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Evidence from a random experiment in Sweden

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Papers in Innovation Studies no. 2021/14

Framing energy choices in consumer decision-making: Evidence from a random experiment in Sweden

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Abstract

Sustainability transitions literature is largely missing the point of view of consumers. This is problematic in efforts to understand how sustainable forms of energy diffuses where consumers are understood as active players in embedding energy efficient technologies in their homes. It remains unclear how consumers make energy-relevant decisions and what constitutes this decision-making process. We address this gap by conducting a random experiment asking consumers to make choices regarding solar energy technologies based on a set of options. Options are framed in either a subtractive or additive way to test how consumers process these choices, whether the type of framing matters in encouraging pro-solar energy behavior, and which solar technologies are preferred. We hypothesize that subtractive framing of energy-relevant choices leads to more options being selected than additive framing, that the type of option framing matters in shaping consumer preferences, and that the framing affects the transition probabilities in the decision-making process. Results show that consumers are susceptible to option framing when making energy-relevant decisions. Respondents were concerned primarily with costs when options were framed additively but exhibited decision difficulties and more pro-solar energy transition behavior when options were framed subtractively. This paper demonstrates the sequential steps in decision-making under subtractive framing, which induces a willingness in consumers to embed more solar energy technologies into their households despite the cost, as opposed to additive framing. This paper contributes a representation of the cognitive process of energy relevant decision-making, empirical evidence on the potentiality of nudging consumers towards more pro-solar energy transition behavior, and the importance of framing tools in encouraging this behavior.

Keywords: additive and subtractive option framing, experimental design, Markov chain, final state distribution, transition probability, distance from initial model, anchoring

Short running title: Framing energy choices in consumer decision-making

JEL codes: C93, D12, C12, D81

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1 Introduction

As the crises of climate change deepens, more sustainable forms of energy will need to be widely adopted across society (Coenen, Hansen, Glasmeier, & Hassink, 2021). Widespread diffusion will require consumers to take up more sustainable forms of energy such as solar energy. Current government programs aimed at convincing consumers to take up more solar energy treat consumers as if they are perfectly rational (Schot, Kanger, & Verbong, 2016) even though there is some evidence that this might not always be the case (Lesic et al., 2019). It remains unclear what constitutes the cognitive process of decision-making of consumers in adopting more sustainable forms of energy. This lack of clarity is in part due to that the energy transitions literature is largely missing a consumer perspective (Coenen et al., 2021; Hansen & Coenen, 2015). This is particularly problematic in efforts to understand how technology diffuses in society where consumers are understood as active players in deciding to take up and embed sustainable technologies in their households (Schot et al., 2016). Knowing how consumers decide to take up more sustainable forms of energy can inform governments how to support consumers interested in undergoing solar energy transitions and how this can be done not just in the best interest of the environment but also the consumers (Hahnel, Chatelain, Conte, Piana, & Brosch, 2020) and in less paternalistic ways (Neumann & Mehlkop, 2020). Thus, this paper interrogates the research questions: **how do consumers make solar energy-relevant decision-making when faced with *option framing?***

We address this gap by conducting a random experiment asking consumers to make choices regarding solar energy services and technologies based on a set of options. Options are framed in either a subtractive or additive way to test how consumers process these choices and how they decide on which options to select. One of the earlier studies on the use of option framing in marketing reports that option framing is a product configuration where the consumers modify the product components, either by adding optional features to a base model, or by subtracting options from a full model (C. W. Park, Jun, & MacInnis, 2000). Essentially, the product is defined by a base model, the minimum set of components, and the options, which can be customized by the consumers. The full model is then made up of the minimum package and all of the options.

We hypothesize that subtractive framing leads to more options being selected than additive framing when applied to solar energy relevant decision-making. Moreover, framing effects also manifest in the transition probabilities in the decision-making process showing how much more pro-solar energy transition consumers are willing to do, and that consumers are, in general, concerned about the cost of solar energy despite a concern for the environment. Moreover, our paper contributes to current studies in energy transitions in three main ways. Firstly, we contribute a cognitive representation of solar energy-relevant decision making of consumers. Secondly, we show that consumers can exhibit decision difficulties and pro-solar energy behavior when processing the monetary consequences and loss of quality in selecting energy options for their households. Thirdly, we show that framing energy choices in a subtractive way can lead consumers into taking up more pro-solar energy behavior than in additive framing.

The remainder of the paper is as follows. **Section 2** reviews the literature on consumers in sustainable transitions and beyond. **Section 3** outlines the theoretical background on consumer decision-making under option framing and identifies hypotheses to be tested. **Section 4** discusses the methodology of the random experiment and a Markov chain model while **Section 5** discusses the results. **Section 6** concludes and discusses the contributions of this paper to the literature on energy transitions.

2 Literature review

Engagements with the question of changes in consumption activities are integrated in the sustainable transitions literature at a high level reasoning “through conceptual categories such as ‘markets and user practices’, ‘culture and symbolic meaning’, and ‘market formation’ (Raven et al., 2021, p. 88). There are still few research in this literature that analyzes consumers down to the micro-level particularly, and how and why consumers take up more sustainable energy practices despite increased interest in consumers (Coenen et al., 2021). Moreover, "current government information policies and market-based instruments tend to have a relatively narrow view of the user as a consumer making conscious rational choices on the energy market from a set of pre-defined options." (Schot et al., 2016, p. 1). Literatures beyond sustainable transitions have shown that this might not always be the case and that consumers may face challenges in rationalizing their actual energy usage and practices (Lesic et al., 2019).

