Future Energy Systems: An Analysis of Public Preferences Based on

Distributional Fairness

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Keep the above text as it is.

Abstract

This paper analyses possible factors explaining people's preferences for future energy systems. The aim of this paper is to examine the influence of the factors Perceived Distributive Fairness (PDF), Perceived Cost/Benefits (C/B), and Perceived Effectiveness (PE) have on the preference and acceptance off future energy system scenarios. Hereby the focus is on two scenarios/pathways described in the IPCC, 2018 namely P2 and P4, with P2 emphasizing a behavioral shift, and P4 emphasizing a greenhouse-gas-intensive lifestyle. The primary focus of this paper lies on how PDF affects the acceptability of the suggested Pathways, either directly, or as mediator to the effect of perceive C/B on acceptability of the pathways, or as a mediator of PE on acceptability of the pathways. A total of 221 participants were used for the final analysis. The results suggest a positive association between PDF and Acceptability of both, P2 and P4 scenarios. Furthermore, the results indicate a mediating relationship between the PDF and perceived C/B on acceptability of the pathways, as well as on the relationship of PE and acceptability of the pathways. Overall, this study provides evidence for the relevance of considering PDF and PE when looking at the acceptability of future energy systems.

Keywords: preference future energy systems, PDF

Introduction

Acceptability of Future Energy Systems via Perceived Distributional Fairness

While cultures, ideologies, and lifestyles vary, people, individuals, scientists and nations come together to see what actions can be taken regarding climate change in a variety of gatherings, such as Fridays for Future protests, UN Climate Change Conferences, or reports like those of the IPCC (Intergovernmental Panel on Climate Change). Together, they look at the necessity for change or adaptations while taking into consideration what individuals, nations, and cooperations want, need, and are able to do. An interplay of introducing new policies and projects and actively experiencing them leads to changes and adaptations that people experience as acceptable and with time even as preferential (Diepeveen et al., 2013).

However, in order to introduce projects and plans that require any form of action, politicians in a democracy and cooperations in a free economy oftentimes need the public's acceptance to assure that neither the projects nor their positions will get canceled (Baur et al., 2022). Factors, such as perceived fairness and effectiveness might influence what the public experiences as acceptable. Perceived distributional fairness hereby looks at whether the projects themselves are perceived as fair. One of the difficulties with policies in regard to climate change, is that measurements need to be taken before climate change takes effect, which means that any action is based on predictive research. This can make it seem as though the two options are to take action or to stay neutral. The reality looks different. The choices that are made are not neutral, but lead to different pathways, working either against climate change or directly towards it. Looking at future energy systems, such as described by the IPCC can give an insight on multiple possible actions when it comes to climate change. This paper focuses on how the aforementioned future energy systems are experienced with regard to PDF, in terms of costs and benefits, how these may influence each other, and how they may impact the overall acceptability of these systems.

Challenges of Climate Change

Researchers have been warning politicians and organizations about irreversible consequences to our planet for a long time (Pester, 2021). Examples of the expected effects of global warming are extreme weather events — from droughts to heavy rainfalls — causing water and food shortages (IPCC, 2022). These effects will develop over time, resulting in parts of the earth becoming unhabitable, leading to mass immigrations, overpopulations, and fights over resources in the parts where they are still available. Most affected will be the upcoming generations, especially in areas that contribute significantly less to the CO_2 emissions than the rest of the worlds most economically thriving nations. However, in the end, every life on earth will be affected, no matter the part of the world they live in. Washington Gov. Jay Inslee said: "We're the first generation to feel the sting of climate change. And we're the last who can do something about it." (Cournoyer, 2019). Thanks to people like Greta Thunberg and organizations such as Fridays for Future, sustainability as well as the consequences of climate change have received more attention from the public (Rukikaire, 2019). While multiple political parties and organizations claim commitments to sustainability goals (Kenner, 2015), direct inferences about public perception, acceptance, and adaptability cannot be made, due to limited research.

Relevance of Acceptability for Change

Acceptability is a relevant factor in facilitating change. This has been supported by a study focusing on overcoming a smoking addiction by making use of feasibility, acceptability, and commitment with regards to self-control (Weinberg et al., 2022). Acceptability, together with commitment, has also been found relevant in clinical settings to achieve change, as can be seen in a study focusing on relieving depression via acceptability and commitment therapy (Zamani et al.,2017). Therefore, for change, such as that described in the IPCC pathways, to be possible, it is important to know which factors influence the public acceptability of proposed changes or adaptations.

The focus of this paper will be on the effect of PDF on the acceptability of pathway suggestions of the IPCC and the mediating factor it has on the relationship of PE and perceived costs/benefits.

Public Acceptability

As aforementioned, the rise and fall of projects is impacted by how acceptable they are perceived to be by the public (Schweizer-Ries, 2008). When a baseline of acceptance exists, policymakers and companies can take steps towards their projects with the hope that people will adapt without protest and welcome changes as a new normal, which in turn would also positively increase the acceptance of the projects themselves over time. The public acceptability of future energy systems, as showcased by the IPCC, will give an indication of what could be feasible to make a reality, at least in terms of public acceptance and, in the best-case scenario, even support. However, the direct impact on policies and projects based in public acceptability is however very limited and therefore still in need of further investigation on how they interact outside of the research environment.

Pathway Suggestions by the IPCC

To see what future energy systems described by the IPCC seem most realistic, we have to look at the acceptance of them and the factors that impact these systems. The IPCC is based in the United Nations and WMO, with thousands of people around the world contributing to their work. Aside from explanations on how events and consequences of climate change are connected, the IPCC reports also offer concrete descriptions to policymakers on different pathway possibilities regarding future energy systems to reach the goal of keeping global warming below the rise of 1.5°C since preindustrial levels. These 1.5°C have been chosen as a "tipping point" by the IPCC, as the effects of climate change will most likely be much harder to reverse or mitigate once this point is crossed. This study looks at a selection of possible influential factors towards the acceptability of the different suggested future energy systems, specifically pathway 2 (PA) and pathway 4 (PB). These two pathways are most distinctive in the ways they would influence people's lives, which is why they were chosen as a focal point in this study. Implementing these pathways globally would require changes to industry and everyday behavior, affecting economies and lifestyles. One of the very notable differences lies in how much overshooting of the 1.5°C they allow for as well as

the way they aim to reach a stable temperature, which would mean getting back to at least 1.5°C by the end of the 21st century.

