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ORIGINAL ARTICLE

Sustainable practices and household resilience: an empirical analysis of behavior change in times of crises

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Abstract Understanding sustainability behavior is essential in tackling the global challenge of climate change. The importance of studying sustainability practices and their dynamics grows in light of recent global crises such as the COVID-19 pandemic and the energy crisis following the Ukraine war. These events both challenge and shape individual sustainable practices, offering opportunities for fostering individual sustainable practices and enhancing societal resilience. An online survey was conducted in Germany (n = 571, May 2023) to investigate sustainable behavior dynamics (mobility, energy-saving, and shopping habits) and to identify segments reflecting behavioral shifts. We found relative stability in sustainable mobility choices compared to pre-crisis times, with a tendency towards reduction, as well as an overall increase in energy-saving and sustainable shopping habits. Factor analyses revealed that sustainable mobility behavior (SMB) and sustainable consumer practices (SCP) formed two separate domains. Cluster analyses further identified four segments within each domain, each exhibiting unique behavioral patterns compared to pre-crisis practices. Examining individual variables, adopting more sustainable mobility practices was associated with sociodemographic factors (income, education, and area of living), higher levels of environmental awareness, institutional trust, and increased risk perceptions. Sociodemographic variables had less influence on sustainable consumer practices. Here, higher levels of knowledge, climate change awareness, trust, and risk perceptions played a significant role. Our findings highlight the importance of separately considering behavioral domains in understanding crises-induced changes in sustainability practices. Moreover, it is important to consider specific individual factors and to develop tailored interventions and policies to promote sustainable practices during volatile times.

Keywords Behavior changes · Crises · Mobility · Energy saving · Consumption

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Introduction

Understanding sustainable behavior is essential in responding to pressing global issues such as climate change and the depletion of natural resources (Newell

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et al., 2021). Sustainable behavior is characterized by the collective actions and choices made by individuals and households to minimize their negative impact on the environment (Steg & Vlek, 2009). These behaviors cover a wide range of daily activities, including but not limited to food consumption, transport choices, energy consumption, and waste management practices (Geiger et al., 2018). Although the role of households and individuals is crucial for resource conservation, its potential contribution has not been fully explored in sustainability transitions (Raven et al., 2021). However, the European Environment Agency has highlighted the need to reduce household energy consumption as a key step towards achieving Europe's low-carbon goals. It is recognized that the future of environmental impact lies not only in the implementation of policy measures, but also in the personal lifestyle choices of the European population (EEA, 2019). Previous research has often treated households as static entities, failing to recognize their dynamic nature and their role in the wider context of systemic change (Raven et al., 2021). However, external factors, particularly those of a disruptive nature such as the COVID-19 pandemic and the post-conflict energy crisis in Ukraine, can have an immediate and significant impact on the sustainable behavior of households (Liobikienė et al., 2023). Therefore, this study aims to understand if and how far recent crises – under consideration of individual factors—shape individual sustainability behavior.

Behavioral change in sustainability transitions

The relevance of sustainable behavior change lies in its ability to deliver sustainability goals in practice. Behaviors typically under investigation include those related to reducing waste, improving energy efficiency, and conserving water and biodiversity. These behavioral changes are an integral part of the transition to a society that values sustainability in all aspects of life (Grin et al., 2010). Understanding the underlying drivers of behavior change is essential for promoting sustainability transitions. The Theory of Planned Behavior (TPB, Ajzen, 1991) provides a well-established framework, suggesting that individual actions are influenced by attitudes, subjective norms, and perceived behavioral control. This theory is central to understanding how attitudes such as environmental awareness drive sustainable lifestyle adaptations in areas such as food consumption, transport, and energy use.

However, research suggests that sustainable behavior is not only a product of individual perceptions and cognitive processes but is also significantly influenced by external socio-economic factors and institutional frameworks (Gifford, 2011). Structural barriers such as the lack of access to sustainable mobility options or economic constraints can significantly impede the adoption of pro-environmental behaviors despite high levels of environmental awareness (Steg & Vlek, 2009). The Comprehensive Action Determination Model (Klöckner & Blöbaum, 2010), that integrates core constructs of the TPB, expands on this by additionally incorporating intentional, normative, and situational influences, showing that external factors such as available infrastructure and social norms play a critical role in shaping environmentally friendly behavior like travel mode choices. Similarly, the Theory of Interpersonal Behavior (Triandis, 1977) emphasizes the importance of facilitating conditions, but also of habitual behaviors, highlighting how past behaviors and external situational influences interact with individual behavior. Moreover, factors such as cultural norms, policy incentives, and technological advances significantly influence the ability of individuals to engage in sustainable practices (Kollmuss & Agyeman, 2002). For example, the adoption of renewable energy is not simply a personal choice, but often depends on policy support and economic incentives.

Recognizing that the path to sustainability transformation is not linear or predictable and has to account for individual-level and external influences, particularly in an era of volatility, it is essential to focus on the development of sustainable behavior in times of crisis.

Crises as catalysts for sustainable behavior

The role of crises in shaping sustainable behavior has emerged as a critical area of research. Global events, such as the COVID-19 pandemic and the subsequent energy crises following the the Russian invasion of Ukraine, have not only disrupted traditional patterns of consumption, but also provided a unique opportunity to accelerate the transition to more sustainable practices. Such crises can act as catalysts, prompting individuals and households to reassess their

consumption habits and adopt more energy-efficient behaviors (Ergen & Suckert, 2021).

Within the context of crises, the concept of resilience is also relevant, due to its transformative capacity in fostering sustainable behavior. In the ecological sciences, resilience has been defined as the ability of a system (an individual, a community, or an ecosystem) to absorb stress, recover from disruptions and maintain its essential functions, structures, and identity (Alexander, 2013; Hosseini et al., 2016). This concept encompasses the ability to adapt to changing conditions and to transform in ways that enhance the system's sustainability, often in response to challenges and disruptions. The concept of resilience has also been used in the field of technical systems in the context of energy and logistics infrastructure. Resilience in this context is not only about the ability of these systems to withstand disruptions, but also their ability to recover quickly and even improve their functionality in the aftermath. It involves proactive planning, robust design, and adaptive management to ensure continuity of service and minimize the impact on society and the economy. Understanding and enhancing the resilience of energy and logistics infrastructure is critical to maintaining the stability and efficiency of our interconnected global systems, especially in the face of increasing uncertainty and complexity (Hamborg et al., 2020).