It has also been theorized that consumers may be doing cognitive work such as mental accounting in rationalizing energy choices and behavior and this line of research shows that consumers are said to be susceptible to labelling techniques in energy related behavior (Hahnel et al., 2020). Furthermore, although there is evidence that shows that consumers are willing to take up more sustainable energy away from fossil fuel, consumers seem to seldom make an active choice to make this energy transition in practice (Neumann & Mehlkop, 2020). They seem to have potential biases when trying to make active energy-relevant decisions and seem to need to be 'nudged' in the direction of taking up transition. This could involve monetary and non-monetary incentives and deliberative ways in which pro-environmental behavior is encouraged and articulated (Neumann & Mehlkop, 2020). For example, consumers presented with different product choices framed as long-term savings lead consumers to choose the most efficient option over the cheapest option (Allcott & Mullainathan, 2010), which suggests that nudging consumers to take up pro-environmental behavior can be practiced by framing options which can encourage consumers to take up energy transition.

In our study, we delve into these framing effects further and scrutinize how framing options for energy technologies affect the decision-making process of consumers. We investigate whether framing options in the two different ways, subtractive and additive framing, induces changes to pro-solar energy behavior. The next section discusses the theoretical background and derives the hypotheses to be tested.

3 Theoretical background

"The instrument of choice architecture represents a promising tool to foster sustainable energy consumption of private households" (Neumann & Mehlkop, 2020, p. 2). Choice architecture involves framing choices (or options), which are said to generate framing effects on the decision-making of consumers. Framing effects refer to how individuals conduct their behavior and select choices based on whether decision problems are formulated as and associated with gains or losses, even if in actuality, the consequences are identical (Tversky & Kahneman, 1974, 1981). This is based on prospect theory that posits that loss aversion is a strong motivation in processes of decision-making (Tversky & Kahneman, 1991). A particular type of framing is option framing and has been applied in marketing research to test consumer choices. As explained in the previous section, option framing can involve two methods, additive framing and subtractive framing (Biswas & Grau, 2008; Wen, Leung, Li, & Hu, 2021). Based on a number of studies (Biswas & Grau, 2008; Herrmann, Hildebrand, Sprott, & Spangenberg, 2013; Levin, Gaeth, Schreiber, & Lauriola, 2002; Lu & Jen, 2016; S. Park & KIM, 2012), consumers end up with more options in the final configuration under subtractive framing. These studies show that the selection results are more favorable with subtractive framing than with the additive version. Technological characteristics of energy products are said to matter significantly to market consumption (Huenteler, Schmidt, Ossenbrink, & Hoffmann, 2016). This is why there is a need to test further whether subtractive framing holds for solar energy technologies. This allows us to derive our first hypothesis.

H_1: The expected number of options in the final configuration of the solar panel package is greater in subtractive framing than additive framing. This implies that consumers exhibit more pro-environmental behaviour in their willingness to pay for more options when faced with options framed in a subtractive manner.

“In many situations, an action gives rise to a compound outcome, which joins a series of changes in a single attribute, such as a sequence of monetary gains and losses or a set of concurrent changes to several attributes” (Tversky & Kahneman, 1981, p. 456). In situations of compound outcomes, consumers are said to construct psychological or mental accounts (Hahnel et al., 2020). Mental or psychological accounts refer to an “outcome frame which specifies the set of elementary outcomes that are evaluated jointly and the manner in which they are combined and a reference outcome that is considered normal or neutral” (Tversky & Kahneman, 1981, p. 456). In constructing these mental accounts, consumers are said to have bounded rationality when it comes to making complex decisions, in general, and in energy-related decisions, in particular. The benefits of solar panels in the short and long terms have been found to be difficult to internalize and process (Lesic et al., 2019). Thus, there is a need to check how consumers make decisions in solar energy-related situations and whether the act of eliminating or adding options makes a difference in how consumers make solar energy-relevant decisions.

Decisions that involve adding options have been found to be difficult to make in the near future whereas subtractive framing has been found to be difficult to make in the distant future (Lu & Jen, 2016). Given how the benefits energy decisions can have a long-term horizon, this can lead consumers to find the process of selecting under the subtractive framing architecture difficult. Closely related to this idea, having a decision task involving a process of rejection leads to more deliberative processing and increases quality considerations (Sokolova & Krishna, 2016). Results on this also shows that decision difficulties under subtractive framing are “similar to situations when decision makers are cognitively depleted or rely on feelings and emotions”(Sokolova & Krishna, 2016). As such, going through different options for solar photovoltaics is likely to induce decision difficulties especially in weighing the benefits and costs. Emotions and feelings like regret can come into play and reinforce the framing effects of subtracting framing (C. W. Park et al., 2000).

In order to examine this process, we use the concept of distance, shown by Lu and Jen (2016) as a promising way to examine potential decision difficulties influencing in the deliberative process. Here we refer to distances in decision making as the sequential decisions or steps that consumers make when they make decisions, with reference to the initial point. The sequential steps modelled in a Markov chain represent the sequential deliberative process in solving the consumer's decision problem. In additive framing, the number of steps is equivalent to the number of options selected. In subtractive framing, the number of options is not equivalent to the number of sequential decisions made since in this choice architecture, one is eliminating options.

H_2: **The final state distributions of distances from the initial solar panel packages are affected by the type of option framing.** This implies that the number of decision steps are affected by the type of option framing. This distance is indicative of the deliberative decision process, which could reflect decision difficulties.

