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Mapping perceptions of energy transition pathways: Ascribed motives and effectiveness

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Abstract
This study examines how people perceive possible pathways of a societal transition towards less carbon intensive means of energy production and use. Data were collected with questionnaires among samples of university students in Norway ($N = 106$) and Germany ($N = 142$). Participants selected from a set of 15 motives those which they considered to be strongly associated with each of 25 pathways, including examples such as public transportation and nuclear power. Participants also rated the effectiveness of each single pathway, that is, their perceived impact on climate change. Results indicate that the various pathways were associated with specific motives; for example, individual actions such as taking public transportation were closely associated with a self-restraint motive, pathways such as nuclear power and market strategies such as carbon offsets were closely associated with motives supporting free market and progress, and technological solutions such as solar panels and hydro power were associated with the motive for sufficient energy supply. The German and the Norwegian sample did not differ markedly in which pathways were associated with which motives; nor did effectiveness ratings for pathways differ between samples. Solar panels, wind farms, and hydropower were on average regarded as having a mitigating impact on climate change, whereas nuclear power was on average considered to have no mitigating impact. The findings are discussed in the context of public engagement with several of the suggested pathways, noting differences in perceptual patterns across samples.

Keywords Climate change · Mental representation · Motives · Effectiveness · Energy transition · Cross-national

Introduction

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Global Warming of 1.5 °C outlines that profound emission reductions are needed to limit global temperatures to 1.5 °C above pre-industrial levels (IPCC, 2018). It specifies that global net anthropogenic carbon dioxide (CO_2) emissions need to drop at around 45% by 2030 compared with levels of 2010, and eventually reach net zero no later than 2050. This in turn necessitates unparalleled transitions of socio-technological systems including but not limited to rapid and widespread changes in the supply and demand of energy (IPCC, 2018). Many and highly different options for socio-technological innovations have been proposed to facilitate these changes, and thus, to achieve a substantial reduction in CO_2 emissions. For such innovations to evolve from niche initiatives to widely adopted solutions, various actors (including policymakers, industry decision-makers, non-governmental organizations, and consumers) need to contribute, each with potentially unique sets of beliefs, interests, and strategies (Köhler et al., 2019). This is where social science research has an important role to play by shedding light on relevant actors and identifying factors that influence their support for energy policies and low carbon technologies. Findings from this line of research can inform measures to promote changes in energy systems (Perlaviciute et al., 2021; Steg et al., 2021).

This study focuses on individuals in their roles as citizens and consumers and investigates how they perceive different

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energy transition pathways (e.g., policy measures, technologies, lifestyle changes). The literature shows that public support for measures directed at tackling climate change may depend on characteristics of the measure itself but also on characteristics of the individuals affected by it (Ščasný et al., 2017). One characteristic that has gained particular attention in this context concerns subjective assessments regarding the *effectiveness* in mitigating climate change. An international study by Bostrom et al. (2012) found that the willingness to support several different policy options consistently increased with perceived effectiveness; policies studied by Bostrom et al. (2012) included general green policies (e.g., research funding initiatives), carbon reduction policies (e.g., fuel efficiency requirements), and engineering solutions (e.g., phasing out fossil fuels by replacing them with nuclear power). Similar findings have been reported for other types of policies, such as national carbon pricing legislation (Dreyer & Walker, 2013; Dreyer et al., 2015), as well as more regionally based policy measures in the form of congestion charges (Kim et al., 2013).

Perceived effectiveness in tackling the problem at hand has been found to not only predict policy support but also which behaviours people intend to perform (Truelove & Parks, 2012). There is furthermore evidence showing that public opinion on whether international agreements are important for combating climate change relates to whether these are perceived as having been successful in the past (Schleich & Faure, 2017), the latter being associated with an increased likelihood to voluntarily engage in mitigation actions at the individual level (Schleich et al., 2018). This fits the general picture that people are overall more supportive of the measure in question if they deem it effective, yet some studies show that the perceived effectiveness may vary both between countries (Schleich et al., 2016) and across different types of climate policies (Lam, 2015; Rhodes et al., 2014; Rosentrater et al., 2013). It is because of this that the reported study includes a cross-national juxtaposition of the climate change mitigation potential that people perceive to be associated with particular pathways.

Individual characteristics that may affect people's willingness to support energy transition initiatives are personal *motives,* which in turn can be rooted in basic human values.[1] Research on environmental issues often focuses on values that reflect concerns about personal resources and outcomes (i.e., egoistic values, hedonistic values), the welfare of other people (i.e., altruistic values), or the state of nature and the environment by and large (i.e., biospheric values) (De Groot & Steg, 2008; Steg et al., 2014). It has been shown, for instance, that people who endorse biospheric values are more likely to accept pricing policies targeted at reducing household carbon emissions (Steg et al., 2005), and participate in smart energy systems (Van Der Werff & Steg, 2016). Increasing the salience of biospheric values may furthermore promote consumer decision making for collective benefit instead of prioritising product attributes that are personally advantageous (Schuitema & De Groot, 2015), whilst environmental appeals tend to be more effective in eliciting behaviour change if they convey value-congruent information (Bolderdijk et al., 2013; Van den Broek et al., 2017).

In addition to being predictive of individual engagement in sustainable energy behaviours (Steg et al., 2015), people's values can shape evaluations and acceptance of energy alternatives along with other situation-specific psychological factors (Perlaviciute & Steg, 2014). An example are public perceptions of nuclear power in the sense that people with strong biospheric values, such as protecting the environment, are more likely to have negative perceptions of nuclear power (Corner et al., 2011; Perlaviciute & Steg, 2015) and less likely to accept it as a means of energy supply (De Groot et al., 2013; Perlaviciute & Steg, 2015). Public views on decarbonisation pathways may further incorporate assumptions about how the respective pathways affect societal life in a broader sense. There is emerging evidence that values such as autonomy and power feature prominently in public discourses about contemporary and future energy systems (Butler et al., 2015; Demski et al., 2015), especially the view that energy should be accessible and available to all of society (Demski et al., 2019).

The present study provides a structural description of how people perceive the relationship between energy transition pathways that are currently under public discussion and possible motives to adopt them. Furthermore, we assess how people perceive the effectiveness of each respective pathway and explore whether these perceptions are related to the identified structure of motives. In the following, we report on the methodological approach employed to map effectiveness ratings of the specific pathways, together with an assessment of associated motives that can play a role in how people perceive climate change and how people may change their behaviour in the face of such a global risk. The combined set of analyses employed survey data that were gathered from student samples at universities in Norway and Germany.[2] The reported findings are part of a research project investigating the mental representation of pathways to

[1] Values reflect "desirable transsituational goals, varying in importance, that serve as guiding principles in the life of a person or other social entity" (Schwartz, 1994, p. 21).

[2] Surveys that were distributed to the Norwegian sample contained extra items addressing a variety of aspects potentially relevant in perceptions regarding potential pathways to energy transition; however, this paper only reports on motives and perceived impacts on climate change. For findings concerning aspects other than those explored in the reported analyses, see Böhm et al. (2018, 2019).

