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Predicting the Acceptance of the Population for a Radioactive Waste Disposal Facility

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Abstract— *Acceptance of a radioactive waste disposal facility is a widely debated topic by the scientific community since very early. There are studies published since the 1980s that have analyzed the support for the siting such a facility.*

The novelty of the current research consists in predicting the factors which influence the acceptance of the population for a radioactive waste disposal facility considering the need of constructing a disposal facility by 2050, a clear condition for a sustenabile development of nuclear energy.

Population, as an important stakeholder in this process, has not consistent opinions in this regard especially because there exist some gaps in the strategy or in approaching the problem from a social point of view. Scientific community studied in different ways factors as risks, benefits, fairness, knowledge, information, trust, support on different communities. Important to mention is that not only technical or economical issues have to be considered in siting process of a radioactive waste disposal facility, but also social issues which are very important and decisive.

The purpose is to analyze the factors that have an effect on the acceptance of a radioactive waste disposal facility. In order to fulfill this objective, an advanced statistical analysis is performed based on the information collected from the questionnaires.

Keywords— *Radioactive waste management/ sustainable development/ predicting factors/ multiple linear regression/ nuclear energy.*

I. INTRODUCTION

The nuclear energy and its generation developed continuously in the last decades even there are several voices which consider that the risks associated are too high. Therefore after Fukushima nuclear accident from 2011 Japan closed for a period its nuclear facilities and Germany planed a final deadline to shut down its nuclear power plants until 2022. However the new global energy crisis may change the already established plans and at EU level there is registered a new lobby which promote nuclear energy investments even at the level of its new energy strategy and its main instrument EU Energy Deal.

In this new context there is a need to push the research in a field which was neglected also in the past because the amount of nuclear waste will increase continuously and the problem of the location for new disposal facilities for nuclear waste is not solved.

The Since 1990 the social dimension of radioactive waste management began to receive more attention and was no longer neglected. Forum of Stakeholder Confidence was founded by Nuclear Energy Agency in 2004. The same year was characterized by the recognition of the stakeholders as a key part in the radioactive waste management. Social acceptance was stated as mandatory in the process of radioactive waste disposal. Negotiation process between parties, population and authorities or experts is part of a methodology developed in Belgium for radioactive waste management to give everyone the opportunity to express their interests [1].

Due to its integrative equation radioactive waste management has to be analyzed under the umbrella of sustainable development with its main dimensions and factors: economy (costs and funding), environment (safety) and society (trust). This analysis must consider also the stability dimension as its main factor [2].

However, information is still a necessity, if insufficient condition for energy-behavioral changes or “knowledge is one important part of the package of elements required for action” [3] and [4]. Even that are a lot of studies related to the nuclear energy only a few are analyzing the disposal facilities locations and ever fewer are considering the main factors which influence the acceptance of the population for such an investment for radioactive waste in their region.

II. LITERATURE REVIEW

A study conducted in Japan showed that population has limited awareness regarding sitting of a radioactive waste disposal facility. Concerns that create anxiety generally refer to radioactivity, life and health impact and taxes [5]. It is important to create awareness about what is going to happen or is happening to facilitate and to ease the process of gaining education and information in the field of radioactive waste [6]. Raising awareness on radioactive waste is a job of the government and local authorities which need to hardly work to accomplish this [7].

One main factor which is associated with nuclear energy and also with the disposal of nuclear and radioactive waste is the risk perceived by the population. Perceived risk is very important for acceptance and location of a radioactive waste disposal facility [8]. USA population has been always in heated debates on the topic of radioactive waste disposal [9]. Countries like Sweden also felt how population perceive the risk encountering many reactions against a disposal facility [10].

Regarding radioactive waste in Sweden more research took place during the time. In 2001, Sjöberg took a survey regarding attitudes and risk perceptions in Sweden [11]. Another study revealed that also politicians from local

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communities had risk perceptions of the same nature as the population [12].

Studies from West Europe countries showed that population oppose to the siting of radioactive waste. In UK population also manifested a prominent level of opposition to radioactive waste [13]. Perceived risk represents an important aspect also in Canada where population opposed to local siting [8].

Kahan et al. (2009) observed that risk perception is a continuous process shaped by psychological aspects and cultural environment [14]. At the population level there are petitioners who report the risk of terrorist attacks to the European Union. Those petitions demonstrate the fact that population is aware or afraid of such possibility.