Furthermore, we look further into the decision making of consumers regarding the options consumers prefer the most, that is, the outcomes they are evaluating jointly, and what they end up selecting under additive and subtractive framing. This allows for a better picture of the types of pro-solar energy technologies in which consumers are interested. In addition, it can reveal the desired types of solar energy-related practices, consumers are willing to embed in their households.

H_3: **The distributions of the selected options are different for the two framing strategies**. This implies that framing can lead to different preferences and intensities of selection of solar energy products.

So far we have proposed hypotheses concerning framing effects but Tversky and Kahneman also posited the importance of the idea of a 'reference point'. Consumers are said to exhibit anchoring behavior (Tversky & Kahneman, 1981), which refers to sticking to the initial point in the decision problem (Tversky & Kahneman, 1991). "Actors also differently judge monetary consequences of a change to the reference point, depending on how these changes are formulated" (Neumann & Mehlkop, 2020, p. 3). In our study, consumers are presented two different initial basic packages that become the reference points for further decisions to be made. The possibility to deviate from these basic packages is through selecting more options (additive framing) and deselecting options (subtractive framing). Given differences in final selections, consumer decisions are said to be, generally, affected by the structure of framing. This is discussed in various consumer behavior studies on different types of framing (Abhyankar, Summers, Velikova, & Bekker, 2014; Biswas, 2009; Donovan & Jalleh, 1999; Kühberger & Gradl, 2013; Mandel, 2014; Sokolova & Krishna, 2016; Tversky & Kahneman, 1991). Thus, $\mathbf{H_4}$ tests for general anchoring behaviour, while $\mathbf{H_5}$ compares anchoring behaviour across the two framing architectures.

H_4: **In the choice process, the non-transition probabilities for the initial solar panel packages tend to be larger than the probabilities of transitions to various options from the initial point.** This implies that consumers are expected to exhibit some anchoring behavior.

H_5: **The tendency of consumers to hold on to the initial solar panel model is stronger in additive framing than subtractive framing.** This implies that anchoring is expected to be more intense in additive framing. Incremental costs can make consumers unwilling to take on more solar energy options.

4 Methodology

Experimental design

A random sample was taken from the population of homeowners in the municipalities of Helsingborg and Ängelholm where 231 respondents were interviewed. Of the 231 respondents, 104 homeowners indicated interest in a basic solar panel package for houses. These 104 respondents were selected for the experimental design where they were equally and randomly allocated to two experiment groups: additive framing and subtractive framing. Respondents in the additive framing group were presented with the basic product as the initial package. Thereafter, they chose which options they would like to include in the final package, in sequential fashion. The four options are as follows:

1. Turnkey (ready-to-use) installation, price SEK 30 000.
2. Extended warranty (20-year warranty instead of 10 years as in the basic package), price: SEK 10 000.
3. Extended charging option for electric cars, price SEK 15 000.
4. Battery for home storage of electricity (for electricity use in the evening), price SEK 55 000.

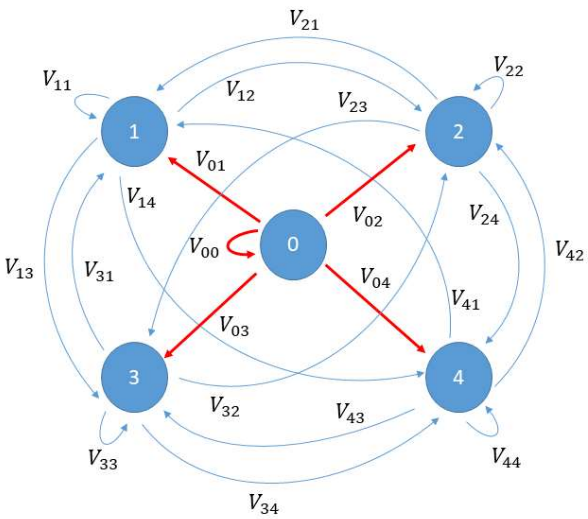
In the other experiment group, subtractive framing, the initial package was the full model, which was composed of the basic product plus all of the four options. Thereafter, the respondents chose which options they would like to exclude from the initial full package, in sequential fashion.

Markov chain

Figure 1. Option Framing in a General Markov Chain

The state S represents the initial model (S=0) and the 4 different options (S=1,2,3,4 – following the numbering of the options in the above list). S=0 refers to the basic package in additive framing and the full package (basic plus all 4 options) in subtractive framing. The transitio V_{ij} captures the movement from state *i* to *j* in the decision process. Note that a movement follows the type of option framing. In additive framing, the transition V_{ij} refers to adding the option *j* to option *i*, whereas in subtractive framing, it refers to deselecting option *j* after option *i*. V_{kk} is a non-transition movement and it simply indicates that the decision stops at option *k*.

Figure 1. Option Framing in a General Markov Chain



5 Results and discussion

The decision movements in the two experimental groups (additive and subtractive framing) are summarized in the following Markov chain diagrams. The transition and non-transition probabilities

V_{ij} indicate the intensities of the various movements from state *i* to state *j*, which are used for certain calculations in the different hypotheses. The diagrams describe the flow of decisions made by the respondents in the two experimental groups.