PA aims to limit the overshoot of 1.5°C to a maximum of 1.6°C, keeping the effect of climate change as low as possible, expecting rapid transitions to future energy production systems and implementation of industry and lifestyle policies. PB does not aim to limit the overshoot of 1.5°C, allowing it to go beyond 1.6°C. It therefore risks higher effects of climate change, expects a slower transition, resulting in overshoot, which is then reversed using carbon capture: a future technology proposed to remove CO_2 from the atmosphere and store it in the ground. Therefore, if PB was implemented, there would be no need to change from the current CO_2-emission-intensive lifestyle. To limit the effects, both pathways aim to return to 1.5°C by the end of the 21st century.

Examples of the proposed energy transitions of PA are reducing the energy demand by 5% by 2030, eating local and seasonal foods, reducing meat and dairy consumption, reducing waste in water, food and transportation industries, using resources more efficiently (e.g. insulation), low emission innovations (e.g. electric vehicles, heat pumps, district heating and cooling, future cars give off less emissions), energy-saving behavior (e.g. walking, cycling, mass transit, lower heating), organizational change (e.g. replacing business travel by video calls), flood protective behavior, heat protective behavior (e.g. green roofs), and efficient water use (e.g. rationing).

Examples of the proposed energy transition of PB increases energy demand by 39% by 2030, with an increased economic growth and globalization, increased meat and dairy consumption, increased demand for fuel, increased worldwide shipping, electrification (e.g. replacing technologies that use fossil fuels, such as coal, oil, and natural gas, with technologies that run on electricity), and building desalination plants.

Important to note is that the IPCC is not making suggestions, they are merely predicting what the future might look like based on the pathways that could be imagined to take place based on research.

Perceived Distributional Fairness as Influential Factor of Acceptability

A variety of research has been done regarding what people find relevant in order to accept certain changes aimed at increasing sustainability in the population by various means. Perceived distributional fairness (PDF) is the perception on how equally an individual feels treated in comparison to others by the norms of society. Considering fairness is an important factor contributing in peaceful decisions coming to be (Garcia and Philpot, 2021). As a component of the four types of justice, it describes an unspecified sense of everyone receiving the same. This notion of the same can be further separated into the ideas of equity, equality and need (Types of Justice, 2022). In that sense, PDF is different from perceived procedural fairness. While the prior focuses on the outcome itself, the latter focuses on how the outcome came to be (Lucas et al., 2015). With regards to public acceptability of future energy systems, PDF in this study is defined by the extent to which people perceive the distribution of positive and negative consequences when implementing the pathways to be fair overall, for themselves, and for others. Scientific findings generally support the assumption that increased fairness would enhance the acceptance of proposed climate protective measures. An example thereof can be found in the perceived fairness regarding locations of wind power farms or travel demand management (Huijts et al, 2011).

While a lot of research references procedural fairness focusing on the decision-making process and phrasing of the aimed change to be fair (e.g. Wolsink (2007); Sauermann & Kaiser, 2010; Sauermann, 2017), there is not a lot of research done in regards to distributional fairness. Multiple studies that do look at distributional fairness only look at the physical location of the effects put into place, such as the location of windmills (e.g. Huijts et al, 2011). These studies look at single projects, may that be for policies, technologies, or behavioral change. The focus on single projects limits the insight that can be gained when looking at global pathways, such as described by the IPCC. This makes it all the more relevant to look at the PDF with regards to broader pathways to see how people experience it's impacts.

Hence, the main hypothesis of this study focuses on the impact of PDF on the acceptability of the suggested pathways, with:

H1: The higher the PDF of the pathways the higher their acceptability.

H1a: The higher the PDF of Pathway A the higher its Acceptability.

H1b: The higher the PDF of Pathway B the higher its Acceptability.
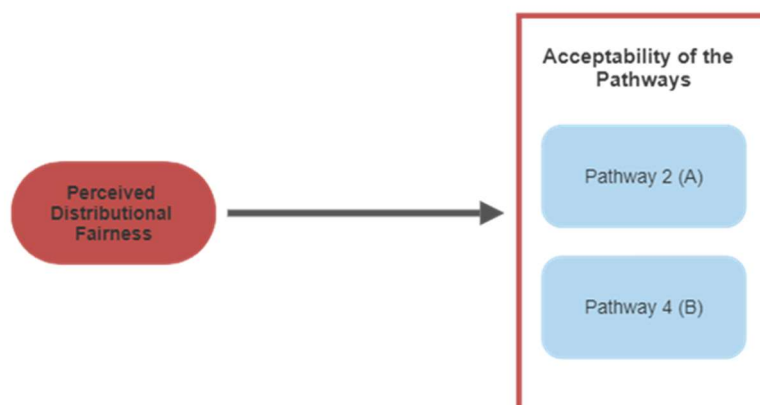
Perceived Costs as Influential Factor of Acceptability via Perceived Distributional Fairness

Higher perceived costs for oneself and others mean that the outcomes of following the pathways are worse for oneself and others, which will likely reduce perceived fairness (e.g.: Schuitema et al, 2011; Maestre-Andrés et al, 2019). Higher perceived costs decrease the PDF.

The study of Kallbekken and Saelen (2011) states that higher support for higher fuel tax by poorer and inequity averse people, could be reached when negative distributional impacts are accounted for. In an experimental study, higher distributional and procedural effects increased the perceived fairness of both of a policy regarding carbon pricing indicating a relevance of PDF. (Maestre-Andrés et al, 2019). Distributional and procedural effects share an impact on the perceived fairness of a policy regarding carbon pricing, positively influencing the acceptability thereof, when increased (Maestre-Andrés et al, 2019). Hereby it has been noted that the second most favorable option of carbon tax revenue use was to even out impacts on low-income households. This significantly increased the acceptability of carbon pricing. The focus is especially on the effects for low-income households, as they are

often disproportionately affected by the consequences (IPCC, 2018), may this be of climate change or implemented reforms (Maestre-Andrés et al, 2019). This leads to the following hypothesis:

H2: Higher perceived costs will decrease the PDF and thus also the acceptability of Pathway A and B (assumed mediation).
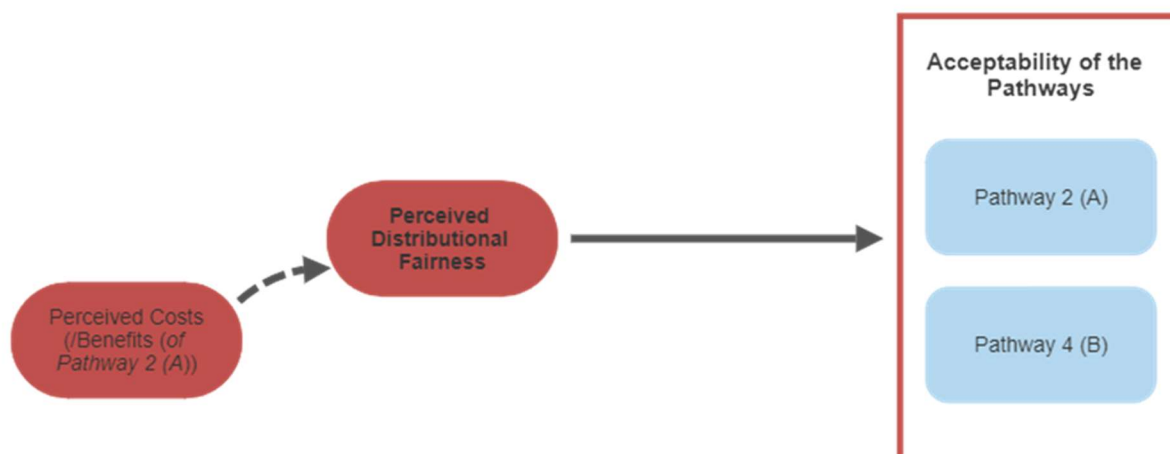
Perceived Effectiveness as Influential Factor of Acceptability via Perceived Distributional Fairness

Perceived effectiveness (PE) in this case is the idea that the pathways can fulfill the aim in mitigating climate change. The meta-analysis by (Bergquist et al., 2022) found significant effects, of both, PDF and PE. Research seems to find contradicting results. While some find that how we perceive distributional fairness is at least impacted by how effective we consider the measurements to be (e.g. Eriksson et al, 2006; Schuitema et al, 2011), others do not seem to find the same results (Sun et al., 2016). Overall, policy measures are considered more acceptable when they are perceived to be fair regarding the influences on one's financial situation, in comparison to others, everyone experiencing the same effects, with the measures being proportional to income and one's contribution to the problems, and how much the outcomes protect nature, environment, and future generations (Schuitema et al, 2011). This leads to the following hypothesis:

H3: Higher PE will increase the PDF and thus also the acceptability of the Pathways (assumed mediation).
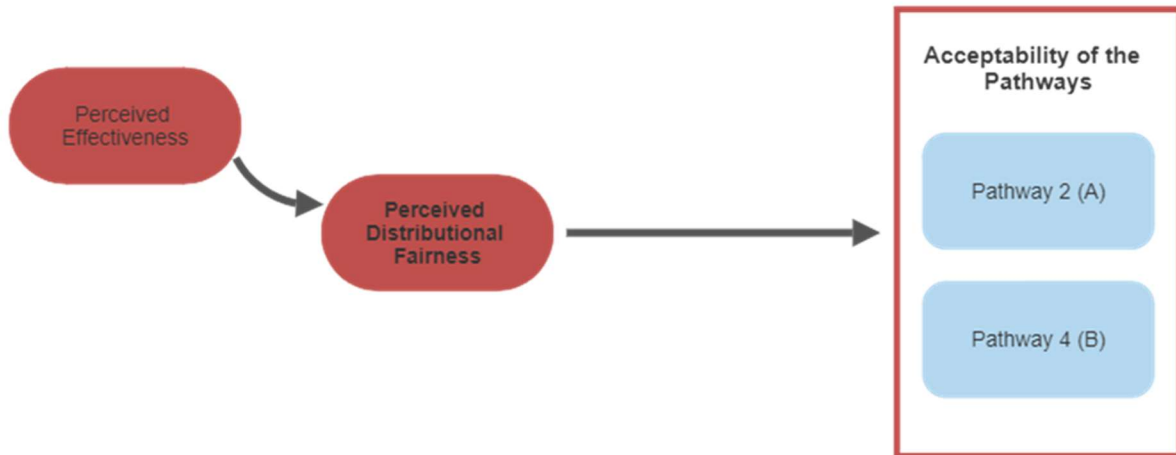
Explorative:

If a person does not consider something to be fair, they are less likely to accept any introduced changes (Schweizer-Ries, 2008), especially when it comes to behavioral changes. In this study, the pathway requiring fewer personal changes is PB, which would under this assumption be the easier and more acceptable path to take. However, there is not much studies to be found, which is why this is merely an explorative hypothesis:

E1: Lower PDF is associated with a higher chance to indicate a preference for Pathway B when choosing between both pathways.
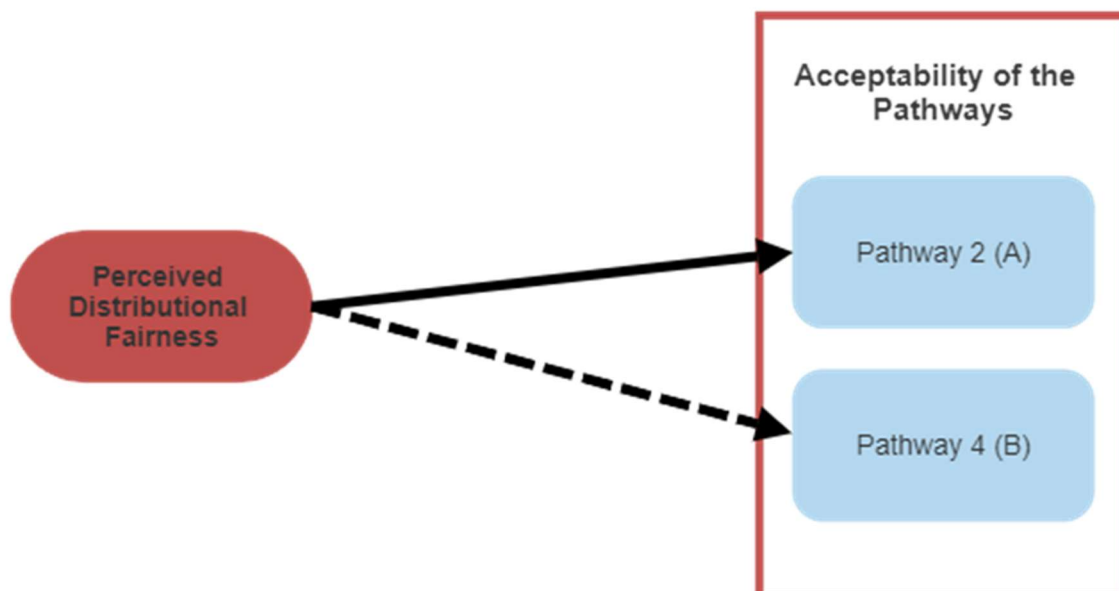
Other Influential Factors of Acceptability in this Study

My team members focus on risk perception of climate change, objective knowledge of climate change, and personal values (biospheric, altruistic, egoistic) as alternative influential factors on acceptability of the pathways.

