Technology in Society 81 (2025) 102780

Contents lists available at ScienceDirect

Technology in Society

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

Cross-validation of the Biofuels Beliefs Scale (BBS) on a European sample: A tool to measure the perception of the technological and contextual features of biofuels

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ARTICLE INFO

Keywords:
Biofuels
Beliefs
Measurement scale
Sustainable energy
Acceptance

ABSTRACT

Studies on the acceptance of renewable and sustainable energy technologies have grown exponentially over the past few decades. While there are a large number of technology acceptance models, none of them includes belief-related variables. Developed within the EC H2020 ABC-Salt project, this contribution focuses on the cross-validation, in a large sample (N = 1016), across eight European countries, of the Biofuels Beliefs Scale (BBS). The BBS is composed of 26 items, organized into six factors (i.e., Policy Making Legitimation, Emissions Sustainability, Global Environmental Sustainability, Technology Compatibility, Local Socio-Economic Sustainability, and Cost Savings). Factors are distinct, reliable, and each one composed of a psychometrically acceptable number of items. The validation procedure fulfilled the adequacy requirements regarding convergent, discriminant, and predictive validity. The BBS could be useful both for testing models on technology acceptance in future studies and for communication campaigns on biofuel-related issues in applied contexts (e.g., pre-/post-assessment, monitoring, etc.).

1. Introduction

Biofuels occupy a significant role in the context of the energy transition. While other renewable sources and electrification are considered as capital for fulfilling energy demand for domestic use and industrial production, biofuels are currently considered one of the most viable, sustainable, and renewable energy technologies for the transport and logistic sector [1]. The shift from fossil fuels to biofuels in everyday life for transportation, power generation, and heating would offer several economic, environmental, and social benefits. However, biofuels still include features that might inhibit their social acceptance [2–4]. There is evidence that the development of the first generation of biofuels (i.e., the ones produced from grown-on-purpose biomass) can lead to negative effects in terms of both greenhouse gas emissions and competition with food production, especially in developing countries [5]. Recent biofuel production techniques have tried to reduce the likelihood of these potentially negative effects, for instance proposing as feedstock the microalgae, which have a number of advantages such as fast growth rate and lack of competition with food production [6]. However, a vibrant public debate has occurred about biofuel's local and global impacts and thus, if biofuels are to be developed at an industrial scale within the EU, public opinion needs to be seriously taken into consideration. In sum, the study of biofuel social acceptance seems quite important for an effective energy transition.

The aim of this paper is to contribute to the understanding of biofuel social acceptance by developing a new tool to measure people's beliefs about biofuels.

1.1. *The relevance of beliefs for technology acceptance*

Beliefs have been considered as important antecedents of behavior in different theoretical models since decades (e.g., see [7,8]), including the well-known Theory of Planned Behavior (TPB, [9,10]). If values have been postulated as the general and abstract principles that guide an

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https://doi.org/10.1016/j.techsoc.2024.102780
Received 18 December 2023; Received in revised form 30 August 2024; Accepted 1 December 2024
Available online 3 December 2024

individual's behaviors, beliefs are the factual statements that people consider to be true or false when they think about a specific object or behavior [11,12].

Beliefs should not be confused with objective knowledge, which is sometimes included in psychological social acceptance models [13]. In fact, while measures of objective knowledge usually focus on assessing how correctly informed people are about biofuels (e.g., with true-false tests), measures of beliefs simply concern how much people trust specific representations, without rating them as correct or wrong. Baral [14] found that people's socio-demographic characteristics are a key factor for their objective knowledge about biofuels. However, research shows that objective knowledge of a topic, as measured by specific psychometric tools (e.g., true-false questions) can be quite irrelevant to decision-making (e.g., [15]). At the same time, beliefs are strongly associated with intention and behavior [16]. Research into hydrogen technologies reveals that beliefs concerning contextual and technology-related aspects, such as perceived effects, exert a more profound influence on acceptance than objective knowledge, as demonstrated in the studies conducted by Achterberg et al. [17] and Huijts and Van Wee [18]. Beliefs should also not be confused with subjective knowledge, i.e. how much individuals think that they know about biofuels. More generally, subjective knowledge can be considered as a sort of contextual self-confidence [19] and has not much to do with specific conceptions people have about this technology. As a general trend, individuals tend to possess limited subjective knowledge about sustainable energy technologies, like biofuels, as noted by Pagiaslis and Krontalis [20]. Subjective knowledge can significantly shape people's beliefs. As shown in the study conducted by Siegrist and Cvetkovich [21], greater knowledge of a dangerous technology is directly associated with a greater tendency not to trust the people responsible for managing that technology, thus accentuating the perceived risk associated with it.

Beliefs, instead, are important because they measure people's representations about a given technology, without judging them [22]. In fact, beliefs are crucial drivers orienting the individuals' responses in terms of attitudes (e.g., acceptability), intentions to adopt (acceptance) or not, and possible behavioral adoption concerning the target of renewable and sustainable energy technology (e.g., biofuels, in the present case). Regarding their concreteness and specificity, beliefs can be challenged via communication, information provision, and experience interventions [23]. For instance, in a recent study about the acceptance of wind energy, Cranmer et al. [24] show that experiencing wind energy infrastructures through virtual reality is an efficient way to weaken prior detrimental beliefs concerning expected visual and acoustic impacts of wind turbines, thus increasing their acceptance.

Since scientific knowledge is socially interpreted in its creation, diffusion, and use, it is crucial to explore the beliefs of different stakeholders, together with their values, aims, and their power relationships [25]. The goal of the present paper is to validate a scale that can be used to reliably assess beliefs about biofuel technology and about the context where it can be employed. Such a scale could then be included in existing technology acceptance models to better understand which specific beliefs affect people's acceptability attitudes and acceptance intentions towards biofuels over and above objective and subjective knowledge.

1.2. *Technology-related and context-related beliefs*

As Fig. 1 shows, a recent qualitative study by Dessi and colleagues (2022) found that the main incentives and barriers to biofuel acceptance can be summarized in three macro-areas: a first macro-area includes beliefs regarding the intrinsic technological aspects of the target technology to be adopted (Technology macro-area); the second macro-area consists of beliefs on the adoption process' contextual factors, i.e., those variables dealing with economics and marketing as well as related policies and administrative measures (Context macro-area); finally, the third macro-area refers to personal factors (cognitive, affective, and social) of its adopter (Person macro-area).

Some social-psychological and interdisciplinary models, like the Sustainable Technology Acceptance Model (SETA, [27]), have tried to explain the acceptance of energy technologies by focusing on the Person macro-area and providing standard tools to measure the related variables (e.g., [28]). The SETA model is among the most comprehensive frameworks for examining the acceptability and acceptance of renewable and sustainable energy technologies. It integrates established

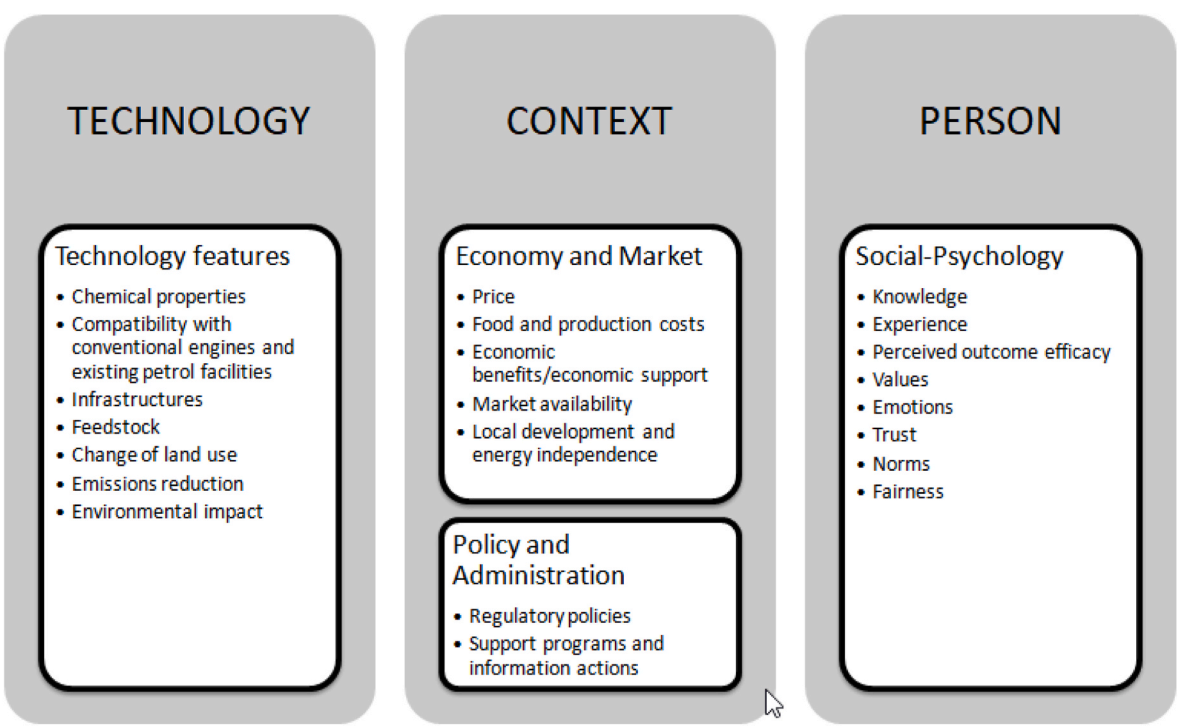


Fig. 1. Macro-areas, factors clusters, and variables related to biofuel acceptance (based on [26]).

theories from social and environmental psychology, such as the theory of planned behavior [29] and the norm activation model [30]. Despite its importance, the SETA primarily focuses on the social-psychological characteristics of adopters, whereas other dimensions - such as perceived technological, contextual, and personal features - which could increase the prediction of the acceptability and acceptance of renewable and sustainable energy technologies, are not considered. To address this gap, Bonaiuto and colleagues [31] recently introduced the integrated sustainable energy technology adoption model (i-SETA), including variables about two categories of beliefs related to biofuels, i.e. contextual and technological - as determinants of biofuels' acceptability and acceptance - which were not considered in existing models.

The present study, deals specifically with beliefs that people have about these under-represented characteristics of biofuels, and aims at developing a tool to measure such beliefs. This tool is developed with the aim of having, for future studies, a validated biofuel belief measure, allowing comparison at different times or between groups. It is important to stress that, rather than on the actual features of a given technology (e.g., biofuels) or of a given context (e.g., a region or a country market and economy, or policy), the target here is to understand the beliefs that people hold on these topics.

Technology acceptance models have so far focused on the role of variables such as values, attitudes, and norms (e.g., [27,32,33]). The positive feature of this kind of models is that, since they include broad psychological variables, most of the items representing the measured variables focus on socio-psychological dimensions (e.g., values, social norms, emotions) and are not tailored to a specific technology in terms of item content. Thus, these models can be tested with different technologies and in different contexts, allowing comparisons. On the other hand, such models seem to be less adequate in providing specific indications about beliefs people have about a specific technology and its context, as that would be possible only via very items focusing on the specific technology or on the specific context.

