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# Engaging youth in the management of radioactive waste: perceptions, intentions and expectations

Robbe Geysmans[a], Catrinel Turcanu[a] and Sigrid Griet Eeckhout[b]

[a]Science, Technology and Society, Belgian Nuclear Research Center SCK CEN, Mol, Belgium; [b]National Agency for Radioactive Waste and enriched Fissile Material, ONDRAF/NIRAS, Brussels, Belgium

**ABSTRACT**

Citizen participation in the governance of radioactive waste is crucial, not only in the siting and design of repositories, but during their construction and operation and even after their closure. However, this need for citizen involvement poses unique challenges due to the long time scales involved in the various phases of radioactive waste management (RWM). As participation needs to span over several generations, the involvement of young people in decision making opens up participation processes to innovation, ensuring at the same time their durability and representativeness. However, young people are currently underrepresented in various national radioactive waste management initiatives, which brings into question the durability and inclusiveness of participation processes. This paper uses a multi-method approach entailing focus groups and surveys to examine young people's perceptions of radioactive waste, their potential involvement in its management, and how such involvement can be facilitated. A representative survey ($N = 1060$) of the Belgian population shows that while risk perceptions and knowledge about radioactive waste are largely similar across age groups, differences exist with regard to the modalities of radioactive waste management (e.g. waste retrievability). We also found that young people (age 18–25) are less inclined to seek active participation in decision-making processes. Focus group discussions further highlight that aligning participatory initiatives with youths' interests (e.g. climate change) and integrating them into existing structures (e.g. school parliaments) could enhance youngsters' awareness and involvement in radioactive waste management.

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Radioactive waste management; participation; youth; intergenerational responsibility

## 1. Introduction

The early days of the nuclear industry were largely defined by technocratic governance approaches, featuring top-down decision-making (Augustine 2018; Simmons and Bickerstaff 2006). However, over time, such technocratic approaches were increasingly met with opposition at international, national and local levels (Kitschelt 1986; Meyer 2014). In the context of radioactive waste management (RWM), this rise of opposition can be exemplified by strong public and political protest against repository projects in the UK, Germany, Belgium and the US, to name only a few (e.g. Atherton and Poole 2001; Hocke and Renn 2009; Richter, Bernstein, and

**CONTACT** Robbe Geysmans Robbe.geysmans@sckcen.be Science, Technology and Society, Belgian Nuclear Research Center SCK CEN, Mol, Belgium.

Farooque 2022; Sundqvist 2014). In an effort to address this opposition, a seeming shift in decision-making occurred towards the end of the twentieth century, moving from top-down technocratic approaches to more democratic procedures, centering on concepts such as public involvement and stakeholder participation. Some authors have referred to this shift as a 'participatory turn' in radioactive waste management, reflecting a 'widespread acknowledgement in the discourse of policy actors and implementing organisations of the importance of social aspects of [RWM] and the need to involve citizens and their representatives in the process' (Bergmans et al. 2015, 347). While this participatory turn can be criticized because of the instrumental use of participation or the potential marginalization of voices in the debate (e.g. Durant 2015; Kuppler 2012), stakeholder participation as an idea and approach has become increasingly central in the implementation of radioactive waste management projects.

The implementation of participatory processes offers complex challenges, not in the least due to the extensive timeframes characterizing RWM projects. Radioactive waste needs to be contained and isolated for periods of several hundred years up to a million years, depending on the waste category and national context. Moreover, also the development and implementation of disposal projects tend to span generations, as it takes many decades to move from initial project planning to siting, operation and closure. An important challenge that emanates from these extensive timeframes, is that citizen involvement will need to be passed from one generation to the next (Kuppler and Hocke 2019; Landström and Bergmans 2015). A necessity thus exists to enthuse younger generations to take up roles in the radioactive waste management process, both in emerging programs where youngsters will be key actors in the decision-making process during the coming years, and in existing programs, where younger generations need to pick up the torch from older generations. Local experiences have shown that the involvement of youth in participatory radioactive waste governance proves challenging (Brazier et al. 2022; Dingenen and Bergmans 2023). In order to better understand how youth can be involved in radioactive waste management and how intergenerational continuity can be ensured, insight needs to be gained in young citizens' perceptions about radioactive waste, their intentions towards and expectations regarding potential participation in RWM, and which factors could facilitate such participation.

