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Participation as a Key Aspect for Establishing Wastewater as a Source of Renewable Energy

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Abstract: Climate change is one of the great challenges of our times. In the search for renewable energy sources, wastewater has received increasing attention in recent years. This is due to the fact that it can serve as a source of electricity and heat supply, as well as a substitute for natural gas. The current literature frequently addresses more technical aspects from a mostly sanitary engineering-orientated perspective. Social aspects related to the energetic use of wastewater still appear to be underrepresented. To support the closure of existing knowledge gaps and to contribute to the development in this field, this article addresses two issues: it defines and characterises key stakeholder groups required to catalyse broader energetic usage of wastewater, and it proposes a participatory approach to support successfully establishing wastewater as a commonly accepted source of renewable energy to best support the ongoing energy transition.

Keywords: digester gas; wastewater heat recovery; external supply; stakeholder involvement; knowledge-building; joint solution; ownership

1. Introduction

Climate change catalysed by the abundant use of fossil energy sources is one of the grand challenges of our times. United Nations address this issue in their 2030 Agenda for Sustainable Development [1], where goal 7 concerns the access to affordable, reliable, sustainable, and modern energy, and goal 13 emphasises the need for urgent actions to combat climate change and its impacts. On the European level, the Energy Strategy and Energy Union initiative of the European Commission [2] comprises several measures towards secure, competitive, and sustainable energy. To meet the requirements of climate protection the reduction of greenhouse gas emissions is imperative. Consequently, the exploitation of currently untapped and climate-friendly resources is becoming increasingly important. In this context, wastewater has been attracting more and more attention in recent years.

From an energetic point of view, wastewater is interesting for three different purposes: (1) electricity supply, (2) heat (and cold) supply, and (3) biogas supply. The related technologies for energy generation are summarised in Figure 1.

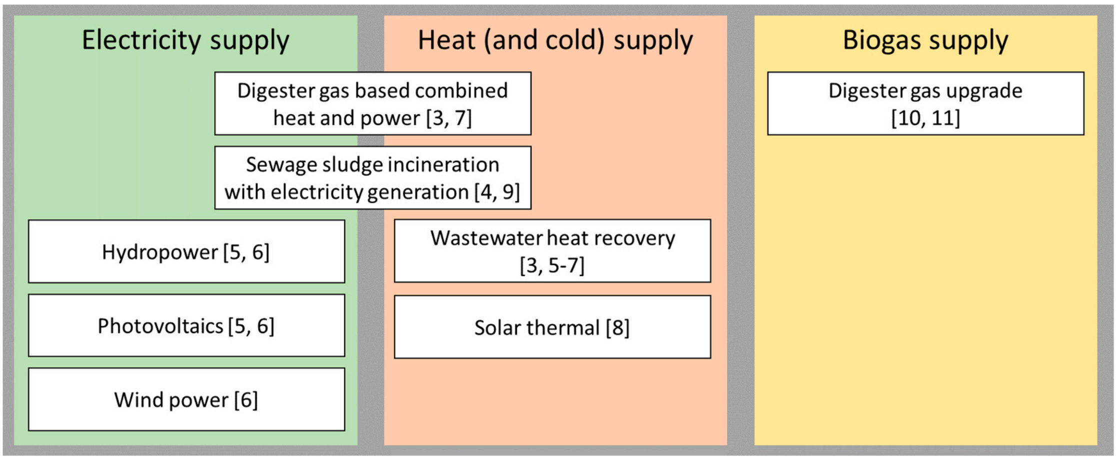

Figure 1. Wastewater-based supply of electricity, thermal energy, and biogas [3–11].

For decades, the available energy has particularly been used for covering the internal demand of the wastewater infrastructure. However, Novak et al. [3] postulate that, due to increased energy generation and operational optimisation, wastewater treatment plants (WWTPs) can achieve energetic self-sufficiency. Kretschmer et al. [12] show that wastewater treatment plants can even be energy positive, whereby thermal energy, in particular, can exceed internal demand many times over. Consequently, the international literature covers a variety of topics concerning wastewater-based energy supply beyond the classic concept of exclusive internal use at wastewater facilities. Kahraman and Celebi [13] experimentally model the performance of heat pumps applied for wastewater heat recovery. Cipolla and Maglionico [14] investigate wastewater flow and temperature patterns as a basis for in-sewer wastewater heat recovery applications. Dürrenmatt and Wanner [15], Abdel-Aal et al. [16], and Elias-Maxil et al. [17] introduce different mathematical models for predicting the impact of wastewater heat extraction on the inflow temperature at wastewater treatment plants. Sitzenfrei et al. [18] apply one of these models to investigate the interactions of decentralised (in-house) and centralised (in-sewer) wastewater heat recovery. Abdel-Aal et al. [19] use another model to estimate the potential for multi-location in-sewer heat recovery at a city scale level. Kretschmer et al. [20] provide a methodological approach for evaluating the suitability of in-sewer heat recovery sites considering both an energetic and a wastewater perspective. Spriet and Hendrick [21] present a techno-economic feasibility study using wastewater for individual residence heating. Kordana [22] describes a SWOT analysis of heat recovery applications in raw and treated wastewater. Neugebauer et al. [23] estimated the thermal energy supply potentials of Austrian wastewater treatment plants considering their particular treatment capacity and spatial context. Kollmann et al. [24] describe a procedure to assess the integration of a wastewater treatment plant into local energy supply concepts considering a spatial analysis, different energy flows, and the ecologic footprint of different supply scenarios. Finally, Schopf et al. [25] investigate potential energetic and economic benefits for wastewater treatment systems associated with digester gas and sewage sludge utilisation.