The intrinsic characteristics of the technology itself (e.g., chemical properties, environmental impact, feedstocks, emissions) and the contextual aspects (e.g., economic/market aspects and political/administrative aspects), as interpreted by potential adopters in relation to their beliefs and perspectives, shape the acceptability, acceptance, and adoption of a particular renewable and sustainable energy technology, as highlighted in the qualitative study on biofuels social acceptance by Dessi et al. [26]. Beliefs concerning the intrinsic characteristics of biofuels exert both positive and negative influences on the technology's acceptance. In terms of negative factors, Jayed et al. [34] identified specific chemical attributes, like the use of vegetable oils in traditional fossil fuel engines, the necessity for new infrastructure development [35], and concerns related to land use changes [2]. Conversely, positive attributes encompass the compatibility of biofuels with conventional engines and existing petrol stations [36], as well as the potential for reducing harmful emissions [37]. Beliefs about contextual aspects also play a crucial role in the acceptance of sustainable and renewable energy technology. In this sense, challenges hindering the acceptance of biofuels include beliefs about the high production costs associated with microalgae [38] and the limited accessibility of biofuels at nearby filling stations [39]. Conversely, contextual factors that promote the acceptance of biofuels include beliefs about their potential to strengthen the local economy [40] and the presence of government support programs [41]. Thus, providing a better and more systematic approach to the measurement of contextual and technological beliefs, to be integrated with the existing models, would provide more concrete hints on how to adjust information and communication in a specific situation, such as in the case of biofuels.

Even though some scholars (see Table 1) have proposed instruments to measure technology-related beliefs, the existing tools are sparse and usually not validated with a systematic psychometric approach (including reliability checks and scale structure exploration). As reported in Table 1, response scales of existing measures are mixed in nature (e.g., Likert or dichotomous scales) and diverse in format (i.e., 5 or 7 points for Likert scales), thus hindering the comparability of existing results. It is certainly true that the literature offers various examples of attempts to measure relevant beliefs for the social acceptance of various energy technologies, including biofuels, but the overall figure is characterized by i) a non-systematic approach (i.e., not oriented toward study reproducibility in different contexts); ii) a limited psychometric rigor (i.e., not involving psychology experts in the item formulation, not combining exploratory and confirmatory factor analysis, and relying on small and not heterogeneous samples), and iii) the use of tools created as *ad hoc* solutions for the very specific study's needs, without any ambition to create a standardized tool with clearly

Table 1
Existing measures of technology-related and context-related[1] beliefs.

Ref	Example	N items	Response scale	Technology	Cronbach's α	EFA, CFA, PCA
Bakhtiyari et al. [42]	Biofuels burn cleaner than regular gasoline	20	1 (very low) – 5 (very high)	biofuel	0.95	CFA
Pagiaslis & Krontalis [20]	Biofuels are responsible for worsening food sufficiency in the Third World	5	1 (strongly agree) – 7 (strongly disagree)	biofuel	0.79	n.a.
Amin et al. [43]	Biodiesel may take up precious agricultural land	4	1 (strongly agree) – 7 (strongly disagree)	biodiesel	0.67	CFA
Cacciatore et al. [44]	Do you think using biofuels[ethanol] will increase, decrease, or have no effect on the cost of fuel at the pump?	1	1 (increase a great deal) – 9 (decrease a great deal)	biofuel	n.a.	n.a.
Moula et al. [45]	The production of biofuels has a direct increasing effect on food prices	5	yes – no	biofuel	n.a.	n.a.
Yaghoubi [46]	Biofuel production leads to an increase in the price of food	9	1 (very low) – 5 (very high)	biofuel	0.89	n.a.
Amin [43]	The government should provide more financial support to researchers and industries in developing biofuels	5	1–7 (different labels)	biodiesel	0.67	CFA
Bakhtiyari et al. [42]	There are insufficient water resources for biofuel production in Iran	21	1 (very low) – 5 (very high)	biofuel	0.93	CFA
Zoellner et al. [47]	The usage of wind energy plants will improve Germany as a business location	80[2]	1 (entirely incorrect) – 5 (completely correct)	renewable energies	n.a.	n.a.
Dragojlovic & Einsiedel [48]	The federal government provides subsidies such as tax credits to certain agricultural groups to develop biofuels	3	1 (strongly disapprove) – 7 (strongly approve)	biofuel	alpha 0.86	n.a.
Zhang et al. [49]	Indicate the degree of importance of different fuel characteristics related to purchasing new car or fuel consumption (e.g., fuel availability, engine modification)	8	1 (not at all important) – 5 (very important)	biofuel	alpha 0.70	PCA
Zoellner et al. [47]	The usage of wind energy plants will improve Germany as a business location	3	1 (entirely incorrect) - 5 (completely correct)	renewable energies	n.a.	n.a.

Notes: n.a. = no analysis presented in the paper.

tested reliability and validity.

There is therefore a literature gap in terms of a reliable and valid tool to measure biofuels beliefs according to a multidimensional structure – i.e., attempting to cover all the relevant features (technology features as well as contextual features in terms of both economics and market and politics and administration) – and employing a standard set of items using the same response scale. Filling such a gap would represent an advancement within the specific field of biofuels social acceptance, and more broadly within the field of renewable and sustainable energy technologies social acceptance, in terms of increased standardization of measurement for the relevant beliefs considered as drivers, or barriers, of biofuels and other new energy technologies acceptability, acceptance, and adoption. Such an effort would offer an immediate reliable and valid tool for the measurement of biofuels beliefs, and more generally would offer a process benchmark for the development of future similar tools to measure any other sustainable and renewable energy technology beliefs. In general, such a scientific endeavor should increase cross-studies comparisons, and thus opportunities for cumulative scientific knowledge.

2. General and specific aims

The current paper aims to propose and cross-validate the Biofuels Beliefs Scale (BBS) on an international sample of general public and stakeholders. This tool will allow scholars to better investigate the specific understanding that diverse stakeholders have of biofuels. The BBS measures beliefs about the biofuels' energy technology *per sé*, as well as about its relevant context including economics/marketing features and politics/administrative features. Consistently with the general aim, two specific research aims have been defined, namely.

- Specific Aim 1: exploration and verification of the scale's factorial structure, to get distinct and reliable factors, each one composed of a psychometrically acceptable number of items;
- Specific Aim 2: testing of the scale's validity, specifically through the psychometric verification of both convergent and discriminant validity [50,51].

3. Method

3.1. Procedure

Recruitment was carried out between July 2021 and January 2022 with participants from eight European countries (Belgium, France, Germany, Italy, the Netherlands, Sweden, Norway, and United Kingdom), both laypeople and biofuel stakeholders. The eight countries were chosen for being partners of the EU project that funded this study and, even if they cannot be considered as a representative EU sample, they are good examples of the variety of EU countries as for what concerns size and different degrees of local biofuels development [52].

The survey was uploaded online (on www.qualtrics.com) and self-administered by participants. To recruit general public participants, the English version of the questionnaire was shared on the Prolific platform (https://www.prolific.com) on July and August 2021. The platform was set to collect one hundred participants per country, balanced by gender and age. To reach biofuel stakeholders, Qualtrics' Online Panel service was employed. This is a commercial service provided by the company Qualtrics to collect data in populations that are not easily reachable on generic platforms (e.g., Prolific). The service actively contacts people belonging to the defined population and asks, in exchange for compensation, to fill in the questionnaire. The initial request to Qualtrics consisted of finding fifty biofuel stakeholders living in the eight Countries included in the EU project. However, the service informed that, considering the specificity of the topic, it was only possible to find biofuel stakeholders from the four largest Countries (Italy, UK, Germany, and France). To ease participation from the stakeholders of each selected country, the questionnaire, originally developed in English, was translated into Italian, French, and German. In this way, four links were created to which the different stakeholders were directed according to their native language. The questionnaires were spread during January 2022. To define participants as "biofuel stakeholders" quality check questions and enforced screening criteria were included at the beginning of the questionnaire (e.g., Work in biofuel/bioenergy sector: If "Definitely not" OR "Maybe not" was chosen then the participants were excluded). The entire project of investigation, detailed in its execution modalities and participants involved, has been submitted to the Ethics Committee of the Department of Psychology of Developmental and Socialization Processes, Faculty of Medicine and Psychology, Sapienza University of Rome (Italy), receiving the approval to proceed (submitted April 28, 2021, final approval May 27, 2021, Protocol n. 742, Pos. VII/15).

3.2. Participants

The sample consisted of 1016 participants (mean age = 32.49, *sd* = 11.50). One hundred participants were from Belgium, 153 from France, 153 from Germany, 152 from Italy, 101 from the Netherlands, 101 from Sweden, 103 from Norway, and 152 from the United Kingdom. Concerning gender, the sample consisted of 419 women (41.2 %) and 598 men (58.8 %). The sample had a high educational level and came from a variety of fields of study ranging from STEM (Science, Technology, Engineering, and Mathematics) disciplines to SSH (Social Sciences and Humanities). In addition, employed participants worked in different organizations (SMEs, Large Companies, Governmental Organizations, Academies and Research Centers, and NGOs) (Table 2). Sampling covered both the general public (79.4 %) and expert stakeholders (20.6 %): regarding expert stakeholders, professional categories that are relevant to biofuels were included, based on a previous mapping study within the same project [53].

3.3. Tools

The focus of this paper is on the validation of the Biofuels Beliefs Scale, which was part of a larger questionnaire including other tools and had the aim of testing a theoretical model of biofuel acceptance (see [31]). The initial BBS consisted of sixty-eight items measuring biofuel features about the "Technology" and the "Context" macro-areas, the latter composed of Economy/Market and Policy/Administration aspects (see Appendix 1 for the list of items and their origin). Such items were developed to measure the features that emerged in the first two macro-areas reported in Fig. 1, based on the qualitative results from Dessi et al. [26], namely.

- for the "Technology" macro-area, the features related to Chemical properties, Compatibility with conventional engines and existing facilities, Compatibility with (current) infrastructures, Perceived feedstock sustainability, Change of land use, Perceived emissions, and Environmental impact;
- for the Economy and Market aspects within the "Context" macro-area, the features related to Price, Food cost, Economic benefits, Economic support, Limited availability on the market, Local development, and Energy independence;
- for the Policy and Administration aspects of the "Context" macro-area, the features related to Regulatory policies on the one side, and Support programs and Information actions on the other side.

All the items were measured via a 7-point Likert-type response scale, from 1 = "strongly disagree" to 7 = "strongly agree".

Different validity criteria were verified, namely: i) convergent

[2] This value refers to the whole questionnaire.

Table 2
Descriptive statistics of the sample.

