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# Climate change benefits and energy supply benefits as determinants of acceptance of nuclear power stations: Investigating an explanatory model

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ABSTRACT

Several countries are currently discussing whether they will rebuild their nuclear power stations in order to continue this type of energy production in the future. The public, with its own opinion about nuclear power stations, has an influential voice in this discussion. As a result, policy makers and nuclear scientists are interested in the public's perception of nuclear power and in what determines this perception. We therefore examined an explanatory model of the public's acceptance of nuclear power based on a telephone survey among a representative sample in Switzerland. The model included such factors as risk perception, benefit perception, affective feelings, and social trust. Moreover, we distinguished between two types of benefit perception: benefit for the climate and a secure energy supply. The model fitted very well to our data and explained acceptance very well. Acceptance was mainly influenced by perceived benefits for a secure energy supply and, to a lesser extent, both by perceived benefits for the climate and by risk perception. Affective feelings about nuclear power appeared to be a central factor in the model. Implications for communication about nuclear power stations and for further research are discussed.



## 1. Introduction

In the fight against climate change, nuclear power can be seen as one possible mitigation strategy, as this type of energy resource has extremely low carbon dioxide emissions during its life cycle (Dones et al., 2004). Another problem that can be solved by relying on nuclear power is the shortage of energy sources, so that a country can be independent from foreign energy sources. Should fossil fuel reserves become insufficient, other cheap energy sources will be needed to fill this gap (see Roth et al., 2009). Alternative energy sources, such as solar and wind energy, are still unable to produce sufficient energy to meet the world's current needs and are currently still quite expensive.

Although public acceptance of nuclear power stations has increased over the years (European Commission, 2008; Nuclear Energy Institute, 2010), the public appears ambivalent about this issue in many countries (e.g., European Commission, 2007a; Pidgeon et al., 2008; Whitfield et al., 2009). Several countries are currently faced with the question of whether to rebuild their nuclear power stations in the next few decades. Hence, policy makers are consulting the public regarding its opinion of nuclear power. Therefore, in the study reported here, we investigated several determinants of the Swiss public's acceptance of nuclear power stations. We specifically focused on the roles of perceived climate change benefits and of perceived energy supply benefits in the acceptance of nuclear power stations. Both types of benefits are used as arguments to promote nuclear power. However, what has not been studied is to what extent these two notions influence the acceptance of nuclear power stations and what has an influence on the perception of these benefits.

In this paper, we report a survey that investigated a broad model to explain people's acceptance of nuclear power stations. We focus on people's risk and benefit perceptions and on two important determinants of these perceptions, namely affective feelings and trust.

## 2. Context

### 2.1. Nuclear power in Switzerland

Electricity in Switzerland is mainly produced by hydroelectric power stations (55.3%) and nuclear power stations (40%) (Swiss Federal Office of Energy, 2010). The remaining 4.7% is a combination of conventional energy production and renewable energy sources. Currently, five nuclear power reactors are operating in Switzerland, located at four different sites in the German-speaking part of the country: Gösgen, Beznau (two reactors), Mühleberg, and Leibstadt. The first nuclear power station, Beznau I, was put

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into operation in 1969, and the last one, at Leibstadt, was started in 1984 (Swiss Federal Office of Energy, 2009).

Rebuilding nuclear power stations may seem unnecessary in Switzerland, as its topography and its precipitation levels are optimal for hydroelectric power production. However, in view of exhausted technical potentials and the negative impact of hydropower plants on local aquatic ecosystems, the country has reached its limit of large-scale hydroelectric power stations (Swiss Federal Office for Energy, 2009). In order to secure the energy supply, Swiss energy policy focuses on a diversified range of energy sources. It thereby aims to prevent too much dependence on fossil fuels or on energy imports from other countries (Swiss Federal Office of Energy, 2007). Consequently, the development of a larger number of renewable energy resources has been stimulated such that this type of production will increase to comprise 10% of Switzerland's total energy generation by 2035. This increase appears technically realizable but is insufficient to replace the current electricity production by nuclear power stations (Hirschberg et al., 2005). This fact, together with a continuing growth in electricity demand, shows that the country will keep depending largely on nuclear power.

Three of the five nuclear power reactors need to be replaced by the year 2025. As a result, Swiss society has started discussing the future of the country's electricity generation. Three applications to replace the three oldest nuclear power stations have been sent to the Swiss Federal Office of Energy and are currently being examined (Swiss Federal Office of Energy, 2009). The Swiss situation is unique when it comes to approving new nuclear power plants, as the public will have a direct vote in this procedure: it is very likely that a facultative national referendum will be organized regarding the approval of the applications. The opportunity to have a direct voice makes examining the Swiss public's acceptance of nuclear power plants particularly noteworthy.

So far, the acceptance of nuclear power among the Swiss has been comparable to that of other European populations. The majority of the respondents (43%) of a representative sample of the Swiss population appeared to oppose nuclear power in 2007 (Stauffacher et al., 2008). A similar percentage of opposition towards nuclear power was found among people from 27 of the EU member states (45%, European Commission, 2008). However, the number of Europeans in favor of nuclear power was larger (44%) than the number of Swiss in favor (33.9%). There appear to be large differences between the 27 different EU member states with respect to their acceptance of nuclear power. EU countries that are largely dependent on nuclear power, such as Lithuania, Sweden, and the Czech Republic, show higher support for nuclear power than do countries without any or with only a few operating nuclear power stations, such as the Netherlands and Germany.

