WORLD NUCLEAR UNIVERSITY

SUMMER INSTITUTE 2019

Networks for Nuclear Innovation

A Magazine containing the results achieved in the Network for Nuclear Innovation projects during the WNU Summer Institute 2019

WORLD NUCLEAR UNIVERSITY

FROM WORLD NUCLEAR UNIVERSITY PRESIDENT

Nuclear electricity generation is growing globally, but it needs to grow faster if the world is to meet future energy demand and mitigate the effects of climate change. The major goal that we have set to achieve by 2050 is to generate 25% of global electricity with nuclear power. Challenges in the technological, regulatory, economic, and social levels of our industry must all be addressed to achieve this growth. In such an international industry, this requires strong international collaboration. Networking is a vital component of international collaboration, and I am delighted to see the central role the Networks for Nuclear Innovation has played in this year's Summer Institute.

Fellows are selected to participate in the Summer Institute in part due to their ambition and enthusiasm for the future of nuclear. The Networks for Nuclear Innovation groups this year produced high quality reports with serious recommendations for diverse aspects of the nuclear future. Information does not respect national boundaries, and I anticipate that the innovative ideas generated during the NNI will be carried forward by the Fellows into their 39 countries. I support the endeavours of these future leaders, and fully believe in their future successes.

Agneta Rising
President
World Nuclear University

ACKNOWLEDGEMENTS

The first edition of the Networks for Nuclear Innovations (NNI) magazine was completed at the Summer Institute 2016. The main concept is to compile the ideas that emerge from the Fellows collaborative work in a publication that could inspire future innovations and serve as reference for the continuous development of important topics in the nuclear area.

We are extremely impressed by the efforts the Fellows and Mentors dedicated to finalize the text within the Summer Institute timeframe, at the same time they were preparing their impactful oral presentation.

We are grateful for the NNI Magazine Editor, Alina Constantin, who made sure all the pieces were correct and in place for its timely publication. The digital version of the NNI magazines can be found at: www.world-nuclear-university.org

Patricia Wieland
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FOREWORD

This year the Summer Institute attracted 82 Fellows representing 39 countries. They bonded in Romania and then gathered in Switzerland, under the close guidance of their mentors, to intensively work on the dedicated projects of the programme – the Networks for Nuclear Innovation. The thematic chosen reflects actual aspects of nuclear industry, which are or have to be driven even more by innovation, to cope with the global context of climate change and accelerated digitalization.

The Fellows developed ideas, concepts and practical solutions to promote innovation in their area chosen while addressing the Sustainable Development Goals. The presentation of their results achieved, during the closing day of the Summer Institute, called for reflection, adaptability and international cooperation. Institutional changes needed, short term, mid-term and long term perspectives, economical aspects and implementation ways were carefully studied by the teams. Some of the messages derived are captured in this brief introduction, being in the same time an invitation for the reader to carefully consider each of the projects described, engage in dialogue and disseminate the most feasible proposals.

Innovative nuclear reactors, the Gen IV and the small modular reactors can be the ingredients of a nuclear renaissance, having increased safety capabilities and ability to target specific customer needs.

In order to encourage the development of Gen IV reactors, it is needed to collaborate at international to consolidate the fundamental features of Gen IV design and simplify the process of validation.

When communicated nuclear energy outside the industry, the Fellows highlighted how important is to come from the same shared values to the social and ethical level in order to be understood and build solid partnerships based on trust. This is key in gaining more acceptance for nuclear and going towards the goals of the Harmony programme.

Different aspects and criteria have to be considered when assessing the feasibility of a nuclear project, this being the base of creating openness and support, as every country has its own particularities. A forum for providing technical advice on feasibility studies and sharing of information has been proposed by one of the teams.

People are a company's most important resource. Even with the most expensive and safest equipment and systems, high-performing organizations shall invest in their people and culture to truly achieve their vision and mission. In order to maintain a proper organizational environment, favourable to development and progress, periodical checks and assessments of the organizational health and state of the culture in the organization have to be performed.