Table 1 List of pathways and their labels, with means and standard deviations for effectiveness ratings

Label	Pathway[a]	Effectiveness ratings[b]			
		Norwegian sample		German sample	
appliances	Energy efficient home appliances (e.g., light bulbs)	6.01	1.09	6.36	1.35
compensate	Climate compensation (e.g., when booking flights)	5.72	1.29	6.23	1.34
sharing	Sharing economy (e.g., carpooling)	6.02	1.16	6.93	1.41
vegetar	Vegetarian food	6.66	1.67	6.32	1.46
flights	Avoid long flights	6.27	1.38	6.94	1.55
walking	Walking and cycling	6.65	1.75	7.34	1.74
engage	Political engagement	6.56	1.65	5.87	1.48
saving	Energy saving (e.g., turn down heating)	6.16	1.29	7.02	1.35
science	Science	7.12	1.88	6.46	1.88
subsidy	Subsidies (e.g., for renewable energy)	6.58	1.47	6.62	1.33
int.agree	International agreements (e.g., on carbon emissions)	6.30	1.77	6.03	1.54
pub.trans	Public transportation	6.45	1.30	6.73	1.52
int.trade	International trade with carbon offsets	5.70	1.84	4.69	1.68
educ	Environmental education (e.g., in school, at work)	6.64	1.66	6.95	1.73
tax	Taxes (e.g., on carbon intensive goods and services)	6.07	1.28	6.15	1.28
regulate	Regulations (e.g., laws to reduce sales of fossil fuel cars)	6.54	1.49	6.78	1.29
urban	Urban planning (e.g., car free zones)	6.33	1.36	6.46	1.45
nuclear	Nuclear power	5.12	2.27	3.46	2.44
wind	Wind farms	6.70	1.63	7.10	1.58
solar	Solar panels	6.86	1.53	7.06	1.64
e_cars	Electric cars	6.42	1.54	6.71	1.75
hydro	Hydropower	6.68	1.71	6.82	1.47
it	Information technologies (e.g., monitor home energy use)	5.97	1.13	6.05	1.15
houses	Energy efficient houses (e.g., geothermal heating)	6.54	1.33	6.95	1.38
ccs	Carbon capture and storage	5.67	1.43	4.48	1.81

[a]Translations of the original stimulus materials presented in each country

[b]Mean (left column of each country) and standard deviation (right column of each country); scale range 1–9, with higher values indicating a greater perceived mitigation impact on climate change

energy transition in these contexts (Böhm et al., 2018, 2019, 2020; Doran et al., 2018).

Method

Participants

Participants were recruited by posting information about the study on a social networking site (Norwegian sample, $N = 106$, $M_{age} = 23.66$, $SD_{age} = 3.67$, 23.6% male, 76.4% female), as well as through contacting students on a university campus (German sample, $N = 142$, $M_{age} = 23.04$, $SD_{age} = 5.74$, 30.3% male, 69.0% female, $n = 1$ did not answer the gender item). They were informed about the broad aims of the study, that participation in the study would be completely voluntary, that they could retract their participation at any time, and that the data collected would be anonymous. It was further explained that each participant was eligible for compensation in the form of a voucher (worth 200 NOK, in Norway) or money (10 €, in Germany).

Materials

A collection of 25 energy transition pathways (Table 1) was assembled as stimulus material, covering a broad range of possible actions, strategies, and policies, each concerned with reducing carbon emissions from energy production and consumption; for instance, regulations (e.g., on fossil fuel cars), subsidies (e.g., for renewables), lifestyle changes (e.g., vegetarianism), or technological innovations (e.g., carbon capture and storage). The pathways were selected, so as to represent the diversity of political, technological, and behavioural strategies to decarbonize energy production and consumption; for more details on the selection process, see Böhm et al. (2018).

Table 2 List of motives and their labels, with original item wording in each country

Label	Motive	Description as used in the surveys	
		Norwegian sample	German sample
SUPPLY	Sufficient energy supply	Tilstrekkelig energiforsyning	Hinreichende Energieversorgung
SAFETY	Safety	Sikkerhet	Sicherheit
SUSTAIN	Sustainability	Bærekraftighet	Nachhaltigkeit
E_PROTECT	Environmental protection	Miljøvern	Umweltschutz
ANIMAL	Animal welfare	Dyrevelferd	Tierschutz
COMFORT	Comfort	Komfort	Komfort
PROFIT	Profit maximization	Profittmaksimering	Profitmaximierung
MARKET	Free market economy	Fri marketsøkonomi	Freie Marktwirtschaft
WEALTH	Wealth	Rikdom	Reichtum
JUST	Social justice	Sosial rettferdighet	Soziale Gerechtigkeit
FUTURE_GEN	Responsibility for future generations	Ansvar for fremtidige generasjoner	Verantwortung für zukünftige Generationen
RESPECT_AUT	Respect for authority	Respekt for autoritet	Respekt vor Autorität
RESPECT_NAT	Respect for nature	Respekt for naturen	Respekt vor der Natur
RESTRAINT	Self-restraint	Selvbegrensning	Selbstbeschränkung
PROGRESS	Unconditional belief in progress	Ubetinget tro på fremgang	Unbedingter Fortschrittsglaube

A collection of 15 motives (Table 2) was addressed, including various aspects considered relevant for evaluating energy transition pathways. This included basic values (such as wealth, safety, environmental protection, animal welfare, comfort, social justice, responsibility for future generations, respect for authority, respect for nature, self-restraint) and other aspects associated with public opinion about energy (such as free market economy, profit maximization, sufficient energy supply, unconditional faith in progress). Motives and pathways served as stimuli for an assignment task, requiring participants to assign to each pathway those motives they considered most closely related to this pathway (see below for complete instructions).

For the sake of simplicity, we will use the term 'pathway' to refer to the investigated energy transition pathways (including general policies, strategies, individual behaviours, technologies, and components thereof), and we will use the term 'motive' to refer to the investigated motivations, values, intentions, and evaluative aspects described above (see Tables 1 and 2 for full descriptions and short labels used in the figures).[3]

[3] In previous publications that employed the same stimulus material, these items were referred to as 'energy transition pathway components' or 'pathway components' in order to indicate that a pathway would be a broader strategy entailing several of such steps. This paper uses the term 'pathway' in reference to each specific step that can possibly be taken to facilitate energy transitions.

Procedure

A master version of the survey was developed in Norwegian, which was translated into German by two of the authors (see below for an English translation of the measurement instructions). Research assistants conducted the surveys separately for each country, either on a computer screen (Norwegian sample) or with a paper questionnaire (German sample). The consent to participate in the study was inferred on account of survey completion. Participants completed the survey on campus, where they also received their compensation.

Assignment Task The section that assessed the associations between motives and pathways started with the following statement: "In the following, we will present various measures that can be taken in connection with the energy transition. These measures are at the top of each page. Each is followed by a list of 15 aspects, which relate to human motives, values or social aspects. Please read the entire list carefully before you begin to answer the questions. For each measure, select those aspects that you feel are most closely related with the measure. You can freely decide which aspects you consider most relevant. For each measure, you can select up to 5 aspects from the list." Each respective pathway was then rated on a separate page, according to the instruction: "[pathway] is strongly related to (please select up to 5 aspects)". Participants could choose which of the presented 15 aspects they considered closely related to the presented measure by clicking directly on the corresponding pathway (Norwegian sample: computer screen) or through ticking a little box on top of each option (German sample: paper questionnaire).

Effectiveness Ratings The section that focused on the perceived impacts on climate change was introduced by the following statement: "In the following, we will again present to you the same measures that can be taken in connection with the energy transition. Now consider for each of these measures to what extent it can have an impact on climate change. Assume that the measure is being implemented on a large scale." Participants were then presented a list containing each of the pathways described above and asked to indicate to what extent each pathway could contribute to either mitigating or amplifying climate change. Responses were given on a nine-point rating scale (1 = Mitigates or limits climate change, 5 = Neither mitigates nor amplifies, 9 = Amplifies climate change; for analyses, values were inverse coded with greater values indicating more mitigation of climate change, shown in Table 1).

In addition to information about their study program, age, and gender, the survey included a binary item addressing the extent to which participants were familiar with energy transition as a concept (i.e., whether participants had heard the term 'energy transition' before they took part in this survey; Norwegian sample: 63 = Yes, 43 = No; German sample: 137 = Yes, 5 = No) and an open-ended item providing the opportunity for giving any remarks about the survey.