In current research, the topic of youth participation in radioactive waste management has only scarcely been explicitly addressed, even though an extensive social science literature on participation in radioactive waste management has accumulated over the years (Hietala and Geysmans 2022; Solomon et al. 2010). This article therefore aims to answer the following questions: How are (Belgian) youngsters (age 18–25) perceiving radioactive waste, and (how) are their perceptions different from citizens who are older than 25 years? What intentions do these members of Generation Z have regarding involvement in RWM? And what expectations do they have towards such involvement? Our research builds on a multi-method approach, combining data from a nationally representative survey among the Belgian population and dedicated focus groups.

## 2. Background

Over the years, extensive research has been conducted to understand how people perceive the risks of radioactive waste (management), linking these perceptions to acceptance of radioactive waste facilities, but also to potentially mediating factors such as perceived benefits, trust, or geographical proximity. Understanding how youth perceives the risks of radioactive waste, and moreover how such perceptions could be different from those of older respondents, seems an important factor to understand the challenge of engaging youth in radioactive waste governance. Various risk perception studies have directed attention to demographic factors, often providing descriptive statistics regarding the sample upon which the study draws. This has led to rather inconsistent findings with regard to age and its impacts on perceptions concerning radioactive waste (management). Some studies provide an indication that younger people seemingly perceive more risk related to radioactive waste (management) than older people

(Jenkins-Smith et al. 2011; Seidl et al. 2013), but others however find no significant differences attributable to age (cfr. Sjöberg and Drottz-Sjöberg 2009). Moreover, differences between older and younger generations regarding radioactive waste perceptions have been surprisingly little studied, with only a couple of studies in the past touching upon this topic, and almost none taking it as a main focus. An exception to this latter point is an older study by Drottz-Sjöberg and Sjöberg (1991), which focuses on differences in risk perception regarding nuclear energy and radioactive waste among Swedish adolescents and the adult population. This study found that in the 1980s, Swedish youngsters who participated in the study ($N = 380$, mean age = 18,2 years) perceived the risk of accidents in radioactive waste management as bigger than conventional personal risks (e.g. traffic accidents, drowning), and also indicated how both adolescent and adult males perceive risk of accidents in radioactive waste management significantly lower than females. However, between adolescents and older adults, differences in risk perception seemed not outspoken or statistically significant.

The relative lack of focus on understanding youth perceptions and attitudes towards radioactive waste is especially noticeable, considering the difficulties experienced with involving young people as stakeholders in RWM. While in many countries a participatory turn has taken place over the past decades, emphasizing the importance of citizen involvement in the governance of radioactive waste (Bergmans et al. 2015; Di Nucci, Rosaria, and Brunnengräber 2019; Lehtonen 2010a,b), experiences have demonstrated that young citizens seem more challenging to reach through existing engagement structures. Dingenen and Bergmans (2023) for example note that members of the Belgian partnerships which were developed for the disposal of low and intermediate level short lived waste expressed concerns about the lack of young people in their current participatory structures. Similarly, Hunold (2002) describes how the Community Liaison Groups which were formed in the early 1990s during the Canadian search for a site for a repository for low level long lived radioactive waste provided a good representation of various demographic groups and occupational backgrounds, but had an underrepresentation of students, young workers and native people.

