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Perceived Risk and Benefit of Nuclear Waste Repositories: Four Opinion Clusters

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Local public resistance can block the site-selection process, construction, and operation of nuclear waste repositories. Social science has established that the perception of risks and benefits, trust in authorities, and opinion on nuclear energy play important roles in acceptance. In particular, risk and benefit evaluations seem critical for opinion formation. However, risks and benefits have rarely been studied independently and, most often, the focus has been on the two most salient groups of proponents and opponents. The aim of this exploratory study is to examine the often-neglected majority of people holding ambivalent or indifferent opinions. We used cluster analysis to examine the sample ($N = 500$, mailed survey in German-speaking Switzerland) in terms of patterns of risk and benefit perception. We reveal four significantly different and plausible clusters: one cluster with high-benefit ratings in favor of a repository and one cluster with high-risk ratings opposing it; a third cluster shows ambivalence, with high ratings on both risk and benefit scales and moderate opposition, whereas a fourth cluster seems indifferent, rating risks and benefits only moderately compared to the ambivalent cluster. We conclude that a closer look at the often neglected but considerable number of people with ambivalent or indifferent opinions is necessary. Although the extreme factions of the public will most probably not change their opinion, we do not yet know how the opinion of the ambivalent and indifferent clusters might develop over time.

KEY WORDS: Ambivalence; nuclear waste; opinion; risk and benefit perception

1. INTRODUCTION

Many countries have decided to phase out nuclear energy or to postpone or cancel plans to build new plants (e.g., Belgium, Germany, the Netherlands, and Switzerland).[1] Still, nuclear waste accumulates, posing a latent threat to humans and the environment and making the issue of nuclear waste disposal relevant and urgent.[1,2] However, so far, nowhere has an actual repository for the long-term storage of high-level radioactive waste been built. The most advanced attempts have been made in Finland (Olkiluoto)[3] and Sweden (Östhammar).[4] One reason for this lack of operating facilities is that projects for high-level nuclear waste repositories have faced strong local resistance. It has been recognized that public involvement is important.[5–7]

Existing studies within a social scientific tradition in nuclear waste research[8] are often concerned with opinions about one or more specific sites or regions and investigate risk perception and/or acceptance of repositories by local residents.[9–12,6] In general, risk and benefit[2] perception is seen as most

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[1]See also http://www.iaea.org/newscenter/news/2011/nuclgrowth.html, retrieved 17.08.2012.

[2]Here and in the remainder of the article, we understand risk as denoting the negative and benefit as the positive aspects of a risk situation.

essential for the acceptance of contested infrastructure,[10,13] and affective response to the topic at hand influences both benefit and risk perception. The two variables tend to be inversely related due to affective influence.[14] Furthermore, trust and confidence have been found to provide considerable explanatory power concerning the acceptance of repositories for nuclear waste:[15–17] the higher both general trust and trust in institutions, the lower the perception of risk, especially of technological risk.[18]

From a methodological perspective, the use of single opinion[3] scales with a clear focus on two opposing positions prevails. The middle faction is either conflated with one of the two extreme groups or even left out of further analysis.[19] In a recent study on nuclear energy and nuclear energy plants by DeGroot and Steg[20] the opponent group "included all respondents who were either opposing nuclear energy (N = 29, 24.0%) or were indecisive about nuclear energy (N = 20, 16.5%)" (p. 1366). A second group comprised "all participants who indicated they were in favor of nuclear energy" (p. 1366). Thus, two opposing groups (*proponents* and *opponents*) were created from the sample. In a study by van der Pligt[21] the participants were asked to state their opinion on nuclear energy, resulting in the establishment of three groups: pro – neutral – anti. The further analysis of the results focused on the two extreme groups, however. This focus on extreme opinions is highly understandable,[22,23] as one typically finds that those who are strongly against a repository perceive more risks, whereas supporters perceive relatively more potential benefits.[9]

Nuclear waste is clearly a controversial issue triggering extreme opinions. But, in contrast, there is evidence from social psychological literature on opinion formation that people can actually hold ambivalent opinions about an object or topic. That is, they show relatively strong positive *and* negative beliefs toward the object at the same time.[24–27] Ambivalence must be distinguished from indifference. For instance, people often tend to be indifferent about political topics that lack concrete and personal relevance.[28,29] Generally, a person can be described as indifferent if he or she shows both relatively low positive *and* negative evaluations of a specific object.[30] However, using a simple one-dimensional opinion scale one cannot distinguish between, for instance, ambivalent people marking the middle position (or a rather moderate position in the case of an even number of answer categories) and actual "middle of the road" opinion. Measuring more dimensions separately may therefore improve insights into opinion characteristics. In previous studies in Switzerland,[31,32] we found people arguing that the problem of nuclear waste disposal must be solved in Switzerland and that it should not be exported to other countries. We found a majority of people still undecided, holding ambivalent opinions (giving high ratings to both the risk and benefit perception items), and so we concluded that it is important to measure both risk and benefit perceptions independently.