In the context of household behavior in crisis, this traditional notion of resilience takes on a more differentiated dimension. Households, as microunits of larger social and ecological systems, demonstrate resilience when they successfully navigate and adapt to the adverse conditions created by global crises such as the COVID-19 pandemic or energy shortages. This involves strategically adjusting resource use and actively adopting behaviors that contribute to the sustainability and well-being of the household (Ansah et al., 2019). For example, shifting to more energy-efficient behaviors, reassessing consumption habits, and adopting sustainable lifestyles are examples of household resilience in action. These adaptive and transformative responses at the household level are critical to fostering broader societal resilience and progress towards achieving the Sustainable Development Goals (SDGs) (Assarkhaniki, et al., 2023).

Recent research has begun to empirically investigate household behaviors in the context of crises and resilient behavior practices. Corbos et al. (2023) found a positive impact of knowledge of energy savings on actual energy-saving behaviors during the energy crisis. This relationship was moderated by responsible behavior, suggesting that mere awareness is not sufficient without a sense of responsibility towards sustainable practices. Liobikienė et al. (2023) investigated the factors that influence energy-saving behavior and identified concerns stemming from the war against Ukraine as the primary influencing factor. This suggests that global crises can significantly shape individual sustainability practices. Novianto et al. (2022) studied the impact of lifestyle changes on home energy consumption during recent crises. They found an increase in the use of household energy appliances, particularly among the middle-upper consumer segments. Monterde-i-Bort et al. (2022) investigated mobility patterns and mode choice preferences during the COVID-19 pandemic in 10 (mostly European) countries. During the pandemic, respondents reduced their mobility, including the use of cars, local public transport, and walking. After the lifting of mobility restrictions, however, their habits reverted almost back to the pre-COVID-19 level.

While global crises and the ability of households to adapt play an important role, individual choices and behavior within households also matter. The following section therefore explores the role of individual factors in sustainability behavior.

Individual factors in sustainable behavior

Individual impact factors play a crucial role in sustainable behavior, acting as both facilitators and barriers to environmental action. Sociodemographic variables such as age, gender, and income significantly influence the likelihood that an individual will engage in sustainable practices. For example, Wiernik et al. (2020) found that older people may be less likely to adopt new environmental behaviors due to deep-rooted habits, while younger people are generally more open to change and innovation.

Societal roles and structural barriers, particularly for vulnerable groups, also have a significant impact on sustainable behavior (Sovacool et al., 2022). The capacity to engage in sustainable behaviour is often dependent on financial resources and access to the required infrastructure (e.g., Axon & Morrissey, 2020). These factors include gender roles, economic disparities, and access to infrastructure, which can

privilege certain individuals while disproportionately burdening others. For example, sustainable behavior can often become a responsibility assigned to women in households due to traditional divisions of labor, as seen in the management of energy consumption and waste (Räty & Carlsson-Kanyama, 2010).

Environmental awareness also plays a key role in sustainable behavior. Individuals with greater environmental knowledge are more likely to engage in sustainable behaviors such as waste reduction and energy conservation. This correlation between knowledge and action suggests that informed awareness is crucial in promoting pro-environmental behavior (Lacroix & Gifford, 2022).

In addition, risk perception, particularly in relation to climate change and environmental threats, has been shown to motivate sustainable behavior (Smith & Leiserowitz, 2022). People who perceive higher levels of environmental risk are more likely to change their behavior to reduce those risks (O'Connor et al., 1999). However, the relationship between risk perception and behavior can be complex and is often mediated by personal values and beliefs (Spence et al., 2012).

Research aims

Although studies on sustainable behavioral change increasingly focus on the micro level of households and individuals and also take into account the increasing volatility caused by times of crisis, there has not yet been a detailed empirical study on the extent and nature of more sustainable behavioral patterns and individual influencing factors in the wake of past crises.

Therefore, this study aims to fill this gap by examining changes in sustainability behavior in the context of recent crises. The following research aims were pursued:

1. Analysis of the pattern and extent of changes in sustainability behaviors triggered by recent crises.
2. Identification and characterization of distinct clusters of behavioral changes.
3. Derivation of policy implications aiming at fostering sustainable behaviors.

Method

To investigate changes in sustainable behaviors and underlying determinants, an empirical quantitative approach was chosen, which will be described in the following sections.

Questionnaire

The questionnaire was modular in design and included the following sections:

- Screening section (age, gender, education, federal state, and income) to target a population-representative group for Germany (individuals > 18 years)
- Demographic data (information on family status, area of residence)
- Attitude-related factors (environmental awareness: 5 items, Cronbach's alpha = 0.86, ESS, 2021 and institutional trust to mitigate climate change: 7 items, Cronbach's alpha = 0.89, Offermann-van Heek et al., 2018)
- Risk perception (regarding the future in general, individual health, and individual financial situation, 3 items, Cronbach's alpha = 0.76, adapted from Arning et al., 2023)
- Behavioral changes: Changes in sustainability behavior compared to the time before the onset of the COVID-19-pandemic and the Ukraine war were measured by four items: "Has your behavior changed because of recent crises such as the COVID-19-pandemic or the energy crisis resulting from the Ukraine war? Compared to the time three years ago:" a) I save energy…, b) I use public transport…, c) I buy sustainably as much as possible…, d) I use a car…. Response alternatives were "much less frequently, less frequently, rather less frequently, equally frequently, somewhat more frequently, more frequently, much more frequently".

The items related to attitude factors and risk perception had to be answered on a six-point Likert scale (1 = strongly disagree to 6 = strongly agree). Items that were formulated negatively were recoded before statistical analysis.