		Italy	United Kingdom	France	Germany	The NL	Sweden	Norway	Belgium
Prolific		100	100	100	100	101	101	103	100
Qualtrics		52	52	53	53	0	0	0	0
Education	**Primary**	2	3	2	6	1	8	5	0
	Lower secondary	2	5	2	3	3	6	9	1
	Upper secondary	46	20	22	48	13	20	25	11
	Post-secondary non-tertiary	20	20	16	18	9	19	9	5
	Bachelor's degree	45	65	49	39	52	33	27	45
	Master's degree	37	36	57	35	22	13	28	33
	Doctorate/PhD	0	3	5	4	1	2	0	5
Field of study	**Natural sciences**	34	27	26	29	19	24	23	20
	Engineering and Technology	43	41	43	42	23	32	31	33
	Medical and Health sciences	8	13	11	16	11	11	7	5
	Agricultural sciences	0	4	4	3	0	1	0	1
	Social sciences	41	39	40	39	36	21	33	30
	Humanities	26	28	29	24	12	12	9	11
Organization	**Academy and Research Centre**	11	23	4	26	6	9	8	6
	Governmental Organization	5	12	18	8	7	9	13	11
	Large Company	48	43	45	58	41	34	44	32
	NGO	6	2	0	4	3	2	0	5
	Small-medium Enterprises	54	51	56	34	32	41	31	43
	Unemployed	28	21	30	23	12	6	7	3

validity, i.e. how well subscales correlate with other measures that are assumed to be related; ii) discriminant validity, i.e. the degree to which two measures are tapping separate constructs [54]; and iii) predictive validity, i.e., the ability of the tool to predict related outcomes [55].

For validity testing, the following measures were considered.

- Values (hedonic, altruistic, biospheric, egoistic, and traditional). The first 16 selected items are issued from the "Environmental Value Survey" (E-SVS; [11,56]); while the last 5 items related to traditionalism are derived from the Schwartz Value Survey (SVS; [57]), measured on the standard one 7-step Likert, with the extremes "opposite to my values" and "of extreme importance". Reliability ranges between α = .70 and α = .91.
- Subjective knowledge about biofuels (adapted from [20]) included 6 items, e.g., 'How knowledgeable are you regarding the production of biofuels?' Answers ranged on a 7-point Likert scale, from "Not at all " to "Completely " (α = .94).
- Biofuels Attitude Scale as Acceptability (BASA, [31]). A semantic differential consisting of 16 adjective pairs, e.g., "I think that biofuel technology is: alien/familiar; harmful/safe", on a 7-step Likert response scale, composed of two factors: Positive Attitude Toward Biofuels (α = .93) and Biofuels Usability (α = .68).
- Biofuels Intention Scale as Acceptance (BISA, see [31]): eleven items, organized into two factors. The factor Use Intention is composed of 5 items, e.g., "How willing would you be to fuel your private vehicle with biofuels?"), with response options ranging from 1 = "Very unwilling" to 7 = "Very willing", with the added, "Not applicable" option, α = .84. The factor Socio-Political Support Intention is composed of 6 items, related to the following question: "If there was a discussion in your area about whether or not to place a biofuel station, how likely would you be to take the following actions in favor or against it" (e.g., Sign a petition; Make a donation). Response scale ranges from 1 = "I would certainly not do this" to 7 = "I would certainly do this", α = .90.
- Items about respondents' socio-demographic characteristics.

3.4. Analyses

For this data elaboration, R Studio version 2022.02.03 was employed, specifically the statistical packages "foreign" [58], "pastecs" [59], "car" [60], "psych" [61], "lavaan" [62], "GPArotation" [63], and "esemComp" [64].

3.4.1. Specific Aim 1: exploration and verification of the scale's factorial structure

Since the BBS items were developed based on both the literature review and the outcomes of a qualitative study [26], an exploratory approach (including a parallel analysis and an exploratory factor analysis, EFA) was applied in the first step after data screening and cleaning.

A cross-validation procedure (see [65,66]) was pursued by randomly splitting the sample into two halves, to develop a model on the first half of the sample (i.e., the calibration sample, N = 512), and then to confirm it on the second half (i.e., the validation sample, N = 505). Moreover, an exploratory structural equation modeling (ESEM) factor analysis was run on the same part of the sample employed for the EFA.

The first analysis, involving the first half of the sample, thus intended to find a preliminary structure of the scale. Since Bartlett's test and Kaiser-Meyer-Olkin (KMO) test confirmed the sampling adequacy and the correlation matrix factorability, the sixty-eight items were submitted to EFA, using the principal axis factoring (PAF). Consequently, Cronbach's alpha values were computed to assess factors' reliability. The following decision criteria were employed: scree-plot and parallel analysis [67,68], minimum average partial (MAP; [69]), and Bayesian information criterion (BIC). Oblimin rotation was initially used for factor interpretation. Since the extracted factors were scarcely correlated, Varimax rotation was chosen for the subsequent steps.

On the same half of the sample, an ESEM analysis was then conducted, employing the maximum likelihood robust estimator. Three solutions were tested: four, five, or six factors. Following Marsh et al. [70,71] we used an orthogonal target rotation with an epsilon value of 0.5. Since there was no specific hypothesis on which indicators should load on the expected factors, the ESEM, i.e., a modern technique integrating the classical EFA, allowed us to further explore the data and confirm the solution that emerged from the previous exploratory analysis.

Later, confirmatory factor analysis (CFA) was run on the second half of the sample, testing four-factor, five-factor, and six-factor models. The robust maximum likelihood (RML) method was employed to account for non-normal data (since Mardia's coefficients were significant; [72]). For inter-model comparisons, since all models were nested, ΔCFI >0.010 was taken as evidence of robust differences in relative model fit Cheung and Rensvold [73].

3.4.2. Specific Aim 2: testing of the scale's validity

Consistently with the call of Rönkkö and Cho [74], for a combination of methods to assess validity, both CFA loadings and zero-order correlations were used to test convergent and discriminant validity.

The CFA approach allows the verification of convergent and discriminant validity [51,75]. Specifically, the size and statistical significance of factor loadings connecting different manifest variables (i.e., items) with a latent variable (i.e., the Policy-Making Legitimation) provide evidence for convergent validity, whereas correlations between latent variables that are lower than their factor loadings provide evidence for discriminant validity ([50], pp. 263–264).

Zero-order correlations (Pearson's *r*) were computed between the scale's factorial scores (as derived from EFA) and other socio-psychological constructs included in the questionnaire (see the Tools section). According to the hetero-trait-mono method coefficient, thresholds for this test are usually considered to be 0.30 (small, thus divergent), 0.40 (mildly convergent), and 0.50 (clearly convergent) [76–80].

4. Results

4.1. Preliminary analyses

Data were checked for univariate and multivariate normality (see Appendix 2). The Shapiro-Wilk's test was significant (all $p < .001$) for all 68 items, meaning that data are not normally distributed and that the planned analysis for testing Aims 1 and 2 can be applied to the data set with consideration of normality assumptions violations. Since sporadic missing data was observed, each missing value was replaced by the mean value of the corresponding variable.

4.2. Specific Aim 1: Exploration and verification of the scale's factorial structure and factors' reliability

The EFA run for fulfilling Specific Aim 1 produced the following outcomes. A significant Bartlett's test of sphericity ($\chi^2(2278) = 13312.3$, $p < .001$), and a Kaiser-Meyer-Olkin (KMO) of 0.88 indicated that the correlation matrix was suitable for factor analysis. The Parallel Analysis scree-plot revealed two visible elbows at the fourth and sixth eigenvalue (see Appendix 3). The Velicer MAP achieved a minimum of 0.01 with seven factors, while BIC achieved a minimum of −8093.83 with six factors. Finally, the parallel analysis indicated an asymptotically flattening trend after the sixth eigenvalue, a solution supported by the BIC.

Due to the presence of two elbows in the parallel scree-plot, we tested a four-factor, a five-factor, and a six-factor solution. The conduction of a series of EFAs allowed the deletion of several items (n = 42), which were excluded for either item saturation on the factor inferior to 0.40 or similar saturation of the same item in different factors, which leads to an ambiguous interpretation. Since different decision rules supported either a seven- or a six-factor solution, but only six eigenvalues were greater than one, six factors were retained and orthogonally rotated for interpretation; moreover, the explained variance of the scale was higher in the six-factor solution. For these multiple reasons, this solution was retained. The final Biofuels Beliefs Scale was composed of twenty-six items (Table 3).

The Exploratory Structural Equation Modeling (ESEM) was used to confirm the results from the EFA, run on the calibration sample. Three solutions were tested, respectively including four, five, or six factors (Table 4).

The four-factor model did not show an acceptable fit to the data. The five- and six-factor models were instead able to achieve an acceptable and a good fit to the data, respectively. The six-factor model (see loadings in Appendix 4) confirmed the structure that emerged from EFA and outperformed the five-factor model on all model selection criteria. The six-factor solution was thus retained for subsequent tests.

Table 5 reports the results of the CFA that was performed to fulfilling Specific Aim 2.

As for the ESEM, the four-factor model presented a not-acceptable fit to the data with CFA analysis. With the same analysis, instead, the five-

Table 3
Factor pattern matrix after VARIMAX rotation.

Item ID	Item content	Loadings	Explained Variance	Α
Contextual features (Policy and Administration) - Policy Making Legitimation			14 %	0.86
P4_Sup1	Political institutions should promote research in the field of biofuels	0.80		
P3_Eco2	The government should provide more financial support to researchers and industries in developing biofuels	0.70		
P4_Pol6	A common political willingness is necessary to support specific biofuel policies	0.70		
P4_Pol1	Policies are needed for the transition from fossil fuels to biofuels	0.67		
P4_Inf3	Scientists should demonstrate to the public why we need to switch to biofuels in the coming years	0.62		
P4_Pol5	An international Biofuels Sustainability Pact would be helpful in securing the sustainability of biofuels production	0.61		
P3_Eco4	The government should provide subsidies such as tax credits to certain agricultural groups to develop biofuels	0.54		
Technological features - Global Environmental Sustainability			13 %	0.86
P2_Env2	Biofuels production threatens plants and wildlife	0.78		
P2_Chan1	Biofuels take up precious agricultural land	0.70		
P2_Chan2	Biofuels, via indirect land use change (ILUC), cause deforestation R	0.66		
P2_Feed1	Biofuels are responsible for worsening food sufficiency for the Third World	0.66		
P2_Env5	Developing biofuels poses harm to the ecosystem and environment	0.64		
P2_Env1	Biofuels have negative environmental impacts	0.61		
Technological features – Emissions Sustainability			7 %	0.80
P2_Emi2	Biofuels use decreases the greenhouse gas emissions	0.83		
P2_Emi1	Increasing the share of biofuels reduces CO2 emissions	0.67		
P2_Chem1	Biofuels burn cleaner than fossil fuels	0.50		
P2_Env4	Biofuels contribute to a better environment	0.44		
Technological features - Technology Compatibility			6 %	0.76
P2_Comp3	Biofuel-based distribution system is compatible with the fossil fuel based one	0.74		
P2_Comp2	Biofuel-based storage system is compatible with the fossil fuel based one	0.73		
P2_Comp1	Biofuel-based transport system is compatible with the fossil fuel based one	0.63		
Contextual feature (Economy and Market) - Local Socio-Economic Sustainability			5 %	0.72
P3_Loc5	The usage of biofuels impairs local business	0.71		

(*continued on next page*)

Table 3 (*continued*)

Item ID	Item content	Loadings	Explained Variance	A
P3_Loc4	Growing biofuel plants reduces the quality of life in local communities	0.56		
P3_Loc6	Biofuels have poor added value at the local level	0.50		
Contextual feature (Economy and Market) - Costs Savings			5 %	0.64
P3_Pri6	Biofuels costs could lead to an increase in transportation-related costs	0.67		
P3_Pri2	Biofuels increase the cost of fuel at the pump	0.62		
P3_Pri3	Biofuel increases the maintenance costs of the car	0.52		

Table 4
Fit indices for the four-factor (4F), five-factor (5F), and six-factor (6F) exploratory structural equation modeling (ESEM) solutions.