The number of people who accept nuclear power seems to have increased in Europe during the last few years, whereas the number of Europeans opposed to nuclear power has decreased (European Commission, 2008). The authors of the Eurobarometer report suggested that the debate about $CO_2$ reduction to mitigate climate change contributed to this change in opinion. However, this explanation has not been investigated. The changes in acceptance of nuclear power over time and the current question of whether to rebuild the old nuclear power plants makes worthwhile a thorough examination of people's acceptance of this type of energy production.

### 2.2. Previous studies regarding the acceptance of nuclear power stations

Research related to the public's acceptance of nuclear power stations has mainly focused on single determinants of perception and acceptance, such as beliefs and attitudes (e.g., Midden and Verplanken, 1990; Otway et al., 1978), affect and worldviews (Peters and Slovic, 1996), and knowledge (European Commission, 2007a,b). A few studies examined the acceptance of nuclear power stations only at site-specific locations (Greenberg, 2009b; Parkhill et al., 2010; Venables et al., 2009). Other studies compared people's acceptance of nuclear power to that of other energy sources (Ansolabehere and Konisky, 2009; Greenberg, 2009a).

People's perception of nuclear power was also compared to that of climate change (Bickerstaff et al., 2008; Pidgeon et al., 2008). These studies showed that if people are explicitly shown the benefit of nuclear power to mitigate climate change and are asked to choose between nuclear power stations or climate change, they cautiously prefer nuclear power stations and its waste over the consequences of climate change (also called "reluctant acceptance", see Bickerstaff et al., 2008; Pidgeon et al., 2008).

Recently, several studies examined what determines people's acceptance of and their willingness to take action against or in favor of nuclear power stations. Perception of nuclear risks appeared to reduce the public's acceptance or its preference for nuclear power (Greenberg, 2009a; Tanaka, 2004; Whitfield et al., 2009). Perceived risks of nuclear power also increased people's willingness to oppose this energy source (de Groot and Steg, 2010). More perceived benefits resulted in more acceptance of nuclear power (Tanaka, 2004) and in less willingness to oppose nuclear power (de Groot and Steg, 2010). Moreover, people's trust in nuclear organizations and in their government played an important role in the acceptance of nuclear power stations (Ansolabehere and Konisky, 2009; Greenberg, 2009a; Tanaka, 2004; Whitfield et al., 2009). Factors that were less often examined but seemed to contribute to the acceptance of nuclear power were perceived environmental harm and perceived costs of nuclear power (Ansolabehere and Konisky, 2009). Personal norms have also been found to have an effect on willingness to take action against or in favor of nuclear power (de Groot and Steg, 2010).

### 2.3. Our hypothesized model of public acceptance of nuclear power stations

In this study, we took several of the factors mentioned above and a few additional ones in order to test a broad model that explains the underlying structure of people's *acceptance* of nuclear power stations. Our model is based on general theories regarding the public's perception of new or unknown technologies and on previous research concerning public acceptance of nuclear power stations. To the best of our knowledge, these theories and research findings have not yet been investigated in one model to explain the public's acceptance of nuclear power.

The field of risk perception research provides many relevant insights into the public's acceptance of new or unknown technologies. Since the early 1970s, the question of how people perceive risks and benefits has received much research attention, as scientists and policy makers are interested in explaining why the general public accepts certain hazardous technologies to a greater extent than they do others, such as nuclear weapons compared to nuclear power (e.g., Fischhoff et al., 1978; Slovic, 1987; Starr, 1969). One of the major findings of this research is that laypeople have difficulty understanding the quantitative information of a hazard (e.g., its probability). Rather, they rely on the hazard's qualitative characteristics, such as its controllability or the dreadedness of the hazard's consequences (Slovic, 1987).

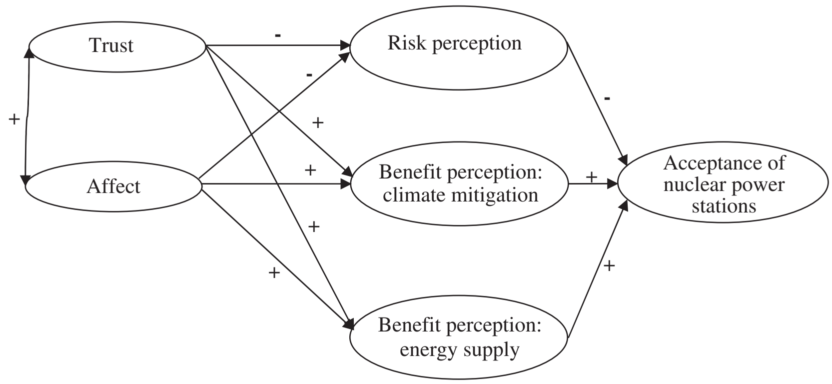


**Fig. 1.** The hypothesized model of laypeople's acceptance of nuclear power.

*Risk perception* and *benefit perception* seem to be two important factors that predict people's acceptance of a technology such as gene technology (Siegrist, 1999, 2000), nanotechnology (Siegrist et al., 2007), and also nuclear power stations (Tanaka, 2004). In most studies, benefit perception appeared to be a stronger predictor of acceptance than did risk perception (but see Tanaka, 2004). Previous studies also indicated that risk perception and benefit perception are negatively correlated (Finucane et al., 2000; Frewer et al., 1998; Wallquist et al., 2010), which is another reason to consider both when explaining people's acceptance of a risk (Siegrist, 1999). We thus assume in our model that both risk and benefit perceptions determine people's acceptance of nuclear power stations (see Fig. 1).