The questionnaire was pre-tested for comprehensibility with a sample of n = 3. The final version of

the questionnaire was reviewed by the Faculty Ethics Committee and approved as ethically unobjectionable. The data for this study was collected in May 2023, which allowed us to capture behavioral changes occurring in response to the aftermath of both the COVID-19 pandemic and the energy crisis following the war against Ukraine.

The sample

A census-representative sample with data of $n = 541$ respondents ($M = 48.79$ years, $SD = 14.6$, 47.5% male, 52.5% female) was analyzed in the study ($n = 1007$ before data cleaning). Most participants completed secondary education (56.4%) according to the International Standard Classification of Education (ISCED, 2011), followed by those with tertiary education (42.5%). Only a small percentage (1.1%) reported primary education as the highest educational degree. Asked for their area of living, 28.1% of participants lived in the city center, 43.3% in the suburbs, and 28.7% in rural areas. In terms of income distribution, the average reported income was in the category 2000–2999€.

Statistical analysis

For a clearer presentation of the results, the information on the behavior-change-related items was summarized into three categories: a) no changes, b) reduced behavior referred to as "less climate-friendly behavior" (summarizing the responses "much less frequently, less frequently, and rather less frequently"), and increased behavior referred to as "more climate-friendly behavior" (summarizing the responses "somewhat more frequently, more frequently, much more frequently"). First, descriptive and factor analyses were applied to understand the distribution of behavioral change data and their dimensional structure. Second, cluster analyses were employed to segment respondent groups based on their behavioral patterns. Third, depending on psychometric scale properties, cluster group differences and individual factors were analyzed by MANOVAs and nonparametric tests.

Results

Descriptive and factorial analysis of behavioral changes

A mixed pattern of behavioral changes compared to pre-crisis times was found (Fig. 1): Regarding public transport, 54.9% indicated no changes, 23.5%, reported reduced usage, and 21.6% reported an increased usage. For the use of cars, most respondents (55.1%) reported no changes, 30.9% reported reduced car usage and 14% reported increased car usage.

Sustainable shopping behaviors also increased compared to pre-crisis times, with 48.2% of participants indicating they shopped more sustainably. No changes were reported by 40.5% and 11.3% indicated reduced sustainable shopping behaviors. Regarding energy-saving behaviors, over two-thirds (68.2%) reported increased energy-saving behavior, 27.2% reported no changes and 4.6% reported less energy-saving behavior.

After analyzing the distribution of behavioral changes, the next step focused on the analysis of their underlying dimensional structure. A factor analysis (principal component analysis with varimax rotation) was employed to determine whether the behavioral changes represented distinct domains

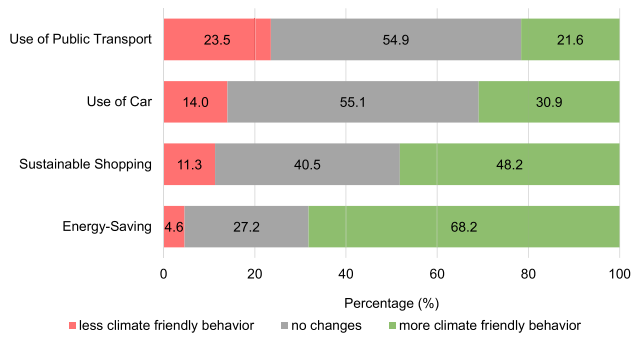

Fig. 1 Sustainability behavior changes due to recent crises ($n = 541$)

Table 1 Factor loadings from the PCA on behavioral change items

	Component	
Variables	1	2
Sustainable shopping behavior	0.858	
Energy-saving behavior	0.851	
Use of car		−0.839
Use of public transport		0.806

The loading of the variable "use of car" is negative because lower car usage indicates higher sustainable behavior levels

or if they formed a singular construct. Bartlett's test of sphericity was significant ($\chi_{(6)} = 240$; $p < .01$), indicating that the data was appropriate for factor analysis. Two components with eigenvalues above Kaiser's criterion of 1 explained 71.1% of the variance (Table 1). The items "use of car" and "use of public transport" loaded on the first factor, labeled as "sustainable mobility behavior" (SMB). The second factor, marked by loadings from "energy-saving behavior" and "sustainable shopping behavior", represented "sustainable consumer practices" (SCP).

Cluster analysis of behavioral changes

For the identified factors "sustainable mobility behavior" (SMB) and "sustainable consumer practices" (SCP) cluster analyses were employed based on the respective factor scores. First, a two-step cluster analysis was run to determine the optimal number of clusters, followed by a K-Means clustering algorithm to partition respondents into distinct groups.

Sustainable mobility behavior

The cluster analysis suggested a four-cluster solution. The identified four clusters differed significantly in car use and public transport usage ($F_{(2,539)} = 3303.1$; $p < .001$, Table 2). Post-hoc tests (Tukey's HSD) indicated significant pairwise differences between all clusters for both car use and public transport usage at $p < .05$.

The following cluster description is based on the original items to provide a more differentiated view of the nature of behavioral change.

Table 2 Descriptive statistics (*M*, *SD* in brackets) for Car Use and Public Transport Usage across clusters

Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Use of car	5.25 (1.33)	2.4 (1.03)	3.9 (0.73)	1.16 (0.37)
Use of public transport	1.54 (0.92)	4.61 (1.06)	3.87 (0.84)	6.44 (0.70)

Cluster 1 (85 cases): For *car use*, 54.1% reported an increase, 43.5% reported no change, and 2.3% reported a reduction. For *public transport*, 92.9% reported a reduction, while 7.1% reported no change. Based on increasing car usage and decreasing public transport usage, the cluster was labeled as "*car-centric converters*".

Cluster 2 (90 cases): For *car use*, 86.7% reported a reduction, 12.2% reported no change, and 1.1% reported an increase. In terms of *public transport*, 46.7% reported an increase in usage, 47.8% no change, and 5.6% reported a reduction. This cluster predominantly reduced their car use while almost equally increasing or maintaining public transport usage and was labeled as *"public transport adopters"*.

Cluster 3 (323 cases): In the biggest cluster, regarding *car use*, 77.4% reported no change, 13.6% reported a reduction, and 9.0% reported an increase. For *public transport*, 76.8% reported no change, 13.3% reported a reduction, and 9.9% reported an increase. As most of this group reported a consistent commuting pattern in their car use and public transport usage, they were labeled as *"stable multimodalists"*.

