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# Public preference of electricity options before and after Fukushima

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The accident at the Fukushima nuclear power plant in spring 2011 spurred Germany and Switzerland to phase out nuclear technology. To ensure future electricity supply, this phase-out requires a strong commitment to accept alternative production technologies and energy strategies. This study examined if and how laypeople's preference for electricity produced by nuclear power and the alternatives in Switzerland has been affected by the Japanese disaster. An online study was conducted in February ($N = 69$) and repeated in June 2011 ($N = 57$), applying the same questionnaire to both samples. The study included a preference rating task involving nuclear, gas, photovoltaics, wind power, and hydropower, and choice-based conjoint tasks. The conjoint tasks contained attributes such as production technologies and price instruments. Participants had to choose their preferred combination of attributes. The results show that laypeople's preference for nuclear power dropped significantly between February and June 2011, whereas their preferences for other technologies changed only marginally. Furthermore, the envisaged mid-term "stepping stones" of gas and electricity imports on the way to renewable energy have been highly unpopular and have remained so after the Fukushima accident. Transitioning from nuclear energy to renewable energy, therefore, will likely be challenging.

**Keywords:** nuclear power; public preference; conjoint analysis

## Introduction

The accident at the Japanese nuclear power plant, Fukushima Daiichi, in March 2011 had a major impact on energy discourse, at least in the German-speaking part of Europe (Siegrist and Visschers 2013). For example, in Switzerland before March 2011, plans existed to replace some of the older nuclear power plants. At the time, many considered nuclear power a long-term viable option. Large-scale power plants, such as nuclear plants, were a core element of the Swiss government's strategy to close the developing electricity supply gap (Oberle et al. 2009). A national vote on the construction of at least one new nuclear power plant was planned for 2013–2014 (Rudolf 2011). A revival of nuclear power was perceived possible (Boersema et al. 2005). However, after the Fukushima accident, the Swiss Federal Council and the parliament decided to phase out nuclear electricity production over the next two to three decades (Bundesrat 2011; Waber 2011).

This decision requires a radical change in the supply and demand of energy in Switzerland and considerable effort and rapid action at all levels of society (Anderson

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et al. 2011a). Until now, 35–40% (about 25 TWh per year) of Swiss electricity production has been nuclear power, while most of the rest is hydropower (55–60%; the remaining 5% are non-hydropower renewable energy, fossil fuels, and commercial waste) (SFOE 2013). During and after the phase-out, a substantial portion of electricity has to be produced by different technologies, efficiency measures need to be implemented, or electricity has to be imported (SFOE 2007; Brugger et al. 2009; Rudolf 2011). In addition, experts do not believe new renewable energy (e.g. photovoltaics [PV]) can be implemented on a large scale within a short or mid-term timeframe – in particular in time to compensate for the phasing-out of the first Swiss nuclear power plants around the year 2020 (Brugger et al. 2009). Unlike, for example, in Germany, PV in Switzerland has increased by a modest 147 MW between 2008 and 2011 (SFOE 2013).[1] Thus, we are in a multiple trade-offs situation: phasing-out nuclear power could imply that combined cycle gas turbines have to be built to supply electricity or that electricity has to be imported from abroad. Gas turbines require reliable gas supplies, while importing electricity requires improvements in the transmission grid infrastructure (Gubser et al. 2005; Oettli et al. 2010). Furthermore, constructing gas turbines may jeopardize Switzerland's climate change objectives (World Wide Fund for Nature 2007; Anderson et al. 2011b). Imported energy may increase electricity prices but could also promote a shift toward renewable energy (Gubser et al. 2005; Oettli et al. 2010; Anderson et al. 2011a).

New renewable energies are generally smaller scale than conventional power plants. Therefore, more installations are required to provide the same amount of energy (Wüstenhagen et al. 2007). Furthermore, of the renewable energies within Switzerland, many have only modest (additional) potential even when a long-term perspective is applied. Hydropower is already used at nearly the limits of what is ecologically feasible (Gubser et al. 2005; SFOE 2007; Oettli et al. 2010). For wind turbines and biomass power plants, the available "resources" are limited to about 4 and 5 TWh per year, respectively (Gubser et al. 2005; SFOE 2007; Oettli et al. 2010). These renewable energies are promising technologies, but on their own, they cannot replace nuclear power in Switzerland. Achieving this would further require strong promotion of PV combined with reduction measures and the optimization of consumption patterns (Meister 2010; Anderson et al. 2011a).