The existing literature certainly provides an excellent insight into a multitude of aspects concerning energetic use of wastewater. However, it seems to primarily concern more technically orientated topics from a mostly sanitary engineering or energy planning point of view, while social aspects appear to play only a subordinate role. This is rather unexpected, as stakeholder participation has already been addressed in different water and environment related regulations. The Arhus convention [26] provides the right to public participation in environmental decision-making. The European Water Frame Directive [27] also highlights the importance of informing, consulting, and including the public in water policy. In this context, Krywkow [28] analogously postulates that not the question whether stakeholder participation might be useful, but how to accomplish it in an efficient and effective manner, should be put in the centre.

To contribute to the closure of existing knowledge gaps and to foster international development and discussion in the field, this article aims at drafting strategies on how to promote the wide application of wastewater energy: (1) it defines and characterises key stakeholder groups required to catalyse broader energetic usage of wastewater, and (2) it proposes a participatory approach to support successfully establishing wastewater as a commonly accepted source of renewable energy, considering how to organise knowledge transfer and how to create ownership within the stakeholder groups for the implementation of wastewater energy generation. Although the research work is based on Austrian national circumstances, it is transferable to other countries that are comparable with respect to wastewater infrastructure, energy supply systems, and governance structures. The "case study Austria" can serve as a template for practitioners and decision-makers to elaborate adapted approaches considering their specific national and local varieties.

2. Materials and Methods

In order to accomplish this work, two methodological steps are needed, that are based on the theory framework presented below: (1) an analysis of key stakeholder groups concerned by the energetic use of wastewater, and (2) an analysis of a participatory process regarding the integration of a WWTP into local energy supply concepts. Both studies took place in the Austrian federal province of Upper Austria. The materials necessary are included in the methods description. The interpretation of the results of both analyses provide the basis for designing the approach for a successful participation, in order to establish wastewater as a renewable energy source.

2.1. Theory Framework

Participation in this article is perceived as taking part in collective decisions. According to Renn [29], participation encompasses all forms of influence on the design of collectively binding agreements by persons and organisations that are not routinely entrusted with these tasks. The understanding of participation in the context of energy system transformation can, therefore, be discussed on the basis of the questions of who is involved in the respective planning process, what role the participants play, and what results are expected from the participatory approach [30]. Regarding the participation in a planning process, it can be, in principle, distinguished between the involvement of the general public, on the one hand, and the participation of stakeholders on the other hand. The former aims to provide all interest groups with the opportunity to express their concerns into a planning process [31], whereas with stakeholder participation, the focus will be on ensuring that any relevant actors are represented in the planning process [32].

According to the degree of involvement in a planning process, different levels of participation can be distinguished [33], which are often represented in stepladders. With the "ladder of citizen participation", Arnstein [34] distinguishes eight rungs in which a differentiation is made according to aspects of power. Pretty [35] differentiates between seven types of manipulative and passive participation up to self-mobilisation. An alternative metaphor to the hierarchical step representation is the "wheel of participation" [36]. Selle [37] distinguishes four layers or stages of actors' participation, each layer supplementing the previous, but not replacing and not in the sense of an ascending line that one understanding of participation can be interpreted as better than the other would be. Other typologies solely differentiate according to the kind of information flows [38], focus on a theoretical basis with the differentiation into normative and/or pragmatic participation [39,40], or differentiate according to the goals that are achieved with participation, such as Okali et al. [41], who differentiate between "research-oriented" and "development-oriented". Tippett et al. [42] define, in the context of spatial and environmental planning, five approaches to establish meaningful participation ("inform", "design", "consult", "deliver", and "monitor").

Planning processes can be perceived as societal learning processes, where learning comprises the identification and analysis of complex problems, as well as planning variants of objectives and measures for future development that have to be agreed upon on the basis of scientifically provable facts, on the one hand, and the negotiation of values and attitudes present in society, on the other hand [43]. Therefore, learning can be perceived as an important means to support sustainable development [44]. The sustainable strategy or learning requires interdisciplinary principles that can lead to the development of personal competencies and the generation of ownership [45]. Participation processes for the implementation of the energy system transformation at the local level can also be seen as learning processes for all participants. Through participation, “socially robust knowledge” [46–48] can be generated as an essential basis for further action in the sense of the guiding principle of sustainable development. In contrast to linear learning paths, which define learning as a sequence of knowledge, understanding, and application [44,49], the concept of learning loops [50,51] drafts a more complex and cyclic approach to learning. One of the most widespread models is that of Argyris [52,53], which distinguishes learning into “single”, “double”, and “triple-loops”. In this concept, visions, actions, and consequences are related to each other, whereby learning about possible consequences can trigger two types of cognitive processes: (1) Single-loop learning means learning on the level of facts, where the identification of unwanted consequences leads to an adaptation of the actions without questioning the underlying values. (2) Double-loop learning enables a learning process on the value level, which includes a reflection of the underlying values and assumptions, especially if no improvements are achieved after the adaptation of measures. Double-loop learning is especially important for the creation of ownership of concepts, methods, and outcomes of planning processes [54]. (3) Triple-loop learning can be understood in the sense of “learning to learn” as a process for generating and maintaining organisational learning ability [55], with which new methods and processes are developed to achieve double-loop learning [53,56].