Cluster 4 (43 cases): For *car use*, all respondents in this cluster, 100%, reported a reduction. Conversely, for *public transport*, 100% reported an increase. Since mobility choices indicate a strong preference for more sustainable commuting options, the cluster was labeled as *"sustainable transit converters"*.

Sustainable consumer practices (SCP)

A four-cluster solution was suggested, followed by K-Means clustering of the SCP-factor score. A MANOVA proved highly significant differences in energy-saving and sustainable shopping behavior across the four clusters ($F_{(2,\ 536)} = 358.12$, $p < .001$).

Post-hoc tests proved that each cluster exhibited distinct patterns in both energy-saving and sustainable shopping behavior ($p < .05$, Table 3).

Next, the clusters will be described regarding their behavioral patterns in energy-saving and sustainable shopping:

Cluster 1 (206 cases): For *energy-saving behavior*, more than one half (59.2%) indicated no change, 37.4% indicated an increase, and 3.4% indicated a reduction. Regarding *sustainable shopping*, 81.1% reported no change, 7.3% an increase, and 11.7% a reduction. This cluster primarily reflected rather consistent behaviors across both domains and was labeled as *"stable shoppers and moderate energy-savers"*.

Cluster 2 (38 cases): For *energy-saving behavior*, 26.3% reported no change, 28.9% an increase, and 44.7% a reduction. In *sustainable shopping*, 94.7% indicated a reduction and 5.3% reported no change. This cluster shows a diverse pattern leaning towards a less sustainable behavior, especially in sustainable shopping. Therefore, it was labeled as *"reduced sustainable practices"*.

Cluster 3 (167 cases): For *energy-saving behavior*, 91.0% indicated an increase, 8.4% indicated no change, and 0.6% indicated a reduction. For *sustainable shopping*, 70.1% indicated an increase, 29.3% no change, and 0.6% a reduction. This cluster was labeled as *"increased sustainable practices"*.

Cluster 4 (130 cases): In both *energy-saving* and *sustainable shopping* behaviors, 99.2% indicated an increase, and 0.8% indicated no change. The dominant pattern in this cluster was an increase in both domains, labeled as *"sustainable consumption champions"*.

To determine whether the two cluster solutions for sustainable mobility behavior (SMB) and sustainable consumer practices (SCP) were based on a similar group structure or assignment of cases, cross-tabulations were calculated (Cohen's Kappa < 0.05), which indicated no agreement between the two clustering assignments. Nevertheless, Fig. 2 provides an overview of the distribution of cases across the respective cluster groups of the two domains of sustainable behavior, i.e., sustainable consumption, and sustainable mobility.

Table 3 Descriptive statistics (*M*, *SD* in brackets) for energy-saving- and sustainable shopping behavior in the four SCP-clusters ($n = 541$)

Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Energy-saving	4.50 (0.84)	3.58 (1.84)	5.61 (0.89)	6.40 (0.65)
Sustainable shopping	3.93 (0.56)	1.92 (0.91)	4.81 (0.63)	6.07 (0.60)

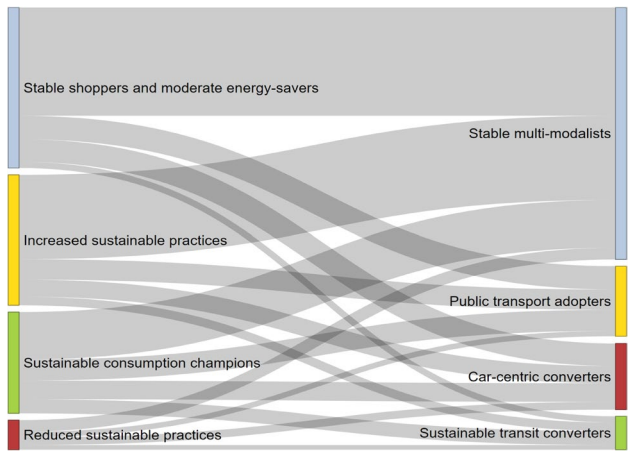

Fig. 2 Sankey diagram of cluster group assignments for the SCP cluster (right) and the SMP cluster (left), ($n = 541$)

Detailed analysis of clusters based on individual factors

Sustainable mobility behavior clusters (SMB)

Sociodemographics Significant differences were found in the income distribution across clusters ($\chi^2_{(3)}$=46.2, p<.001) as well as for education ($\chi^2_{(3)}$=36.0, p<.005). Post-hoc tests revealed that Cluster 4 (sustainable transit converters) had a significantly higher percentage of individuals in the lowest income category (32.6%). Regarding education, Cluster 3 (stable multi-modalists) had a higher proportion of individuals in the tertiary education level (29.1%) compared to the other clusters. For the remaining variables (age, gender, area of living) no significant differences were found.

Knowledge For subjective sustainability knowledge, an ANOVA revealed no significant differences across clusters (n.s.).

Attitudinal variables For climate change awareness (CCA) and institutional trust (IT), significant differences between the cluster groups were revealed (CCA: $F_{(3,\ 537)}$=8.55, p<.001; IT: $F_{(3,\ 537)}$=8.44, p<.001). CCA in Cluster 1 (car-centric converters, M=3.2, SD=1.4) was significantly lower than in Cluster 3 (stable multi-modalists, M=3.6, SD=1.2) and Cluster 4 (sustainable transit converters, M=4.1, SD=1.4), which displayed the highest CCA. For IT, Cluster 4 (sustainable transit converters, M=3.1, SD=1.0) exhibited the highest level of trust, while Cluster 1 (car-centric converters) reported the lowest (M=2.6, SD=1.0).

Risk perception Cluster 4 (sustainable transit converters, M=5.1, SD=1.3) displayed the highest risk perception, while Clusters 2 (public transport adopters, M=4.7, SD=1.2) and 3 (stable multi-modalists, M=4.7, SD=1.0) displayed the lowest ($F_{(3,537)}$=3.5, p=.05).