Technological solutions will have to be paralleled with behavioural ones. For instance, as new energy infrastructures will have to be accepted (Wüstenhagen et al. 2007), necessary energy efficiency measures will need to be taken (Oettli et al. 2010). Electricity pricing and thus consumption may need to be "smartened"(smart metering, see, e.g. Gyamfi and Krumdieck 2011), and the adaptation to electricity shortages may have to be addressed (Steg 2008; Gyamfi and Krumdieck 2011). Studies conducted before the Fukushima accident postulated that people in Switzerland would probably be ready to accept the replacement of existing nuclear power plants (Brunner and Farago 2007; Vimentis 2008; Alpiq 2009; Axpo 2010). Previous research has described the majority of such support as "reluctant acceptance" given the lack of preferred alternatives (Pidgeon et al. 2011). Several studies conducted after Fukushima have shown increasing opposition toward nuclear power (Kessides 2012; Mez 2012; Thomas 2012). Interestingly, a longitudinal study examining the stability of laypeople's attitudes regarding nuclear power in Switzerland showed only a moderate negative impact of the Fukushima accident (Siegrist and Visschers 2013). Looking at renewable energies, considerable research has been conducted concerning acceptance of or preference for these technologies (Bergmann et al. 2004; Wüstenhagen et al. 2007; Longo et al. 2008; Luthi and Prassler 2011).

However, most of these studies focused on a single technology or technology type (e.g. renewable) and thus did not tackle the real complexities of combinations of different technologies supplying electricity. These studies are therefore limited in their ability to answer the question of whether the public is aware of these trade-offs. Indeed, nuclear power has been shown as not the least preferred option among respondents who are confronted with multiple technology descriptions and involved trade-offs (Pidgeon et al. 2008; Fleishman et al. 2010). These studies, however, assess preferences for energy portfolios or energy technologies only once and, therefore, cannot show whether preferences are stable over time and how they are affected by such events as a major catastrophe in the field of energy.

Similar to the study by Fleishman et al. (2010), our study picks up the idea of energy portfolios (i.e. a combination of different energy technologies and policies) and their involved trade-offs. However, instead of complete portfolios, our design involved comparing concepts consisting of a combination of energy policies, electricity supply measures, and pricing instruments. This included nuclear and renewable technologies presented in realistic concepts and subsequent trade-offs. Our study also included a two-wave design before and after the accident at the Fukushima nuclear power plant in Japan. We first explore whether the public is aware of the multiple trade-offs situation and is prepared for a radical change in the Swiss energy system. Our second goal is to investigate the potential influence of the Fukushima accident on decision processes regarding the Swiss mid-term energy policy. More specifically, we aim to examine (1) how different energy supply portfolios are perceived, (2) if the Fukushima accident had an effect on these perceptions, and (3) if respondents are aware of the complex trade-off situations and the related necessary decisions that Switzerland faces in the mid-term. Since considering energy supply portfolios instead of single-supply solutions is important (Stirling 2010), we aim to add new insights to the research area of preferences for energy supply portfolios taking into account a potential "Fukushima effect".

We used several research strategies to approach this goal. We used a conjoint analysis to provide participants with complex trade-off situations involving various mid-term energy options for Switzerland. In contrast to classical survey methods in which participants rate different aspects of a decision independently, conjoint analysis combines different facets of a decision situation, and thus forces participants to make trade-off decisions. We also collected answers from direct rating questions on specific aspects of future energy policy. We collected data before and after the Fukushima accident in the same population – a subset of the general population. Thus, we were able to investigate the influence of this event on decisions regarding energy portfolios.

## Method

### *Choice-based conjoint analysis*

Conjoint analysis has been widely applied in psychology and marketing research. The number of studies focusing on electricity is limited, however, though it has increased in recent years (e.g. Álvarez-Farizo and Hanley 2002; Bergmann et al. 2006; Longo et al. 2008; Kwak et al. 2010; Luthi and Prassler 2011). For the present studies, a choice-based conjoint analysis was applied. Choice-based conjoint analysis is a stated preference method and "allows the researcher to measure the relative values of attributes that have been considered jointly by the respondent" (Alriksson and Öberg 2008, p. 244). The analysis' strength is that it provides a more realistic representation of complex situations involving trade-offs compared to single-attribute ratings (Alriksson and Öberg 2008). Since respondents have to evaluate trade-offs, conjoint studies reduce the risks of strategic answering (Auspurg et al. 2009). Respondents choose their preferred option(s), and based on these preferences, the utilities for each attribute level are calculated (Alriksson and Öberg 2008). A potential weakness of choice-based conjoint analysis is that preferences are elicited inefficiently, providing very little information per respondent and thus requiring larger samples for reliable results (Sawtooth 2008). As a minimal requirement, the number of respondents multiplied by the number of tasks and the number of alternatives (concepts), divided by the maximum number of levels, should equal at least 500 (Orme 2010a). The present studies consisted of 10 tasks, with three concepts in each task and three levels per attribute; therefore, at least 50 respondents were required for reliable results.

