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The public's intention to vote for continued use of woody biomass for energy in Denmark: a cognitive hierarchy perspective

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Abstract

Background To be socially robust, renewable energy policies aiming at achieving a low-carbon society require public support. Woody biomass is an important renewable energy source. It accounts for a large share of the renewable energy consumption in several EU countries. However, its sustainability credentials are contested. Little is known as yet about how the public perceives woody biomass. This paper aims to examine the public's intention to vote for continued use of woody biomass, and to find out whether this voting intention can be explained using the cognitive hierarchy model. This model posits that values, attitudes and beliefs predict higher order cognitions like intention. We extend the model by including an additional variable (perceived benefit). Although the model is widely used in connection with natural resource management issues, it has not yet been applied to the case of increasingly contested energy sources like woody biomass. We use Denmark as a case study given that woody biomass makes up the largest share of the renewable energy mix in the country.

Results Results of a nationwide questionnaire-based survey of the general public show that a large proportion of Danes are undecided about their attitudes towards, and their intention to vote for, woody biomass. Structural equation modeling results show that belief in the mitigation potential of woody biomass has a significant positive effect on both attitudes and voting intention. Altruistic and egoistic values have a significant positive effect on attitudes, which in turn have a significant positive influence on voting intention. We also confirm the mediating role of attitudes.

Conclusions Understanding public opinion-making processes can help to promote environmental decision-making that takes due account of public perceptions of the ways in which energy transitions come about. The cognitive hierarchy model is an apt framework with which to predict voting intention in the context of contested energy sources.

Keywords Bioenergy, Public acceptance, Public perception, Cognitive hierarchies, Value-attitude-behavior (VAB) model, Opinion formation

Background

There are less than four years left to break the rising CO_2 curve if the temperature rise on the planet is to be limited to 1.5 °C [1]. One of the initiatives to overcome our reliance on non-renewable energy sources is using bioenergy derived from woody biomass. Although it is often assumed that woody biomass energy is carbon neutral, its mitigation potential and the timescales over which that mitigation can be realized have been questioned (e.g., [2,

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3]). Moreover, the energy crisis we are currently facing as a result of Russia's invasion of Ukraine has accentuated concerns about increased consumption of woody biomass [4, 5].

Woody biomass perception studies have focused largely on a limited number of stakeholders and less so on civil society (exceptions include [6, 7]). This is surprising given that public attitudes influence policy decisions and can direct change in democratic countries [8], and given that lack of public support has at times been an obstacle to the effective implementation of environmental policies [9].

Tackling climate change calls for a sound understanding of the psychological processes at play in human behavior [10, 11]. Hence, this study aims to provide a better understanding of the cognitive and socio-psychological factors influencing the formation of public views on woody biomass. Public acceptance of the use of woody biomass for energy needs to be examined by investigating not just attitudes towards it but also potential behavior. In the study reported here, the most likely (albeit hypothetical) type of behavior of relevance is assumed to be a referendum, i.e. a direct vote by the electorate on a proposal, law or political issue. Thus we examine voting intentions. Such intentions are distinct from actual voting behavior [12]. It should also be noted that factors such as individuals' self-interest might play an important role in their voting intentions [13, 14]. Duty motives and social incentives can also be relevant [14].

Specifically, we investigate the voting intentions of the Danish public in a referendum on continued use of woody biomass. Denmark is particularly well suited for this kind of study. Concern about climate change is at the forefront of the Danish public's consciousness [15], and there is political consensus over highly ambitious climate targets [16]. Woody biomass energy represents the largest share of renewable energy consumption in the country [17, 18]. Its use is expected to be one of the most important factors in Danish climate policy in the coming years [19]. However, because the carbon neutrality of woody biomass cannot be guaranteed, and since this energy source is also scarce, some have called for Denmark's biomass consumption to be reduced (e.g., [20, 21]).

Theoretical framework

This study draws on the value-attitude-behavior (VAB) cognitive hierarchy model first presented by Homer and Kahle in 1988 (see [22]). Within the VAB framework, values interact with other cognitive factors to constitute a foundation for attitudes, which in turn have an effect on intention and/or behavior [23, 24]. Values are conceptualized as abstract life goals [25]. Eagly and Chaiken (see [26]) define an attitude as "*a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor*" (p.1). Behavioral intention, which can be defined as "*a willful state of choice where one makes a self-implicated statement as to a future course of action*" (see [27], p. 145), is the most immediate determinant of behavior [28]. Factors outside the originally envisioned VAB model are likely to influence intention either directly or indirectly through their interaction with other variables in the model. In this context, there have been recent calls for the examination of the effect of socio-demographic characteristics in studies using the VAB approach [29, 30].

Figure 1 shows the adapted version of the VAB model used in this study. Public support for policy decisions aiming at reducing emissions is usually depicted as something that is associated with values, attitudes and perceptions [31]. To reflect the *perception* factor, we added the variable "*perceived benefit*"—operationalized as *belief in the mitigation potential of woody biomass*. Beliefs are often defined as cognitions that posit an association between an object and an attribute, or another object [26, 32]. Previous research has pointed out that acceptance of climate and energy policies is associated with perceived policy effectiveness [9, 33]. We aim to explore in detail both the structure of, and the relationships between, the constructs proposed in Fig. 1. The Methods section explains how each of the constructs were operationalized.

Socio-psychological models drawing on the VAB theory have been used in theoretical and empirical research into, for example, environmental behavior (e.g., [34–37]), natural resource management (e.g., [38–40]), and conservation (e.g., [41–43]). The model has also been applied extensively in studies of attitudes to, and behavior affecting, wildlife (e.g., [44–49]). To the best of our knowledge, however, no studies have used a socio-psychological model to assess public support for contested energy policies. More generally, evidenced analysis of the relationship between socio-psychological factors and behaviors in the energy domain has not yet been provided [29]. Our aim is to begin to remedy this shortcoming.

The so-called "attitude-behavior gap", which arises where behavior fails to reflect attitudes, is well known [50]. Studies in the Theory of Reasoned Action and Theory of Planned Behavior have shown that the correlation between attitudes and behavior is not always strong. This discrepancy has been investigated extensively (e.g., [51–55]), and it has been suggested that the lack of correlation may be influenced by factors such as subjective norms or perceived control over performance of the behavior [56].