Figure 2. Additive Framing in Markov Chain

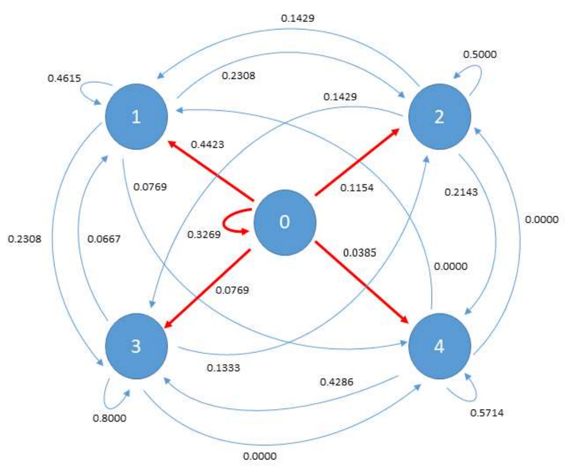
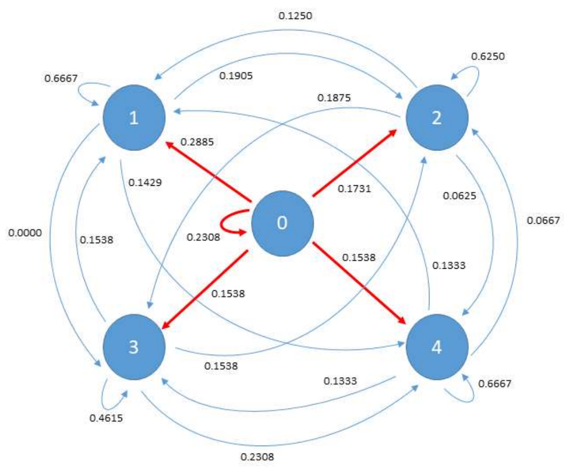


Figure 3. Subtractive Framing in Markov Chain



H_1: The expected number of options in the final configuration of the solar panel package is greater in subtractive framing than additive framing.

The classic results from option framing studies favour the subtractive architecture. As discussed in many previous studies (Biswas & Grau, 2008; Herrmann et al., 2013; Levin et al., 2002; Lu & Jen, 2016; S. Park & KIM, 2012), subtractive framing leads to a greater number of selected options than additive framing. It is of interest to check if this classic expectation holds for solar panel packages. Since the variable of interest, the number of selected options, is discrete with unknown theoretical distribution, a plausible way to evaluate the hypothesis is to use a two-sample permutation test where the test distribution is estimated by Monte Carlo simulation. To do this, for each of the framing strategies, the frequency distributions for the number of selected options are derived from a Markov chain selection process. In this situation, we derive the combined final state distributions of the number of selected options. This discrete distribution ranges from 0 to 4, where the marginal and combined distributions are shown in Table 1. The statistical null hypothesis for this test is H_{1o}: $\mu_A = \mu_S$, where μ_A and μ_S are the average number of selected options for additive and subtractive framing, respectively.

The null hypothesis assumption states that the distribution is equivalent for both option frames. Empirically, this is the combination of the resulting marginal distributions, as shown in the column *Combined* in Table 1. To derive the mean difference distribution, a permutation procedure is used. Several pairs of corresponding samples are repeatedly taken in a random fashion. For each pair, the mean is calculated for each sample. Note that both samples in the pair have n_1=n_2=52 observations, in line with the experimental design. The simulation is based on the combined distribution, following the null hypothesis of equivalent distribution. We then evaluate the associated probability of the resulting mean difference for the actual study. If the associated probability based on the Monte Carlo distribution is smaller than 0.05, then we reject the null hypothesis of mean equivalence. We will also use Cohen's effect size conventions to categorize the strength of the difference of the mean number of selected options (Burns & Burns, 2008).

As shown in Table 1, the marginal and combined distributions of the number of options in the two framing situations are given. One can compute for the mean number of selected options using the marginal frequency distributions. Subtractive framing yields an average of 2.75 options, while additive framing has 1.19. As expected, subtractive framing leads to a greater number of options than additive framing even in the case for solar energy technologies. For the solar panel package, the estimated mean difference of the two option framing designs is 1.56. A crucial question at this point: *Is this difference significant*?

Table 1

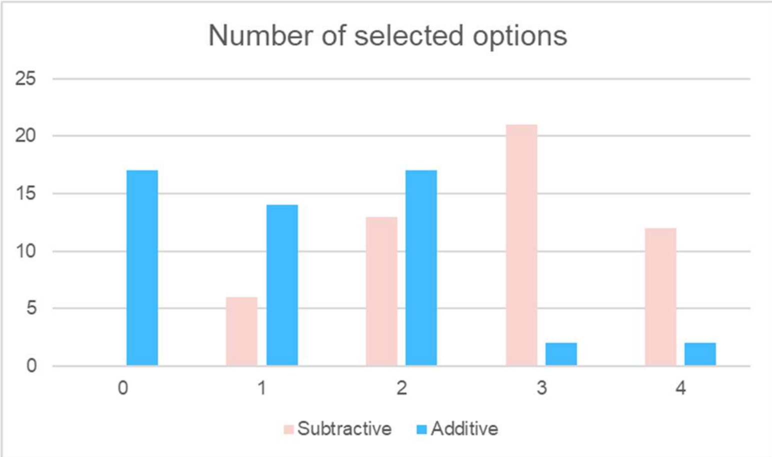
Frequencies of number of selected options

Number of options	Subtractive	Additive	Combined
0	0	17	17
1	6	14	20
2	13	17	30
3	21	2	23
4	12	2	14
	52	52	104

According to the permutation test based on 50 000 observed simulations, the associated probability of the mean difference of 1,56 is extremely small, close to zero. This implies that the null hypothesis of equivalent means is rejected. The difference of the expected number of selected options between additive and subtractive framing is significant. Hence, μ_A is significantly lower than μ_S.

