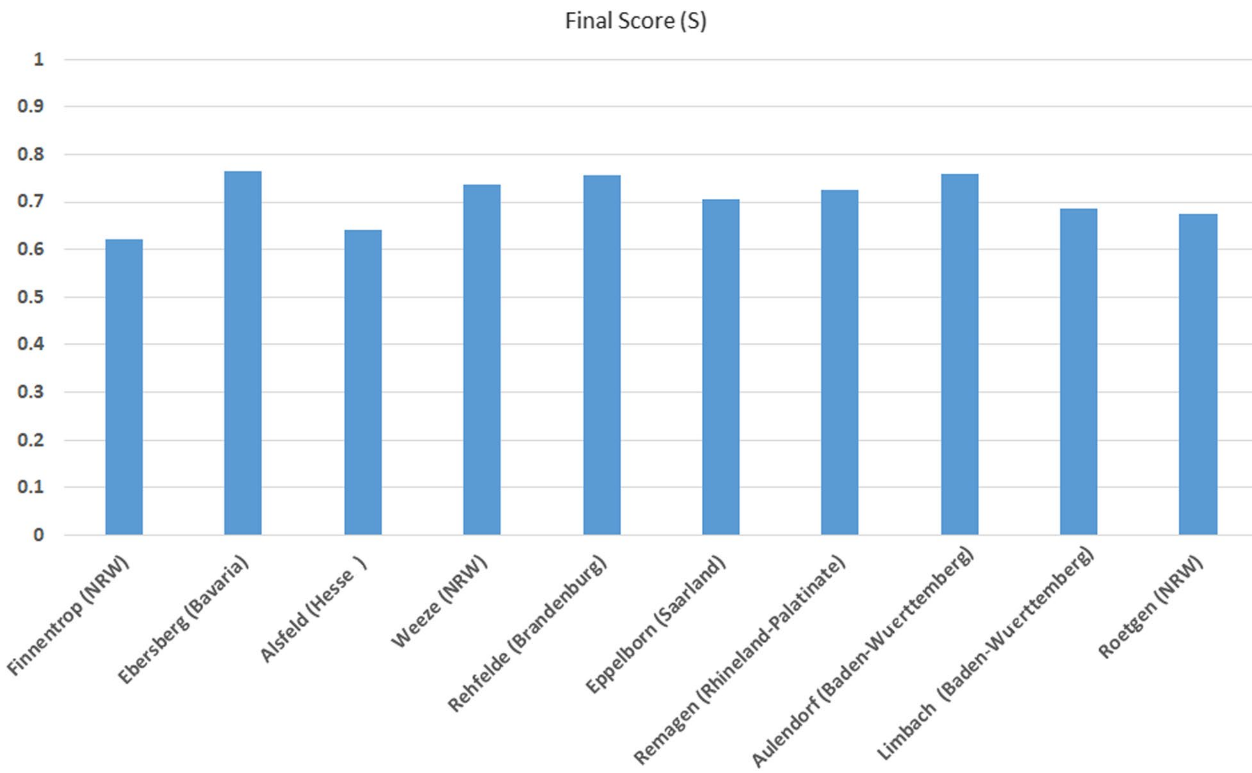

Fig. 5 Comparison of the sustainability performance of the selected rural municipalities in Germany based on the aggregated final score (*S*)

decision-makers and authorities to quickly and systematically review and evaluate the sustainability performance of their entities of interest and compare it with the highest achieved values. Consequently, rural communities can identify their strengths and weaknesses. However, our approach does not show any percentage progress compared to recent years, but only a snapshot of the current sustainability performance of the selected municipalities according to their latest published data similar to other well-known SDG index and dashboard providers [77].

Although the selected sets of indicators is comprehensive, they are not specifically designed for the rural level. Thus, some economic or environmental dependencies might be identified when monitoring the municipalities, or some level of customization may be necessary to account for specific country or regional characteristics. For example, if there is no river near the observed municipality, then the indicator for phosphorus in flowing water is not included. In rural areas with fewer than ten thousand residents, the registered businesses per year may not be included. The main reason is that this indicator counts the number of newly registered businesses per ten thousand inhabitants, and so if the rural municipality has below this population, then the results will not be accurate.

