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Pathways to energy transition: A faceted taxonomy

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Abstract

The paper deals with the public perception of energy transition pathways, that is, strategies towards sustainable ways of energy use. Implementing sustainable pathways poses a major challenge for organizations and society. Using a facet theoretical approach, we investigate the structure of people's mental models of such pathways. Three facets are defined capturing the conceptual structure of transition pathways. Facet A (Level) distinguishes three elements: individual behaviors, societal actions, and technologies. Facet B (Type) distinguishes energy efficiency from curtailment pathways. Facet C (Impact domain) distinguishes five domains of potential impact of an energy transition pathway: economy, community, human health, nature, and life quality. A computer-administered survey with items derived from the facet design was administered to a student sample ($N = 106$). A multidimensional scaling analysis yields regional regularities for Facets A and B. For Facet A polar regions can be clearly distinguished according to the facet elements. Facet B shows regions exhibiting a modular structure with curtailment pathways located in the center and efficiency pathways in the periphery. Facet C shows a less clear pattern, showing the two elements economy and nature at opposing ends of an axial structure. Implications for the communication and management of sustainable energy transitions in society and organizations are discussed.

Keywords: facet theory analysis, energy transition, climate change, mental models, sustainable behavior

Pathways to energy transition: A faceted taxonomy

The decarbonization of society has become a major policy objective with respect to climate change mitigation, both nationally and internationally (European Commission 2011; United Nations Framework Convention on Climate Change 2015). This objective can only be met with fundamental shifts in the ways energy is used and generated, which in turn require widespread public acceptance and support (Steg, Perlaviciute, and van der Werff 2015). Individual decisions and behaviors contribute to the energy transition in manifold ways, for example through domestic energy use and transportation choices, through acceptance of technologies, through purchasing of appliances, goods, and services, and through political support of policy strategies and voting choices in political elections. Thus, in order to promote the decarbonization of society, it is important to know how the public thinks about different routes to accomplishing this objective.

Organizations, and the individuals constituting them, play an important role with respect to the question of whether the energy transition can be successful. Organizations are able to influence environmental attitudes and behaviors of their employees, and possibly also of their customers. For example, providing information about the total amount of energy used in their office building can motivate individual efforts to save energy among employees (Carrico and Riemer 2011). Other studies indicate that public perceptions of corporate motives can affect trust in organizations dealing with climate change mitigation (De Vries, Terwel, Ellemers, and Daamen 2015; Terwel, Harinck, Ellemers, and Daamen 2009), and managerial assessments of climate change risks have been shown to influence corporate strategies addressing the regulation of carbon emissions (Bui and de Villiers 2017; Kumarasiri and Gunasekarage 2017).

We focus on one aspect of the public perception of energy transition pathways, namely on people's mental models about such pathways. Mental models are a set of causal beliefs about the causes and consequences of a target activity, event, or situation. Mental models allow people to explain past events and to anticipate the future. Previous research has shown that mental models are a crucial factor in shaping people's responses to environmental issues such as climate change (Bostrom 2017; Böhm and Pfister 2001, 2015; Stern and Raimi 2015). How people react to risks, whether they are willing to engage in actions, and which policies they support depends on their mental models. For example, which climate change policies people support has been shown to depend on which causes they ascribe to climate change and which impact they believe the policies have on climate change (Bostrom et al. 2012).

The aim of this paper is to investigate the structure of people's mental models about energy transition pathways. In the following section, we will review the pertinent literature on the public perception of energy and energy sources. The objective of this review is to identify the relevant dimensions of energy transition pathways that may structure people's mental models. The review will lead us to hypothesize three such dimensions: (a) whether the pathway targets energy-related actions of individual citizens, of societal actors, or technological solutions; (b) whether the pathway entails curtailment in desired activities or increased energy efficiency of activities; and (c) the extent to which different impact domains (e.g., economy, human health, nature) are affected by the pathway.

In this paper we examine whether these dimensions and their components can be empirically identified using a facet theoretical approach. The investigation of theoretical constructs and how they correspond with empirical regularities is the core objective of facet theory. We will define the three dimensions as facets of mental models and report a survey study in which we implemented the corresponding facet design.

Mental Models About Energy Transition Pathways

Individual Behaviors, Societal Actions, or Technological Solutions?

Climate change and energy transition are multifarious phenomena that can be addressed at many different levels. Two broad components of energy transitions are human energy-related behaviors and activities, motivated by pro-environmental attitudes and appropriate incentives, and the provision of sustainable energy sources, most notably renewable energies, fostered by organizations, companies, and politics. Energy sources are embedded in a context of infrastructure, technologies, regularities and policies, all of which contribute to their acceptability on the public as well as on the community level (Perlaviciute and Steg 2014). Adger, Arnell, and Tompkins (2005) point out that adaptation to climate change is made up of actions at different levels through society, from individuals and groups to governments. The same levels apply to human energy behaviors and activities more generally, not only to adaptation. Individuals contribute in manifold ways and in various roles to energy transition (Steg, Perlaviciute, and van der Werff 2015; Whitmarsh, Seyfang, and O'Neill 2011). They consume energy at home and at their workplace, they purchase energy efficient appliances or invest in energy efficiency measures in their buildings, they vote for green policies or form and engage in environmental groups. Governments create and determine structural conditions through policies and regulation on a national level and through international agreements.

In sum, we propose the *Level* at which the core action of a pathway is located as one dimension of people's mental models about energy transition pathways. We distinguish three levels: individual behaviors, societal actions, and technologies. Individual behaviors are energy related behaviors that are performed by individuals, for example at home or at their workplace. Societal actions are taken on a larger scale of social aggregation such as communities or governments. The level of technologies refers to the availability and usage of large-scale energy technologies such as renewable energy systems.

Curtailment or Efficiency?