To analyse the results, counts and multinomial logit and hierarchical Bayes estimations were applied (Sawtooth 2008; Orme 2010b). Multinomial logit is a method for calculating more robust utilities (Sawtooth 2008). These utilities are group utilities and do not indicate individual respondents (Sawtooth 2008). Individual-level utilities can subsequently be estimated using the hierarchical Bayes method. This method estimates an individual's utilities by "borrowing" information from other similar individuals (Howell 2009). The method applies an iterative procedure, carrying out thousands of iterations, with the first few thousand "used to achieve convergence, with successive iterations fitting the data better and better" (Johnson 2000, p. 9).

### *Study design*

The first study was conducted in mid-February 2011 as part of a master's thesis on future Swiss electricity supply (Rudolf 2011). The second study was conducted the following June. Both studies contained rating questions about people's opinion on the construction of new power plants and conjoint tasks. Respondents were provided with a short introductory text to the survey. The text included information on the current composition of Swiss electricity production, the developing electricity supply gap, and the limits of hydropower.

Respondents were asked to indicate their support for the construction of new power plants (hydropower, nuclear, gas, wind, and PV) on seven-point Likert scales ranging from 1 ("strongly against") to 7 ("strongly in favour"). The second study also contained a new question previously not posed about what should be done if, in the mid-term, renewable energies proved insufficient to ensure a sufficient supply of electricity. The following options were proposed:

- importing electricity,
- weakening environmental laws to enable more renewable energies,
- reducing building and heritage protection to enable more renewable energies,
- constructing gas power plants,
- reducing the Swiss population's right to object to renewable energy projects,
- reducing the rights of environmental organizations to oppose renewable energy projects, and
- increasing electricity prices until supply and demand equilibrate.

These options were rated on seven-point Likert scales ranging from 1 ("strongly against") to 7 ("strongly in favour"). The conjoint attributes (Table 1) were developed

Table 1. List of conjoint attributes and level descriptions (translated from German).

| Attributes | Levels |
|---|---|
| New Swiss plants | Construction of one *nuclear power plant*<br>Construction of three *gas power plants*<br>One-seventh of Swiss roof area is equipped with PV |
| Pricing instrument | Smart metering: Electricity tariffs, dependent on total Swiss consumption and calculated hourly, are imposed. During peak demand, the tariff is twice as high as it is today. Every household receives a tariff display<br>Energy taxes: The electricity tariff is supplemented with an energy tax which increases the tariffs by 50%. All revenue from the tax is evenly reimbursed to all inhabitants<br>Freedom of choice: Consumers can choose their electricity product. The most expensive is 2.5 times as expensive as the normal/cheapest electricity product |
| Further strategy | Focus on production: Further production plants are constructed, which produce the same amount of electricity as those above (type: gas, nuclear, PV to be redefined)<br>Focus on consumption: Laws are implemented prescribing strict standards for all electric appliances. Inefficient appliances are banned.<br>Imports: Switzerland satisfies up to 25% of its electricity demand via imports (in particular during times of high demand such as cold winter months) |

based on the results of expert interviews, group discussions, and literature analysis (Rudolf 2011). The attribute "new Swiss plants" consisted of three levels: combined cycle gas turbines, nuclear power plants, and PV. These technologies, the only currently mature and feasible large-scale production options for Switzerland, were also the three options most frequently discussed during the expert, political, and public deliberations, before March 2011, on how to close the supply gap applying a primarily national (and not international) approach. Each option was based on an annual production of 11.2 TWh of electricity. This made the options comparable for respondents (Table 1), though from a technical perspective the three power plant types produce very different qualities of electricity (peak, base, and intermittent/variable, respectively). In the surveys, each option was displayed with a picture of the technology (Figure 1). As the three options represented distinct technologies, it was assumed that respondents had basic knowledge of the technologies' differences. "Pricing instruments" consisted of energy taxes, smart metering, and choice of electricity mix. These instruments were either already implemented in (parts of) Switzerland or undergoing pilot testing (Iten et al. 2003; Degen et al. 2013). The pricing instruments were defined qualitatively to avoid correlations with the technologies applied in "new Swiss plants". Such correlations would have resulted if quantitative instruments (actual price levels) were used and would have required prohibitions. "Strategy" consisted of the three main approaches for closing the supply gap: increasing production, decreasing consumption, and importing electricity. These approaches were necessary as a single option of the first attribute (11.2 TWh) would not be sufficient to close the supply gap. These attributes and levels form the basis for the construction of so-called concepts. Each concept is a combination of one level of each of the three attributes. Respondents were provided a short introductory text explaining the tasks. Afterward, each respondent had to evaluate 10 random tasks and one fixed holdout task. This means that in each task respondents had to choose their preferred option from