Finally, to find out which of the individual factors contributed the most to sustainable mobility behavior changes, a stepwise regression was run with individual variables as predictors. The model was statistically significant (F(3,537)=10.62, p<.001, Table 4) and accounted for approximately 6% of the variance in changes in mobility behavior (R^2=0.06). Climate change awareness (β=0.19, p<.001), income (β=−0.1, p<.05), and area of living (β=−0.1, p=<.05) were significant predictors. Higher levels of climate change awareness, living in the city center, and a lower income were associated with changes to more sustainable mobility.

Sustainable consumer practices clusters (SCP)

Sociodemographics Only income showed a statistically significant difference across the clusters ($\chi^2_{(18)}$=29.57, p=.05). Cluster 2 (reduced sustainable practices) had the lowest average income level (M=2.9, SD=1.5), while Cluster 3 (increased sustainable practices) and 4 (sustainable consumption champions) had the highest (M=3.8, SD=1.7 and SD=1.8, respectively). Age, gender, area of living, and education did not significantly differ in the cluster groups.

Knowledge For subjective sustainability knowledge, we found significant differences across clusters ($F_{(3,537)}$=11.94, p<.001). Cluster 4 (sustainable consumption champions) had the highest average knowledge (M=4.0, SD=1.2), while Cluster 2 (reduced sustainable practices) had the lowest (M=3.0, SD=1.6).

Table 4 Stepwise linear regression results predicting changes in sustainable mobility behavior from climate change awareness, income, and area of living

Predictor	B	*SE*	β	*t*	*p*	*VIF*
(Constant)	−0.08	0.18	—	−0.43	n.s	—
Cl. Change Awareness	0.15	0.03	0.19	4.61	<.001	1.00
Income	−0.06	0.02	-0.11	−2.49	<.005	1.01
Area of Living	−0.13	0.06	-0.1	−2.36	<.005	1.00

B unstandardized coefficient, *SE* standard error, β standardized coefficient, *t* t-value, *p* p-value, *VIF* variance inflation factor. R^2 =0.06

Attitudinal variables The SCP-clusters significantly differed in their climate change awareness ($F_{(3,537)}=38.4, p<.001$) and institutional trust ($F_{(3,537)}=9.1, p<.001$). Cluster 4 (sustainable consumption champions) had the highest CCA ($M=4.4$, $SD=1.1$), while Cluster 2 (reduced sustainable practices) had the lowest ($M=2.7$, $SD=1.3$). Cluster 4 also had the highest trust ($M=3.3$, $SD=1.0$), and Cluster 2 the lowest ($M=2.5$, $SD=1.0$).

Risk perception Cluster 4 (sustainable consumption champions) had the significantly highest average risk perception ($M=5.1$, $SD=1.2$), while Cluster 2 (reduced sustainable practices) reported the lowest ($M=4.5$, $SD=1.6$), ($F_{(3,537)}=8.09$, $p<.001$).

Finally, a stepwise linear regression with the individual variables as predictors of changes in sustainable consumer practices was employed. The model was statistically significant ($F_{(4, 536)}=40.22$, $p<.001$, Table 5), and accounted for approximately 23% of variance ($R^2=0.23$). Higher levels of climate change awareness ($\beta=0.4$, $p<.001$), increased risk perceptions ($\beta=0.12$, $p<.05$), higher knowledge on climate change ($\beta=0.04$, $p<.05$), and higher age ($\beta=0.08$, $p<.05$) were associated with positive changes in sustainable consumer practices (SCP).

Discussion

Understanding sustainable behavior, especially in the face of recent crises, is essential in tackling global challenges such as climate change. The practices of individuals are central in this context, given their impact on broader sustainable outcomes. Based on empirical data of a representative German sample, we examined self-reported changes in key sustainable behavior domains compared to pre-crises-times: mobility, energy consumption, and shopping. In the following, we discuss the dynamics of behavioral change, followed by the impact of individual differences, combined with implications for policy measures.

Dynamics of sustainable behavioral change

Recent crises such as the COVID-19 pandemic and the energy crisis due to the war against Ukraine exerted different effects on the two domains of sustainability behavior. Although significant potential for change toward sustainable mobility practices was anticipated due to current crises (Csutora & Zsóka, 2023), our results indicate that there was rather little change—or high stability—in mobility practices. Over half of the participants reported no change in their mobility practices. We assume that external factors like lockdowns, differing work commitments (home office), public transport availability, or societal norms shaped mobility behavior (Renn et al., 2022). On the other hand, we found a significant shift in sustainable consumer practices: Most participants reported increased energy-saving behaviors and nearly half reported more sustainable shopping practices. This may either be a result of economic factors (increased food and energy prices) or an increased awareness (Liobikienė et al., 2023). Comparing the extent of changes in both sustainability domains, our findings indicate a different elasticity

Table 5 Stepwise linear regression results predicting sustainable consumer practices from age, climate change awareness, knowledge, and risk perception

Predictor	B	*SE*	β	*t*	*p*	*VIF*
(Constant)	−2.12	0.23	—	−9.11	< .001	37.92
Age	0.01	0.00	0.08	2.15	< .05	1.00
Cl. Change Awareness	0.31	0.03	0.4	9.37	< .001	1.27
Knowledge	0.06	0.03	0.08	1.99	< .05	1.23
Risk Perception	0.10	0.04	0.12	2.98	< .05	1.03

B unstandardized coefficient, *SE* standard error, β standardized coefficient, *t* t-value, *p* p-value, *VIF* variance inflation factor. $R^2=0.23$

of behaviors. Behaviors such as energy-saving and sustainable shopping were more adaptable to change, primarily because they are less influenced by external factors and more by individual choices. This suggests accordingly that policy interventions should create external conditions to foster more sustainable mobility habits. Further, the comparative analysis of changes within the two sustainability behavior domains suggests high consistency and limited spillover effects (Puntiroli et al., 2022). This means that adopting sustainable practices in one area (e.g., energy-saving) does not necessarily lead to sustainable decisions in another area (e.g., mobility). This differentiation emphasizes the need for targeted interventions across different domains of sustainability. Finally, the shift towards sustainable consumer practices suggests an emerging recognition of the importance of (energy) resilience at the household level and underscores the potential of individual behavior in shaping a more resilient energy and consumption landscape (Bertoldi, 2022). To ensure long-term environmental sustainability, policymakers should prioritize initiatives that support and promote household energy resilience.

