Energy Policy 132 (2019) 1176–1183

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Designing local renewable energy communities to increase social acceptance: Evidence from a choice experiment in Austria, Germany, Italy, and Switzerland

Valeriya Azarova[a], Jed Cohen[a], Christina Friedl[a], Johannes Reichl[a,*]

[a] Energy Institute at the Johannes Kepler University Linz, Altenberger Straße 69, 4040, Linz, Austria

ARTICLE INFO

Keywords:
Power-to-Gas
Social acceptance
RES
Choice experiment
Renewable energy community
Local energy community

ABSTRACT

Resistance of the local population to new energy infrastructure may hinder achieving the European Union's goal that 32% of energy consumption come from renewable sources. A vast literature is available on the social acceptance of specific renewable energy technologies, but existing research lacks assessments regarding comprehensive transformations to local energy systems. Moreover, the promising energy storage technology power-to-gas has not yet been addressed in acceptance studies. This paper fills these gaps by analysing data from a choice experiment survey with 2000 respondents across four nations (Germany, Austria, Italy, and Switzerland). Results from the analysis show that solar farms and power-to-gas infrastructure increase acceptance of local energy communities, while wind farms have an ambiguous effect, and gas power plants and power lines decrease acceptance. The derived monthly willingness to pay estimates for the acceptance-increasing technologies ranges from 8.5€ for power-to-gas to 29.5€ for photovoltaics. Additionally, we investigate whether stated support from political opinion leaders at the local, national, and EU levels can increase the acceptance of renewable energy systems. Results suggest that Italian choices are influenced by the opinions of EU and national governmental bodies (+3.5% and +2.7%), and that Swiss choices are sensitive to the opinions of local politicians (+2.3%).

1. Introduction

European countries are committed to increasing renewable energy production to at least 32% of the share of energy consumed in the EU by 2030 and 20% by 2020 (European Commission, 2018, 2009). The increase of renewable energy production by about 66% between 2006 and 2016 (Eurostat, 2018) reflects the political consensus of this ambition, while also demonstrating strong private support for such policies. However, at the same time resistance to certain renewable energy projects, like wind parks or hydropower plants, has turned out to be a major issue for further developments. In addition, renewable electricity production from intermittent sources requires supportive infrastructure, such as additional power lines, storage technologies or backup generation; technologies that are also confronted with limited public acceptance (Cohen et al., 2016a; Friedl and Reichl, 2016, Cohen et al., 2014; Cotton and Devine-Wright, 2012; Devine-Wright, 2008; Devine-Wright, 2005). Moreover, even when general public opinion polls are positive, strong local opposition may occur when it comes to the realization of nearby projects (Liebe and Dobers, 2019).

No striking solution to the challenge of public acceptance has evolved so far, but promising approaches are emerging. One of these approaches are participatory local energy communities, which the European Commission has identified as having positive benefits for acceptance of the energy transition: "*Local citizen participation in renewable energy projects through renewable energy communities has resulted in substantial added value in terms of local acceptance of renewable energy* […]" (European Commission, 2018). Renewable energy communities are characterised by groups of citizens, social entrepreneurs, public authorities and community organisations participating in the energy transition by jointly investing in, producing, selling, distributing and consuming renewable energy. Benefits of energy communities are expected to go beyond counteracting climatic change, including positive regional, economic, and environmental impacts, which are identified as a major drivers of public acceptance (Cohen et al., 2016a).

However, public acceptance and participation in local energy communities is not limited to the acceptance of one specific energy technology or installation, but to the acceptance of all administrative and technological elements needed for a sufficient local energy system. In addition, the process how local residents are involved in finding the right configuration of such endeavours and how their preferences are

* Corresponding author.
E-mail address: reichl@energieinstitut-linz.at (J. Reichl).

https://doi.org/10.1016/j.enpol.2019.06.067
Received 30 January 2019; Received in revised form 4 June 2019; Accepted 29 June 2019
0301-4215/

balanced with supra-regional economic and political interests can play a decisive role as well. Webler et al. (2001) provide an in-depth assessment of the topic including the derivation of recommendations in the context of a forest planning process, while Bull et al. (2008) focus on the effects of participation processes with a focus on the role of citizens' experience. Wilsdon and Willis (2004) provide a discussion of the topic from a wider angle with an emphasis on public engagement.

While numerous analyses deal with the acceptance of specific technologies (Paravantis et al., 2018; Roddis et al., 2018; Sposato and Hampl, 2018; Sovacool and Lakshmi Ratan, 2012; Yuan et al., 2011), or optimizing administrative frameworks for energy communities (Baruah and Enweremadu, 2019; Horbach and Rammer, 2018; Khan et al., 2018), existing research lacks comprehensive acceptance assessments of the entirety of local energy systems rather than just their elements (an instance where research addresses the inextricably intertwined social and technical level of energy innovations in the context of smart cities is found in Corsini et al., 2019).

In addition to the underrepresentation of a system-level perspective in acceptance research, some promising emerging technologies are not found in previous studies. In this study, we strive for a system-level understanding of public acceptance, as we posit that the acceptance to specific technologies may not be equal to the sum of its parts when it comes to accepting a community level change in energy infrastructure and provision.

A number of these new technologies are yet at a low technology-readiness-level (e.g. the promising approach based on nitrifying-enriched activated sludge (Sepehri and Sarrafzadeh, 2018)), while others have reached the maturity to be tested and demonstrated at the industrial level. One such technically mature, while in the social-acceptance context under-researched, technology that could play a key role in a future sustainable energy system is called Power-to-Gas (PtG), which refers to a chemical process for converting surplus electricity into burnable gases like hydrogen and methane. An electricity system aiming for a very high share of renewables needs storage capacity for times of high demand and/or low production from wind, sun and other intermittent sources (see e.g. Lund et al., 2016; Ould Amrouche et al., 2016). While the most efficient solution for large-scale electricity storage is pump-hydro storage, its application is limited by many factors, most obviously geographical prerequisites. The gases produced in a PtG process can be fed into the already existing gas grid,[1] and thus do not require additional investment in transport and pipeline infrastructure. While PtG has been investigated from the business and economic point of view, the social perspective and the acceptance of PtG are often left unexplored (Eveloy and Gebreegziabher, 2019; Leeuwen and Mulder, 2018; Mazza et al., 2018). This work is the first to explicitly investigate the acceptance of power to gas technology in local communities.