Results

Our analysis is exploratory and descriptive. First, we analyse the assignments of motives to pathways via correspondence analysis (Greenacre, 2007), identifying clusters within and relationships between the two categories; we also examine differences between the Norwegian and the German sample. Second, we analyse the perceived effectiveness of the pathways for mitigating climate change, again considering differences between samples. Third, we connect perceptions of effectiveness with the structural map of motives and pathways.

Correspondence of Motives and Pathways

From the assignment task, we obtain for each sample an aggregated contingency table, representing the co-occurrence frequencies of motives and pathways; that is, each cell of the table shows how many participants ascribed a motive to the respective pathway. We analysed the contingency tables of the two countries separately via correspondence analysis (Greenacre, 2007; Nenadic & Greenacre, 2007). Correspondence analysis (CA) can be viewed as a method that yields a low-dimensional visualization of the similarities of the categories of two categorical variables.

A mapping of motives and pathways in two dimensions is depicted in Fig. 1 for the Norwegian sample, and in Fig. 2 for the German sample. The plots show so called symmetric biplots: Each motive is depicted as a vector (the length indicating how strongly the motive influences the overall structure, and motives pointing approximately in the same direction have similar frequency profiles across the pathways). Each pathway is depicted as a dot; pathways which are located close to each other have similar profiles of frequencies across motives. The orthogonal projection of a pathway dot onto a motive vector indicates how strongly the pathway is associated with the respective motive. Pathways located near the centre of the diagram and short motive vectors represent average-like frequency profiles. In contrast, pathways at the periphery and long motive vectors represent specific profiles that deviate from the average profile; for details, see Greenacre (2010).

Figure 1 (Norwegian data) shows two prominent motive formations: Animal welfare (ANIMAL) with a single strongly associated pathway, namely, vegetarian food, and sufficient energy supply (SUPPLY) with hydropower, wind farms, and solar panels as strongly associated pathways. In opposition to energy supply on the vertical dimension are the motives of comfort (COMFORT) and self-restraint (RESTRAINT) with the associated pathways avoiding long flights, public transportation, energy saving, and walking. The vertical dimension is thus characterized by a contrast of technology-oriented pathways such as hydropower, attributed to the motive to provide sufficient energy supply, and behaviour-oriented pathways such as public transportation, attributed to the motive of self-restraint. Another opposite to energy supply on the vertical axis is the motive of social justice, primarily being associated with the pathway taxes.

The horizontal dimension in Fig. 1 indicates a contrast between animal welfare and market orientation: Motives such as profit maximization (PROFIT), free market economy (MARKET), wealth (WEALTH) and respect for authority (RESPECT_AUT) are strongly related and represent a cluster of motives that are perceived as fostering political/economic pathways involving international agreements on carbon emissions and international trade with carbon offsets, as well as taxes on carbon-intensive goods and political engagement. Also, belief in progress (PROGRESS) and safety concerns (SAFTETY) point in the same direction. Opposed to this faith in the market and in progress is the motive of animal welfare, presumably a catch-all concept for the belief that respecting nature (including animals) is an encompassing strategy to mitigate climate change.

Note that Dimension 1 (market versus nature) and Dimension 2 (supply versus restraint) are orthogonal; pathways which are partly compatible with both dimensions are rare: Eating vegetarian food, a restraint that complies with animal welfare, on the one hand, and the use of nuclear power,

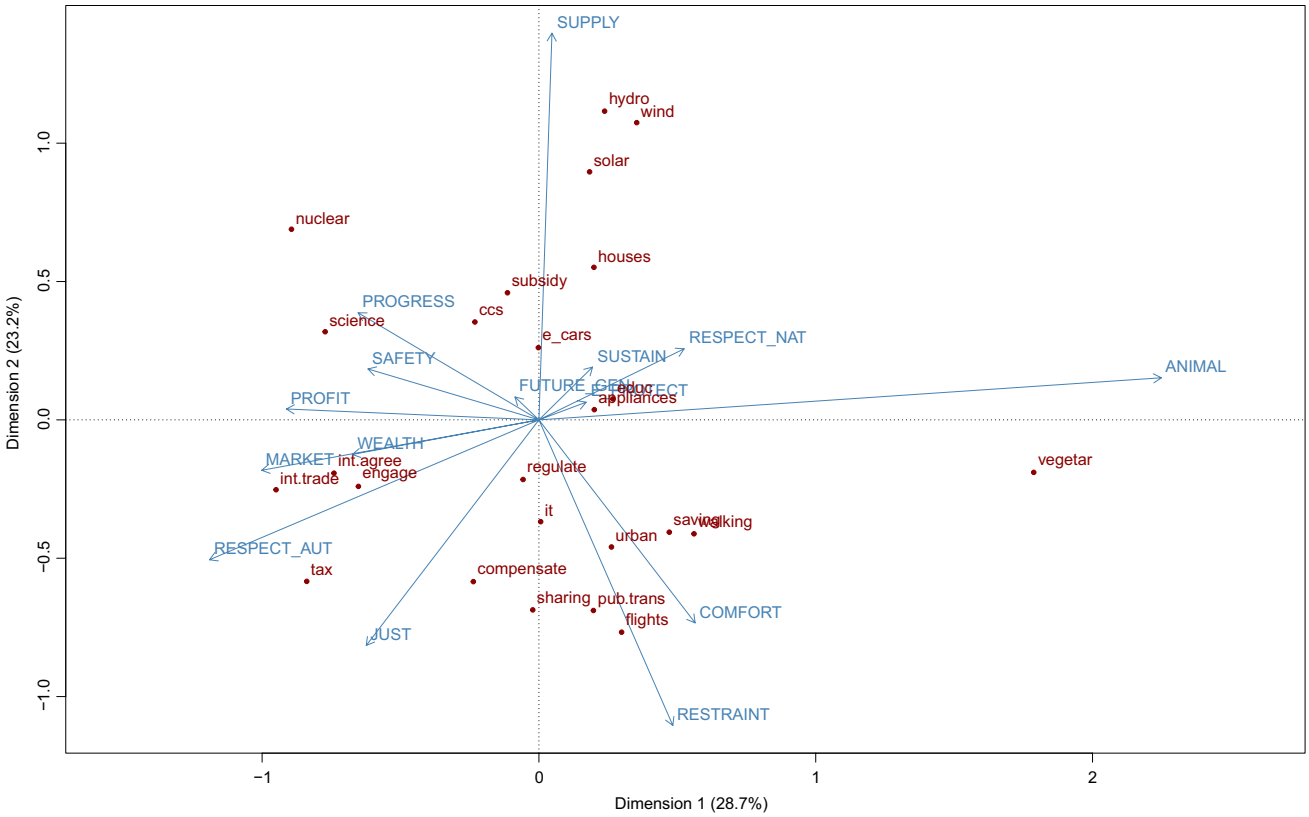

Fig. 1 Correspondence analysis of the co-occurrence matrix of motives (arrows, motives in upper-case letters) and pathways (dots, pathways in lower-case) (Norwegian sample). Biplot of two-dimensional solution (see Tables 1 and 2 for full descriptions of short labels)

providing sufficient supply as well as economic profits, on the other hand, might represent candidates that integrate both dimensions.

A correspondence analysis with the German data (Fig. 2) yields results fairly similar to the Norwegian configuration. Dimension 1 shows a contrast between market/profit orientation and respect for nature, and Dimension 2 is characterized by a motive for sufficient energy supply, associated with hydro-, solar-, and wind-power. However, a few noteworthy differences can be identified: The pursuit of social justice (JUST) and respect for authority (RESPECT_AUT) are closely related to each other and opposite to the supply motive (SUPPLY). Also, the concern for animal welfare and the self-restraint motive basically point in the same direction, involving a vegetarian diet as the singular associated pathway. Interestingly, the pathway of political engagement (however specified), grounded in social justice and respect for authority motives, is somewhat singular.