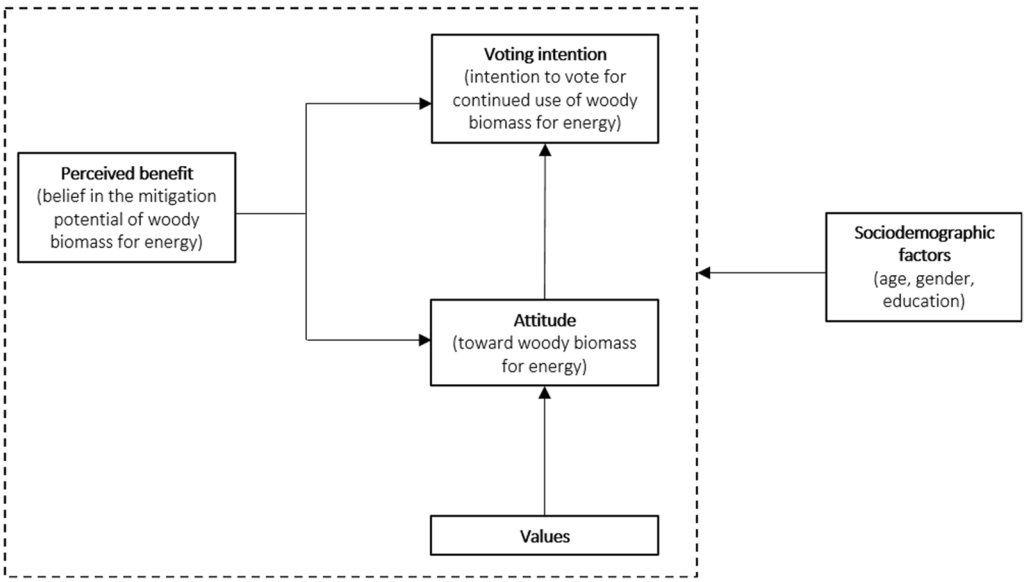

Fig. 1 Conceptual representation of a cognitive hierarchy model of voting intention

To overcome the difficulties here policy interventions may be necessary. In the present context, studies clarifying the impact of factors such as values and beliefs on public perception and intentions could enable policy interventions that are more comprehensive and effective to be developed. However, given the reported discrepancy between attitudes and behavior, the current study aims to evaluate the relationship between attitudes and *voting intention* as a way of evaluating public support for energy policy.

Aims and hypothesis development

The aim of this study is to assess the Danish public's views on woody biomass, and the cognitive and socio-psychological factors affecting them, within a cognitive hierarchy framework. The specific objectives of the study are threefold. First, to elucidate voting intention, measured as intention to vote for continued use of woody biomass. Second, to explore value structures and views on woody biomass (namely attitudes towards its use and belief in its mitigation potential) that are relevant to understanding voting intention. Third, to assess the contribution of the independent variables at each level of the cognitive hierarchy model, including the study of voting intention as a function of values, attitudes and perceived benefit. The potential effects of socio-demographic factors (age, gender and education) on the predicted relationships in the model are also examined. We shall now develop a series of hypotheses to explore the contribution of variables at each level of the proposed hierarchy, in line with the third objective.

Hypothesized role of values

Values have been found to predict not only attitudes, but also constructs higher up in the cognitive hierarchy, including intentions [57–62]. Previous research has shown that pro-environmental attitudes, behavioral intentions and behaviors are positively predicted by altruistic and/or biospheric values and negatively predicted by egoistic values (e.g., [58, 63–65]). Assuming that woody biomass is a "green" energy source—which is the way it is often portrayed in Denmark—then having a positive attitude towards it, and being likely to vote for its continued use, can be seen as "pro-environmental" attitudes and intentions, respectively. We would expect that people caring about the wellbeing of their peers and future generations (those scoring higher on altruistic values) or about the protection of the environment (those scoring higher on biospheric values) will have more positive attitudes towards woody biomass, and therefore a higher likelihood of voting for its continued use. Finally, we would expect that people attaching more importance to themselves (those scoring higher on egoistic values) will tend instead to have a negative attitude towards it, and thus a lower likelihood of voting for it. Based on this, we constructed hypotheses **H1a**, **H1b**, **H2a**, **H2b**, **H3a** and **H3b** (see Table 1).

Hypothesized role of perceived benefit

Specific beliefs about an object predict attitudes to that object. In the consumer behavior literature, it is often posited that a consumer's perception of the benefits of a particular product significantly has an effect on their

Table 1 Hypothesized roles of values, belief (perceived benefit) and attitudes

	Hypotheses	
Values	H1a	Altruistic values have a significant positive effect on attitudes
	H1b	Altruistic values have a significant positive effect on intention
	H2a	Biospheric values have a significant positive effect on attitudes
	H2b	Biospheric values have a significant positive effect on intention
	H3a	Egoistic values have a significant negative effect on attitudes
	H3b	Egoistic values have a significant negative effect on intention
Belief	H4	Perceived benefit has a significant positive effect on attitudes
	H5	Perceived benefit has a significant positive effect on intention
Attitudes	H6	Attitudes have a significant positive effect on intention
	H7a	Attitudes have a mediating role in the relationship between altruistic values and intention
	H7b	Attitudes have a mediating role in the relationship between biospheric values and intention
	H7c	Attitudes have a mediating role in the relationship between egoistic values and intention
	H7d	Attitudes have a mediating role in the relationship between perceived benefit and intention

intention to buy that product [66]. Likewise, an individual's belief in the positive environmental outcome of an energy source is associated with attitudinal and behavioral intentions regarding this source [66]. For instance, García-Maroto et al. [67] hypothesize that the belief about the potential environmental benefits of biomass has a positive effect on attitudes to it. In our case, we would assume that an individual who believes in the mitigation potential of woody biomass would have a positive attitude towards it and would have a higher likelihood of voting for its continued use. Based on this, hypotheses **H4** and **H5** were advanced (Table 1).