Finally, participation can be seen as a means of securing and increasing acceptance, and as an opportunity to open up decision-making processes to stakeholders in order to support the implementation of policies or plans like the use of wastewater energy. The term “acceptance” describes the positive evaluation of an object of acceptance by a subject of acceptance [57,58], and is a precondition for successful implementation strategies that have to include more than acceptance, such as the creation of ownership by single- and double-loop learning. Furthermore, this paper provides a framework for triple-loop learning—a reflection on how learning for the implementation of wastewater energy might work by stakeholder integration and participatory processes that aim at creating ownership, so that the relevant stakeholders “own” and “want” the concept of wastewater energy use as a cornerstone for successful implementation. Therefore, the paper and the methods address two main issues: (1) the identification and analysis of stakeholders (answering the question: who should learn?); and (2) the participatory process itself (or: how should this learning take place?).

2.2. Stakeholder Analysis

The stakeholder analysis was carried out to collect background information for promoting energetic use of wastewater in Austria. The analysis pursued three objectives: (1) identifying key stakeholder groups; (2) gathering the current level of awareness and acceptance of key stakeholder groups concerning energetic use of wastewater; (3) defining appropriate means of information transfer (information paths) to close related knowledge gaps. Table 1 provides an overview on the data collected.

To properly address the objectives presented above, stakeholder-related information was collected from different sources: preliminary literature analysis and subsequent interviews for pre-identification of potential stakeholders, more detailed stakeholder interviews using different methods (face-to-face and telephone interviews, emails). Surveys were either semi-structured and based on an interview guide, or fully-structured and based on a questionnaire. For each stakeholder group, customised survey documents were developed. All interviews had a thematic focus; consequently, transcription was not verbatim, but limited to a summary of key quotations (according to Miller quoted in Tracy [59]). The content analysis, related to the results presented in this article, is based on a deductive approach (according to Mayering [60]), the basic structure of the analysis and the definition of main categories are given by the abovementioned three objectives. All analyses described had a quantitative focus, and were either carried out manually or were computer-aided using MAXQDA and Microsoft Excel. The related results are presented by means of descriptive statistics.

Table 1. Stakeholder analysis data—aim of survey, interview partners, applied methods, sample sizes, and response rates.

Key Aim of Survey (Interview)	Interview Partner (Stakeholder Group)	Interview Method	Sample Size	Response Rate
Identification of key stakeholder groups Information paths (partly)	Regional government—Surface water management division	Face-to-face (semi-structured)	$n = 2$	100% (10/10) *
	Regional government—Energy planning division		$n = 1$	
	University—Institute of sanitary engineering		$n = 1$	
	Biomass association		$n = 2$	
	Energy supply company		$n = 1$	
	National funding agency	Telephone (semi-structured)	$n = 2$	
	Association of climate and energy model regions		$n = 1$	
	Network for local climate protection		$n = 1$	
	Regional energy saving association	Email questionnaire	$n = 1$	
	Housing association		$n = 1$	
Awareness and acceptance Information paths (partly)	Wastewater utilities (wastewater association)	Telephone (semi-structured)	$n = 63$	79% (50/63)
	Energy suppliers—large utilities		$n = 3$	100% (3/3)
	Energy suppliers—contractors		$n = 13$	69% (9/13)
	Municipalities (urban settlements of more than 3000 inhabitants)	Email questionnaire	$n = 112$	26% (29/112)
	Energy consumers (major housing cooperatives)		$n = 26$	50% (13/26)

* of all 10 addressed stakeholder groups.

The first objective, identification of key stakeholder groups, was based on a preliminary analysis of topic-related literature (pre-identification of potential stakeholder groups addressed in the literature) and subsequent semi-structured face-to-face interviews with experts from different professional fields. The selection of the potential interview partners followed a snowball approach [59]. Per stakeholder group, one interview was carried out involving one or maximum two interview partners. The transcripts were searched manually for the mentioning of stakeholder groups. In the following, expert opinions on stakeholder characteristics as (i) decision-making power, (ii) influence on other stakeholders, and (iii) expected level of knowledge, formed the basis for identifying key stakeholder groups meeting all three characteristics.

Information for the second objective, current awareness (knowledge about different technologies for energy generation from wastewater) and general acceptance of energetic use of wastewater, was collected by semi-structured telephone interviews and fully-structured email questionnaires. Analysis of the transcripts and questionnaires was carried out, computer-aided, applying the main search categories concerning awareness and acceptance. In the current context, awareness of technologies concerns the specific knowledge on four different technologies directly related to the generation of energy from wastewater: (1) energetic use of digester gas, (2) heat recovery from wastewater, (3) sewage sludge utilisation, and (4) hydropower installations. Solar and wind power utilisation was not considered as they do not bear a direct relationship to wastewater. For data collection via telephone and email, the interview partners listed their known technologies (active knowledge). In addition, but only during the telephone interviews, interview partners were further asked about their awareness of technologies not listed at the first stage (passive knowledge).