To examine the similarity of the motivational structures in the two samples, we concatenated the two contingency tables into one table, doubling the motives into one set for Norway and one set for Germany. This yields a table with 25 columns (pathways), and 30 rows (motives), with 15 rows representing the motive assignments of the Norwegian sample, and the other 15 rows representing the motive assignments of the German sample to the 25 pathways. A correspondence analysis of the concatenated table is shown in Fig. 3. For better legibility, the motives are now depicted as dots and not as vectors as in Figs. 1 and 2. A motive's dot corresponds to the endpoint of its vector.

Clearly, the two locations of each motive for the two countries are all next to each other, with a few exceptions. For example, the progress motive for the German sample is more closely related with e-cars, energy-efficient houses and renewable energies (hydro, solar, wind), whereas for the Norwegian sample believing in progress is more closely associated with science and policy-oriented pathways (international trade, taxes). Also, the comfort motive is more distinctly associated with behaviour-oriented pathways (walking, no long-distance flights) in the Norwegian sample, whereas comfort plays no prominent role in distinguishing the pathways in the German sample. However, these differences are minor; overall, the analysis suggests that the perceived motivational structure underlying possible energy transition pathways is highly similar in the two samples.

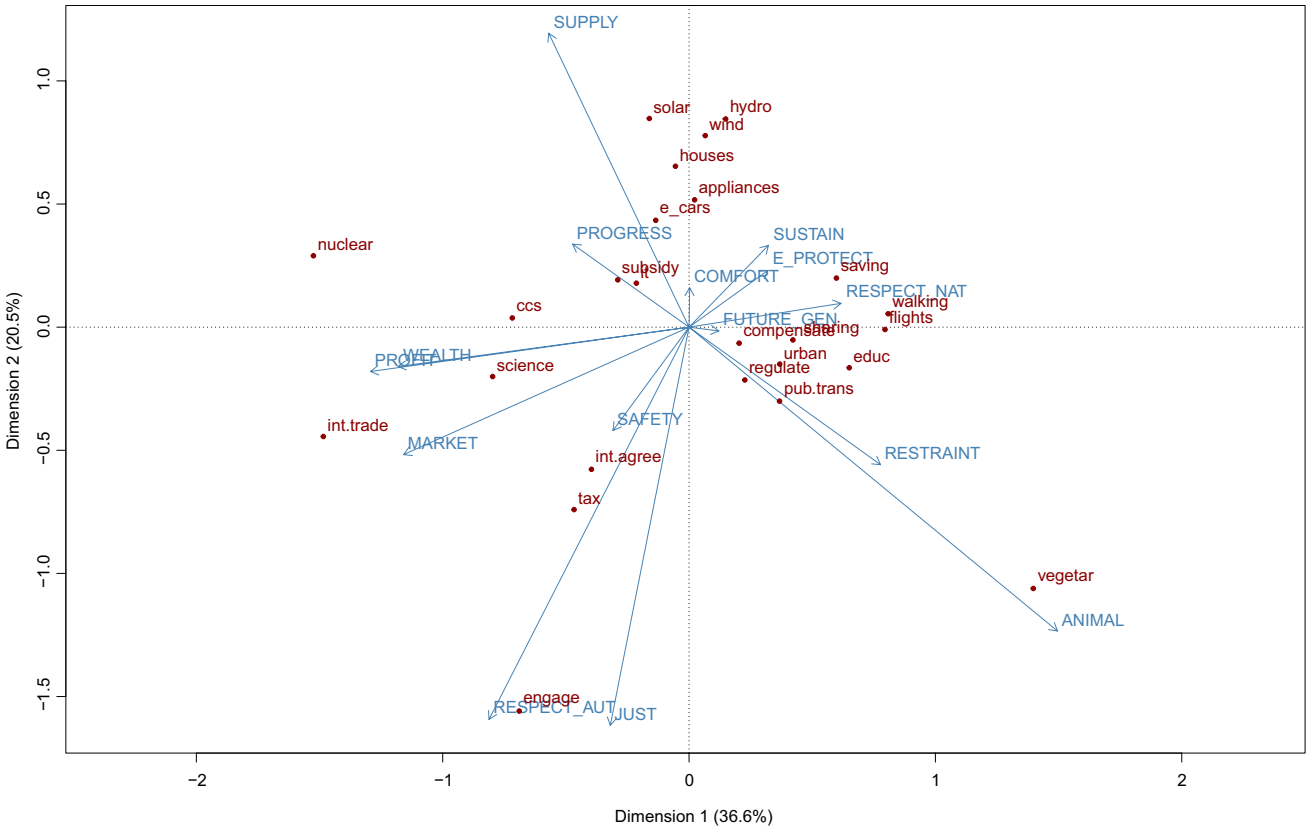

Fig. 2 Correspondence analysis of the co-occurrence matrix of motives (arrows, motives in upper-case letters) and pathways (dots, pathways in lower-case) (German sample). Biplot of two-dimensional solution (see Tables 1 and 2 for full descriptions of short labels)

Effectiveness of Pathways

For the Norwegian sample, science, solar energy, and wind energy are the three most effective pathways to mitigate climate change, and international trade with carbon offsets, carbon capture and storage, and nuclear power are the three least effective (Table 1). For the German sample, the top three pathways are walking and cycling, wind farms, and solar panels; the least effective are the same as for the Norwegian sample, namely, international trade with carbon offsets, carbon capture and storage, and nuclear power. The mean ratings of the pathways are very similar at the extremes in each sample, with the noteworthy difference that the pathway perceived as most effective is science in Norway but walking and cycling in Germany.

The mean effectiveness ratings for the 25 pathways yield a correlation between the Norwegian and the German sample of $r = 0.75$ (Kendall's $\tau = 0.46$); the scatterplot is shown in Fig. 4 (only for descriptive purposes the linear regression line is included, in blue; solid black lines at 5 indicate the midpoints of the rating scale). Generally, effectiveness ratings in the two samples are fairly similar; sharing economy, energy saving, and avoiding long flights obtain relatively higher ratings in the German compared to the Norwegian sample, whereas vegetarian food, political engagement, and science are seen as relatively more effective in the Norwegian sample. Paradigmatic economic and technology-oriented pathways such as international trade with carbon offsets, carbon capture and storage, and nuclear power are perceived as relatively non-effective in both samples. All pathways except the three least effective obtained average scores above 5 in each sample, which is the midpoint of the rating scale, and thus are perceived at least somewhat useful for climate change mitigation.

Mapping Motives and Effectiveness of Pathways

To relate effectiveness to the motives-pathways structure, we constructed a single summated contingency table by adding up the co-occurrence frequencies of the Norwegian and German sample. We also averaged the effectiveness ratings across the two samples. A correspondence analysis of the summed frequency table yielded a configuration highly similar to those obtained previously. Then, the average effectiveness ratings of the pathways were fitted into the two-dimensional configuration of pathways via a general additive model procedure (Wood, 2003); in particular, best fitting contours of effectiveness were obtained and plotted onto the correspondence

