International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Reaching the Green Label by Safely Dispose the Radioactive Waste. Social Implications

Greta-Marilena Pușcașu[1]
[1]Business Administration Doctoral School, Bucharest University of Economic Studies, Bucharest, Romania, 010374,
Email address: vitioanu.greta@yahoo.com

Abstract**—** *The topic of nuclear energy and radioactive (RW) waste is daily addressed both nationally and internationally because of its impact over current and next generations. Clearly, radioactive waste management is both a technical and societal issue. The ways in which the population reacts to such a subject and the ways in which the management of radioactive waste is perceived remain topics of major interest, investigated throughout the scientific community. Reaching the green label in the transition process to a clean future involve a safe disposal process of radioactive waste and a higher importance given to the social dimension. The aim of the study consists in exploring the process of locating a radioactive waste disposal facility, analyzing, and determining the key factors that influence this process in a framework of green energy and population perception. All data were obtained via questionnaires (N=213). The population investigated consists of residents living throughout Romania, in the adjacent area to the nuclear power plant, RW storages or in other remote areas. This research followed identification of the existence or non-existence of the relationship between the location of a RW disposal facility and a variety of factors, such as: attitude, importance, information and involvement.*

Keywords**—** *Nuclear energy/ green target/ radioactive waste/ Spearman correlation/ social dimension*.

I. INTRODUCTION

Nuclear energy represents the most advantageous option for electricity production when considering air pollution and growing demand for electricity. Nowadays, the topic of sustainable development is often discussed. Nuclear energy can be used in the context of sustainable development by being an electricity source with limited environmental impacts. Radioactive waste requires proper management by the stakeholders involved in the chain. To meet the radioactive waste requirements means to accomplish the sustainable development approach and green label of the nuclear energy. Population perception plays a significant role in case of nuclear energy production, as well for the location of a radioactive waste disposal facility [1, 2]. Population perception is also important for a robust development.

The promoters for nuclear energy argue that nuclear use can have a significant contribution to decarbonize the economy on a lower cost as the cost which is required to maintain fossil fuels. On the opposite side there are environmental associations or even the national energy politicians (e.g., Germany) which consider (after the Fukushima disaster) that the use of nuclear energy is too dangerous for the safety of the environment. Therefore in 2011 the German Federal Government consider that until 2022 the nuclear energy generation must be stopped in Germany. Since 2011 the main related subjects were the development of the logistic for transportation and disposal of radioactive waste. But only until 2030 has to be selected and approved the site where the radioactive waste will be disposed [3].

The general observation is that the population perceptions regarding the risk of nuclear energy is strongly influenced by disasters. Therefore, in Japan, in 2010 (before Fukushima) only 11% of the population thought that Japan shouldn't use nuclear power. But only one year later after the Fukushima disaster this percent increase in July 2011 to 42% [4].

However, at this despite has to be added that since the beginning of the Atomic Age a final solution for the problem of the disposal of radioactive waste was not decided.

Every year nuclear power plants are producing significant quantities of nuclear waste as a side-product in the process of the electricity generation. Radioactive waste is also produced when the nuclear fuel is reprocessed [3].

Together with the spent fuel, the radioactive waste is hazardous for the human organism, and it has to be disposed for many years. Therefore, high level radioactive waste has to be isolated from the population for over hundreds of thousands of years. The main technology consists in disposing the high radioactive waste in deep underground. The location of this facility is very important due to the fact that the neighbourhood perceives potential risk and implications of high level radioactive waste.

The process of nuclear spent fuel disposal is regulated at states level and involves different stages (e.g., U.S): on site storage, storage at an interim storage facility, permanent disposal at a geologic facility and also the transport from the reactor site to an interim storage and/or geologic disposal facility [5]. These stages are influenced by the level of radioactivity of the waste and by the costs of its storage or disposal.

Generally, the waste production stage is followed by the waste storage and disposal and the main focus is on where to construct such a nuclear facility.

If talking about nuclear fuel the on-ground storage costs mean the costs of storing the waste in a wet or dry storage facility and the disposal costs include the construction costs of a geological facility and the encapsulation and transportation costs.

In EU, the new decarbonize targets and the promotion of the renewable energy sources may be associated also with a life extension of the nuclear power plants or even with the build of new nuclear power reactors. In this scenario finding options for radioactive waste disposal is mandatory.