Another message strongly reinforced was that creating and maintaining a valuable and well prepared human capital is crucial for nuclear but has also to keep the pace with the technology infusing now all aspects of people's life. Organizations have to be aware and prepared to allocate the needed resources while having a sound and adaptive strategy. Governments, academia, and nuclear industry stakeholders can join efforts to create an internationally connected nuclear industry network where individuals possessing qualifications needed are much easier identified, as well as shortages or surpluses of particular skills.

We hope that the reader will enjoy the content and find value in it.
Yours sincerely,
Alina Constantin
Editor-in-Chief

CHANGE. CONNECT. CONVINCE.

Innovative Communication Strategies to Nuclear Waste Management

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Abstract

Although the nuclear industry has demonstrated a safety record for several decades, the management, transport and disposal of radioactive waste is still one of the most controversial aspects of the nuclear fuel cycle today. However, the barrier in nuclear waste management is not a technical one, but rather a matter of communication with stakeholders. Indeed, most current communication strategies are not adapted to their target audience and the intended messages are not properly understood by the majority of the civil society. This NNI report delivers a general overview on waste management options with the purpose of addressing the main questions and prevailing issues among the stakeholders. The report concentrates on providing an innovative communication strategy aimed to shift public perception of nuclear waste management and to increase public trust and acceptance of nuclear energy as a whole. Our message is mainly addressed to decision makers (government) but also to the civil society (public and non-governmental organizations). The objectives of our communication strategy are threefold: share consistent and trustful information, share responsibility and share transparency. Three different audiences were identified as the key decision makers for whom the communication needs to be optimized, including schoolchildren, civil society and nuclear industry employees. Some measures have also been proposed to evaluate the effectiveness of the communication channels when implementing the communication strategy. This project will contribute to shifting public perception of nuclear waste management, therefore increasing public trust and acceptance of nuclear energy.

1. Introduction

Like all industries, the generation of electricity produces waste. Nuclear waste emits radiation and it needs to be managed safely and effectively. With the development of nuclear industry, the quantity of radioactive waste that we need to manage is increasing, but this remains **extremely low** compared to other forms of energy production and to the industry in general. Although the nuclear industry has demonstrated a safety record for several decades, the management and disposal of radioactive waste is still one of the most controversial aspects of the nuclear fuel cycle today [1]. However, the barrier in nuclear waste management is **not technical**, but a matter of **communication with stakeholders**.

This report presents a general overview on waste management options and provides the audience with an innovative communication strategy aimed to **shift public perception** of nuclear waste management and to **increase public trust and acceptance** of nuclear energy as a whole. The report is addressed to decision makers (government) as well as to the civil society (public and NGOs).

2. Nuclear waste management

2.1. What is nuclear waste?

Compared to other energy producers that externalize the costs of their waste on the society and environment, the nuclear industry is the only one that takes **full responsibility for all its waste**. Nuclear waste includes spent (burnt) fuel and operational waste from the nuclear power plants, waste from spent fuel recycling (when performed), waste from dismantling (decommissioning) nuclear installations, waste from nuclear medicine, agriculture, industry and research. Radioactive waste is normally classified as low, intermediate and high levels, according to the amount and types of radioactivity and consequently the demands in managing it [1]. The most difficult type of waste to manage is high-level/long-term waste arising from nuclear power generation. Nevertheless, high-level/long-term waste represents only a **very small fraction** of the total amount of nuclear waste and has been handled, transported, and stored for many decades virtually **without incident**, and certainly without harm to anyone. The cost of managing and disposing all nuclear waste is very small (less than a tenth of the total electricity bill).