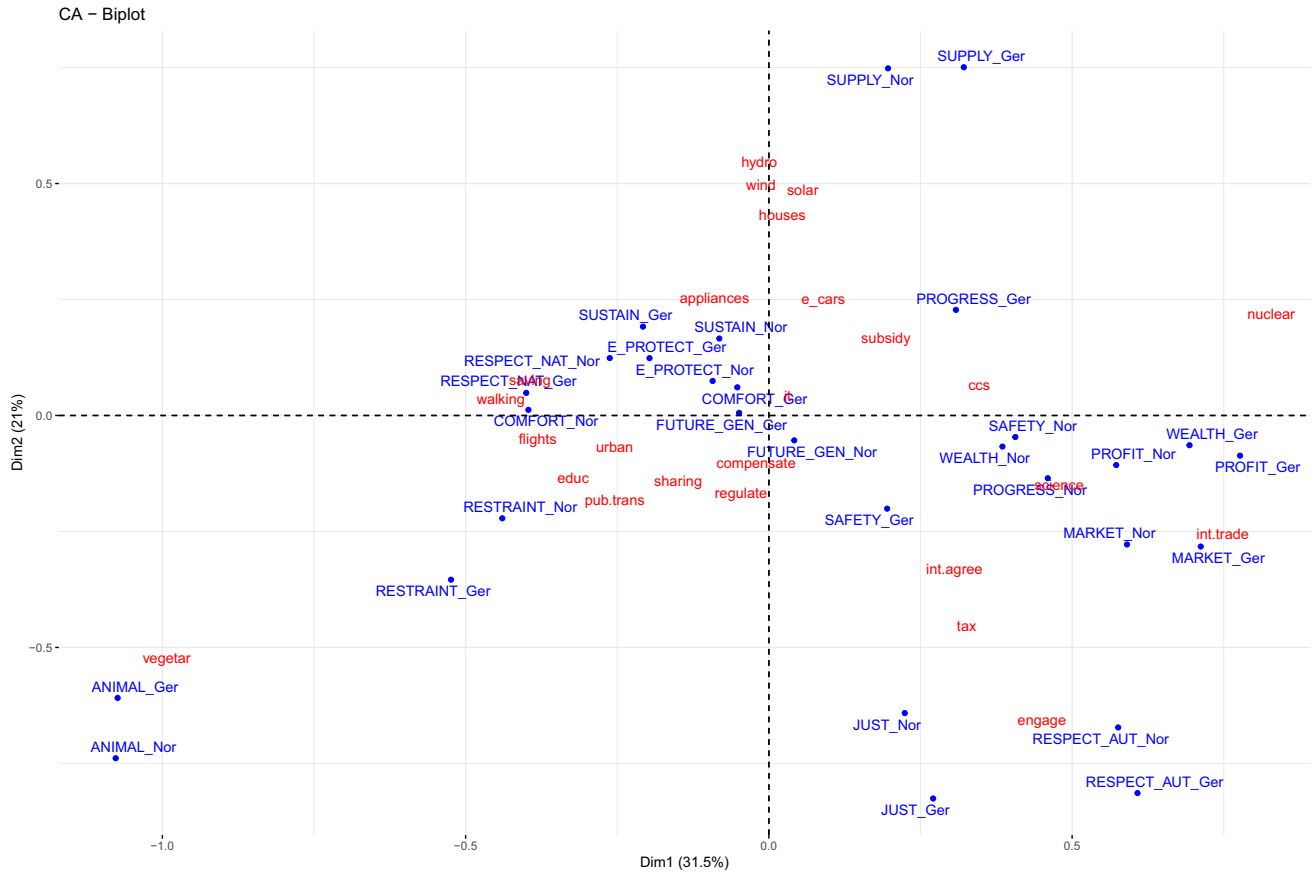

Fig. 3 Correspondence analysis of the co-occurrence matrix of motives (in upper-case letters and blue dot), and pathways (in lower-case letters). Norwegian and German sample combined, suffixes Nor and Ger indicate the respective sample. Biplot of two-dimensional solution (see Tables 1 and 2 for full descriptions of short labels)

map using the ordisurf-function from the vegan package in R (Oksanen et al., 2020).

Figure 5 shows that average effectiveness continuously increases from the lower right to the upper left. The contour lines indicate regions of estimated equal effectiveness, and the two arrows labelled effectNOR and effectGER show the differences between the two samples with respect to effectiveness. For example, pathways low in perceived effectiveness are nuclear power and international trade with carbon offsets, and pathways perceived as highly effective are vegetarian food and environmental education. This average trend can be modulated into the Norwegian data that gravitate more towards vegetarian food and education, and the German data leaning more towards walking and cycling, and urban planning. Generally, the overall trend is highly similar for the two samples.

Discussion

An increasing body of literature suggests that views on pathways to decarbonize the energy system can be structured based on a variety of judgments and perceptions. This includes factors such as valence judgments, impact ratings, and perceived similarities amongst others (Böhm et al., 2018, 2019, 2020; Doran et al., 2018). Our results complement this literature based upon an analysis of the motives that people associate with specific energy transition pathways, which was complemented by an exploration of the pathways' perceived climate change mitigation potential. The discussion below focuses on how these results potentially contribute to understanding public

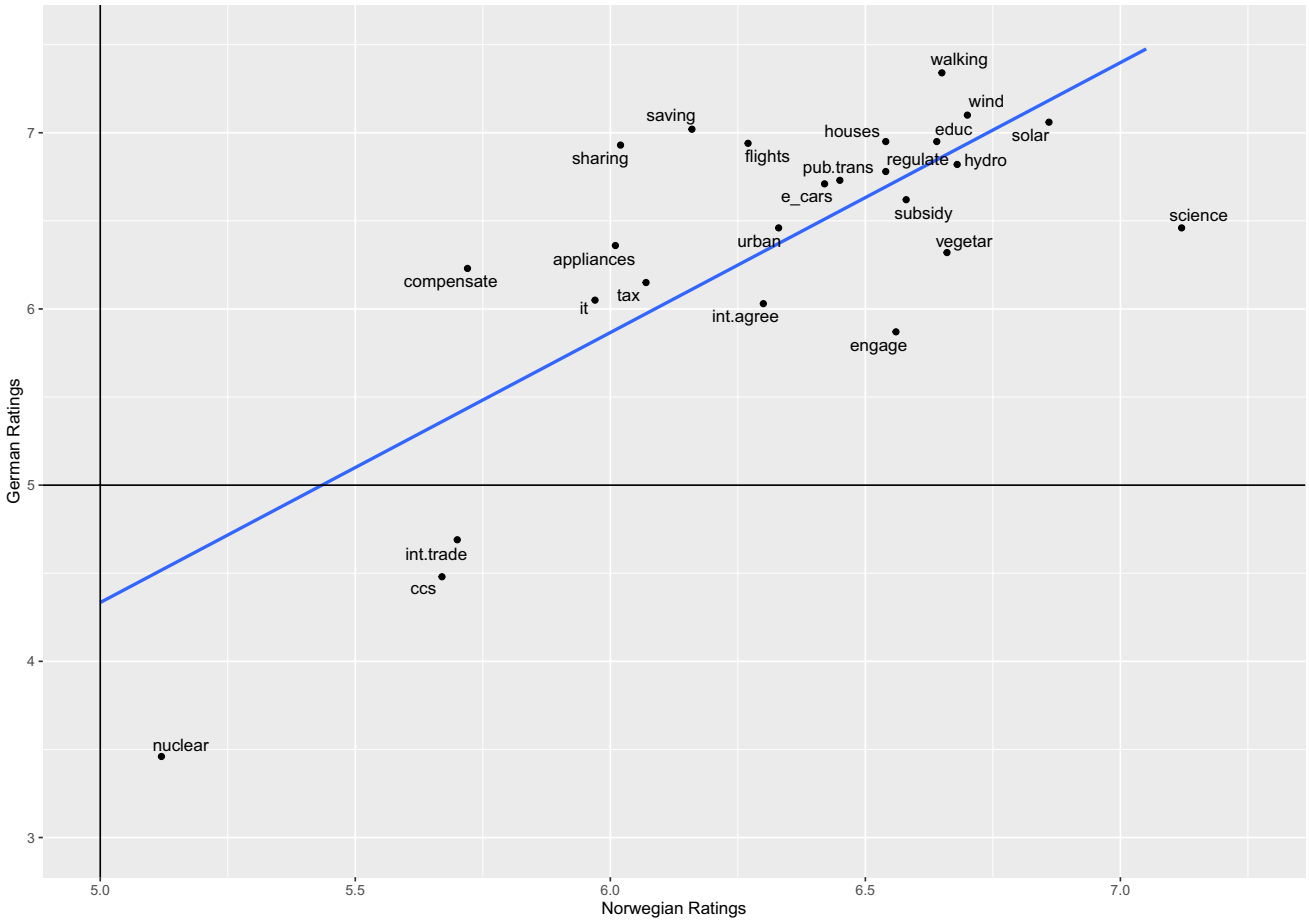

Fig. 4 Scatterplot of Norwegian and German effectiveness ratings (average ratings per sample), with fitted linear regression line

engagement with energy transition, thereby accenting identifiable differences between samples, and informing policy and planning in the sphere of energy transitions.