The challenge of involving younger citizens is particularly important for two main reasons. First, in light of procedural justice, it is problematic that the voice of certain demographic groups would not be heard in the governance of radioactive waste (Krütli et al. 2015; Vilhunen et al. 2022). Second, given the extended time frames involved in the development and implementation of waste management strategies, a need exists to engage new generations in the decision-making process, to ensure the continuity of the participatory process also beyond site selection (e.g. Brazier et al. 2022, Sierra and Ott 2022). Various efforts have therefore been made to target younger citizens in information and participation campaigns regarding radioactive waste. In a 2022 flyer published by the Forum on Stakeholder Confidence of the OECD Nuclear Energy Agency, reference is for example made to communication materials developed for young school children in the UK, educational resources provided for the same age group in France, or video production contests on the topic of radioactive waste management in Japan (NEA 2022). Similarly, a recent national debate on high-level long lived radioactive waste disposal in Belgium had a dedicated track oriented towards schools, with the participation of 1090 students (16 to 18 years old), of whom 118 volunteered to participate in a concluding 'youth summit' to discuss and share 18 overarching recommendations on the topic of geological disposal (KBS Koning Boudewijn Stichting 2024a). Dedicated research efforts have also been made in several countries to understand the potential of young citizens' engagement through internet and social media initiatives (Lütters et al. 2024; NEA 2007). These initiatives demonstrate the need to move beyond 'one-size-fits-all' approaches to citizen participation in radioactive waste management, and highlight how needs and expectations regarding participation initiatives differ across different demographic and socio-economic groups.

Young citizens participate in society in ways which differ from those of older age groups. Political scientists have identified shifts from what has been called 'duty-based' citizenship to 'engaged' citizenship, or from 'traditional' to more creative, individualized or expressive forms of

participation (Dalton 2008; Hooghe and Oser 2015; Theocharis and van Deth 2018). Various accounts state that more traditional forms of civic participation (which can be described as formal and bureaucratic) might be decreasing, while participation 'in non-hierarchical and informal networks, in addition to a variety of life-style related sporadic mobilization efforts' (Stolle and Hooghe 2005, 159) is increasing, especially among younger generations (see e.g. Chryssochoou and Barrett 2017; Mirra and Garcia 2017; Rainsford 2017; Weiss 2020). Particular attention has been directed to digital forms of participation, emphasizing youth's familiarity with and frequent use of internet and social media (Banaji and Buckingham 2010; Ruess et al. 2023; Vissers and Stolle 2014). This literature highlights how forms of participation tend to shift, with youth also finding their way to more informal, horizontal and non-traditional means to express their opinions, share their thoughts and otherwise engage themselves in civic and political life. Such insights -combined with an identified need to engage youth in governance and decision-making on grand societal challenges- has led to a variety of efforts aimed at understanding and supporting youth participation in fields such as (environmental) sustainability (Dickson-Hoyle et al. 2018), air pollution (Brickle and Evans-Agnew 2017; Nolan et al. 2021) or climate change (Kolleck and Schuster 2022).

## 3. Methods

A multi-method approach is used to better understand youth perceptions about and participation in RWM, building on the quantitative analysis of data from a national survey among the Belgian population, and the qualitative analysis of data from four focus groups with young adults. While they both capture insights on youth participation, survey and focus groups were designed and conducted independently of each other (see below for a more detailed description of both methods). The former allowed gaining a general insight in potential differences between age groups at a population level, whereas the latter delved more deeply in specific views, expectations and concerns of youngsters. For both forms of data, 'youth' is understood as young adults who at the moment of data gathering were aged between 18 and 26, making them members of Generation Z – born between the late 1990s and early 2010s (Dimock 2019).