We thereby wanted to make a distinction between two types of benefit perception related to nuclear power. As described above, supporters currently use two arguments to promote nuclear power: (1) it will secure the fulfillment of our energy demands, and (2) it is $CO_2$ neutral and, therefore, an effective mitigation strategy against climate change (see Adamantiades and Kessides, 2009; Bang, 2010; Watson and Scott, 2009). The influence of both arguments on acceptance has not been investigated yet. We will therefore investigate how large the influence of people's *perceived benefits for the climate* is on acceptance and how this influence relates to their *benefit perception of a secure energy supply*.

Additionally, we suggest that risk perception and benefit perception are influenced by *affect*. It is a well-established finding in risk perception research that people's affective feelings about a hazardous event influence risk and benefit perceptions. The so-called "affect heuristic" explains that people assess a hazardous event based on a pool of feelings (Finucane et al., 2000). If these feelings are mainly positive, people see little risk and many benefits as the consequences of an event. Contrarily, if they mostly experience negative feelings related to the event, people perceive few benefits and high risks. Some researchers label affective feelings as general attitudes, e.g., people's general attitude towards nuclear power (cf. Eiser et al., 2002; Poortinga and Pidgeon, 2005; Poortinga and Pidgeon, 2006). Both affective feelings and general attitudes are supposed to influence factors that are more specific, such as risk perception.

Another relevant finding in risk perception research is the role of *social trust* (Earle et al., 2007; Jungermann et al., 1996; Siegrist, 2000). Social trust is defined here as people's reliance on others as a result of expecting beneficial outcomes from them. Thus, people base their social trust on social relations. People do not always have sufficient knowledge about the risks of an event to be able to make an informed decision about it. In these cases, people appear to rely on their social trust in the relevant actors in order to determine their own risk and benefit perceptions (Siegrist, 2000). Laypeople also use social trust as a heuristic to determine risk and benefit perceptions.

Many laypeople report that they feel uninformed about the safety of nuclear power stations (European Commission, 2007b). Therefore, they cannot rely on their knowledge about the past performance of the relevant actors as an indicator of the risks of nuclear power; rather, they focus on their social trust in these actors (Earle et al., 2007). Thus, we included social trust in our model.

Although both affect and trust seem to be important determinants of risk and benefit perceptions, the causal relation between affect and trust has not yet been established; thus, we cannot define its direction in our model (Visschers and Siegrist, 2008). Some argue that affect is a general evaluation that influences people's trust. This is the so-called "causal chain" account (Eiser et al., 2002; Poortinga and Pidgeon, 2006). Trust has been found to influence risk perception (e.g., Jungermann et al., 1996; Siegrist et al., 2000). One could also imagine that social trust is the source of affect. Trust is namely based on similar values (e.g., between a layperson and an authority) (Earle et al., 2007). The evaluation of value similarity results in affective feelings towards this issue, which determines one's risk perception directly. As both suggested causal directions seem plausible, we do not form any hypotheses in our model regarding this issue; rather, we assume that trust and affect are covariates and that both influence risk and benefit perceptions.

## 3. Research aims

In sum, we aimed to investigate two questions in this study. First, we wanted to test our explanatory model of people's acceptance of nuclear power. Based on prior research, we included in this model the constructs of acceptance, risk perception, benefit perception for climate change mitigation, benefit perception for a secure energy supply, affect, and trust (see Fig. 1).

Second, we were interested in examining how perceived benefits of nuclear power for the climate and perceived benefits for a secure energy supply relate to people's acceptance of nuclear power stations. To test these two questions, we conducted a telephone survey among a representative sample of the Swiss population.

## 4. Method

### 4.1. Sample

A professional survey company interviewed, by telephone, 817 (66.8%) inhabitants of the German-speaking part of Switzerland

and 405 (33.2%) inhabitants of the French-speaking part. The total response rate was 26%. The sample was randomly chosen from the Swiss telephone directory. We used quota sampling to obtain a representative sample of the Swiss population. The quotas were set by region (67% from the German-speaking part, 33% from the French-speaking part), gender (50–50%), and age (35% 15–39 years old, 45% 40–64 years old, and 20% 65 years old and up).

The sample's mean age was 49.2 years ($SD=17.2$, ranging between 18 and 92 years), and approximately half of the sample was male (50.2%). Most respondents had finished a vocational school (44.4%), some had finished college or university (29.4%), others had completed higher secondary school (15.5%), and some finished up to primary or lower secondary school (10.6%). Two respondents did not report their education levels.