When it comes to the structural map of which motives people associate with various energy transition pathways, two dimensions emerged from the analyses. First, pathways relying on technological solutions appear to be perceived in opposition to those relying on behaviour change. Technologies such as hydropower or solar panels were in turn closely related with the motive of sufficient energy supply, whereas individual lifestyle aspects such as walking or public transportation tended to be associated with one motive especially, namely, self-restraint. The latter finding could indicate that people construe these aspects as being elements of sufficiency-oriented lifestyles; for example, one may reduce everyday car trips by choosing to walk or take public transportation instead. Second, pathways relying on political/economic measures clustered together with motives indicating a faith in the free market economy and science. This in turn contrasted with vegetarianism, a pathway that was associated with the motive of animal welfare. Under the tentative assumption that participants equate animal welfare with respect for nature, the identified motive structure implicates that nature preservation and economic interests are construed as opposites when people contemplate about the possible implications of energy transition; for further analyses supporting this interpretation, see Böhm et al. (2019, 2020).

While the comfort motive showed a close relationship with individual lifestyle aspects in the Norwegian sample (Fig. 1), this perceptual pattern did not stand out in the German sample (Fig. 2). The finding that aspects like walking and cycling, complemented by avoiding flights, were furthermore associated with self-restraint can be interpreted to suggest that behaviour change is construed as an inconvenience to the extent that it imposes a loss of comfort. This fits studies showing that the willingness to engage in energy conservation, either outside or within the household, can be reduced when people anticipate that their personal comfort could be compromised (Barr et al., 2005; Gaspar et al., 2017). An alternative view on this finding is that putting an emphasis on comfort and wellbeing may promote low-carbon lifestyles. For example, research on the role of contemplative practices in sustainable consumption suggests

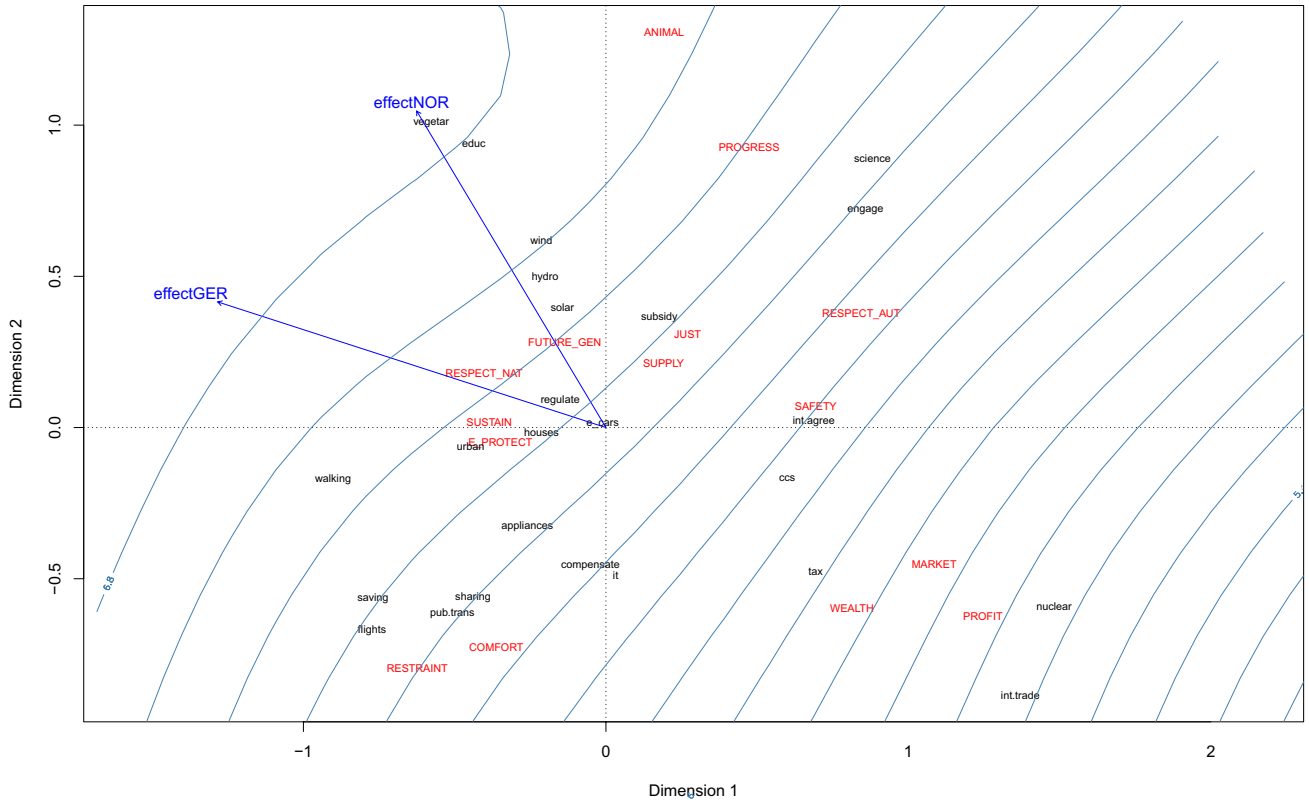

Fig. 5 Correspondence analysis of the combined co-occurrence matrix of the Norwegian and German sample (sum of co-occurrence frequencies). Symmetric Plot of two-dimensional solution, with fitted effectiveness ratings of Norwegian and German sample. Arrows indicate direction of increasing pathway effectiveness; curved lines indicate gradient of effectiveness, increasing from lower right to upper left

that practicing mindfulness can increase individual wellbeing and decrease the importance attached to materialistic values (Geiger et al., 2019).

Behaviour-oriented pathways like the avoidance of long-distance flights were consistently placed in opposition to an unconditional belief in progress. At the same time, progress showed different associations in the two samples (Fig. 3). In the German sample, technology-oriented pathways showed a particularly close association to an unconditional belief in progress, whereas in the Norwegian sample, the same progress motive was more strongly oriented towards science and policy-oriented pathways. This may reflect differences in how participants envision preferred future pathways towards decarbonization, and their implications for individual citizens and households. Advancements in technology could be seen as a way to reduce emissions without necessarily requiring changes in individual lifestyles (e.g., electric cars), whereas regulative policies can be implemented to ensure that the burden of decarbonization will be shared across society (e.g., taxes).

A look at the structural maps seems to indicate country specific patterns for the role of political engagement in assisting energy transitions. Notably, in the German sample, this pathway was closely associated with both social justice and respect for authority. Psychologically, participants perhaps look at political engagement as a means to ensure that decarbonization does not disadvantage particular groups, even if this challenges governmental practice.[4] This resonates with a recent nationally representative survey where a sizeable number of respondents (> 50%) expressed discontent regarding the role of the German government in addressing climate change, including an inattention towards social justice (Setton, 2019). Forthcoming studies could attempt to disentangle which specific principles are evoked when participants think about the issue of social justice in the context of energy transition. For instance, some may think about the extent to which its costs and benefits are dispersed across

[4] Over the last decade, German citizens' satisfaction with the federal government's commitment to climate protection appears to have been decreasing substantially (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020).

society, whereas others understand the term social justice as reflecting the extent to which citizens can participate in the process of deciding where and how emission reductions are targeted. A number of studies highlight the role of distributional and procedural fairness in understanding public engagement with energy transitions, for instance the acceptance of local energy projects such as on-shore wind farms (Sonnberger & Ruddat, 2017, 2018).