2.2. How does nuclear compare to other electricity generation sources?

Compared with fossil energy sources and other renewable sources such as wind, hydro or biomass, nuclear power plants are amongst the **lowest greenhouse gas emitters** over the whole lifecycle. Nuclear energy is **sustainable** and can decisively contribute to fulfilling the goals of sustainable development. Lifecycle emissions of natural gas and coal generation are 15 and 30 times greater than nuclear respectively [2]. In addition, fossil fuel and biomass waste pollution from fine particles alone, not to mention climate change effects driven by CO_2 emissions, are estimated to kill almost 9 million people every year [3], that is a little more than the whole population of Switzerland.

In addition to greenhouse gas emissions, each electricity generation technology produces other types of wastes that need to be managed, such as non-recyclable silicon in solar panels, fiberglass in wind turbines, coal ash from coal power plants etc. Figure 1 compares all solid waste volume with energy generation technology

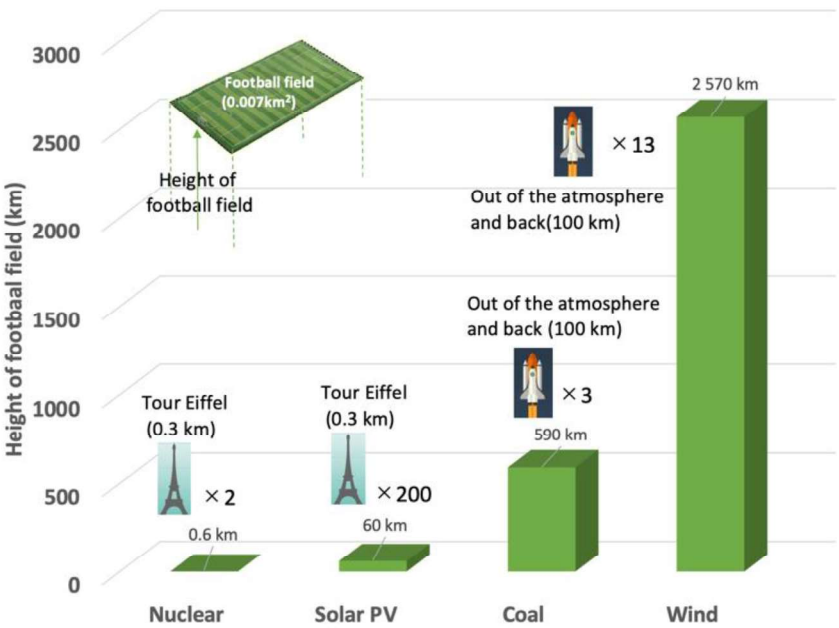

FIG.1. Comparison of cumulative waste volume by energy type in 2050.

[4][1]. The figure shows the cumulative waste volumes that each technology would produce if they generated a tenth of the global electricity demand (~2500 TWh) for the next 30 years till 2050. Solar photovoltaics produces around 100 times more waste volume than nuclear, whereas wind and coal ash volumes are higher by a factor of 1000 compared to nuclear.

2.3. What are the current options in waste management?

Low and intermediate level waste is generated at all stages of the fuel cycle and constitutes the large majority of the total nuclear waste. It has a low radioactive content, making it suitable for disposal in near surface facilities, currently in operation in many countries. To minimize the required space, treatment or conditioning processes such as incineration, compaction and physical transforming are currently used before disposal, reducing waste volume up to a third of the initial one [5].

Temporary storage facilities for the high-level nuclear waste already exist. The spent fuel from reactor can be recycled for recovering the valuable materials from it, or it can be safely stored and finally disposed without reprocessing (Fig. 2). With technology advancing, the spent fuel can actually be used as new fuel in 4th generation reactors, allowing a **substantial increase in sustainability**.