### 4.2. Questionnaire

The questionnaire consisted of eight constructs in total, and answering all the questions lasted a maximum of 15 min. Six constructs are of interest to the analyses reported here: the acceptance of nuclear power stations, perceived benefits of nuclear power stations for climate change mitigation, perceived benefits for a secure energy supply, risk perception of nuclear power stations, trust in several actors, and affective feelings about nuclear power. In Table 1, the constructs and their items are mentioned, together with their mean scores. Unless reported otherwise, all items were measured on 5-point Likert scales; higher scores indicated higher values of the variables measured.

Affect was measured by two items using the affective imagery method (Peters and Slovic, 1996), a method in which respondents are first asked to mention their spontaneous association with nuclear power stations and then to rate the affective quality of this image on an 11-point Likert scale (ranging from −5: extremely negative to 0: neutral and 5: extremely positive). Respondents were asked to do this twice, thus resulting in two affect ratings.

### 4.3. Procedure

An interviewer personally contacted all respondents over the telephone. The interviewer first explained the topic of the study ("nuclear power") and asked whether the interviewee was willing to participate in a 15 min telephone interview. If the interviewee was unable to do the interview at that moment, an appointment was made for the interview. Those persons contacted who were unable to make a new appointment, who had insufficient German- or French-speaking skills, or who did not answer the telephone after nine calls (because the phone was not answered or for technical reasons, such as dialing a fax number) were excluded from the sample. Persons contacted who were unwilling to participate were registered as non-responders.

First, the interviewer checked whether the respondent fitted into the sample based on the region, age, and gender quotas needed for a representative sample. Then, the questionnaire was assessed. Last, the respondent's education level was requested of them. The interviewer ended the telephone call by thanking the respondent for his/her participation.

### 4.4. Data analysis

Not every respondent of the original sample ($N=1222$) was able to mention two associations and, thus, rate the affective quality of both, which resulted in missing data for the two affect items. In the analyses of this paper, we only included respondents who provided two associations and two affective ratings ($N=967$) because we concluded that replacing these missing values by

**Table 1**
Questionnaire items per scale, including their mean values (and standard deviations) and standardized factor loadings in the final model.

| Items per scale [a] | *M* (*SD*) | Standardized factor loadings |
|---|---|---|
| *Acceptance* | | |
| 1. Switzerland needs a lot of electricity; people should therefore accept nuclear power stations. | 2.81 (1.43) | 0.73 |
| 2. According to me, we can renounce nuclear power stations without any problems[b]. | 3.31 (1.44) | 0.64 |
| 3. We need nuclear power stations because renewable energy sources alone do not produce sufficient electricity. | 3.29 (1.36) | 0.76 |
| *Benefit perception for climate mitigation* | | |
| 4. The increased adoption of renewable energy resources, such as solar and wind power, will reduce climate change more than nuclear power stations[b]. | 1.92 (1.10) | 0.68 |
| 5. The reduction of electricity use by the public, for instance using more efficient appliances, can reduce climate change much better than nuclear power[b]. | 2.20 (1.16) | 0.70 |
| *Benefit perception for secure energy supply* | | |
| 6. Nuclear power stations protect Switzerland from an electricity bottleneck. | 3.44 (1.25) | 0.70 |
| 7. Industry would still have a secured energy supply without nuclear power stations[b]. | 3.38 (1.28) | 0.64 |
| 8. The standard of living would decrease in Switzerland without nuclear power stations. | 3.03 (1.36) | 0.65 |
| *Risk perception* | | |
| 9. The accident risks in Swiss nuclear power stations are small[b]. | 2.35 (1.12) | 0.82 |
| 10. Swiss nuclear power stations are safe[b]. | 2.36 (1.10) | 0.82 |
| *Trust* | | |
| 11. …in the operators of nuclear power stations | 3.07 (1.22) | 0.85 |
| 12. …in the inspecting authorities of nuclear power stations | 3.53 (1.06) | 0.74 |
| 13. …in scientists in the field of nuclear power | 3.58 (1.08) | 0.74 |
| 14. …in the Swiss Federal Office of Energy | 3.38 (0.98) | 0.57 |
| *Affect* | | |
| 15. If you think of (image 1), does this evoke a negative feeling or, rather, a positive feeling for you? | −0.77 (3.52) | 0.61 |
| 16. If you think of (image 2), does this evoke a negative feeling or, rather, a positive feeling for you? | −1.09 (3.47) | 0.55 |

[a] All items were measured on 5-point Likert scales, with increasing scores indicating higher values on the item, except for items 15 and 16, which were assessed on 11-point Likert scales, ranging from −5 (very negative) to 0 (neutral) and to 5 (very positive).
[b] Item was recoded.

estimating them from the affect ratings of other respondents' mental images would be unreliable.

One hundred and twenty-eight respondents (13.24%) did not answer all of the remaining survey questions (items 1–14 in Table 1). In this group of respondents with missing data, the most frequent number of missing values was two (3.83% of the sample) or three (4.03% of the sample). We used the Expectation-Maximization (EM) algorithm—based on the maximum likelihood approach—in SPSS 16.0 in order to replace missing values. The values of the variables of related constructs were used to estimate the missing values.