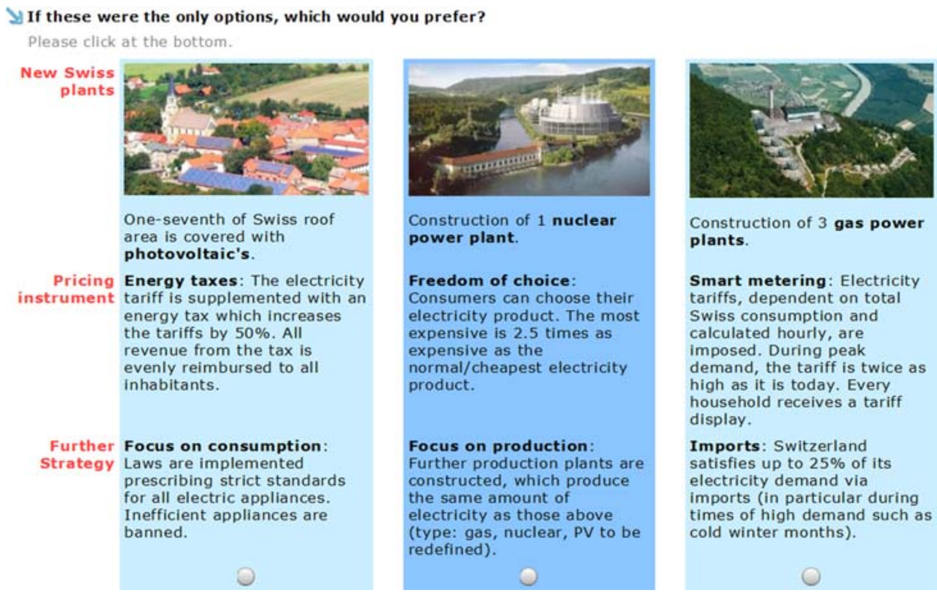


Figure 1. Example of the choice tasks translated from German.

the three options shown (concepts). Figure 1 shows an example of a task. For the 10 random choice tasks, a balanced overlap was chosen as the generation method. A status quo (“none”) option was not offered.

The survey concluded with questions about age, gender, and education. Respondents were also asked to indicate their political position on a 10-point Likert scale ranging from 1 (“completely left”) to 10 (“completely right”).

### *Sample and inherent survey limitations*

The majority of respondents were members of a Swiss orienteering club. They were invited to participate by email. In total, the same 110 people, between 18 and 73 years of age, and consisting of approximately 40 women and 70 men, were invited both times to participate. Response rates were high, with 63% for the first study ($N = 75$, though six did not complete the conjoint tasks) and 52% for the second study ($N = 57$). Although the same people were contacted via email in both studies, the respondents were not entirely identical. In the first study, 52 men and 23 women (self-reported) participated; 44 men and 13 women participated in the second study. The mean age of respondents was 43.9 years in the first survey and 44.9 years in the second survey (Switzerland: 42 years for the age group 18–65). Almost two-thirds ($N = 42$) of the respondents in the first study also participated in the second. In both surveys, the educational levels were high, with university the most common (Study 1: 42.1%; Study 2: 29.8%; Swiss average: 23.7%) (FSO 2013). For both studies, the average political position was close to the centre of the 10-point scale ($M_1 = 4.7$, $SD_1 = 1.9$, $M_2 = 4.5$, $SD_2 = 1.7$). Non-parametric tests showed that the respondents in the two studies did not differ significantly in terms of age, gender, education, or political position.

### *Preparations for data analysis*

Data analysis was carried out using Sawtooth software (SMRT, CBC/HB) and SPSS V.19. This software was used to conduct the studies and, in particular, to use the hierarchical Bayes method to estimate individual-level utilities that were exported to SPSS for analysis. The levels of "political position" were recorded with the levels 1–3 as the political "left" ($n_1 = 23$, $n_2 = 18$), 4–6 the political "centre" ($n_1 = 36$, $n_2 = 29$), and 7–9 the political "right" ($n_1 = 17$, $n_2 = 10$). No respondent indicated "10" as a political position. As the study had not been planned to be repeated, no tracking codes were used in the first study, and the majority of the respondents' IP addresses changed in the time between the two studies. Subsequently, respondent data files from February and June could not be reliably identified as belonging to the same respondent. With only partially overlapping samples, we decided that the two studies would be treated as independent samples, though with strongly overlapping samples. On the plus side, all results derived from independent sampling with overlapping samples are conservative, reducing the possibility of false significant results.

## Results

### *Preference ratings for production technologies and alternatives to renewable energies*

In the direct rating questions, the renewable technologies PV, hydropower, and wind were highly preferred in both studies. Gas and nuclear power initially rated somewhat negatively. Following the Fukushima accident, nuclear power dropped to clearly unfavourable. Only nuclear power was significantly affected by the major nuclear accident at the Fukushima plant ($U = 1500.5$, $z = -3.02$, $p < 0.01$, $r = 0.26$) and dropped one point in preference (Table 2). In contrast to the first study, in which nuclear and gas power were on par, nuclear power was now rated significantly more negatively $H(2) = -2.19$, $p < 0.05$.