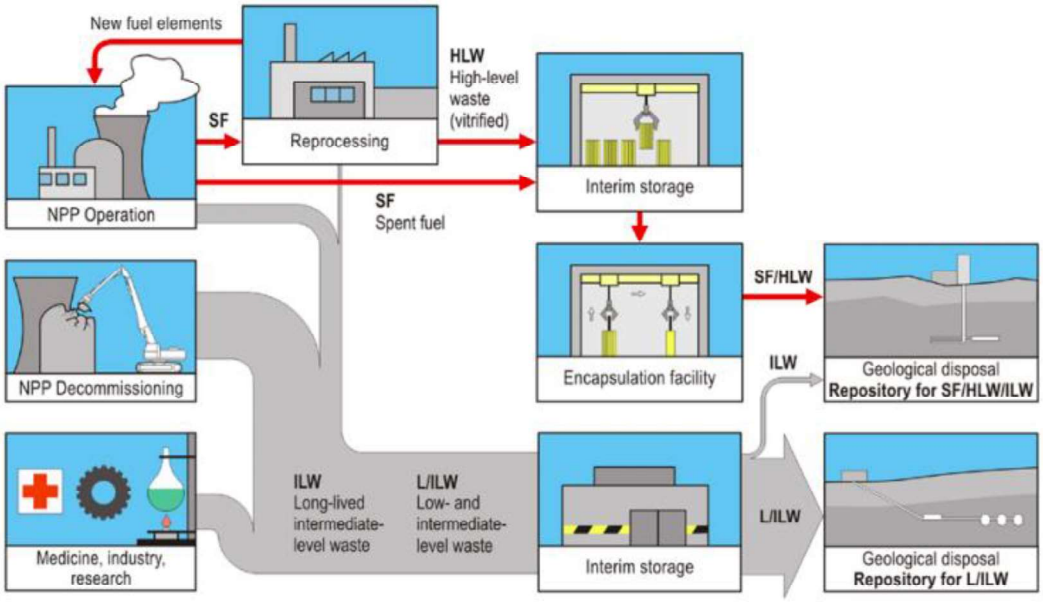

FIG. 2. Current options in radioactive waste management [6].

As an alternative to long-term storage, uranium can be separated from spent fuel by a chemical process, as some countries have already safely demonstrated at an industrial scale for decades. The material recycled in this way is used again as nuclear fuel, recovering even more energy. Another advantage of recycling is the significant reduction in the volume of high-level waste to about one-fifth [7]. Moreover, the level of radioactivity of the waste is decreasing to only a tenth of the initial value [8].

Other technologies for recycling of spent fuel have been demonstrated on a small scale and could be adapted for future types of nuclear fuels if necessary. Transmutation is another option that

[1] Data were compiled from the following sources:
a) GHENAI, C., Life Cycle Analysis of Wind Turbine, Ocean and Mechanical Engineering Department, Florida Atlantic University USA
b) Radioactive Waste in Perspective, OECD-NEA Report (2010)
c) https://www.wind-watch.org/faq-size.php
d) https://brightstarsolar.net/common-sizes-of-solar-panels/
e) https://www.wholesalesolar.com/blog/how-long-do-solar-panels-last/
f) https://www.solarpowerrocks.com/solar-basics/how-much-electricity-does-a-solar-panel-produce/
g) https://www.nagra.ch/en/volumesen.htm

can transform long-lived radioactive elements into significantly shorter-lived elements by burning them using an advanced 4th generation nuclear reactor. The goal is to have waste that becomes radiologically harmless in only a few hundred years, while reducing the footprint of the geological disposal and improving social acceptance [9].

2.4. What about transportation?

The proper transportation of nuclear materials and radioactive wastes is very important for the sustainability of nuclear industry. Transport of radioactive wastes has an **excellent safety record** (more than 44 000 shipments of high-level waste since 1962). No container with highly radioactive material has ever been breached or leaked [10]. As the most exposed part of the nuclear fuel cycle, transport becomes the focus of numerous social protests. The safety of transportation is accomplished by the concept of **defense in depth**: a combination of strict regulatory systems, specialized companies with rich experience, reliable operation procedures, and very solid containers providing mechanical integrity and radiation shielding, even under extreme accident conditions [11].

