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RESEARCH AND THEORY

An interdisciplinary approach for successful municipal energy transition communication

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Abstract

The energy transition toward a sustainable, decentralized energy supply requires the active participation of local municipalities. Its success depends on acceptance and participation across all sections of the population. A role-specific communication strategy is therefore essential to meet the different communication and information habits, value systems, and needs. In this study, a corresponding transactional communication approach is proposed and evaluated, in which communication is understood as a dynamic and interactive process that is oriented toward preference-specific roles. The methodological approach transfers both Jakobson's communication model from linguistics and Freeman's matrix from stakeholder management to the context of municipal energy transition communication. In line with our newly proposed agile reference process, a contextualization-based instead of a predominantly functionally oriented energy transition communication strategy can thus be formulated. Applying Jakobson's model, roles are described primarily in terms of their communicative aspects rather than their functional meaning. The new interdisciplinary approach is demonstrated using the example of a municipality. Results are used to demonstrate a role-specific communication strategy as the base of the subsequent derivation of role-specific actions and instruments.

Keywords Interdisciplinary approach · Communication · Roles · Energy transition

Introduction

Challenges for German municipalities

Sources of renewable electrical energy, such as wind or photovoltaic power plants, are small-scale and in many cases located close to consumers, unlike large-scale fossil electrical plants (Di Silvestre et al. 2018). Therefore, the transformation of the existing energy system landscape, primarily based on fossil primary energy, toward sustainable energy supply implies decentralization (Heldeweg and Saintier 2020). In addition, the transition requires land or rooftop space that is available primarily in rural areas at an economically feasible cost (Benedek et al. 2018). In total, this leads to a significant shift from central large-scale supply facilities operated by large corporations to decentralized facilities individually operated by municipalities and individual households (Synwoldt 2021). Within this development, municipalities assume a crucial and often new role as energy providers. The active participation of municipalities and individual households is an essential factor for a successful energy transition. According to a KfW/Prognos study, approximately €46 billion per year (a sixfold increase according to KfW) of public funds will be needed for investments in the energy transition in Germany alone over the next 25 years (Thomas Krebs 2021). These investments, based on the technological path of the KN2045[1] scenario, are allocated to federal investments,

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[1] The technology path of the KN2045 scenario by Prognos indicated measures and steps Germany can take to achieve its climate targets even before 2050 (Deutschland 2021)

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municipal investments, and support for private investments. Energy expansion measures will account for a substantial portion of municipal budget investments. The contribution expected from municipalities is essential because, for the success of global or national climate change, the implementation of the energy transition at the municipal level plays the central role described above. The associated responsibility represents a disruptive shift in the self-perception of municipalities. For instance, there is currently no municipal provision mandate in the German heating sector. Municipalities are currently inadequately prepared for this responsible task (Beer et al. 2022). Therefore, answers and according supportive measures are required in three areas to enable municipal leadership, responsibility, and related tasks:

1. Technology: Which energy provision technologies should be prioritized for expansion planning at which locations on the municipal level and with what intensity? (Stadler et al. 2022)
2. Economy: How can the implementation of the expansion plan be financed? Who should operate the facilities? What form can municipal participation take? (Tanaka et al. 2022)
3. Communication: What information is needed in which way and by whom? How do we create discourse as a basis for acceptance and participation? (Radtke and Canzler 2019)

In the context of this paper, we focus on the last of the above topics in an interdisciplinary approach. Communication plays an important integrative role and supports technical and economic activities. However, according to the state of the art, it is not yet known how targeted communication should be designed to methodically and systematically support municipalities in their local energy transition. The topic implies the development of an effective and efficient communication strategy as a basis for a successful municipal energy transition.

Relevance of communication roles

For more than two decades, investigations of alternative approaches for a green transition and climate change mitigation have been subject of technical discussions (Nilsson and Mårtensson 2003; Scheller and Bruckner 2019). A considerable body of international scholarly literature is also analyzing the correlation between citizen engagement and its accompanying citizen-oriented communication in this field (see, e.g., Whitmarsh et al. 2012). The meaning of "citizen voices" by initiatives at a municipal level is specifically highlighted by Phillips et al. (2012). However, previous projects on municipal energy transition have predominantly considered individual change aspects, focusing on either technology *or* economy *or* communication (e.g., Thomas Krebs 2021; Eggers 2017; Chang et al. 2021; Akyol et al. 2022). The overall perspective that addresses equally the technical and economic challenges as well as the successful communication between the involved municipal stakeholders has been neglected. Focused communication establishes the basis for participation and acceptance. Nevertheless, involved recipients bring their own specific communication and information habits. Due to individual explanatory patterns, opinions, and expectations, generic and generalized communication strategies are only partially effective (Schweizer-Ries et al. 2013). Therefore, it is necessary to understand the stakeholders and their habits and needs in order to enable targeted communication. The a) selection of a suitable communication model as well as the b) division of stakeholders into different communication roles based on this model are of particular importance, because they enable the selection of role-specific communication instruments as well as the effective addressing and information selection for involved stakeholders with a recipient-oriented approach. Through targeted information on the involved interest groups, acceptance and participation can be achieved as a basis for a successful municipal energy transition.

Based on the above-described approach, identification, characterization and classification of communication roles must allow to...

(a) reflect ("understand") specific communication habits and needs of associated citizens within the context of municipal energy transition,
(b) categorize and prioritize communication (rather than functional) role-specific efforts according to a phrased communication strategy, and
(c) select communication tools specific to the role.

In addition to choosing an appropriate communication model, the aforementioned goals also require an appropriate tool for prioritizing the stakeholders that can be identified by the model. In order to highlight the gap that needs to be filled in this context, we first provide a brief overview of the state of the art in contemporary communication approaches in the context of municipal energy transition.

A review of contemporary communication approaches for municipal energy transition

In the field of communication science, numerous models of communication or the communication process exist, which differ in various aspects. Additionally, communication studies propose a variety of additional key elements in communication analysis, like the role of disturbance sources,

processes of encoding and decoding messages, or the problematization of entities like sender and recipients. This paper does not and cannot provide a comprehensive insight into that vast scholarly field and is on purpose reductive here. With regard to the objectives to be achieved, some of the models are only suitable to a limited extent and only address particular aspects. At a higher level, there are three different theoretical approaches to understanding the process of communication, namely transmission, transactional, and constitutive communication models (Burkart 2007).

Transmissional models, also known as linear or sender-receiver models, are traditional and straightforward models of communication, which view communication as a one-way process, in which information is transmitted from a sender to a receiver. Transactional models emphasize the dynamic and interactive nature of communication. Unlike the transmissional models, this approach recognizes that communication is a two-way process, in which both the sender and receiver simultaneously play the roles of encoding and decoding messages (Burkart 2007). Constitutive models take a more interpretive and symbolic approach to communication. Instead of focusing solely on the transmission of information or the exchange of messages, these models consider communication as the process that creates and shapes social reality or shared meanings (Burkart 2007).

In the context of municipal energy transition as a specific application case, a model that solely focuses on discourse structure, such as environmental discourse in general, is too comprehensive. Additionally, a pure signal transmission, i.e., a linear sender-receiver model, is not relevant as other factors such as context and language play a role in the context of municipal energy transition. Furthermore, a bidirectional, dynamic communication process between sender and receiver, for instance, decision-makers and citizens, is crucial to establish communication as a basis for participation. Hence, a transactional communication model is suitable because it...

(a) considers communication as a transaction involving an exchange of information, ideas, and meanings,
(b) regards feedback as a central aspect enabling mutual understanding and adjustments during the communication process,
(c) takes into account the influence of context, cultural background, and individual perceptions on communication.

Understanding the communication habits and needs in the context of municipal energy transition is one of the central objectives of this study. By leveraging the mentioned characteristics of transactional communication models, these habits and needs can be analyzed.

One of the most widely used representatives of transactional communication models is Schultz von Thun's four-sided model (Von Thun 2013). Incorporating different ideas from psychology, von Thun assumes that every message contains four equally important aspects. Each communication process involves these four perspectives, i.e., factual level, self-disclosure, relationship level, and appeal level, which can influence each other.

- The *factual level* focuses on conveying objective and matter-of-fact information such as data and facts.
- *Self-disclosure* involves the implicit sharing of information about the sender's values, emotions, motives, and other personal aspects consciously or intendedly.
- At the *relationship level*, information is exchanged regarding the connection and dynamics between the sender and receiver of the message.
- The *appeal level* includes the expression of desires, advice, instructions, or commands by the sender, which he requests from the receiver.