Studies indicate that besides of the technical risk assessments [15], other aspects like public participation, cooperation and consultation with the stakeholders are important for decision-making process when discussing about radioactive waste [16]. This position is also favorable because can help to understand if solutions adopted and their implications are tolerated by population and other stakeholders. Population should not be excluded from the involvement in such technical and complex issue like radioactive waste because they can be extremely capable and willing. Transparency is very important in the sustainable development approach of the nuclear waste. Willingness of the stakeholders determines population to be much trustable and to accept various technical decisions much more easily. Early involvement of the stakeholders and population in different processes is time saving with remarkable results for both parties [17]. Internationally, has been recognized, that lack of implication from the side of national stakeholders committed to strong opposition to nuclear energy, other related plans or to radioactive waste disposal facilities. This opposition is powered due to the lack of population access to timely and accurate information related to the process of establishing of the location for radioactive waste disposal facilities [18].

Population involvement is advantageous for policymaking by facilitating the process of radioactive waste management through new and democratic ideas, as well as knowledge and experience [19]. European Commission uses E-TRACK to involve population in energy policies. E-TRACK was set up through the agreement of Directorate-General for Energy (DG ENER) and Joint Research Centre (JRC) and the first initiative addressed participation of population in radioactive waste management. For every type of radioactive waste (low, intermediate, or high level), cooperation at any level it is acknowledged to have beneficial implications [20].

Acceptance is the first social concern when discussed about radioactive waste emplacement and is closely related with population involvement in radioactive waste management. Korean government has taken many steps over time to find a location for a radioactive waste disposal facility. Since 1980s, Korean population protested the efforts of the government claiming that waste would harm the economy. However, the population accepted the construction of a disposal facility following a referendum [21].

An interesting model for analyzing the public acceptance of a radioactive waste facility was proposed by Lehtonen, where the main dimensions are economic and socio-political legitimacy, interactional trust, and institutionalized trust [22]. In this approach legitimacy indicate the acceptance of an investment by the local community. More detailed economic legitimacy estimates the minimum costs and the benefits related to this acceptance. As a step further the socio-political legitimacy enables the protection of the local community against factors which may impact the social, environmental, or even its cultural life. To promote an important project (e.g., the implementation of a radioactive waste disposal facility) the investor has to explain to the local community the importance of the project and its benefits.

Another main factor which influenced the acceptance of a nuclear energy waste disposal facility is represented by interactional trust, which is validated through mutual trust. For gaining trust the investor should convince the local community that this new investment will act in their interest. Important tools for gaining this trust are the image of the investor as an organization, its technical and financial resources but also the respect for the local traditions and sure the mutual dialogue. Therefore, the development of an investment project for establishing a location for a radioactive waste disposal facility, together with the local community build trust and increase the public acceptance of the project. A special form is the institutionalized trust, which is considered an evolved form of trust based on an interaction between the values and the interests of the organization and of the local community. If this dimension is going to be low enforced, the local community has the opportunity to design activities as part of the project for the location of a radioactive waste disposal facility.

Lee T. (1990) showed that the opposition to radioactive waste is influenced by the knowledge population have. Government should be informed about some issues representative in case of population views: knowledge, understandings, information, and their behavior [13].

Also, energy costs have implications over many decisions and on how population perceive costs. The excessive costs of construction of a nuclear power plant covers low operating costs, so that the economics of nuclear industry stay unclear between population thoughts.

Comparing with renewable energy sources which are 20% cheaper regarding construction costs, nuclear energy has higher efficiency thus offsetting the costs. Nuclear energy is economically feasible due to low costs of power generation [23]. However, the costs related to nuclear waste disposal facilities even are very high are not integrated in the nuclear energy cost model.

III. Research Methodology

According to the main studies presented in the literature review the acceptance of a radioactive waste disposal facility is affected by many factors such as: risks, benefits, knowledge, costs, trust and even by sociodemographic factors.

Based on the literature and based also on previous research, were established the following factors: involved risks, terrorist attack risk, disposal location, electricity costs, nuclear energy trust, individual benefits, and knowledge.

As a very often tool used for research studies, a questionnaire was developed to collect the necessary data. Respondents were not chosen by specific criteria.

Authors and other collaborators participated in the distribution of the questionnaires in paper format or in digital format. Responses were collected in both formats, processed, and analysed ultimately. There were no interviews or other discussions between the researchers and potential respondents, so the opinion of the respondents was not disturbed or influenced.

The questions focused on both nuclear energy and the management and disposal of radioactive waste. The questionnaire included different types of questions, with multiple answers, numerical answers, Likert scale answers. All questions used in this research were based on 5 points Likert scale to assess the strength of statement agreement or disagreement. The statement in this case was the acceptance of a radioactive waste disposal facility. Likert scales are used in statistical methods with confidence and have a satisfactory degree of accuracy [25].