2.5. How does long-term storage work?

The long-term effects of high-level radioactive wastes make it necessary to ensure the safety of the waste storage facility for several tens of thousands of years. Many options have been investigated, but nowadays the scientific community agrees on the **deep disposal in a geological repository**. This confines long-lived/high-level radioactive waste in stable rock deep under the ground and isolates it from humans and natural environment on the ground [12]. A **multi-barrier system** combining deep underground "natural barriers" (such as rock, salt or clay) with "engineered barriers" consisting of several protective layers (such as steel or concrete) is commonly used [13]. The idea of such multiple barrier systems is shared internationally. Several nations have been working on deep geological repositories, among which Finland, Sweden, France and the United States are the most advanced. In most countries, waste is stored so that it is readily retrievable from repositories.

Any potential site is assessed to ensure safety and suitability in terms of technical, environmental and socio-economic aspects. The site should be able to safely contain and isolate the waste over the very long term, as demonstrated by a series of mechanical and geochemical analyses. In addition, the site should be located in a region where the overall impact on society is acceptable and beneficial effects are enhanced. The communication strategy accompanying the site selection is essential and early stakeholder engagement is key to its success.

2.6. How do we transfer the knowledge to future generations?

Since nuclear projects last many years and involve numerous stakeholders in different phases, there is a constant work of knowledge transfer, in order to guarantee the preservation of what is known [14]. As the greatest number of grid connections of power reactors were in 1984 [15], slowing down until the 21st century, it is of great importance that the experienced professionals continue to transfer to the new generation the accumulated knowledge in order that the industry can maintain its technical excellence, given the undergoing renaissance of the nuclear industry in the last years.

3. Developing an innovative communication strategy

The overall motivation of this report is contributing to **shifting public perception** of nuclear waste management and to increasing **public trust and acceptance** of nuclear energy, since the majority of the public perceives nuclear waste disposal as one of the major problems affecting nuclear industry. A better communication strategy will help defining the target audience and consistently articulating the message, so that all the stakeholders share the same mental model. Understanding the audience allows directing the efforts more precisely, and with the alignment of nuclear industry employees, board and other stakeholders, it will be easier to get the message across [16]. In this sense, Figure 3 shows the step-by-step actions for developing an innovative communication strategy plan for nuclear waste management.

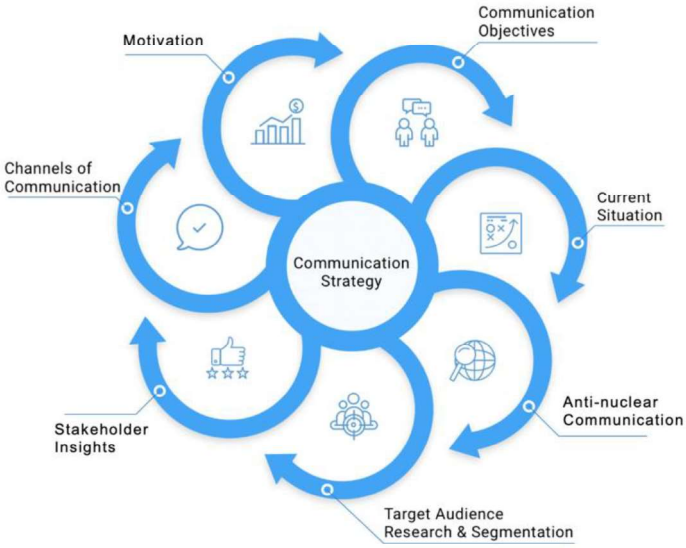

FIG. 3. Communication strategy plan (adapted from [16]).

3.1. Communication objectives

The public communication can be approached in various ways but the message always needs to be clear and understandable. The people with more knowledge and better understanding of nuclear energy will be more open to accept and support the building of radioactive waste management disposal in their surroundings.