This model, which emphasizes the complexity of communication, finds particular resonance in communication psychology and can be used to improve communication skills in various areas (Röhner et al. 2016). However, von Thun's model neglects contextual factors. The context, including cultural, social, and situational factors, can significantly influence the meaning and impact of a message (Röhner et al. 2016). Nevertheless, the model has been considered in projects related to environmental communication and energy transition. In order to illustrate the obstacles to overcome in environmental communication, Augustine (2018) utilizes Schulz von Thun's communication model together with the threshold model of environmental communication (Kleinhückelkotten and Wegner 2010). This approach implies not only the selection of appropriate information but also its preparation. The threshold model of environmental communication establishes the context for the topic of "environment." However, Augustine emphasizes that the assumption of homogeneity among the targeted group of citizens is a challenge for effective environmental communication. The Schulz von Thun model offers good possibilities for carrying out a structured analysis of communication. It can also enhance communicative skills, such as consciously choosing the right words to convey information clearly and considering the relationship with the conversation partner. The reference to the context, for example, municipal energy transition, is only implicitly considered and not actively incorporated into the model. Therefore, the selection of a model that also takes into account the contextual context is necessary.

Another representative of transactional models is the communication model of Jakobson (1993). This model describes the different elements and functions that are present in a communication situation, like the Code, Channel, Message, and Context. This approach, which has mainly been used in

linguistics but not in the context of municipal energy transition, is particularly suitable for capturing the communication habits and needs of citizens in a structured way. It also takes into account the context in which communication takes place. It has already been successfully applied beyond linguistics in fields like packaging design (Lemon 2019) and communication processes in management accounting and control systems (Pärl 2012). Hence, the usage of this model beyond linguistics is a promising approach.

In addition to the appropriate communication model, a strategy is necessary to work with the communication roles.

This paper is structured as follows: First, the newly proposed methodology to create and characterize communication roles as the basis for a successful municipal energy transition along with its underlying methodical base is described. Then, the new communication role concept is embedded in an agile reference process based on an equally new methodical approach to formulating an energy transition communication strategy. Finally, based on this methodology, an instantiation in a German municipality is exemplified and concluded by a discussion.

A novel methodology of identifiying and describing communication roles

In contrast to previous projects and studies, the presented article aims to first identify the actors and subsequently categorize them into roles according to their communication needs and habits and not according to their function. In the second step, these roles are categorized and prioritized in order to derive an effective and efficient communication strategy for each of them. Such an interdisciplinary approach to challenges in energy transition — and in consequence to other societal challenges and changes — is key to tackling nowaday's complex problems sustainably and hereby to convince people of the necessity to act without perpetuating further social divides. Mapping the complexity of the challenge in an innovative research system leads to a reduction in analytical depth in the individual disciplinary sections of this paper, but at the same time, it allows for a highly applicable interdisciplinary approach to successful municipal energy transition communication.

With the help of the communication model according to Roman Jakobson, the different roles can be described. By transferring the model from linguistics to the field of municipal energy transition, communication habits and needs can be represented in this context. By applying this transactional communication model, the roles are not described based on their functional perception, but rather the communicative aspect takes precedence. This allows the above objectives (a) and (b) to be fulfilled. The systematic description of roles forms the basis for the selection of role-specific communication tools.

Jakobson's linguistic communication model is based on six factors, which are shown in Fig. 1 and will be explained below (Jakobson 1993).

1. *Sender* (emotive or expressive function): refers to the expression of emotions, feelings, or subjective attitudes of the speaker or author. The language serves the speaker, who expresses personal attitudes and opinions.
2. *Receiver* (conative function): Refers to the impact of a statement on the listener or receiver. The emphasis is on influencing, persuading, or prompting the listener to take certain actions.
3. *Context* (referential, denotative, or cognitive function): Language is used to convey information or represent something. It concerns the presentation of facts or situations.
4. *Channel* (phatic function): Exchange of ritualized formulas that serve to maintain the communication channel or strengthen social interaction between conversational partners. It is achieved through the use of clichés or social phrases that may lack deep substantive meaning but keep the conversation flowing.
5. *Code* (metalinguistic (i.e., explanatory) function): Serves to explain, comment on, or define language itself.
6. *Message* (poetic function): Focuses on esthetics and creative use of language. The form and structure of language are used to create linguistic peculiarities, metaphors, rhymes, or rhythmic patterns that attract the reader's or listener's attention and emphasize the linguistic expression.

The linguistic model according to Roman Jakobson must be adapted for the present case of municipal energy transition.

The *sender* is the person who sends a message to the receiver. In the field of municipal energy transition, in which we are active, there are very different transmitters and they cannot always be clearly identified. The transmitters include, for example, the municipality, citizens, but also other stakeholders and members of the public, who represent different opinions and send them to the various receivers. For this

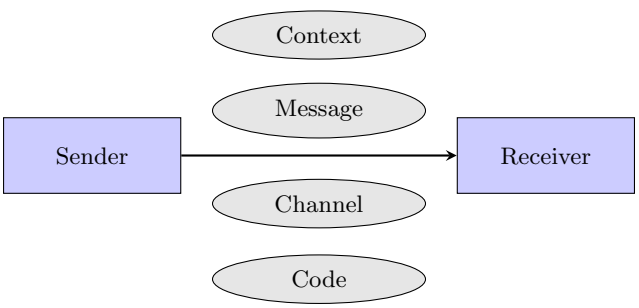

Fig. 1 Communication model according to Roman Jakobson

reason, the group of transmitters will not be considered in more detail in this context. The *receiver* is the person who receives the message. In this case, it is again difficult to delineate one single exact receiver. Rather, the diverse receivers bring along different preconditions, communication habits, and needs. Thus, the receiver as a factor serves as a placeholder for the communication roles that have been developed as described in this paper. If the habits and needs of the receivers are known, the impact of a message can be better assessed. Therefore, the receiver functions as an implicit part of the model, influencing and delimitating the shape of communication roles. Subsequently, the aspects of context, channel, code, and message are of particular importance. The *context* describes the circumstances or environment, in which the content is communicated. In this case, the question is, at which events and in which environment does an exchange on the municipal energy transition take place. The *channel* describes via which means of communication and with how many people the communication takes place. This includes, for example, social media, information events, or other media. To illustrate this use more transparently, the term *contact* is used instead of *channel*. The *code* describes the language that is used or desired. It is defined by rules or conventions that determine the meaning of a message. The *message* describes the content, which is intended to attract the attention of the receiver or which is desired by the receiver. In this case, for example, this includes information on individual measures relating to the energy transition or on concepts of the municipality for the local energy transition.

In brief, the following factors are assigned to the individual aspects:

- The *sender* is the person or institution who sends a message to a *receiver*.
- The *context* describes the circumstances in which communication takes place.
- The *message* is the content that is desired by the receiver.
- The *contact* represents the medium through which communication takes place and the number of people involved.
- The *code* is defined by rules and conventions that determine the meaning of a message, i.e., the language used, expressions, and grammar.

This model considers all essential elements of the communication process. It ensures that all aspects of communication, including the sender, receiver, message, code, channel, and context, are taken into account. Furthermore, the clear structure enables a thorough understanding and analysis of the complex relationships involved in communication. The model is a useful tool for analyzing all communication habits and needs of citizens in the context of the municipal energy transition in a structured way. It also enables a comparison to be made between the target and actual status. The distinction between pure functions — defined by tasks and duties of the people — and communication roles — defined by clustering the anonymous responses into the 4 factors (context, message, contact, and code) of Jakobson's communication model — shall propose an innovative way of designing communication strategies. The assumption often held that certain functions require a monocausal way of communicating has proven to be too reductive and generalist. With the help of Jakobson's communication model, the focus on sender and recipient has been shifted to the 4 factors that shape communication according to this model, thus allowing to analyze and identify habits and needs without having in mind a priori which stakeholder group communicates.

Communication strategy — reference process

Based on the methodological foundation for the identification of communication roles described above, the formulation of a communication strategy based on this also requires a) the methodological framework for the development of such a strategy and b) a reference process that integrates these methodological elements. We propose new approaches for both parts in the following two subsections.