Greta-Marilena Pușcașu, "Reaching the green label by safely dispose the radioactive waste. Social implications" *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 2, pp. 94-98, 2022.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

II. Literature Review

Relevant information from literature regarding location of a radioactive disposal facility and a variety of factors that could be correlated with that location, such as: attitude towards nuclear energy, importance given to nuclear energy as a solution for electricity needs in the next decade, information regarding the management and disposal of radioactive waste and involvement in the construction stages of a radioactive waste disposal facility are shown below.

A. Radioactive Waste Management

Due to the International Atomic Energy Agency (IAEA) between 10 and 37 million packages of radioactive materials are transported globally in one year. In percentage, 65% is radioactive waste from medicine, 23% from industry and 12% represents nuclear waste [3]. There is to mention that in the category of radioactive waste are included gases, liquids and materials which have radioactive properties.

Even that the perception of the population regarding nuclear power was improved in the last years, there are uncertainties for disposal of the radioactive waste [6]. Disposal of radioactive waste is considered the last phase for the radioactive waste management. The main steps in case of the radioactive waste management as presented by the IAEA and in accordance with the type of waste are as following: handling, pre-treatment, treatment, conditioning, transport, storage, and disposal [7, 8].

Disposal as a final solution for the radioactive waste management (case of high-level radioactive waste) is based until now on geological disposal. In these facilities the high-level radioactive waste is considered to be disposed for many thousands of years in order to be isolated from living organisms.

A radioactive waste disposal strategy is influenced by different factors with economic, political, or even environmental particularities. So far, studies have indicated that no state has long-term geological disposal facilities (over 100 years) recognized as safe [9, 3].

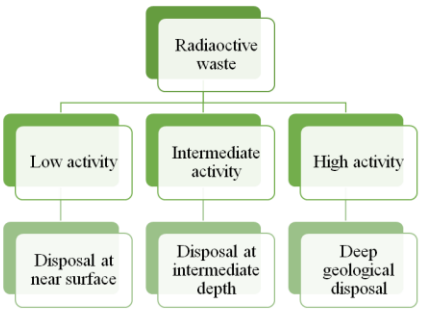

Fig. 1. Radioactive waste classification and the back end.

A new program for radioactive waste management is discussed at the US Government level. The program proposes the following steps:

• to complete the construction and start the operation of a pilot plant (for spent nuclear fuel disposal).

• to establish sites necessary for intermediate waste storages.

• to decide on a site for constructing a geological disposal for spent nuclear fuel and high level radioactive waste, deadline 2048 [3].

B. Attitude of the population

Regarding the attitude of the population towards nuclear energy was found that all discussions about nuclear energy must address the radioactive waste produced by the nuclear reactors [10].

Population attitude to nuclear energy has many implications and is, in turn, influenced by many aspects. Involvement of the population in decision-making leads to successful implementation and execution of the projects [11]. Another study found that population with a high level of knowledge about nuclear energy is much more able to objectively approach the risks and benefits [12]. Japan population affected somehow by the unpleasant issues of nuclear energy tend to react different than those which were not affected directly.

C. Importance given to nuclear energy

The importance of nuclear industry increases constantly. Nuclear energy is a carbon-free electricity source, can produce on large-scale and can assure energy security. Depending on how important the population thinks nuclear power is, many projects may have different courses.

D. Information population have regarding the management and disposal of radioactive waste

The degree of information population has regarding management and disposal of radioactive waste is decisive for such a complex project as a disposal facility development. How informed population is stays mostly in local authorities' hands. They can organize sessions in which valuable information is presented to the large public. Certainly, central bodies or international experts can support local bodies. This represent an important stage in the process because accurate, up to date and catchy information should be provided [13]. Population should be empowered with knowledge in order to understand the complexity of radioactive waste management.

E. Involvement of the population in nuclear projects

Opposition of the population on RW determined national and international representatives to involve public in decision-making processes. At both levels, national and international, stakeholders should present to the population clarity, justice, sincerity, and trust. Early involvement of the population in any process regarding radioactive waste will lead to benefits for both parties [13].