To achieve the objective of this paper, the following hypotheses have been established:

H1. Risks involved by a radioactive waste disposal facility negatively influence the acceptance of a radioactive waste disposal facility.

H2: The risk of terrorist attack negatively influences the acceptance of a radioactive waste disposal facility.

H3: Choosing a disposal location only from a technical/geological point of view negatively influences the acceptance of a radioactive waste disposal facility.

H4: A high cost of electricity negatively influences the acceptance of a radioactive waste disposal facility.

H5: The trust given to nuclear energy as part of an ideal energy mix negatively influences the acceptance of a radioactive waste disposal facility.

H6: Individual benefits obtained in case of a radioactive waste disposal facility siting positively influences the acceptance of a radioactive waste disposal facility.

H7: The presence of knowledge about the radioactive waste positively influences the acceptance of a radioactive waste disposal facility.

IV. Data Analysis and Results

Identifying the predictive factors and their importance on the location of a radioactive waste disposal facility was the main objective of this study.

Research question: Which factors are significantly predicting the acceptance of a radioactive waste disposal facility?

To estimate which of the seven independent variables presented above has the greatest impact on the dependent variable, a multiline regression model was used.

Thus, the defined multiple linear regression model is:

$$y=\beta_0+\beta_1 x_1+\beta_2 x_{2+}\beta_2 x3_{3+}\beta_4 x_{4+}\beta_5 x_{5+}\beta_6 x_6+\beta_7 x_{7+}\varepsilon$$

Were,

y = dependent variable

x_1-x_7 = independent variables

β_0= intercept term

β_{1-} β_7 = model parameters

ε = residuals

TABLE 1. Descriptive Statistics

	Mean	**Std. Deviation**	**N**
Acceptance	3.72	1.508	566
InvolvedRisks	3.68	.960	566
AttakRisk	2.33	1.313	566
DisposalLocation	1.96	.995	566
ElectricityCosts	4.15	.772	566
NuclearEnergyTrust	2.92	1.427	566
IndivBenefits	4.03	.799	566
Knowledge	3.75	1.502	566

Table 1. illustrate descriptive statistics of the variables used in this model. In Table 2. the correlation coefficients matrix is shown. Table 2. emphasize that between the dependent variable and independent variables exist correlations even if they are weak. Correlations are either positive or negative, as can be seen in the table below, which is normal. Moreover, Pearson correlations are statistically significant for all variables included in the model (Table 2.)

The multilinear regression model was estimated by the smallest squares method (OLS). It was used the ENTER method. This analysis showed that five of the independent variables are significant predictors. Table 3. shows the description of the model. Table 4 illustrate ANOVA results, and Table 5 shows the coefficients of the regression model.

Table 4 shows that the regression model is statistically significant (F = 23.912; Sig. < .001). The correlation coefficient (R = .480) reveals that the acceptance is correlated with the independent variables. The coefficient of determination (R-square = .231) shows that 23.1% of the variation of the dependent variable is explained by the variation of the independent variables. If the Durbin-Watson (D-W) test has a value close to 2, then the regression equation has no autocorrelation problems. In this case D-W test has showed a value of 1.695, so the regression is valid from this point of view.

Table 5. illustrate which independent variable is significant (Sig.<.05). Also, table 5 shows that variance inflection factors (VIF) are less than 3 and tolerance values are more than 0.4, meaning that there is no collinearity between the independent variables.

That being said, the multiple linear regression equation obtained through the statistical package SPSS is:

$$y = 5.434 - .336\cdot x_1 - .196\cdot x_2 - .266\cdot x_3 - .154\cdot x_5 + .346\cdot x_6$$

It is concluded that of the seven statistical hypotheses, five were accepted (H1, H2, H3, H5 and H6), while two were rejected (H4 and H7). The significant factors used for predicting the acceptance of a radioactive waste disposal facility are involved risks, terrorist attack risk, disposal location, nuclear energy trust and individual benefits.