Concerning the perception of nuclear waste, there is a focus in research on *risk* perception, denoted as potentially negative outcomes. Perceived *benefits* of a nuclear waste repository are not as obvious as, for instance, positive aspects of nuclear power plants (such as relatively cheap electricity for households, businesses, and industries, and arguably low CO_2 emissions). This might be a reason why perception of benefits of nuclear waste repositories are seldom explicitly included in studies with few exceptions.[11,9]

The goal of this study was to investigate whether we can meaningfully differentiate more opinion groups besides the positive and negative extremes for the domain of nuclear waste. We were, first, interested to see if we could find distinct patterns of risk and benefit perceptions. Second, we investigated whether these different patterns also show different opinions about a repository. More precisely, we aimed at shedding light on the middle spectrum of opinions by disentangling potential ambivalent and indifferent opinion groups. The overall objective was to explore the added value of using more dimensions compared to using one single opinion rating.

2. METHODS

2.1. Sample

In our study, we deal with the case of one (or two) prospective deep geological repositories (DGR) in German-speaking Switzerland as planned by the Swiss Federal Office of Energy.[33] In total, 202 municipalities in eight different German-speaking

[3]We use the term opinion, whereas other authors may use other terms such as attitude. The terminology seems to be inconsistent within the research community. In our view, opinion comprises beliefs about a target object or topic including affective and cognitive elements.

cantons[4] are being considered in the site-selection process. We investigated opinions inside and outside potentially affected regions in communities of different sizes. For the survey, we selected affected communities randomly from three cantons (Aargau, Schaffhausen, and Zürich) and nonaffected communities from five other cantons (Basel, Bern, St. Gallen, Luzern, and Schwyz). The addresses were obtained from the register of residents of the respective communities. The questionnaire was sent to a total of 1,247 persons, 18 envelopes were returned unopened because the address was wrong or the letter was rejected. The response rate after two reminders was 41% ($N = 511$), and 500 questionnaires could be used for data analysis.[5] The response rate of men and women was almost identical (females: 49%). There were similar numbers of participants from affected and unaffected communities (affected: $N = 230, 46\%$). The mean age of the sample comprising persons from 18 to 65 years is $M = 46$ ($SD = 13.4$; Switzerland: $M = 42$ years; $SD = 0.05$).

2.2. Independent Variables

To assess risk and benefit perception in a way that allows distinguishing different factions of respondents, including potential ambivalent and indifferent groups, we used six risk perception items and five benefit perception items adapted from a Swiss national survey[32] containing statements on environmental, ethical, and health risks as well as mainly economic benefits (see Table III). The respondents indicated their level of agreement with each statement, which was linked to the risks and benefits of a DGR on a 7-point Likert scale (1 = "I do not agree at all" to 7 = "I fully agree"). Table III shows the statements as well as the means and standard deviations from the overall sample (last column). We used these items to perform a cluster analysis. To characterize the clusters we calculated the mean values of all risk and benefit perception ratings, respectively, thus creating a risk perception scale and a benefit perception scale. The internal consistency, described by Cronbach's α, is at least good for both scales; risk (6 items, $\alpha = 0.916$) and benefit (5 items, $\alpha = 0.859$).

[4]See also http://www.bfe.admin.ch/radioaktiveabfaelle/index.html?lang=en (retrieved 05.12.2011)

[5]Eleven questionnaires were filled in inappropriately and had to be excluded from further analysis.

2.3. Dependent Variables

Previous studies found that the acceptance of a repository for radioactive waste also depends on the respondent's opinion on nuclear energy.[22] We therefore measured opinions on the use of nuclear energy in general, the perceived value of nuclear energy for security of electricity supply, and the import of electricity as an alternative to Switzerland having its own nuclear energy plants (see Table V). We use these results to characterize the clusters in addition to a sociodemographic description.