Finally, the normalization approach based on the quantitative data is more operational than the other approaches. Since our normalization method is conducted according to the current sustainable development goals, it can be modified regarding new regulations and policies, and other reasonable normalization methods can be developed. Therefore, the proposed approach is helpful to compare the sustainability performance of both rural and more aggregate (e.g., country, state, federal) levels.

Conclusion and policy implications

For the evaluation and assessment of the sustainability performance of rural municipalities, a clean and readily available dataset that announces the performance of rural municipalities is essential. Regularly updated databases and annual sustainability reports can make the benchmarking approach more dynamic, reliable and feasible for implementation. Thus, the role of dataset creation in the pursuit of sustainability benchmarking needs to be considered further. Therefore, future research should aim to address this limitation by exploring ways to obtain and incorporate historical data, thus enabling a more comprehensive and longitudinal assessment of the sustainability performance of rural municipalities to track their progress over time. Additionally, better data can be obtained by conducting large-scale surveys, which would provide a more extensive and detailed understanding of the indicators and factors influencing sustainable development in these municipalities.

Our study does not aim to provide a definitive representation of all rural municipalities in Germany, but rather to contribute valuable insights into the sustainability performance of selected rural areas. By conducting a detailed analysis of these specific cases, we can identify key challenges and opportunities unique to rural communities and develop targeted strategies for a sustainable development. Our research serves as a starting point for further investigations in this important field.

The findings of our study have important theoretical and practical implications for the field of sustainability assessment in rural municipalities. From a theoretical perspective, this study contributes to the existing literature by proposing a novel sustainability benchmarking system specifically tailored for rural areas. By incorporating dimensions such as the ecological, economic, and technological ones as key performance indicators (KPIs), the study offers a comprehensive framework for evaluating the sustainability performance in rural municipalities. Additionally, the recognition of digitalization as a crucial aspect of societal transition adds a new dimension to sustainability assessment. The methodological advancements in indicator selection, refinement, and filtering criteria enhance the rigor and validity of the benchmarking process.

Moreover, the explicit consideration of data availability, measurability, comprehensibility, comparability, and reliability criteria addresses the challenges associated with sustainability assessments in rural contexts. This contributes to the methodological advancement of sustainability benchmarking and provides a valuable reference for future research in similar settings. From a practical standpoint, the developed sustainability benchmarking system has several implications for rural municipalities and relevant stakeholders. Firstly, it offers a practical tool for rural municipalities to assess and monitor their sustainability performance. By identifying strengths and weaknesses across different dimensions, municipalities can prioritize their sustainability efforts and allocate resources effectively.

Overall, the adopted methodology of aggregating indicators, normalizing values, and deriving a single score enables us to assess the sustainable performance of municipalities and highlight variations among them. Our findings can inform policy-making and decision-making processes in rural areas. The identified dimensions and indicators can guide the development of targeted strategies and interventions to enhance sustainability in rural communities. Policymakers can utilize the benchmarking results to design policies, programs, and initiatives that address the specific sustainability challenges faced by rural municipalities. Lastly, the use of radar charts as a graphical tool for visualizing sustainability performance enables effective communication and knowledge sharing among various stakeholders. The clear presentation of data in radar charts facilitates the understanding of sustainability gaps and areas and scope for improvement. This promotes collaboration and the exchange of best practices among rural municipalities, fostering a collective effort towards sustainable development.

Appendix 1

See Table 5.

Table 5 The 83 indicators used to assess the sustainability performance of rural municipalities in Germany

No.	Indicator
1	Emission of greenhouse gases (GHG)
2	Promotion of renewable energy sources
3	Economic and efficient use of energy sources
4	Ambient air quality improvement
5	Total phosphorus input in flowing waters
6	Reduction of noise pollution
7	New business registrations
8	Reducing income inequality
9	Access to public free WiFi
10	Access to high-speed Internet
11	Population with access to electricity
12	Energy intensity in terms of primary energy and GDP
13	International flows in support of clean energy

Table 5 (continued)