Next, we tested the model presented in Fig. 1 by means of structural equation modeling (SEM). SEM is a statistical analysis procedure that tests how well a hypothesized model fits to a dataset. It combines confirmatory factor analysis, used to validate the measurement of the latent constructs, with regression analysis, used to investigate the paths between the latent constructs. Besides its valuable combination, we used SEM because it can simultaneously examine several structural relations between latent constructs. Parameters were estimated using the maximum likelihood method in the Analysis of Moment Structures program (AMOS) version 18.0. See the Appendix for more information about SEM, its criteria, and AMOS.

We first conducted a confirmatory factor analysis to check the quality of the construct scales. All factor loadings ($\lambda$'s) were substantial ($\lambda$'s $> 0.47$) and significant, as the critical ratios of all variables (i.e., the variable estimate divided by its standard error) were larger than 1.96 ($p$'s $< 0.05$). The items thus represented their construct well enough to be included in our model.

Because we included only two items for the affect construct, the risk perception construct and the benefit perception for climate mitigation construct in the path model, we defined constrained parameters for the error values of the two variables of each construct so that only one error value needed to be estimated per construct. Our sample was relatively large, so significant chi-square tests were insufficient for assessing the goodness-of-fit of the model. Therefore, we used the comparative fit index (CFI), the standardized root mean square residual (SRMR), and the root mean square error of approximation (RMSEA) as criteria for our model (see the Appendix and Hu and Bentler, 1999). Additionally, we looked at the theoretical background of the model as a criterion for the fit of the model (Iacobucci, 2009).

We first tested the model presented in Fig. 1, which was based on the theoretical background outlined above and on findings from previous studies. To see whether the model could be improved by including other relations between the constructs, we considered the theoretical background and the modification indices (MIs) with their respective expected parameter change (EPC). We used the difference in $\chi^2$ to test the improvement of the new model.

## 5. Results

### 5.1. Descriptives of the constructs

We first looked at the descriptives of the constructs' acceptance, risk perception, benefit perception for climate change mitigation, benefit perception for energy supply, affect, and trust (see Table 1 for the means and standard deviations of the individual items). Respondents' mean acceptance of nuclear power stations lay around the midpoint of the five-point Likert scales ($M=3.14$, $SD=1.15$). The construct had an unimodal distribution ($Mode=3.33$), which justified treating acceptance as a continuous variable rather than examining acceptance in categories (e.g., opposed–neutral–in favor). Respondents reported similar moderate levels of perceived benefits for a secure energy supply ($M=3.29$, $SD=1.05$) and of trust in the four actors ($M=3.39$, $SD=0.88$). Their perceived risk of nuclear power stations was a bit lower than the midpoint of the scale ($M=2.36$, $SD=1.02$), as was their perceived benefit for climate change mitigation ($M=2.06$, $SD=0.97$). The average affective rating of the nuclear power station images appeared slightly negative ($M=-0.93$, $SD=2.87$, measured on a scale ranging from $-5$ to 5).

### 5.2. Structural equation models of the suggested models

The model presented in Fig. 1 proved to have an acceptable fit ($\chi^2(97)=311.57$, $p=0.0001$, CFI$=0.963$, SRMR$=0.039$, RMSEA$=0.048$). Moreover, the standardized regression weights of all but one of the tested parameters were significant and in the expected directions ($p$'s $< 0.01$); the effect of trust on perceived benefit for the climate was not significant ($\beta=-0.12$, $p=0.19$). Last, the squared multiple correlations (SMCs) were moderate to substantial for all constructs ($0.44 < \text{SMCs} < 0.85$). Risk perception, benefit perception for climate mitigation, and benefit perception for a secure energy supply explained 85% of the variance in acceptance of nuclear power stations. Benefit perception for energy supply had the most influence ($\beta=0.72$) on acceptance of nuclear power stations, whereas benefit perception for climate mitigation ($\beta=0.17$) and risk perception ($\beta=-0.18$) had smaller effects on acceptance. Affect had large influences on both benefit perceptions ($\beta$'s $> 0.61$) and had a reasonable influence on risk perception ($\beta=-0.28$). Last, trust appeared to determine a large part of the respondents' risk perception ($\beta=-0.54$) but only a small part of their benefit perception for a secure energy supply ($\beta=0.19$). Trust and affective feelings were strongly correlated ($\beta=0.71$).

Because the path between trust and perceived benefit for the climate was non-significant in the initial model, we decided to delete this path. Conceptually, this also made sense because the respondents may not associate these actors with environment or climate protection but rather with energy production, development, or policy. Although this again resulted in a model with an acceptable fit ($\chi^2(98)=313.48$, $p=0.0001$, CFI$=0.962$, SRMR$=0.040$, RMSEA$=0.048$), the deletion of the path between trust and benefit for the climate did not reduce the fit of our model ($\Delta\chi^2(1)=1.91$, $p=0.20$).

Next, we looked at the modification indices (MIs) to find correlations between the error terms of the items in the model. A high MI for a correlation between two error terms could indicate that the two items related to these error terms had overlapping contents, which would justify relaxing this correlation in our model. We indeed found that the inclusion of the correlations between the error terms of items 13 and 14, between those of items 12 and 14, between those of items 11 and 13, and between those of items 7 and 8 would result in a substantial improvement of the model fit.