The dependent variable comprised items to measure opinions on a DGR in a summative manner using common opinion items. Previous studies of ours show that people accept a DGR within the country ("solution in Switzerland") more readily, but are rather skeptical with respect to their own community as a place for a repository;[31] the so-called NIMBY phenomenon.[34,35] We therefore included three items covering opinions on a repository in (1) "Switzerland," (2) "your region," and (3) "your community." The respective questions were introduced by "What do you think about a DGR in . . ." followed by (1), (2), or (3). Responses could be given after the prompt "I am ...." on a scale ranging from 1 = totally against it and 7 = totally in favor.

2.4. Statistical Analysis

We used hierarchical cluster analysis with the Ward method and squared Euclidean distance measure[36,37] as an exploratory technique for investigating whether groups of respondents could be characterized by similar risk and benefit perception ratings related to DGR. Thus, the clusters were generated by the named number of risk and benefit perception items (not the respective scales). We standardized all items between values of 0 and 1, which is a viable procedure for the Ward method,[38] to ensure that the magnitudes or scales of the input variables do not affect the dissimilarity measure (in our case Euclidean distance). To clarify the procedure we highlight the steps from the three- to a four- and five-cluster solution (see Table I). One can infer from a detailed analysis that 97 cases were split from the third cluster and form the new Cluster 4. The other cases remain in the previous Clusters 1 and 2. In a next step, Cluster 2 loses 99 cases to the new Cluster 5. We do not report results for clustering solutions with five clusters, however, because the interpretation appeared too difficult in this case. Instead, we focus on and

Table I. Different Steps of Cluster Solutions

3-Cluster Solution	4-Cluster Solution	5-Cluster Solution
Cluster 1 ($N = 161$)	Cluster 1 ($N = 161$)	Cluster 1 ($N = 161$)
Cluster 2 ($N = 174$)	Cluster 2 ($N = 174$)	Cluster 2 ($N = 75$)
Cluster 3 ($N = 149$)	Cluster 3 ($N = 97$)	Cluster 3 ($N = 97$)
	Cluster 4 ($N = 52$)	Cluster 4 ($N = 52$)
		Cluster 5 ($N = 99$)

characterize the clusters of the four-cluster solution by sociodemographic data and respective opinions about nuclear energy in general.

Because it is well known that cluster analysis results can be sensitive to the order of the cases, we conducted several analyses with different case sequences. The case numbers within the resulting clusters differ somewhat; however, the significant differences with respect to the dependent variables constitute a stable pattern in all solutions. To test for significant differences between the clusters obtained with respect to respondents' general opinion on DGR (three items/dependent variables: (1) "Switzerland," (2) "your region," and (3) "your community"), we performed an analysis of variance (ANOVA). Because Levene's test of homogeneity of variances is significant for all three dependent variables ($p < 0.001$) and the group sizes are unequal, we used Games-Howell as a *post hoc* test for statistical significance.[39] Because the dependent variable (acceptance of DGR) is nonnormally distributed (bimodal) we additionally performed an analysis with the nonparametric Kruskal-Wallis test, which is very robust to nonnormally distributed variables.[40]

To identify which of the variables included in this study (risk, benefits, and opinions on nuclear power) explain which amount of variance with respect to the dependent variable "DGR in your region" we conducted a linear regression analysis for each cluster.

3. RESULTS

3.1. Descriptive Overall Results

Risk perception and benefit perception are, as expected, negatively correlated ($r = –0.355$; $p < 0.01$, $N = 500$). The correlation is rather low, indicating no exclusive relationship. To check for differences in opinion on DGR between nonaffected and affected communities and between community classes, we used ANOVA. No significant differences between these categories with respect to the risk and benefit perception items, the dependent variables, or the risk and benefit perception scales could be identified (see Table II). We thus used the whole sample for further analysis. The absence of significant differences may seem surprising, since one could assume that those affected by the site selection process might be more concerned by or might oppose a DGR. However, there is no one-to-one relationship between being (objectively) affected and (subjectively) concerned.[41] Rather, we conclude that some of those objectively affected might currently not be (psychologically) concerned and vice versa.