The objectives of this communication strategy are to **share consistent and trustful information, share responsibility and transparency**. Sharing information is related to knowledge exchange and knowledge management. Being transparent while sharing the information builds trust and acceptance, and it is vital in the nuclear industry. The trust increases during the time, step-by-step, after a lot of engagement with stakeholders. The other objective is to share the responsibility, in the sense that all stakeholders (civil society and government) must be committed to the waste management issues and be prepared to respond adequately and quickly to the demands of society.

3.2. Current situation

The current anxiety and objection of public stem mainly from a **lack of confidence** and of a clear vision to the future and of the decision-making process. Most countries have already been operating communication programmes dedicated to waste management. However, these programmes are intended to only provide information via websites, seminaries and field tours.

The Nuclear Energy Agency recommends **adequate public participation** in all programme stages [17]. By doing so, the public ensures that they can influence the program and that the outcomes are reflecting their expectations. However, many countries are not fully satisfying with this recommendation and this brings out serious setbacks to the process.

The nuclear industry in general is **not sufficiently active** in sharing with the public its responsibilities and its confidence in the safety of nuclear waste management. At the same time, the public is not intensively involved in the decision-making process to reflect their expectations and concerns related to waste management.

3.3. Anti-nuclear communication

The public perception of the nuclear industry has been shaped by its association to military activities (nuclear weapons tests) and the three high-profile accidents that the industry has experienced (Three Mile Island in 1979, Chernobyl in 1986, and Fukushima in 2011). Less serious incidents resulting in small radioactive releases from operating plants have strengthened these perceptions. The strong activity of **anti-nuclear groups and organizations**, together with audience-driven **media reports** and apocalyptic movies, have exacerbated the sentiment that all "artificial" radiation and nuclear waste are extremely dangerous and have terrifying consequences on human health and the environment.

While these statements can easily be addressed and disproved with fact-based science, it is difficult to change the people's perception when faced with an anti-nuclear communication strategy focused on **fears and emotions**. Very strong imagery associating nuclear waste with desolate fields devoid of life, movies about the occurrence of horrible genetic mutations and cancers or even acrobatic events aimed at penetrating the sites of nuclear repositories are all part of a unified strategy conveying the message that nuclear waste is not safe. On the other hand, most antinuclear activists **avoid scientific confrontation** and often respond with half-truths or false misconceptions. The typical anti-nuclear rhetoric demands for **absolute guarantees** that a future nuclear incident cannot ever occur, without properly quantifying the consequences of such an event on public health and environment, and putting this into perspective with respect to natural radiation levels and other accepted risks.

4.1. Target audience and communication channels

Three different audiences were identified as the key decision makers for whom the communication needs to be optimized. The first group are **schoolchildren** at the age of 10 to 18. These are future decision makers in the long term, and are the most unbiased group of the population and hence more open minded to receive information. The second group is the **civil society** - the decision makers in the short term and hence a crucial group. The biggest obstacle for this group is that a large majority of them already have a firm opinion on matters, and convincing them with facts that go against their principles is more difficult. The third and final group is the people within the **nuclear industry** itself, i.e. the employees. Although the work force in the nuclear industry has some general ideas on nuclear waste management, the industry itself appears to be complacent on the issue. It is vital that people working in nuclear put the back-end of the nuclear cycle (decommissioning and waste management) on the same pedestal as building new power plants.

In order to identify the communication channels adapted for different audiences, the following formula was used: *Identify audience -> identify key message -> identify reason to believe -> identify the appropriate channel*. The following tables summarize the key communication messages and channels for each target audience.

TABLE 1. Key messages to be addressed to the target audience.

Target Audience	Schoolchildren	Civil society	Nuclear industry employees
Key Messages	Waste is normal: all electricity generation technologies produce waste; Nuclear industry produces the least amount of waste per unit of energy produced		Waste management is as important as new builds.
Engagement	Focus on medium / long term impacts	Focus on short term impacts	Pro-active rather than reactive
Reason to believe	Proven process: nuclear waste has been managed and transported safely for decades. All information and processes regarding waste management are transparent and easy to access and in consultation with the public.		Confidence in the regulatory processes, the safeguards and design, and the entire fuel life cycle management.