Dietz et al. (2009) suggested that there are two types of actions that can be targeted in order to accomplish energy savings. The first type, which they refer to as curtailment actions, aims to reduce energy consumption in terms of making adjustments towards and/or cutting back on certain activities and habitual behaviors. Examples for this may include turning off lights, turning down heating, or driving less often by car. The second type, which they refer to as efficiency actions, seeks to improve upon how available amounts of energy are consumed within a given situation. Examples for efficiency actions are purchasing energy efficient light bulbs, buying energy efficient household appliances, or making investments in home insulations. While each of the two types can play their part in accomplishing energy savings, efficiency actions appear to have the greater potential in this regard (Gardner and Stern 2008). Public perceptions on the issue differ in so far that laypeople tend to think about energy conservation mostly in connection with curtailment actions (Kempton, Harris, Keith, and Weihl 1985; Attari, DeKay, Davidson, and De Bruin 2010). This may lead to the public supporting less effective policies, as perceived effectiveness has been shown to be the most important predictor of what kinds of decarbonization strategies people support (Bostrom et al. 2012).

Stern and colleagues had primarily individual behaviors in mind when they introduced the distinction between curtailment and efficiency. We argue that the two types of action can also be applied to the levels of societal actions and technologies. On the level of societal actions, policies can aim at promoting either energy efficient behaviors and technologies (efficiency action, e.g., subsidies for energy efficient appliances) or at reducing energy- or carbon-intense practices and technologies (curtailment action, e.g., taxation of carbon-intense products). On the level of technologies, we define efficiency technology pathways as technologies that do not reduce the current level of consumption or generation of fossil fuel based energy (e.g., carbon capture and storage), while curtailment technology pathways are defined as technologies that reduce fossil fuels (e.g., renewable energies).

Hence, the second dimension of mental models about energy transition pathways that we propose is the *Type* of action as either efficiency or curtailment.

Economy, Community, Human Health, Nature, and Life Quality

The acceptability of energy alternatives among the general public depends on how people evaluate the collective and individual consequences of these energy alternatives, and on fairness considerations (Perlaviciute and Steg 2014). The way in which energy is produced and used has a myriad of diverse impacts, affecting people's well-being, the economy, and the overall functioning of society (European Commission 2011). A crucial factor that determines how people evaluate the costs and benefits of sustainable energy behaviors and energy alternatives is their values (Perlaviciute and Steg 2014; Steg, Perlaviciute, and van der Werff 2015). Three classes of values have been identified in the literature on the role of value orientations in environmental behavior and energy use (Böhm and Pfister 2011; Poortinga, Steg, and Vlek 2004; Soyez, Hoffmann, Wünschmann, and Gelbrich 2009; Stern and Dietz 1994): (a) egoistic values focussing on the personal well-being (e.g., health, wealth), (b) social values focussing on the well-being of the society (e.g., equality, social justice), and (c) and biospheric values focussing on the well-being of nature (e.g., preserving the environment).

We therefore assume that the impacts of energy transition pathways that are relevant to the public are those that affect these three domains – the self, the social community, or the natural environment. Based on studies on environmental values (Böhm and Pfister 2011; Poortinga, Steg, and Vlek 2004) we differentiate individual impacts and societal impacts into more specific domains. Specifically, we distinguish five *Impact domains* as the third dimension of mental models about energy transition pathways: health and life quality as individual impact domains, economy and community as societal impact domains, and nature.

Research Aims

The current paper draws on the existing literature on mental models, and investigates the public perception of various pathways to energy transition. More specifically, we focus on public causal beliefs about the impacts of such pathways. According to our mental models approach, people will take action to reduce energy consumption only if they consider these actions effective. The findings from this paper will help to clarify which concepts are relevant to the public perception of energy transition pathways. This will ultimately also help identify possible barriers and facilitators for the propagated energy transition, and by this means, inform policy and management targeted at promoting the decarbonization of society.

We hypothesize that three dimensions structure mental models about energy transition pathways: the *Level* of the core action that is undertaken in the pathway (individual behaviors, societal actions, technological solutions), the *Type* of the action (curtailment, efficiency), and the effects of the action on value-relevant *Impact domains* (economy, community, human health, nature, life quality.). These three dimensions will be defined as facets according to facet theory (see next section). We will then present a study that follows a facet theoretical approach. The aim is to confirm level, type, and impact domain as taxonomic classifications that structure the public perception of energy transition pathways.

A Facet Theory Approach

Our approach proceeds along the lines of standard facet analysis (Guttman 1954; Guttman and Greenbaum 1998; Levy 2014). First, we outline the definitional framework of the research domain of interest, namely, causal beliefs concerning the impact of pathways to energy transition. The conceptual framework is then formalized as a mapping sentence, which serves to select a suitable sample of items for empirical measurement. The assessments obtained from a sample of participants are then correlated, and the correlation matrix is submitted to ordinal Multidimensional Scaling (MDS) ((Amar 2005)Borg & Groenen, 2005). Based on the two- and three-dimensional configurations, an attempt is made to identify regional patterns that correspond to the faceted definition; that is, we partition the representational space in such a way that distinct regions represent different facet elements. Customary regional partitions that mirror the facet elements such as polar, axial or modular arrangements (simplex, circumplex) are focused upon (Cohen 2014).