Table II. Comparison of Values for the Samples from Affected and Nonaffected Communities; the Differences Are Not Significant; Mean Values, Standard Deviations (in Brackets), and p Values Are Given

	Nonaffected ($N = 265$–266)		Affected ($N = 232$–233)		
	M	SD	M	SD	p Value
Risk perception scale	4.9	1.65	4.8	1.58	0.234
Benefit perception scale	3.4	1.41	3.5	1.44	0.440
DGR in own region	3.8	1.95	3.5	1.93	0.229
DGR in Switzerland	4.4	1.83	4.2	1.97	0.147
DGR in own community	3.5	2.00	3.3	2.02	0.345
Are you at the moment for or against nuclear energy	3.9	1.98	4.0	1.98	0.402
Nuclear energy serves supply security	4.9	1.68	5.0	1.66	0.608
If we use nuclear energy it is better to generate it in our country	5.2	1.70	5.1	1.68	0.637

A more detailed look at the data also reveals differences between men and women. Women rated the benefits (benefit scale; $M = 3.4$, $SD = 1.36$) of DGR as high as men ($M = 3.6$, $SD = 1.47$). However, women rated the risks (risk scale) of DGR significantly higher than men ($M = 5.1$, $SD = 1.43$ compared to $M = 4.3$, $SD = 1.68$; $F_{(1,498)} = 35.7$, $p < 0.01$), a finding consistent with previous risk perception studies.[42,43]

3.2. Description of Clusters

In this paragraph, we describe the four clusters. We start by presenting the ratings of the cases in each cluster on the risk and benefit perception scales and items (see Fig. 1 and Table III). Cluster 1 ($N = 161$) shows high risk perception ratings but low benefit

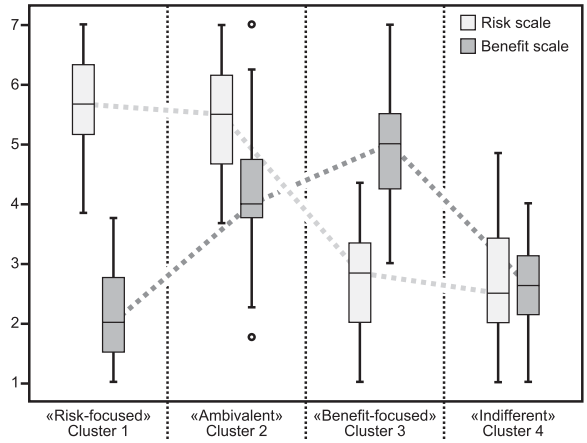

Fig. 1. Cluster ratings on the benefit and risk scales. The scales range from 1 = "I do not agree at all" to 7 = "I totally agree." "4" marks the middle position. Box plots show the median (—) as well as the quartiles (box) and the data range (whiskers) and outliers (○). One can identify the different scales ratings of the clusters.

perception ratings, whereas Cluster 3 ($N = 97$) shows high benefit ratings but very low risk perception ratings. Cluster 2 ($N = 174$) shows comparatively high ratings on both perception scales, whereas Cluster 4 ($N = 52$) shows only moderate ratings on both scales. Therefore, we can clearly distinguish a *risk-focused* (Cluster 1) from a more *benefit-focused* group (Cluster 3) of participants. Moreover, an *ambivalent* group can be identified that shows relatively high values for risks as well as for benefits (Cluster 2). Cluster 4 could be interpreted as responding only moderately to risk and benefit perceptions. In accordance with the literature cited, we label this cluster *indifferent*.

The ratings of the ambivalent Cluster 2 on the benefit perception scale are comparable to those of the benefit-oriented Cluster 3, while at the same time the risk perception ratings are comparable to those of the risk-focused Cluster 1 on the risk perception scale. Given a 99.9% interval (ANOVA with

Table III. Cluster Ratings on Benefits (b) and Risks (r) with Mean Values and Standard Deviations; the Scale Ranged from 1 = "I Do Not Agree at All" to 7 = "I Totally Agree;" "4" Marks the Middle Position

Risk (r) and Benefit (b) Perception Items/Cluster	Cluster 1 *Risk-Focused* ($N = 161$)		Cluster 2 *Ambivalent* ($N = 174$)		Cluster 3 *Benefit-Focused* ($N = 97$)		Cluster 4 *Indifferent* ($N = 52$)		Total ($N = 484$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Benefits										
Establishment of new workplaces (b)	2.1	1.18	4.7	1.33	4.5	1.15	3.6	1.70	3.9	1.84
Improvement of regional infrastructure (b)	2.0	1.05	3.8	1.59	5.2	1.47	2.7	1.23	3.2	1.70
Reduced taxes for local residents (b)	2.3	1.54	4.4	1.48	4.7	1.35	2.2	1.29	3.6	1.90
Economical stimuli for the local trade (b)	2.1	1.03	3.9	1.35	4.5	1.29	2.3	1.03	3.3	1.62
Promotion of sustainable development of the siting region (b)	1.9	1.04	3.7	1.28	3.1	1.30	2.5	1.34	3.2	1.59
Benefit perception scale	2.1	0.81	4.2	0.86	5.0	0.90	2.7	0.73	3.5	1.42
Risks										
Release of radioactivity in transport accidents (r)	5.6	1.50	5.7	1.23	2.4	1.57	3.1	1.45	4.9	1.85
Health risks for yourself because of the deep geological repository (r)	5.6	1.31	5.3	1.26	2.9	0.98	2.3	0.97	4.5	1.85
Health risks for later generations because of the deep geological repository (r)	6.3	0.82	5.9	1.08	2.7	1.26	3.1	1.59	5.1	1.84
Damage to the environment because of the repository (r)	5.9	1.23	5.5	1.33	2.8	1.47	2.3	1.01	4.7	1.95
Release of radioactivity to groundwater due to damaged canisters (r)	5.8	1.44	5.7	1.33	2.0	1.57	2.4	1.27	4.8	2.00
Risk perception scale	5.7	0.83	5.5	0.94	2.7	0.89	2.7	0.96	4.7	1.62