Communication strategy phrasing by PI-Matrix

The origin of the power and interest network or matrix (PI-Matrix) goes back to Freeman's model (Freeman 1984), which is intended to show two key aspects in the context of stakeholder analysis: The first aspect refers to the various interests that make an external entity attractive to an organization or a project and thus make it a stakeholder. The second aspect concerns the degree of influence that these entities can exert on the actions and performance of the organization or a project. According to Freeman, stakeholders who have both significant power and interests that align with the goals of a project (or more broadly, a venture) are of the utmost importance and are the most important target group for communication. This group encompasses not only the immediate decision-makers but also those whose opinions carry weight. This group should, according to Freeman, be regularly engaged. On the other hand, stakeholders who exhibit either high interest but limited power or high power but limited interest should be kept informed or satisfied, as suggested by Freeman. These individuals or groups make up the secondary audience. The third stakeholder group is made up of participants who have equally little interest and power. In Freeman's opinion, this group should receive the least attention, but should at least be given the opportunity to maintain their interest (however small).

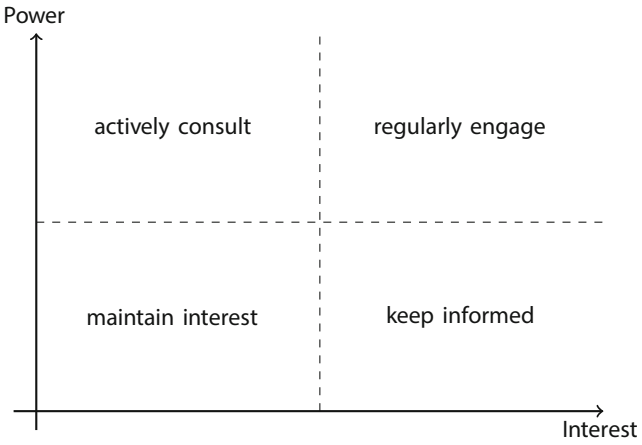

Fig. 2 PI-Matrix according to Freeman (1984)

Originating from the environment of stakeholder analysis, Freeman's PI-Matrix approach enables the qualitative definition of stakeholder or role-specific communication objectives. Along with Freeman's recommendations of stakeholder involvement, the PI-Matrix proves to be a valuable tool for formulating an effective communication strategy as the basis for efficient tactical communication measures.

In the context of municipal energy transition communication, we suggest using the PI-Matrix in two ways: Firstly, the PI-Matrix enables the derivation of a communication strategy for individually identified roles through dedicated communication goals, in their original meaning. Secondly, the PI-Matrix can additionally serve as a decision criterion to check the completeness of stakeholder group identification by checking the coverage of each PI-Matrix quadrant after the survey and cluster analysis. The second application of the PI-Matrix is based on the idea of covering the full range of interest groups in large cohorts. Therefore, the approach allows not only to identify and characterize the stakeholders who should be addressed as key players but also those for whom at least a communication offer should be provided.

Figure 2 shows the PI-Matrix with communication objectives assigned to its four quadrants and indicated in parentheses below:

- High Power, High Interest (Regularly Engage): individuals should be fully involved to satisfy them
- High Power, Low Interest (Actively Consult): individuals must be actively addressed
- Low Power, High Interest (Keep Informed): individuals should be adequately informed to satisfy them
- Low Power, Low Interest (Maintain Interest): the interests of individuals should be monitored and exchange is possible if necessary to maintain a positive relationship

In the best sense of a strategy formulation, the PI-Matrix allows the assignment of identified groups (which later represent individual communication roles) to clearly differentiated communication goals as well as a suitable communication framework.

Reference process

For the formulation of the reference process, we propose an agile approach according to Hakola (2017) that allows an iterative situation-based learning in the communal environment with highly individual character. This reference process may be carried out in several steps along with a quality check feedback loop as illustrated in Fig. 3. By running different loops, additional survey data can be collected to improve data completeness and quality. The initial steps gather data about communication habits and needs ("Survey"), and identify a data cluster ("Cluster Analysis"), which can then be assigned to a communication strategy evaluation in terms of a Power-Interest(PI)-Matrix ("PI-Matrix Creation"). This is followed by a quality check to test if all relevant squares of the PI-Matrix are covered and thereby characterized by at least one identified cluster. Only upon this condition, it is recommended to proceed by a one-to-one assignment of these identified clusters to communication roles ("Role Definition") that may subsequently be used to phrase a role-specific communication strategy and to derive appropriate, i.e., role-specific, communication measures.

The atypical use of a PI-Matrix to formulate a communication strategy can be derived indirectly from the process flow. Therefore, this approach is first explained. All of the following sub-chapters are dedicated to clarifying the individual process elements described above. To this end, they provide details of the sub-steps shown in Fig. 3 on the one hand and, on the other hand, provide key results of the pilot application.

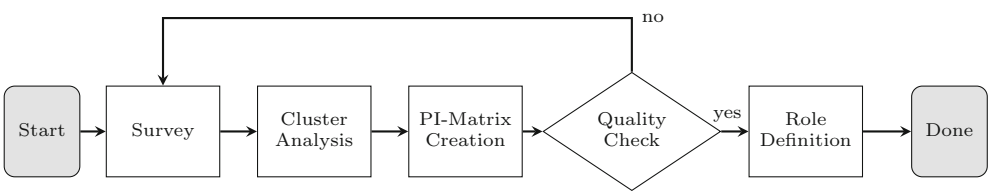

Fig. 3 Reference process for the identification of communication roles as an integral part of a communication strategy

In the first block of the process proposed in Fig. 3, stakeholder clusters are to be identified and classified in the PI-Matrix until all quadrants are filled and the associated groups are sufficiently characterized. In this process block, it is not yet possible to speak of roles, as the individual clusters initially only represent the sum of the common characteristics determined by surveys. The role assignment can only be derived from the subsequent evaluation of the features characterizing the clusters. However, this assignment should only take place once all relevant stakeholder groups have been identified as clusters, i.e., after the first process block has been completed. In the pilot application, this required three iteration loops, which are described below.

Even before the start of the first round, it had already been noted that in the context of communication on municipal energy transition, the level of interest shown by citizens was not a directly measurable variable. Accordingly, interest was approximated by (activity) intensity for all subsequent work. It describes the extent to which the respective group of people consider themselves concerned with the topic of the municipal energy transition. The intensity thus reflects people's self-assessment and is a qualitative representation of the intensity of engagement with the topic of the municipal energy transition.

Results — exemplary application

For the purposes of demonstration and validation, an exemplary implementation will be presented in the following together with results from a pilot application in a German reference community.

The reference community itself, Höhenkirchen-Siegertsbrunn, with its 11,000 inhabitants, is located 17 km southeast of Munich. As one of 29 municipalities in the district of Munich, Höhenkirchen-Siegertsbrunn made a voluntary commitment in 2017 to reduce its annual per capita emissions by 54 % from 13 tons of carbon dioxide in 2010 to 6 tons per year and citizen by 2030. With a local share of renewable energy of less than 25 % (2017), the energy sector is the area with the greatest municipal influence on reducing CO2 emissions. Accordingly, the municipality has subsequently focused on technical planning for a conversion of the municipal energy system, e.g., through ground-mounted photovoltaics, wind turbines, or a geothermally fed heating network. For all options, problematic constellations have already become apparent within the first planning year. One example of this is wind power: The area around Höhenkirchen-Siegertsbrunn is located in a so-called "low wind zone," in which particularly high wind turbines must be erected for economic operation. At the same time, the area in which the turbines are to be erected is part of a landscape conservation area that is also used as a local recreation area. Public protests were therefore to be expected. These considerations prompted the local council to place acceptance and participation on an equal footing with the ecological and economic goals of the energy transition at an early stage. This led to the foundation of the project "Communal Energy Transition Supporting Communication" (KEuKo), funded by the DBU (Deutsche Bundesstiftung Umwelt).

In the application example, power is determined by group membership and the degree of networking within the community. It can be derived either from a position of power, e.g., membership of the local council, teaching staff, club committees, etc., or from a high degree of networking power, which is reflected in the size of a person's communication circle.

First iteration

Creation and distribution of the survey

The first process step as shown in Fig. 3 includes all actions from the preparation of a survey to its distribution and the collection of response data. The data collected must allow citizens to be characterized by communication relevant features that allow a subsequent assignment to consistent roles based on a meaningful role definition. For this purpose, a questionnaire was created to collect data on municipality relevant communication habits and needs. The survey primarily consists of quantitative questions but also includes qualitative elements.

The survey was divided into several overarching themes to allow for systematic data collection based on Jakobson's factors. Through quantitative data analysis, statements can be made about the preferred communication channels and the context in which communication and exchange preferably take place. By means of qualitative analysis, the language and content desired by citizens in relation to municipal energy transition can be investigated. The questions aimed to identify both communication habits and communication needs in order to be able to identify the weak points in current communication.

For data generation, an online survey was created using the limesurvey software (LimeSurvey GmbH 2006). Since the percentage of internet users in Germany is around 95% (Lohmeier 2022), it seemed necessary to ensure that also individuals without online access could participate in the survey. Therefore, a paper version of the survey was created as an additional distribution medium.