	4F	5F	6F
χ2	774.83	580.71	389.69
Df	227	205	184
P	0.000	0.000	0.000
CFI	0.89	0.93	0.94
TLI	0.84	0.88	0.95
RMSEA [90 % CI]	0.07 [0.06, 0.07]	0.06 [0.050.07]	0.05 [0.040.05]
SRMR	0.04	0.03	0.02
AIC	41374.78	41224.67	41084.65
BIC	41900.34	41843.46	41792.45
SABIC	41506.7	41380	41262.4

Table 5
Fit indices for the four-factors (4F), five-factors (5F), and six-factors (6F) confirmatory factor analysis (CFA).

	4F	5F	6F
χ2	952.64	612.44	560.37
df	285	283	280
p	0.000	0.000	0.000
CFI	0.87	0.95	0.96
TLI	0.86	0.94	0.95
RMSEA [90 % CI]	0.07 [0.06, 0.07]	0.05 [0.04 0.05]	0.04 [0.04 0.05]
SRMR	0.12	0.06	0.05
AIC	41347.75	41011.55	40965.48
BIC	41626.57	41298.82	41265.42
SABIC	41417.08	41082.98	41040.06

and the six-factor models were able to achieve both a good fit to the data. The six-factor model outperformed the five-factor model on three out of three model selection criteria (i.e., AIC, BIC, and SABIC). Lastly, because of its consistently better performance across different indices of fit (i.e., CFI, TLI, RMSEA, and SRMR), the six-factor model was retained for subsequent tests.

Concerning validity, the use of CFA yielded a six-factor solution that fulfills both convergent and discriminant validity criteria (see [50]). In particular, inspecting the magnitude and the statistical significance of factor loadings connecting different observed variables (i.e., items) with a latent variable (e.g., Cost Savings, Policy Making Legitimation, etc.) allows for testing convergent validity, whereas correlations between latent variables that are lower than their factor loadings provide evidence for discriminant validity [50]. Factor loadings are presented in Fig. 2, while correlations between variables are presented in Table 6.

4.3. Specific Aim 2: Validation of the scale's factorial structure

Lines 1–6 present correlations between the BBS factors; Lines 7–12 indicate correlations between the BBS and some variables employed in studies on biofuel acceptance, i.e., values and subjective knowledge on biofuel; Lines 13–16 show correlations between the BBS factors and measures of biofuel acceptability and acceptance.

4.3.1. Convergent and discriminant validity

Correlations among factorial scores are reported: all the correlations between factors, in absolute value, vary between 0.00 and 0.48; these are lower than their factor loadings since among the latter the lower one equals to. 49 on the corresponding latent variable. This outcome is proof of convergent validity, thus providing evidence also for discriminant validity.

Discriminant validity is accounted by the correlations of BBS factors with Values [11]; [57] and Subjective knowledge about biofuels. As expected, such correlations were found as non-significant or of small magnitude, ranging from 0.06 to 0.33.

4.3.2. Predictive validity

The correlations between BBS factors and some potential dependent variables were computed for verifying the predictive validity. The Biofuels attitude components, i.e., Positive Attitude Toward Biofuels and Biofuels Usability, showed differences in their relationship with BBS factors. In fact, Biofuels Usability was not associated or only weakly associated (*r* ranging from 0.07 to 0.27) with BBS factors, and this suggests that the feasibility of biofuels' usage is a different construct but still related to beliefs about biofuels. On the other hand, the Positive Attitude component is positively associated with BBS factors (*r* ranging from 0.12 to 0.60), demonstrating a degree of association with beliefs about biofuels from small to large. Finally, Use Intention and Socio-Political Support Intention (components of the Acceptance scale), were positively associated with beliefs about biofuels (*r* ranging from 0.11 to 0.51), showing a degree of association with beliefs about biofuels from small to large.

5. Discussion

5.1. A standard self-report scale to measure biofuel beliefs

The goal of this study was to develop and validate a Biofuel Beliefs Scale to measure what people think about specific technology-related and context-related characteristics of biofuels. The outcomes of the cross-validation analyses allow to obtain a set of distinct and reliable factors, each of them including an acceptable number of items, in line with Specific Aim 1. The subsequent validation procedure fulfilled the adequacy requirements regarding convergent, discriminant, and predictive validity [50,51], consistently with the Specific Aim 2.

More in detail, a six-factor scale composed of twenty-six items that have a stable structure and satisfactory fit indices emerged. Such factors were respectively labeled Technology Compatibility, Emissions Sustainability, Global Environmental Sustainability (for the technological features); Local Socio-Economic Sustainability and Cost Savings (for the market-economics contextual features); and Policy Making Legitimation (for the administrative-policy contextual features). These dimensions cover both aspects of the beliefs that emerged in Dessi et al. 's (2022) results and of beliefs identified in the literature review: i.e., on the one side Technology aspects, and on the other side Contextual aspects, which covers both biofuels' economy and policy issues. More specifically, Global Environmental Sustainability, Emissions Sustainability, and Technology Compatibility concern the Technology aspects; while Policy Making Legitimation, Costs Savings, and Local Socio-Economic Sustainability tap into the Contextual factors macro-area. More specifically, Policy Making Legitimation regards Politics and Administration, while both Cost Savings and Local Socio-Economic Sustainability represent Economics and Market.

The content and distinctiveness of the emerging factors embrace all the aspects that were found by the previous scattered non-systematic

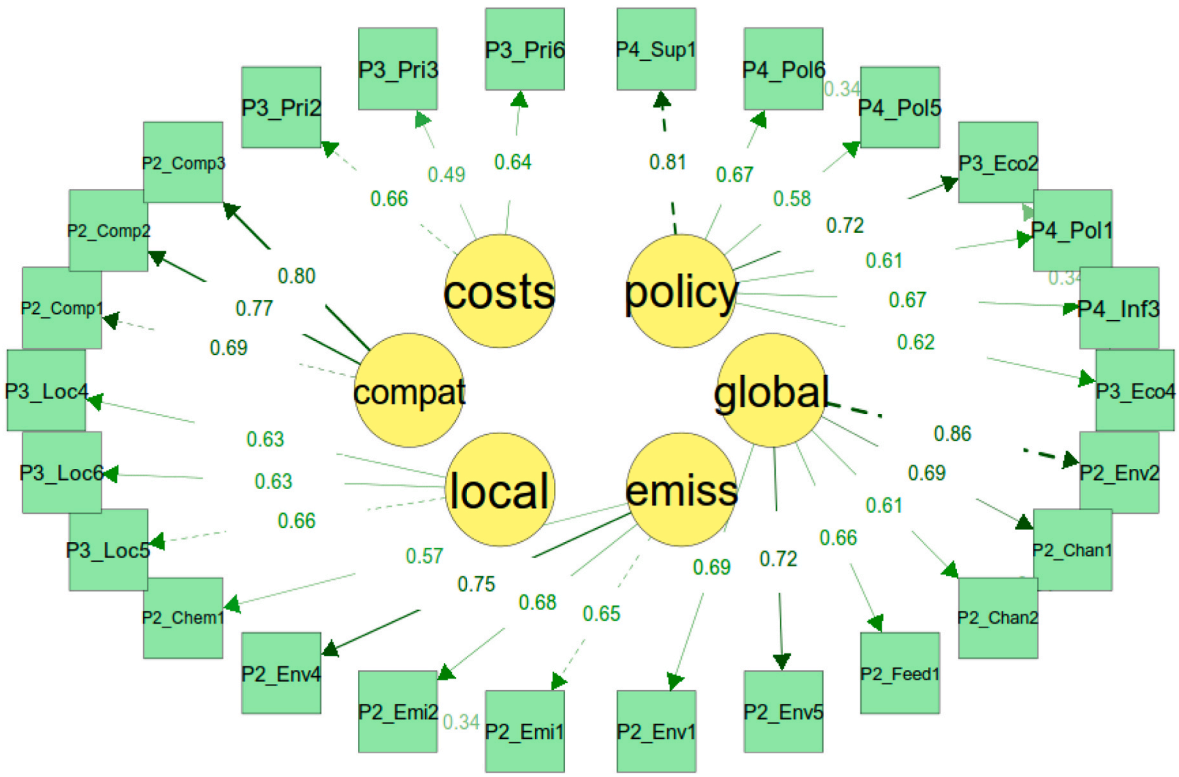


Fig. 2. Factor loadings between items and latent variables.
Notes: policy = Policy-Making Legitimation; global = Global Environmental Sustainability; emiss = Emissions; local = Local Socio-Economic Sustainability; compat = Technology Compatibility; costs = Cost Savings.

and poorly standardized research literature on the topic. For instance, biofuels' global impacts and emissions had already been examined by Bakhtiyari et al. [42] in Iran and by Pagiaslis and Krontalis [20] in Greece, but in both these cases using single items. Also, beliefs about biofuels' prices and their impact at the local level have already been investigated [44], [46], [45]. Other studies had instead considered the role of policymaking and the importance of economic benefits associated with the use of biofuels [43,48]. Technology Compatibility has rarely been considered in literature, but, for instance, Milazzo et al. [36] mention it as one of the prominent issues to deal with to ease the spread of biofuels. Local effects of biofuels were instead previously analyzed in a study about public acceptance of renewable energies in Germany [47].

With the present contribution, BBS is to our knowledge the first standard multidimensional self-report scale to offer a systematic comprehensive set of factors capable of simultaneously measuring all the relevant beliefs regarding both technological and contextual features of biofuels, overcoming the fragmentation highlighted above. BBS factors could be considered in future research for different purposes, such as to test their role as drivers, or barriers, concerning acceptance, and criteria to test the efficacy of interventions aiming to improve those beliefs with targeted public and stakeholders. Beliefs about biofuels can also be of fundamental importance in shaping the type of policy subsystem (e.g., collaborative, or adversarial), and the relative balance of power between policy coalitions that are responsible for implementing the recent technology. As reported by Rietig [25], there is a close link between scientific knowledge, learning, and beliefs, especially in the field of environmental policymaking and in its relationships with economic development-focused policies. The European Renewable Energy Directive was dominated by political disagreements between two polarized coalitions. There was an initial agreement on increasing the share of renewable energies in transport that turned into conflict after new scientific evidence emerged on the potential negative environmental impacts of first-generation biofuels. As reported, beliefs can be dynamic and could uncover pre-existing conflicts between policymakers. Therefore, the collaborative policy subsystem shifted to an adversarial policy subsystem [47]. Within such scenarios, a tool like the BBS could help to fulfill the twofold goal of measuring the beliefs compatibility of different involved actors and, at the same time, offering a standardized instrument to compare ideas and opinions of the different agents of change.