Table IV. Description of the Clusters by Demographic Variables; Political Attitude Was Measured from 1 = Leftmost to 10 = Rightmost by the Question: "How Would You Rate Your Political Attitude on a Scale from 1 to 10?"

	Age ($N = 477$)		Political Attitude ($N = 482$)		Gender ($N = 484$)	
	M	*SD*	*M*	*SD*	Female	Male
Cluster 1						
Risk-Focused	44.5	12.24	4.8	1.89	57%	43%
Cluster 2						
Ambivalent	44.5	13.97	5.4	1.87	56%	44%
Cluster 3						
Benefit-focused	47.0	14.01	6.2	1.72	40%	60%
Cluster 4						
Indifferent	48.9	13.47	5.1	1.65	28%	72%
Total	45.5	13.42	5.3	1.89	49%	51%

Games-Howell multiple comparisons) the mean benefit perception values of the ambivalent Cluster 2 ($M = 4.2$, $SD = 0.856$) are only marginally significantly different from those of the benefit-focused cluster ($M = 5.0$, $SD = 0.903$; lower and upper bound –1.19 and –0.33, $p < 0.001$). That is, the effect is weak compared to the other relations. Similarly, the mean ratings of the ambivalent Cluster 2 on the risk perception scale ($M = 5.5$, $SD = 0.942$, $p = 0.270$) are not significantly different from those of the risk-focused cluster ($M = 5.7$, $SD = 0.831$; lower and upper bound: –0.19 and 0.54).

Next, we characterize the clusters sociodemographically (see Table IV). Cluster 1 (*risk-focused*) comprises more women, people in middle age and of moderate political opinion. The *indifferent* cluster (Cluster 4) ranges around the political middle position, contains more men, and shows the highest mean age of all clusters. The *benefit-focused* Cluster 3 shows a mean age of 47 years, a tendency toward the political right, and a share of almost 60% men. The *ambivalent* cluster (Cluster 2) contains a majority of women, shows a lower mean age, and rather moderate political opinion. The *risk-focused* Cluster 4 is also younger, politically more left, and counts more women. We continue by reporting patterns with respect to the items related to nuclear energy (see Table V).

Nuclear energy (1) is a *benefit-focused* cluster. The other clusters clearly reject nuclear energy (as in *risk-focused* Cluster 1) or show a moderate negative opinion (as in *indifferent* Cluster 4 and *ambivalent* Cluster 2). These differences are not significant (Games-Howell ANOVA, $p < 0.001$) between the *ambivalent* Cluster 2 and the *indifferent* Cluster 4 ($p = 0.44$) and the *benefit-focused* Cluster 3 and the *indifferent* Cluster 4 ($p = 0.016$). The statement on supply security,(2) however, is supported strongly by the *benefit-focused* Cluster 3 and moderately by the *ambivalent* Cluster 2 and the *indifferent* Cluster 4. Here, significant differences can be found between the *benefit-focused* Cluster 3 and all other clusters ($p = 0.003$ and $p < 0.01$). The statement on opposition to the import of electricity from foreign nuclear energy plants is accepted by all clusters (mean values > 4) but exceptionally by Cluster 3. This hints at a tradeoff between Switzerland's own nuclear energy production and the import of energy from nuclear energy plants located in other countries (most subjects in our sample prefer domestic production). The differences between Cluster 3, and Clusters 1 and 2 are significant ($p < 0.001$).