The third objective of the stakeholder analysis concerns different means of information transfer (information paths). The gathering of related information also took place during the surveys presented in Table 1. The contents of the transcripts were searched for information paths in a manual or computer-aided way. However, this survey objective is considered to be very country-specific. Consequently, this article will not go into related details, and only briefly refers to a few key outcomes of broader validity.

2.3. Participatory Process Analysis

A participatory process carried out according to the principles of action research (AR) [61], in order to demonstrate and assess the possibilities of wastewater energy recovery for an Austrian WWTP located in the federal province of Upper Austria, serves as case study for this work. With the participation process, a "community of practice" (CoP) and "friendly outsider" were involved in "search conferences", in order to investigate the question of whether and in what form the WWTP can play a role as a regional energy cell in a future energy supply and, thus, contribute on the local level to the implementation of the energy system transformation.

The term "community of practice" refers to those local actors who are involved in the participation process. In the case study process, three institutions were represented in the CoP: from the beginning of the process, (a) the wastewater utility itself as decision-maker (represented by the managing director and the operations manager on the operational level and members of the board on the political level), and (b) the municipality where the WWTP is located (represented by the city councillor for spatial planning, building matters, and energy, as well as representatives of the community administration) as stakeholders were involved in the participatory process. With reference to the focal points developed together with the participants in the first workshop, an association of municipalities aiming at the intercommunal setting and development of business locations (represented by members of the management board), in whose decision-making authority the design of a possible regional energy supply for future business locations falls, was included as a representative of possible future heat consumers in the vicinity of the WWTP. In the case study process, the heating and cooling supply for a planned intercommunal business area was examined, among other things. Accordingly, at the time of project processing, no companies had yet been identified as potential energy consumers to be classified as relevant actors and to be involved in the process.

The research team, which develops solutions in a co-generative process together with the CoP, is called "friendly outsider" (FO). In the case study process, the research team consisted of representatives of research organisations and companies who contributed to the AR process with expertise in the fields of sanitary engineering, spatial planning, environmental assessment, process analysis, heat pump technologies, and energy systems.

The meetings of all actors involved in the AR process, including CoP and the FO, are referred to as "search conferences" [61,62]. These aim to initiate a "collective process of inquiry creating learning options for all those participating" [61]. Within the framework of the case study process, a total of six such meetings were held over a period of about fifteen months between the project kick-off with the wastewater utility, and the final workshop with representatives of all actors involved in the process. The "search conferences" each represented cumulative points of interaction with the local stakeholders. Between these meetings, continuous communication with the stakeholders was maintained through telephone or email contacts. The subject of the meetings was the joint definition of the local framework conditions and objectives of the research work, the presentation, discussion, and reflection of interim results from the project work and, in the final project meeting, the presentation of the results of the feasibility study, which was made available to the CoP as a basis for decisions on the possible implementation of measures for the use of wastewater energy.

Additionally, a standardised procedure for participatory planning in urban water management [63] was developed in accordance with a planning process design in the field of integrated spatial and energy planning [64], and already applied in a case study in Upper Austria, in order to clarify the possibilities of energetic use of wastewater on a local level, which involved municipalities, utilities, and wastewater infrastructure. This process design serves as a further basis for the present considerations.

3. Results

3.1. Definition and Characterisation of Key Stakeholder Groups

Pre-identification of relevant stakeholder groups was based on a review of different literature sources (national legal guidelines, etc.) searching for stakeholders potentially concerned by energetic use of wastewater. These results provided the basis for subsequent expert interviews. Finally, the identified stakeholders can be summarised as follows (in alphabetic order): civil engineers, energy consumers, energy suppliers, funding authorities, legislators, municipalities, service providers, universities (research and educational institutions dealing with wastewater management, energy planning, spatial planning), wastewater associations, wastewater utilities, and water authorities. Subsequently, the above-presented expert interviews helped to narrow down the results of the literature review and to define key stakeholder groups based on the (i) individual decision-making power, (ii) influence on other stakeholders, and (iii) expected level of knowledge. Based on the content analysis of the interviews, four key stakeholder groups were finally identified for deeper analysis: (1) wastewater utilities, (2) municipalities, (3) energy suppliers, and (4) energy consumers (represented by major housing cooperatives).

Interviews with these key stakeholder groups were conducted to get better understanding on their current awareness (knowledge) concerning the different technologies and their general acceptance regarding energetic use of wastewater, as well as on their preferred and/or potential sources of information. The main interview results are summarised in Table 2.

Wastewater utilities showed a very high response rate of 79% (see response rates in Table 1). Investigations revealed that their awareness of technologies to generate energy from wastewater can be considered as very high. 98% of the interrogated operators know of the possibility to generate energy from digester gas and sewage sludge. 88% are aware of wastewater heat recovery, and 77% of hydropower utilisation in the wastewater flow. Furthermore, there is great acceptance of energetic use of wastewater in this stakeholder group as 96% of the respondents have a positive opinion on the issue. The most common sources for retrieving information are the Austrian water and waste association (organisation of seminars, publication of technical guidelines etc.), exchange of experiences and knowledge-sharing in the course of local sewer and WWTP neighbourhood meetings, as well as wastewater-related (national) journals.