The survey enabled cluster analyses to be carried out based on the aspects (features) according to Roman Jakobson.

To conduct the survey, suitable instruments first had to be selected for distribution. The goal was to reach as many individuals as possible, which is why the survey was distributed through various available channels in the reference munici-

pality. These channels included the municipal newsletter, a Facebook group of the municipality, the municipal website, and an email through the municipal mailing list. In addition, postcards with QR codes were created and distributed through mailbox inserts. A total of 2800 postcards were distributed using this method. To achieve a homogeneous distribution and representativeness, the town was divided into areas, and a specific number of postcards was allocated to each area. The paper version of the survey was made available for pickup at the municipality.

Data collection took place between July 12 and August 21, 2022. During this time, the online survey was available, and the paper version could be picked up at the municipality and submitted in an envelope.

Potentially, all residents of the municipality over the age of 15 could participate in the voluntary survey. This corresponds to approximately 9200 residents living in approximately 4000 households (Bock 2019). The goal was to have 100 individuals participate in the survey to achieve a 1% minimal response rate.

By the end of the survey period, 227 valid responses had been received.

Identification of clusters

A cluster analysis according (Janssen and Laatz 2017) was used to identify stakeholder groups (cluster) of comparable features with respect to their power and intensity in municipal energy transition. The features themselves are supposed to characterize communication habits and needs. Using this method of exploratory data analysis, clusters were formed on the basis of carefully selected analysis variables.

The two-step cluster analysis was performed using the SPSS software (IBM SPSS Statistics 2022). The clusters were formed based on the questionnaire criteria interest (activity intensity) in energy transition in the reference community, interest (activity intensity) in community life, communication network regarding energy transition in the reference community, and community life and group membership. These variables were chosen as they allow to analyze power and intensity of the respective clusters using the Jakobson factors. The results of the analysis yield various clusters that differ in terms of their intensity and degree of interconnectedness.

The cohort was divided into three clusters and an additional cluster 4 with all persons who were not assigned to a cluster by the SPSS analysis due to missing responses in one of the analysis variables. Since all fields, except the last response, were not mandatory, not every question received a response. Clusters 1 and 3 were combined due to similarities in communication and group affiliations. On the other hand, Cluster 2 was further divided into subcluster 2a and b. Cluster 2b was assigned to individuals who indicated belonging to groups with high power by virtue of their positions. The different steps are shown in the following Fig. 4.

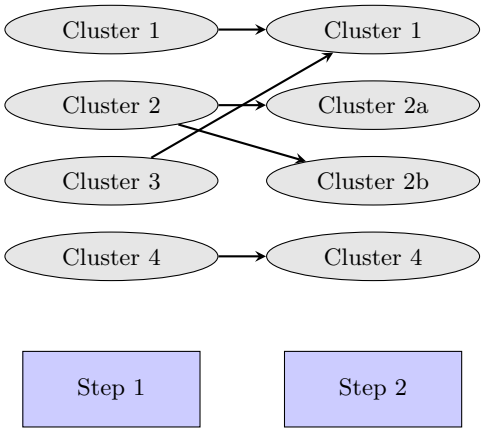

Fig. 4 Steps 1 and 2 of the cluster analysis with SPSS

Performing a quality check, the four different clusters were assigned to the PI-Matrix. For this purpose, the different values for power and intensity were calculated as the weighted arithmetic mean values for "Group Power" and "Connect Power." The result is shown in Fig. 5. The calculation principles and assumptions are presented in the Appendix 2.

It can be observed that Cluster 2b possesses both high "Group Power" through its group affiliation and is also well-connected within the community. The high "Group Power" arises from their membership in the municipal council or community working groups. All individuals in this role are either members of the municipal council or affiliated with a working group. On the other hand, Cluster 2a has very low influence through group affiliation but is also well-connected within the community. Cluster 1 and 4 have low "Group Power" and "Connect Power."

Before assigning the clusters to the quadrants of the PI-Matrix, the intensity with which people deal with municipal

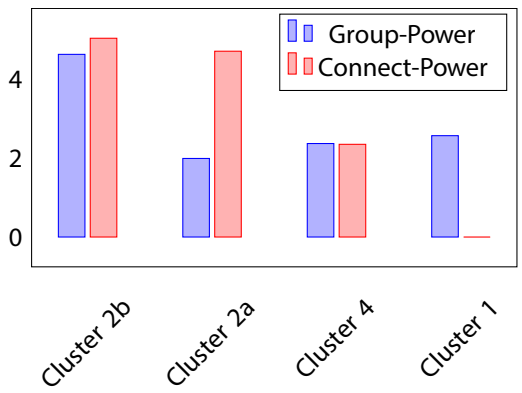

Fig. 5 Power shares, divided into Group and Connect Power

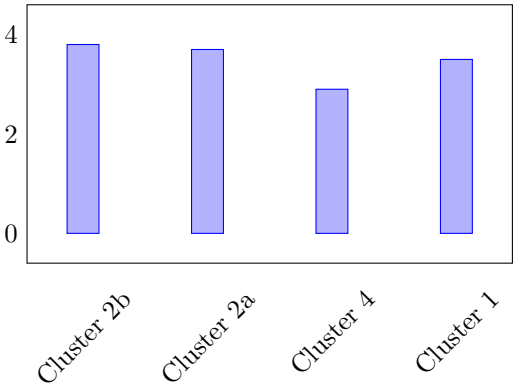

Fig. 6 Intensity results of the individual clusters on the topics of energy transition in the municipality and municipal life (maximum value: 5)

issues had to be determined. The value was calculated as the average of the answers given. Results are shown in Fig. 6.

As shown in Fig. 7, after the first iteration, and thus survey, only four clusters were identified. These clusters all deal with the topic of energy transition with high intensity. Therefore, a further iteration had to be carried out to determine the roles in the two left quadrants.

Second iteration

Creation and distribution of the survey Since no clusters could be identified in the two left quadrants of the PI-Matrix in the first iteration, a second iteration loop was performed. In order to identify clusters with people who do not intensively deal with the topic of municipal energy transition, a street survey was selected as an appropriate tool. In this survey, citizens were directly approached at two locations in the municipality for two days and asked to participate in the survey generating 47 additional responses.

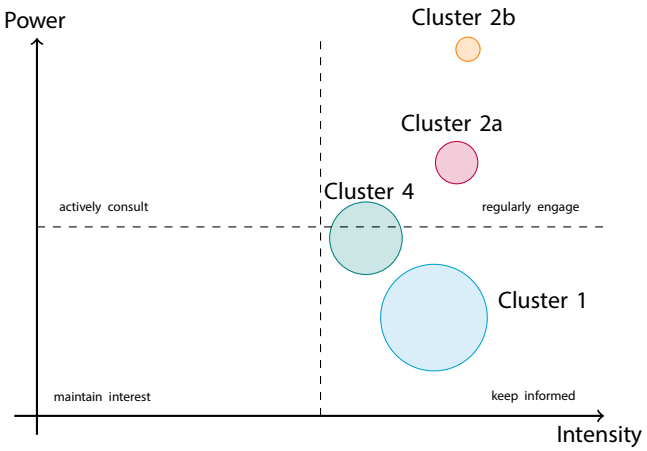

Fig. 7 PI-Matrix after first iteration step (bubble size related to survey participants; diameter corresponds to the proportion of people participating in the survey)

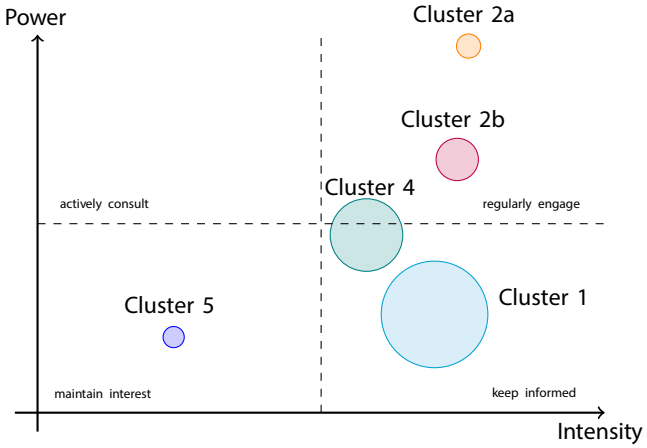

Fig. 8 PI-Matrix after second iteration step (bubble size related to survey participants; diameter corresponds to the proportion of people participating in the survey)

Identification of clusters The answers were sorted according to activity intensity in the topic of municipal energy transition and then either assigned to the existing clusters or, in the case of "low intensity," assigned to a new cluster. The second iteration, thereby, identified Cluster 5. It contains people who reveal little or no activity intensity in the topic of municipal energy transition. Cluster 5 was also assigned to the PI-Matrix (Fig. 8).