Purpose of the Present Study

The IPCC (2018) has made multiple suggestions they deem feasible with regards to incorporating future energy systems. These described Pathways of future energy systems can help to keep the impact of global warming as low as possible. However, for politicians, companies, and individuals to come together to implement these pathways, it needs to be understood what is important and acceptable to the public, for them to be willing to adapt to the suggested pathways. To quote directly from the IPCC, 2018: "Public acceptability depends on the individual's evaluation of expected policy consequences, the perceived fairness of the distribution of these consequences, and perceived fairness of decision procedures (high confidence).". This study hopefully fills a gap in addressing what is relevant for people to accept the suggested pathways of the IPCC with special focus on PDF.

Method

Participants

Our pre-registered study was approved by the Ethics Committee Psychology of the University of Groningen and is in accordance with the declaration Helsinki ("World Medical Association Declaration of Helsinki", 2022). The pre-registration can be found under https://osf.io/kfh6x . The study was accessible from 26th of April 2022 to 20th of May 2022, via Qualtrics. The survey could be individually filled in via computers or smartphones and would only allow for one total completion in form of self-reports. Participants were recruited via snowballing and via Sona. Sona participants consist of a pool of first year psychology students and are granted 0.5 Sona credits upon participation, while the rest of the participants did not receive any compensation. The snowballing participants were recruited via convenience sampling (word-to-mouth, social media, personal networks). Additionally, flyers were placed at university buildings within the city of Groningen in the Netherlands.

Procedure

After filling in the informed consent form and giving their demographics, participants received questions and information in the following order: risk perception of climate change, objective knowledge of climate change, personal values (biospheric, altruistic, egoistic), pathway description and comprehension questions thereof (in order to continue with the survey, this part needed to be filled in), perceived effectiveness, cost/benefits, perceived distributional fairness, acceptability of the pathways, choice of a pathway, feasibility of the pathways, and the option to introduce factors they would include, change, or prefer in the Pathways if they were a policymaker, and lastly the option to leave comments. Item order for all scales, except the last two, was randomized. Participants were free to go back and forth between the questions, which allowed for changing responses; the last responses given were saved. Since the responses were saved, participants had the option to take breaks, allowing for them to fill in the survey within the time span of a week and thus returning and leaving the survey in their own time.

Design & Measurements

This study was an observational survey study, so no manipulations or treatments were applied. No blinding of the subjects was involved in this study. It was a cross-sectional design. The focus of the measurements in this paper lies on the acceptability of the pathways, the PDF, C/B, and the PE. Other variables in the study were climate change risk perception, biospheric, egoistic, and altruistic values, and knowledge. For more details on those, please refer to: https://osf.io/kfh6x .

Demographics.

Age and gender were indicated by the participants.

Acceptability.

The measured outcome variable (DV) is Acceptability, which was measured with the use of three items, with a scale of (not at all acceptable (1) - very acceptable (7)) (scale adapted from Perlaviciute et al., 2021) (see Figure A4). Further, it was measured which of the two pathways the participants would choose if they had to (see Figure A3). For simplicity

reasons, the two Pathways used from the IPCC, Pathway 2 and Pathway 4, were renamed within the study to Pathway A (PA) and Pathway B (PB) respectively.

The independent variables (IV) carrying the focus in this analysis will be the perceived distributional fairness (PDF), cost/benefits (C/B), and the perceived effectiveness (PE).

Perceived Distributional Fairness.

Hereby PDF conceptualizes how fair one perceives the pathways to be distributed for oneself, others, and the both in juxtaposition, using a total of 12 items, with a 7-point Likert Scale, ranging from strongly disagree (1) - strongly agree (7) (see Figure A5). This included four different questions, repeated for the two Pathways each, and one time of the overall perception of the proposed pathways. The items were based on items by Eriksson et al., 2006. The subscale for PDF of PA with 4 items had a Cronbach's α of .79. The subscale for PDF of PB with 4 items had a Cronbach's α of .88. The subscale for PDF of the Pathways overall had, with 4 items, a Cronbach's α of .82 (see Table B1).

Perceived Cost/Benefits.

To measure the perceived costs/benefits, a total of 12 items, 6 for each Pathway, were used on a 7-point Likert Scale, rating the items from 1 (strongly disagree) to 7 (strongly agree) (see Figure A6). The items analyzed whether one's personal life, and quality of life would be affected by the Pathways. The same questions were asked in reference to others' personal lives and quality of life. Further, it was looked at whether the pathways would bring their life closer to their ideal lifestyle, and whether they would impact others' well-being. The subscale for perceived costs/benefits for PA with 6 items had a Cronbach's α of .87. The subscale for perceived costs/benefits for PB with 6 items had a Cronbach's α of .90 (see Table B1).

Perceived Effectiveness.

To measure the PE of the pathways, a total of 8 items, 4 per pathway, were used on a 7-point Likert Scale, rating the items from 1 (strongly disagree) to 7 (strongly agree) (see Figure A7). The items looked at whether one perceived the suggested measures by the pathways would impact the mitigation of climate change. The subscale for PE for PA with 4

items had a Cronbach's α of .79. The subscale for PE for PB with 4 items had a Cronbach's α of .87 (see Table B1).

Analysis.

In total 304 recorded responses were collected, of which 221 are included in the analysis. In case of missing data, case-wise deletion will be made use of if values of a variable are missing, e.g., a participant gets discarded if they skipped an item needed for the analysis of a particular researcher. In this case 83 people were dropped because of incompletion of the variables analyzed in this paper. The final sample consists of 135 women and 80 men, 5 who identify otherwise, and 1 who preferred not to say. These were all within the age range of 18 to 68 years old (M = 24.1, SD = 9.4). The people needed about 15 Minutes to fill in the survey (Mdn = 15.6).