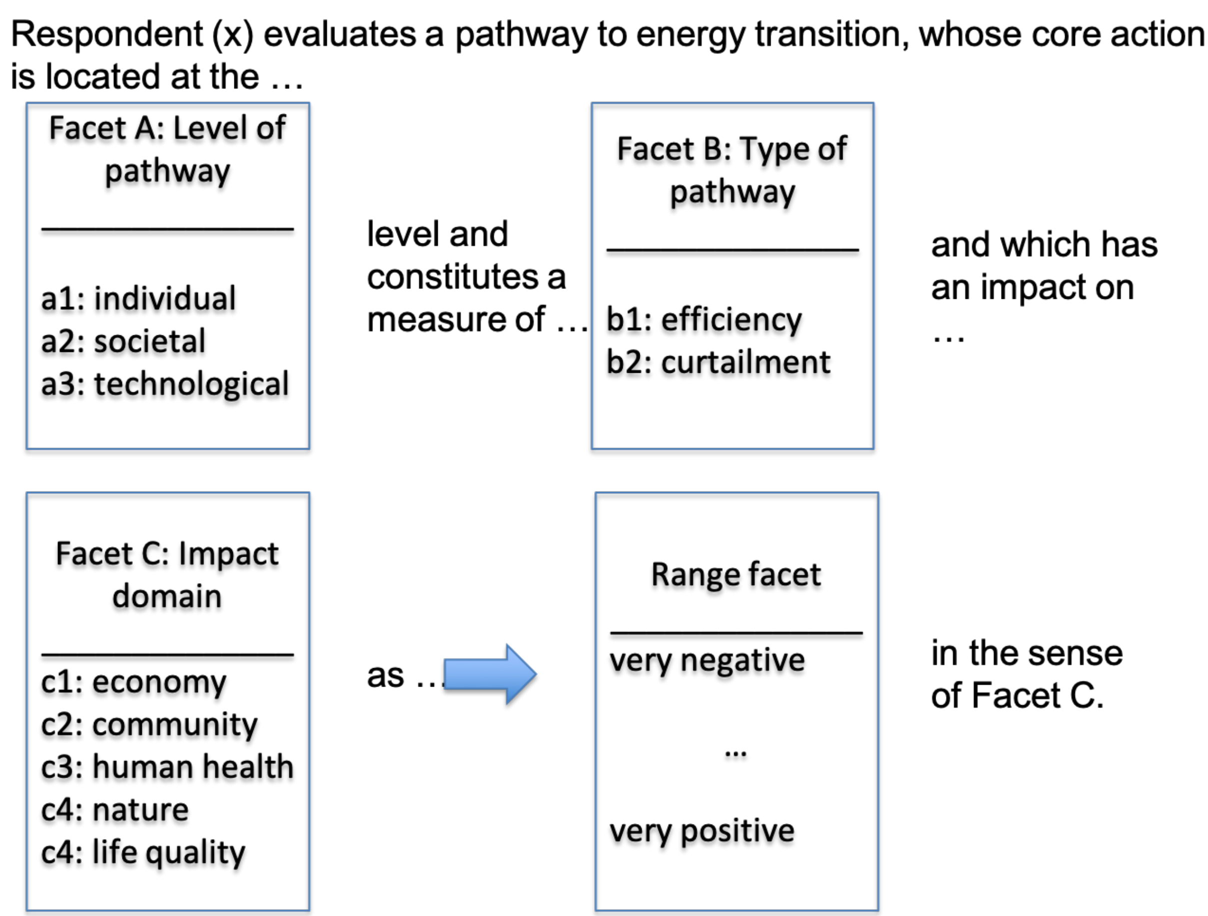
As outlined in the preceding section, we assume that, concerning their perceived causal impact, pathways to energy transition can be distinguished according to three facets:

Facet A (Level) refers to the behavioral level at which the pathway is implemented; it consists of three unordered elements: (1) individual behaviors, (2) societal actions, and (3) technologies.

Facet B (Type) refers to the type of action that is implemented. It draws on a classification of environmental behaviors (Gardner and Stern 2008; Dietz et al. 2009) and distinguishes two elements: (1) energy efficiency and (2) energy curtailment.

Facet C (Impact domain) distinguishes five domains as targets of potential impact of an energy transition pathway: (1) economy, (2) community, (3) human health, (4) nature, and (5) life quality.

The respective mapping sentence is displayed in Figure 1.



Methods

Participants

A sample of 106 students from a Norwegian university participated in the study. Most of them were enrolled in one of the university's psychology programs. They were recruited via university Facebook posts, mailing lists, and announcements in lectures. They received a universal shopping coupon worth NOK 200 as an incentive for their participation. Their age ranged from 19 to 39 years (M = 23.66, SD = 3.67); 76.4 % were female.

Material

All materials were presented in a computer-administered survey. Respondents were instructed that they would be presented with a list of potential measures that can be taken as part of an energy transition strategy. Table 1 shows the pathways that were used as elements of Facet A (Level of pathway, with 3 elements: individual behaviors, societal actions, technologies) and Facet B (Type of pathway, with 2 elements: efficiency, curtailment). Facet C (Impact domain) consisted of the five elements economy, community, human health, nature, and life quality. Participants were asked to rate the impact of each pathway on each of the five impact domains on a rating scale that ranged from -10 (very negative impact) via 0 (neutral) to +10 (very positive impact). For each structuple (i.e., for each distinct combination of one element from each and every of the three facets) one specific item was constructed. Hence, each participant responded to 3 × 2 × 5 = 30 items. For example, the item corresponding to structuple <A1: individual behavior, B1: efficiency, C1: economy> asked participants to rate on a scale from very negative to very positive which effect *Energy efficient home appliances (e.g., light bulbs)* have on the *economy* (for a list of all items see Appendix). The facet questionnaire was part of a larger survey that asked for further evaluations of the pathways (e.g., free associations); these are not relevant to the current analysis and will not be reported in this paper.

[INSERT TABLE 1 ABOUT HERE]

Design and procedure

The study was conducted in a computer lab room at the university. Participants took part in groups of 5 to 15. Each participant was placed at a desk with an individual computer; the individual places were separated into cubicles by partition walls placed at the sides and the front of each desk. Each of the six pathways was presented on top of the computer screen; below it, the five impact domains were listed, each impact domain followed by an 11-point rating scale. The order of both the pathways and the impact domains was randomized across participants. On average, participants needed 45 minutes for the entire session.

Results

The analysis was conducted via ordinal MDS (Multidimensional Scaling) using the smacof package (De Leeuw and Mair 2009) of the R statistical environment (R Core Team 2017). Input data were Pearson correlations r_{ij} among items, which were transformed to dissimilarities d_{ij} via $d_{ij} = \sqrt{1 - r_{ij}}$.

Results will be presented in three steps. First, we describe the two-dimensional MDS solution including all 30 items; second, we average across Facet C and portray the two-dimensional MDS solution for the six aggregated items representing Facets A and B only. Third, we describe the three-dimensional MDS solution including all 30 items.