After the second iteration, the PI-Matrix still showed one (upper left) quadrant to which no cluster could be assigned. A third iteration loop therefore had to be carried out to identify clusters with people who have a high level of influence in the municipality but are not involved in the topic of the municipal energy transition.

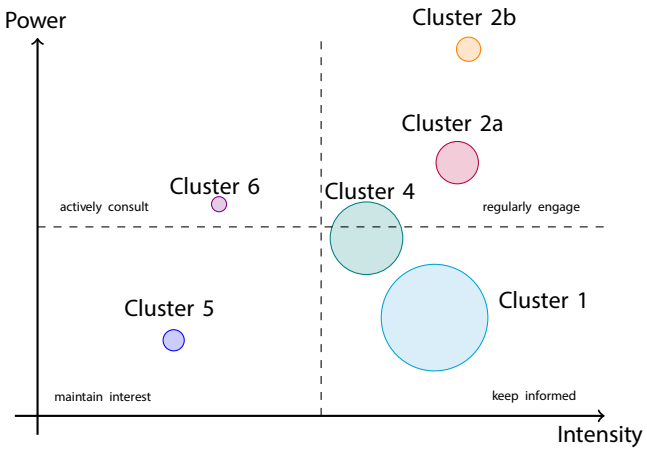

Fig. 9 PI-Matrix after third iteration step (bubble size related to survey participants; diameter corresponds to the proportion of people participating in the survey)

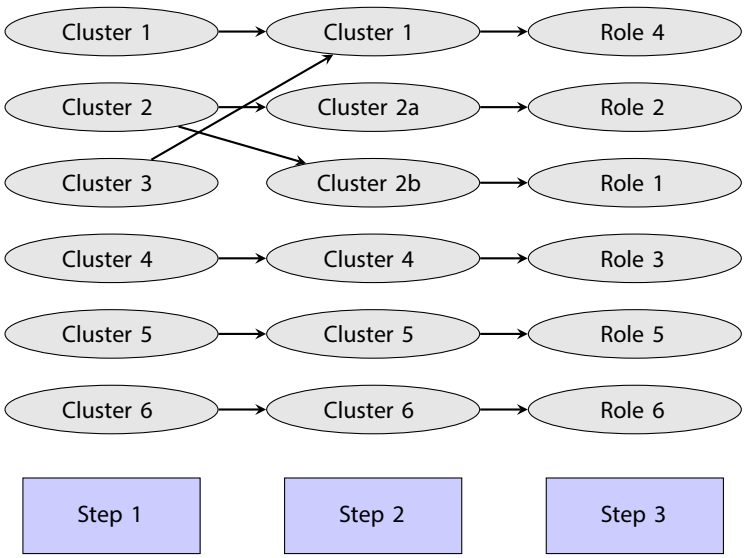

Fig. 10 Three-step cluster analysis and role assignment

Third iteration

Creation and ditribution of the survey In order to reach people with high influence but low activity intensity in the community, in the third iteration loop the survey was distributed by email to a variety of "high power" groups of people in the community. This included people who have a high degree of influence due to their position, such as educators, school teachers, sports or music club chairmen, or church leaders. The people were asked to take part in the online survey by email. This third survey generated 23 additional responses.

Identification of clusters During the evaluation, as in the second iteration, the corresponding persons were assigned to already existing clusters and a new Cluster 6 could be identified. This cluster includes people who have influence qua office but are not or hardly involved with the topic of municipal energy transition. The cluster was assigned to the PI-Matrix (Fig. 9).

Once the quality objective of identifying a cluster in each of the different quadrants of the PI-Matrix had been achieved, the habits and needs of the clusters could be analyzed in the next step using the Jakobson factors.

Definition of communication roles

In this process step, the communication habits and needs of the individual roles are analyzed using the criteria of code, context, channel, and message from Jakobson's communication model. As illustrated in Fig. 10, the communication roles identified so far can now be assigned to individual communication roles.

The communication role definition started with a qualitative Mayring-based content analysis of the comments (Mayring 2015). Accordingly, codes were defined in the first step. These codes were developed and described based on the text material itself to ensure consistent coding (see Appendix 1). The text was then coded against the predefined categories. After coding, relationships or specific features were analyzed and interpreted. To ensure the validity of the results, the coding was also performed by another person who was not involved in the coding process. The results were then compared. The proportions of the respective codes, as depicted in Fig. 11, were obtained. It can be observed that the most frequently identified code was C1. 22 % of the open-ended comments contained passages criticizing inadequate information provided by the municipality. This was followed by codes C5 (14 %) and C11 (12 %), which either pertained to the topic of heat or expressed general dissatisfaction with the current path of the energy transition at the federal level.

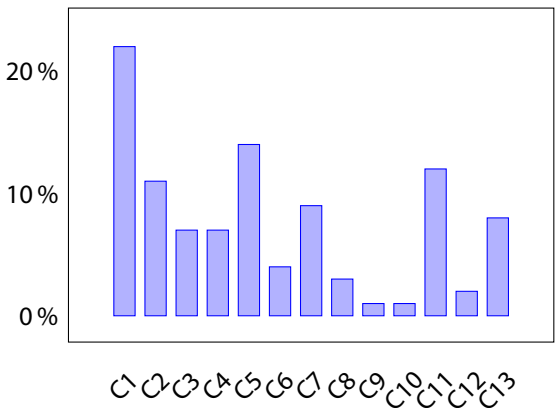

Fig. 11 Proportions of responses to the respective codes

After the qualitative data had also been analyzed, the respective roles could be described according to the aspects of Jakobsons communication theory.

Role 1

Individuals belonging to Role 1 (Cluster 2b) are characterized by a high level of group or connect power (see Fig. 5). They are members of the municipal council or various working groups of the community and therefore also reveal high intensity. Through their affiliations and communication behavior, they play a crucially active role in community life. Individuals in this role have a high level of education (Masters), and 75 % of them own the property they reside in. To gather information on municipal topics they rely on municipal newsletters (83%), information events (56%), and working groups (44%).

Contact (Channel): These individuals typically communicate with up to 30 people.

Context (Embedded): The exchange primarily takes place in working groups, during municipal council and other meetings, community information events, and other official gatherings.

Message (Content): These individuals have a need for comprehensive concepts related to the community's energy transition. They also lack sufficient information (33%) and would like specific decisions on relevant topics concerning the municipal energy transition.

Code (Language): Individuals in this role criticize the verbalization of communicated topics (25%) and have a need for (technically) substantiated data, calculations, and studies to support decisions or proposals. Therefore, the language used for this role should be more technical in nature.

Role 2

Individuals belonging to Role 2 (Cluster 2a) primarily exhibit a large communication network and therefore connect power (see Fig. 5). These individuals are actively engaged in community life. The gender distribution is balanced, and the educational level of this role ranges from bachelor's to master's degree. A majority of individuals in this role are property owners (88 %) in the community they reside in. To gather information on municipal topics, they rely on the municipal newsletter (94 %), the community's website (56 %), and information events (53 %).

Contact (Channel): These individuals communicate with up to 100 people.

Context (Embedded): Communication with others primarily takes place in a private setting, followed by information events or clubs.

Message (Content): Individuals in this role have a need for information on measurements already conducted in the community and would also like to know the status of specific measures. They tend to be skeptical of the state of the nationwide energy transition or nationwide measures and are dissatisfied with the current situation.

Code (Language): Communication should be conducted in clear, understandable, and transparent language.

Role 3

The third role (Cluster 4) is assigned to the lower right section of the PI-Matrix. It has low power but reveals strong interest (i.e., high intensity) in the topic of energy transition in the community. Communication mainly occurs within familiar or anonymous environments. The gender distribution is equal, and the highest level of education is a bachelor's degree. 88 % of the individuals in this role are homeowners of the property they reside in. For information acquisition, these individuals predominantly rely on the municipal newspaper (91 %) or the community website (40 %).

Contact (Channel): Individuals in this role have contact with up to 10 people, occasionally reaching up to 100 people. They primarily prefer an anonymous way of communicating such as surveys to connect and engage with others.

Context (Embedded): Communication primarily takes place in private contexts within the family or among acquaintances (60 %). On the other hand, informational events are rarely utilized (6 %).