In the analyses we overall make use of Logistic Regression, Simple and Multiple Regression, Mediation Analysis via PROCESS Makro (Hayes, 2022). In case of violations of the homoscedasticity or normality assumption being violated, appropriate transformations will be conducted. The standard inference criteria of p < .05 criterion will be used to determine whether any of the results of the analyses will be considered statistically significant. To test hypothesis H1, H1a, and H1b, a Simple Linear Regression was performed, for each the Acceptability of PA, PB, and the pathways overall, with the usage of the dependent variables PDF of PA, PDF of PB, PDF of the pathways overall. To test the assumed mediation effect of perceived higher costs on PDF, a PROCESS Makro analysis (Hayes, 2022) was performed. Here the focus is on the direct effect between the independent variable perceived costs/benefits and the dependent variable acceptability of the pathway, with considering an indirect effect via the assumed mediating variable PDF. To analyze H 3 the mediating role of the PDF of PA on the relationship between PE of PA and acceptability of PA was assessed. To analyze E1, a binary logistic regression was performed to examine the association of PA Perceived distributional fairness, PB Perceived distributional fairness, and pathways overall Perceived distributional fairness with the likelihood of picking PA or PB.

Results

Descriptive Statistics

Out of the 221 respondents, 36.2 % of the participants identified as male, 61.1% as female, 2.3% as other, and 0.5% preferred not to say. The average age of the participants was 24.1 years (SD = 0.6) with a minimum of 18 years and a maximum of 68 years. The mean of the acceptability of both pathways is 4.4 (SD = 0.8), the acceptability of pathway A 5.6 (SD = 1.3), and of pathway B 3.2 (SD = 1.6). When having to choose, 84.2% of the participants preferred pathway A, the remaining 15.8% pathway B. The average of PDF of pathway A is 4.4 (SD = 0.8), and of pathway B is 3.8 (SD = 1.4), and 3.5 (SD = 1.3) for the Pathways overall. For costs/benefits the average response for pathway A is 3.6 (SD = 0.8), and for pathway B is 2.6 (SD = 0.8). An average 5.4 (SD = 1.0) was found for the PE of pathway A, and a 3.1 (SD = 1.4) for Pathway B (see Table B2).

Hypothesis 1

Table 1 shows that PDF overall scores predicted the Acceptability of both Pathways, $R^2 = .16, F(1, 219) = 41.73, p < .001$ (see table 10). In line with Hypothesis 1 (H1), these findings suggest a small positive relationship between the PDF of both pathways overall and their acceptance. Specifically, 16% of the variance in the acceptability of both pathways can be explained by PDF overall.

Table 1

Simple Linear Regression Results of the Acceptability of both Pathways

Predictor	B	95% CI		Sig	Fit
		LL	UL		
Constant	3.475	3.184	3.765	<.001	
PDF of P	.253	.176	.330	<.001	
					R²=.156

Table 2 shows the implication of the predictor variable PDF of PA predicting the Acceptability of PA, $R^2 = .17, F(1, 217) = 74.97, p < .001$ (see table 10). In line with H1a, this means that the data suggests a positive relationship between the PDF of PA and the

acceptance thereof, of which 17% of the variance seen in the acceptability of PA is explained by the PDF of PA.

Table 2

Simple Linear Regression Results of the Acceptability of Pathway A

Predictor	B	95% CI		Sig	Fit
		LL	UL		
Constant	3.691	3.104	4.278	<.001	
PDF of PA	.439	.308	.570	<.001	
					R²=.166

Table 3 displays the implications of the predictor variable PDF of PB' on the acceptability of PB, R^2 = .26, F (1, 218) = 43.48, $p < .001$ (see table 3).

This means 26% of the variance seen in the Acceptability of PB can be explained by the PDF of PB.

Table 3

Simple Linear Regression Results of the Acceptability of Pathway B

Predictor	B	95% CI		Sig	Fit
		LL	UL		
Constant	1.073	.569	1.576	<.001	
PDF of PB	.547	.422	.671	<.001	
					R²=.257

Hypothesis 2

To analyse H 2, the mediating role of the PDF of PA on the relationship between perceived costs/benefits of PA and acceptability of PA was assessed. A significant indirect effect of perceived costs/benefits of PA on acceptability of PA was found (b = .162, 95%CI [0.05, 0.28])(see Table 4). The direct effect of perceived costs/benefits of PA on acceptability of PA was also significant with the mediator present (b = .681, p< .001). Thus, PDF of PA partially mediated the relationship between perceived costs/benefits of PA and acceptability of PA.

Table 4

Indirect Effect of C/B via PDF on Acceptability

	Effect	Boot SE	LL	*UL*
PDF of PA	.162	.058	.048	.275
PDF of PB	.243	.085	.082	.412

The mediating role of the PDF of PB on the relationship between perceived costs/benefits of PB and acceptability of PB was assessed. A significant indirect effect of perceived costs/benefits of PB on acceptability of PB was found *(b = .243, 95%CI [0.08, 0.41]) (see table 4)*. The direct effect of perceived costs/benefits of PB on acceptability of PB was also significant with the mediator present (b = .957, p< .001). Thus, PDF of PB partially mediated the relationship between perceived costs/benefits of PB and acceptability of PB.

Even though the results are significant, a conclusion cannot be made for H2. Too late I realized that I could not simply reverse code perceived costs/benefits to look at perceived costs instead of the intertwined questions regarding C/B. The operational mistake was made before the study began, thus causing the hypothesis ineligible for a conclusion and fitting analysis. Therefore, this analysis with the variables of H2 can only be seen as an exploration of the relationship between PDF as a mediator on the relationship between perceived costs/benefits and acceptability of the pathways.

Hypothesis 3.

A significant indirect effect of PE of PA on acceptability of PA was found *(b = .106, 95%CI [0.04, 0.18])* (see Table 5). The direct effect of PE of PA on acceptability of PA was also significant with the mediator present *(b = .633, p< .001)*. Therefore, PDF of PA partially mediated the relationship between PE of PA and acceptability of PA.

Additionally, the mediating role of the PDF of PB on the relationship between perceived costs/benefits of PB and acceptability of PB was assessed. A significant indirect effect of PE of PB on acceptability of PB was found *(b = .125, 95%CI [0.07, 0.20]))*. (TABLE) The direct effect of PE of PB on acceptability of PB was also significant with the mediator

present *(b = .679, p< .001)*. Thus, PDF of PB partially mediated the relationship between PE of PB and acceptability of PB. These results support H3, suggesting the presence of a mediation of PDF in the relationship between PE and acceptability of the pathways.