Hypothesized role of attitudes

Attitude towards a behavior has proven to be a predictor that helps to explain intention [68–70]. This also applies to energy-related intentions [71–74]. García-Maroto et al. [67] hypothesize that attitude has a positive effect on the intention to adopt biomass heating. Similarly, Lee et al. [75] hypothesize that attitudes to energy saving positively predict intention to save energy. Following this, **H6** was proposed (Table 1). We also consider the mediating role of attitudes. Although we hypothesize that values predict intention directly (**H1b**, **H2b** and **H3b**), these have been mainly found to indirectly predict intention and/or behavior through attitudes (e.g., [30, 76]). Moreover, as we posit in **H4**, it is hypothesized that perceived benefit has an effect on attitudes, and since in turn it is also hypothesized that it predicts intention, a mediating role of attitudes in the perceived benefit-intention relationship is also expected. With this in mind, hypotheses **H7a** to **H7d** were proposed (Table 1).

Figure 2 summarizes our research model, including the constructs and expected relationships. **H7a**, **H7b**, **H7c**, and **H7d** (not illustrated in the diagram) are the result of the multiplication of different paths, namely **H1a*H6**, **H2a*H6**, **H3a*H6**, and **H4*H6**, respectively. Given the ambiguous results as regards the effect of socio-demographic factors, we did not propose any specific hypotheses associated with these, nor include them in Fig. 2, but treated them instead as control variables that were used to examine whether the predicted relationships in the model differed across socio-demographic groups.

Methods

Participants and procedure

An online questionnaire was sent in spring 2021 to a sample of the Danish population identified in a panel of 100,000 Danish citizens administered by a survey agency (*Voxmeter*). Permission to use the questionnaire, the English version of which is available in Additional file 1, was granted by the Research Ethics Committee at the Faculty of Science and the Faculty of Health and Medical Sciences (University of Copenhagen) (Approval No. 514-0191/21-5000).

Participants were recruited using soft quotas for age, gender and geographical region. A final sample size of 1,023 was obtained after excluding respondents who completed the survey in less than seven minutes (the minimum time deemed necessary to complete it) and respondents submitting questionable answer patterns such as straightlining. In all, 37 participants were discarded based on these criteria. A response rate of 20% was achieved (see Table 2).

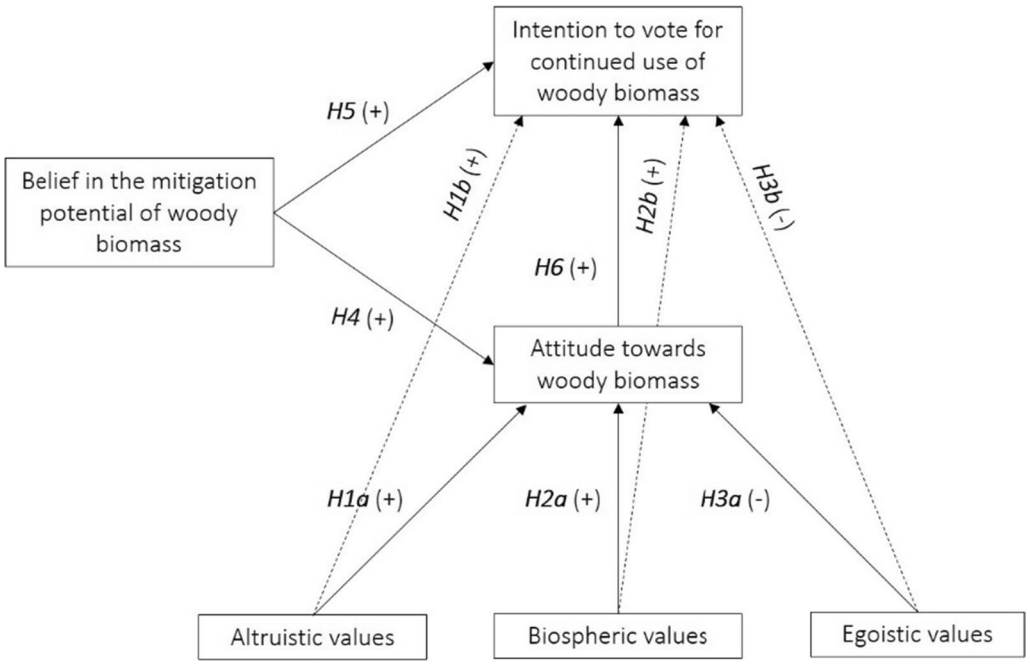

Fig. 2 Research model proposed for the study of intention to vote for woody biomass for energy. Continuous lines refer to hypothesized direct effects and dotted lines refer to hypothesized indirect effects

Table 2 Recruitment process

Status	%	n
Invited	100	5400
Quota full	16.2	876
Quota partly	3	163
Successful	19.6	1060
Excluded[a]	3.49	37

[a] 37 respondents were excluded from the 'successful pool'

51% of respondents were female and 49% were male. The sample age range was 19 to 83 (mean = 49.42, standard deviation = 15.86) (see Table 3). When comparing our sample with the available Danish population statistics, we found that it overrepresented people with higher education but was reasonably representative in terms of gender and region and only showed slight deviations for age. Before the survey was launched, the questionnaire was pre-tested using a cognitive interview technique [77, 78] with 11 randomly selected Danish respondents. The main purpose was to ensure that the questionnaire was clear and easy to understand. Following changes to improve the wording and clarity, a pilot test with 100 randomly selected Danish citizens was conducted. Both the pre-test and pilot test helped improve the formulation and response options. Further, the pilot test was used to estimate the survey completion time.