From the combined distribution, the estimated standard deviation is 1.27, and the Cohen effect size is simply the ratio of the difference of means and the standard deviation of the combined distribution. Hence, the Cohen effect size for this difference is calculated at $d = 1.23$. Following the Cohen effect size conventions, a value d greater than 0.80 implies a *large* effect size. On the average, subtractive framing can lead to a significantly higher number of options of solar energy technologies selected by consumers, with observed difference of 1.56.

The difference in the expected number of selected options in solar energy technologies seems to be quite obvious when inspecting the contrasting distributions of the two framing strategies, as follows:



The distribution for subtractive framing has high peaks in values 3 and 4, while additive framing has a heavy concentration in 0, 1, and 2. This contrast shows a tendency for subtractive framing to end up with more selected options in solar energy technologies than additive framing. This means that subtractive framing encourages consumers to take on more energy transition by opting to use more solar energy technologies.

H_2: The final state distributions of distances from the initial solar panel packages are affected by the type of option framing.

To describe the aggregated movements in the framing decision process, we define a final state distribution from the initial solar package, where each movement represents a particular decision regarding an option. This distribution shows the frequencies of the number of decision steps taken after the presentation of the initial package. The framing strategies have different initial solar packages, which act as reference points for the decision process. In additive framing, one starts with the basic package and the respondent decides which of the options are added in a sequential manner. In subtractive framing, the reference point is the basic solar package plus all of the four options (full model), where the decision process calls for sequential elimination, if any, of the options. The number of decision steps can also be referred to as the distance from the initial reference point or package. In whichever framing strategy, the number of decision steps varies from s=0 to s=4. For additive framing, $s=j$ means that j options are added, whereas in subtractive framing, $s=j$ indicates that j options are subtracted. In both additive and subtractive framing, the measure *s=j* reveals that the respondent made *j* decision steps.

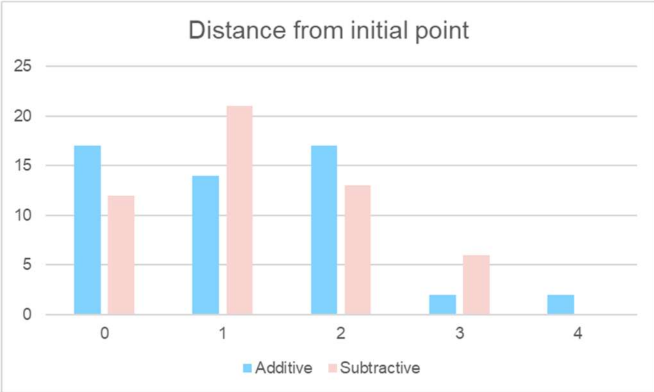
At the onset, it is of primary interest to determine if the number of decision steps are different in the two option framing strategies. Whether or not the average distances are equivalent is an issue, which addresses the mean component of $\mathbf{H_2}$. The statistical null hypothesis for this test is H_{2Ao}: $d_A = d_S$, where d_A and d_S are the mean distances for additive and subtractive framing, respectively. To verify this, the approach used in $\mathbf{H_1}$ is applied, that is, Monte Carlo simulation of the distance distributions for the two option framing strategies. Concomitantly, to give a deeper understanding of $\mathbf{H_2}$, we would like to test the equivalence of the two distance distributions. The statistical null hypothesis is H_{2Bo}: $D_A = D_S$, where D_A and D_S are the distance distributions of the additive and subtractive framing, respectively. Should the null hypothesis of distribution equivalence be rejected, then $\mathbf{H_2}$ is strongly supported.

In Table 2, the empirical distance distributions are given. The mean values of the distances can be computed from this table. For additive framing, the mean distance is 1.19, while the corresponding value for subtractive framing is 1.25. Thus, the absolute mean difference is 0.06. We wish to verify whether or not this difference is significant.

Table 2
Frequency distributions of distances

Distance	Additive	Subtractive	Combined
0	17	12	29
1	14	21	35
2	17	13	30
3	2	6	8
4	2	0	2
	52	52	104

Applying the Monte Carlo procedure, the absolute value mean difference of 0.06 is found to have an associated probability of 0.732. This implies that we cannot reject the null hypothesis of equivalent mean distances. On the average, the number of decision steps is the same for additive and subtractive framing. The graphical distributions of the distances for the two framing strategies are given in the figure below:



We evaluate the equivalence of the distributions using Pearson's Chi-square test, where distance categories 3 and 4 are combined due to low observed frequencies. The statistic value of 3.1954 ($p=0.3625$) falls below the critical value of 7.8147, implying that the two distributions could be equivalent.

From a general perspective, the results of no difference between mean distances and the equality of the distribution of the distances from the initial point between the two option framings imply that the number of decisions made in the experimental decision process is the same in both framings. However, if the distributions of distances are equal, the two framing strategies will not yield the same final packages. Adding 1 option to the base model in additive framing will not give the same package as eliminating 1 option from the full model in subtractive framing. The results do not support **H_2**. The final state distributions of distances from the initial solar panel packages are not significantly affected by the type of option framing. The equivalence of the final state distributions of distances from the initial solar panel packages suggests that the intensity of avoiding the risk of incurring higher expenses for solar panel options in additive framing is of the same magnitude as avoiding the risk of loss of quality and lesser benefits from extra solar energy options in subtractive framing.

H_3: The distributions of the selected options are different for the two framing strategies.