Table 5

Indirect Effect of PE via PDF on Acceptability

	Effect	Boot SE	LL	*UL*
PDF of PA	.106	.036	.044	.184
PDF of PB	.125	.035	.065	.201

Explorative Hypothesis 1

Multicollinearity was checked beforehand, resulting in a tolerance of .825 for PA Perceived distributional fairness, .653 for PB Perceived distributional fairness, and .574 for pathways overall Perceived distributional fairness. When checking the standardized residual values, two outliers were reported (Std. residual of 2.744 and 5.154), which were kept in the analysis. The model was statistically significant at X^2 (3, 221) = 38.79, p > .001, suggesting the possibility of distinguishing between those who would choose PA and PB. Between 16.2% (Cox & Snell R^2) and 28.1% (Nagelekerke R^2) of variance in the dependent variable could be explained by the model. It correctly classified 83.1 % of cases. The Beginning Block classified 84.5% of cases correctly. At this point, it might be relevant to note that of the 221 participants, 185 chose PA and 34 chose PB.

The odds ratio for PA's PDF was .315 suggesting that every increase in PA's PDF, participants were .315 times more likely to choose PB. The odds ratio for PB's PDF was 1.545, indicating that for every increase in PB's PDF, participants were 1.545 times more likely to choose PB. Likewise, the odds ratio for pathways overall PDF's odds ratio of 1.79, suggesting for every increase in pathways overall PDF, participants were 1.79 times more likely to choose PB. This is supportive of the explorative hypothesis E1. The summarized logistic regression analysis can be found in Table C4.

Discussion

In this study, we sought to examine the effects of PDF on the acceptability of two different pathways aimed at mitigating climate change. In hypothesis (1) we looked at the direct effect of PDF, in hypothesis (2) and (3) we investigated its effect as a mediator for C/B on acceptability, and for PE on acceptability respectively. Lastly, in the explorative hypothesis we examined whether PDF could be a predictor of having a preference of one pathway over the other. The specific hypotheses formulated are: (H1) The higher the PDF of the pathways, the higher their acceptability, (H1a) The higher the PDF of Pathway A the higher its acceptability, and (H1b) The higher the PDF of Pathway B the higher its Acceptability.(H2) Higher perceived costs will decrease the PDF and thus also the acceptability of Pathway A and B (assumed mediation), and (H3) Higher PE will increase the PDF and thus also the acceptability of the pathways (assumed mediation). (E1) Lower PDF is associated with a higher chance to indicate a preference for pathway B when choosing between both pathways.

The results of (H1) indicate a small positive relationship between the PDF overall and the acceptance of the two pathways, with the PDF being able to explain 16% of variance in the acceptance of pathway A and B combined. When analyzing the pathways separately, (H1a) shows a 17% variance which is explained by the PDF of pathway A. Pathway (H1B) shows 26% variance which is explained by the PDF of pathway B.

As mentioned before, the results of (H2) are only to be taken as explorative datapoints because of the operational mistake. When looking at PDF as a mediator between not just costs as stated in the hypothesis, but C/B - as the items describe - and the acceptability of the pathways, we find an indirect effect of 16% for pathway A, and of 23% of pathway B. These priorly indicated indirect effects are the differences between the total effect of C/B on acceptability and the direct effects of C/B on acceptability controlling for PDF.

The same assessment style with the correct operationalizations for (H3) shows an indirect effect of 11% for pathway A, and 13% of pathway B. This analysis supports the hypothesis of the PE of the pathways as being partially mediated by PDF.

Looking at the explorative hypothesis, the data suggests that the lower the PDF of

pathway A is, the likelier it becomes that pathway B would be preferred as a choice over pathway A, and when the PDF of pathway B increased, so would the likelihood of choosing pathway B over pathway A.

The findings align with previous research, such as the Meta-analysis of Bergquist et al. (2022) which shows policy specific beliefs are majorly affected by PE and perceived fairness. This may be attributed to the information-motivation-behavioral skill model by Fisher and Fisher (Kiene et al.,2013), which showcases that if a person not only receives new information but comprehends it, the chance of that person adapting the behavior based on the new information increases. In terms of PDF contributing to acceptance, one can make the assumption that this would contribute to decisions being accepted peacefully as described by Garcia and Philpot (2021). Since this theoretical observational study is held more general, it can be seen as a small addition to more specified, but practical studies, such as the one conducted by Huijts et al (2011). This study describes the positive relationship between distributional fairness and changing attitudes towards the installation of windmills in their close surroundings, but does not look at the impact of perceived distributional fairness for a broader concept, such as the pathways introduced by the IPCC.

One limitation of our survey study is the risk of biases that arise with self-reports, such as social desirability and recall bias. We tried to account for these by using neutral statements and allowing subject access to information we provided throughout the study. However, it remains information, that is emotionally triggering and politically loaded. Additionally, some of the implications of the pathways were not very clear in the descriptions. This can be seen in commentary that participants left, such as doubting the existence of climate change or being overwhelmed by the volume of questions. While these types of comments were comparatively rare, they are not negligible.

Additionally, the study maintains a bias towards young female university students belonging to a single institute, possibly with a very similar cultural background, as these constituted the majority of our participants. Furthermore, we made use of a convenience sample, which limits the generalizability of our findings.

Additionally, the effect of the political climate in which this discussion takes place needs to be included when analyzing participant responses. For an example, the start of the Russia-Ukraine war in 2022 impacted the way European participants, a majority of our participants, view their own energy resources. (Abnett & Blenkinsop, 2022.; euronews. 2022).

Nevertheless, this survey also presented an opportunity for participants to express excitement and propose ideas regarding small changes in behavior achieving a more sustainable future. An example mentioned was a specific news section designated to talk about both regional and worldwide initiatives for climate change mitigation, providing inspiration on the one hand, and acknowledging the realities of climate change on the other.

An important limitation is the previously mentioned operation mistake regarding H2, specific to that section of the study. However, considering the positive relationship found in this context, future studies focusing on PDF acting as a mediator in the relationship of costs/benefits and acceptance of future energy systems could yield promising results.

These findings make it more relevant to showcase the pathways of future energy systems and finding solutions that are not just perceived as effective and procedurally fair, but also as distributionally fair. While more research is necessary, these early results show the relevance of PDF on the public acceptance of climate change mitigating measures.

Future studies should further explore the relationships between acceptance, actual behavioral change and the variables PDF, PE, and C/B via the means of manipulating the predictors of experiments. While it is valuable to have more general perspectives on how these variables affect each other, looking at practical, visible changes in the process will help define what is meant by future energy systems and how these directly influence individuals and communities. Furthermore, it would be interesting to investigate not just correlations as done in this study, but also causalities. Subsequently, it would be intriguing to investigate how multiple examples of differently expressed perspectives on a future energy system, such as through news-channels or influencers, may impact those experiences of fairness, effectiveness, and consequently acceptance with regards to behavioral adaptations.