The response rate of municipalities represented by mayors was only around 26% and, thus, the lowest of all stakeholder groups. Awareness of municipalities can be considered improvable. While at least about 50% of the respondents are aware of utilisation of digester gas and heat recovery from wastewater, the utilisation of sewage sludge and hydropower are more or less unknown today. The general attitude of this stakeholder group, with regard to the energetic use of wastewater, can also be seen as very positive, with an acceptance rate of about 97%. Information to municipalities might be delivered by municipal journals and online platforms, through the national association of municipalities (information events), as well as through several national and regional associations, and networks active in the field of energy management and environmental (climate) protection.

Table 2. Results from interviews with key stakeholder groups.

Stakeholder Group	Awareness of Technologies	Acceptance of Wastewater Based Energy Generation	Potential Information Sources (except for Wastewater Utilities in Random Order) *
Wastewater utilities	Digester gas utilisation: 98% (47 of 48) Wastewater heat recovery: 88% (42 of 48) Sewage sludge incineration: 98% (47 of 48) Hydropower: 77% (37 of 48)	Positive: 96% (44/46) Negative: 4% (2/46) No opinion 0% (0/46)	Austrian Water and Waste Association (94%) (Local) Sewer and WWTP neighbourhoods (55%) (National) wastewater journals (36%) Service providers (28%) Knowledge sharing with other wastewater utilities (17%) Internet (11%) Civil engineers (9%)
Municipalities	Digester gas utilisation: 48% (14 of 29) Wastewater heat recovery: 52% (15 of 29) Sewage sludge incineration: 3% (1 of 29) Hydropower: 14% (4 of 29)	Positive: 97% (28/29) Negative 0%(0/29) No opinion: 3% (1/29)	(National) municipal journals and online portals National association of municipalities National association of climate and energy model regions National network for local climate protection (climate alliance) Regional energy saving association Regional cluster for energy and environmental technology companies
Energy consumers (major housing cooperatives)	Digester gas utilisation: 8% (1 of 13) Wastewater heat recovery: 23% (3 of 13) Little awareness: 23% (3 of 13) No awareness: 46% (6 of 13)	Positive: 38% (5/13) Negative: 15% (2/13) No opinion: 46% (6/13)	(National) energy journals National association of climate and energy model regions National network for local climate protection (climate alliance) Regional energy saving association Regional cluster for energy and environmental technology companies
Energy suppliers – large suppliers	Sufficient knowledge: 67% (2 of 3) Insufficient knowledge: 33% (1 of 3)	Positive: 100% (3/3) Negative: 0% (0/3) No opinion: 0% (0/3)	(National) energy journals National association of climate and energy model regions National network for local climate protection (climate alliance) Regional energy saving association Regional cluster for energy and environmental technology companies
Energy suppliers – contractors	Sufficient knowledge: 11% (1 of 9) Insufficient knowledge: 89% (8 of 9)	Positive: 67% (6/9) Negative: 33% (3/9) No opinion: 0% (0/9)	

* Percentage of information paths only collected for wastewater utilities.

Energy consumers, represented by major housing cooperatives, showed a response rate of 50%. They have the lowest awareness among all investigated stakeholder groups. About 23% of the respondents are aware of heat recovery from wastewater. The other technologies are more or less unknown. Concerning the acceptance of wastewater-based energy supply also, here, a relative majority of around 38% (versus 15%) had a positive attitude to the issue. However, one has to keep in mind that the absolute majority represented by 46% of the respondents still has no opinion on the topic at all. Information transfer (and knowledge-building) might be provided, again, through national and regional associations, and networks active in the field of energy management and environmental (climate) protection. Furthermore, (national) energy journals may serve as an additional information source.

The group of energy suppliers addressed in this article considers two stakeholders: large energy suppliers and contractors (e.g., building service companies). The response rate of the former was 100%, and the latter around 69%. In Table 2, the presentation of the interview results slightly differs from the one chosen for the three other stakeholder groups. Although, initially planned in the same (quantitative) way as those with the other stakeholder groups, the related interviews finally turned out to have a more qualitative character. Many interview partners (especially from the large energy suppliers) appeared very interested in the issue and, thus, several aspects were discussed during the telephone calls. The gathered information concerned, among others, practical aspects and barriers of implementing energetic use of wastewater (in the Austrian context). Related (qualitative) results are summarised in Kretschmer and Ertl [65]. The (quantitative) evaluation concerning the awareness and acceptance can be summarised as follows. The awareness of the different technologies varies significantly. While two thirds of the large energy suppliers seem to have sufficient knowledge concerning the different technologies, this applies only for about 11% of the contractors. Concerning the acceptance, large energy suppliers, as well as contractors, appear very positive. For provision of information, almost the same sources could be identified as for the group of energy consumers. Precisely, this concerns (national) energy journals, as well as related national and regional associations and networks.

3.2. Core Elements and Design of Successful Participation

Figure 2 depicts the proposed procedure for participatory planning, in order to establish wastewater as source of renewable energy in relation to core elements of successful participatory approaches [63,66].