No.	Indicator
14	Research in renewable energy production
15	Investment in energy efficiency
16	FDI for infrastructure and technology to sustainable development services
17	Primary energy consumption
18	Final energy consumption in households per capita
19	Share of renewable energies in gross final energy consumption
20	Share of electricity from renewable energy sources in electricity consumption
21	Heat consumption from renewable energies
22	Proportion of bodies of water with good ambient water quality
23	Amount of water- and sanitation-related activities and programs
24	Proportion of local communities participating in water and sanitation management
25	Proportion of domestic and industrial wastewater flow safely treated
26	Proportion of informal employment in total employment, by sector and gender
27	Material footprint per capita, and per unit of GDP
28	Domestic material consumption per capita, and per unit of GDP
29	Proportion of population covered by a mobile network, by technology
30	Proportion of small-scale industries in total industry value added
31	Proportion of small-scale industries with a loan or line of credit
32	CO_2 emissions per unit of value added
33	Number of cities with regional development plans that respond to population dynamics
34	Number of cities with regional development plans that ensure a balanced territorial development
35	Number of cities with regional development plans that increase local fiscal space
36	Proportion of population with convenient access to public transport
37	The agriculture orientation index for government expenditures
38	Amount of fossil-fuel subsidies per unit of GDP (production and consumption)
39	Proportion of domestic budget funded by domestic taxes
40	Fixed Internet broadband subscriptions per 100 inhabitants, by speed
41	Proportion of individuals using the Internet
42	Population unable to keep home adequately warm
43	Greenhouse gases emissions intensity of energy consumption
44	Investment share of local GDP
45	Average CO_2 emissions per km from new passenger cars
46	Value added in environmental goods and services sector
47	Greenhouse gas emissions intensity of energy consumption
48	Estimated soil erosion by water
49	Official development assistance as a share of gross national income
50	Young people neither in employment nor in education and training
51	Employment rate
52	Population covered by the Covenant of Mayors for Climate and Energy signatories
53	Emissions of local air pollutants (SO_2, NO_x, NH_3, NMVOC and $PM_{2.5}$)
54	Gini income coefficient after social transfers
55	Nitrate in groundwater
56	Number of people gaining access to drinking water
57	Final energy consumption in freight transport
58	Species diversity and landscape quality
59	Proportion of homes using smart home monitoring systems
60	Percentage of electric vehicles
61	Number of public EV charging stations
62	Number of recharges at EV charging stations

Table 5 (continued)

No.	Indicator
63	Foreign direct investment, net inflows
64	Fossil fuel energy consumption (% of total)
65	Investment in energy with private participation
66	Renewable internal freshwater resources, total (billion cubic meters)
67	Firms experiencing electrical outages (% of firms)
68	Start-up procedures to register a business
69	Time required to get electricity (days)
70	Time required to start a business (days)
71	Investment in water and sanitation with private participation
72	Ease of doing business rank
73	Tax revenue (% of GDP)
74	Total tax and contribution rate (% of profit)
75	Research and development expenditures (% of GDP)
76	Imports of goods and services (% of GDP)
77	Energy imports, net (% of energy use)
78	Population density (people per square km of land area)
79	Wage and salaried workers (% of employment)
80	Unemployment rate (% of total labor force)
81	Public private partnerships' investment in ICT
82	Fixed telephone subscriptions (per 100 inhabitants)
83	Territorial protection

Abbreviations

GHG	Greenhouse gases
SDG	Sustainable development goal
FTTH	Fiber to the home
RES	Renewable energy sources
KPI	Key performance indicator
WHO	World Health Organization
ECO	Economic
SOC	Social
TEC	Technological

Acknowledgments
This research was funded by the E.ON SE - E.ON ERC Project D15—Sustainability Benchmarking System for Rural Communities conducted by FCN-ECO (Chair of Energy Economics and Management) at the Institute for Future Energy Consumer Needs and Behavior (FCN). Comments received from the E.ON representatives in the project team are gratefully acknowledged.

Author contributions
MK: conceptualization, data curation, formal analysis, investigation, methodology, project administration, validation, visualization, writing—original draft. RM: conceptualization, funding acquisition, methodology, project administration, resources, validation, visualization, writing—review and editing.

Funding
Open access funding provided by Norwegian University of Science and Technology The authors received financial support from E.ON SE for the development of the sustainability benchmarking system for rural municipalities presented in this article (see Acknowledgments).

Availability of data and materials
The information regarding the indicators and measures included in the analysis is acquired from public websites. The coded information used for the analysis is summarized in Table 3 and Table 2.

Declarations

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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Received: 21 February 2023 Accepted: 22 November 2023
Published online: 12 December 2023

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