Previous research on the acceptance of energy communities stresses the importance of attitudes, visual perceptions, perceived environmental harm, perceived energy cost and personal risk as factors that have an impact on an individual's opposition to energy technologies such as coal, natural gas, nuclear power, and wind power plants (Johansson and Laike, 2007; Liebe and Dobers, 2019). The effect of the proximity of these energy infrastructures to homes is also examined in several studies (see e.g. Nelson et al., 2017; Bjørn Aaen and Lyhne, 2016; Devine-Wright, 2012), framed under the so-called "Not-in-My-Backyard" phenomenon, whereby the public perceives infrastructure projects as necessary, but opposes these projects in their own neighbourhoods (Schively, 2007). Yet the results of these studies are mixed showing that proximity may have a positive, negative or no impact on acceptance, depending on type of power plant and national context considered (Ansolabehere and Konisky, 2009; Ek, 2005; Read et al., 2013).

As Liebe and Dobers (2019) claim, the concept of proximity may play a less important role than social norms in the respective region, in particular how climate change or renewable energies are perceived by the social group to which the individual belongs. Social, group, and cognitive norms have been shown to drive energy related behaviours in various contexts, for example in the adoption of household energy efficiency (Sopha and Klöckner, 2011), energy consumption (Stephenson et al., 2010), and involvement in community energy projects (Kalkbrenner and Roosen, 2016). In the context of building acceptance for a local energy community, it is critical to understand the social and group norm dynamics with respect to the leadership and participatory process to improve acceptability and the success of the community energy transition. Past literature has not yet directly addressed this question, and yet it is one area where policy can be influential by designating leadership roles and creating a regulatory environment for participation. Policymakers often signal support for elements of the energy transition either directly through directives or speeches, or through the enactment of supporting legislation. In this paper, we test the effect of stated support for elements of energy communities by policymakers at different levels of government, local, national, and European. This is a first step in understanding the optimal policy stance with respect to local energy communities in Europe, and helps to understand any positive or negative effects that the support of political opinion leaders may have on acceptance.

This paper aims to fill the gaps in the literature discussed above regarding energy communities, namely, the lack of system-level consideration in the acceptance of energy communities, and the lack of PtG acceptance research. We also add to the policy literature discussing the effects of social norms on acceptance by explicitly considering the role of political opinion leaders in shaping citizen acceptance to energy communities. To do so, this paper presents an analysis of survey data collected from 2000 households in four European countries, Germany, Austria, Italy, and Switzerland. The survey includes a choice experiment presenting a hypothetical situation where the local energy system in transformed into a sustainable energy system that can include financial contributions from the residents. The experiment is designed to examine the preferences of European households for different configurations of local energy communities in their area.

In the next sections, we provide a detailed explanation of the methodology applied in the survey, followed by the econometric analysis. We then conclude by examining the determinants of social acceptance and the preferred structures for renewable energy communities in our four sample nations.

2. Data

This section explains the public acceptance survey conducted in Austria, Switzerland, Italy and Germany between November and December 2017 and provides a descriptive analysis of the responses and the survey sample. As the survey took place in 2017 all prices and values listed are in 2017 Euros, or the 2017 equivalent of noted currencies.

2.1. survey process and questionnaire

The survey implementation included three interactions with each potential participant:

i) A first contact via phone or email to ensure the willingness of the candidate to participate in the study and to check demographic quotas to achieve representativeness at the country level. Willing candidates completed a screener questionnaire about their basic demographic information.
ii) Distribution of a booklet through postal mail or email accompanied

[1] On overview legal limitation for the four investigated countries is provided in https://www.storeandgo.info/fileadmin/downloads/publications/Kreeft_G.J._2018_-_Legislative_and_Regulatory_Framework_for_Power-to-Gas_in_Italy_Germany_and_Switzerland.pdf.

by a note reminding respondents about the purpose of the study and reaffirming the confidentiality of their responses. The main purpose of the booklet was to provide graphical examples of how a community can look with and without a predominantly renewable energy system. The way an installation of an energy technology changes the look of a landscape can have a significant impact on peoples' perceptions and acceptance of the new installation. Therefore, the choice experiment supplied visualizations of different scenarios of energy communities, in addition to the textual explanations, to account for this critical 'viewshed' impact.

iii) The main questionnaire was administered by phone or email. The first section of the survey included general interest questions, while the second section of the survey was the choice experiment.

Respondents were recruited by the market research firm Efficiency3[2] based on a randomized sampling procedure. The final sample comprises 2.000 households, 500 per country (Germany, Switzerland, Italy and Austria). Each of the four country samples is divided into "Sample A″ and "Sample B″, which correspond to a 50% Online and 50% CATI (by phone with supporting materials sent via postal or electronic mail) method to balance survey mode effects. In the CATI mode, respondents were pre-recruited by a screening questionnaire, after which the booklet was sent (online or via post, as desired by the respondent), and the interviews were conducted upon receipt of the booklet. The availability of the booklet was verified before starting the CATI interviews, to ensure the respondents had the visual representations in front of them during the interview. The telephone interview took about 25 min. The online respondents received the booklet via email, and could proceed directly to the web-based version of the survey.

The main questionnaire, as well as the screener and the booklet, are found in the Annex. The screener questionnaire included quotas to ensure a representative sample among the population of Austria, Germany, Switzerland, and Italy. In order to get an adequate sample we implemented a pre-selection with four questions regarding age, profession, hometown, and income. Quotas are found in Table 1 and the demographic distribution of the final sample is given in Table 2.

Additional socio-demographic characteristics of the respondents were collected including their ownership status regarding their home, the number of the people living in the household, the number of children under age 14, and the education level of the interviewed person.

The next part of the questionnaire focused on general opinions regarding renewable energy and related technologies. These questions are closely related to the social acceptance topic and encapsulate the respondent's general attitudes towards energy and environmental issues, and new energy projects, which have been shown to be important factors in acceptance (Johansson and Laike, 2007; Toke et al., 2008). This section also included questions about the current ownership of energy technologies, heating, cooling, and household appliances. Further questions asked after experiences with any larger plants for the production or storage of renewable energy that may be located in the respondent's neighborhood. Additionally, information about experiences with their electricity and heat supplier were collected.