F. Green label of nuclear energy

European Commission introduced a new package which included also the EU Taxonomy Climate Delegated Act through which plans to sustain the sustainable investments. Such support requires clarification of economic activities that may lead to the achievement of EU objectives, including energy sector [14]. In February current year was also approved by the Commission the Complementary Climate Delegated Act which included also the nuclear energy activities in order

Greta-Marilena Pușcașu, "Reaching the green label by safely dispose the radioactive waste. Social implications" *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 2, pp. 94-98, 2022.

to meet the objectives of the European Green Deal [15]. Decreasing the greenhouse gas emissions and reaching the climate neutrality are among the most important objectives set by the European Commission. Through this Act the nuclear energy was considered an energy source able to mitigate the climate change, but some issues, including that of radioactive waste management, remained without a firm conclusion. Disposing the radioactive waste and spent nuclear fuel in deep geological disposals is still the safest solution for the present, but over time many technical, economic and social factors have made final disposal to still be a research question. Disposing the radioactive waste is a necessary criterion related to climate change so as not to cause any harm to any other environmental objective [14].

III. Research Methodology

Questionnaire was used as research tool for data collection. Constructs of the questionnaire aimed to identify population's perception and attitude of nuclear energy and radioactive waste. Online formats, as well as printed formats were used. A homogeneous distribution of the questionnaires was followed and the participants in the study were not by special criteria selected. All participants were informed in advance at the beginning of the questionnaire about the purpose of the study and the confidentiality. For this study a number of 213 validated responses were used. Respondents belong to all age categories.

The study used Spearman correlation to check the strength and direction of association between the selected variables. The non-parametric correlation analysis comprised the following independent variables: attitude, importance, information and involvement. Location of a radioactive waste disposal facility was treated as dependent variable. The data collected from the questionnaires were processed and analyzed horizontally and vertically based on simple and complex methods (non-parametric correlation method). As a non-parametric method, Spearman correlation helps to determine the relationship not considering the distribution type.

The research was based on the following four hypotheses (H1, H2, H3, H4):

• H1: The location of a radioactive waste disposal facility is positively influenced by the attitude of the population towards nuclear energy as a form of electricity production.

• H2: The location of a radioactive waste disposal facility depends on the importance given by the population to nuclear energy to meet the needs of electricity in the next decade.

• H3: The degree of information population has on the management and disposal of radioactive waste positively influences the location of a radioactive waste disposal facility.

• H4: The degree of involvement of the population in the construction process of a radioactive waste disposal facility influences the location of a radioactive waste disposal facility.

Research on population attitude, their involvement and other related perceptions related to nuclear energy and radioactive waste has the potential to help, clarify and understand the research objective and hypotheses and finally to contribute to the identification of efficient solutions.

Based on this analysis, we intended to determine which social factors influence the location of a radioactive waste disposal facility. Results of this research have been obtained by using Excel for database analysis and IBM SPSS Statistics to understand data and to solve the research objective.

IV. Data Analysis and Results

The data presented in Tables I and II illustrate the balanced distribution between gender and age of the 213 respondents.

TABLE I. Gender distribution of respondents

S. No.	Gender	Frequency (number)	Percent (%)
1	Female	93	43,66
2	Male	120	56,33
3	Total	213	100

TABLE II. Age distribution of respondents

S. No.	Age group	Frequency (number)	Percent (%)
1	< 21 years old	11	5,16
2	21- 30 years old	54	25,35
3	31- 40 years old	81	38,03
4	41- 50 years old	36	16,90
5	> 51 years old	31	14,55
6	Total	213	100

Regarding respondents' activity field, most of them work in services (24,88%), in consultancy 23,00% and in education 17,84%, while for each other activities presented in Table III. the proportion were below 10%.

TABLE III. Respondents' activity field

S. No.	Activity	Frequency (number)	Percent (%)
1	Production	12	5,63
2	Trade	13	6,10
3	Consultancy	49	23,00
4	Services	53	24,88
5	Public administration	4	1,88
6	Education	38	17,84
7	Healthcare	18	8,45
8	Defence	7	3,29
9	Others	19	8,92
10	Total	213	100

Regarding the work experience, mostly have more than 6 years of experience (52,58%), followed by 3-5 years category, and then by category with less than 3 years experience, as shown in Table IV.