In the second study, participants were provided a scenario in which renewable energies are not (yet) sufficient to satisfy demand. The results revealed that only the option "reducing building and heritage protection" received a clearly favourable rating ($M = 4.9$, SD = 1.7). Reducing the rights of environmental organizations ($M = 4.3$, SD = 2.1) and increasing electricity prices ($M = 4.6$, SD = 1.7) were rated as somewhat favourable. The remaining options, reducing the population's right to object ($M = 3.7$, SD = 1.7), weakening environmental laws ($M = 3.7$, SD = 1.9), importing electricity ($M = 3.2$, SD = 1.6), and constructing gas plants ($M = 2.7$, SD = 1.5), were all rated unfavourably.

Table 2. Acceptance of production options (i.e. their construction).

| | Nuclear *M* (SD) | Gas *M* (SD) | PV *M* (SD) | Hydropower *M* (SD) | Wind *M* (SD) |
|---|---|---|---|---|---|
| Study 1 | 3.2 (2.1) | 3.2 (1.4) | 6.3 (1.1) | 5.4 (1.4) | 5.6 (1.5) |
| Study 2 | 2.1 (1.5) | 2.7 (1.4) | 6.5 (0.7) | 5.4 (1.4) | 5.9 (1.2) |
| U | 1500.0 | 1814.0 | 2034.5 | 2118.5 | 1906.0 |
| *z* | −3.02* | −0.87 | −0.53 | −0.09 | −1.12 |

Note: Sample sizes: $N_1 = 69$, $N_2 = 57$ (except for gas, where $N_2 = 56$).
*Significant at the 1% level.

Table 3. Attribute importance and result of non-parametric tests of the conjoint levels between the first study ($N = 69$) and the second study ($N = 57$) using hierarchical Bayes estimations.

| | | New Swiss plants | | | Pricing instruments | | | Strategy | |
|---|---|---|---|---|---|---|---|---|---|
| Importance study 1 | | 0.614 | | | 0.152 | | | 0.234 | |
| H(2) | | 198.4* | | | 4.4 | | | 30.7* | |
| Importance study 2 | | 0.618 | | | 0.100 | | | 0.282 | |
| H(2) | | 336.8* | | | 48.4* | | | 0.6 | |
| | Nuclear | Gas | PV | Smart | Tax | Choice | Production | Consumption | Import |
| Mean study 1 | − 1.6 | − 1.5 | 3.2 | − 0.5 | 0.3 | 0.2 | − 0.2 | 1.3 | − 1.1 |
| Mean study 2 | − 4.6 | − 0.8 | 5.4 | 0.4 | 0.2 | 0.2 | − 0.3 | 2.4 | − 2.1 |
| Mann–Whitney U | 945 | 1598 | 897 | 737 | 1317 | 1317 | 1801 | 737 | 976 |
| *z* | − 5.0* | − 1.8 | − 5.2* | − 6.0* | − 3.2* | − 3.2* | − 0.8 | − 6.0* | − 4.9* |

*Significant at the 1% level.

### ***Conjoint analysis results***

Analysis of counts shows that the attributes' importance remained stable (Table 3). In both studies, "new Swiss plants" was the most important attribute, followed by "further strategy". Distribution of levels was significant for both studies. In contrast, "pricing instruments" was the least important attribute since its levels were non-significantly distributed in both studies.

PV had the highest utility in both studies. Subsequently, all concepts (the combination of one level of each attribute: e.g. PV, smart metering, reducing consumption) containing PV were the most preferred. In the first study, following PV, the concepts that included nuclear power were preferred over those that included gas power. The least preferred concepts were gas power combined with imports. In the second study, this changed. The utility of gas power changed from − 1.5 to − 0.8, while nuclear power decreased from − 1.6 to − 4.6. The concepts including nuclear power and imports were the least preferred

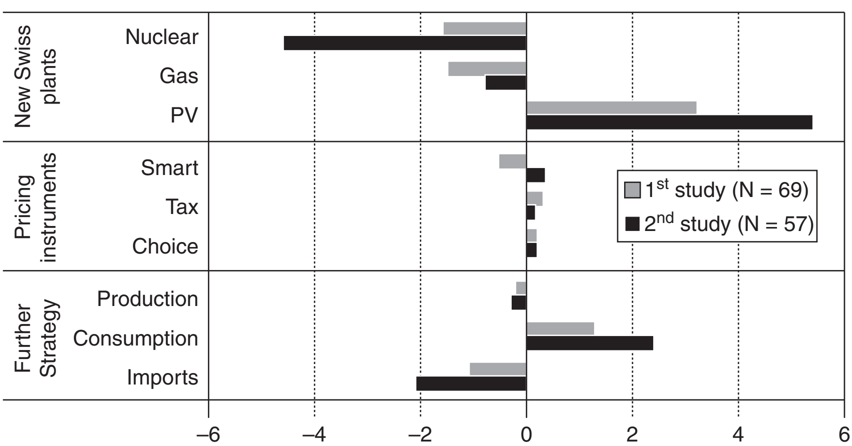


Figure 2. Level utilities for the first study ($N = 69$) and the second study ($N = 57$).

in the second study. Reducing consumption also received stronger support after the Fukushima accident, increasing from 1.3 to 2.4, while imports by design decreased from −1.1 to −2.1 (Figure 2).