We would like to compare the resulting frequency distributions of the selected options for the two framing processes. To evaluate this hypothesis, we compare the distributions of options in the final configurations. In this case, we simply differentiate the resulting empirical distributions. Which options stand out in the final selection in the two experimental frames? Does the intensity of selection differ in the two option frames? A simple proportions test is applied for each option, to evaluate the significance of the differences of the percentages of selection for additive and subtractive framing designs. The statistical null hypotheses are H_{30j}: $p_{Aj} = p_{Sj}$, for option j=1,2,3,4, where p_{Aj} and p_{Sj} are the corresponding proportions for option *j* for additive and subtractive framing, respectively. The final tally of selected options for the two framing strategies are given in Table 3. As noted earlier in **H_1**, the average number of options is significantly higher in subtractive framing than additive framing. This mean difference in the two types of framing is also extended to the final aggregated selected options.

Table 3
Selection percentage per option

Option	Additive Framing	Subtractive Framing	*Combined*	*Difference of proportions*
Turnkey (ready-to-use) installation, price SEK 30 000.	26 (50%)	31 (60%)	57 (55%)	Not significant (p=0.3054)
Extended warranty (20-year warranty instead of 10 years as in the basic package), price: SEK 10 000.	14 (27%)	36 (69%)	50 (48%)	Significant (p=0.0000)
Extended charging option for electric cars, price SEK 15 000.	15 (29%)	39 (75%)	54 (52%)	Significant (p=0.0000)
Battery for home storage of electricity (for electricity use in the evening), price SEK 55 000.	7 (13%)	37 (71%)	44 (42%)	Significant (p=0.0000)
n	*52*	*52*	*104*	

In additive framing, the most popular option is *turnkey (ready-to-use) installation*, with 50% of the additive subgroup selecting this option. For the other options, selection percentages are less than 30%, particularly *battery for home storage of electricity*, the most expensive option, where only 13% have chosen this option. The two cheaper options, *extended warranty* and *extended charging option for electric cars*, were respectively selected by 27% and 29% of the additive subgroup. In subtractive framing, we have different intensities of choices, where at least 60% of the subsample selected each option. The most popular option is *extended charging option for electric cars*, where 75% decided to keep this feature. A clear difference compared with the additive framing group is that 71% would like to have the most expensive option, *battery for home storage of electricity*, whereas only 13% in the additive framing group selected this option. The two other options, *extended warranty* and *turnkey (ready-to-use) installation* obtained 69% and 60%, respectively.

The proportions test show that subtractive framing resulted in significantly greater selection percentages for the options: *extended warranty*, *extended charging option for electric cars*, and *battery for home storage of electricity*. Only the option *turnkey (ready-to-use) installation* is not significantly different in both option framing designs. Combining the two experimental groups, roughly 55% of the respondents chose *turnkey (ready-to-use) installation*, the highest over-all selection percentage. The option *turnkey (ready-to-use) installation* appears to be the strongest option in the combined group, and this might be due to critical installation regulations, which require certified technical competence. The stability of the selection proportions in the two framing designs can probably be an indication that *turnkey (ready-to-use) installation* should be a fixed feature in the solar panel package. For the other three options, the disparities of selection proportions posted by additive and subtractive framings are at least 40%. The type of framing influenced how the respondents evaluated these options. A possible explanation is that participants in the additive framing group focused on the effect of incremental costs, while participants in subtractive framing were concerned with the diminishing quality of the solar panel package and decision difficulties in rejecting solar energy technologies. Incremental costs prevented additive framing participants from selecting options, while diminishing quality and future economic and environmental gains hindered deselection in subtractive framing.

H_4: In the choice process, the non-transition probabilities for the initial solar panel packages tend to be larger than the probabilities of transitions to various options from the initial point

At the early stage of the decision process, the respondent makes a decision as to whether or not the initial solar panel package should be modified. As mentioned earlier, in additive framing design, the initial model is simply the basic package, and the modification at this stage is adding any of the four options. On the other hand, the initial point for subtractive framing is the full model, that is, basic plus all of the 4 options. Modification in subtractive framing calls for the deselection of any of the 4 options. Anchoring behavior suggests that respondents tend to maintain or hold on to whatever initial package they have at the first stage. To evaluate hypothesis 4, we compare the movements from the initial models in the Markov chains. Let v_{0j} be the transition probability from initial model *0* to an option or state *j=0,1,2,3,4.* The non-transition probability v_{00} indicates the percentage of respondents who remain at the initial model, not making any transition nor modification.

One way of evaluating hypothesis 4 is by comparing the non-transitional probability v_{00} with the total transition probability $= \sum_{i=1}^{4} v_{0i}$. The cumulative transition probability P is the sum of tendencies of all movements from initial package to any of the 4 states or options. We test the statistical null hypothesis H_{4Ao}: $v_{00} = P$ using the standard $\times^2$ goodness-of-fit test. This null hypothesis assumes that the non-transition movement is equally strong as the combined transitions to the options. A significant inequality further qualifies the intensity of anchoring in the framing scenarios. A $v_{00} > 0.50$, for example, is a rather strong indication of non-transition, which is a clear manifestation of anchoring or holding on to the initial package.

Another way of evaluating **H_4** is by testing the statistical null hypothesis H_{4Bo}: v_{00} = max v_{0j}, where j=1,2,3,4. While the previous test combines all relevant transition movements, H_{4Bo} compares the non-transitional probability v_{00} with the maximum transition probability v_{0j} at the initial point. If the null hypothesis H_{4Bo} is not rejected, then anchoring is equally strong as the maximum transition to an option from the initial package. The null hypothesis H_{4Bo} is tested using the standard $\times^2$ goodness-of-fit test.