Concerning Specific Aim 2, results showed that most correlations between factors are low, ranging between 0.06 and 0.48. Thus, discriminant validity is confirmed for all the factors. Moreover, the study shows that, on average, beliefs about biofuels are associated with relevant outcomes, such as Biofuels Acceptability (Attitudes) and Acceptance (Intentions), thus consistently with the predictive validity hypothesis. However, any conclusion about BBS factors' predictive validity should be further tested through longitudinal studies. Similarly, measurement invariance (on the geographical and on the temporal scale) is yet to be tested, since the current sample was too small and unbalanced for this kind of analysis [81].

The high number of items eliminated during the analysis needs to be mentioned as a potential limitation of this study. More than half of the items were removed during the analyses because they had either poor saturation on all the factors or multiple saturations on different factors. However, this important selection of items is not surprising considering the exploratory nature of this study. In this sense, it is plausible that the factor analysis technique helped to select the clearest and least ambiguous items included in the original pool.

5.2. Applications and future research

Research on biofuels is growing and, while there are already several technology acceptance models, none of them seems to include psychometrically reliable and valid measures of context-related and technology-related beliefs, typically relying on *ad hoc* measures. In

Table 6
Zero-order correlations between BBS factors, Values, Subjective knowledge, BASA factors, and BISA factors.

		Policy	Global	Emiss	Compat	Local	Costs	BioV	EgoV	EdonV	TradV	AltrV	SubjK	PosAtt	Feasab	Use
1	Policy															
2	Global	0.22***														
3	Emiss	0.48***	0.39***													
4	Compat	0.17***	−0.10**	0.18***												
5	Local	−0.23***	−0.41***	−0.19***	−0.09**											
6	Costs	0.15***	−0.16***	0.16***	0.06*	0.17***										
7	BioV	0.19***	0.05	0.12***	0.02	0.00	−0.05									
8	EgoV	−0.04	−0.01	0.06	0.12***	0.20***	0.21***	0.04								
9	EdonV	0.13***	0.08**	0.13***	0.02	0.00	0.11***	0.25***	0.26***							
10	TradV	−0.02	0.04	0.08*	0.07*	0.26***	0.14***	0.18***	0.47***	0.22***						
11	AltrV	0.23***	0.09**	0.14***	−0.01	−0.06*	−0.06	0.60***	−0.07*	0.28***	0.11***					
12	SubjK	0.06	−0.05	0.17***	0.27***	0.10**	0.33***	0.03	0.32***	0.02	0.21***	−0.05				
13	PosAtt	0.60***	0.50***	0.62***	0.19***	−0.30***	0.12***	0.17***	0.07*	0.18***	0.09**	0.20***	0.16***			
14	Feasab	0.07*	0.11***	0.24***	0.27***	0.05	0.05	0.14***	0.27***	0.07*	0.28***	0.07*	0.43***	0.33***		
15	Use	0.37***	0.20***	0.35***	0.18***	0.01	0.21***	0.27***	0.25***	0.04	0.24***	0.22***	0.39***	0.43***	0.41***	
16	Supp	0.51***	0.27***	0.38***	0.11***	−0.28***	0.06	0.23***	−0.05	0.17***	−0.03	0.25***	0.01	0.65***	0.14***	0.26***

Notes: Policy = Policy-Making Legitimation; Global = Global Environmental Sustainability; Emiss = Emissions; Local = Local Socio-Economic Sustainability; Compat = Technology Compatibility; Costs = Cost Savings BioV= Biospheric Values; EgoV = Egoistic Values; EdonV = Edonic Values; TradV = Traditional Values; AltrV= Altruistic Values; SubjK= Subjective Knowledge; PosAtt = Acceptability (Positive Attitude); Feasab = Acceptability (Feasability); Use = Acceptance (Intention to use); Supp = Acceptance (Intention to political Support).

outlining the importance of social science applications in sustainable biofuels aviation research, Anderson et al. [82] pointed out that existing studies on biofuels demonstrate the centrality of the context in understanding how to best approach the implementation of renewable energy projects at both local and global level. Most of the existing research is based on not easily quantifiable and reproducible metrics (vs. the ones provided here by a standardized survey): the preference for these types of indicators leads to an incomplete assessment, in the best scenario, and to invalid conclusions and inaccurate predictions, in the worst scenario. This preference so far also contributed to inadequate research at the local level, where biofuel development has the most important impact [82]. Since research on biofuels is growing and there is a lack of social-psychological tools to measure what people think about them (i.e., biofuel beliefs), BBS has many implications both for research and applications. In the context of research, including BBS in the current technology acceptance models would allow better integration of specific beliefs into the technology acceptance models (Hujits et al., 2012), since such a dimension has so far been neglected in comparison to other variables (typically, other features of the person unrelated with the specific targeted energy technology). This would be also consistent with the approach of other behavioral models, such as TPB [10] and VBN [12].

From an applied perspective, this study provides a tool that fulfills the need of social science methods scrutinizing public acceptance of biofuels [82]. Energy governance includes a number of stakeholders - such as NGOs, intergovernmental organizations, private companies, public-private partnerships, transnational advocacy networks, and financial institutions. Being able to compare the beliefs of the different stakeholders can be useful to inform local policies and strategies, including public initiatives of citizen engagement and involvement, in order to plan the local sustainability transition and drive the progress toward the Sustainable Development Goals (SDGs by UN [83]). Further studies should test the stability of this factorial structure in a European representative sample, as well as in non-European cultural and linguistic contexts. Moreover, ideally, non-paid participants should be involved in the studies, to limit the effect of extrinsic motivation and compensation-related sample bias on study results. The quantitative nature of this tool allows to run comparisons across contexts, even though an integration with qualitative methods could help to account for the context dependency of results.

It is also possible that some of the items will not work in all context and that some of the items we have excluded would work with specific publics. Further work conducting ANOVAS and cluster analyses to for stakeholder segmentation and trying to understand different interpretations of the items or identifying items that work/do not work in specific publics is certainly welcome.

In this sense, it is to remark how, since biofuel is such a novel technology, it is likely that beliefs around this topic will change not only quantitatively, but also qualitatively. New beliefs may emerge through different times and places that are not accounted for in the tool here proposed. It is thus likely that to account for the plastic structure of beliefs, this tool will have to be adapted and updated in the future following belief changes proposed by different epistemic communities. For instance, the factor focusing on the compatibility of biofuel with current infrastructures might need to be updated when new infrastructures will be available.

As a research application, it will be interesting to include these measures of beliefs in existing models to predict the acceptability of biofuels and similar technologies (e.g., as in the SETA model; Hujits et al., 2012). Discrete choice experiments would be a particularly valuable tool to consider adoption intentions contrasted by different alternatives (e.g., EVs, traditional fossil fuels), and not looking at biofuels alone. Another interesting avenue consists of using the BBS to check for the efficacy of interventions aiming to contrast misbeliefs and misinformation about biofuels and the context in which they can be applied. In these respects, overall, the BBS tool represents one of the possible many contributions that a Social Science and Humanities (SSH) perspective can offer to the implementation of the Directive (EU) 2018/2001 of the European Parliament and the Council of December 11, 2018 on the promotion of the use of energy from renewable sources.

6. Conclusion

Since current technology acceptance models seem to have neglected the role of specific beliefs, the goal of this study was to develop a tool to measure biofuels beliefs, and, more specifically, beliefs related to the technological features of biofuels with their social and environmental impacts; and to the context where the biofuels would be implemented, considering the relevant economics and politics. To reach such a goal, a 26-item scale was developed that included six factors: Policy Making Legitimation, Emissions Sustainability, Global Environmental Sustainability, Technology Compatibility, Local Socio-Economic Sustainability, and Cost Savings.

In a recent literature review about biofuels' public opinion in the EU countries, Løkke et al. [5] called for research approaches integrating information deriving from both qualitative and quantitative data to capture the complexity of public perception about emerging technologies (see also [82] for a similar suggestion). Consistently, the development of the Biofuels Beliefs Scale was pursued through a mixed method approach: item development was framed both on the results deriving from a qualitative study based on interviews [26], and on the adaptation of previously published surveys, reflecting a quantitative perspective. Further studies should consider implementing this scale within existing technology acceptance models and theories (e.g., [27,31]), to acknowledge the role of beliefs in the social-psychological processes driving behavioral choices towards new renewable and sustainable energy technologies. From a practical point of view, the use of BBS would help monitor assessments in a range of promoting initiatives for better communication about biofuels, to diffuse its use among stakeholders. This would be particularly relevant for specific corporate stakeholders, especially in the field of transport [82] and logistics, for which choosing sustainable fuels is often an action of Corporate Social and Environmental Responsibility. A use of BBS at the institutional level would also allow for a better understanding of lay people's attitudes toward biofuels and, ultimately, to inform local policies, thus contributing to make our society as more sustainable by relying on cleaner and renewable fuels. As outlined by [84], to make biofuels more acceptable and accepted, appropriate leveraging is needed. Often, the resistance and skepticism toward biofuels technologies are linked to inherent unconvincing technology characteristics, and mistrust toward the adoption context, as well as to some adopters' features. Thus, BBS can also be combined with qualitative methods, such as in-depth interviews, focus groups, or ethnographic investigations focused on understanding these beliefs, their underlying contexts, and their dynamic change, which might also bring to update the tool. Additionally, BBS could play a pivotal role in designing studies employing formative methods: for example, within participatory workshops or deliberative polling which could be employed to foster greater engagement and enhance knowledge capacity among stakeholders.

Achieving the goal of biofuels' adoption requires a comprehensive approach to promote its acceptability and acceptance by also considering multiple biofuels features whose beliefs can be known and monitored by appropriate standard tools such as the BBS. Similar tools could also be developed with reference to other new renewable and sustainable energy technologies for the same purposes: the development of the BBS could serve as a benchmark in this respect too.

CRediT authorship contribution statement

Silvia Ariccio: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Oriana Mosca:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Federica Dessi:** Project administration, Data curation, Conceptualization. **Ferdinando Fornara:** Writing – review & editing, Supervision, Methodology, Formal analysis. **Marino Bonaiuto:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization.