Items 13 and 14 assessed trust in nuclear energy scientists and trust in the Federal Office for Energy, which are two independent actors. Respondents may therefore have perceived them as similar. Items 12 and 14 focused on regulatory agencies: the inspecting authorities of nuclear power stations and the Federal Office for Energy. This may have resulted in an overlapping interpretation of the two items, which explains the presence of their correlation in our model. Items 11 and 13, trust in nuclear power stations and in scientists, have in common that both actors are experts in nuclear science, which may have resulted in overlapping trust estimations. Items 7 and 8 assessed people's perception of the benefit of nuclear power for the Swiss economy.

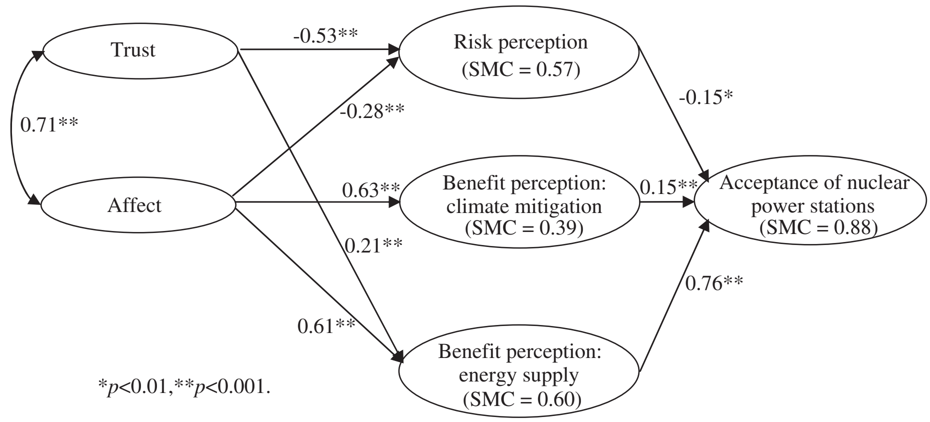


**Fig. 2.** Results from the structural equation modeling procedure for the final model; values indicate standardized regression weights and standardized multiple correlations (SMCs).

Because of this similarity, relaxing the correlation between these two error terms seemed sensible.

The addition of the correlations between these error terms improved our model fit ($\chi^2(94)=237.16$, $p=0.0001$, CFI=0.975, SRMR=0.034, RMSEA=0.040), which was found to be statistically significant ($\Delta\chi^2(4)=75.52$, $p=0.001$). All paths were significant ($p$'s $< 0.005$), in the predicted direction, and of similar strength to those of our initial model. The final model is presented in Fig. 2. Table 1 presents the standardized factor loadings of each item on its construct in the final model.

In sum, our respondents' acceptance of nuclear power stations was mainly determined by the perceived benefit for a secure energy supply. Apart from the deletion of the path between trust and perceived benefit for the climate, our final model was similar to our hypothesized model.

## 6. Discussion

### 6.1. Overview

This study aimed at testing a broad model that may explain people's acceptance of nuclear power stations. In previous research, several constructs had been suggested and examined regarding what factors influence people's acceptance of complex technologies, but a model based on risk and benefit perceptions and their determinants, affect and trust, had not yet been investigated. We distinguished between two types of benefit perception in our model: perceived benefit for a secure energy supply and perceived benefit for the climate. Additionally, we investigated the roles of trust and affect in relation to risk perception and benefit perception.

Our model explains our data very well, suggesting that various constructs should be considered to explain people's acceptance of nuclear power stations. These constructs should include not only people's perceived benefit and perceived risk of nuclear power stations but also their affective feelings related to this topic and their trust in various actors. We do not assume that our model can perfectly explain people's acceptance of nuclear power stations, let alone of any other unfamiliar or complex technology. However, we based the constructs and the relations between them on well-known theories and on results from previous studies. Our data confirm that this theoretical and empirical background can explain the acceptance of nuclear power stations very well. Nevertheless, there may be other relevant constructs that we did not include in our model. Examples of additional constructs could be people's values (Whitfield et al., 2009), their personal norms (de Groot and Steg, 2010), or their knowledge and beliefs about nuclear power (Midden and Verplanken, 1990).

### 6.2. Benefit perception and risk perception

Our findings showed that acceptance of nuclear power stations was mostly influenced by people's benefit perception for a secure energy supply and, to a much smaller extent, by their benefit perception for climate mitigation or by their risk perception. Several studies already indicated that benefit perception appears to be more important for the acceptance of a hazard than is risk perception (Siegrist, 1999, 2000; Siegrist et al., 2007). Thus, people attribute more significance to the benefits of a hazardous technology than to its risks when determining their acceptance of it.

Interestingly, our results showed that regarding their acceptance of this type of power station, people considered the advantages of nuclear power for the climate to be less important than its advantages for a secure energy supply. Although nuclear power stations are often promoted as producing no $CO_2$, the public does not seem to consider this an important argument in support of nuclear power stations. Previous studies reported that people reluctantly accepted nuclear power stations to mitigate climate change when they were explicitly asked to choose between two "evils": climate change or nuclear power stations (Bickerstaff et al., 2008; Pidgeon et al., 2008). The majority of participants in these studies, however, indicated a preference for renewable energy sources over nuclear power.