Prior evidence indicates that categorizations between individual-, technology-, and policy-oriented measures are fundamental to people's thinking about the impacts of different decarbonization strategies (including impacts on human life, nature, and the economy; Böhm et al., 2019, 2020). Contrary to our expectation to find a similar pattern for perceptions addressing impacts specific to climate change, the current data showed that effectiveness ratings are not uniformly linked to these overarching categories. Solar power and wind farms were among the pathways with the highest effectiveness ratings in both samples. The single most effective pathway, however, differed: science was rated most effective in Norway whereas in Germany walking and cycling had the highest ratings. The latter finding is in line with previous research indicating that most citizens in Germany consider a reduction of energy use in transport important for the overall success of the energy transition (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020). Other pathways that were deemed relatively more effective in the German than in the Norwegian sample are sharing economy, energy saving, and avoiding long flights. Noting that the reported analyses are based on a limited number of observations, these rankings should be interpreted with considerable caution until replicated using nationally representative data.

Despite these differences in which pathways are regarded as particularly effective mitigation responses, there were several cross-national resemblances. Among the pathways that received the lowest effectiveness ratings in both samples was international trade with carbon offsets. This finding is surprising, considering that emissions trading is considered one of the cornerstones of the European Union's long-term climate policy, operating in both Germany and Norway (despite Norway not being a EU member state; European Commission, 2018). Moreover, a recent survey with a national representative sample in Germany suggests that the vast majority of citizens (> 80%) deem an increase in the price of carbon emission rights a very or somewhat important measure of the energy transition (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2020). Maybe, this public support of international trade with carbon offsets is rooted in it being a seemingly cost-efficient strategy of energy transition that causes little disruption in people's daily routines, rather than on believes in its effectiveness.

Conclusion

Societal transitions towards sustainable energy systems rely on technological (e.g., energy-efficient home appliances) and social innovations (e.g., changes in dietary habits). Both types of innovations typically develop in niches (Hölsgens et al., 2018) and may or may not establish themselves in societal regimes, for example, depending on public attitudes and willingness to support the innovations by adopting new technologies or social practices. The present study sheds light on various energy transition pathways, capturing both existing solutions as well technological and social innovations that currently constitute niches, such as carbon capture and storage, or sharing economy. Our findings regarding pathway-specific motives and effectiveness perceptions can inform measures to support the diffusion of existing solutions and adoption of niche innovations. Considering that perceived effectiveness of climate policy measures tends to be positively associated with individual support for the respective measures (e.g., fuel efficiency requirements on certain vehicles; Bostrom et al., 2012), the current findings have the potential to inform social marketing campaigns implemented to increase public acceptance of and active participation in energy transition pathways. Such campaigns may furthermore draw upon the motivational underpinnings of specific pathways, identified in this study. For pathways that share the same motives, campaigns targeted at one of them may directly or indirectly (e.g., through positive behavioural spill-over effects; Lanzini & Thøgersen, 2014) also promote support for other associated pathways. Keeping in mind that the present study did not measure pathway acceptance as such, more research is needed to further validate our interpretation of the structural maps, ideally based on nationally representative data.

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Data Availability The datasets analysed in the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics Statement This study was in compliance with the Norwegian Social Science Data Services (NSD) privacy regulations and the general guidelines for research ethics by the Norwegian National Committees for Research Ethics in the Social Sciences and the Humanities (NESH).

References

Barr, S., Gilg, A. W., & Ford, N. (2005). The household energy gap: Examining the divide between habitual- and purchase-related conservation behaviours. *Energy Policy, 33*(11), 1425–1444. https://doi.org/10.1016/j.enpol.2003.12.016

Böhm, G., Doran, R., Hanss, D., & Pfister, H.-R. (2020). Pathways to energy transition: Replication of a faceted taxonomy. *Umweltpsychologie, 24*(1), 153–161.

Böhm, G., Doran, R., & Pfister, H. (2018). Laypeople's affective images of energy transition pathways. *Frontiers in Psychology, 9*, 1–15. https://doi.org/10.3389/fpsyg.2018.01904

Böhm, G., Doran, R., Rødeseike, A., & Pfister, H. (2019). Pathways to energy transition: A faceted taxonomy. *International Studies of Management & Organization, 49*, 1–17. https://doi.org/10.1080/00208825.2019.1623981

Bolderdijk, J. W., Gorsira, M., Keizer, K., & Steg, L. (2013). Values determine the (in)effectiveness of informational interventions in promoting pro-environmental behavior. *PLoS ONE, 8*(12), 1–7. https://doi.org/10.1371/journal.pone.0083911

Bostrom, A., O'Connor, R. E., Böhm, G., Hanss, D., Bodi, O., Ekström, F., Halder, P., Jeschke, S., Mack, B., Qu, M., Rosentrater, L., Sandve, A., & Sælensminde, I. (2012). Causal thinking and support for climate change policies: International survey findings. *Global Environmental Change, 22*(1), 210–222. https://doi.org/10.1016/j.gloenvcha.2011.09.012

Butler, C., Demski, C., Parkhill, K., Pidgeon, N., & Spence, A. (2015). Public values for energy futures: Framing, indeterminacy and policy making. *Energy Policy, 87*, 665–672. https://doi.org/10.1016/j.enpol.2015.01.035

Corner, A., Venables, D., Spence, A., Poortinga, W., Demski, C., & Pidgeon, N. (2011). Nuclear power, climate change and energy security: Exploring British public attitudes. *Energy Policy, 39*(9), 4823–4833. https://doi.org/10.1016/j.enpol.2011.06.037

De Groot, J. I. M., & Steg, L. (2008). Value orientations to explain beliefs related to environmental significant behavior: How to measure egoistic, altruistic, and biospheric value orientations. *Environment and Behavior, 40*(3), 330–354. https://doi.org/10.1177/0013916506297831

De Groot, J. I. M., Steg, L., & Poortinga, W. (2013). Values, perceived risks and benefits, and acceptability of nuclear energy. *Risk Analysis, 33*(2), 307–317. https://doi.org/10.1111/j.1539-6924.2012.01845.x

Demski, C., Butler, C., Parkhill, K. A., Spence, A., & Pidgeon, N. F. (2015). Public values for energy system change. *Global Environmental Change, 34*, 59–69. https://doi.org/10.1016/j.gloenvcha.2015.06.014

Demski, C., Thomas, G., Becker, S., Evensen, D., & Pidgeon, N. (2019). Acceptance of energy transitions and policies: Public conceptualisations of energy as a need and basic right in the United Kingdom. *Energy Research and Social Science, 48*, 33–45. https://doi.org/10.1016/j.erss.2018.09.018

Doran, R., Böhm, G., & Hanss, D. (2018). Using card sorting to explore the mental representation of energy transition pathways among laypeople. *Frontiers in Psychology, 9*, 1–11. https://doi.org/10.3389/fpsyg.2018.02322

Dreyer, S. J., & Walker, I. (2013). Acceptance and support of the Australian carbon policy. *Social Justice Research, 26*(3), 343–362. https://doi.org/10.1007/s11211-013-0191-1

Dreyer, S. J., Walker, I., McCoy, S. K., & Teisl, M. F. (2015). Australians' views on carbon pricing before and after the 2013 federal election. *Nature Climate Change, 5*(12), 1064–1067. https://doi.org/10.1038/nclimate2756

European Commission. (2018). *A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*. COM(2018) 773 Final. Retrieved November 4, 2019, from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. (2020). *Environmental awareness in Germany 2018 - Results of a representative population survey*. Retrieved January 9, 2021, from https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/umweltbewusstsein_2018_en_bf.pdf

Gaspar, R., Antunes, D., Faria, A., & Meiszner, A. (2017). Sufficiency before efficiency: Consumers' profiling and barriers/facilitators of energy efficient behaviours. *Journal of Cleaner Production, 165*, 134–142. https://doi.org/10.1016/j.jclepro.2017.07.075

Geiger, S. M., Grossman, P., & Schrader, U. (2019). Mindfulness and sustainability: Correlation or causation? *Current Opinion in Psychology, 28*, 23–27. https://doi.org/10.1016/j.copsyc.2018.09.010

Greenacre, M. (2007). *Correspondence analysis in practice* (2nd ed.). Chapman & Hall.