Acknowledgments

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This project has received funding from the European Commission Horizon 2020 research and innovation program under grant agreement number 764089 ("ABC-SALT: Advanced Biomass Catalytic conversion to middle distillates in molten SALTs"). The entire project of investigation, detailed in its execution modalities, has been submitted to the Ethics Committee of the Department of Psychology of Developmental and Socialization Processes, Faculty of Medicine and Psychology, Sapienza University of Rome (Italy), receiving the approval to proceed (submitted April 28, 2021, final approval May 27, 2021, Protocol n. 742, Pos. VII/15).

Appendices.

Appendix 1
BBS Items and their origin.

Item	Source (adapted from)
Technology	
P2_Chem1 Biofuels burn cleaner than fossil fuels	Bakhtiyari et al. [42]
P2_Chem 2 Biofuel technology is immature	Dessi et al. [26]
P2_Chem 3 The technical production process of biofuels is more efficient than fossil fuels	Dessi et al. [26]
P2_Comp1 Biofuel-based transport system is compatible with the fossil fuel based one	Dessi et al. [26]
P2_Com2 Biofuel-based storage system is compatible with the fossil fuel based one	Dessi et al. [26]
P2_Com3 Biofuel-based distribution system is compatible with the fossil fuel based one	Dessi et al. [26]
P2_Com4 Biofuels are incompatible with conventional engines	Dessi et al. [26]
P2_Com5 Existing petrol facilities are unfit for biofuels	Dessi et al. [26]
P2_Infr1 Biofuels are the only viable renewable energy for the transport sector	Dessi et al. [26]
P2_Infr2 A transport system based only on biofuels implies too many burdens	Dessi et al. [26]
P2_Feed1 Biofuels are responsible for worsening food sufficiency for the Third World	Krontalis and Pagiaslis [20]
P2_Feed2 Biofuels based on food crops are sustainable	Dessi et al. [26]

(*continued on next page*)

Appendix 1 (*continued*)

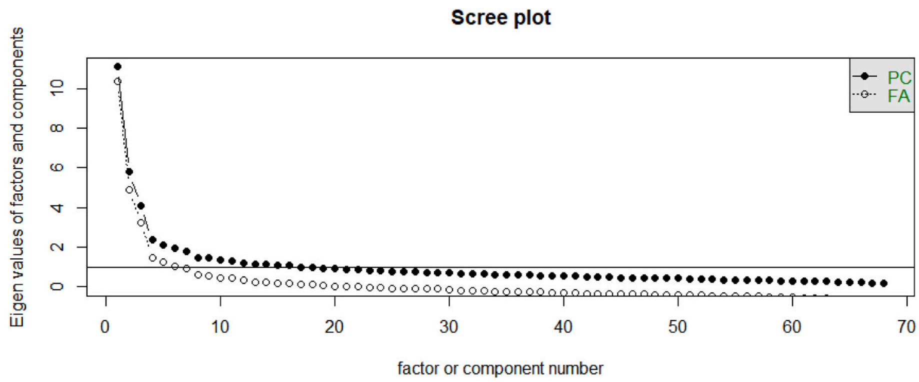
Item	Source (adapted from)
P2_Feed3 Biofuels enable us to turn agricultural waste into energy	Bakhtiyari et al. [42]; Dessi et al. [26]
P2_Feed4 Biofuels based on agricultural wastes and residues threaten food and feed crops	Dessi et al. [26]
P2_Chan1 Biofuels take up precious agricultural land	Amin et al. [43]
P2_Chan2 Biofuels, via indirect land use change (ILUC), cause deforestation	Dessi et al. [26]
P2_Chan3 Current land usage affords biofuel feedstock production	Dessi et al. [26]
P2_Chan4 Biofuel's production is compatible with sustainable land management	Dessi et al. [26]
P2_Emi1 Increasing the share of biofuels reduces CO2 emissions	Bakhtiyari et al. [42]
P2_Emi2 Biofuels use decreases the greenhouse gas emissions	Gracia et al. [85]
P2_Emi3 Biofuels and fossil fuels have the same impact on air quality	Dessi et al. [26]
P2_Env1 Biofuels have negative environmental impacts	Bakhtiyari et al. [42]
P2_Env2 Biofuels production threaten plants and wildlife	Bakhtiyari et al. [42]
P2_Env3 Increased use of biofuels mitigates the global warming problems	Bakhtiyari et al. [42]
P2_Env4 Biofuels contribute to a better environment	Dessi et al. [26]
P2_Env5 Developing biofuels poses harm to the ecosystem and environment	Amin et al. [43]
Context: Economy/Market	
P3_Pri1 Biofuels are cost-effective compared to other renewable options	Dessi et al. [26]
P3_Pri2 Biofuels increase the cost of fuel at the pump	Cacciatore et al. [44]
P3_Pri3 Biofuel increases the maintenance costs of the car	Gracia et al. [85]
P3_Pri4 The transformation of production from fossil fuels to biofuels requires a relevant capital investment	Dessi et al. [26]
P3_Pri5 The transformation from fossil fuels to biofuels is advantageous for production companies	Dessi et al. [26]
P3_Pri6 Biofuels costs could lead to an increase in transportation-related costs	Dessi et al. [26]
P3_Pri7 In the long term, biofuels cost less than fossil fuels	Dessi et al. [26]
P3_Pri8 In the short term, biofuels cost less than fossil fuels	Dessi et al. [26]
P3_Cost1 Biofuel production leads to an increase in the price of food	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Cost2 When choosing among raw materials for producing biofuels, the first to be used should be those that lead to the lowest impact on food prices	Skipper et al. [86]
P3_Cost3 The production of biofuels has a direct increasing effect on food prices	Moula et al. [45]
P3_Cost4 Using biofuels decreases the price of food	Cacciatore et al. [44]
P3_Eco1 Biofuels hardly provide economic benefits	Dessi et al. [26]
P3_Eco2 The government should provide more financial support to researchers and industries in developing biofuels	Amin (2017)[43]
P3_Eco3 When choosing among raw materials for producing biofuels, the first to be used should be those that lead to the lowest amount of agricultural subsidies	Skipper et al. [86]
P3_Eco4 The government should provide subsidies such as tax credits to certain agricultural groups to develop biofuels	Dragojlovic & Einsiedel [48]
P3_Mark1 Biofuels are able to cover a significant fraction of our current fuel demand	Dessi et al. [26]
P3_Mark2 There is a lack of selling points for biofuels	Dessi et al. [26]
P3_Mark3 There are insufficient resources for biofuel production to match the demand	Bakhtiyari et al. [42]
P3_Mark4 Existing service networks are good to promote biofuels implementation	Zhang et al. [49]
P3_Loc1 Biofuel production creates more jobs at the local scale	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Loc2 Developing biofuels helps rural development	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Loc3 Biofuels can generate additional income for rural people	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Loc4 Growing biofuel plants reduces the quality of life in local communities	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Loc5 The usage of biofuels impairs local business	Zoellner et al. [47]
P3_Loc6 Biofuels have poor added value at the local level	Dessi et al. [26]
P3_Ene1 Increasing production of biofuels reduces dependence on foreign oil	Bolsen & Cook (2008)
P3_Ene2 Use of biofuels can make local people self-reliant in energy terms	Yaghoubi et al. [46]; Bakhtiyari et al. [42]
P3_Ene3 Biofuels impede local energy independence	Dessi et al. [26]
P3_Ene4 Biofuels cannot guarantee local petroleum independency	Dessi et al. [26]
Context: Policy/Administration	
P4_Pol1 Policies are needed for the transition from fossil fuels to biofuels	Dessi et al. [26]
P4_Pol2 It is useless to promote biofuel international agreements and standardisation	Scarlat & Dallemand [41]
P4_Pol3 Each country should avoid to regulate itself in the field of biofuels	Scarlat & Dallemand [41]
P4_Pol4 Proliferation of biofuel standards leads to lower confidence among various stakeholders	Scarlat & Dallemand [41]
P4_Pol5 An international Biofuels Sustainability Pact would be helpful in securing the sustainability of biofuels production	Scarlat & Dallemand [41]
P4_Pol6 A common political willingness is necessary to support specific biofuel policies	Dessi et al. [26]
P4_Sup1 Political institutions should promote research in the field of biofuels	Dessi et al. [26]
P4_Sup2 There is no need for biofuel promotion to be done at many institutional levels	Dessi et al. [26]
P4_Inf1 There is a scarce need for information actions by companies about biofuels	Dessi et al. [26]
P4_Inf2 The massive impact of NGOs on public opinion is crucial for biofuels	Dessi et al. [26]
P4_Inf3 Scientists should demonstrate to the public why we need to switch to biofuels in the coming years	Dessi et al. [26]

Appendix 2
Descriptive statistics, skewness, kurtosis, and Normality Test on all the scale's items (n = 68).