Most of the changes were statistically significant (Table 3). The utility of PV increased significantly from the first study ($M = 3.2$, $SD = 2.6$) to the second study ($M = 5.4$, $SD = 2.3$), $U = 897.0$, $z = -5.2$, $p < 0.01$, $r = 0.47$. Nuclear power in turn significantly dropped in preference between the first study ($M = -1.6$, $SD = 3.9$) and the second study ($M = -4.6$, $SD = 3.0$), $U = 945.0$, $z = -5.0$, $p < 0.01$, $r = 0.45$. The changes in gas power preference, however, were non-significant between the first study ($M = -1.5$, $SD = 2.0$) and the second study ($M = -0.8$, $SD = 2.0$), $U = 1598.0$, $z = -1.8$, ns, $r = 0.16$.

Preference for reducing consumption changed significantly from the first study ($M = 1.3$, $SD = 1.0$) to the second study ($M = 2.4$, $SD = 1.0$), $U = 737.0$, $z = -6.0$, $p < 0.01$, $r = 0.54$. Subsequently, acceptance of imports also dropped significantly from the first study ($M = -1.1$, $SD = 0.9$) to the second study ($M = -2.1$, $SD = 1.2$), $U = 976.0$, $z = -4.9$, $p < 0.01$, $r = 0.43$.

### *Changes in preference for nuclear power based on political position*

When grouped by political affiliation, acceptance of nuclear power in the rating questions significantly decreased among the political centre ($n_1 = 36$, $n_2 = 29$), but not among either the political left ($n_1 = 23$, $n_2 = 18$) or the political right ($n_1 = 17$, $n_2 = 10$) from the first to the second study (Table 4). Again, in the conjoint analysis, the political left ($n_1 = 22$, $n_2 = 18$) and the political centre ($n_1 = 34$, $n_2 = 29$) were significantly less opposed to nuclear power in the first conjoint study than in the second study. The political right's preference ($n_1 = 14$, $n_2 = 10$) did not change significantly.

None of the other analysed options showed contrasting results when grouped by gender, educational level, or political position. As an example, support for reducing consumption increased among all respondents regardless of socio-demographic grouping, while support for gas power did not change among any respondents. For the holdout task, the mean absolute error based on the individual holdout ratings and the individual holdout predictions were 1.75 for the first survey and 4.45 for the second survey.

## Discussion

In this study, we investigated the potential influence of the Fukushima accident on decision processes regarding the mid-term energy policy in Switzerland. In particular, we

Table 4. Analysis of political position differences concerning nuclear in both the rating and the conjoint questions between the two studies.

| Nuclear Political position | Rating questions: Left | Rating questions: Centre | Rating questions: Right | Conjoint tasks: Left | Conjoint tasks: Centre | Conjoint tasks: Right |
|---|---|---|---|---|---|---|
| $N_1$ | 23 | 36 | 17 | 22 | 34 | 14 |
| $N_2$ | 18 | 29 | 10 | 18 | 29 | 10 |
| Mean study 1 (SD) | 1.7 (1.6) | 3.5 (2.1) | 3.8 (2.3) | −3.1(3.1) | −1.4 (3.8) | −0.4 (4.4) |
| Mean study 2 (SD) | 1.8 (1.1) | 2.1 (1.3) | 2.9 (2.2) | −5.1(2.5) | −4.9 (2.7) | −2.9 (4.2) |
| Mann–Whitney U | 189 | 314 | 64 | 108 | 189 | 44 |
| $z$ | −0.5 | **−2.8*** | −1.2 | **−2.5**** | **−4.2*** | −1.5 |

*Significant at the 1% level; **significant at the 5% level.

aimed to examine how different energy supply portfolios (Stirling 2010) are perceived and whether the Fukushima accident had an effect on these perceptions. More specifically, we investigated whether the respondents were aware of the complex trade-off situations and the related necessary decisions that Switzerland faces in the period before and during the complete phase-out. The results imply that thus far only one preference has been compellingly changed by the Fukushima accident. The explicit rating questions and the implicit conjoint analysis showed significantly increasing opposition to new nuclear power plants. In the first study, gas and nuclear power were viewed as roughly equally (un) favourable in the rating questions, but when forced to choose between these two in the conjoint questions, the majority of respondents preferred nuclear power. In the second study, the rating for nuclear power dropped significantly below that for gaspower (which remained unaffected). These results correspond to previous surveys following severe nuclear accidents. For example, after Three Mile Island and Chernobyl, surveys showed a significant decline in public support for nuclear power, unless the support was already very low (Melber 1982; Eiser et al. 1989; Renn 1990; Pidgeon et al. 2008). In some cases, support over time slowly increased again.