TABLE IV. Work experiences distribution of respondents

S. No.	Experiences	Frequency (number)	Percent (%)
1	< 3 years	42	19,72
2	3-5 years	59	27,70
3	> 6 years	112	52,58
4	Total	213	100

TABLE V. Residence distribution of respondents

S. No.	Residence area	Frequency (number)	Percent (%)
1	Urban	173	81,22
2	Rural	40	18,78
3	Total	213	100

Most of the respondents (81,22%) live in urban areas, showing that countryside population was not so able to answer to the questionnaire, this exceeding the level of knowledge

Greta-Marilena Pușcașu, "Reaching the green label by safely dispose the radioactive waste. Social implications" *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 2, pp. 94-98, 2022.

and the interest of that population.

The income of respondents is situated at an average national level, as the results revealed in Table VI (about 40% for 3000-3999 lei).

TABLE VI. Gross Income of respondents (2000 lei are about 450-500 euro)

S. No.	Monthly average income (lei)	Frequency (number)	Percent (%)
1	< 2000	12	5,63
3	2000- 2999	55	25,82
4	3000- 3999	84	39,44
5	4000-6999	45	21,13
6	> 7000	17	7,98
7	Total	213	100

The study continued with the vertical analysis of the data. Every hypothesis was individually analyzed based on the Spearman rho correlation method. This vertical analysis helped us to confirm or not the research hypotheses. Table VII shows the correlation coefficient between the attitude of the population towards nuclear energy and the location of a radioactive waste disposal facility (Spearman rho=.512, p<.001). This correlation emphasizes that the atittude towards nuclear energy positively influences the location of a radioactive waste disposal facility. If population consider nuclear energy an important way to satisfy the electricity demand, then the acceptance of a disposal facility increases. Hypothesis (H1) is confirmed.

The correlation coefficient between the importance given by the population to nuclear energy to meet the needs of electricity in the next decade and the location of a radioactive waste disposal facility showed a value of Spearman rho=.616, p<.001, suggesting that the importance given to nuclear energy by the population positively influences the location of a radioactive waste disposal facility. As higher the importance given, the higher the acceptance of a such disposal facility. Hypothesis (H2) is confirmed.

The value of Spearman correlation coefficient computed between the degree of information population have regarding the management and disposal of radioactive waste and the location of a radioactive waste disposal facility is negative and moderate (Spearman rho=-.,411, p<.001). The correlation coefficient identified suggests that the more informed the population, the lower the acceptance of a radioactive waste disposal facility. However, the value of the Spearman correlation coefficient is low due to the fact that the population does not have sufficient and easily accessible information from the stakeholders, does not know how to look for such information or has no interest. The Spearman correlation matrix also points out that the correlations between the degree of information population have and the other variables are weak or non-existent.

Between the involvement of the population regarding the construction of a radioactive waste disposal facility and the location of a radioactive waste disposal facility a positive and weak correlation was established (Spearman rho =.308, p<.001). This value shows that involvement of the population in different stages of setting up a radioactive waste disposal facility is associated at a low level with the acceptance of a radioactive waste disposal facility.

TABLE VII. Spearman correlation matrix

			Location	Attitude	Importance	Information	Involvement
Spearman's rho	Location	Correlation Coefficient	1,000	,512**	,616**	-,411**	,308**
		Sig. (2-tailed)	.	,000	,000	,000	,000
		N	213	213	213	213	213
	Attitude	Correlation Coefficient	,512**	1,000	,714**	-,044	,482**
		Sig. (2-tailed)	,000	.	,000	,525	,000
		N	213	213	213	213	213
	Importance	Correlation Coefficient	,616**	,714**	1,000	-,088	,648**
		Sig. (2-tailed)	,000	,000	.	,200	,000
		N	213	213	213	213	213
	Information	Correlation Coefficient	-,411**	-,044	-,088	1,000	-,182**
		Sig. (2-tailed)	,000	,525	,200	.	,008
		N	213	213	213	213	213
	Involvement	Correlation Coefficient	,308**	,482**	,648**	-,182**	1,000**
		Sig. (2-tailed)	,000	,000	,000	,008	.
		N	213	213	213	213	213

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

V. CONCLUSION

This study clearly emphasize that location of a radioactive waste disposal facility is influenced by social factors. Furthermore, is mandatory to recognize that radioactive waste disposal requires not only technical attention, but also population participation, consultation and information in order to find whether the solutions, chosen for waste management are tolerated by the population and other involved parties.