The two-dimensional solution with all 30 items is depicted in Figure 2. We measure goodness of fit using the Stress-1 index (Borg and Groenen 2005), yielding a value of *0.204*. This value is much smaller than the mean stress of 0.34 ($2\sigma = 0.01$) derived from simulations with random configurations using 30 items in two dimensions (Mair, Borg, and Rusch 2016; Spence and Ogilvie 1973). However, these random stress norms constitute a Null hypothesis of pure random data and thus provide only limited information about goodness of fit. A more informative check is a permutation test based on random permutations of the original data matrix (Mair et al., 2016). The respective permutation test yields a mean stress of 0.32 ($2\sigma = 0.02$), and a one-sided test (with $\alpha = 0.5\%$) yields a critical value of 0.30. Hence, the observed stress value of 0.204 is significantly smaller than what would be expected under random data, indicating a good fit of the two-dimensional configuration to the data.

The configuration can be partitioned by Facet A into a wedgelike arrangement of the three facet elements (individual, societal, and technological pathways). This regional pattern suggests that Facet A plays a polar role with unordered elements, each element expanding from a common origin into a different direction (Levy 2014). Facet B plays a modular role: The configuration can be partitioned into two quasi-concentric circles with Facet Element 2 (curtailment) located in a central ellipsoid region and Element 1 (efficiency) located at the periphery of the configuration. The combination of a polar and a modular facet with a common origin is called a radex, which is a typical pattern resulting from the combination of an ordered facet (Facet B) with an unordered one (Facet A), and has repeatedly been found in other domains (Levy 2014). For Facet C (Impact domain) no simple regional pattern can be detected in the two-dimensional configuration.

[INSERT FIGURE 2 ABOUT HERE]

[INSERT TABLE 2 ABOUT HERE]

Since Facet C (Impact domain) does not show a clear regional pattern, we averaged across Facet C elements yielding six aggregated items representing the combinations of elements from Facets A and B; averaging may be assumed to lead to more reliable correlation coefficients and hence to a more stable regional pattern. The two-dimensional MDS solution yields a Stress value of *0.002* (Stress-1); with only six items, an effectively perfect fit in two dimensions can be obtained. However, with only six items, even random data would fit equally well (permutation test: mean stress = 0.05, critical value = 0.001; random stress norm: mean stress = 0.06, 2σ = 0.08). Figure 3 confirms the radex regional pattern found previously (Figure 2), with Facet A (Level) establishing a polar partitioning, and Facet B (Type) yielding a modulating partitioning with facet elements pertaining to curtailment located in the inner region and elements pertaining to efficiency located in the outer region of the configuration.

[INSERT FIGURE 3 ABOUT HERE]

Compared to the non-aggregated two-dimensional solution displayed in Figure 2, the three-dimensional solution of all 30 items yields an improved stress value of *0.142* (Stress-1). The mean stress value from a permutation test is 0.32, with a critical value (α = 5%) of 0.31. The random stress norm for 30 items and 3 dimensions is 0.24 (2σ = 0.01). Both tests indicate a good fit of the three-dimensional solution.

The planes obtained from plotting Dimensions 1 against 2 and Dimensions 1 against 3 basically reproduce the findings from the two-dimensional solution. Plotting Dimensions 2 against 3 (Figure 4) reveals an interesting regularity with respect to Facet C: Facet Element 1 (economy) and Element 4 (nature) are located at opposite ends of the configuration, with Elements 2, 3, and 5 (community, human health, quality of life) being interspersed in between. This suggests an axial (Shye, Elizur, and Hoffman 1994; Levy 2014) role of Facet C, with elements ordered from nature to economy, with social elements in between. Table 2 summarizes the results concerning the roles of the facets.

[INSERT FIGURE 4 ABOUT HERE]

Discussion

From the literature review presented, we derived the assumption that three dimensions structure mental models about energy transition pathways: the *Level* of the core action that is undertaken in the pathway, the *Type* of the action, and the impacts of the action on value-relevant *Impact domains*. These three dimensions were explored according to a facet theoretical approach with the aim to confirm level, type, and domain as taxonomic classifications that structure the public perception of energy transition pathways. Results suggest that our faceted definition of pathways to energy transition represents an empirically valid underpinning of how people perceive and mentally represent the impacts of transition strategies. However, results also suggest some limitations and adjustments.

For Facet A, level of the pathway, a clear empirical correspondence could be established. The three elements of Facet A can be partitioned in a polar way, forming wedge-like regions

(Figures 2 and 3). Hence, there is a distinction with regard to pathways located at the individual level (e.g., energy efficient home appliances), pathways found at the societal level (e.g., subsidies), and pathways consisting of technological solutions (e.g., carbon capture and storage). Formally, Facet A plays a polar role representing an unordered set of three elements. Since the range facet represents judgments about positive/negative impacts on various domains, this result suggests that people ascribe different potential impacts to energy transition pathways that are located at different levels; possibly implying that they consider the combination of strategies at different levels necessary to change the energy sector in the long run. A further reading of these findings is that participants think about energy transition as an objective that requires action going beyond changes in individual behaviors and decisions. This view matches scholarly debates construing sustainable energy transition as a multifarious challenge, whereby contextual factors such as laws and regulations can influence public support for this transition (Perlaviciute and Steg 2014; Steg, Perlaviciute, and van der Werff 2015; Clayton et al. 2015). However, additional levels or differentiations may possibly exist, for example, a distinction of the societal level into political regulations and cultural practices, or between local and global strategies might be plausible; such amendments are easily integrated using a faceted framework (Shye 2014, 2015).