The political left is the strongest opponent of nuclear power and was so before and after the Fukushima accident. Subsequently, they did not (have to) adjust their position following the major nuclear accident. The political centre shows the most striking change in preference. In the first study, the political centre's opinion on nuclear power was comparable to that of the political right with a slightly less-than-neutral position. An interpretation of this is that these voters were "reluctant acceptors"(see Pidgeon et al. 2008). As such, although not necessarily favouring nuclear power per se, these respondents presumably considered its benefits (or at least its perceived necessity) to outweigh the risks. In addition, on the issue of nuclear waste, survey studies in Switzerland found that a large share of participants was ambivalent about a nuclear waste repository (Stauffacher et al. 2008). This ambivalent group can be characterized as perceiving both high risks and high benefits of nuclear waste (Seidl et al. 2013). It seems that this ambivalent group (cf. also Poortinga and Pidgeon 2006), which corresponds to the political centre's opinion, does not have a polarized opinion regarding nuclear waste and is particularly sensitive to external information when making judgments (Moser et al. 2012). The influence on opinions may depend on the way of communication such as print communications that cover positive and negative aspects nudging peoples' deliberative decisions (Fleishman et al. 2012). Similarly, one could argue that the information about the Fukushima accident had a much stronger negative effect on people with (formerly) ambivalent opinions regarding nuclear power compared to participants with polarized opinions. Following the Fukushima accident, the political centre's opinion is now in line with that of the political left, who are clearly opposed to nuclear power. The political right remains the least opposed to nuclear power, even after the Fukushima accident (though their rating also dropped to "rather against").

No other preferences changed considerably. In both studies, approval of renewable technologies such as hydropower, wind power, and PV was high, while imported electricity and gas power were viewed unfavourably. Also, in both studies PV was the most preferred electricity production option in the ratings and in the conjoint analysis. The significant increase in the conjoint utility of PV following the Fukushima accident should be interpreted as a shift of preferences away from nuclear power and not as an actual increase in PV preference (or gas power, for that matter). Following PV, gas power is now rated significantly higher than nuclear power. However, although the utility of gas power increased considerably, it remained negative and was still less than the utility of nuclear power in the first study.

When presented with a scenario in which renewable energies are insufficient to satisfy demand (the question was asked only in Study 2), respondents were generally unwilling to accept non-renewable alternatives or measures that promote renewable energies but impact on other values. The only options that received weak support were decreasing building and heritage protection and increasing electricity prices. This brings the observed support for measures reducing consumption of the conjoint into perspective and must thus be seen in part as the result of opposition against imports. As various reports have revealed (SFOE 2007; Brugger et al. 2009; Oettli et al. 2010), increasing electricity prices is currently seen as a crucial instrument in decreasing consumption. Although Swiss electricity consumption reached a record high in 2010 with growth rates of around +4% (Scruzzi 2011), electricity prices have been dropping continuously for the past 15 (SFOE 2009). This trend has now been broken in the electricity tariff communications of most of the Swiss electricity suppliers for 2014. However, the electricity bill remains a small expenditure (less than 1% of gross income) in the budget of the average Swiss household (FSO 2012). Beyond general support for renewable energies, respondents remain skeptical to opposed with respect to concrete renewable projects, necessary measures for promoting these projects, non-renewable alternatives (e.g. gas power plants), and imports.

This result implies that respondents view household electricity availability, phase-out, renewable energies promotion, and measures to ensure supply security as basically unrelated entities. In other words, the results suggest that participants are not aware of the complex trade-off situation involved in the coming transformation of the energy system: most participants prefer PV. However, they are not willing to accept solutions to ensure supply security (e.g. imported electricity, construction of gas power plants) that at least in the mid-term must complement Swiss renewable energies until they are sufficiently implemented to meet demand.

The studies have several limitations. First of all, our study could not address the full complexities resulting from real portfolios comprising much more combinations of energy technologies. However, it adds to current literature on electricity options the important element of trade-offs in technology selection by energy users providing few realistic (mature) options. To reduce the full complexity the focus has been on electricity production techniques in a short-to-medium term time frame.

Also, as previously mentioned, the February and June samples could not be matched entirely and thus had to be treated as independent. Moreover, the small sample sizes and the composition of the sample itself do not allow full generalization of the results. The sample contained a disproportionate number of well-educated respondents and men, but relatively few women. The small sample and choice-based conjoint analysis were used because the first sample (February 2011) was not intended as a longitudinal survey but as a pretest for a larger survey to follow. Only after March 2011 was the decision made to conduct a longitudinal survey. For a larger survey, the recommended requirements for the choice-based conjoint analysis are 1000 representations per main-level effect instead of the minimal 500 (Orme 2010a). In addition, for small samples and explorative research such as in this survey, adaptive conjoint analysis and adaptive choice-based conjoint analysis are alternatives to choice-based conjoint analysis (Orme 2010a). However, the results correspond to the current state of the debate. Preferences for renewable production technologies and against nuclear power were very pronounced, significant, and in line with current Swiss political and media debates on electricity production. Another weakness is that the study did not examine how stable the found effects are. In particular, it would be interesting to know more about the participants in the centre of the political spectrum and whether the observed shift regarding nuclear power is stable or will change back to the previous state in a little while.