Table 3 Socio-demographic characteristics of the sample (unweighted) and comparison with the Danish population

	Sample (n = 1023) (%)	Danish population 2021[a] (%)
Gender		
Female	50.64	50.26
Male	48.88	49.74
Other	0.29	–
Do not wish to say	0.2	–
Age (years)		
18–34	20.43	27.38
35–49	30.89	22.92
50–64	24.44	24.52
65 or more	24.24	25.19
Education		
Primary, high school, vocational training	40.96	64.96
Higher education (1–5 years), and PhD	58.85	35.05
Do not know	0.2	–
Region		
Hovedstaden	28.93	31.76
Sjælland	14.47	14.37
Syddanmark	23.66	20.95
Midtjylland	22.78	22.82
Nordjylland	10.17	10.10

[a] Census data available at Statistics Denmark (www.dst.dk)

Measurements

Values

Values were measured using the Brief Inventory of Values (BIV) (see Additional file 2) developed by Stern et al. (see [63]) and validated by previous researchers (e.g., [79, 80]). Each value was composed of three items. Respondents were told that there are a series of items associated with some guiding principles and asked to signal the importance of each of them in their lives on a 5-point Likert scale. The original BIV includes five values directed upon distinctive objects (shown in brackets): *altruistic* (the welfare of others), *biospheric* (the environment and the biosphere), *egoistic* (oneself), *traditional* (family structure and function) and *openness to change* (novelty and excitement). We decided to use the first three of these in our model, since previous research had pointed up the importance of these in explaining environmental behavior (e.g., [58, 79–89]).

Attitudes towards and perceived benefit of woody biomass

Attitudes towards woody biomass were measured by asking respondents how they feel about replacing fossil fuels with woody biomass to generate energy. Attitudes were measured on a 5-point Likert scale (*very negative* to *very positive*). We assessed respondents' perceived benefit of woody biomass by asking them to rate their level of agreement with the assumption that using woody biomass for energy emits less GHG emissions than using non-renewable energy sources on a 5-point Likert scale (*strongly disagree* to *strongly agree*) with an *I don't know* off-scale option. Both attitudes and perceived benefit are reported in a previously published paper using the same dataset (see [15]).

Voting intention

Voting intention was measured by presenting respondents with the following question: "*Imagine that the government asks in a referendum about whether woody biomass should continue to be used for energy instead of fossil fuels. How likely is it that you would vote Yes for continued use of woody biomass for energy?*". Voting intention (i.e., likelihood of voting for continued use of woody biomass) was measured on a 5-point Likert scale ranging from *very unlikely* to *very likely*.

Socio-demographic (control) variables

Previous studies have indicated that age, gender and education are associated with energy and environmental behaviors [90–98], including energy conservation behaviors [99–103]. Thus, we included these as control variables. Age is a continuous variable recoded into a categorical variable with three categories (18–34, 35–49 and ≥ 50). For gender and education two binary variables were generated representing the male and female dichotomy and the lower education and higher education dichotomy, respectively.

Data analysis

Data analyses included descriptive analyses and reliability analyses using IBM SPSS Statistics version 28.0 and structural equation modeling (SEM) with bootstrapping estimation using the AMOS 28.0 statistical package. Univariate results for the variables voting intention, attitudes, perceived benefit and values are reported using a weight variable that adjusts respondents' age, gender and region to the population census. For the BIV, items within each of the value structures were averaged to calculate individual respondents' scores on each scale. The reliability of the inventory was tested to confirm that the individual items measured their respective constructs consistently [104] using Cronbach's alpha (α) reliability coefficients.

SEM was performed to test the hypothesized structural model (see Fig. 2). We followed the recommendation of Anderson and Gerbing (see [104]) to validate the model using a two-step strategy. We first performed confirmatory factor analysis (CFA) using maximum likelihood (ML) estimation to assess the psychometric properties of the measurement model as evaluated through model fit indices. Here we also tested whether standardized factor loadings were above 0.4 [105, 106]**.** Further, we tested the structural validity of the measurement model by assessing its convergent and discriminant validity, and its construct reliability. The average variance extracted (AVE) for each construct was evaluated to assess convergent validity, which was confirmed when AVE ≥ 0.5 [107]. Discriminant validity refers to the degree to which the different dimensions are actually distinct [104]. It is confirmed if the AVE of each latent variable is larger than the square of the correlation estimates among constructs [107, 108]. Finally, construct reliability consists of composite reliability (CR) and Cronbach's α, of which acceptable levels are 0.6 [109] and 0.7 [110], respectively. In a second step, the structural model fit was assessed using ML estimation. The goodness-of-fit indices used to evaluate the fit of the measurement and structural models were the ratio of chi-square (χ^2) to degrees of freedom (χ^2/df), the comparative fit index (CFI), the Tucker Lewis index (TLI), the normed fit index (NFI), the standardized root mean square residual (SRMR), the root mean square error of approximation (RMSEA), and the p of close fit (PCLOSE) [111, 112]. Models with a χ^2/df in the range of 2 to 5, RMSEA and SRMR having values close to (or

lower than) 0.08 and 0.06, respectively, and CFI, TLI and NFI values close to 0.95 or higher were taken to present an acceptable fit [113–116]. The mediation role of attitudes was tested using user-defined estimands and bootstrapping at a 95% confidence interval with 5,000 samples [117, 118] and standardized indirect effects, and the confidence interval of the lower and upper bounds and the *p* values associated with the hypothesized attitude-mediated paths were reported.

Finally, we conducted multigroup SEM analyses to test whether there were significant changes in the measurement parameters and structural paths across socio-demographic groups. We followed the analysis of multigroup invariance proposed by Byrne et al. (see [119]) in which sets of parameters are constrained to be equal across groups of the control variable in a logically ordered and increasingly restrictive manner. Invariance testing involves checking whether the added equality constraints imply a statistically significant decrease in the fit of the model relative to an unconstrained model through χ^2 value difference ($\Delta\chi^2$) tests. These invariance tests begin with an evaluation of the equivalence of the measurement model in which the equality of factor loadings is tested across groups. If measurement invariance is observed, factor loadings are constrained to be equal and subsequent tests of the structural parameters are performed requiring the regression coefficients (so-called structural weights) among the different variables to be group-invariant. If significant differences arose, we screened for critical ratio values $\geq \left| 1.96 \right|$, which indicate the existence of a statistically significantly different path between groups at $p < 0.05$.

In the SEM analyses, *values* are latent continuous variables. *Perceived benefit* is treated as a dichotomous variable where 1 = belief (*strongly agree* or *agree* response options to the statement about woody biomass leading to less emissions) and 0 = other (remaining response options). *Attitudes* and *voting intention*, although they are ordered categorical variables, were treated as continuous. This was justified by their distribution (i.e., skewness and kurtosis $\leq |2.0|$), the fact that they had at least five ordered scale points and the further fact that we wanted to consider their underlying latent continuum [120–122].