We found empirical support for the theoretical distinction between actions concerned with curtailment and actions concerned with efficiency, as postulated in Facet B (Type). Facet B appears to play a modulating role, partitioning the space into an inner region populated by curtailment items, and an outer region populated by efficiency items (Figures 2 and 3). This type of regionality imposes an order on the elements of Facet B, going from central to peripheral. On the one hand, this implies that Facet B elements represent aspects of energy transitions that participants consider as distinct with regard to their perceived impacts. On the other hand, a modulating role suggests that some inherent dimension establishes an order among facet elements. Empirically, items in the center of the configuration are on average more closely correlated than items on the periphery. Psychologically, this suggests that people discriminate less among strategies and their impacts if curtailment is involved, in contrast to strategies that emphasize increases in efficiency without imposing restrictions on people's consumption habits; curtailment, in a way, appears to be psychologically more central and homogeneous than efficiency. This finding reinforces the notion that curtailment and efficiency represent distinct categories in the context of energy saving, in terms of their impacts and in terms of their psychological properties (Gardner and Stern 2008). It also has implications for how information about possible pathways to energy transition is communicated, for instance about their relative importance in promoting this transition. Informing the public about the actual impact of different actions is important since laypeople frequently identify curtailment actions as an effective way to conserve energy (Attari, DeKay, Davidson, and De Bruin 2010), which is contrary to the opinions shared among experts (Gardner and Stern 2008).

Facet C failed to partition the space of the energy transition items into separable regions based on the two-dimensional MDS configuration. However, the configuration obtained from a three-dimensional MDS and taking the plane spanned by Dimension 2 versus Dimension 3 reveals an interesting pattern. We find a polarity contrasting perceived impacts on nature and perceived impacts on economy, while the remaining impact domains are located mainly in the space between these two opposites (Figure 4). We may impose an axial regionality, ordering Facet C elements from impact on nature to impact on economy, with the elements health, community, and quality of life located in the middle region. The structure gives room to speculate at the underlying mental model about energy transition pathways, and their perceived impact on community, human health, and quality of life. One communality among these impact domains is that they are concerned with human life in one way or another. It could be that participants think that environmental preservation tends to be at odds with economic interests, and that various aspects of human life are caught between such an antagonistic relationship; for a related discussion, see Pidgeon (2012) or Pfister and Böhm (2001). This suggests a reformulation of Facet C into three ordered impact domains: nature, human life, and economy.

Research shows that an increasing share of the public believes that corporations should contribute their part in dealing with societal challenges (Maignan 2001; Mohr, Webb, and Harris 2001), including climate change (Unsworth, Russell, and Davis 2016). This kind of public support could help pave the way for policy measures aimed at regulating carbon emissions from the corporate sector. Examples of these measures are restrictions on the use of fossil fuels, and subsidies for investments in renewable energy systems. One major finding in our study was that the perceived impacts of various energy transition pathways were distinguishable with regard to the level at which they operate. This facet comprised actions implemented at the societal level, including organizations, businesses, and corporations. Forthcoming studies may want to scrutinize the proposed levels, and in addition, to explore if some pathways are perceived to be more effective in accomplishing energy transitions than others.

The preceding discussion has implications for how public perceptions of energy transition pathways could shape the context in which organizations operate; in addition, there are arguments for why corporations could benefit from changing the ways in which they use energy. An argument commonly put forward in favor of interventions targeting energy use among employees is that it can save money, for instance by lowering electricity consumption (Carrico and Riemer 2011; Matthies, Kastner, Klesse, and Wagner 2011). Although the present study did not focus on energy use in organizations per se, it contributes to understanding how managers, executives, and other decision makers might respond to policy regulations on carbon emissions. Specifically, Figure 2 shows that item assessments on curtailment were located more closely to each other than item assessments on efficiency were. This could mean that when laypeople think about actions to save energy, they have a more diverse understanding of the impacts of efficiency than they have of the impacts of curtailment. Clearly, further research will be needed to investigate this claim, including research on possible reasons such as people's knowledge about different energy behaviors. This would provide important insights for how management strategies targeting these behaviors can be successful.

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Tables

Table 1

Pathways presented as elements for Facet A (Level of pathway) and Facet B (Type of pathway).

	Type of pathway	
Level of pathway	Efficiency	Curtailment
Individual behavior	Energy efficient home appliances (e.g., light bulbs)	Energy saving (e.g., turn down heating)
Societal action	Subsidies (e.g., for renewable energy)	Regulations (e.g., laws to reduce sales of fossil fuel cars)
Technologies	Carbon capture and storage	Solar panels

Note: One pathway was selected for each combination of facet elements from Facets A and B.

Table 2

Summary of regional patterns and fit indices.

Facet	*Analysis*	*Separation Index*	*Stress*	*Role of Facet*
A: Level	2-D with 30 items	1.00	0.204	polar
A: Level	2-D with 6 aggregated structuples	1.00	0.002	polar
B: Type	2-D with 30 items	0.77	0.204	modular
	2-D with 6 aggregated structuples	1.00	0.002	modular
C: Type	3-D with 30 items	0.54	0.142	axial (opposition of economy and nature)

Note. The separation index quantifies the degree to which the assumed regional hypothesis corresponds with the empirical configuration (based on the number of items inside/outside the predicted regions), with 0 indicating worst and 1 indicating optimal fit (Amar, 2005).

Appendix

Complete List of Items Used in the Study

All materials were presented on a computer screen. Participants were informed that they would be presented with various steps that may be taken as part of energy transition; energy transition was explained as long-term changes in energy systems that are introduced with the aim to contribute to a more sustainable society. Rating instructions read as follows (English translation): "Please rate for each step what impact it may have on the following five domains: economy, community, human health, nature, life quality (from very negative to very positive). Assume that each step is being implemented to a large extent."

On the following screens, one pathway was presented at the top of the screen, followed by the question (English translation) "What impact does this have on these different domains?". Then the five domains were listed, each accompanied by an 11-point rating scale ranging from -10 to +10. Verbal labels were added to the endpoints and the midpoint of the scale: -10 (very negative) … 0 (neutral) … +10 (very positive).