TABLE 2. Correlation coefficients matrix

		Y	X1	X2	X3	X4	X5	X6	X7
Pearson Correlation	(Y) Acceptance	1.000	-.136	-.321	-.203	-.256	-.204	.271	.160
	(X1) InvRisks	-.136	1.000	.072	-.056	-.028	-.257	.250	-.078
	(X2) AttakRisk	-.321	.072	1.000	.052	.458	.196	-.271	-.141
	(X3) DispLocation	-.203	-.056	.052	1.000	.114	.033	-.090	.004
	(X4) ElectricityCosts	-.256	-.028	.458	.114	1.000	.092	-.303	-.171
	(X5) NuclEnTrust	-.204	-.257	.196	.033	.092	1.000	-.318	-.124
	(X6) IndivBenefits	.271	.250	-.271	-.090	-.303	-.318	1.000	.124
	(X7) Knowledge	.160	-.078	-.141	.004	-.171	-.124	.124	1.000
Sig. (1-tailed)	(Y) Acceptance	.	.001	.000	.000	.000	.000	.000	.000
	(X1) InvRisks	.001	.	.043	.094	.252	.000	.000	.032
	(X2) AttakRisk	.000	.043	.	.109	.000	.000	.000	.000
	(X3) DispLocation	.000	.094	.109	.	.003	.219	.016	.461
	(X4) ElectricityCosts	.000	.252	.000	.003	.	.015	.000	.000
	(X5) NuclEnTrust	.000	.000	.000	.219	.015	.	.000	.002
	(X6) IndivBenefits	.000	.000	.000	.016	.000	.000	.	.002
	(X7) Knowledge	.000	.032	.000	.461	.000	.002	.002	.
N	(Y) Acceptance	566	566	566	566	566	566	566	566
	(X1) InvRisks	566	566	566	566	566	566	566	566
	(X2) AttakRisk	566	566	566	566	566	566	566	566
	(X3) DispLocation	566	566	566	566	566	566	566	566
	(X4) ElectricityCosts	566	566	566	566	566	566	566	566
	(X5) NuclEnTrust	566	566	566	566	566	566	566	566
	(X6) IndivBenefits	566	566	566	566	566	566	566	566
	(X7) Knowledge	566	566	566	566	566	566	566	566

TABLE 3. Regression Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.480[a]	.231	.221	1.331	.231	23.912	7	558[a]	.000	1.695

a. Predictors: (Constant), Knowledge, DisposalLocation, InvolvedRisks, AttakRisk, NuclearEnergyTrust, IndivBenefits, ElectricityCosts
b. Dependent Variable: Acceptance

TABLE 4. ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	296.519	7	42.360	23.912	.000[b]
	Residual	988.485	558	1.771		
	Total	1285.004	565			

a. Dependent Variable: Acceptance
b. Predictors: (Constant), Knowledge, DisposalLocation, InvolvedRisks, AttakRisk, NuclearEnergyTrust, IndivBenefits, ElectricityCosts

TABLE 5. Regression Model Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	5.434	.616		8.816	.000					
	X1	-.336	.063	-.214	-5.345	.000	-.136	-.221	-.198	.859	1.163
	X2	-.196	.050	-.171	-3.942	.000	-.321	-.165	-.146	.734	1.363
	X3	-.266	.057	-.176	-4.684	.000	-.203	-.195	-.174	.982	1.019
	X4	-.163	.084	-.084	-1.934	.054	-.256	-.082	-.072	.737	1.357
	X5	-.154	.043	-.146	-3.576	.000	-.204	-.150	-.133	.832	1.202
	X6	.346	.080	.183	4.335	.000	.271	.181	.161	.772	1.295
	X7	.065	.038	.065	1.689	.092	.160	.071	.063	.940	1.064

a. Dependent Variable: Acceptance

V. CONCLUSION

Based on research literature and on the current analysis, the following conclusions were stated. Main factors which have an effect on the acceptance of a radioactive waste disposal facility are involved risks, terrorist attack risk, disposal location, nuclear energy trust and individual benefits.

The analysis performed in this study showed that an increase of 1 percentage point (pp) in case of individual benefits obtained because of locating a disposal facility will conduct to an increase of .346 pp in the acceptance.

Individual benefits were determined as positively influencing the acceptance of a radioactive waste disposal facility.

The other results show that an increase of 1 pp in the risks perceived in the case of a radioactive waste disposal, respectively in the terrorist attack risk implies a decrease of .336 pp in the acceptance of a radioactive waste disposal facility, respectively of .196.

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Furthermore, results illustrated in Table 5. show that 1 pp increase in the choice of location implies a decrease of - .266 in the acceptance of a radioactive waste disposal facility.

An increase of 1 pp in the trust in nuclear energy leads to a decrease of - .154 in the acceptance of a radioactive waste disposal facility.

An increase in the acceptance of a radioactive waste disposal facility caused by the decrease of trust in nuclear energy is caused by fear of radioactive waste and the desire to dispose of it quickly and safely so as not to endanger it people's lives.

Apart of all the factors included in this study, the strongest one is represented by the risks involved by a radioactive waste disposal facility.

The final conclusion of the study says that factors as involved risks, terrorist attack risk, disposal location, nuclear energy trust and individual benefits are important factors and that they can be used with very high confidence as predictors in the process of siting of a radioactive waste disposal facility.

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