Results

Perceptions of woody biomass for energy

Intentions to vote for woody biomass

Around 46% of respondents reported that it was *neither likely nor unlikely* that they would vote in favor of continued use of woody biomass (Table 4). A quarter (25%) said that it was *likely* that they would do so and around 6% that it was *very likely*. Around 17% and 6% reported that it was *unlikely* and *very unlikely*, respectively.

Attitude towards and perceived benefit of woody biomass

The highest share (45%) of respondents stated that they were *neither positive nor negative* in their attitude to woody biomass. While 30% of respondents were *positive and* 9% were *very positive*, 12% were *negative* and 4% were *very negative*. Turning to respondents' belief in the mitigation potential of woody biomass, almost two-thirds reported being undecided by answering either *I don't know* (32%) or *neither agree nor disagree* (26%), while 29% and 5% agreed and strongly agreed, respectively. Only around 6% and 2% disagreed and strongly disagreed, respectively.

Results of structural equation analyses

Measurement model results

Model fit CFA revealed that the measurement model (Fig. 3) had a good fit to the data (χ^2/df = 4.251, SRMR = 0.041, RMSEA (CI90%) = 0.056 (0.045–0.068), CFI = 0.971, TLI = 0.957, NFI = 0.963, PCLOSE = 0.163). All the standardized factor loadings (β) of the individual items in relation to their respective latent constructs were above 0.4 and significant at the $p < 0.001$ level, indicating that the three-factor BIV has acceptable construct validity (Table 5).

Construct reliability and validity Table 6 shows descriptive statistics for the values scales. The altruistic and biospheric values had a higher level of agreement (higher mean) than the egoistic values. The scales presented acceptable levels of skewness and kurtosis, not exceeding the threshold of ± 2 [123, 124]. Further, the CRs of the three value scales were all above 0.6, indicating good reliability. We found *good* convergent validity for the bio-

Table 4 Descriptive statistics (%) for voting intention, attitude and perceived benefit (unweighted n = 1023)

Variable						
	Very unlikely	Unlikely	Neither likely nor unlikely	Likely	Very Likely	
Voting intention	6.0	16.6	46.1	25.1	6.1	
	Very negative	Negative	Neither positive nor negative	Positive	Very positive	
Attitude	3.6	12.3	44.8	30.4	8.9	
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	I don't know
Perceived benefit	2.4	6.3	25.5	28.9	4.8	32.1

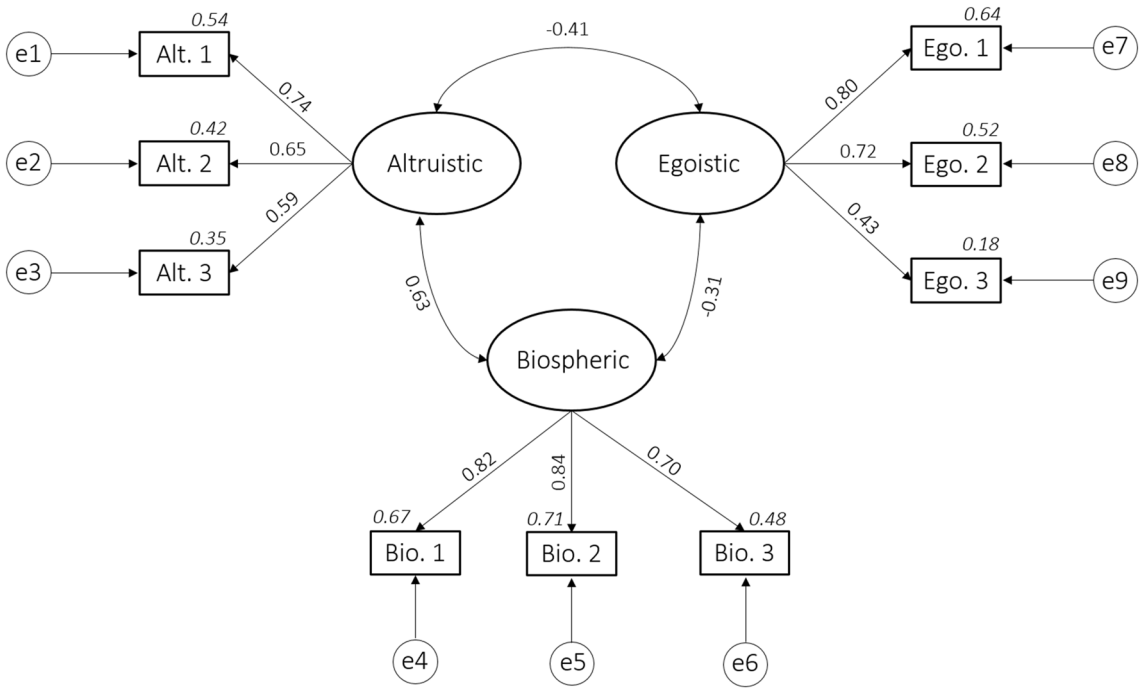

Fig. 3 Measurement model results (standardized factor loadings). Alt. 1: Social justice, correcting injustice, care for the weak; Alt. 2: Equality, equal opportunity for all; Alt. 3: A world of peace, free of war and conflict; Bio. 1: Respecting the earth, harmony with other species; Bio. 2: Protecting the environment, preserving nature; Bio. 3: Unity with nature, fitting into nature; Ego. 1: Social power, control over others, dominance; Ego. 2: Authority, the right to lead or command; Ego. 3: Wealth, material possessions, money (BIV scale developed by [63])

Table 5 Internal and convergent reliability of measurement model

Variable		Parameter estimation			
Construct	**Indicator**	**Unstandardized factor loading**	**Standard error**	***t* value**	**Standardized factor loading**
Altruistic	Alt. 1[a]	1.000			0.736
	Alt. 2	1.014	0.064	15.868*	0.652
	Alt. 3	0.751	0.051	14.849*	0.588
Biospheric	Bio. 1[a]	1.000			0.820
	Bio. 2	1.028	0.040	25.584*	0.841
	Bio. 3	0.925	0.042	22.158*	0.696
Egoistic	Ego. 1[a]	1.000			0.799
	Ego. 2	0.960	0.070	13.747*	0.720
	Ego. 3	0.533	0.049	10.972*	0.426