Furthermore, while the different components were analyzed individually and looking at mediator effects, we missed out on the opportunity of looking at all the different predictors looked at in the study in a multiple regression analysis.

In conclusion, our study provides significant findings emphasizing the relevance of perceived distributional fairness and perceived effectiveness as contributing factors to the acceptability of future energy systems. It adds to the very limited research done about how the pathways explained by the IPCC are perceived. Because of this, it also needs more research to see if the results are replicable and generalizable as a whole, but possibly also with the subcomponents in the pathways. Overall, this research aids in deepening our understanding of perceived distributional fairness and serves as a building block for future research in this direction.

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Appendix A: Descriptions, Scales, and Item

Figure A1

Pathway Descriptions

Pathway descriptions <u>Pathway Descriptions</u>
Hover over text in bold for an explanation of key terms.

We are interested in people's stand toward changes suggested by the **IPCC** to limit the **effects expected from global warming**. To avoid an increase beyond **1.5°**, the IPCC has suggested multiple pathways.

Implementation of these pathways requires changes to *industry* and *everyday behaviour on a global level*. They will affect our *lifestyles* and *economy*.
The two pathways we are focusing on differentiate in two main aspects: the **overshoot** they allow for, and the way they aim to reach a stable temperature.
<u>Pathway A</u> aims to limit the overshoot of 1.5°C to a maximum of 1.6°C, keeping the effect of climate change as low as possible.
<u>Pathway B</u> does not aim to limit the overshoot of 1.5°C, allowing it to go beyond 1.6°C, risking higher effects of climate change.

To limit the effects, both pathways aim to return to 1.5°C by the end of the 21st century.

Pathway A expects rapid transitions to future energy production systems and implementation of industry and lifestyle policies. Pathway B expects slower transitions, resulting in overshoot, which is then reversed using carbon capture. There would be no need to change from the current CO2-emission-intensive lifestyle.

Details of the proposed energy transitions can be seen below:

<u>Pathway A reduces energy demand by 5% by 2030</u> Eating local and seasonal foods Reducing meat and dairy consumption Reducing waste in water, food and transportation industries Using resources more efficiently (insulation etc.) **Low emission innovations** Energy-saving behaviour (walking, cycling, mass transit, lower heating) Organisational change (replacing business travel by video call) Flood protective behaviour Heat protective behaviour (green roofs) Efficient water use (rationing)
<u>Pathway B increases energy demand by 39% by 2030</u> Increased economic growth and globalisation Increased meat and dairy consumption Increased demand for fuel Increased worldwide shipping **Electrification** Building desalination plants to convert seawater into freshwater
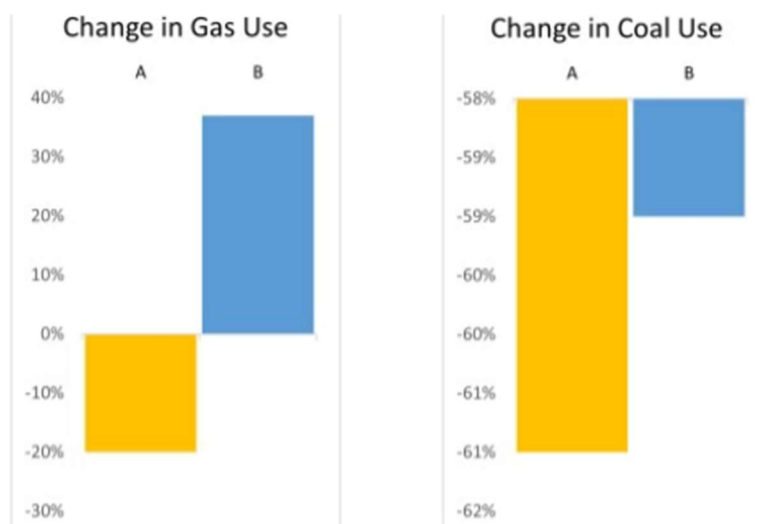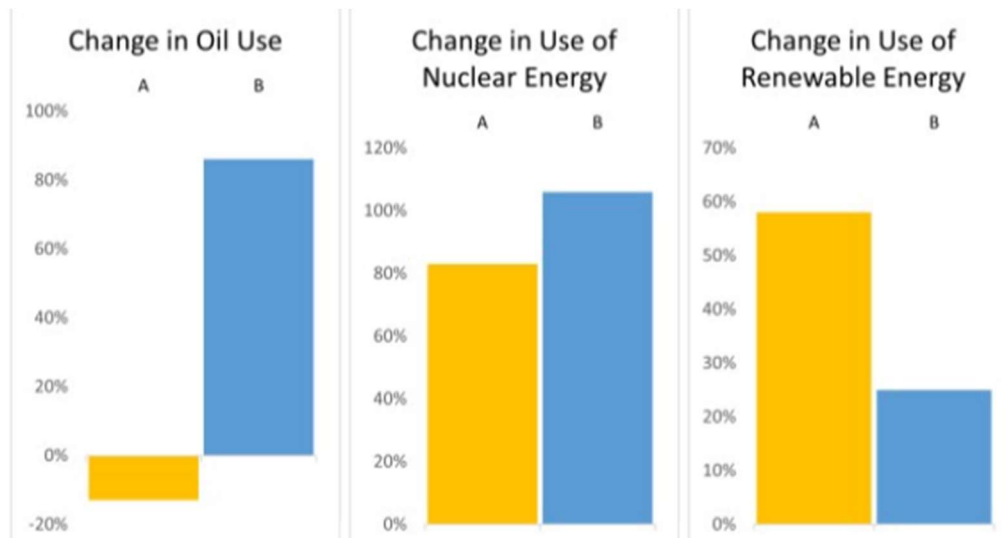
Figure A2

Pathway Descriptios Summary

Pathway A:	Pathway B:
- **no or limited** exceeding of 1.5°C of global warming to a maximum of 1.6°C - Far reaching **lifestyle** changes (e.g. less meat consumption, reduced heating, using mass transit instead of cars) - Very limited use of carbon dioxide removal techniques, great reliance on **renewable** energy sources, decrease in fossil fuel energy sources	- Will **exceed** 1.6°C of global warming - **Maintenance** of current CO2-emission-intensive-**lifestyle** - Heavy reliance on **carbon dioxide removal** techniques, less use of renewable energy, increased use of **fossil fuel** energy resources (oil)

Figure A3

Pathway Preference Item

Q16 Which pathway do you prefer?