Cluster-specific sustainable behaviors and impact of individual factors

The varied patterns of sustainable behavior changes underscore the fact that individuals react differentially to crises. While some took it as an opportunity to adopt more sustainable behaviors ("sustainable transit converters" and "sustainable consumption champions"), others remained locked in old habits ("stable shoppers and moderate energy-savers") or even changed their behavior to less sustainable ones ("car centric converters", "reduced sustainable practices"). This suggests that while certain segments of society willingly shift towards more sustainable behaviors—particularly in times of crisis—others encounter substantial barriers and external constraints. These include socio-economic limitations, inadequate infrastructure, or a lack of institutional support (e.g. Sovacool et al., 2024), which may hinder their ability to engage in sustainable practices despite their willingness. Therefore, the existence of clusters that either remained static or transitioned towards less sustainable behaviors poses a critical challenge. Thus, simply raising awareness or experiencing a crisis does not automatically lead to positive behavioral shifts (e.g., Venghaus et al., 2022). Given the rising political polarization and the prevalence of climate skepticism, it is crucial to prioritize these groups displaying less sustainable behaviors to better understand and address the barriers they face, and identify potential incentives for change (e.g., Moberg et al., 2021).

The inclusion of individual factors revealed that the (non-)adoption of sustainable behaviors is influenced by several factors including socio-demographics, knowledge, attitudinal factors, and risk perception, which highlights the importance of multi-dimensional approaches in understanding and promoting sustainable behaviors. Regarding *sociodemographics*, the lower *income* of "sustainable transit converters"' indicates economic constraints leading to more sustainable choices. Similarly, higher *income* and *education* of the SCP-cluster "sustainability champions" may provide individuals the means to make more sustainable choices. For policymakers, this suggests considering the options of increased subsidies or incentives to improve affordability across all income groups. The *area of living* was a significant predictor in the SMB domain, underscoring the role of urban infrastructure in sustainable mobility choices. Urban areas often have better public transport infrastructure and more incentives or restrictions regarding car usage, making sustainable commuting more feasible. This highlights the importance of improving public transport and promoting sustainable mobility options also in non-urban areas. However, it is important to consider that people with lower financial capabilities may prioritize cost-efficiency over sustainability (e.g., Liobikienė et al., 2023). Economic factors become even more relevant in times of crisis, which may further exacerbate financial hardships. Regarding attitudinal factors, those with higher *climate change awareness* were more inclined to engage in sustainable behaviors, both in mobility and consumption. The regression analysis further validated this finding, showing a strong association between climate change awareness and positive changes in both mobility and consumer practices. Another factor, which was significant in predicting sustainable consumer practices was subjective sustainability *knowledge*. The better-informed individuals were about sustainability topics, the more they were engaged in sustainable shopping and energy-saving behavior. Knowledgeable consumers seem to be better equipped to make informed decisions, suggesting that communication and awareness campaigns can

play a pivotal role in promoting sustainable consumer practices. *Risk perception* was another influential factor, i.e., those who perceived higher risks associated with climate change were more likely to adopt sustainable consumer practices (e.g., Arning et al., 2018). This implies that understanding the consequences of climate change can significantly impact sustainability behavior. Accordingly, the communication of climate change consequences should also be included in educational and communication activities. *Trust* in institutions was also important, especially in the context of sustainable mobility in predicting sustainability behavior changes. Clusters with higher trust levels were more inclined towards sustainable practices, suggesting that institutional trust can guide individuals towards more sustainable choices (e.g., Rayner, 2010). However, an essential point to consider is the low proportion of explained variance in the regression analyses, especially for mobility behavior. This suggests that the complexity of sustainable (mobility) behavior extends beyond these individual factors. Each cluster represents a distinct response to the crises, influenced by a combination of individual characteristics and, other, unmeasured systemic or structural factors, which underscores the need for a comprehensive research approach.

Policy implications

The results of our study advise targeted policy interventions to effectively promote sustainable behavior. Specifically, policymakers should recognize socio-economic differences and their implications for more diversified and targeted policy-design. Most notably, income level and climate change awareness were found to impact sustainable consumption choices and mobility behavior. Accordingly, policy interventions specifically targeting at affordability across income groups and educational or communication campaigns to increase the level of knowledge related to sustainability challenges should be prioritized. Both of the above have recently been addressed by European Union (EU) and German national policy initiatives. As part of the European Green Deal, the EU pursues significant action towards consumer empowerment with the objective of providing consumers with access to information needed to make informed sustainable consumption choices, while protecting them against corporate green washing activities (European Commission, 2024). On the German national level, following the Russian invasion of Ukraine and the consecutive surge in energy prices, the German government issued a relief package consisting of various measures including fuel tax reductions, heating cost subsidies, but also measures that specifically targeted at students or retirees (German Federal Government, 2022). In January 2024, the revised Building Energy Act (GEG) was enacted, which – for the first time – includes an income-dependent component allowing for higher subsidies for households with lower or medium income levels (BMWSB, 2024). The effectiveness and behavioral impacts of such targeted policy interventions should thus be subject of further scientific monitoring and evaluation in the future. Furthermore, energy saving behavior has been found to be most reactive to change in times of crises. Future research should therefore target the question, whether the heightened willingness to change towards energy saving behavior likewise suggests that policy interventions targeting this topic will be especially effective.

Methodological considerations and future research

Our findings need to be contextualized within certain methodological limitations.

Our analysis was based on the use of self-reported data which may cause biases, such as the social desirability bias, which may have influenced participants to over-report socially favorable behaviors, such as sustainable actions, while underreporting less desirable behaviours. Furthermore, inaccuracies in recalling past behaviours could have affected participants' ability to accurately remember their consumption and mobility choices over time. Future studies should therefore aim to triangulate self-reported data with objective consumption data (e.g., utility bills, transportation records). Alternatively, longitudinal approaches that track behavior in real time could provide more reliable insights by reducing the reliance on participants' memory.