[a] The first (λ) path was set to 1, and therefore no standard errors or *t* values are given. *$p < 0.001$

spheric scale (AVE > 0.5). The altruistic and egoistic scales had *acceptable* convergent validities, since their AVEs were relatively close to what is considered a good convergent validity value of ≥ 0.5. The biospheric values scale had adequate reliability (α = 0.827), showing a satisfactory level of internal consistency. The altruistic and egoistic values scales had lower reliabilities, with α coefficients of 0.687 and 0.675, respectively. Further, our results confirmed the discriminant validity of the scales (see further details in Additional file 3). To sum up, the measurement model reliability, validity and CFA results supported using SEM to analyze the data.

Structural equation model results and overview of the hypothesis tests

The hypothesized structural equation model showed a good fit (χ^2/df = 3.391, SRMR = 0.053, RMSEA (CI90%) = 0.048 (0.040–0.057), CFI = 0.970, TLI = 0.956,

Table 6 Descriptive statistics (unweighted n = 1023) and convergent validity and construct reliability results

Variable		Descriptive statistics				Convergent validity	Construct Reliability	
Construct	**Indicator**	**Mean**	**SD**	**Skewness**	**Kurtosis**	**AVE**	**CR**	**Cronbach's α**
Altruistic	Alt. 1	4.15	0.62	− 0.694	1.015	0.438	0.695	0.687
	Alt. 2							
	Alt. 3							
Biospheric	Bio. 1	4.00	0.66	− 0.585	0.751	0.621	0.698	0.827
	Bio. 2							
	Bio. 3							
Egoistic	Ego. 1	2.34	0.70	0.310	0.081	0.446	0.83	0.675
	Ego. 2							
	Ego. 3							

Mean scale values (from 1 to 5). SD = Standard Deviation. AVE = Average Variance Extracted. CR = Composite Reliability

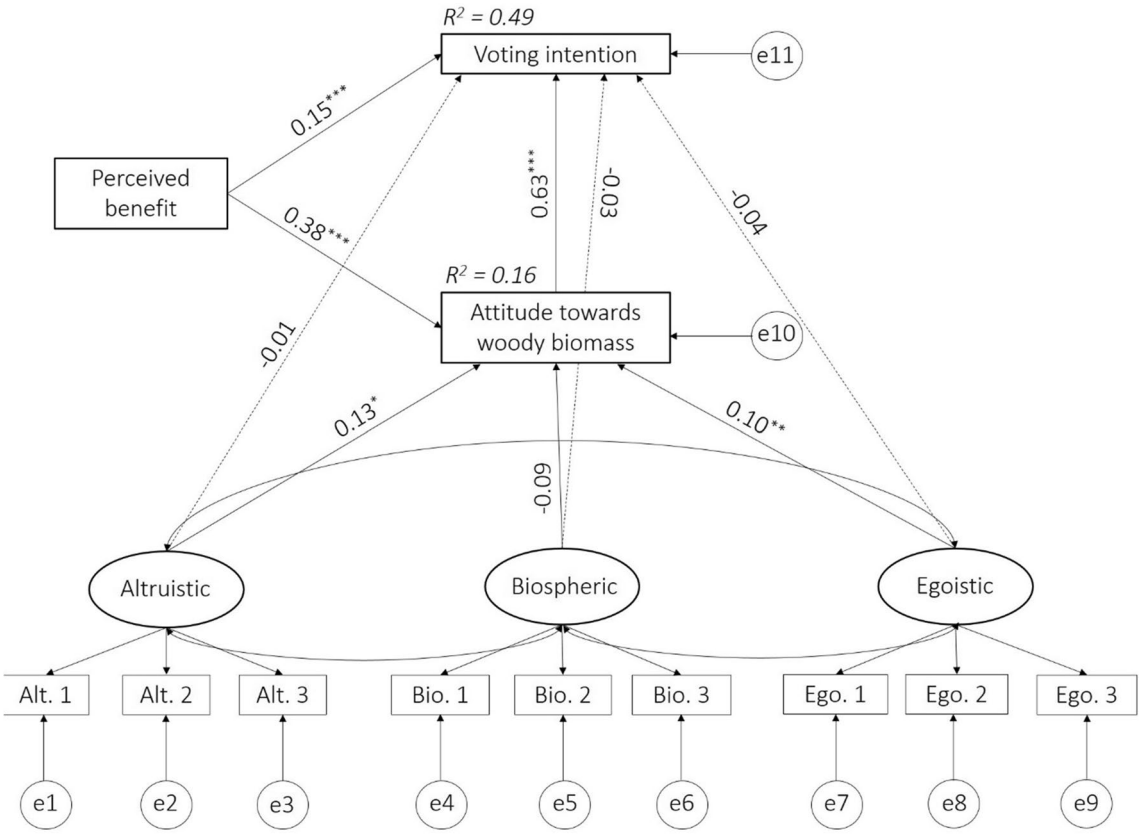

Fig. 4 Structural equation model results (standardized regression coefficients). ***$p < 0.001$, **$p < 0.01$, * $p < 0.05$

NFI = 0.958, PCLOSE = 0.610). Figure 4 shows the path diagram of the structural equation model. Values explained 16% of the variance in attitudes ($R^2 = 0.16$). Attitudes and perceived benefit explained 49% of the variance in voting intention ($R^2 = 0.49$). SEM results for the direct and indirect paths are shown in Tables 7 and 8, respectively. Altruistic values had a statistically significant positive effect on attitudes ($\beta = 0.134$, $p < 0.05$), in line with **H1a**. However, the biospheric values did not predict attitudes at the statistically significant level ($\beta = -0.089$, $p > 0.05$), thus providing no evidence for acceptance of **H2a**. The egoistic values had a statistically significant positive effect on attitudes ($\beta = 0.103$, $p < 0.01$). This positive association is not consistent