2.2. choice experiment

In order to investigate acceptance of renewable energy communities in the four sample nations, we include a choice experiment in the survey. In a choice experiment, a limited number of hypothetical scenarios are revealed to respondents, and respondents are asked to choose which of the scenarios they would prefer if confronted with the same situation in real life. In every choice set, we showed respondents three alternatives total, two alternatives representing different potential configurations of renewable energy communities and one representing the status-quo in their community. Each of the energy community scenarios (alternatives 1 and 2) contained a number of additional energy production facilities and/or infrastructures for storage and/or transport in contrast to alternative 3, the status-quo, where no additional equipment would need to be installed.

Respondents were informed about the change to the cost structure under each of the alternatives. They were told if an alternative incurred additional costs for installations and operation, these costs were put on top of their monthly electricity bill over the next five years. The cost attribute varied between the values: 0€, 2€, 10€, 25€, 50€, or 100€ for Austria, Germany and Italy, and 0/2/10/25/55/110 CHF for Switzerland. Any scenario depicting a hypothetical local energy community had one of these values was randomly assigned as a cost for this sustainable transition, while the status quo option was always free of additional cost.

Energy communities investigated in our study are combinations of one or more of the following technologies: a wind park, a gas-fired power plant, photovoltaic panels, a PtG facility, and an extension of overhead power lines. Technically meaningful combinations of these technologies were designed with support from a panel of energy technology experts of researchers from the European Commission funded project Store&Go,[3] to ensure the energy communities depicted were realistic and feasible.

In a complex choice situation, requiring judgment of a combination of individual technologies, previous studies using discrete choice experiments have included icons or pictures to depict attribute levels in order to make the choice options easier for the respondent to digest. This can reduce the potential effects of cognitive disengagement or heuristic choice patterns (see e.g. Cohen et al., 2016b; Campbell et al., 2008). Furthermore, Johansson and Laike (2007) suggest that visual perception and view shed effects have an impact on the acceptance or opposition to renewable energy technologies. Thus, inclusion of visuals demonstrating how each potential technology looks and how the potential energy community will look is highly important in our case. We designed a booklet containing the visual representation of the scenarios from Table 3 located in a suburban landscape for each of the choice options. These pictures were shown together with a text description of the local energy community and associated technologies for each of the available options in each choice set. The images of the visual representations were identical in all four surveyed countries and are found in the online appendix.

Respondents were asked to inform us about their most preferred alternative and their least preferred alternative in five consecutive choice sets. Scenarios used in our study are found in Table 3 and Figure 1 provides an overview of the electricity mix in the four surveyed countries to show the experience of the respective population with the different resources for electricity production.

The choice task was introduced to the respondents by the following statement:

"The following questions deal with different scenarios concerning the energy infrastructure in your neighborhood. In the following, you will see in every scenario 3 options how the electricity demand of your neighborhood can be supplied in the future, all representing the provision of the same amount of electricity at the same level of supply reliability as you experience it today. When a scenario contains the construction of new infrastructure, like a wind power plant, consider these to be approximately 500 m away from your home. One of the alternatives within the scenarios is the current energy production from a mix of different energy sources, both fossil and renewable. It is situated further away from your hometown.

Please keep in mind that each of the scenarios of energy provision,

[2] http://www.efficience3.com/en/.

[3] Store&Go is a Horizon 2020 project investigating the potential of power to gas technology, see more at https://www.storeandgo.info/.

Table 1
Defined quotas for the survey sampling process to ensure representability

Question in the screener regarding the…	Quota
Age	Maximum 35% per age band, not less than 10% per age band (see Table 2)
Profession	Minimum of 70% to be employed (full time & part time)
Area	Maximum 70% per code[a]
Monthly net income[b] per household	30% approx. high income – no less than 20%[c] 40% approx. middle income – no less than 30% 30% low income – no less than 20%[d]

[a] a) Town/city (with more than 10,000 inhabitants) and b) A village or very small town (with less than 10,000 inhabitants).
[b] Income brackets are derived from national statistics: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_di01&lang=de.
[c] 2.500 Euro (AT), 2.300 Euro (GER), 1.800 Euro (IT), 5.100 CHF (CH).
[d] 1.500 Euro (AT), 1.300 Euro (GER), 1.000 Euro (IT), 3.100 CHF (CH).

Table 2
Descriptive statistics comparing the survey samples across surveyed nations.

	Indicator	Germany		Austria		Switzerland		Italy	
		n	percentage	n	percentage	n	percentage	n	percentage
	Respondents per country	500	25.0	500	25.0	500	25.0	500	25.0
1	**AGE**								
	20–34	115	23.0	108	21.6	105	21.0	97	19.4
	35–45	98	19.6	106	21.2	100	20.0	101	20.2
	46–65	171	34.2	170	34.0	176	35.2	177	35.4
	> 65	116	23.2	116	23.2	119	23.8	125	25.0
2	**Profession**								
	Employed	315	63.0	282	56.4	267	64.6	251	50.2
	full time	257	51.4	230	46.0	261	52.2	201	40.2
	part time	58	11.6	52	10.4	62	12.4	50	10.0
	Not working - Full time University or college student	33	6.6	15	3.0	7	1.4	26	5.2
	Not working – Unemployed, house-wife/house-husband or in training	67	13.4	83	16.6	55	11.0	92	18.4
	Not working – retired	85	17.0	120	24.0	115	23.0	131	26.2
3	**Area**								
	Town/city (with more than 10,000 inhabitants)	334	66.8	263	52.6	232	46.4	372	74.4
	A village or very small town (with less than 10,000 inhabitants)	166	33.2	237	47.4	268	53.6	128	25.6
4	**Monthly net income per household**[a]								
	Low	159	31.8	144	28.8	151	30.2	131	26.2
	Middle	163	32.6	171	34.2	171	34.2	213	42.6
	High	178	35.6	185	37.0	178	35.6	156	31.2
5	**Gender**								
	Female	246	49.2	266	53.2	273	54.6	254	50.8
	Male	254	50.8	234	46.8	227	45.4	246	49.2

[a] Income bands were set country-wise: Low/Medium/High in AT were < 1500 €/1500 € to 2500 €/ > 2500 €; in DE were < 1300 €/1300 € to 2300 €/ > 2300 €, in IT were < 1000 €/1000 € to 1800 €/ > 1800 €, and in CH were < 3100 Fr./3100 Fr. to 5100 Fr/ > 5100 Fr.