### *3.1. Quantitative research*

Quantitative data were gathered through a large-scale institutional public opinion survey on perceptions and attitudes of the Belgian population towards nuclear applications and ionizing radiation. This article draws on the 2021 edition of the survey, which collected data from a representative sample of Belgian adults (18+) with respect to province, region, level of urbanization, gender, age and professionally active status (Hoti, Perko, and Turcanu 2022). Data was gathered in December 2020 and January 2021 and was obtained through Computer-Assisted Web Interviewing (CAWI) using a stratified random sample (stratification regarding number of inhabitants in Belgian municipalities). A total of 1060 respondents filled in the survey (response rate 6.6%). Ethical approval for the survey was issued by the ethical committee of the University of Antwerp (Belgium), under application number SHW_20_77.

In this study, we analyze the survey items addressing radioactive waste management, specifically personal risk perception, knowledge about current management of high-level long-lived waste, attitudes towards geological disposal of high-level long lived waste and public participation in decision processes. Table A1 in the Appendix gives an overview of the various items and answering categories included in the survey.

*Risk perception* regarding radioactive waste was measured with the statement 'How do you perceive the potential risk to your health within the next 20 years from each of the following sources?', with radioactive waste as one among 14 sources. *Knowledge* on radioactive waste was measured by asking 'What do you think happens at this moment with high-level radioactive waste

in Belgium?', with as answering categories 'Buried underground', 'Burned', 'Stored on surface' (correct answer), 'Recycled', 'Other' and 'Don't know/no answer'. *Attitudes* to radioactive waste management were measured as the level of agreement with four items (see Table A2 in the Appendix). Items on *participation* in RWM focused on the desired involvement of various actors and personal intentions to participate (Table A3 in the Appendix). Personal participation intention was probed by asking: 'If plans existed to construct an underground disposal facility for high-level radioactive waste near your home, to what extent would you like to be involved in the decision- making process?', with the following answer options: 1= 'I don't want to participate', 2.='I want to receive information about the facility', 3='I want to receive information and express my opinion', 4='I want to participate in a dialogue towards a decision', 5='I want to be an active partner in the decision-making process', 6='I would never agree to have a disposal site near my home and would protest against it', as well as '7=Don't know/no answer". Answer options 2–5 are derived from the four levels of participation proposed, among others, by Krütli et al. (2010) -information, consultation, collaboration and empowerment- and have also been used in other studies (Turcanu et al. 2014; Hoti et al. 2021). The additional, sixth answering category was included to account for those participants who would find such a situation so unacceptable that they would refrain from any form of invited participation.

To investigate potential differences in perceptions and attitudes between different age categories, we conducted a one-way analysis of variance (ANOVA) with Welch test in case of unequal variances among the age groups. The three age categories distinguished between respondents born between 2003 and 1996 (category 1 – Generation Z, aged 18–25 at the time of the survey), those born between 1960 till 1995 (category 2 – roughly Generation X and Y, aged 26–60), and those born before 1960 (category 3 - Babyboomers, aged 61+)). Tukey or Games-Howell Post-Hoc tests, respectively, were applied depending on whether the homogeneity of variances was satisfied or not. All statistical analyses were carried out using the SPSS package version 29.0.

### *3.2. Qualitative research*

In addition to survey data, four focus groups were conducted in October 2022. These focus groups were organized in the context of an international workshop on stakeholder engagement, held in Dessel, Belgium, by the OECD NEA Forum on Stakeholder Confidence (FSC). The FSC is an international platform for radioactive waste management professionals (regulators, implementers, industry experts, researchers, and academics) that aims at improving stakeholder involvement in radioactive waste governance. Established in 2000, the FSC has a long history of promoting engagement through publications, meetings, and workshops (NEA 2024).

The 2022 workshop featured presentations, group discussions, and a serious game (developed by SITEX, the Sustainable network for Independent Technical Expertise on radioactive waste management (https://www.sitex.network/)). The event focused on citizen participation in radioactive waste management, with a particular emphasis on youth involvement. Youngsters from various countries were invited to discuss their experiences, perspectives, and expectations regarding stakeholder engagement in radioactive waste management (RWM). Some attendees had a pre-existing interest in nuclear waste management, while others had no prior exposure to the topic. This latter group consisted of Master students in product design from the University of Antwerp (Belgium). These students only participated during part of the program, attending some presentations and a visit to an interactive exhibition on radioactivity and radioactive waste management.