	Mean	Std.dev	Skewness	Kurtosis	Shapiro-Wilks *
P2_Chem1	5.21	1.34	−0.78	0.33	0.9
P2_Chem_2	3.93	1.45	−0.14	−0.63	0.95
P2_Chem_3	4.42	1.27	−0.23	0.03	0.93
P2_Comp1	4.52	1.3	−0.38	0.03	0.93
P2_Comp2	4.44	1.25	−0.22	0.06	0.93
P2_Comp3	4.55	1.25	−0.24	−0.07	0.93
P2_Comp4	4.05	1.56	−0.09	−0.76	0.95
P2_Comp5	4.07	1.37	0.03	−0.46	0.94
P2_Infr1	3.11	1.62	0.41	−0.76	0.92
P2_Infr2	3.78	1.41	0.08	−0.36	0.95
P2_Feed1	3.56	1.52	0.06	−0.62	0.93
P2_Feed2	4.27	1.5	−0.32	−0.43	0.94
P2_Feed3	5.43	1.13	−0.8	1.13	0.89
P2_Feed4	4.41	1.45	−0.22	−0.54	0.94
P2_Chan1	4.09	1.5	−0.11	−0.62	0.95
P2_Chan2	4.33	1.3	−0.11	0.14	0.92
P2_Chan3	4.32	1.05	0.14	0.87	0.88
P2_Chan4	4.54	1.26	−0.42	0.07	0.93
P2_Emi1	4.97	1.28	−0.62	0.27	0.92
P2_Emi2	4.9	1.32	−0.6	0.23	0.92
P2_Emi3	4.75	1.55	−0.54	−0.39	0.93
P2_Env1	3.78	1.48	−0.08	−0.7	0.95
P2_Env2	3.9	1.4	−0.09	−0.5	0.95
P2_Env3	4.44	1.27	−0.34	−0.06	0.94
P2_Env4	4.95	1.2	−0.67	0.74	0.91
P2_Env5	3.66	1.38	0.05	−0.42	0.94
P3_Pri1	4.4	1.26	−0.23	0.01	0.94
P3_Pri2	3.23	1.89	0.25	−1.35	0.88
P3_Pri3	2.91	1.86	0.51	−1.09	0.86
P3_Pri4	4.54	2.01	−0.81	−0.77	0.82
P3_Pri5	4.45	1.2	−0.17	0.19	0.93
P3_Pri6	3.47	2	0	−1.53	0.86
P3_Pri7	4.94	1.34	−0.53	0.17	0.92
P3_Pri8	3.59	1.35	0.28	−0.27	0.94
P3_Cost1	3.9	1.32	−0.01	−0.12	0.94
P3_Cost2	5.1	1.33	−0.49	−0.13	0.92
P3_Cost3	4.03	1.21	−0.01	0.17	0.93
P3_Cost4	3.35	1.26	0.08	−0.08	0.92
P3_Eco1	3.52	1.29	0.26	0.01	0.94
P3_Eco2	5.3	1.33	−0.84	0.6	0.9
P3_Eco3	4.71	1.24	−0.14	−0.22	0.93
P3_Eco4	4.88	1.38	−0.6	0.13	0.92
P3_Mark1	4.42	1.35	−0.39	−0.21	0.94
P3_Mark2	4.34	1.43	−0.19	−0.52	0.95
P3_Mark3	4.44	1.27	−0.2	−0.03	0.94
P3_Mark4	4.4	1.22	−0.08	−0.02	0.94
P3_Loc1	4.72	1.1	−0.23	0.45	0.91
P3_Loc2	4.72	1.14	−0.25	0.37	0.92
P3_Loc3	4.95	1.11	−0.38	0.44	0.92
P3_Loc4	3.72	1.37	0.08	−0.33	0.94
P3_Loc5	3.56	1.26	0.14	−0.04	0.93
P3_Loc6	3.68	1.22	0.13	0.15	0.93
P3_Ene1	5.25	1.22	−0.68	0.25	0.9
P3_Ene2	4.88	1.19	−0.61	0.59	0.91
P3_Ene3	3.72	1.34	0.08	−0.41	0.95
P3_Ene4	4.39	1.23	−0.06	0.08	0.93
P4_Pol1	5.52	1.17	−1.05	1.64	0.87
P4_Pol2	3.06	1.47	0.67	−0.19	0.91
P4_Pol3	3.65	1.47	0.28	−0.48	0.94
P4_Pol4	3.93	1.22	−0.15	0.17	0.91
P4_Pol5	5.29	1.13	−0.65	0.66	0.9
P4_Pol6	5.41	1.12	−0.79	0.99	0.89
P4_Sup1	5.49	1.21	−0.98	1.28	0.88
P4_Sup2	3.2	1.43	0.51	−0.25	0.93
P4_Inf1	4.11	1.5	−0.17	−0.58	0.94
P4_Inf2	4.67	1.15	−0.23	0.54	0.91
P4_Inf3	5.69	1.25	−1.19	1.54	0.84
P4_Inf4	3.02	1.61	0.67	−0.37	0.9

Note: All Shapiro-Wilks tests are significant ($p < .001$).

Appendix 4. Standardized factor loadings from the Six-Factor Exploratory Structural Equation Modeling target rotation of the BBS. The full line represents the sampled data, the dotted line represents the simulated data.



Appendix 4Standardized factor loadings from the Six-Factor Exploratory Structural Equation Modeling target rotation of the BBS.

Item	Policy	Global	Emiss	Compat	Local	Costs
P4_Sup1	0.81					
P3_Eco2	0.7					
P4_Pol6	0.7					
P4_Pol1	0.68					
P4_Inf3	0.62					
P4_Pol5	0.61					
P3_Eco4	0.55					
P2_Emi2		0.83				
P2_Emi1		0.68				
P2_Chem1		0.50				
P2_Env4		0.44				
P2_Env2			0.78			
P2_Env5			0.65			
P2_Chan1			0.70			
P2_Env1			0.61			
P2_Feed1			0.67			
P2_Chan2			0.67			
P2_Comp2				0.72		
P2_Comp3				0.73		
P2_Comp1				0.62		
P3_Loc5					0.70	
P3_Loc4					0.55	
P3_Loc6					0.49	
P3_Pri6						0.67
P3_Pri2						0.62
P3_Pri3						0.51

Notes: Policy = Policy-Making Legitimation; Global = Global Environmental Sustainability; Emiss = Emissions; Local = Local Socio-Economic Sustainability; Compat = Technology Compatibility; Costs = Cost Savings.

Data availability

Data will be made available on request.

References

[1] T.M. Letcher, Future Energy: Improved, Sustainable and Clean Options for Our Planet, Elsevier, 2020.

[2] H.C. Chin, W.W. Choong, S.R.W. Alwi, A.H. Mohammed, Issues of social acceptance on biofuel development, J. Clean. Prod. 71 (2014) 30–39.

[3] M.R. Anuar, A.Z. Abdullah, Challenges in biodiesel industry with regards to feedstock, environmental, social and sustainability issues: a critical review, Renew. Sustain. Energy Rev. 58 (2016) 208–223.

[4] R. Alizadeh, P.D. Lund, L. Soltanisehat, Outlook on biofuels in future studies: a systematic literature review, Renew. Sustain. Energy Rev. 134 (2020) 110326.

[5] S. Løkke, E. Aramendia, J. Malskær, A review of public opinion on liquid biofuels in the EU: current knowledge and future challenges, Biomass Bioenergy 150 (2021) 106094.

[6] M. Abbasi, M.S. Pishvaee, S. Mohseni, Third-generation biofuel supply chain: a comprehensive review and future research directions, J. Clean. Prod. 323 (2021) 129100.

[7] I. Ajzen, B.L. Driver, Prediction of leisure participation from behavioral, normative, and control beliefs: an application of the theory of planned behavior, Leisure Sci. 13 (3) (1991) 185–204.

[8] J.S. Black, P.C. Stern, J.T. Elworth, Personal and contextual influences on househould energy adaptations, J. Appl. Psychol. 70 (1) (1985) 3.

[9] A. Yuriev, M. Dahmen, P. Paillé, O. Boiral, L. Guillaumie, Pro-environmental behaviors through the lens of the theory of planned behavior: a scoping review, Resour. Conserv. Recycl. 155 (2020) 104660, https://doi.org/10.1016/j.resconrec.2019.104660.

[10] J. Vining, A. Ebreo, Emerging theoretical and methodological perspectives on conservation behavior, in: R.B. Bechtel, A. Churchman (Eds.), Handbook of Environmental Psychology, John Wiley & Sons, Inc, 2002, pp. 541–558.

[11] J.I.M. de Groot, L. Steg, Value orientations to explain beliefs related to environmentally significant behavior, Environ. Behav. 40 (2008) 330–354, https://doi.org/10.1177/0013916506297831.

[12] P.C. Stern, New environmental theories: toward a coherent theory of environmentally significant behavior, J. Soc. Issues 56 (3) (2000) 407–424, https://doi.org/10.1111/0022-4537.00175.

[13] E. Schwitzgebel, Belief' in Zalta, Edward, the Stanford Encyclopedia of Philosophy, The Metaphysics Research Lab, Stanford, CA, 2006. http://plato.stanford.edu/entries/belief/. retrieved on 2008-09-19.

[14] N. Baral, What socio-demographic characteristics predict knowledge of biofuels, Energy Pol. 122 (2018) 369–376.

[15] L.O. House, J. Lusk, S.R. Jaeger, B. Traill, M. Moore, C. Valli, W. Yee, Objective and subjective knowledge: impacts on consumer demand for genetically modified foods in the United States and the European Union, AgBioforum 7 (3) (2004) 113–123.

[16] I. Ajzen, N. Joyce, S. Sheikh, N.G. Cote, Knowledge and the Prediction of behavior: the role of information Accuracy in the theory of planned Behavior, Basic Appl. Soc. Psychol. 33 (2) (2011) 101–117.