Message (Content): Individuals in this role seek information regarding the status of specific measures, such as wind, solar photovoltaic (PV), and heat. Additionally, they would like solutions to specific problems, such as district heating and heat networks.

Code (Language): Communication should employ clear, understandable, and transparent language.

Role 4

Individuals in the fourth role (Cluster 1) are characterized by low group power and no connect power. The communication circle of these individuals includes a maximum of up to 10 people. 71 % of individuals in this group are male, and the highest level of education is a bachelor's degree. 87 % of these individuals are homeowners of the property they reside in. Despite having a small communication circle, they participate in public discourse. For information acquisition, they rely on the community newspaper (98 %), informational events (46 %), or the community website (44 %).

Contact (Channel): Individuals in this role have contact with up to 10 other people.

Context (Embedded): Communication primarily occurs within the private sphere (87 %) or at informational events (36 %).

Message (Content): Individuals in this role seek information about the status of specific measures, such as wind, solar photovoltaic (PV), and heat. They would also like information about the municipality's concept, such as independent energy supply.

Code (Language): Communication should employ clear, understandable, and transparent language. The information should be formulated in a way that is generally comprehensible.

Role 5

Individuals belonging to Role 5 (Cluster 5) are hardly active in local groups and have a small communication circle. They reveal little or no activity intensity in the topic of municipal energy transition. These individuals prefer to obtain information via the digital media platforms of the municipality.

Contact (Channel): Individuals in this role have contact with up to 10 other people.

Context (Embedded): Communication primarily takes place within the private sphere or within a smaller circle.

Message (Content): Individuals in this role desire content that delves into details while also providing a general overview of the topic.

Code (Language): The content should be formulated in a way that is generally understandable.

Role 6

People who belong to Role 6 (Cluster 6) have a high level of influence (power) due to their position (e.g., teacher at a local school, kindergarten teacher, etc.), which grants them significant influence within the community or over community members. However, they show little or no activity intensity on the topic of municipal energy transition. These individuals prefer to obtain information through the municipal bulletin or posters/notice boards.

Contact (Channel): Individuals in this role have contact with up to 10 other people.

Context (Embedded): Communication primarily takes place within the private sphere or within a smaller circle.

Message (Content): No statements can be made

Code (Language): No statements can be made

Adaption of the PI-Matrix bubble size

The PI-Matrix so far only reflects the proportion of individual roles among the survey participants. A total of around 300 people took part in the three surveys, which corresponds to a share of 3% based on the population of the reference municipality in 2017 (9,134 inhabitants in 2017, minus 1,776 individuals under the age of 16 who were not eligible to participate in the survey) (Bayrisches Landesamt für Statistik 2019). For subsequent implementation measures, however, it seems beneficial to show the actual proportion of people within the municipal population represented by the respective cluster. The bubble sizes in the PI-Matrix must therefore be adjusted. For this purpose, assumptions have to be made and the social structure of the citizens in the municipality has to be analyzed in comparison to the survey.

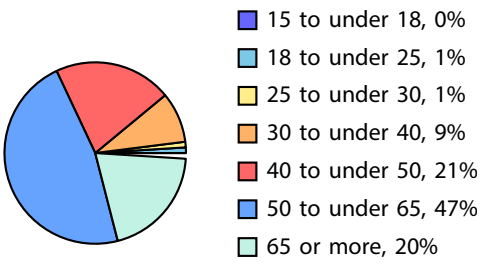

Fig. 12 Age distribution of survey participants

It is noticeable that significantly more men than women participated in the survey (male participants: 63 %). According to the survey conducted by the Bavarian State Office for Statistics, the proportion of male citizens is 49 % (2017) (Bayrisches Landesamt für Statistik 2019). Therefore, female participants in the survey are underrepresented. Furthermore, the homeownership rate among the survey participants averages 80 %, while the homeownership rate in the reference municipality is 54 % (2011) (Landtag 2019). Additionally, the average age of survey participants is 54.5 years, while the Integrated Sustainable Urban Development Concept (ISEK) of the municipality indicates an average age of 42.5 years (Bock 2019). This can also be observed from the diagrams in Figs. 13 and 12. It is evident that the proportion of individuals aged 50 to under 65 is significantly higher at 47 % compared to the actual proportion. Furthermore, the under-30 age group is underrepresented in the survey, accounting for only 2 %.

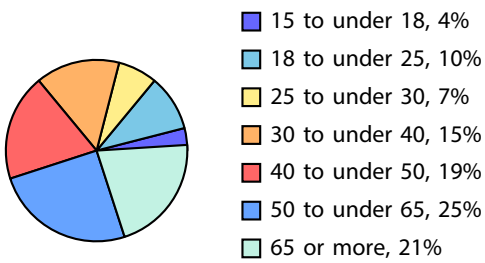

Fig. 13 Age distribution of residents in the reference community Höhenkirchen-Siegertsbrunn according to (Bayrisches Landesamt für Statistik 2019)

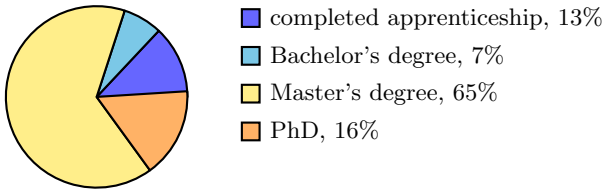

Fig. 14 Highest educational attainment of survey participants

Analyzing the average educational level of each cluster, it can be observed that a large majority of respondents have an academic degree. Compared to the data from the Federal Statistical Office on educational attainment in Bavaria (Bundesamt 2019), a significantly different picture emerges here as well, illustrated in the charts in Figs. 14 and 15. It is evident that the feedback shows a clear overrepresentation of Master's and diploma degrees.

Due to the deviations between the survey results and the actual situation in the community, the bubble sizes in the PI-Matrix should be adjusted to reflect a more realistic representation of the proportion of each role among the community members. To make these adjustments, various assumptions need to be made. Based on the survey feedback, it can be assumed that property owners are more involved in the topic of municipal energy transition compared to individuals who are renting. This seems plausible, as property owners have the opportunity to implement measures such as photovoltaics, solar thermal energy, or the installation of a heat pump themselves. Therefore, renters are more likely to be positioned in the left area of the PI-Matrix. Based on this assumption, the proportions of individuals for the left and right sides of the PI-Matrix were determined. Assumptions were also made for the proportions of individuals in the upper two quadrants of the PI-Matrix. The detailed calculations and additional assumptions can be found in Appendix 4. Based on these assumptions, the following adjusted PI-Matrix is obtained in Fig. 16.

The PI-Matrix illustrates that most of the municipality's inhabitants are likely to be found in the lower left quadrant. According to the classical assignment of this quadrant, the individuals represented by it should be informed to maintain a positive relationship, but it does not require excessive time investment. People in Roles 3 and 4, who fill the bottom right

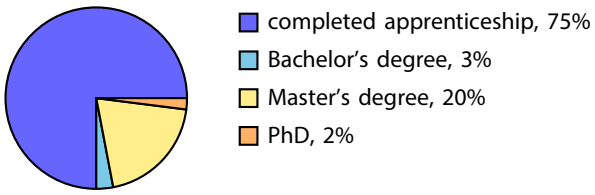

Fig. 15 Highest educational attainment (2019) according to (Bundesamt 2019)

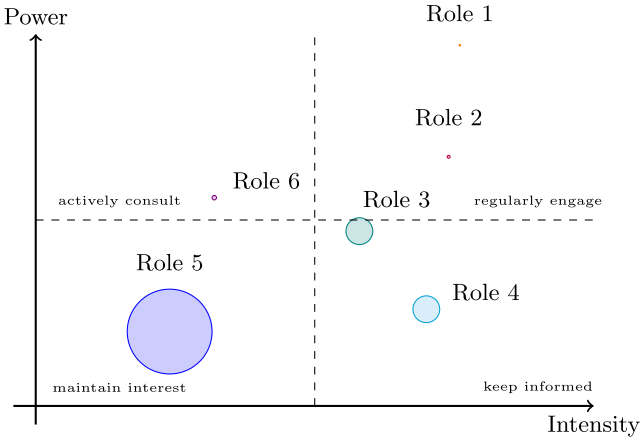

Fig. 16 Adjusted PI-Matrix (based on assumptions; diameter corresponds to the proportion of people within the municipal population represented by the respective cluster)

quadrant of the PI-Matrix and make up the second-largest proportion of citizens, should be actively kept up to date. Otherwise, this group risks being left behind and the potential associated with it will not be sufficiently utilized. As they represent a large part of the population, they can be very useful in supporting and participating in community decisions or actions. The people in Roles 1 and 2 represent only a small proportion of the municipality's inhabitants. From a communication perspective, however, they are the most important group due to their high level of influence and intensity. These stakeholders need to be regularly involved and should also be able to contribute themselves. Their support and cooperation can significantly influence and support the community in decision-making processes. Despite the low intensity with which individuals in Role 6 engage with the topic of municipal energy transition, they should be informed and kept satisfied. When decisions are made, individuals in this role can have a significant impact through their influence. For each role, it is important to consider the individual habits and needs described in the role model when selecting appropriate communication tools and deriving communication strategies.