It may not come as a surprise that with respect to nuclear power stations, people place more value on energy supply benefits than on climate benefits. Specifically, people notice energy benefits directly: they receive electricity and heating in their houses. Climate benefits, on the other hand, are not noticed immediately. Thus, a secure energy supply is personally relevant, whereas climate change reduction is not (Lorenzoni and Pidgeon, 2006). Furthermore, to mitigate climate change, the public knows that it is not enough when one country, let alone one individual, switches to power generation by nuclear power stations and other $CO_2$-neutral energy sources. Individual members of the public think that this abstract problem has a global cause and, therefore, requires actions that are more global, so they easily pass off their responsibility to others (Leiserowitz, 2006).

### 6.3. Relation trust, affect, and risk perception

In addition, the results of this study revealed the important roles of trust and affect on risk and benefit perceptions, which has seldom been studied (Visschers and Siegrist, 2008). Our results indicated that both trust and affect can influence risk and benefit perceptions. The relation between the two constructs appeared to be strong. We did not hypothesize a certain direction between affect and trust because previous studies indicated that both directions were possible. For instance, trust can be a precursor of affect, because a change in people's trust in a social relation evokes feelings (e.g., a violation of trust induces anger), which then influences people's attitudes. Alternatively, affect may be a general positive–negative evaluation and, therefore, first influences people's trust before it can determine their risk and benefit perceptions (e.g., Eiser et al., 2002; Poortinga and Pidgeon, 2006).

An experimental study is needed to investigate the exact causal relation between trust, affect, and risk perception. In such a study, the effects of variations in trust should be assessed with regard to people's affective and risk evaluations. Similarly, the influence of variations in affect should be measured on trust and on risk evaluations.

Our results suggested that affect might be more important than trust for explaining people's acceptance of nuclear power stations. Affect namely influenced risk perception and both benefit perceptions, whereas trust only influenced risk perception and perceived benefit for a secure energy supply. Moreover, affect had a stronger influence on these constructs than did trust.

The important role of affect in people's acceptance of this type of power station corresponds with the idea that emotions have a direct impact on risk evaluations (Loewenstein et al., 2001). It is also in line with the finding that a hazard's dreadedness is an important determinant of people's risk perception (Dohle et al., 2010; Fischhoff et al., 1978), and that affect has a strong inverse relation to risk and benefit perceptions (Finucane et al., 2000).

Our finding that trust had a direct influence on risk perception confirms the assumption that people use their evaluation of social relations as a proxy for their knowledge about the safety of a technology, such as its risks (Earle et al., 2007). If people do not feel knowledgeable about an issue, they use, instead, their trust evaluation of the relevant actors in order to form an opinion about the issue. In this study, trust probably had no or only a small direct effect on benefit perceptions because the actors we included in our trust construct are irrelevant with regard to the perceived benefits for the climate and for Switzerland's energy supply.

### 6.4. Limitations

As mentioned above, we acknowledge that we may not have considered all relevant psychological determinants in our model to explain people's acceptance of rebuilding nuclear power stations. The relatively low squared multiple correlation (SMC) of the benefit perception for climate, for example, indicates that determinants other than affect and trust may influence this concept. Awareness of climate change and personal values related to economical welfare could be relevant for explaining this type of perceived benefit.

One could also argue that knowledge about nuclear power should have been included in our model. Some scholars suggest that knowledge determines people's reliance on affect and trust (i.e., the affect heuristic) (Slovic et al., 2004). People with little knowledge about a hazard are believed to rely on affect and trust to determine their risk and benefit perceptions, whereas people that are more knowledgeable will use an analytical approach to evaluate a hazard or new technology and, hence, neglect their trust and affective feelings. The role of knowledge in respect to affect, trust, risk perception, benefit perception, and acceptance has not been found to be straightforward, however. For example, a study that included knowledge to explain laypeople's acceptance of a biotechnology showed no effect of this determinant on acceptance and showed only small effects on risk and benefits perceptions (Connor and Siegrist, 2010). Moreover, it has been found that the less knowledge people have about a hazard, the more they rely on trust when forming their risk and benefit perceptions (Siegrist and Cvetkovich, 2000). As laypeople indicated that they have little knowledge about nuclear power stations in previous studies (European Commission, 2007b; Siegrist and Cvetkovich, 2000), this seems to imply that they rely on affect and trust when evaluating this issue so that their knowledge can be ignored. Accordingly, we did not consider knowledge in this study.

Another determinant that could have been included in our model is values. Previous studies, for example, revealed that traditional and altruistic values have significant, but small influences on people's acceptance of nuclear power (Whitfield et al., 2009). It may be that these values have a big influence on people's trust and their affective feelings and, thus, have an indirect effect on acceptance. Moreover, other values that are more closely related to nuclear power stations may be important for explaining affect, such as values related to technological progress or to interference with nature.