Table 7 Structural equation modelling results (direct paths) and hypothesis testing

	Standardized direct effect	*p*	BC 95% CI	Hypothesis	Consistency found?
Altruistic → attitude	0.134	0.014	0.025; 0,424	H1a	Yes
Altruistic → intention	− 0.013	0.750	− 0.183; 0.135	H1b	No
Biospheric → attitude	− 0.089	0.059	− 0.289; 0.003	H2a	No
Biospheric → intention	− 0.025	0.486	− 0.153; 0.090	H2b	No
Egoistic → attitude	0.103	0.008	0.028; 0.249	H3a	No[a]
Egoistic → intention	− 0.036	0.231	− 0.146; 0.039	H3b	No
Perceived benefit → attitude	0.377	< 0.001	0.610; 0.850	H4	Yes
Perceived benefit → intention	0.152	< 0.001	0.207; 0.403	H5	Yes
Attitude → intention	0.630	< 0.001	0.603; 0.707	H6	Yes

BC CI = bias-corrected confidence interval

[a] Although egoistic values predicted attitudes at the statistically significant level, the direction is not as hypothesized and thus we found no evidence for accepting H3a

Table 8 Structural equation modelling results (indirect paths) and hypothesis testing

	Standardized direct effect	*p*	BC 95% CI	Hypothesis	Consistency found?
Altruistic → attitude → intention	0.144	0.025	0.016; 0.27	H7a	Yes
Biospheric → attitude → intention	− 0.087	0.060	− 0.188; 0.004	H7b	No
Egoistic → attitude → intention	0.089	0.011	0.020; 0.166	H7c	Yes
Perceived benefit → attitude → intention	0.478	0.000	0.396; 0.567	H7d	Yes

BC CI = bias-corrected confidence interval

with the directionality of **H3a**. Believing in the mitigation potential of woody biomass had a significant positive effect on attitudes ($\beta = 0.377$, $p < 0.001$) and voting intention ($\beta = 0.152$, $p < 0.001$), confirming **H4** and **H5**, respectively. Attitudes had a significant positive effect on voting intention ($\beta = 0.630$, $p < 0.001$), in line with **H6**. We found no evidence for accepting **H1b**, **H2b** and **H3b** owing to a lack of significant paths from values to voting intention. The mediating role of attitudes was found for the paths *altruistic → attitude → intention* (**H7a**) ($\beta = 0.144$, $p < 0.05$), *egoistic → attitude → intention* (**H7c**) ($\beta = 0.089$, $p < 0.05$) and *perceived benefit → attitude → intention* (**H7d**) ($\beta = 0.478$, $p < 0.001$). While the total indirect effect of altruistic values on intention through attitude was statistically significant, the direct effect was not ($\beta = -0.013$, $p > 0.05$). Therefore, attitude appeared to play a full mediating role in predicting the relationship between altruistic values and intention. The same can be said about the mediating role of attitudes in the path between egoistic values and intention. We did not find an indirect effect in the case of the *biospheric → attitude → intention* path, and therefore our data were not consistent with **H7b**.

Multigroup analyses

There were no differences in the measurement parameters and structural relationships across age and education. We found a lack of measurement invariance for gender. Nevertheless, additional analyses revealed that the difference lies solely in a factor loading of one of the statements associated with the egoistic values scale, namely "*Authority, the right to lead or command*" ($\beta_{female} = 0.754$; $\beta_{male} = 0.693$). When we ran a multigroup model for the variable gender omitting this statement, measurement invariance was confirmed (see Additional file 4 for detailed results).

Discussion

An important finding of the study concerns undecidedness, as reflected in the attitude, perceived benefit and intention constructs employed. The undecidedness in voting intention is in line with previous studies, which have found a weak intention to use renewable energy in general [125, 126], but also in bioenergy, including biomass, in particular [127, 128]. Other authors have, however, found stronger public intention to use renewable energy technologies [129–131]. The lack of a strong public voting intention might suggest that woody biomass

would neither be widely embraced nor rejected if Danish people were given the chance to decide. Where perceived benefit is concerned, two thirds of our respondents were unsure about the mitigation potential of woody biomass. This could be partly explained by the finding that most Danes have a poor knowledge of woody biomass [15] or suggest that they do not care enough about this particular issue. Lack of clear public support for, or rejection of, energy sources can be a substantial barrier to bringing about a transition to a low-carbon economy [132, 133], posing a challenge for policy makers and industry stakeholders alike. However, people who do not care about the types of renewable energies used might simply accept their use without questioning their adequacy.

We aimed to capture the factors that help to explain voting intention. We found support for the assumption that values predict attitudes, as altruistic and egoistic values have a positive effect on attitudes. However, the strength of the association is often higher in studies focusing on, for example, preference for biofuels or connection to nature [134, 135]. This is probably because these are well-known topics that people find it easier to link to personal values. Unlike some studies (e.g., [62, 136, 137]) we did not find a direct effect of values on intentions. However, this lack of direct effect corroborates socio-psychological and sociological research [29, 59, 138, 139], where results often show that attitudes predict intentions better than values [140, 141].

The effect of altruistic values on attitudes is in keeping with extensive research reporting an association between altruism and pro-environmental behavior [142–148]. That association is most probably explained by the fact that stronger pro-social views are associated with views on the benefits of addressing environmental issues for society as a whole. The positive association found between egoistic values and attitudes contrasts with results from studies that find a negative association between these values and pro-environmental policies like reducing energy use [149, 150]. It is possible that individuals with stronger egoistic values attach importance to the mitigation effects of woody biomass for one's own wellbeing [151]. Since the argument that egoistic individuals hold an attitude based on the maximization of their own benefit (in this case, the utility of a natural resource for human purposes) has been brought up elsewhere [152], perhaps the directionality we saw can be explained by utilitarian variables not studied here, or alternatively by value-instantiating beliefs (i.e., determinants of the strength and direction of the value-attitude path) that might be different for different individuals [153]. We found no evidence that biospheric values predict attitudes to woody biomass for energy. This is contrary to previous studies showing a positive association between these values and energy-related behaviors [154–156]. However, our results echo those of Groh and Ziegler (see [157]), who found that environmental values—conceptually similar to biospheric values—had no significant effect on household electricity consumption in Germany. It is possible that individuals with strong biospheric values do not draw on these in forming their attitudes, because they do not consider woody biomass to be a sustainable energy source. Moreover, Dietz et al. (see [158]) argued that the strength with which people hold particular values may depend on the specific context. Since decisions that affect the environment are influenced by a broad array of considerations, particular environmental factors may be given little weight [159]. If this were correct, it could be that, where woody biomass is concerned, individuals do not think of the potential negative environmental consequences when reporting their attitude or intention, which could in turn be partly explained by their lack of familiarity with that energy source [15] and therefore their lack of awareness of the potential environmental risks and benefits. The Danish public might draw on altruistic and egoistic values alone because they see the use of woody biomass not so much as an environmental issue, but rather as one involving social and individualistic demands for such things as availability of resources for and the wellbeing of society and/or oneself.