The existing literature points out that many failed projects took place around the world through the fact that population refused the proposed applications, policies and projects related to radioactive waste disposal facilities. Therefore, the efforts of stakeholders to raise public awareness of the benefits of nuclear energy must be taken into account and put into practice immediately in view of the positive effects it could have on future nuclear projects. Considering the information population have in terms of management of radioactive waste we found that there exists an urgent need in providing clear and accurate information. The current lack of information negatively influences the radioactive waste location in a

Greta-Marilena Pușcașu, "Reaching the green label by safely dispose the radioactive waste. Social implications" *International Research Journal of Advanced Engineering and Science*, Volume 7, Issue 2, pp. 94-98, 2022.

disposal facility. At the same time, research has shown that the population is not involved and is not sufficiently involved in nuclear projects, such as the construction of a radioactive waste disposal facility, which is detrimental to radioactive waste management.

In conclusion, according to this study, we reiterate the importance of considering the population a stakeholder and an active player in the process of radioactive waste management so that the way to reaching the green label is an efficient and a successful one.

REFERENCES

[1] C. Sun and X. Zhu, "Evaluating the public perceptions of nuclear power in China: evidence from a contingent valuation survey," *Energy Policy*, vol. 69, pp. 397-405, 2014.

[2] S. Wang, J. Wang, S. Lin and J. Li, "Public perceptions and acceptance of nuclear energy in China: The role of public knowledge, perceived benefit, perceived risk and public engagement," *Energy Policy*, vol. 126, pp. 352-360, 2019.

[3] M. Esser, A. Borremans, A. Dubgorn and A. Shaban, "Nuclear waste transportation: quality assurance and control," *Transportation Research Procedia*, vol. 54, pp. 871–882, 2021.

[4] M. Nishikawa, "Neutral respondents' perceptions about geological disposal facilities," *Energy Reports*, vol. 7, pp. 5119–5129, 2021.

[5] F. Diaz-Maurin, J. Yu and R. C. Ewing, "Socio-technical multi-criteria evaluation of long-term spent nuclear fuel management strategies: a framework and method," *Science of the Total Environment*, vol. 777, issue 146086, pp. 1-11, 2021.

[6] K. Dungan, R. W. H. Gregg, K. Morris, F. R. Livens and G. Butler, "Assessment of the disposability of radioactive waste inventories for arange of nuclear fuel cycles: inventory and evolution over time," *Energy*, vol. 221, issue 119826, pp. 1-43, 2021.

[7] *Selection of efficient options for processing and storage of radioactive waste in countries with small amounts of waste generation IAEA-TECDOC-1371*, International Atomic Energy Agency (IAEA), Vienna, 2003.

[8] A. Asahara, D. Kawasaki and S. Yanagihara, "Study on strategy construction for dismantling and radioactive waste management at Fukushima Daiichi nuclear power station," *Nuclear Engineering and Design*, vol. 374, issue 111066, pp. 1-8, 2021.

[9] L. Rodríguez-Penalonga and B. Y. Moratilla-Soria, "A review of the nuclear fuel cycle strategies and the spent nuclear fuel management technologies," *Energies*, vol. 10, issue 1235, pp. 1-16, 2017.

[10] M. E. Kraft, "Nuclear power and the challenge of high-level waste disposal in the United States," *Polity*, vol. 45, issue 2, pp. 265-280, 2013.

[11] R. Xavier, N. Komendantova, V. Jarbandhan and D. Nel, "Participatory governance in the transformation of the South African energy sector: critical success factors for environmental leadership," *Journal of Cleaner Production*, vol. 154, pp. 621-632, 2017.

[12] E. Park and J. Y. Ohm "Factors influencing the public intention to use renewable energy technologies in South Korea: effects of the Fukushima nuclear accident," *Energy Policy*, vol. 65, pp. 198-211, 2014.

[13] *EURATOM Projects, Radioactive waste management and public participation: what have we learnt so far*, European Commission (EC), Joint research centre, Institute for energy and transport, Publications office of the European Union, Luxembourg, 2015.

[14] European commission (EC), Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives, Official Journal of the European Union, 2021.

[15] European commission (EC), Commission Delegated Regulation (EU) amending Delegated Regulation (EU) 2021/2139 as regards economic activities in certain energy sectors and Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities, 2022.