Greenacre, M. (2010). *Biplots in practice*. Fundación BBVA.

Hölsgens, R., Lübke, S., & Hasselkuß, M. (2018). Social innovations in the German energy transition: an attempt to use the heuristics of the multi-level perspective of transitions to analyze the diffusion process of social innovations. *Energy, Sustainability and Society, 8*(1). https://doi.org/10.1186/s13705-018-0150-7

IPCC. (2018). Summary for Policymakers. In *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.

Kim, J., Schmöcker, J. D., Fujii, S., & Noland, R. B. (2013). Attitudes towards road pricing and environmental taxation among US and UK students. *Transportation Research Part a: Policy and Practice, 48*, 50–62. https://doi.org/10.1016/j.tra.2012.10.005

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State

of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Lam, S. P. (2015). Predicting support of climate policies by using a protection motivation model. *Climate Policy, 15*(3), 321–338. https://doi.org/10.1080/14693062.2014.916599

Lanzini, P., & Thøgersen, J. (2014). Behavioural spillover in the environmental domain: An intervention study. *Journal of Environmental Psychology, 40*, 381–390. https://doi.org/10.1016/j.jenvp.2014.09.006

Nenadic, O., & Greenacre, M. (2007). Correspondence analysis in R, with two- and three-dimensional Graphics: The ca Package. *Journal of Statistical Software, 20*(3), 1–13. https://doi.org/10.18637/jss.v020.i03

Oksanen, J., Blanchet, F. G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P. R., O'Hara, R. B., Simpson, G. L., Solymos, P., Henry, M., Stevens, H., Szoecs, E., & Wagner, H. (2020). *vegan: community ecology package. R package version 2.5–7*. https://cran.r-project.org/package=vegan

Perlaviciute, G., & Steg, L. (2014). Contextual and psychological factors shaping evaluations and acceptability of energy alternatives: Integrated review and research agenda. *Renewable and Sustainable Energy Reviews, 35*, 361–381. https://doi.org/10.1016/j.rser.2014.04.003

Perlaviciute, G., & Steg, L. (2015). The influence of values on evaluations of energy alternatives. *Renewable Energy, 77*, 259–267. https://doi.org/10.1016/j.renene.2014.12.020

Perlaviciute, G., Steg, L., & Sovacool, B. K. (2021). A perspective on the human dimensions of a transition to net-zero energy systems. *Energy and Climate Change, 2*, 100042. https://doi.org/10.1016/j.egycc.2021.100042

Rhodes, E., Axsen, J., & Jaccard, M. (2014). Does effective climate policy require well-informed citizen support? *Global Environmental Change, 29*, 92–104. https://doi.org/10.1016/j.gloenvcha.2014.09.001

Rosentrater, L. D., Sælensminde, I., Ekström, F., Böhm, G., Bostrom, A., Hanss, D., & O'Connor, R. E. (2013). Efficacy trade-offs in individuals' support for climate change policies. *Environment and Behavior, 45*(8), 935–970. https://doi.org/10.1177/0013916512450510

Ščasný, M., Zvěřinová, I., Czajkowski, M., Kyselá, E., & Zagórska, K. (2017). Public acceptability of climate change mitigation policies: A discrete choice experiment. *Climate Policy, 17*, S111–S130. https://doi.org/10.1080/14693062.2016.1248888

Schleich, J., Dütschke, E., Schwirplies, C., & Ziegler, A. (2016). Citizens' perceptions of justice in international climate policy: An empirical analysis. *Climate Policy, 16*(1), 50–67. https://doi.org/10.1080/14693062.2014.979129

Schleich, J., & Faure, C. (2017). Explaining citizens' perceptions of international climate-policy relevance. *Energy Policy, 103*, 62–71. https://doi.org/10.1016/j.enpol.2017.01.014

Schleich, J., Schwirplies, C., & Ziegler, A. (2018). Do perceptions of international climate policy stimulate or discourage voluntary climate protection activities? A study of German and US households. *Climate Policy, 18*(5), 568–580. https://doi.org/10.1080/14693062.2017.1409189

Schuitema, G., & de Groot, J. I. M. (2015). Green consumerism: The influence of product attributes and values on purchasing intentions. *Journal of Consumer Behaviour, 14*(1), 57–69. https://doi.org/10.1002/cb.1501

Schwartz, S. H. (1994). Are there universal aspects in the structure and contents of human values? *Journal of Social Issues, 50*(4), 19–45. https://doi.org/10.1111/j.1540-4560.1994.tb01196.x

Setton, D. (2019). *Social sustainability barometer for the German Energiewende: 2018 Edition. Core statements and summary of the key findings*. Institute for Advanced Sustainability Studies. https://doi.org/10.2312/iass.2019.014

Sonnberger, M., & Ruddat, M. (2017). Local and socio-political acceptance of wind farms in Germany. *Technology in Society, 51*, 56–65. https://doi.org/10.1016/j.techsoc.2017.07.005

Sonnberger, M., & Ruddat, M. (2018). Disclosing citizens' perceptual patterns of the transition to renewable energy in Germany. *Nature and Culture, 13*(2), 253–280. https://doi.org/10.3167/nc.2018.130204

Steg, L., Dreijerink, L., & Abrahamse, W. (2005). Factors influencing the acceptability of energy policies: A test of VBN theory. *Journal of Environmental Psychology, 25*(4), 415–425. https://doi.org/10.1016/j.jenvp.2005.08.003

Steg, L., Perlaviciute, G., Sovacool, B. K., Bonaiuto, M., Diekmann, A., Filippini, M., Hindriks, F., Bergstad, C. J., Matthies, E., Matti, S., Mulder, M., Nilsson, A., Pahl, S., Roggenkamp, M., Schuitema, G., Stern, P. C., Tavoni, M., Thøgersen, J., & Woerdman, E. (2021). A research agenda to better understand the human dimensions of energy transitions. *Frontiers in Psychology, 12*, 1–11. https://doi.org/10.3389/fpsyg.2021.672776

Steg, L., Perlaviciute, G., & van der Werff, E. (2015). Understanding the human dimensions of a sustainable energy transition. *Frontiers in Psychology, 6*, 1–17. https://doi.org/10.3389/fpsyg.2015.00805

Steg, L., Perlaviciute, G., van der Werff, E., & Lurvink, J. (2014). The significance of hedonic values for environmentally relevant attitudes, preferences, and actions. *Environment and Behavior, 46*(2), 163–192. https://doi.org/10.1177/0013916512454730

Truelove, H. B., & Parks, C. (2012). Perceptions of behaviors that cause and mitigate global warming and intentions to perform these behaviors. *Journal of Environmental Psychology, 32*(3), 246–259. https://doi.org/10.1016/j.jenvp.2012.04.002

Van den Broek, K., Bolderdijk, J. W., & Steg, L. (2017). Individual differences in values determine the relative persuasiveness of biospheric, economic and combined appeals. *Journal of Environmental Psychology, 53*, 145–156. https://doi.org/10.1016/j.jenvp.2017.07.009

Van Der Werff, E., & Steg, L. (2016). The psychology of participation and interest in smart energy systems: Comparing the value-belief-norm theory and the value-identity-personal norm model. *Energy Research & Social Science, 22*, 107–114. https://doi.org/10.1016/j.erss.2016.08.022

Wood, S. N. (2003). Thin plate regression splines. *Journal of the Royal Statistical Society. Series B: Statistical Methodology*, *65*(1), 95–114. https://doi.org/10.1111/1467-9868.00374