In our study we focused on general behaviors such as saving energy, using public transport, and buying sustainably. For a more detailed analysis of cluster profiles, we suggest that future studies incorporate a larger and more detailed set of variables, particularly in sustainable consumption behaviors. Future research should also assess the motives or

forces behind sustainable behavior changes to capture the interplay between financial constraints and sustainability-driven behaviors to better contextualize these changes. Further, future studies should include additional individual, systemic and structural factors such as social norms, flexibility to work from home, policy, and regulation to gain a deeper understanding of behavioral changes in times of crises. A further area in which more detailed data is required is in the assessment of whether expressed preferences align with actual behaviours concerning sustainable mobility and consumption. Another aspect is the timing of the data collection, which took place in May 2023. This timing allowed us to capture behavioral responses influenced by both the COVID-19 pandemic and the energy crisis following the war against Ukraine. However, focusing on a single time point may overlook ongoing fluctuations in behavior and market dynamics. Further, the study provides insights into self-reports on behaviors over three years, but the temporal stability of these changes is still unclear. It remains open whether these shifts represent short-term responses to specific crises or indicate longer-term behavioral adaptations. A longitudinal study would offer a more comprehensive understanding of how these behaviors evolve over time in response to external crises. In addition, the generalizability of our findings remains to be determined: are these patterns of behavioral change globally consistent or specific to geographical or cultural contexts? Future research might benefit from integrating mixed methods (e.g., Csutora et al., 2021) to ensure a comprehensive understanding of sustainable behavior. Finally, the study's focus on Germany limits the applicability of its findings to other regions. Variations in infrastructure, cultural norms, and policy frameworks across countries may result in different behavioral outcomes. Therefore, cross-national comparative studies should be expanded to include diverse national contexts, ensuring a more comprehensive understanding of behavioral shifts during crises.

Conclusions

In examining changes in sustainable behavior after recent crises, our study revealed both stable and changing patterns of behavior in the German population. Our results showed that a significant proportion of individuals maintained their pre-crisis behavior. Distinct clusters were identified, representing individuals who either adopted more sustainable practices, did not change, or reverted to less sustainable practices. The inclusion of individual factors into the analysis of clusters of sustainability behavior change showed that climate change awareness and income influenced these behaviors, but their limited explanatory power underlines the potential role of broader systemic factors. Policies that address both individual and systemic aspects are therefore crucial for a widespread transition to sustainability.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval This study falls under the category of non-invasive, non-clinical research involving human subjects. Nevertheless, the questionnaire was reviewed by the ethics committee for empirical social science research at RWTH Aachen (No. 2022_010_FB7_RWTH Aachen).

Consent Study participants provided informed consent after being informed that their involvement is voluntary, anonymous, and can be terminated at any point. Additionally, they were briefed on the methods of data collection, as well as the purpose for which the data would be gathered and stored.

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

References

Arning, K., van Heek, J., & Ziefle, M. (2018). Acceptance profiles for a carbon-derived foam mattress. Exploring and segmenting consumer perceptions of a carbon capture and utilization product. *Journal of Cleaner Production, 188*, 171–184.

Arning, K., Engelmann, L., & Ziefle, M. (2023). Ready to fly? Comparing acceptance and behavioral usage intentions of CO2-based aviation fuels in four European countries. *Frontiers in Energy Research, 11*, 1156709.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alexander, D. E. (2013). Resilience and disaster risk reduction: An etymological journey. *Natural Hazards and Earth System Sciences, 13*(11), 2707–2716.

Ansah, I. G. K., Gardebroek, C., & Ihle, R. (2019). Resilience and household food security: A review of concepts, methodological approaches and empirical evidence. *Food Security, 11*(6), 1187–1203.

Assarkhaniki, Z., Sabri, S., Rajabifard, A., & Kahalimoghadam, M. (2023). Advancing sustainable development goals: Embedding resilience assessment. *Sustainability Science, 18*(5), 2405–2421.

Axon, S., & Morrissey, J. (2020). Just energy transitions? Social inequities, vulnerabilities and unintended consequences. *Buildings & Cities, 1*(1), 393.

Bertoldi, P. (2022). Policies for energy conservation and sufficiency: Review of existing policies and recommendations for new and effective policies in OECD countries. *Energy and Buildings, 264*, 112075. https://doi.org/10.1016/j.enbuild.2022.112075

BMWSB. (2024). Gebäudeenergiegesetz (Building Energy Act). Federal Ministry for Housing, Urban Development and Building. https://www.bmwsb.bund.de/SharedDocs/topthemen/Webs/BMWSB/DE/GEG/GEG-Top-Thema-Artikel.html. Accessed April 24, 2024.

Corbos, R.-A., Bunea, O.-I., & Jiroveanu, D.-C. (2023). The effects of the energy crisis on the energy-saving behavior of young people. *Energy Strategy Reviews, 49*, 101184. https://doi.org/10.1016/j.esr.2023.101184

Csutora, M., Zsoka, A., & Harangozo, G. (2021). The Grounded Survey–An integrative mixed method for scrutinizing household energy behavior. *Ecological Economics, 182*, 106907.

Csutora, M., & Zsóka, Á. (2023). Crises as incubators of sustainable mobility patterns? Evidence from two shock events. *Sustainable Development*. https://doi.org/10.1002/sd.2578

EEA. (2019). The European environment — state and outlook 2020: knowledge for transition to a sustainable Europe, European Environment Agency. https://www.eea.europa.eu/soer/publications/soer-2020. Accessed 14.09.2023.

Ergen, T., & Suckert, L. (2021). „Crises" as catalysts for more sustainable futures? The case of the first oil crisis and the role of multilayered interpretative struggles. *Economic Sociology. Perspectives and Conversations, 22*(2), 15–23.