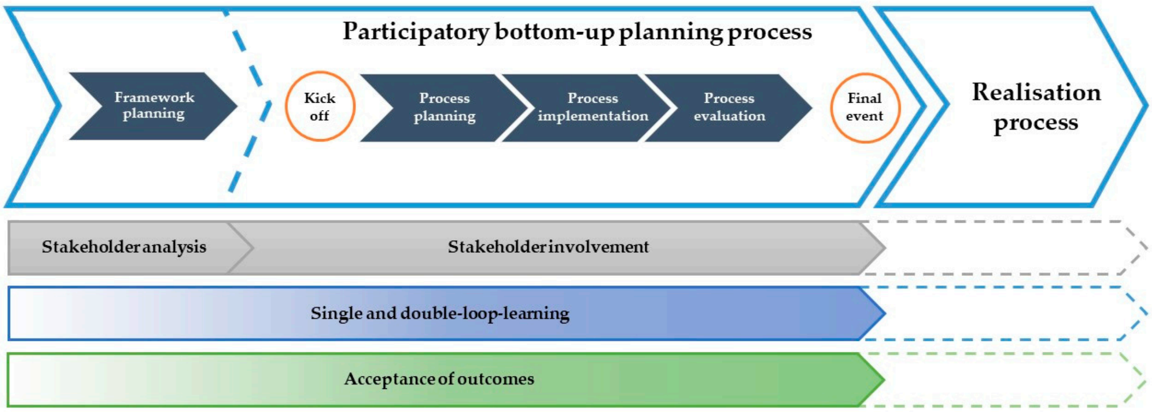

Figure 2. Participation design for establishing wastewater as a renewable energy source (based on [63,66]).

The participatory planning process, as depicted in the first line in Figure 2, can be divided into different phases, starting with a kick-off meeting and ranging up to the final event. The process is initiated with the kick-off event, followed by the planning of the participation process. The process implementation can be carried out in the form of consecutive workshops in which visions and goals are developed and, building on these, implementation measures are developed in a topic-specific discussion. Finally, an evaluation of the process is carried out, and the process is concluded with a final event. Subsequently, the solutions developed in the participatory planning process are implemented in the course of the realisation process.

In principle, the process has to be carried out in two steps with different target groups, in accordance with Stoeglehner et al. [64]: as top-down framework planning and participatory bottom-up planning. The first step involves planners (researchers), and the local and regional decision-making bodies. It serves the purpose of informing decision-makers, and jointly defines the scope of action of decision-makers in step two, the participatory process. The outcomes are not predefined planning variants for a decide-announce-defend model [67,68] of decision-making, but decision-makers can already create ownership, and identify with the potential scope of planning variants as a precondition to be able to negotiate with stakeholders and show positive attitude towards the use of wastewater energy. Still, they can show flexibility in the debate with stakeholders to include their opinions and objectives in the planning outcome. In the second step, the planning process has to be carried out a second time together with the stakeholders, so that they have a chance to bring in their concerns and interests, also develop ownership and, therefore, contribute to the implementation of the selected planning alternative.

The three coloured bars below the process scheme symbolise core elements of successful participation approaches. The establishment of wastewater as a renewable energy source is a task for a large number of actors who need to be involved in respective planning processes. A stakeholder analysis at the beginning of the process identifies the relevant actors for an involvement in the process, which should be maintained over the duration of the entire participation process, ranging from planning to implementation and evaluation.

Participation processes can also be understood as social learning processes in which two types of cognitive processes take place, according to the concept of "learning loops": learning on the factual level "single-loop learning", and learning on the value level "double-loop learning". Successful stakeholder participation goes beyond the mere provision of information for interested parties and those affected, and helps to empower stakeholders to act on the basis of their expanded knowledge [69].

Stakeholder involvement in the planning process ensures that relevant results are achieved for those involved. This contributes to an increase in the acceptance of planned implementation measures, and the motivation to actually implement them. The colour gradient symbolises an increase over the duration of the participation process.

4. Discussion

Interviews of the four key stakeholder groups revealed the following information: (1) Awareness concerning the energetic use of wastewater, as displayed in Figure 3, is rather unequally distributed among the different groups. While wastewater utilities can be considered as already very well informed, the other stakeholder groups still showed several knowledge gaps. The figure does not include energy suppliers as their interview results cannot be compared directly to the other stakeholder groups, due to the more qualitative character of the conducted interviews. (2) General acceptance of energetic use of wastewater, as displayed in Figure 4, appears very high across all the different groups. Although several interview partners (energy consumers group) indicated not having an opinion on the issues (due to lack of knowledge). (3) Potential information sources of the different stakeholders strongly depended on their thematic background and, thus, also differ between the stakeholder groups. While wastewater utilities appear somehow encapsulated in their professional field, the three other groups show certain overlapping information paths in the field of energy.