3.3. Dependent Variable: Opinion on DGR

The overall pattern yielded from the analysis shows significantly higher mean ratings for the item "DGR in Switzerland" ($M = 4.3$, $SD = 1.89$) than for a more proximate DGR in one's own region ($M = 3.7$, $SD = 1.95$; $t = 13.1$, $p < 0.01$) and community ($M = 3.4$, $SD = 2.02$; $t = 15.3$, $p < 0.01$, using paired *t*-tests with a 99% confidence interval). The results of the ANOVA to compare the clusters with respect to the opinion on DGR can be seen in Table VI. The overall effect shows significant differences between the clusters (DGR in Switzerland: $F_{(3,480)} = 67.2$, DGR in own region: $F_{(3,480)} = 92.6$, DGR in own community: $F_{(3,480)} = 99.9$, all $p < 0.001$). The overall results of the Kruskal-Wallis test were also significant for each DGR item (DGR in Switzerland: $H(3) = 146{,}504$, DGR in own region: $H(3) = 175{,}158$, DGR in own community: $H(3) = 180{,}523$, all $p < 0.001$). Except Clusters 3 and 4, which differ not significantly with respect to the items "DGR in Switzerland" ($p = 0.137$, using Games-Howell multiple comparisons) and "DGR in own community" ($p = 0.279$) all differences between all clusters are significant at the 0.01 level. In addition, we find high acceptance of a DGR in the *benefit-focused* cluster (Cluster 3) and strong opposition to a DGR in the *risk-focused* Cluster 1. The *ambivalent* cluster (Cluster 2) shows ratings near or below the middle category of 4. The *indifferent* Cluster 4 shows higher ratings for these items and is not significantly different

Table V. Differences Between the Clusters with Respect to Opinions About Nuclear Energy; the Overall Differences Between the Clusters Are All Significant ($p < 0.01$); We Refer to the Three Items in the Main Text by Citing the Numbers in Circles

	1 In General: Are You at the Moment in Favor of or Against Nuclear Energy? (1 = Totally Against; 7 = Totally in Favor)		2 How Much do You Agree with the Following Statement? "Nuclear Energy Serves Electricity Supply Security." (1 = I Do Not Agree at All; 7 = I Totally Agree)		3 Currently, Nuclear Energy Produced in Switzerland Accounts for 40% of the Total Electricity Production. How Much Do You Agree with the Following Statement? "If We Use Nuclear Energy for Electricity Production, it is Better to Produce it in Switzerland, Rather Than Importing it, for Example, from France." (1 = I Do Not Agree at All; 7 = I Totally Agree)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Cluster 1 *Risk-Focused* ($N = 160$–161)	2.9	1.73	4.1	1.75	4.7	1.77
Cluster 2 *Ambivalent* ($N = 173$–174)	4.0	1.73	5.1	1.34	5.0	1.57
Cluster 3 *Benefit-Focused* ($N = 97$)	5.4	1.74	6.0	1.34	6.0	1.41
Cluster 4 *Indifferent* ($N = 52$)	4.4	1.97	5.1	1.57	5.5	1.73
Total ($N = 483$–484)	3.9	1.98	5.0	1.66	5.2	1.69

from Cluster 3 at the 99.9% confidence interval (Games-Howell multiple comparisons: $p = 0.042$).

3.4. Regression Analysis

The results of the linear regression analysis for each of the clusters with the dependent variable being acceptance of "DGR in own region" reveals differences between the clusters shown in Table VII. The risk perception scale contributes to the explanation of acceptance of DGR for all clusters except for the "indifferent" cluster. For this cluster, the only variable contributing significantly is "if we use nuclear energy it is better to generate it in our country." For the ambivalent cluster clearly both risks and benefits perception scales contribute significantly. Interestingly, the benefits perception scale does not add very much in the case of the *benefit-focused* cluster; rather, risks contribute negatively.

Table VI. Ratings of the Risk/Benefit-Clusters with Respect to the Dependent Variables on DGR; Ratings from 1 = Totally Against It to 7 = Totally in Favor; "4" Marks the Middle Position; One Can Identify Increasing Opposition with Growing Proximity of the Potential Repository (Except in Cluster 3, Which Shows Average Values Always Above 5, Meaning at Least Moderate Acceptance)

	DGR in Switzerland		DGR in Own Region		DGR in Own Community	
	M	*SD*	*M*	*SD*	*M*	*SD*
Cluster 1 *Risk-Focused* ($N = 161$)	3.2	1.74	2.5	1.52	2.1	1.49
Cluster 2 *Ambivalent*	4.1	1.72	3.3	1.72	3.0	1.72
Cluster 3 ($N = 174$) *Benefit-Focused* ($N = 97$)	5.9	1.13	5.6	1.25	5.4	1.41
Cluster 4 *Indifferent* ($N = 52$)	5.4	1.40	4.8	1.62	4.7	1.72
Total($N = 484$)	4.3	1.89	3.7	1.95	3.4	2.02