Table 3
Configurations of renewable energy communities as used in the choice experiment.

Scenario	Alternative 1	Alternative 2	Alternative 3
1	Photovoltaic (PV) panels + PtG facility	gas-fired power plant	Status-quo
2	Small gas-fired power plant + power lines	PV panels + PtG facility	Status-quo
3	Three wind turbines + PtG facility	PV panels + overhead power lines	Status-quo
4	Three wind turbines facility + small gas-fired power plant	Three wind turbines + PtG facility + gas-fired power plant	Status-quo
5	PV panels + PtG facility + gas-fired power plant	Three wind turbines facility + overhead power lines	Status-quo

whether it involves the construction of new infrastructure in your community or not, comes at a different cost. These costs will be split between all households in your community and the respective share payable by your household will be given along with each of the following scenarios. This sum of money represents a monthly fee and you will be charged for it over the next 5 years. It will be collected by your community by putting them on top of your electricity bill."

The statement was followed by an assertion that the booklet would be needed for the next questions and then an explanation of the procedure for the subsequent choice tasks. The actual choice set was preceded by a treatment script for a subset of randomly selected respondents. The treatment script stated that a political representative supported one of the three alternatives in the subsequent choice set. Such support could come from the mayor of the residential municipality, the federal chancellor, or the European Commission. One of these three political representatives was assigned randomly to respondents who received the treatment script, and a recommendation was revealed before each choice set. Additional to the three treatment

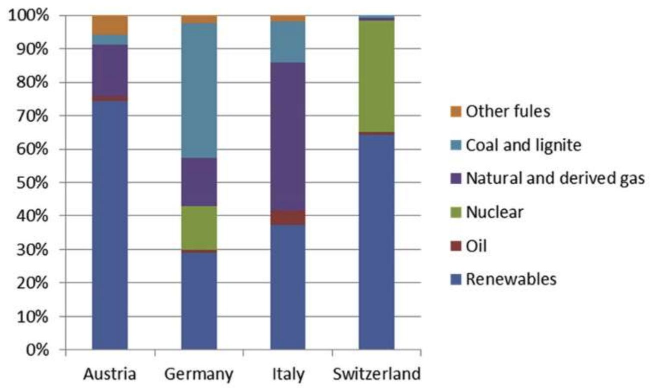

Fig. 1. Electricity production mix[4] in 2016[5] of the four nations in our sample. Source: Austrian, German and Italian data comes from the European Environmental Agency[6]; Swiss data comes from the Swiss Federal Department of the Environment, Transport, Energy and Communications.[7]

groups corresponding to the three political representatives, 25% of the sample was assigned to the control group where no political support was communicated.

The support of the respective politician was stated as e.g.: "[…] *Please also consider in your decision that you became aware from media reports that* ***the mayor of your home town*** *strongly* supports ***Alternative 1***".

2.3. data analysis methods

As discussed in the description of the choice experiment in Section 2.2, we observe the ranks respondent i assigns to the three revealed alternatives in five consecutive choice sets. Following economic random utility theory we can conceptualize the ordinal ranking that each respondent i gives to the $j = 1,2,3$ alternatives as corresponding to the utility level that the respondent assigns to the alternatives (McFadden, 1974). We model directly the latent quantity of the respondent's utility level, where the utility respondent i assigns alternative j is denoted η_{ij}. Including a status-quo response in each choice set ensures that the choice sets are feasible and allows an interpretation of our results within a random utility framework (Louviere et al., 2010).

The most frequently used econometric model to analyse discrete choice experiments with ranked outcomes is the rank-ordered logit model (see e.g. Chapman and Staelin, 1982; Hausman and Ruud, 1987; Beggs and Hausman, 1981). However, in its basic form, this model assumes that all respondents have common preference parameters and that independence from irrelevant alternatives (IIA) holds (Hanley et al., 1998). The assumption of similar preference is likely to be violated in our survey, since the sample contains respondents from across four nations. We employ country fixed effects to capture nation-specific heterogeneity in preferences. The alternative-specific rank-ordered probit model is used to relax the IIA assumption by estimating the variance–covariance parameters of the latent-variable errors.

The rank-ordered probit regression allows for specifying the independent variables in two ways: alternative-specific variables, in which the values of each variable vary with each alternative (three alternatives per choice set), and case-specific variables, which vary with each choice set or respondent, but not between alternatives within a choice set. Formally, the model of the latent utilities can be written as:

$$\eta_{ij} = x_{ij}\beta + z_i\alpha_j + \xi_{ij} \quad (1)$$

where x_{ij} are the alternative-specific independent variables that include specific characteristics of each option in the suggested scenarios including technologies used, price, and political support. The z_i are the case-specific independent variables which include respondent i's characteristics like age, gender, education. The error term ξ_{ij} follows a multivariate normal distribution with zero mean and covariance matrix Σ. As the levels of the utilities in (1) are not identified, the model is estimated for the differences in utilities between pairs of alternatives within a given choice set. Hence, if individual i ranks the three alternatives with alternative 3 as the preferred alternative and alternative 1 is the least preferred alternative, then the probability of this ranking given β and α_j is the probability that:

$\eta_{i,2} - \eta_{i,3} \le 0$ and $\eta_{i,1} - \eta_{i,2} \le 0$, and $\eta_{i,1} - \eta_{i,3} \le 0$, jointly. The parameters of the probit model in (1) is estimated using the maximum simulated likelihood technique.

3. Results

The objective of the choice experiment is to identify which configuration of a renewable energy community can increase its acceptance by the local population. The transformation of a municipality into a renewable energy community requires as a precondition a willingness to abandon the status-quo. The status-quo is represented by alternative 3 in our study, and hence we provide our results as the change in probability of choosing alternative 3 under different configurations of the renewable energy community. This section first presents the results for alternative-specific variables including price, technologies, and the level of political support, followed by an overview of case-specific

Table 4
Marginal effects of alternative specific variables on the acceptance of renewable energy communities.