Role definition concludes the process of identifying and characterizing communication roles.

Discussion and outlook

The paper on hand proposes a transactional communication approach, in which communication is understood as a dynamic and interactive process that is oriented toward preference-specific roles. From a methodological point of view, the approach is based on the transfer of Jakobson's communication model from linguistics and Freeman's matrix from stakeholder management to the context of municipal energy transition within

a newly proposed reference process. Thereby, for the first time, a contextualization-based instead of a predominantly functionally oriented form of energy transition communication has been designed and evaluated. Applying Jakobson's model, roles are described primarily in terms of their communicative aspects rather than their functional meaning. The new approach is demonstrated using the example of the municipality Höhenkirchen-Siegertsbrunn in the south of Germany. Results are used to demonstrate a role-specific communication strategy derivation and serve to demonstrate or clarify the new approach that is not per se limited to the area of municipal energy transition communication. The basic idea is that communication roles form the basis for the definition of a communication strategy allowing the subsequent derivation of role-specific actions and instruments may also be transferred to a wide variety of other applications.

The new transactional communication approach to identify and characterize communication roles is demonstrated by an example in the municipal energy transition field along with a proposed process on an exemplary base. It follows a two-stage procedure: First, the actors involved are carefully identified by cluster analysis according to features derived from Jakobson's communication model plus an individual characterization of the aspects of a PI-Matrix. In the second stage, the identified actor clusters are characterized by Jakobson's communication model features and prioritized to provide the basis for formulating a tailored communication strategy for each role. The transfer of Roman Jakobson's communication model to the area of the municipal energy transition enables a differentiated understanding of communication habits and needs in this context. Instead of defining roles exclusively through functional attributes, the study emphasizes the communicative aspect and thus highlights the decisive role of communication in shaping the energy transition. In addition to demonstrating the new methodological approach itself, its exemplary implementation has already provided an initial outlook on the practical implications of its consistent application: The cost-benefit ratio is always present from the perspective of the municipal administration when it comes to decisions on communication measures. Therefore, measures for the lower left quadrant would have been reduced to zero in the past. In contrast to this, the new approach based on the Freeman matrix created an awareness within the local government of the need to maintain an active communication offer to these community members (the most represented in terms of population according to Fig. 16) even with a minimum of their own (current) participation intensity. Nevertheless, the consequences of using the Freeman matrix should be elaborated and considered in more detail in future work.

In the presented process of identifying the existing communication roles in the municipality, an iterative survey concept plays a decisive role in identifying the roles and their communication habits and needs up to a required quality level. The process and its proposed implementation form inherently provide the opportunity to carry out a quality check using the Power-Intensity-Matrix. Specifically, the process was only defined as complete when a role could be identified in each of the four quadrants of the PI-Matrix. The implementation example demonstrates both the necessity and the quality gain achieved through this possibility of an active quality check. Without the quality check, Roles 5 and 6 would not have been identified. By iteratively conducting several surveys, six different roles were identified and described in detail. The results enable the creation of a communication strategy in line with the roles.

By iterative application of the survey, evaluation, and quality check loop, it was possible to assign a role to each quadrat of the PI-Matrix and to describe their communication habits and needs. Other forms of survey, e.g., as part of a citizens' assembly, could also be considered in order to determine communication habits and needs in other municipalities. In addition, people with high decision-making power in the municipality should be approached directly and asked to participate in a survey. The complete coverage of all important stakeholder groups involved in a topic still seems to be an issue that has not yet been sufficiently addressed. The combination of Roman Jakobson's communication model with the PI-Matrix, however, appears as a highly promising approach. It reveals a high potential for role-based communication far beyond the demonstrated example in the municipal energy transition communication area. The interdisciplinary and innovative approach presented has proven to be a useful contribution to the definition of a municipal communication strategy in the field of energy transition. It also adds scientific value to the application of a linguistic model to scholarly fields beyond. Although the overall success of such an approach naturally depends on response rates of surveys, the model shows that specifically, quadrants with low interest and low power are the most challenging to address while often being the greatest part of the given municipality. In the future, a more comprehensive situational analysis of communication habits might enhance the accuracy of communication roles and thus the impact of the communication strategy. A further interesting field of application of this interdisciplinary model might also be other topics such as mobility concepts on the municipal level.

Appendix A: Specified codes for qualitative analysis

Table 1 Specified codes

Category	Code	Description
Lack of information by the municipality (Insufficient information/ Intransparent communication)	**C1**	Responses that pertain to missing information regarding a specific plan or the current status of energy infrastructure development in the community. This includes responses that demand clear communication regarding the status quo and timeline set by the community. Additionally, there has been a expressed desire for transparency regarding ongoing and planned projects
Advocacy for wind power	**C2**	Answers that explicitly support wind power
Mobility	**C3**	Responses that address topics related to mobility and transportation infrastructure. This includes issues such as expanding charging infrastructure, improving public transportation (ÖPNV), and enhancing bicycle paths
Advocacy for photovoltaics/solar thermal energy	**C4**	Answers that explicitly advocate photovoltaics or solar thermal energy
Advocacy for alternative heat sources	**C5**	Answers that deal with the energy transition in the heating sector. This includes geothermal energy and the expansion of a local/district heating network
Lack of information on already carried out planning/ measurements	**C6**	Responses criticizing that planning or measurements (e.g., geothermal or wind power) have already taken place, but now no more information follows on how to proceed
Dissatisfaction with current commitment to advancing the energy transition (need for action by the municipality)	**C7**	Responses criticizing that the municipality shows too little commitment/motivation to push something forward or lack of time planning
Opportunities to participate	**C8**	Desire for participation opportunities or willingness to participate in the expansion of renewable energies
Rejection of nuclear power	**C9**	Answers that reject support nuclear power
Advocacy of nuclear power	**C10**	Answers that explicitly support nuclear power
General dissatisfaction with the current situation	**C11**	Dissatisfaction with the energy transition at federal level, etc
Satisfaction with contact to the municipality	**C12**	Responses that rate the contact with the municipality positively
Verbalization/ Language	**C13**	Code (language) according to Jakobson: how is communication carried out, what language is used, are there wishes/ expressions of the citizens in this regard?

Appendix B: Calculation of the weighted arithmetic means for the Power-Coefficient

Table 2 Groups of the reference municipality (AK is the German abbreviation for working group)

High-Power Group	Low-Power Group
Municipal Council	Parents' Council
AK Work & Economy	Local Sports Association
AK Energy & Environment	Music Association
AK Youth	Parishes
AK Child & Family	Fire brigade
AK Local development & Mobility	Other
AK Seniors	
AK Cohabitation	

The Power coefficient is calculated using weighted arithmetic means, distinguishing between "Group" Power ($\bar{x}^g$) and "Connect" Power ($\bar{x}^c$) according

$$\bar{x}^{g,c} = \frac{\sum_{i=1}^{n} w_{i,g,c} \cdot x_i}{\sum_{i=1}^{n} w_{i,g,c}}, \quad (1)$$

where x_i is the share of the persons of the respective role in the groups or the communication circles, $w^{i,g,c}$ ist the weight, i is the index of the categories and n is the maximum index of the categories.

The "Group" and "Connect" powers are weighted differently:

Table 3 Weighting for the formation of "Group Power"

	High-Power Group	Low-Power Group	Other
Index i	1	2	3
Weight $w^{i,g}$	0.8	0.1	0.1

Groups with high power were assigned an increased weighting, as belonging to these groups is associated with a more influential position.