4. DISCUSSION

In this study, we investigated patterns of opinions on a DGR for nuclear waste in Switzerland. We used two dimensions, measuring risk and benefit evaluations separately to access two of the main determinants of opinions about DGR in Switzerland. In addition, we measured opinion on a DGR with one

Table VII. Results from the Regression Analysis; Standardized Values of the Risk and Benefit Perception Scales as Well as the Nuclear Power Items Are Shown for Each Cluster; Dependent Variable Was Acceptance of "DGR in Own Region"; the Risk Perception Scale Contributes Significantly in the Case of Clusters 1, 2, and 3, the Benefit Perception Scale, Only for Clusters 1 and 2

	Cluster 1 *Risk-Focused* ($N = 161$)	Cluster 2 *Ambivalent* ($N = 174$)	Cluster 3 *Benefit-Focused* ($N = 97$)	Cluster 4 *Indifferent* ($N = 52$)
Adjusted R^2	0.238	0.332	0.400	0.194
Risk perception scale	−0.33***	−0.47***	−0.56***	−0.18
Benefit perception scale	0.18*	0.25***	−0.06	0.09
Are you at the moment for or against nuclear energy	0.12	0.02	−0.15	0.12
Nuclear energy serves supply security	−0.04	0.05	0.17	−0.02
If we use nuclear energy it is better to generate it in our country	0.12	0.15*	0.27**	0.37*

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

item for each of three spatial scales (1) a repository in Switzerland, (2) a repository in the region where one lives, and (3) a repository in the own community. We could thus compare the ratings for the bi-dimensional measure (risks and benefits scales) with the three one-dimensional measures of acceptance of DGR. We chose this procedure because we consider opinions to be multidimensional constructs.[19,24] Even in the case of a nuclear waste repository—where benefits may not be so apparent compared to risks—there are some potentially positive aspects perceived by many. People can show high or low ratings on both dimensions at the same time, indicating that opinions are not one-dimensional in the sense that high risk perception necessarily equals low benefit perception (although both dimensions are negatively correlated).

We identified four clusters with specific risk-benefit perception profiles and distinct opinions on DGR (for each of the three location items) as well as on nuclear energy in general. In particular, we identified one cluster with high benefit ratings, which is in favor of DGR and nuclear energy and one cluster with high risk perception ratings opposing both. One additional cluster showed ambivalence, that is, high ratings on both the risk and benefit perception scales and a moderate opinion on DGR and nuclear energy. One cluster seems to be indifferent, rating low on both risk and benefit perception scales. With respect to its opinion on DGR this cluster shows relatively high values, but still below those of the *benefit-focused* cluster. Males and older participants are more frequent in the *benefit-focused* cluster and the indifferent cluster. Females, on the other hand, form the majority in the ambivalent and risk-focused clusters, which is in line with other studies reporting gender differences in risk perception, especially of nuclear technology.[43,42] The results of the linear regression analysis show an interesting pattern.[6] Although the risk perception scale contributes to the explanation of acceptance of DGR in one's own region in the case of the risk-focused cluster, the benefit perception scale fails to contribute in the case of the *benefit-focused* cluster. For this cluster a comparatively high negative contribution from the risk perception scale puzzles the observer. One would instead expect a high contribution from the benefit perception variable. The cluster was labeled "benefit oriented" in the context of the other cluster patterns; it indeed shows a comparatively high mean value in the benefit perception scale ($M = 5.0$). However, it also shows an extremely low value for risk perception ($M = 2.7$). Presumably, it is less a case of expecting benefits than neglecting risks that contributes to acceptance of DGR in one's own region.

In a thematically related study, Sjöberg[9] used risk and benefit perception scales to assess acceptance of a repository in Sweden. However, this study focused on stakeholders with rather extreme opinions. The results show that the opponents are more extreme than the proponents of a repository and may be more visible in the public discourse. These results are comparable to the benefit- and risk-focused Clusters 1 and 3 in this study, respectively. However, by covering a more complete spectrum of opinions our study provides additional insights into two further opinion groups in the middle range. These ambivalent and indifferent groups actually include a considerable portion of the participants.