Variable	Marg. Eff.	Std. Err.	z-statistic	P > z
Price	0.0014***	0.0000	−27.37	0
Technology				
PV	−0.0298***	0.0043	6.85	0
PtG	−0.0139***	0.0030	4.62	0
Gas plant	0.0106***	0.0039	−2.72	0.007
Wind farm	−0.0064	0.0044	1.45	0.147
Power lines	0.0109***	0.0028	−3.83	0
Political support				
Germany				
Mayor	−0.0048	0.0073	0.66	0.51
Chancellor	0.0014	0.0067	−0.22	0.829
EU	0.0048	0.0067	−0.72	0.471
Austria				
Mayor	0.0048	0.0076	−0.64	0.524
Chancellor	−0.0094	0.0080	1.17	0.243
EU	0.0015	0.0074	−0.21	0.834
Switzerland				
Mayor	−0.0225***	0.0086	2.62	0.009
Chancellor	−0.0088	0.0083	1.07	0.284
EU	−0.0108	0.0078	1.4	0.161
Italy				
Mayor	−0.0114	0.0085	1.33	0.182
Chancellor	−0.0269***	0.0091	2.95	0.003
EU	−0.0351***	0.0100	3.51	0

*** marginal effect is significant on the 1% level; marginal effects denote the change in the probability a respondent prefers the status quo option over a transition to a renewable energy community.

[4] https://www.eea.europa.eu/data-and-maps/indicators/overview-of-the-electricity-production-2/assessment-4.

[5] https://www.uvek.admin.ch/dam/uvek/de/dokumente/energie/faktenblatt2-energiegesetz-energieversorgung.pdf.download.pdf/03_Faktenblatt_2_Energieversorgung_der_Schweiz_und_internationale_Entwicklung.pdf.

[6] Due to their subordinate role in the Swiss electricity mix, official statistics only provide the sum of electricity from oil, natural and derived gas and coal and lignite. Together, these 3 categories account for 2.3% of the total Swiss electricity production. In this figure, each of these categories was assigned a third of these 2.3%.

[7] Data for Switzerland stems from 2015.

variables including variables such as age, education, and gender. A list of variable names and definitions and the untransformed coefficient estimates from the models are provided in Tables A1 and A2 of the Annex.

The marginal effects in Table 4 and Table 6 are interpreted as the effect of a one-unit increase in the referenced variable on the probability that a respondent prefers the status quo over a transition to a renewable energy community. The marginal effects are calculated with all other variables fixed to their sample means. In the case of price, if the monthly costs of a proposed renewable energy community is increased by one euro, the probability that a respondent prefers maintaining the status-quo increases by 0.14% (see first column of Table 4). While a significant relationship between the costs of transitioning to a renewable energy community and the acceptance of such is not surprising, the magnitude of the effect is relatively moderate. Even under additional monthly costs of about 70€, the probability a respondent prefers a transition to a renewable energy community over the status quo decreases by only 10%.

Looking next at the impact of specific technologies, we find that including PV and PtG in the configuration of a renewable energy community significantly increases the probability that a respondent prefers a new local energy community to the status quo by ~3% and ~1.5%, respectively. Including gas plants in a local energy community significantly decreases the social acceptance of such a transition, increasing the probability a respondent prefers the status quo by 1%. A negative effect on acceptance of the same magnitude is identified for overhead power lines. This is unsurprising due to the common findings of past literature that power lines negatively affect the view shed and have perceived deleterious health effects (Cohen et al., 2016a; Soini et al., 2011). In this respect, our results show it is important to investigate energy community solutions that require as little additional electricity transmission capacity as possible, at least when transmission involves visible overhead lines. Such solutions could involve PtG, which stores excess electricity locally, instead of feeding it into the distribution/transmission grid, and can transport energy through gas pipelines. Interestingly, the addition of wind farms to a renewable energy community does not show an effect on acceptance, with a marginal effect that is not statistically significant. While the positive low-carbon and sustainable nature of wind power is widely accepted, the long-range visibility, noise, and local environmental concerns can lead to opposition to local wind farm siting and has been shown to decrease local property values (Cohen et al., 2014; Friedl and Reichl, 2016; Sims and Dent, 2007).

Under the "political support" heading, Table 4 reports the findings regarding the administrative dimension investigated in our choice experiment, namely the effect of political support for a certain alternative from various opinion leaders. In this model, country-specific effects are estimated, meaning that the effect of support from each administrative entity, local, national, and EU, is allowed to vary across the four countries investigated. In Germany and Austria, political support is not shown to influence responses to the choice experiment. However, in case of Switzerland we find a positive effect from support of the local government. Specifically, if a Swiss mayor was said to support a respective alternative, the probability that the endorsed renewable energy community project is preferred increases by 2.2%. In contrast to the Swiss findings, the results for Italy show that national and EU level support increase the level of acceptance while local support has no effect. These results show the importance of investigating and taking into consideration the specific political situation of a country and trust in different policymaking branches; while Italians put more weight on the suggestions of national or EU opinion leaders, the Swiss prefer the advice of their local leaders. These findings are in line with the analysis of Kollmann and Reichl (2015) who find a strong interdependency of trust in the governmental institutions and a population's willingness to accept environmental policies associated with tax increases. Their analysis also shows Switzerland as one of the nations with highest confidence in their local government, with Italy exhibiting less trust in local governments. Similarly, the Corruption Perceptions Index 2017[8] finds that Switzerland has the 3rd lowest corruption rating for government officials while Italy is significantly higher with the 54th lowest corruption rating. Our results suggest that these broader issues of trust in governmental bodies can also affect their efficacy as opinion leaders in improving acceptance and participation in the energy transition.

We derive willingness to pay (WTP) estimates for the presence of specific technologies in the local energy community based on the results of the rank-ordered probit model shown in Tables 4 and 6, and A2. WTP estimates and their 95% confidence intervals (CI) are calculated as $-\frac{\beta_{tech}}{\beta_{price}}$ where β_{price} is the coefficient on the "Price" variable in Table A2 of the Annex, and β_{tech} is the coefficient for the variable of the technology type specified. The quantities describe how much more in monthly electricity cost over the next 5 years the average respondent is willing to pay if the associated technology is included in the local energy community. The results of this exercise reiterate those shown in Table 4 and reaffirm the results of past studies, most notably that local consumers are willing to pay higher electricity rates for an electricity mix with a substantial proportion of solar-generated power (Vecchiato and Tempesta, 2015; Cicia et al., 2012; Borchers et al., 2007). Our estimate of a €29.52 per month willingness to pay for substantial solar generation is in line with past WTP estimates from choice experiments that find a value of ~€60 in Italy (Cicia et al., 2012), ~€12 in Italy (Vecchiato and Tempesta, 2015), and ~€21[9] in the USA (Borchers et al., 2007). Though it is important to note that estimates are not perfectly comparable due to differences in choice set design and the specification of solar-power provision between studies. Further results from Table 5 show that the presence of power-to-gas and wind farms in the local energy community increase WTP for the transition by about €9 per month. In contrast, gas fired power plants and more transmission lines in the energy community decrease the WTP for the transition by €10.32 and €11.59, respectively.