○ Pathway A (1)

○ Pathway B (2)

Figure A4

Pathway Acceptability Scale

Q15 To what extent do you think pathway A is acceptable?

	not at all acceptable (1)	unacceptable (2)	slightly unacceptable (3)	neutral (4)	slightly acceptable (5)	acceptable (6)	very acceptable (7)
I think pathway A is... (1)	○	○	○	○	○	○	○

Q34 To what extent do you think pathway B is acceptable?

	not at all acceptable (1)	unacceptable (2)	slightly unacceptable (3)	neutral (4)	slightly acceptable (5)	acceptable (6)	very acceptable (7)
I think pathway B is... (1)	○	○	○	○	○	○	○

Figure A5

Scale: Perceived Distributional Fairness (PDF)

Q57 Pathway A: Please rate the following statements regarding fairness from strongly disagree to strongly agree.

	strongly disagree (1)	disagree (2)	slightly disagree (3)	neither agree nor disagree (4)	slightly agree (5)	agree (6)	strongly agree (7)
The proposed measures of pathway A are overall fair for me. (1)	○	○	○	○	○	○	○
The proposed measures of pathway A are overall fair for others. (3)	○	○	○	○	○	○	○
Others and I will be equally affected by the implications of pathway A. (4)	○	○	○	○	○	○	○
The energy demands of pathway A are equally fair for me and others. (5)	○	○	○	○	○	○	○

Figure A6

Scale: Perceived Cost/Benefits (C/B)

Q19 To what extent do you agree or disagree with the following statements if pathway A was implemented?

The implementation of pathway A....

	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly Agree (5)
would positively affect my personal life (1)	○	○	○	○	○
would positively impact my quality of life (6)	○	○	○	○	○
would bring life closer to my ideal way of living (7)	○	○	○	○	○
would positively affect the lives of others (8)	○	○	○	○	○
would positively impact the quality of life for others (10)	○	○	○	○	○
would positively impact the well-being of others (11)	○	○	○	○	○

Figure A7

Scale: Perceived Effectiveness (PE)

Q2 In regards to pathway A (for more information about the pathways, look at the summary at the bottom of the page), to what extent do you agree with the following items?

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
The pathway provides a sufficient mean to limit global warming to 1.5°C by the end of the 21st century (1)	○	○	○	○	○	○	○
The pathway provides a clear mean for reducing the consequences of climate change (2)	○	○	○	○	○	○	○
The pathway facilitates limiting the effects of climate change (3)	○	○	○	○	○	○	○
By following this pathway, global warming would be limited to 1.5°C by the end of the 21st century (4)	○	○	○	○	○	○	○

Appendix B: Reliabilities of Scales and Descriptive Statistics

Table B1:

Scales Reliability Statistics for the Independent and Dependent Variables

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
PDF of PA	.788	.787	4
PDF of PB	.883	.883	4
PDF of PO	.824	.828	4
C/B of PA	.870	.871	6
C/B of PB	.903	.905	6
PE of PA	.792	.792	4
PE of PB	.866	.867	4

Table B2:

Descriptive Statistics Overview

	Mean	SD	Min	Max	Std. Error	N
Demographics						
Duration (in seconds)	14114.1403	80890.77721	101.00	810098.00	5441.30251	221
Age (in years)	24.10	9.377	18	68	.631	221
Gender	1.67	.543	1	4	.037	221
Acceptability of Pathway(s)						
Overall	4.3665	.84292	1.00	7.00	.05670	221
A	5.58	1.261	1	7	.085	221
B	3.15	1.552	1	7	.104	221
Preference between Pathway A and B						
	1.16	.366	1	2	.025	221
Perceived Distributional Fairness of Pathway(s)						
Overall	3.5260	1.33300	1.00	7.00	.08967	221
A	4.3205	1.17388	1.00	7.00	.07914	220
B	3.7854	1.44098	1.00	7.00	.09737	219
Perceived Cost/Benefits of Pathway						
A	3.5674	.77235	1.00	5.00	.05207	220
B	2.6131	.81155	1.00	5.00	.05459	221
Perceived Effectiveness of Pathway						
A	5.4114	.95986	1.00	7.00	.06471	220
B	3.0886	1.34897	1.00	7.00	.09095	220
Valid N						216

Appendix C: Statistic Summaries of the Hypotheses

Table C1

Summary Statistics of the Simple Linear Regressions for H1, H1a, and H1b

Explanatory Variable	F	df1	df2	*p*-value	*R² adj*
H1 : PDF of PO	41.730	1	219	<.001	.156
H1a: PDF of PA	43.484	1	218	<.001	.162
H1b: of PB	74.969	1	217	<.001	.253

Table C2

Summary Statistics of the Mediation Analysis via PROCESS Makro for H2

	F	MSE	df1	df2	*p*-value	*R²*
C/B on Acceptability of PA without PDF	50.887	1.126	1	217	<.001	.156
C/B on Acceptability of PA mediated by PDF	47.652	1.114	2	216	<.001	.306
C/B on Acceptability of PB without PDF	91.700	1.466	1	217	<.001	.297
C/B on Acceptability of PB mediated by PDF	82.737	1.381	2	216	<.001	.434

Table C3

Summary Statistics of the Mediation Analysis via PROCESS Makro for H3

	F	MSE	df1	df2	*p*-value	*R²*
PE on Acceptability of PA without PDF	27.833	1.203	1	217	<.001	.114
PE on Acceptability of PA mediated by PDF	62.842	1.017	2	216	<.001	.368
PE on Acceptability of PB without PDF	43.516	1.744	1	2016	<.001	.168
PE on Acceptability of PB mediated by PDF	130.062	1.107	2	215	<.001	.548

Table C4

Summary Logistic Regression Coefficients E1: Likelihood of Choosing PA or PB

Variable	B	SE	Wald	95 % CI		Sig.	OR
				LL	UL		
Constant	-1.154	.918	1.396			.237	.338
PA Perceived distributional fairness	-1.154	.275	17.628	.184	.541	.000	.315
PB Perceived distributional fairness	.435	.187	5.410	1.071	2.229	.020	1.545
pathways overall Perceived distributional fairness	.582	.245	1.396	1.107	2.895	.018	1.790

Note. total *N* = 219, df = 1. CI = confidence interval; LL = lower limit; UL = upper limit.