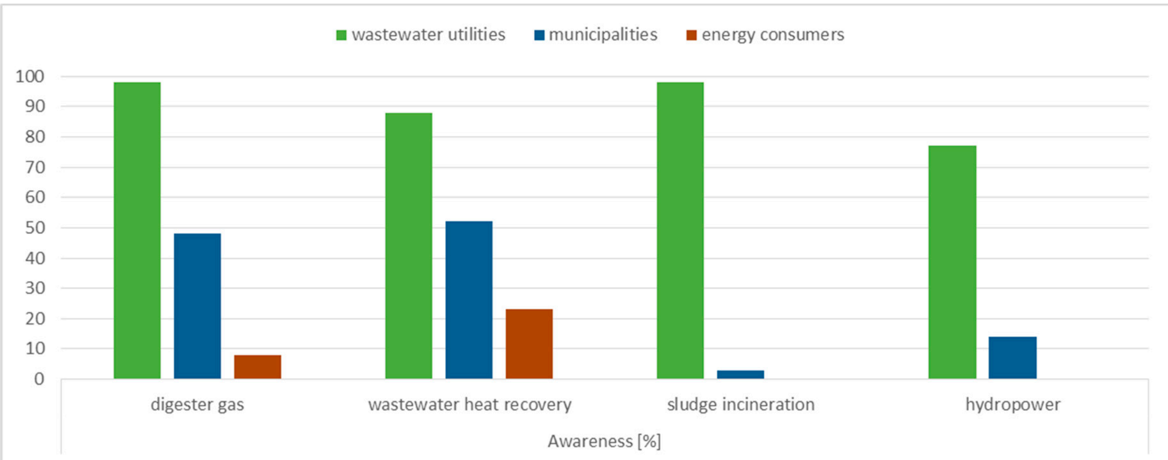

Figure 3. Awareness concerning the energetic use of wastewater.

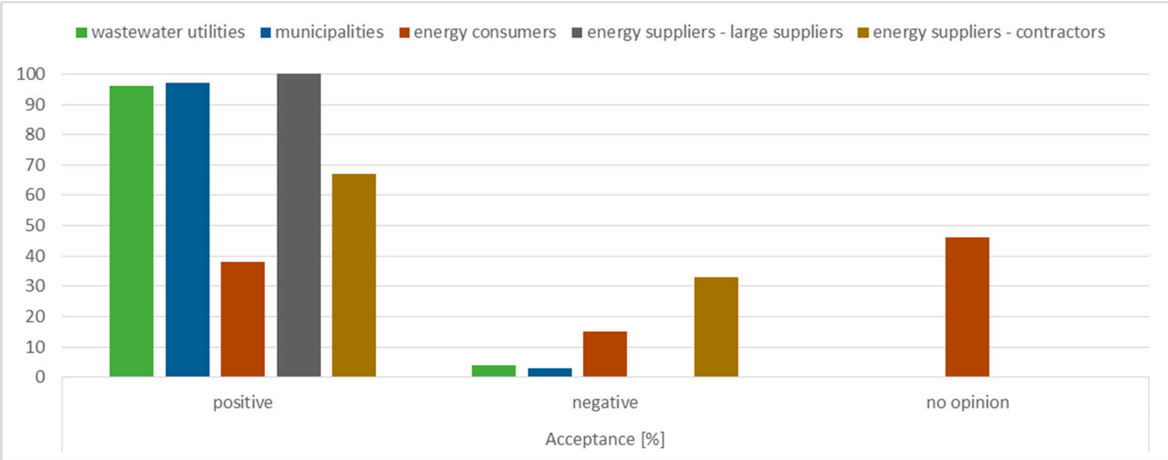

Figure 4. Acceptance concerning the energetic use of wastewater.

However, it is apparent that a successful implementation of the energy system transformation and the establishment of wastewater as a source of renewable energy, respectively, at the local level, is a task for a large number of actors who have to make decisions and implement them. This results in a need for dialogue and coordination between different social groups [30]—decision-makers; stakeholders, who represent certain interests; experts, who can bring in specific knowledge; and laypersons as members of a public that is initially perceived as indifferent to the issue [70]. According to the model of communicative and collaborative planning, the discussion of options for future developments can be seen at the centre of planning with the aim to achieve a consensus between decision-makers, planners, and the public [71,72].

Due to the decentralised nature of energy efficiency and the provision of renewable energies, the local level is particularly important as a strategic dimension of energy system transformation, in order to bring supranational and national requirements into concrete actions [73]. The local level is often the starting point for system changes, communities become "initial seedbeds in transitions" [74], and are increasingly important for the energy system transformation [75]. Municipalities as competent bodies for local spatial planning are essentially responsible for the design of spatial structures that determine both the energy demand, as well as the renewable energy generation potentials. Consequently, for establishing wastewater as a renewable source of energy, municipalities have a key function. However, despite their potential position, investigations revealed that many municipalities (mayors) consider energy from wastewater a sole domain of wastewater utilities today. This is also illustrated by the fact that another 13 email questionnaires (not considered in Table 1) were directly forwarded from the municipality to the related wastewater utility. Consequently, clarification about the responsibility of municipalities in the field of wastewater-related energy supply is still needed. It also has to be reiterated that a response rate of about 26% within municipalities is the lowest among all interviewed stakeholder groups. The generation of knowledge within the framework of participative planning processes can contribute to a better understanding of the problem addressed in the process.