CI – is the 95% confidence interval bound for the estimate derived by the delta method. Euro values for 2017 are converted into dollars based on the November 2017 exchange rates.

Turing the focus to the case-specific characteristics shown in Table 6, we find statistically significant effects for the age, gender, and education level of the respondent, and the presence of children in the household. All the other tested factors including income, rural vs. urban residence, previous knowledge about PtG, and negative experiences with the electricity provider show no effect on social acceptance in our sample. The country fixed effects estimates show that the propensity to choose the status quo as the most preferred option is not systematically influenced by the country of residence. Considering the effect of age, we observe that compared to the group of 20–35 years old, being in the groups of 35–45 and 45–65 year olds increases the probability of choosing the status-quo as the most preferred option by about 1.5%. The middle-aged groups are thus generally less accepting on a transition to a renewable energy community, though interestingly this effect is not present for the over-65 age group. Female respondents are also more likely to prefer the status quo compared to males. We find weak evidence that the respondent's level of education has an effect on the likelihood to accept a proposed renewable energy community. The marginal effects of education are interpreted relative to the omitted category of people with a university degree. Compared to this group, respondents with secondary or elementary school as their highest level of education are 2% more likely to prefer the status quo; however this effect is only weakly statistically significant (at the 10% level). On the other hand, households with kids have a significantly lower probability

[8] https://www.transparency.org/news/feature/corruption_perceptions_index_2017.

[9] Converted from 2007 USD to 2018 Euros based on CPI rates and Jan 23, 2018 Euro to USD exchange rate.

Table 5
Willingness to pay estimates for technologies to be included in local energy communities (2017€ per month, 2017$ equivalents given in braces).

	PV	PtG	Gas plant	Wind farm	Power lines
WTP estimate	€29.52 [$35.42]	€8.53 [$10.23]	-€10.32 [- $12.38]	€9.7 [$11.64]	-€11.59 [$13.91]
Lower 95% CI	€21.26 [$25.51]	€2.68 [$3.21]	-€19.29 [-$23.15]	€0.71 [$0.85]	-€18.29 [$21.95]
Upper 95% CI	€37.79 [45.34]	€14.38 [$17.26]	-€1.36 [-$1.63]	€18.7 [$22.44]	-€4.88 [$5.86]

Table 6
Marginal effects of socio-demographic factors determining social acceptance of renewable energy communities.

Case-specific variables	Marg. Eff.	Std. Err.	z-statistic	P > z
Germany	−0.0001	0.0077	−0.02	0.986
Austria	0.0047	0.0075	0.63	0.53
Italy	−0.0128	0.0085	−1.5	0.134
Age 35-45	0.0188**	0.0092	2.04	0.042
Age 45-65	0.0160*	0.0081	1.96	0.05
Age > 65	0.0128	0.0122	1.05	0.292
Part time job	0.0143	0.0095	1.5	0.133
Student	0.0013	0.0149	0.09	0.929
Housewife/husband	−0.0096	0.0078	−1.23	0.219
Retired	0.0086	0.0101	0.85	0.394
Rural	0.0089	0.0057	1.56	0.119
Female	0.0127**	0.0054	2.33	0.02
Elementary or secondary school	0.0220*	0.0117	1.89	0.059
Professional training	0.0020	0.0077	0.26	0.793
A-levels	0.0006	0.0075	0.09	0.932
Household size	0.0040	0.0032	1.27	0.204
Kids	−0.0189**	0.0077	−2.46	0.014
Protest	0.0091	0.0152	0.6	0.549
Ptg-knowledge	−0.0007	0.0062	−0.12	0.906
Years in home	0.0003	0.0004	0.78	0.434
Owner	−0.0037	0.0061	−0.62	0.537
Near plants	−0.0001	0.0055	−0.01	0.989
Negative provider experience	0.0062	0.0081	0.77	0.442
Power outage	−0.0017	0.0081	−0.21	0.835
High-income	−0.0008	0.0071	−0.11	0.915
Middle-income	0.0053	0.0075	0.71	0.477

*** marginal effect is significant on the 1% level; ** marginal effect is significant on the 5% level; * marginal effect is significant at the 10% level. The marginal effects are interpreted as the change in the probability of choosing the status quo as the most preferred option for a one-unit increase in the associated variable. The omitted category for country-comparison is Switzerland. The omitted category for age is 20–35 years old. The omitted category for occupation is full time working respondents. The omitted category for education is University or college degree. The omitted category for income is low income.

to prefer the status-quo, decreasing the probability of choosing the status quo by 2%. This last finding may suggest that parents consider a longer-term perspective in their decisions with respect to their community energy systems than others do.

4. Conclusion and policy implications

This article investigates the acceptance of local renewable energy communities in four European countries, Germany, Austria, Italy, and Switzerland. We examine the preferences of citizens of these nations regarding various feasible configurations of renewable energy communities and the technologies used in potential transformations. As a direct policy contribution, we investigate whether signalled support for specific configurations of energy communities from political entities at the local, national, and EU levels, can increase the acceptance of renewable energy transitions. Data for this study come from a choice experiment survey that collected 500 responses from each sample nation. The data are analysed using a rank-ordered probit model with country fixed effects to avoid the IIA assumption intrinsic in the logit model and to control for preference heterogeneity across nations.