Table 4 Weighting for the formation of "Connect Power"

	bis 10	11 bis 30	31 bis 100	über 100
Index i	1	2	3	4
Weight $w^{i,c}$	0	0.3	0.3	0.4

Individuals who communicate with more people in the community have greater influence due to their larger communication circle and stronger networking. The "Power" coefficient p is then derived from the sum of the weighted arithmetic means according

$$p = \bar{x}^g + \bar{x}^c. \quad (2)$$

Appendix C: Communication roles based on Roman Jakobson

Table 5 Communication habits and needs as well as characteristics of the identified roles (KG: communication habit, KB: communication need)

Role	Role characteristics	Role definition		Communication model according to Roman Jakobson			
		Notable characteristics	Interaction	Code (Language)	Context (Embedded)	Contact (Channel)	Message (Content)
Role 1	Age: 56.73, Sex: male, Education level: Master, Living arrangements: Owner	AKs and local council (Group Power: 4.7; Connect Power: 5.1)	Decisively active in municipal life	KB: (technical), provable data, calculations, studies	KG: Exchange at meetings, meetings and other official events, exchange at larger events	KG: contact with up to 30 people, use of AKs, GR meetings, info events KG: Use of municipal newsletter, information events, AKs	KB: overarching concepts municipality on energy transition, concrete decisions, content in depth in detail
Role 2	Age: 52.86, Gender: parity, Education level: bachelor, Living arrangements: Owner	large communication circle (Group Power: 2.0; Connect Power: 4.7)	Communicatively active in municipal life	KB: clear, transparent language, information both generally understandable, and technical information	KG: Exchange in the private environment, but also at larger events	KG: Contact with up to 30 or occasionally up to 100 people KG: Exchange in associations or at info events KG: Use of municipal newsletter, website, information events	KB: Content in depth and rich in detail KB: Information on measurements carried out in municipality, status on concrete measures
Role 3	Age: 54.05, Gender: parity, Education level: bachelor, Living arrangements: Owner	AKs and associations (Group Power: 2.4; Connect Power: 2.4)	Communication in the familiar environment, anonymous	KB: clear, transparent language	KG: Communication with family and acquaintances KG: no participation in info events	KG: Contact with up to 10 persons and occasionally up to 100 persons KG: private contacts, anonymous "channels" (surveys, etc.) KG: Use of municipal newsletter, website	KB: Status on concrete measures (wind, sun, heat), solutions to concrete problems
Role 4	Age: 54.8, Sex: male, Education level: bachelor, Living arrangements: Owner	AKs and associations (Group Power: 2.6; Connect Power: 0)	Participates in the public discourse	KB: clear, transparent language KB: Information mainly generally understandable	KG: Exchange in the private environment KG: Exchange at information events	KG: Contact with up to 10 people KG: Use of information events and private contacts KG: Use of municipal newsletter, information events, website	KB: Status on concrete measures (wind, sun, heat), Info on the concept KB: Content should be rich in detail in depth

Table 5 continued

Role	Role characteristics	Role definition		Communication model according to Roman Jakobson			
		Notable characteristics	Interaction	Code (Language)	Context (Embedded)	Contact (Channel)	Message (Content)
Role 5		Hardly in municipal groups (Group Power: 2.0; Connect Power: 0)	Little or no attention is paid to the municipal energy transition	KB: Information generally understandable	KB: Exchange rather in private environment or smaller groups	KG: Information preferably in personal exchange and digital media of the municipality	KB: Provide in-depth content but also give a broad overview of the topic
Role 6	Age: 44, Sex: female, Education level: bachelor, Living arrangements: parity owners	Power qua office (teacher, head of sports club, etc) (Group Power: 4.8, Connect Power:0.8)	Little or no attention is paid to the municipal energy transition	KB: no statements can be made	KB: Exchange rather in private environment or smaller groups	KG: Information preferably in via municipal newsletter or posters/ notices	KB: no statements can be made

Appendix D: Calculations for adjusting the PI-Matrix

Table 6 Assumptions and calculation of the number of citizens with and without interest in the topic of municipal energy transition

Ownership situation Ownership rate reference municipality (2011)	54 %	Remarks Source: Landtag (2019)
Private households Reference municipality (2011)	4192	Source: Bayrisches Landesamt für Statistik (2019)
of which in ownership	2264	Source: Bayrisches Landesamt für Statistik (2019)
Inhabitants reference municipality (2011)	9856	Source: Bayrisches Landesamt für Statistik (2019)
Average number of persons per household	2.35	Calculation of average number of persons per household (number of inhabitants divided by number of households)
Persons in ownership	5322	Number of households Ownership * average number of persons per household
Households and inhabitants increased (compared to 2011)		
Private households HöSi (2017)	4642	Source: Bayrisches Landesamt für Statistik (2019)
of which in ownership	2507	
Inhabitants reference municipality (2011)	9134	All citizens who are over 15 years of age (as other people did not participate in the survey) Source: Bayrisches Landesamt für Statistik (2019)
Persons in ownership	5894	Number of households Ownership * average number of persons per household
Persons in rented property	3240	Number of households renting property * average number of persons per household
Assumption: The majority of tenants are less interested in the topic municipal energy transition because they can implement fewer measures themselves.		Assumption supported by: survey results: Survey participants to 80 % in ownership and study on Energy transition from the perspective of the population: tenancy is relevant barrier to investment in renewable energy supply systems Setton (2020)
Interest	0.2	Assumption: only 1/5 of the tenants are interested in the topic municipal energy transition
No Interest	0.8	Assumption: 4/5 of the tenants are not interested in the topic municipal energy transition

Table 6 continued

Ownership situation Ownership rate reference municipality (2011)	54 %	Remarks Source: Landtag (2019)
Number of interested tenants	648	Number of persons in the rented property * 0.2
Number of non-interested tenants	2592	Number of persons in the rented property * 0.8
Assumption: among the owners, half are interested in the topic municipal energy transition, the other half have no interest.		Assumption: Home ownership rate significantly higher among people aged 65 and over Sagner and Voigtländer (2019). Since the topic of municipal energy transition is not yet as present among older persons as it is among the younger generations, only half of the owners are interested
Interest	0.5	Assumption: 50 % of the owners are interested in the topic municipal energy transition
kein Interesse	0.5	Assumption: 50 % of the owners are not interested in the topic municipal energy transition
Number of interested owners	2947	Number of persons in ownership * 0.5
Number of non-interested owners	2947	Number of persons in ownership * 0.5
Number of persons		
Interest in energy transition	3595	Number of interested owners + number of interested tenants
No interest in energy transition	5539	Number of non-interested owners + number of non-interested tenants

Table 7 Assumed proportions of persons per role based on the assumptions from Table 6

	Description	Assumed Number of persons	Share of persons	Remarks
Role 1	Municipal council members, AK members	100	1 %	The municipal council has about 25 members, there are 7 working groups in the municipality. On average, around 15 people will belong to the working groups. This means that about 130 people would belong to Role 1. Since presumably not all persons are interested in the topic municipal energy transition or are concerned with it, 100 persons were assumed
Role 2	Strong communicators, networked people in the community	200	2 %	In Role 2 there are people who are strongly networked in the community. These include teachers, club leaders, priests, kindergarten staff, etc. If one estimates the number of people who can be assigned to one of these offices, one obtains a total number of about 400–500 people. Since the majority of the persons are presumably less interested in the topic of municipal energy transition, 200 persons were assumed for Role 2
Role 3	high level of education, mainly owners	1647	18 %	Subtracting the number of people with interest from the 300 people (sum of Roles 1 and 2) and dividing by two gives the number of people for Roles 3 and 4. It is assumed that these two roles have an equal share of interest.
Rolle 4	high level of education, mainly owners	1647	18 %	
Role 5	low Power, low Intensity	5239	57 %	If the 300 people from Role 3 are subtracted from the number of people with a rather low interest, the number of people for Role 5 is obtained
Role 6	high Power, low Intensity	300	3 %	Role 3, like Role 2, includes people who are strongly networked or who have influence in the community through their office, as in Role 1. Therefore, 300 people were accepted for this role

Table 8 Power and intensity components of the respective roles (calculated and assumed values)

	Intensity	Power	Share of persons	Remarks
Role 1	3.8	9.2	1 %	Calculated values for Power and Intensity
Role 2	3.7	5.7	2 %	Calculated values for Power and Intensity
Role 3	2.9	3.8	18 %	Calculated values for Power and Intensity
Role 4	3.5	1.7	18 %	Calculated values for Power and Intensity
Role 5	1.3	2.5	57 %	Assumed values for Power and Intensity (Middle of the quadrant)
Role 6	1.3	7.5	3 %	Assumed values for Power and Intensity (Middle of the quadrant)

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Data availability All data included in this study are available upon request by contact with the corresponding author.

Declarations

Ethics approval and consent to participate Informed consent was obtained from all participants in the study. Participants were informed in detail about the aims of the study, the procedures, the potential risks, and their right to withdraw at any stage. To protect the confidentiality of participants, all data collected was anonymized and stored securely. Identifying information was removed and only the research team had access to the anonymized data.

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