Structuple	*Item (Pathway – Impact domain)*	*M*	*SD*
A1B1C1	Energy efficient home appliances (e.g., light bulbs) - Economy	2.56	3.54
A1B1C2	Energy efficient home appliances (e.g., light bulbs) - Community	3.88	3.10
A1B1C3	Energy efficient home appliances (e.g., light bulbs) – Human health	1.61	2.57
A1B1C4	Energy efficient home appliances (e.g., light bulbs) - Nature	4.67	2.45

Structuple	*Item (Pathway – Impact domain)*	*M*	*SD*
A1B1C5	Energy efficient home appliances (e.g., light bulbs) – Life quality	1.41	2.85
A1B2C1	Energy saving (e.g., turn down heating) - Economy	4.63	3.50
A1B2C2	Energy saving (e.g., turn down heating) - Community	4.33	3.28
A1B2C3	Energy saving (e.g., turn down heating) – Human health	1.13	2.75
A1B2C4	Energy saving (e.g., turn down heating) - Nature	5.06	2.61
A1B2C5	Energy saving (e.g., turn down heating) – Life quality	-0.43	3.33
A2B1C1	Subsidies (e.g., for renewable energy) - Economy	2.20	3.70
A2B1C2	Subsidies (e.g., for renewable energy) - Community	4.10	2.77
A2B1C3	Subsidies (e.g., for renewable energy) – Human health	2.40	2.66
A2B1C4	Subsidies (e.g., for renewable energy) - Nature	4.90	2.82
A2B1C5	Subsidies (e.g., for renewable energy) – Life quality	2.06	2.68

Structuple	*Item (Pathway – Impact domain)*	*M*	*SD*
A2B2C1	Regulations (e.g., laws to reduce sales of fossil fuel cars) - Economy	-0.22	3.22
A2B2C2	Regulations (e.g., laws to reduce sales of fossil fuel cars) - Community	4.15	3.64
A2B2C3	Regulations (e.g., laws to reduce sales of fossil fuel cars) – Human health	4.15	3.23
A2B2C4	Regulations (e.g., laws to reduce sales of fossil fuel cars) - Nature	6.06	2.61
A2B2C5	Regulations (e.g., laws to reduce sales of fossil fuel cars) – Life quality	1.04	3.45
A3B1C1	Carbon capture and storage - Economy	0.10	2.53
A3B1C2	Carbon capture and storage - Community	1.39	2.91
A3B1C3	Carbon capture and storage - Human health	1.51	2.79
A3B1C4	Carbon capture and storage - Nature	1.86	4.34
A3B1C5	Carbon capture and storage – Life quality	0.55	1.97
A3B2C1	Solar panels - Economy	3.34	3.70
A3B2C2	Solar panels - Community	4.33	2.83
A3B2C3	Solar panels – Human health	2.51	2.70
A3B2C4	Solar panels - Nature	5.69	2.73
A3B2C5	Solar panels – Life quality	1.79	2.87

Figures

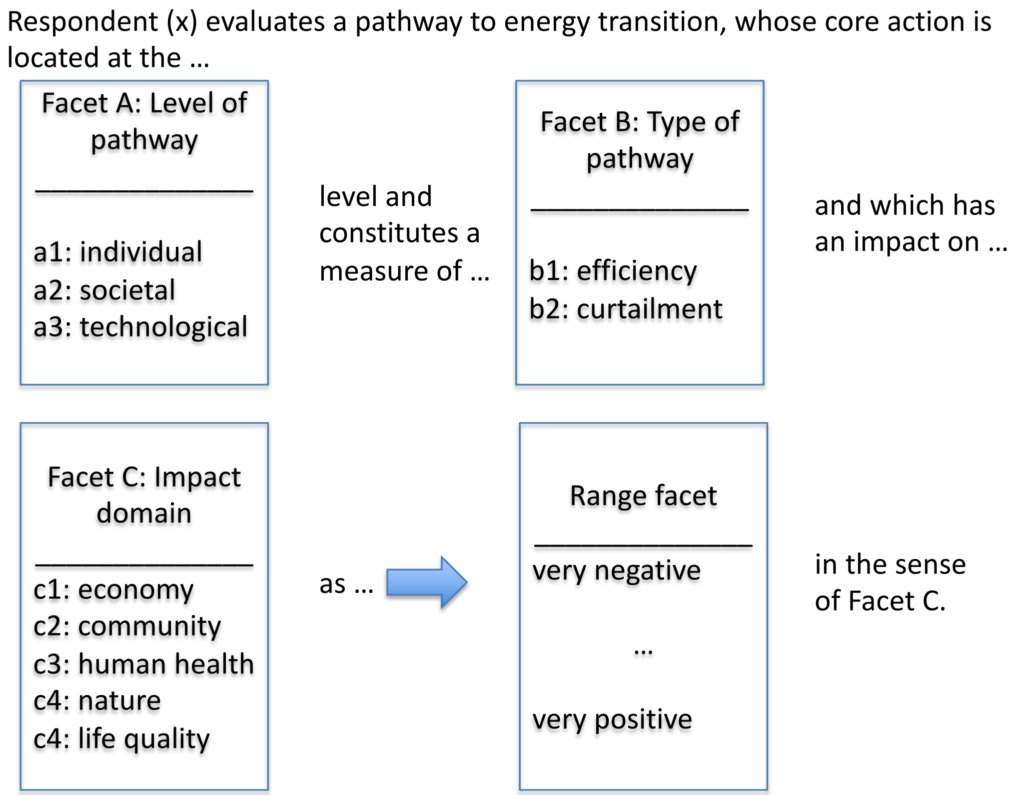

Figure 1. Mapping sentence of a person's evaluation of the impacts of a pathway to energy transition.