Moving on to the role of attitudes, we found that these positively determined intention. This result is in keeping with studies on pro-environmental behavior (e.g., [69, 159–161]) and consumption of renewable energy (e.g., [142, 152, 162]). Moreover, our results fit well with those obtained by García-Maroto et al. [67], who have found that attitudes positively predict intention to purchase biomass heating. Attitude was also the strongest predictor of intentions in our study. Halder et al. (see [127]), likewise, found attitude to be the most influential variable in explaining intentions to use bioenergy. We also found that attitudes are full mediators in the path between altruistic values and intention and between egoistic values and intention, confirming the finding, made in several studies, that the effect of values in the hierarchy is primarily indirect and operates via their effect on higher order cognitions [38, 39, 163–165]. Moreover, attitudes mediate the perceived benefit-intention path, so that perceived benefit predicts attitudes directly and voting intention indirectly. But perceived benefit also predicts intention directly. These results are in line with previous studies (e.g., [67, 166, 167]). Socio-demographics did not emerge as moderators, perhaps because these are less influential than psychological factors in opinion-formation [168].

To summarize, then, our results point to public undecidedness. They also confirm the hierarchy of values,

attitudes, perceived benefit and intention. The hierarchy confirmed by our results is in keeping with results recently reported by García-Maroto et al. [67], who found that intention to adopt biomass heating in Spain is determined by values, attitudes and perceptions of the benefits of biomass. Our results have a series of implications. First, the factors that proved influential in the formation of intention could assist decision-making over low-carbon energy transitions and energy futures by ensuring that this process is responsive to the motivational needs of the public. Second, we expect our research to offer hints helping with the task of developing an understanding of opinion-formation beyond the particular case of woody biomass for energy.

Limitations of the study include the following. It was cross-sectional, so we cannot be sure that the confirmed hypothesized relationships are indeed causal. Also, external factors, outside the VAB model, may have an effect on intention [169]. Moreover, our sample overrepresented individuals with higher education. This overrepresentation could potentially flaw the study findings. However, additional analyses (not reported in the Results section) showed that educational differences had very limited impact. They had no statistical association with attitudes ($r_s = 0.001$, $p = 0.98$) and voting intention ($r_s = 0.023$, $p = 0.47$). Further, in the SEM analyses we found no differences in the measurement parameters and structural relationships across education levels. So, any educational misrepresentation is likely to have been very limited. There were, however, educational differences regarding perceived benefit of woody biomass (χ^2 (5, $n = 1021$) $= 16.26$, $p < 0.01$). Hence, further studies might be improved by exploring the relation between educational differences and beliefs about the environmental adequacy of novel renewable energy options. Another limiting factor relates to research into *voting intention* (not behavioral intention or actual behavior). Although one might anticipate a strong correlation between voting intention and actual voting behavior, our data does not reveal how people would actually vote. Furthermore, voting can be seen as an expressed *opinion*, and opinion does not necessarily correspond to a behavior. In this context, future research focusing on novel energy policy interventions might benefit from measuring *behavioral* intentions and/or actual behaviors. Finally, we captured human values on a reduced scale [63] using established categories that may not reflect the more specific values associated with the use of woody biomass for energy. Future studies may therefore benefit from a more granular exploration of the value structures here (e.g., by developing a scale to measure values relating to the utilization *versus* the preservation of natural resources) to better grasp the role of these in the formation of attitudes and intentions. Moreover, future studies should explore additional situational and psychological factors including *awareness* of the environmental, social and/or economic consequences of woody biomass, *trust* in climate targets and governments, and *risk* perception.

Conclusion

This study examined whether, and in what way, the Danish public's intention to vote for continued use of woody biomass could reflect its wider cognitive hierarchies. Our results show that the largest share of Danes are undecided about their intention to vote for continued use of woody biomass. They also shed light on how a person's intention to vote for woody biomass can be predicted by more abstract notions, as reflected in a cognitive hierarchy drawing on a VAB model with a novel added variable: perceived benefit. Structural equation modelling results provide evidence for the overall adequacy of the model, demonstrating that a cognitive hierarchy framework is likely to be useful when we are addressing conflicts surrounding renewable energy sources. In our study, the cognitive and the socio-psychological underpinnings of intention formation turned out to be complex. This confirms that questions about how governments can effectively promote the development of less carbon-intensive societies can be challenging, especially when we are relying on contested sources of energy like woody biomass.

Supplementary Information

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Additional file 1. Outline of the questionnaire-based survey used to collect the data.

Additional file 2. Brief Inventory of Values developed by Stern et al. (1998) and used to measure 'values'.

Additional file 3. Additional structural equation analysis results not shown in the main manuscript.

Additional file 4. Multigroup analysis results not shown in the main manuscript.

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Author contributions

PUL: conceptualization, methodology, formal analysis, investigation, writing—original draft, writing—review & editing, visualization, project administration. TBL: conceptualization, writing—review & editing. CG: conceptualization, writing—review & editing. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Permission to use the questionnaire was granted by the Research Ethics Committee at the Faculty of Science and the Faculty of Health and Medical Sciences (University of Copenhagen) (Approval No. 514-0191/21-5000). To ensure the protection of the respondents, informed consent was a requirement for participation in the questionnaire.

Consent for publication
Not applicable.

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

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