In addition to the two statistical hypotheses discussed above, it is of interest to investigate whether the movements at the initial point are uniform. When the non-transitional and transitional probabilities are equivalent, then all possible movements are equally attractive, leading to a diminished anchoring effect. Preferences appear when the movements are not uniform nor equivalent, where some transitions are more pronounced or significantly larger. The chi square goodness-of-fit test is used to evaluate the null hypothesis H_{4Co}: $v_{00} = v_{01} = v_{02} = v_{03} = v_{04}$.

The resulting movements at the initial model is measured by the following transition probabilities and frequencies:

Transition at the Initial State

Movement	**Probability**			**Frequency**		
	Additive	*Subtractive*	*Combined*	*Additive*	*Subtractive*	*Combined*
v_{00}	0,3269	0,2308	0,2788	17	12	29
v_{01}	0,4423	0,2885	0,3654	23	15	38
v_{02}	0,1154	0,1731	0,1442	6	9	15
v_{03}	0,0769	0,1538	0,1154	4	8	12
v_{04}	0,0385	0,1538	0,0962	2	8	10
				52	52	104

As shown in the table, the non-transitional probability v_{00} is the second largest movement in both additive and subtractive framing, as well as in the combined group. Around 33% chose the basic model in additive framing, and roughly 23% chose the full model in subtractive framing, with an aggregated non-transition of 28% for both frames. The non-transitional probability v_{00} is the percentage of the respondents holding on or anchoring to the initial package. A strong support for anchoring behavior is that v_{00} has the largest magnitude at the initial state in both experimental structures. However, the maximum observed transition probability in both framing experiments is v_{01}, the percentage of respondents who add or subtract *turnkey installation*.

The results of the first set of goodness-of-fit tests (H_{4Ao}: $v_{00} = P$) for the three groups, *additive*, *subtractive*, and *combined*, are given below:

Goodness-of-fit tests for non-transition and combined transition

Movement	*Observed frequency*			*Expected frequency*			Ho: Voo & (P = V_{01} to V_{04}) are equal		
	Additive	*Subtractive*	*Combined*	*Additive*	*Subtractive*	*Combined*	*Additive*	*Subtractive*	*Combined*
V_{00}	**17**	**12**	**29**	**26**	**26**	**52**	3,12	7,54	10,17
V_{01} to V_{04}	**35**	**40**	**75**	**26**	**26**	**52**	3,12	7,54	10,17
V_{01}	23	15	38	23	15	38	6,23	15,08	20,35
V_{02}	6	9	15	6	9	15	**0,0126**	**0,0001**	**0,0000**
V_{03}	4	8	12	4	8	12	Reject Ho	Reject Ho	Reject Ho
V_{04}	2	8	10	2	8	10			
	52	52	104	52	52	104			

For these tests, the null hypothesis we wish to evaluate is H_{4Ao}: $v_{00} = P$, where $P = \sum_{i=1}^{4} v_{0i}$, the cumulative transition probability at the initial point. The test statistic follows a chi-square distribution, X^2(df=1). For all the three groups, the non-transition and cumulative transition probabilities are significantly different, with the associated p-values way below 0.05. Although significantly less than P, v_{00} somehow reflects the intensity of holding on to the initial package. For the three groups, the anchoring tendency ranges from 0.23 to 0.33. There is, however, a stronger tendency to move on to other options at the initial point. A majority of the respondents made modifications to the initial solar panel package.

As mentioned earlier, another way of analyzing hypothesis 4 is by testing the statistical null hypothesis H_{4Bo}: $v_{00} = \max v_{0j}$, where j=1,2,3,4. In both frames, the maximum observed transition is v_{01}. The results of the goodness-of-fit tests for H_{4Bo} are as follows, where the test statistic also follows a chi-square distribution, X^2(df=1):

Goodness-of-fit tests for non-transition V_{00} and maximum transition V_{01}

Movement	*Observed frequency*			*Expected frequency*			Ho: Voo & V_{01} are equal		
	Additive	*Subtractive*	*Combined*	*Additive*	*Subtractive*	*Combined*	*Additive*	*Subtractive*	*Combined*
V_{00}	**17**	**12**	**29**	**20**	**14**	**34**	0,45	0,17	0,60
V_{01}	**23**	**15**	**38**	**20**	**14**	**34**	0,45	0,17	0,60
V_{02}	6	9	15	6	9	15	0,90	0,33	1,21
V_{03}	4	8	12	4	8	12	**0,3428**	**0,5637**	**0,2715**
V_{04}	2	8	10	2	8	10	Do not reject Ho	Do not reject Ho	Do not reject Ho
	52	52	104	52	52	104			

In all groups, v_{00} and v_{01} are not significantly different. The tendency to hold on to the initial package is as strong as the movement to the first option, *turnkey (ready-to-use) installation*, whether the framing is additive or subtractive. On the individual level, anchoring is comparably of equal intensity as the maximum transition from the initial solar panel package. The test results for H_{4Ao} and H_{4Bo}, clearly indicate that v_{00} is not dominantly greater than the transition probabilities. At best, the non-transition movement is as intense as the maximum transition to a particular option. The options have affected the movements and decisions in both frames. To investigate whether the movements at the initial points are uniform, a goodness-of-fit test is done on the movements at the initial point, assuming equal frequencies for the 5 possible movements. The test statistic follows a chi-square distribution X^2(df=4). The results for the tests for H_{4Co}: $v_{00} = v_{01} = v_{02} = v_{03} = v_{04}$ are as follows:

Goodness-of-fit test for uniformity of movements at initial point

Movement	***Observed frequency***		***Expected frequency***		**Ho: Voo & Vo_1 are equal**	
	Additive	*Subtractive*	*Additive*	*Subtractive*	*Additive*	*Subtractive*
V_{00}	**17**	**12**	10,4	10,4	4,19	0,25
V_{01}	**23**	**15**	10,4	10,4	15,27	2,03
V_{02}	6	9	10,4	10,4	1,86	0,19
V_{03}	4	8	10,4	10,4	3,94	0,55
V_{04}	2	8	10,4	10,4	6,78	0,55
	52	52	52	52	32,04	3,58
					0,0000	**0,4663**
					Reject Ho	**Do not reject Ho**

Contrasting results are observed for the two option frames. In additive framing, the uniform assumption is rejected, whereas in subtractive framing, the movements can be considered as uniform. This contrast is a possible indication of the difference in decision framework. In additive framing, the respondents are more focused on the incremental price of options. Note, however, that the functional option *turnkey (ready-to-use) installation* is the more popular alternative, which is worth the price increase. This essential option is significantly preferred over the other alternatives. In subtractive framing, the different solar energy options are more or less uniformly attractive to the consumer. Moreover, the non-transition and transition probabilities are equal. This uniformity in subtractive framing movements shows that the solar energy options are perceived more in terms of utilities rather than the more sensitive incremental prices.

At this point, we can say that additive framing leads to behaviour primarily concerned with costs. The respondents only include solar energy products in terms of which ones they feel are absolutely necessary. Whereas, we interpret the subtractive framing decision process as difficulties in deciding over what to reject, concerns over loss of quality, and possibly an emotional response to doing more things for the environment. In this frame, the respondents may exclude those options, which give less loss in the perceived quality of the final package. The different effects on anchoring and transitions can be seen through these types of behaviour.

H_5: The tendency to hold on to the initial solar panel model is stronger in additive framing than subtractive framing.

This hypothesis compares the non-transition probabilities at the initial model for additive and subtractive framing. The effect of incremental costs in additive framing is expected to be more pronounced than the influence of diminishing quality in subtractive framing. If this is the case, then anchoring is relatively stronger in additive framing. A standard comparison of non-transition probabilities will be used to test **H_5**. The statistical null hypothesis H_{5o} : $v_{00(additive)} = v_{00(subtractive)}$ is used for this independent proportions test.

The resulting non-transitional probabilities at the initial point are as follows: $v_{00(additive)}$ =32.7% and $v_{00(subtractive)}$ = 23.1% for additive and subtractive framing, respectively. These observed percentages show that anchoring is slightly stronger in additive than subtractive framing, as we expected. However, using the standard proportions test, the observed difference of the two non-transitional percentages is not significant (p=0.2771). We cannot reject the null hypothesis of equal proportions. The intensity of anchoring is equivalent in both framing designs. This is an obvious advantage for subtractive framing, since holding on to the initial point implies having the full model (with all 4 options) as the final package. With the turnkey installation as an option instead of being included in the basic package, we might expect some effects on the non-transitional probability at the initial point, particularly in additive framing, due to the strict regulations regarding installations and connections to the electrical power system. Most of the consumers do not have the necessary competence to perform this kind of highly regulated installation. This would increase the probability to include this option in both framing situations.

6 Conclusions

This paper set out to answer the research questions on *how consumers make* solar energy-relevant decision-making *when faced with option framing*? We found that consumers tend to select more solar energy technologies in subtractive framing than in additive framing. Additive framing tends to trigger concerns over costs despite concerns over the environment and consumers being in favour of solar energy. We also found that the intensity of the desire to avoid incurring higher expenses in adding more solar energy technologies in additive framing is of similar magnitude as the desire to avoid losses of quality from selecting extra solar energy options in subtractive framing. Our results show that the type of framing influenced how the respondents evaluated solar energy options. Incremental costs prevented additive framing participants from selecting options, while diminishing quality and future economic and environmental gains hindered deselection in subtractive framing. As such, this paper contributes a representation of the cognitive process of energy relevant decision-making, empirical evidence on the potentiality of nudging consumers towards more pro-solar energy transition behavior, and the importance of framing tools in encouraging this behavior.

Moreover, we can say that additive framing leads to respondents only wanting to include solar energy technologies they feel are absolutely necessary. We refer to subtractive framing decision process as some form of difficulties in decision making on which options to reject over concerns over loss of quality. Consumers tend to exclude options leading to less losses in the perceived quality of solar energy technologies. Anchoring is observed in these behaviors and the intensity of which is found to be equivalent in both types of framing decision architectures. As a framing device, this suggests that subtractive framing is an enabler in nudging consumers towards solar energy transition, since holding on to the initial point implies having the full model (with all 4 options) as the final package.

A limitation of this paper is that the choices observed here may not reflect the eventual outcomes and preferences (Neumann & Mehlkop, 2020) but it does capture the behavioral tendencies of consumers when faced with energy relevant decision-making. The implication of these results is that consumers are willing to be nudged to support solar energy technologies and do more for the environment with some even willing to go beyond the basic package in the subtractive framing architecture. The results of this paper also suggests that the type of option framing matters in encouraging consumers to take up solar energy technologies, and that consumers are sensitive to how solar energy products are communicated and are offered. The sustainability and energy transitions literature should account for this when examining the diffusion of technology and how governments articulate programs of support for energy transition programs.

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