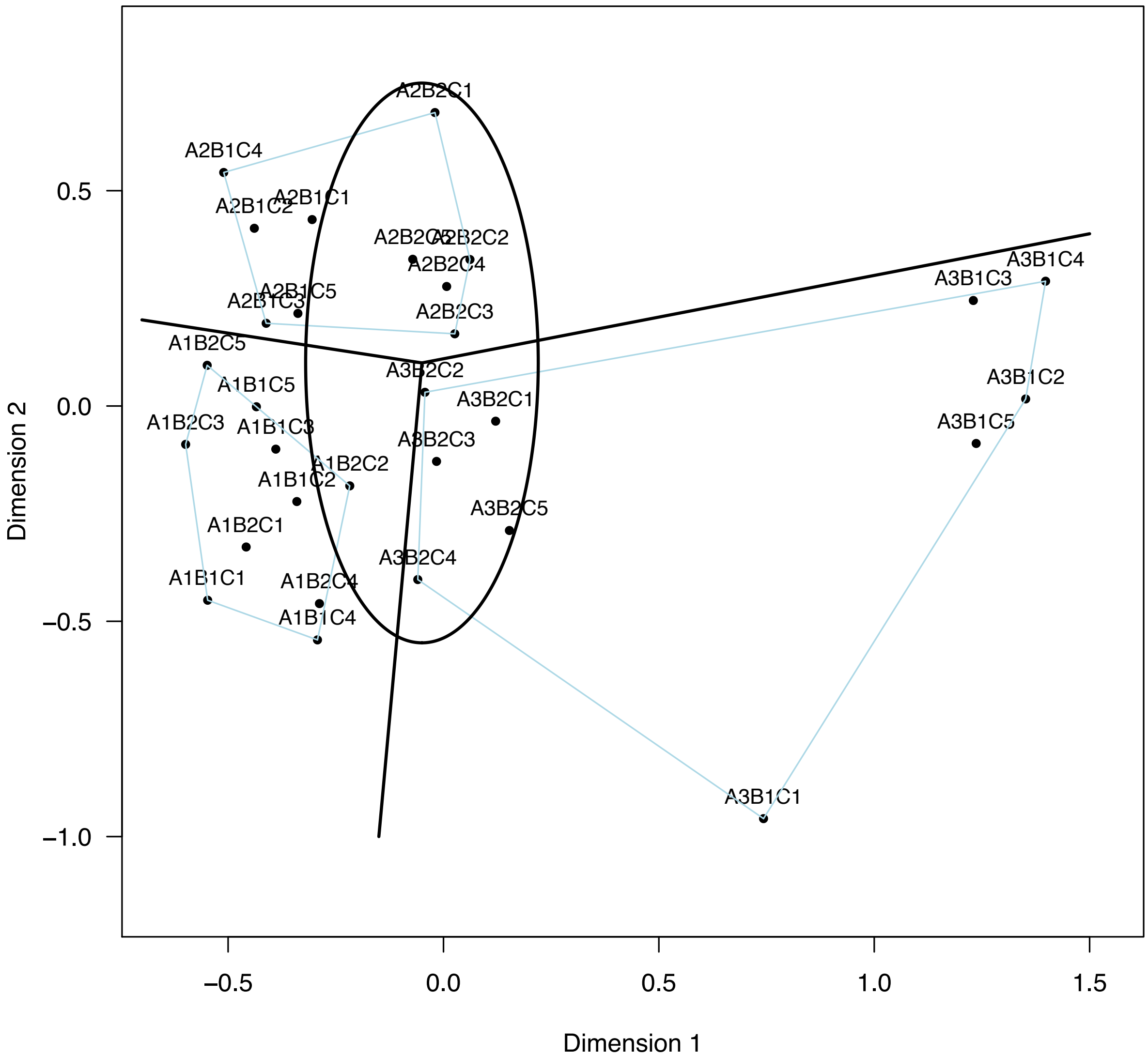

Figure 2. Two-dimensional ordinal MDS configuration of 30 items, with radex regionality superimposed (items are labeled as AnBnCn according to facet elements). Items corresponding to the elements of Facet A are connected by the convex hull (light polygons), emphasizing the non-overlapping regional pattern.