We find that if the technologies of PV and PtG are substantially used in the proposed local renewable energy system this increases the probability a respondent accepts the local energy transition. We complete the first ever assessment of the social acceptance of power-to-gas, and find that this storage type likely will not face the same acceptance problems as have been noted for pump-hydro in some instances (Steffen, 2012). In contrast, no strong recommendation for including wind power in the configuration of a renewable energy community can be made based on our results. This likely reflects the conflicting outcomes of local wind generation, where on one hand local wind farms can decrease property values (Sims and Dent, 2007), on the other hand green power from wind sources may be preferred to conventional generation sources (Borchers et al., 2007). In line with these results on acceptance, we find a positive WTP for wind in the local electricity generation mix of €9.70 per month, and a much higher WTP for solar of €29.52 per month, generally reflecting the results of past choice experiment studies (e.g. Vecchiato and Tempesta, 2015; Cicia et al., 2012; Borchers et al., 2007). Counter to the beneficial effects for social acceptance from some of the studied renewable energy technologies, including the more conventional infrastructure of overhead power lines and natural gas generators in the local energy system is shown to decrease local support. Hence, we conclude that the type of energy generation included in a local energy community project has to be carefully chosen in accordance with local preferences to ensure that the local energy transition will meet high levels of support from affected citizens.

Looking at the socio-demographic characteristics, we find effects of age, gender and education on social acceptance: older groups, females and respondents with lower education have lower acceptance for renewable energy systems. Although the effect of education is only weakly statistically significant. From the policy perspective, in order to increase the acceptance of renewable energy community projects, our results suggest that educational programs and advertising campaigns could be targeted towards these less accepting groups of citizens.

In the context of building acceptance for a local energy community policies are important, both in their ability to make the project cheaper or easier to complete, but also in terms of their potential signalling of support for a project from a policymaking entity. Politicians and governmental institutions can serve as opinion leaders for energy related topics. In this paper, we test the effect of hypothetical stated support from local, national, and EU-level politicians on the acceptance of transitions towards local renewable energy communities across four European nations. We find that political support can indeed plays a role for the acceptance of such communities; however, the effect differs between countries. For the Italian case, support on national or EU level has a positive effect on social acceptance, while for Switzerland only the support of the community's local leader can enhance acceptance levels. No such effects are found for Germany and Austria, and we find no evidence that political support for a project can lead to ‘pushback’ in the form of lower acceptance across the four nations tested. These results confirm the necessity to consider not only the technical or operational configuration of a project, but also the country-specific political, and group norms. Those political entities that the public has more confidence in can be chosen to spearhead the push towards energy transition, which may increase acceptance and participation within some national contexts.

Acknowledgements

We gratefully acknowledge the comments and suggests by three anonymous referees. Funding for this research under the European Commission's Horizon 2020 program and the project Store&Go, grant number 691797.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2019.06.067.