From the investigation results, we conclude that awareness-raising and capacity-building has to be oriented on the specific demands of the respective stakeholder groups. Such courses can follow the principle of customised education programmes [23,76], where further education offers are organised according to action research principles: in this concept, the learning outcomes are defined together with the target group, in the light of the objectives the target group wants to reach—in this case the implementation of wastewater energy use—and the existing knowledge base is defined, as well as the knowledge gaps analysed and the learning demand derived. On this basis, educational programmes are designed—normally as short intensive courses—and implemented, evaluated, and further developed if needed. In this way, the related knowledge transfer (tailor-made training courses, information campaigns, etc.) can be carried out through information channels relevant for the respective target groups.

Within the framework of a participation process designed according to the principles of AR, there is not only an intensive exchange of information between the actors involved (CoP and FO). The process contributes to an understanding, not only of one's very own role, but also of the perspectives of the respective actors, as well as to an improved understanding of the underlying issues of wastewater energy use in the context of energy system transformation. Learning processes are, thus, supported both at the factual level (single-loop learning) and at the value level (double-loop learning). Learning processes at the factual level are to be seen in connection with the thematic contents on the functional principle, technologies, and possibilities of wastewater energy use. In many cases, stakeholders are detained from taking meaningful action by their perception of the factual level, which might considerably vary from scientifically provable facts. Erker et al. [77] identified this problem as a major barrier for different societal groups to engage in measures for a sustainable energy transition. Also, specific misperceptions concerning wastewater energy use, e.g., that extracting heat from water might disturb the cleaning process of the WWTP, can prevent stakeholders from further considering the topic, even though heat extraction in the WWTP effluent does not only have no impact on the cleaning process at all, but might even have positive ecological effects on the receiving water course, because of lower inflow temperatures [78].

Learning processes at the value level, which can be mainly connected to double-loop learning, refer to the willingness and recognition of the benefit of integrating wastewater treatment plants into the regional energy supply system. These discussions are especially important to clarify demand questions and systemic variants. In order to support these learning processes, the appraisal of planning consequences has to be done with planning methods that reduce the information load on decision-makers, reduce complexity, can be easily communicated, and allow for the negotiation of values. Such a method is, for instance, the ecological footprint in certain variants like the energy footprint after Stoeglehner or the sustainable process index [79], which was also successfully applied in case studies related to wastewater energy [24]. With this measure, stakeholders can learn how possibilities to reduce environmental pressures of society by the use of wastewater energy depend on the primary energy source, e.g., that the main factor for environmental benefits of heat generation is the source of electricity generation for the heat pumps. In this way, on the level of values, trade-offs between environmental gains and economic costs can be openly discussed and negotiated, based on measures that can be intuitively realised. The "friendly outsider" contributes scientific findings to the process, e.g., the footprint or greenhouse gas emissions calculations or cost calculations of different planning variants, and discusses the implications of such results for potential decisions with the CoP related to the specific knowledge of the actors involved. Through networking and exchange of information and experiences, mutual qualification processes are supported, which can lead to more relevant and effective results, and can contribute to the creation of ownership and, subsequently, can support the implementation of the jointly developed planning results.

By participating in planning processes for the transformation of the current energy system, objectives can be pursued on at least two levels [80]: (1) On the one hand, participation should contribute to creating understanding for an energy supply on the basis of renewable energy sources, in order to be able to discuss corresponding projects in a constructive discussion climate. (2) On the other hand, participants should be made active actors in the energy system transformation process, who contribute to the transition by making decisions at the individual level, e.g., through energy-saving lifestyles with a conscious choice of residential locations, forms of mobility, consumer behaviour, or financial and/or organisational participation in projects to implement the energy system transformation.

As already mentioned before, the analysis focused on the Austrian federal province of Upper Austria. However, due to the rather general character of the intended objectives (relevant stakeholder groups, possible variations in levels of awareness and acceptance, different sources of information), we consider the results informative for other regions of the world with comparable wastewater infrastructure, energy supply systems, and governance structures. This is due to the fact that they can provide insight into the rather complex issue of stakeholder management.

5. Conclusions

Wastewater as a source of renewable energy can provide interesting opportunities in terms of electricity and heat supply, as well as a substitute for natural gas. In spite of a multitude of application possibilities, the focus of practical implementations primarily still concerns WWTP-internal energy demands today. To support a broader awareness and acceptance of energy from wastewater, we consider targeted participation of stakeholders from different professional fields a crucial point. Appropriate involvement in the planning process facilitates knowledge-building and increase of awareness which, in turn, can be considered key aspects for better recognising energetic use of wastewater as a potential option for local energy supply beyond the premises of the wastewater infrastructure. Finally, participation fosters the building of ownership leading to solutions of broadest support.

Today, it seems that "technical" issues have a slight starting advantage compared to "process-oriented" ones. This might be explained by the fact that planning activities have a complex structure, different levels of spatial reference, and a wider temporal horizon, compared to purely finding technical solutions for agreed planning options. Therefore, we propose that a participatory approach, as introduced in this paper, is necessary to further promote energetic use of wastewater, and to gain a stronger foothold in the field of renewable energies. We consider the related efforts justified. Wastewater, as a renewable local resource, provides different possibilities for climate-friendly energy generation. Consequently, it can be considered as another relevant piece of the puzzle on the path to a transformation from the current energy system largely based on fossil energy sources to a future one based on renewables.

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