[17] P. Achterberg, D. Houtman, S. Van Bohemen, K. Manevska, Unknowing but supportive? Predispositions, knowledge, and support for hydrogen technology in The Netherlands, Int. J. Hydrogen Energy 35 (12) (2010) 6075–6083.
[18] N.M. Huijts, B. van Wee, The evaluation of hydrogen fuel stations by citizens: the interrelated effects of socio-demographic, spatial and psychological variables, Int. J. Hydrogen Energy 40 (33) (2015) 10367–10381.
[19] M. Brucks, The effects of product class knowledge on information search behavior, J. Consum. Res. 12 (1) (1985) 1–16.
[20] A. Pagiaslis, A.K. Krontalis, Green consumption behavior antecedents: environmental concern, knowledge, and beliefs, Psychol. Market. 31 (5) (2014) 335–348.
[21] M. Siegrist, G. Cvetkovich, Perception of hazards: the role of social trust and knowledge, Risk Anal. 20 (5) (2000) 713–720.
[22] S. Jovchelovitch, Re-thinking the diversity of knowledge: cognitive polyphasia, belief and representation, Psychologie et Société 5 (1) (2002) 121–138. ISSN 1636-9416.
[23] A. de Leeuw, P. Valois, I. Ajzen, P. Schmidt, Using the theory of planned behavior to identify key beliefs underlying pro-environmental behavior in high-school students: implications for educational interventions, J. Environ. Psychol. 42 (2015) 128–138, https://doi.org/10.1016/j.jenvp.2015.03.005.
[24] A. Cranmer, J.D. Ericson, A. Ebers Broughel, B. Bernard, E. Robicheaux, M. Podolski, Worth a thousand words: presenting wind turbines in virtual reality reveals new opportunities for social acceptance and visualization research, Energy Res. Social Sci. 67 (2020) 101507, https://doi.org/10.1016/j.erss.2020.101507.
[25] K. Rietig, The links among contested knowledge, beliefs, and learning in European climate governance: from consensus to conflict in reforming biofuels policy, Pol. Stud. J. 46 (1) (2016) 137–159.
[26] F. Dessi, S. Ariccio, T. Albers, S. Alves, N. Ludovico, M. Bonaiuto, Sustainable technology acceptability: mapping technological, contextual, and social-psychological determinants of EU stakeholders' biofuel acceptance, Renew. Sustain. Energy Rev. 158 (2022) 112114, https://doi.org/10.1016/j.rser.2022.112114.
[27] N.M. Huijts, E.J. Molin, L. Steg, Psychological factors influencing sustainable energy technology acceptance: a review-based comprehensive framework, Renew. Sustain. Energy Rev. 16 (1) (2012) 525–531.
[28] H. Taherdoost, A review of technology acceptance and adoption models and theories, Procedia Manuf. 22 (2018) 960–967.
[29] I. Ajzen, The theory of planned behavior, Organizational behavior and human decision processes 50 (2) (1991) 179–211.
[30] S.H. Schwartz, Normative influences on altruism, Adv. Exp. Soc. Psychol. 10 (1977) 221–279. Academic Press.
[31] M. Bonaiuto, O. Mosca, A. Milani, S. Ariccio, F. Dessi, F. Fornara, Beliefs about technological and contextual features drive biofuels' social acceptance, Renew. Sustain. Energy Rev. 189 (2024) 113867, https://doi.org/10.1016/j.rser.2023.113867. ISSN 1364-0321.
[32] J.I. de Groot, L. Steg, W. Poortinga, Values, perceived risks and benefits, and acceptability of nuclear energy, Risk Anal.: Int. J. 33 (2) (2013) 307–317.
[33] N. Contzen, A.V. Handreke, G. Perlaviciute, L. Steg, Emotions towards a mandatory adoption of renewable energy innovations: the role of psychological reactance and egoistic and biospheric values, Energy Res. Soc. Sci. 80 (2021) 102232.
[34] M.H. Jayed, H.H. Masjuki, R. Saidur, M.A. Kalam, M.I. Jahirul, Environmental aspects and challenges of oilseed produced biodiesel in Southeast Asia, Renew. Sustain. Energy Rev. 13 (9) (2009) 2452–2462.
[35] K. Arning, J. Offermann-van Heek, A. Linzenich, A. Kätelhön, A. Sternberg, A. Bardow, M. Ziefle, Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany, Energy Pol. 125 (2019) 235–249.
[36] M.F. Milazzo, F. Spina, A. Vinci, C. Espro, J.C.J. Bart, Brassica biodiesels: past, present, and future, Renew. Sustain. Energy Rev. 18 (2013) 350–389.
[37] P. Upham, C. Oltra, À. Boso, Towards a cross-paradigmatic framework of the social acceptance of energy systems, Energy Res. Social Sci. 8 (2015) 100–112.
[38] C. Oltra, Stakeholder perceptions of biofuels from microalgae, Energy Pol. 39 (3) (2011) 1774–1781.
[39] W.E. Tyner, Biofuels and food prices: separating wheat from chaff, Global Food Secur. 2 (2) (2013) 126–130.
[40] T. Selfa, L. Kulcsar, C. Bain, R. Goe, G. Middendorf, Biofuels Bonanza?: exploring community perceptions of the promises and perils of biofuels production, biomass and bioenergy 35 (4) (2011) 1379–1389.
[41] N. Scarlat, J.F. Dallemand, Recent developments of biofuels/bioenergy sustainability certification: a global overview, Energy Pol. 39 (3) (2011) 1630–1646.
[42] Z. Bakhtiyari, M. Yazdanpanah, M. Forouzani, N. Kazemi, Intention of agricultural professionals toward biofuels in Iran: implications for energy security, society, and policy, Renew. Sustain. Energy Rev. 69 (2017) 341–349.
[43] L. Amin, H. Hashim, Z. Mahadi, M. Ibrahim, K. Ismail, Determinants of stakeholders' attitudes towards biodiesel, Biotechnol. Biofuels 10 (1) (2017) 1–17.
[44] M.A. Cacciatore, D.A. Scheufele, A.R. Binder, B.R. Shaw, Public attitudes toward biofuels: effects of knowledge, political partisanship, and media use, Polit. Life Sci. 31 (1–2) (2012) 36–51.
[45] M.M.E. Moula, J. Nyari, A. Bartel, Public acceptance of biofuels in the transport sector in Finland, International Journal of Sustainable Built Environment 6 (2) (2017) 434–441.
[46] J. Yaghoubi, M. Yazdanpanah, N. Komendantova, Iranian agriculture advisors' perception and intention toward biofuel: green way toward energy security, rural development and climate change mitigation, Renew. Energy 130 (2019) 452–459.
[47] J. Zoellner, P. Schweizer-Ries, C. Wemheuer, Public acceptance of renewable energies: results from case studies in Germany, Energy Pol. 36 (11) (2008) 4136–4141.
[48] N. Dragojlovic, E. Einsiedel, What drives public acceptance of second-generation biofuels? Evidence from Canada, Biomass Bioenergy 75 (2015) 201–212.
[49] Y. Zhang, Y. Yu, T. Li, B. Zou, Analyzing Chinese consumers' perception for biofuels implementation: the private vehicles owner's investigating in Nanjing, Renew. Sustain. Energy Rev. 15 (5) (2011) 2299–2309.
[50] V. Corral-Verdugo, Structural equation modeling, in: R. Bechtel, A. Churchman (Eds.), Handbook of Environmental Psychology, Wiley, New York, 2002, pp. 256–270.
[51] R.P. Bagozzi, Y. Yi, L.W. Phillips, Assessing construct validity in organizational research, Adm. Sci. Q. 36 (1991) 421–458.
[52] EurObserv'ER, Solid biomass barometer, Available online: https://www.eurobserv-er.org/pdf/solid-biofuels-barometer-2021/, 2021. (Accessed 19 August 2024).
[53] N. Ludovico, F. Dessi, M. Bonaiuto, Stakeholders mapping for sustainable biofuels: an innovative procedure based on computational text analysis and social network analysis, Sustainability 12 (24) (2020) 10317.
[54] R. Krause, K.A. Whitler, M. Semadeni, Power to the principals! An experimental look at shareholder say-on-pay voting, Acad. Manag. J. 57 (1) (2014) 94–115, https://doi.org/10.5465/amj.2012.0035.
[55] J. Fenn, C.-S. Tan, S. George, Development, validation and translation of psychological tests, BJPsych Adv. 26 (5) (2020) 306–315, https://doi.org/10.1192/bja.2020.33.
[56] L. Steg, J.I.M. De Groot, Environmental values, in: S. Clayton (Ed.), The Oxford Handbook of Environmental and Conservation Psychology, Oxford University Press, 2012, pp. 81–92, https://doi.org/10.1093/oxfordhb/9780199733026.013.0005.
[57] S.H. Schwartz, Universals in the content and structure of values: theoretical advances and empirical tests in 20 countries, Adv. Exp. Soc. Psychol. 25 (1992) 1–65. Academic Press.
[58] R.C. Team, R. Bivand, V.J. Carey, S. DebRoy, S. Eglen, R. Guha, B. Pfaff, Package 'foreign, 2022.
[59] P. Grosjean, F. Ibanez. Pastecs: package for analysis of space-time ecological seriesR package version 1.4.2, 2024. https://CRAN.R-project.org/package=pastecs.
[60] J. Fox, G.G. Friendly, S. Graves, R. Heiberger, G. Monette, H. Nilsson, M.A.S. S. Suggests, The Car Package, vol. 1109, R Foundation for Statistical Computing, 2007.
[61] W. Revelle, Psych: Procedures for Personality and Psychological Research, 2017.
[62] Y. Rosseel, D. Oberski, J. Byrnes, L. Vanbrabant, V. Savalei, E. Merkle, M. Y. Rosseel, Package 'lavaan', 2017, p. 1. Retrieved June, 17(2017.
[63] C. Bernaards, R. Jennrich, M.P. Gilbert, Package 'gparotation, 2015. Retrieved February, 19, 2015.
[64] M.T. Silvestrin, L. de Beer, esemComp: ESEM-within-CFA syntax composer, R package version 0.2 (2022). https://mateuspsi.github.io/esemComp.
[65] K.H. Yuan, L.L. Marshall, R. Weston, Cross-validation by downweighting influential cases in structural equation modelling, Br. J. Math. Stat. Psychol. 55 (1) (2002) 125–143.
[66] M.W. Browne, R. Cudeck, Alternative ways of assessing model fit, in: K.A. Bollen, J. S. Long (Eds.), Testing Structural Equation Models, Sage, Newbury Park, CA, 1993, pp. 136–162.
[67] R.B. Cattell, The Scree Test for the number of factors, Multivariate Behav. Res. 1 (2) (1966) 245–276.
[68] J.L. Horn, A rationale and test for the number of factors in factor analysis, Psychometrika 30 (2) (1965) 179–185, https://doi.org/10.1007/BF02289447.
[69] W.F. Velicer, Determining the number of components from the matrix of partial correlations, Psychometrika 41 (3) (1976) 321–327.
[70] H.W. Marsh, O. Lüdtke, B. Muthén, T. Asparouhov, A.J. Morin, U. Trautwein, B. Nagengast, A new look at the big five-factor structure through exploratory structural equation modeling, Psychol. Assess. 22 (3) (2010) 471.
[71] H.W. Marsh, O. Lüdtke, B. Nagengast, A.J. Morin, M. Von Davier, Why item parcels are (almost) never appropriate: two wrongs do not make a right—camouflaging misspecification with item parcels in CFA models, Psychol. Methods 18 (3) (2013) 257.
[72] A. Satorra, P.M. Bentler, A scaled difference chi-square test statistic for moment structure analysis, Psychometrika 66 (4) (2001) 507–514.
[73] G.W. Cheung, R.B. Rensvold, Evaluating goodness-of-fit indexes for testing measurement invariance, Struct. Equ. Model. 9 (2) (2002) 233–255.
[74] M. Rönkkö, E. Cho, An updated guideline for assessing discriminant validity, Organ. Res. Methods 25 (1) (2022) 6–14.
[75] R.P. Bagozzi, L.W. Phillips, Representing and testing organizational theories: a holistic construal, Adm. Sci. Q. 27 (3) (1982) 459–489.
[76] J. Cohen, Statistical Power Analysis for the Behavioral Sciences, second ed., Erlbaum, Hillsdale, NJ, 1988.
[77] R.J. Cohen, M. Swerdlik, E. Sturman, Psychological Testing and Assessment, eighth ed., McGraw-Hill, NY, 2013.
[78] R.J. Gregory, Psychological testing: history, principles, applications. Boston, MA: pearson Education.Grob, A. (1995). A structural model of environmental attitudes and behaviour, Journal of environmental psychology 15 (3) (2011) 209–220.
[79] J.C. Nunnally, I.H. Bernstein, Psychometric Theory, 3, McGraw-Hill, New York, 1994.
[80] D.T. Campbell, D.W. Fiske, Convergent and discriminant validation by the multitrait-multimethod matrix, Psychol. Bull. 56 (2) (1959) 81.
[81] M. Yoon, M.H. Lai, Testing factorial invariance with unbalanced samples, Struct. Equ. Model.: A Multidiscip. J. 25 (2) (2018) 201–213.

[82] Brian J. Anderson, Daniel W. Mueller, Season A. Hoard, Christina M. Sanders, Sanne AM. Rijkhoff, Social Science Applications in Sustainable Aviation Biofuels Research: Opportunities, Challenges, and Advancements, vol. 9, Frontiers in Energy Research, 2022 771849.

[83] United Nations General Assembly, Transforming Our World: the 2030 Agenda for Sustainable Development, United Nations, New York, NY, USA, 2015.

[84] S. Adelung, R. Venderbosch, B. Sridharan, J. Wallinder, J. Weyand, M. Bonaiuto, Public report on the marketability of the ABC-SALT middle distillates biofuels, ABC-Salt Deliverable 2.11, released on September the 30th, (2022) 2022.

[85] A. Gracia, J. Barreiro-Hurlé, L.P. y Pérez, Overcoming the barriers for biodiesel use in Spain: an analysis of the role of convenience and price, J. Clean. Prod. 172 (2018) 391–401.

[86] D. Skipper, L. Van de Velde, M. Popp, G. Vickery, G. Van Huylenbroeck, W. Verbeke, Consumers' perceptions regarding tradeoffs between food and fuel expenditures: A case study of US and Belgian fuel users, Biomass Bioenergy 33 (6–7) (2009) 973–987.