The study has some limitations. First, it is exploratory in nature, using cluster analysis. More research on the issue is certainly needed. Second, we did not include measures of salience in the study, which might be important in distinguishing factual indifference from other opinions. In other words, one could also ask how important the topic is to participants, irrespective of their stated opinion. Third, this

[6]We are thankful to an anonymous reviewer for suggesting performing this regression analysis.

study was conducted before the nuclear accident in Fukushima in March 2011. We do not know what effect this may have had on the opinions about the nuclear waste repository project in Switzerland. However, some insight can be derived from a study we recently conducted. Preliminary results after cluster analyzing the data in the same way as in this study indicate that no indifferent cluster can be identified, but that there are three different risk-focused clusters and a moderately *benefit-focused* one. Thus, presumably a shift in opinion following the Fukushima event has taken place. Further analysis is necessary to confirm this assumption. We conclude from these results that it is worthwhile investigating the temporal aspects, that is, opinion *dynamics*. To complement these investigations, an agent-based simulation approach (multiagent system) seems appropriate as it has yielded respectable results in modeling opinion formation and dynamics.[44,45] This approach can be useful to test the underlying assumptions about the structure of opinions and the mechanisms for their change to assess the dynamic aspect on an individual and a collective level. A population of artificial agents, heterogeneous with respect to their risk/benefit perception profile (and potentially other variables such as trust) can interact with each other and receive information from simulated actors such as the media or political agents. One then can measure the influence of this information on the individual opinion profile of an agent but as well on the overall population, that is, on "public opinion." A fourth, more general, limitation concerns the sample and the specific political and societal conditions in Switzerland. Therefore, generalizations to other countries should only be made with care and on the basis of an analysis of the respective situation. A social scientific study comparing opinion patterns in different countries or regions could potentially yield interesting insights into cultural specificities and respective opinion patterns, especially by including a multidimensional measure for political/ideological attitude.

5. CONCLUSIONS

It has been recognized that public involvement is crucial in the site-selection procedure.[5–7] For instance, in Sweden a participatory process had been conducted, and in Switzerland such a process is currently underway to find appropriate locations and to gain the acceptance of the public.[46,4] The process in Switzerland is complex and delicate. Those factions of the public who are undecided so far may change their minds in the future, depending on the design and the development of the participatory process. Like Poortinga and Pidgeon,[47] we show in our study that there are more than the two extreme groups that form the discourse about an issue; in our case about waste repositories and nuclear energy. This indicates that it is worth taking a closer look at these intermediate groups. The added value of our study might be seen in a more complete picture of the current opinion landscape, which might help with adapting communication strategies to gain access to the concerns of the "silent majority." For the issue of the siting process for nuclear waste, the relevance of the currently undecided group(s) can be illustrated by the following considerations. Besides the local opposition of communities and the political tension during the official process, the Swiss public can influence the process in another way. The decision of the Swiss parliament (expected by 2021) on the license for a nuclear waste repository could be opposed by a national referendum. This means that the Swiss public can then vote in favor of or against the decision of parliament and in the end may stop the process at this stage, possibly postponing the process for an indefinite time period. Considering the official process and the time perspective of 2021, it is essential to know more about the ambivalent and indifferent majority of the public because the greatest volatility should be expected within the indifferent and ambivalent clusters, although research does not totally agree on that point. The new study mentioned earlier at least points in that direction. We acknowledge that ambivalence can be considered a sensible response to a complex issue such as nuclear waste. However, the question remains (serving as a topic for further research): How stable are ambivalent (and indifferent) opinions? There are studies that show ambivalent opinions as being less stable than distinct opinions.[48,49] However, this finding cannot be generalized.[19] We presume it depends on the complexity of the topic and whether there is a need for actual decisions. Particularly in the Swiss context, those who are currently undecided basically have two options when facing a decision at the polls on a referendum. Either they can be persuaded by opinion makers during the process to vote in favor of or against a repository, or, to maintain their ambivalence they could abstain from deciding at the polls at all. As indicated, the topic is strongly related to values, and opposing interest groups may try to persuade members of the public to vote according to their view. Thus,

procedural fairness and public perception of it play an important role in the acceptance of contested infrastructure such as a repository for nuclear waste.[50] In this study we did not aim at predicting potential decisions in a vote. We are convinced that assessing the (current state of) acceptance of a DGR does not allow a definite conclusion on potential yes/no—decisions in the years to come. Rather, we assume that not only risk and benefit considerations will play a role when it comes to actual decision situations. Other variables such as trust and also more pragmatic ones such as responsibility (we as "the Swiss" have to do this) might likely become relevant in solving this problem. In other words, one can be ambivalent in some respects, but one concern might turn out to be most decisive for the actual decision.

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