References

Devine-Wright, P., 2005. Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy 8 (2), 125–139.
Ansolabehere, S., Konisky, D.M., 2009. Public attitudes toward construction of new power plants. Publ. Opin. Q. 73 (3), 566–577 Oxford University Press.
Baruah, D.C., Enweremadu, C.C., 2019. Prospects of Decentralized Renewable Energy to Improve Energy Access: A Resource-Inventory-Based Analysis of South Africa.
Beggs, S.C., Hausman, J., 1981. Assessing the potential demand for electric cars. J. Econom. 17 (1), 1–19.
Bjørn Aaen, S.K., Lyhne, I., 2016. Beyond public acceptance of energy infrastructure: how citizens make sense and form reactions by enacting networks of entities in infrastructure development. Energy Policy 96, 576–586.
Borchers, A.M., Duke, J.M., Parsons, G.R., 2007. Does willingness to pay for green energy differ by source? Energy Policy 35 (6), 3327–3334.
Bull, R., Petts, J., Evans, J., 2008. Social learning from public engagement: dreaming the impossible? J. Environ. Plan. Manag. 51 (5), 701–716.
Campbell, D., Hutchinson, W.G., Scarpa, R., 2008. Incorporating discontinuous preferences into the analysis of discrete choice experiments. Environ. Resour. Econ. 41, 401–417.
Chapman, R.G., Staelin, R., 1982. Exploiting rank ordered choice set data within the stochastic utility model. J. Mark. Res. 19 (3), 288–301.
Cicia, G., Cembalo, L., Giudice, T.D., Palladino, A., 2012. Fossil energy versus nuclear, wind, solar and agricultural biomass: insights from an Italian national survey. Energy Policy 42, 59–66.
Cohen, J.J., Reichl, J., Schmidthaler, M., 2014. Re-focussing research efforts on the public acceptance of energy infrastructure: a critical review. Energy 76, 4–9.
Cohen, J.J., Moeltner, K., Reichl, J., Schmidthaler, M., 2016a. An empirical analysis of local opposition to new transmission lines across the EU-27. Energy J. 37 (3), 59–82.
Cohen, J.J., Moeltner, K., Reichl, J., Schmidthaler, M., 2016b. Linking the value of energy reliability to the acceptance of energy infrastructure: evidence from the EU. Resour. Energy Econ. 45, 124–143.
Corsini, F., Certoma, C., Dyer, M., Frey, M., 2019. Participatory energy: research, imaginaries and practices on people contribute to energy systems in the smart city. Technol. Forecast. Soc. Change 142, 322–332.
Cotton, M., Devine-Wright, P., 2012. Making electricity networks "visible": industry actor representations of "publics" and public engagement in infrastructure planning. Publ. Understand. Sci. 21 (1), 17–35.
Devine-Wright, P., 2008. Reconsidering Public Acceptance of Renewable Energy Technologies: A Critical Review. Delivering a Low Carbon Electricity System: Technologies, Economics And Policy.Reconsidering Public Acceptance of Renewable Energy Technologies: A Critical Review. Delivering a Low Carbon Electricity System: Technologies, Economics And Policy.
Devine-Wright, P., 2012. Explaining "NIMBY" objections to a power line: the role of personal, place attachment and project-related factors. Environ. Behav. 45 (6), 761–781.
Ek, K., 2005. Public and private attitudes towards "green" electricity: the case of Swedish wind power. Energy Policy 33 (13), 1677–1689.
European Commission, 2009. Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Off. J. Eur. Union 140, 16–62.
European Commission, 2018. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. Off. J. Eur. Union 328, 82–209.
Eurostat, 2018. Renewable Energy Statistics. Retrieved from. https://ec.europa.eu/eurostat/statistics-explained/pdfscache/7177.pdf.
Eveloy, V., Gebreegziabher, T., 2019. Excess electricity and power-to-gas storage potential in the future renewable-based power generation sector in the United Arab Emirates. Energy 166, 426–450.
Friedl, C., Reichl, J., 2016. Realizing energy infrastructure projects–A qualitative empirical analysis of local practices to address social acceptance. Energy Policy 89, 184–193.
Hanley, N., Wright, R., Adamowicz, V., 1998. Using choice experiments to value the environment. Environ. Resour. Econ. 11 (3), 413–428.
Hausman, J., Ruud, P., 1987. Specifying and testing econometric models for rank-ordered data. J. Econom. 34 (1–2), 83–104.
Horbach, J., Rammer, C., 2018. Energy transition in Germany and regional spill-overs: the diffusion of renewable energy in firms. Energy Policy 121, 404–414.
Johansson, M., Laike, T., 2007. Intention to respond to local wind turbines: the role of attitudes and visual perception. Wind Energy 10 (5), 435–451.
Kalkbrenner, B.J., Roosen, J., 2016. Citizens' willingness to participate in local renewable energy projects: the role of community and trust in Germany. Energy Res. Soc. Sci. 13, 60–70.
Khan, M.A.M., Rehman, S., Al-Sulaiman, F.A., 2018. A hybrid renewable energy system as a potential energy source for water desalination using reverse osmosis: a review. Renew. Sustain. Energy Rev. 97, 456–477.
Kollmann, A., Reichl, J., 2015. How trust in governments influences the acceptance of environmental taxes. In: Kollmann, A., Schneider, F., Reichl, J. (Eds.), Political Economy and Instruments of Environmental Politics. MIT Press Ltd, pp. 53–69.
Leeuwen, C. van, Mulder, M., 2018. Power-to-gas in electricity markets dominated by renewables. Appl. Energy 232, 258–272.
Liebe, U., Dobers, G.M., 2019. Decomposing public support for energy policy: what drives acceptance of and intentions to protest against renewable energy expansion in Germany? Energy Res. Soc. Sci. 47, 247–260.
Louviere, J.J., Flynn, T.N., Carson, R.T., 2010. Discrete choice experiments are not conjoint analysis. J. Choice Model. 3 (3), 57–72.
Lund, H., Poul Alberg Østergaard, D.C., Mathiesen, B.V., 2016. Energy storage and smart energy systems. Int. J. Sustain. Energy Plann. Manag. 11, 3–14.
Mazza, A., Bompard, E., Chicco, G., 2018. Applications of power to gas technologies in emerging electrical systems. Renew. Sustain. Energy Rev. 92, 794–806.
McFadden, D., 1974. Conditional logit analysis of qualitative choice behaviour. In: Zarembka, P. (Ed.), Frontiers in Econometrics. Academic Press New York, New York, NY, USA, pp. 105–142.
Nelson, H.T., Swanson, B., Cain, N.L., 2017. Close and connected: the effects of proximity and social ties on citizen opposition to electricity transmission lines. Environ. Behav. 50 (5), 567–596.
Ould Amrouche, S., Rekiou, D., Rekiou, T., Bacha, S., 2016. Overview of energy storage in renewable energy systems. Int. J. Hydrogen Energy 41 (45), 20914–20927.
Paravantis, J.A., Stigka, E., Mihalakakou, G., Michalena, E., Hills, J.M., Dourmas, V., 2018. Social acceptance of renewable energy projects: a contingent valuation investigation in Western Greece. Renew. Energy 123, 639–651.
Read, D.L., Brown, R.F., Thorsteinsson, E.B., Morgan, M., Price, I., 2013. The theory of planned behaviour as a model for predicting public opposition to wind farm developments. J. Environ. Psychol. 36, 70–76.
Roddis, P., Carver, S., Dallimer, M., Norman, P., Ziv, G., 2018. The role of community acceptance in planning outcomes for onshore wind and solar farms: an energy justice analysis. Appl. Energy 226, 353–364.
Schively, C., 2007. Understanding the NIMBY and LULU phenomena: reassessing our knowledge base and informing future research. J. Plan. Lit. 21 (3), 255–266.
Sepehri, A., Sarrafzadeh, M.H., 2018. Effect of nitrifiers community on fouling mitigation and nitrification efficiency in a membrane bioreactor. Chem. Eng. Process. Process Intensification 128, 10–18.
Sims, S., Dent, P., 2007. Property stigma: wind farms are just the latest fashion. J. Prop. Invest. Financ. 25 (6), 626–651.
Soini, K., Pouta, E., Salmiovirta, M., Uusitalo, M., Kivinen, T., 2011. Local residents' perceptions of energy landscape: the case of transmission lines. Land Use Policy 28 (1), 294–305.
Sopha, B.M., Klöckner, C.A., 2011. Psychological factors in the diffusion of sustainable technology: a study of Norwegian households' adoption of wood pellet heating. Renew. Sustain. Energy Rev. 15 (6), 2756–2765.
Sovacool, B.K., Lakshmi Ratan, P., 2012. Conceptualizing the acceptance of wind and solar electricity. Renew. Sustain. Energy Rev. 16 (7), 5268–5279.
Sposato, R.G., Hampl, N., 2018. Worldviews as predictors of wind and solar energy support in Austria: bridging social acceptance and risk perception research. Energy Res. Soc. Sci. 42, 237–246.
Steffen, B., 2012. Prospects for pumped-hydro storage in Germany. Energy Policy 45, 420–429.
Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., Thorsnes, P., 2010. Energy cultures: a framework for understanding energy behaviours. Energy Policy 38 (10), 6120–6129.
Toke, D., Breukers, S., Wolsink, M., 2008. Wind power deployment outcomes: how can we account for the differences? Renew. Sustain. Energy Rev. 12 (4), 1129–1147.
Vecchiato, D., Tempesta, T., 2015. Public preferences for electricity contracts including renewable energy: a marketing analysis with choice experiments. Energy 88 (Suppl. C), 168–179.
Webler, T., Tuler, S., Krueger, R., 2001. What is a good public participation process? Five perspectives from the public. Environ. Manag. 27 (3), 435–450.
Wilsdon, J., Willis, R., 2004. See-through Science: Why Public Engagement Needs to Move Upstream. Demos, London.
Yuan, X., Zuo, J., Ma, C., 2011. Social acceptance of solar energy technologies in China—end users' perspective. Energy Policy 39 (3), 1031–1036.