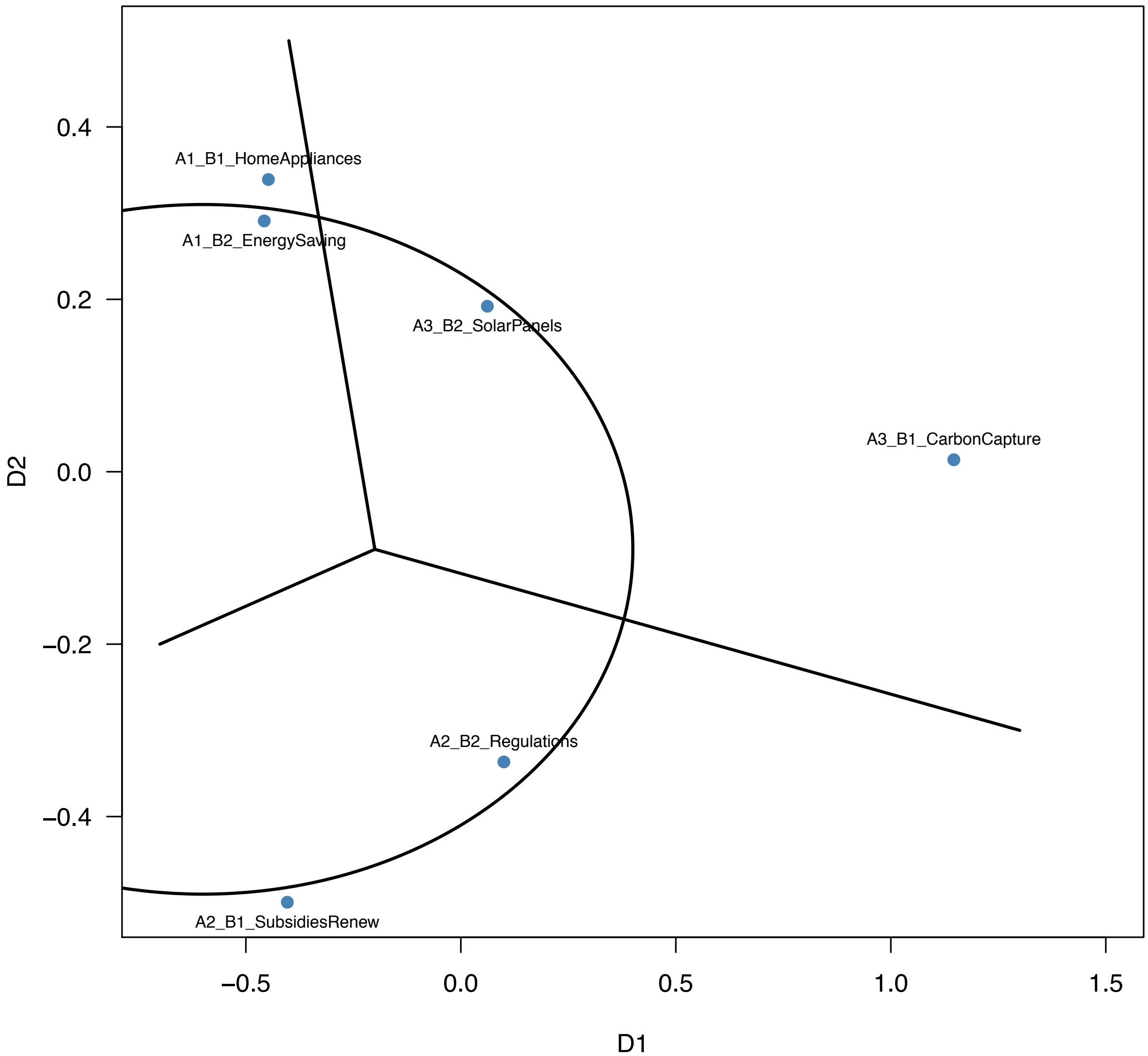

Figure 3. Two-dimensional ordinal MDS configuration of six items representing Facets A and B (aggregated across Facet C), with radex regionality superimposed (structuples are indicated as AnBn; abbreviated item descriptions are added, cf. Appendix and Table 1).

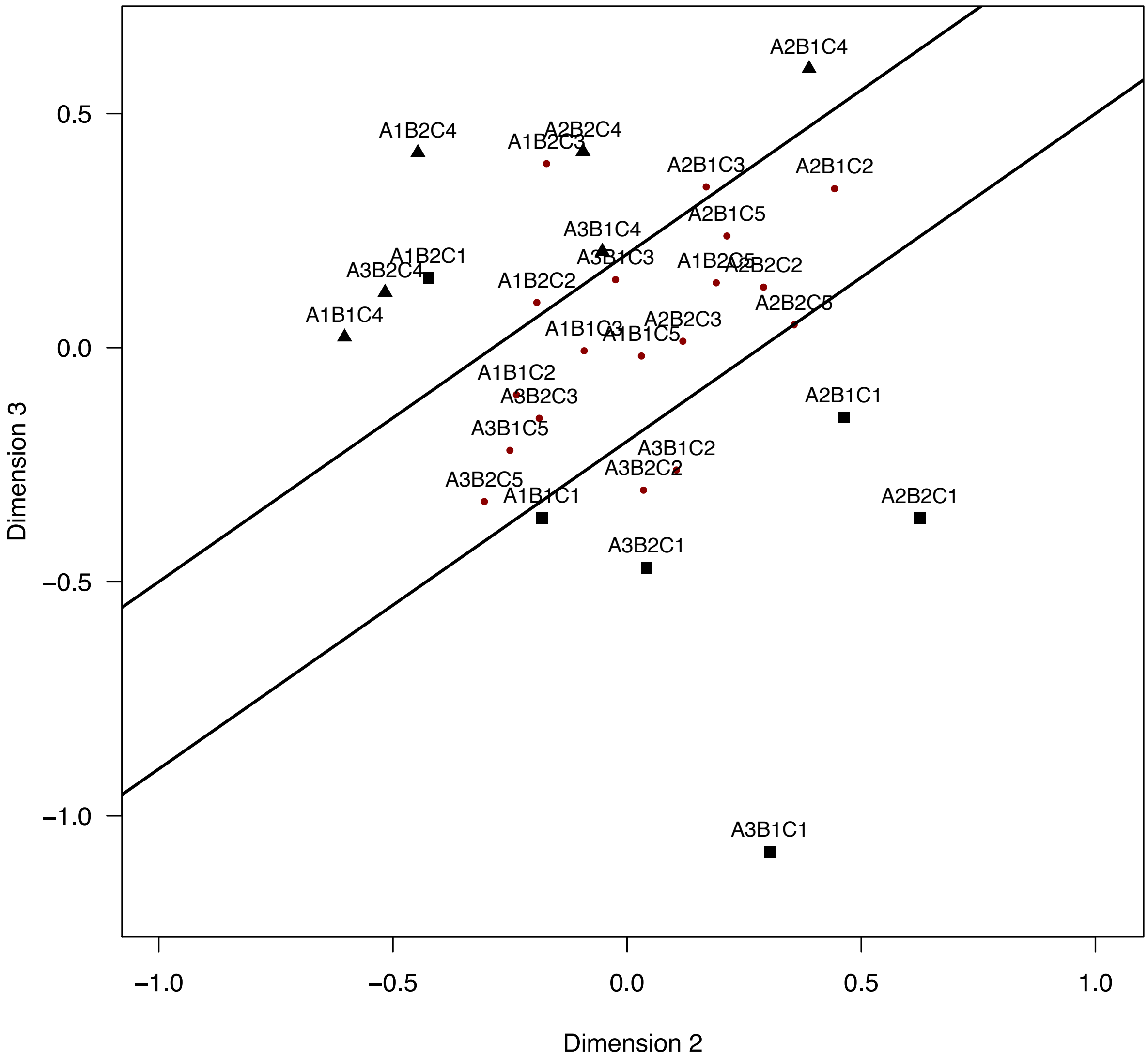

Figure 4. Three-dimensional ordinal MDS configuration of 30 items, showing the plane spanned by Dimensions 2 and 3, with axial separation superimposed (structuples are indicated by AnBnCn; C1 elements are depicted as squares, C4 elements are depicted as triangles).