Based on the response times, the use of pictures for only one attribute facilitated the use of heuristics focusing on the attribute "new Swiss plants". An analysis of the samples (including separate analyses of users of heuristics and non-heuristic participants) revealed that these heuristics were used by 20% of the participants. Although heuristic users had more pronounced preferences (focusing entirely on PV or in a few cases nuclear power), they did not change the general "hierarchy" of preferences in the overall sample.

In general, the applied methods (rating questions and conjoint tasks) have strengths and weaknesses. However, one strength of the present survey is that both methods were applied and revealed similar results, which is a good indicator of general sample validity.

A comparison of the results of the two methods shows that although both measured preference changes, the preference rating is a more conservative instrument for measuring these changes than the conjoint analysis. Since the conjoint method forces respondents to consider trade-offs, these results could subsequently be interpreted as being more robust. With the exception of a very small group of respondents (7% of the sample) who had a very clear first preference for nuclear power that differed from the majority's preference for PV, the analysis showed that the sample was homogenous.

Ultimately, the studies provide an interesting insight into the reactions of a specific group of respondents to a major nuclear accident that occurred in a highly developed country familiar with nuclear technology. In time, it will be of great interest to analyse whether and why such changes in preference are observed in other countries and whether the changes remain stable. It may well be that although some respondents, as in the present studies, changed their preference, others see no reason to do so (e.g. because they were already opposed to nuclear power or because they do not view the events of the Fukushima accident as applicable to their environment). Existing studies already provide examples of this (Kessides 2012; Thomas 2012; Siegrist and Visschers 2013). It would also be valuable to investigate not only if respondents are aware of existing technology trade-offs but also the degree of their awareness and understanding. The energy portfolios of such future studies should also reflect on the changes in the maturity of technologies such as deep geothermal energy and the increasing importance of the transmission and distribution grids.

## Conclusion

The results of the studies imply that Switzerland's decision to phase out nuclear electricity production currently corresponds with the opinions of the population. Notably, the shift of politically centrist voters from an opinion comparable to politically right voters to an opinion comparable to politically left voters implies that in an upcoming (hypothetical) national vote, the majority of voters would object to new nuclear power plants. The results of the current study imply that promoting renewable energies and related instruments will be challenging. From our point of view, two issues in particular thus must be considered.

First, even if the Swiss "Energiestrategie 2050" will undergo a national vote, voting decisions will almost certainly also be made related to the acceptance of single energy technologies, such as (local) voting for or against wind farms, and not related to larger energy portfolios. Thus, the inherent trade-offs do not become visible in public discussions. The dilemma is that respondents preferred (renewable) options that on their own are not yet feasible. Instead, respondents rejected the necessary non-renewable supplementary technologies and were wary once directly confronted with measures necessary for promoting renewable energy. Thus, the respondents appeared to view each technology and measure within its own context and evaluate it without considering it as part of a complex coupled system. This of course mirrors the actual public discourse. However, awareness has to shift to the trade-offs to sensibly discuss the preferences and the feasibility of visions and strategies of future energy supply (Trutnevyte and Stauffacher 2012).

In addition to this need to explicitly address trade-offs in public debates, psychological strategies must be used to change people's behaviour, for example, through information, education, and modelling along with informing them of their consumption (Steg 2008). The aim is to further increase awareness of electricity consumption in general and thus lead citizens to more conscious and economic use of this resource (Anderson et al. 2011a). A second part of this strategy lies in changing the context in which decisions are made to make energy conservation more attractive: better products, changes in infrastructure, changes in pricing policies, and legal measures (Steg 2008).

However, considering the size of the problem, society as a whole has to change. We thus also identify the need to address companies and the public sector. Laypeople, whose opinions were examined in this study, are only one part of society, albeit they form a very important one, regarding the power of vote (especially in Switzerland).

If this is not successful within the next 20 years or so, and Switzerland, by the late 2030s or early 2040s (still), depends on significant amounts of gas power or non-renewable imports, it would signify a failure at the political, economic, and societal level to support renewable technologies and all therewith required measures and technologies. On a larger scale, the same considerations may also apply to the whole of Europe, in particular, given the European Union's objectives to reduce energy consumption and increase efficiency and use of renewable energies. The consequences of this, and the then available alternatives (e.g. geothermal, fourth-generation nuclear power), are at present only in the realm of speculation.

## Note

1. Provisional values published by Swissolar (Swissolar 2014) indicate that PV production has increased by a further 508 MW by the end of 2013.

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