ESS Round 9: European Social Survey. (2021). ESS-9 2018 Documentation Report. Edition 3.1. Bergen, European Social Survey Data Archive, Sikt - Norwegian Agency for Shared Services in Education and Research, Norway for ESS ERIC. https://doi.org/10.21338/NSD-ESS9-2018

European Commission. (2024, March 27). *New EU rules to empower consumers for the green transition enter into force*. Directorate-General for Energy. Retrieved from https://energy.ec.europa.eu/news/new-eu-rules-empower-consumers-green-transition-enter-force-2024-03-27_en

Geiger, S. M., Fischer, D., & Schrader, U. (2018). Measuring what matters in sustainable consumption: An integrative framework for the selection of relevant behaviors. *Sustainable Development, 26*(1), 18–33. https://doi.org/10.1002/sd.1688

German Federal Government. (2022). Tangible relief for citizens. https://www.bundesregierung.de/breg-en/news/federal-laender-consultations-2139802. Accessed April 24, 2024.

Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *American Psychologist, 66*(4), 290–302. https://doi.org/10.1037/a0023566

Grin, J., Rotmans, J., & Schot, J. (2010). *Transitions to sustainable development: New directions in the study of long term transformative change*. Routledge.

Hamborg, S., Meya, J. N., Eisenack, K., & Raabe, T. (2020). Rethinking resilience: A cross-epistemic resilience framework for interdisciplinary energy research. *Energy Research & Social Science, 59*, 101285.

Hosseini, S., Barker, K., & Ramirez-Marquez, J. E. (2016). A review of definitions and measures of system resilience. *Reliability Engineering & System Safety, 145*, 47–61.

International Standard Classification of Education (ISCED). (2011). *Comparative social research* (Vol. 30). UNESCO Institute for Statistics.

Klöckner, C. A., & Blöbaum, A. (2010). A comprehensive action determination model: Toward a broader understanding of ecological behaviour using the example of travel mode choice. *Journal of Environmental Psychology, 30*(4), 574–586.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*(3), 239–260.

Lacroix, K., & Gifford, R. (2022). Psychological barriers to energy conservation behavior: The role of knowledge and motivation. *Review of General Psychology, 26*(3), 255–270.

Liobikienė, G., Matiiuk, Y., & Krikštolaitis, R. (2023). The concern about main crises such as the Covid-19 pandemic, the war in Ukraine, and climate change's impact on energy-saving behavior. *Energy Policy, 180*, 113678. https://doi.org/10.1016/j.enpol.2023.113678

Moberg, K. R., Sovacool, B. K., Goritz, A., Hinojosa, G. M., Aall, C., & Nilsson, M. (2021). Barriers, emotions, and motivational levers for lifestyle transformation in

Norwegian household decarbonization pathways. *Climatic Change, 165*, 1–25.

Monterde-i-Bort, H., Sucha, M., Risser, R., & Kochetova, T. (2022). Mobility patterns and mode choice preferences during the COVID-19 situation. *Sustainability, 14*(2), 2. https://doi.org/10.3390/su14020768

Newell, P., Twena, M., & Daley, F. (2021). Scaling behavior change for a 1.5-degree world: Challenges and opportunities. *Global Sustainability, 4*, e22. https://doi.org/10.1017/sus.2021.23

Novianto, D., Koerniawan, M. D., Munawir, M., & Sekartaji, D. (2022). Impact of lifestyle changes on home energy consumption during pandemic COVID-19 in Indonesia. *Sustainable Cities and Society, 83*, 103930. https://doi.org/10.1016/j.scs.2022.103930

O'Connor, R. E., Bord, R. J., & Fisher, A. (1999). Risk perceptions, general environmental beliefs, and willingness to address climate change. *Risk Analysis, 19*(3), 461–471.

Puntiroli, M., Moussaoui, L. S., & Bezençon, V. (2022). Are consumers consistent in their sustainable behaviors? A longitudinal study on consistency and spillover. *Journal of Business Research, 144*, 322–335. https://doi.org/10.1016/j.jbusres.2022.01.075

Räty, R., & Carlsson-Kanyama, A. (2010). Energy consumption by gender in some European countries. *Energy Policy, 38*(1), 646–649.

Rayner, S. (2010). Trust and the transformation of energy systems. *Energy Policy, 38*(6), 2617–2623.

Raven, R., Reynolds, D., Lane, R., Lindsay, J., Kronsell, A., & Arunachalam, D. (2021). Households in sustainability transitions: A systematic review and new research avenues. *Environmental Innovation and Societal Transitions, 40*, 87–107. https://doi.org/10.1016/j.eist.2021.06.005

Renn, O., Engels, A., Mack, B., Becker, S., & Camier, C. (2022). Will short-term behavior changes during the COVID-19 crisis evolve into low-carbon practices? *GAIA-Ecological Perspectives for Science and Society, 31*(3), 158–166.

Smith, N., & Leiserowitz, A. (2022). The role of emotion in global warming policy support and opposition. *Risk Analysis, 42*(4), 681–697.

Sovacool, B. K., Carley, S., & Kiesling, L. (2024). Energy justice beyond the wire: Exploring the multidimensional inequities of the electrical power grid in the United States. *Energy Research & Social Science, 111*, 103474.

Sovacool, B. K., Newell, P., Carley, S., & Fanzo, J. (2022). Equity, technological innovation and sustainable behaviour in a low-carbon future. *Nature Human Behaviour, 6*(3), 326–337.

Spence, A., Poortinga, W., Butler, C., & Pidgeon, N. F. (2012). Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change, 2*(6), 46–49.

Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology, 29*(3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004

Triandis, H. (1977). *Interpersonal behaviour*. Brooks/Cole Pub. Co.

Offermann-van Heek, J., Arning, K., Linzenich, A., & Ziefle, M. (2018). Trust and distrust in carbon capture and utilization industry as relevant factors for the acceptance of carbon-based products. *Frontiers in Energy Research, 6*, 73.

Venghaus, S., Henseleit, M., & Belka, M. (2022). The impact of climate change awareness on behavioral changes in Germany: Changing minds or changing behavior? *Energy, Sustainability and Society, 12*, 8.

Wiernik, B. M., Ones, D. S., & Dilchert, S. (2020). Age and employee green behaviors: A meta-analysis. *Frontiers in Psychology, 11*, 567.