A reason for the smaller influence of trust on risk and benefits perceptions than of affect in our model may be that our trust construct included only a few specific actors: respondents were asked to evaluate their trust in operators, inspecting authorities, scientists, and the Swiss Federal Office of Energy. Respondents who were unfamiliar with one or some of these actors may have had difficulty evaluating their trust. However, if we had used broader-formulated items to measure social trust related to nuclear power stations (e.g., "I rely on the authorities involved in nuclear power production"), we would not have known which actor or actors the respondents had in mind when answering, which would have resulted in large variances in these items.

We focused our study on the topic of rebuilding nuclear power stations because this is currently an issue in Switzerland and in many other countries. This made a detailed investigation of people's acceptance of this particular issue relevant. Therefore, we did not ask our sample about its views concerning other energy sources, such as views regarding their risk and benefit perceptions of expanding hydroelectric power or of building fossil fuel power stations in Switzerland. Additionally, the risk perception construct concentrated on accidents in nuclear power stations and did not cover other risks, such as that of radioactive waste. Including other energy sources and other risk items in our survey could have given our results a different perspective. Both limitations should be dealt with in further research.

### 6.5. Implications for communication and for further research

Although our model may not be comprehensive, based on our findings we tentatively suggest a few implications for communicating to the public on the subject of rebuilding nuclear power stations. Our model showed that people's perceived benefit for a secure energy supply might have the largest direct impact on their acceptance of nuclear power stations. Hence, the acknowledgement of a secure energy supply is likely to increase acceptance, whereas contesting its advantages for our energy supply will reduce acceptance.

The finding that the perceived benefit for climate change mitigation seems to play a relatively small role needs further investigation. It is important to find out why this may be the case: do people consider climate change irrelevant to their lives or do they think climate change has causes other than $CO_2$ emissions? By exploring the underlying mental models related to climate change and nuclear power stations (Bostrom et al., 1994), communicators can develop material that tackles possible misconceptions or that emphasizes existing correct beliefs regarding the relationship between these issues in order to promote the acceptance of nuclear power stations.

Although the influence of risk perception on acceptance appeared relatively small, it should not be neglected in communication. This is especially true for supporters of nuclear power stations, whose opinions are less stable than those of opponents and who are, therefore, more easily affected by negative information about this issue (Midden and Verplanken, 1990).

The central role of affect implies that communicating positive images about nuclear power is likely to result in more perceived benefit and more acceptance of nuclear power stations. Similarly, distributing negative affective images about this issue will slightly increase risk perception and reduce acceptance of nuclear power stations.

Several researchers suggested that risk perception research should focus on specific emotions and how these influence the perception and acceptance of hazardous events rather than concentrate on general affect (Böhm, 2003; Pfister and Böhm, 2008). Different emotional responses (e.g., anger vs. fear) to a hazardous event can result in different attitudinal and behavioral responses. Knowing what kind of emotional response an environmental problem evokes may thus facilitate better communication with the public. More research is needed to investigate the kinds of emotions nuclear power stations induce and how these emotions relate to subsequent attitudes and behaviors.

The last recommendation for developing communication about nuclear power stations is related to trust in the involved actors. Trust appeared to have an important influence on people's acceptance of nuclear power stations, mainly through its effect on risk perception. Thus, presenting trustworthy actors to the public seems important for decreasing risk perception and increasing acceptance. Trustworthy actors appear to be those who have values similar to the values of the public (Earle et al., 2007). To facilitate communication with the public, it is recommended that communicators examine whether the values of the involved actors are similar to those of the public.

To sum up, our study revealed the relative importance of and the relations between several constructs that explain people's acceptance of nuclear power stations. We may not have included all relevant determinants of acceptance in our model. Based on our findings, we can suggest focusing on the benefit for a secure energy supply and, to a lesser extent, on the benefit for the climate and on risk perception when communicating with the public about nuclear power stations. More research is however needed to verify and extend our explanatory model. Moreover, we still need to find out how each of these factors can be addressed in communication and how the combination of these factors in communication shapes the public's acceptance of nuclear power stations.

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## Appendix. Structural equation modeling (SEM)

Structural equation modeling (SEM) is a statistical analysis method applied to covariance data to test a hypothesized model of various observed and/or unobserved variables. An unobserved or latent construct consists of several observed variables. SEM can analyze multiple structural equations of causal relations simultaneously in an attempt to fit them to the data (Byrne, 2001). One of the advantages of SEM over multiple linear regressions is that SEM can also analyze mediation effects. SEM always starts with the development of a theoretical model. The model is then fit to the dataset using, for example, the computer program Analysis of Moment Structures (AMOS).

Several indicators can be used to qualify the results of SEM. The main statistical outcome is the chi-square statistic, which tests the hypothesis that the observed covariance matrix and the reproduced covariance matrix based on the tested model are different (i.e., the lower the value, the better the fit). Because the chi-square statistic is very sensitive to sample size, other goodness-of-fit statistics have been developed. We relied on the standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), and the comparative fit index (CFI) (Hu and Bentler, 1999; Iacobucci, 2010). All three statistics have values between 0 and 1. A large SRMR indicates a poorly fitting model, whereas an SRMR close to 0.09 signifies a well-fitting model to the data. For the RMSEA, a value equal to or smaller than 0.05 indicates a close fit. A CFI value equal to or over 0.95 indicates a good fit. All these fit indices are descriptive; they are not based on inferential statistics but on rules of thumb to determine the goodness-of-fit.

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