TABLE 2. Communication channels and content.

Schoolchildren	Civil society	Nuclear industry employees
Media: Emotion-focused advertisement campaigns highlighting the benefits of nuclear and nuclear waste management. Use all media channels available including written, broadcast, as well as social media. Employ specialized companies with expertise in public communication campaigns.		**Incentives** for employees to be more engaged in discussions with the public and media through direct contact and social media, in parallel to the official communication channels.
Entertainment: Board games /Video games / Smartphone App - subconsciously giving a more positive image of nuclear.		
Virtual reality tours of geological repositories (because some are not accessible due to distance or regulatory restrictions)		Increased international **cooperation** within the industry for sharing of best practises between the various countries.
School field **trips**, school science workshops, summer camps	**Technical visits** to repositories	Compulsory **technical visits** to repositories for employees in the industry
Display the waste amounts created by each technology in your generation mix along with the **electricity bill** - just like a carbon footprint for flying. Provide the option to choose your electricity mix depending on waste generation.		Give more importance to the back-end in the WNU curriculum - lessons about **waste management** in different countries.
Tools: fitness band with dosimeter showing the real-time radiation in daily life, so that one has a better idea of the exposed doses - such as higher doses while flying, while travelling in Kerala (India) or the Swiss Alps. Visible **dosimeters in public places** (stations, city centres) showing the background radiation.		
	Hotline - to address fake news or wrong viral information, Call Centre (Q&A)	More **technical information** for the employees, in the form of lectures about waste management. Simple take-away messages addressing public concerns.
	Public forums with anti-nuclear NGOs to actively address their concerns. Engage open-minded influencing environmentalists to shift their perception from anti-nuclear to pro-nuclear using climate-change based evidence	
Address the idea of **confirmation bias** - for example through a game - to show how certain mental models influence our decisions, how we are influenced by the media etc.		
Running competition on site of repository **–** organize events to increase public engagement within the repository sites.		

Among the highlights of the proposed communication strategy, some focus on **sharing information** in a clear and simple way, including familiarizing the public with the background radiation through the use of portable dosimeters on fitness bands, promoting entertaining games or stimulating nuclear industry employees to get more engaged in public discussions. Other channels aim at **sharing responsibility** about the consequences of energy-related waste, such as including the volume of CO_2 produced per type of energy in the electricity bill or running advertisement campaigns on the sustainability of nuclear energy compared to fossil fuels and some renewable energies. Finally, other channels focus on **sharing transparency** through engaging field trips or events centered around waste facilities, virtual reality tours or public discussions with antinuclear NGOs.

When these communication channels are implemented, it is important to evaluate the effectiveness of the communication with the targeted audiences. There are many evaluation tools, such as online surveys, face-to-face surveys, stakeholder interviews, case studies, social media monitoring, etc. Different evaluation methods can be used depending on the type of activity, the stage of implementation, or the resources available for evaluation [18].

4. Conclusion

Lack of confidence in nuclear waste management and negative public perception have been a major concern since the start of use of nuclear energy. The current communication strategies are not well understood by a large portion of the population. This NNI group focused on developing an

innovative communication strategy to shift this negative perception and increase the public trust, targeted for school children, civil society, and nuclear industry employees as the key stakeholders in the decision-making process related to nuclear waste management. A step-by-step communication strategy plan has been proposed to identify and analyse the project objectives, current situation, research on anti-nuclear communication activities, as well as to develop innovative communication channels for the targeted audiences. Some measures have also been proposed to evaluate the effectiveness of the communication channels when implementing the communication strategy.

This project will open the door for effectively communicating nuclear waste management with the public, and thus gaining more trust and support from the public.

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