To ensure homogeneity within focus groups and heterogeneity between them (Freeman 2006), a total of four focus groups were organized.

In the first two focus groups, participants were already familiar with RWM. A convenience sample of eight young adults with a background in RWM volunteered to participate, with seven from France and one from Germany. Two focus groups with four participants each were formed.

These participants had various connections to RWM, including engineering students specializing in nuclear energy, a youth council member involved in site selection for a geological repository in Germany, and a member of an environmental organization.

In the other two focus groups, participants consisted of product design students without prior engagement in RWM. They were recruited through their professor at the University of Antwerp. Twelve students agreed to participate, all of whom indicated that they were generally uninformed about RWM before the workshop. These students were divided into two focus groups, each with six participants.

Informed consent was obtained from all participants, who were briefed on the purpose of the research, i.e. to explore their perceptions, needs, and expectations regarding RWM and the involvement of young stakeholders in this field. The focus group discussions covered the following topics: perceptions of radioactive waste and its management, expectations and opinions on stakeholder involvement in RWM (e.g. decision-making processes and citizen engagement), and potential barriers and facilitators to engaging young people in RWM.

## 4. Results

### *4.1. Perceptions of radioactive waste*

When bringing up the topic of radioactive waste in the focus groups with youngsters who did not have previous engagement with the topic, participants expressed rather negative perceptions of such waste, highlighting the potential dangers that it offers to humans and the environment. At the same time, they also emphasize that it seems a rather distant issue to which they did not really give a lot of thought or consideration before the focus group.

> It's also not like I really think about what it is or anything. I just know that it's a danger to humans and to humanity or something, I think (Participant focus group 3)

Interestingly, in the focus groups with youngsters who did have previous experiences, less emphasis was placed on potential dangers of radioactive waste. While in the latter groups, standpoints were certainly expressed that such waste needs to be minimized and handled safely due to potential risks, it was also considered as a by-product of our persistent and growing energy needs, and 'a price for continuing to increase our economy' (Participant focus group 1). Besides familiarity with the topic of radioactive waste management, other factors may also have played a role in these seemingly different findings, for instance the different cultural backgrounds of the participants, their educational backgrounds, or the focus group dynamic itself.

Looking more broadly at the wider public in Belgium in order to compare perceptions of young adults with those of other age categories who participated in the survey, it is interesting to notice that younger respondents had risk perceptions of radioactive waste ($M = 4.33$; SD = 1.36) which are similar to those of the highest age category ($M = 4.35$; SD = 1.41), and slightly lower than the middle category ($M = 4.09$; SD = 1.41) ($F(2,1020) = 4.13$; $p = 0.02$ in the ANOVA test); However Post-Hoc tests indicated that differences were statistically significant only between the middle and highest age category ($p = 0.02$ in Tuckey's Post-Hoc test).

### *4.2. Radioactive waste management*

When it comes to their views on the current management of radioactive waste, participants in the two focus groups with youth who were not previously engaged with the topic expressed a lack of awareness on how waste is currently being managed or intended to be managed.

> Only a few days ago did I find out that it wasn't underground. I thought it had been underground for a long time. So, it's really something that I know absolutely nothing about (Participant focus group 4).

This is also confirmed by the survey results, showing that knowledge about the current management of high-level radioactive waste in Belgium is sparse. Similar to other age groups, only 14.4% of the young adults know that it is currently stored on the surface (16.3%, respectively 14.8%, in age categories 2 and 3). Instead, almost half (48% in category 1, 50% in category 2 and 54% in category 3) think that it is buried underground.

In all focus groups, it was recognized that given the current status of radioactive waste management, the challenge ahead is a complex and multifaceted one. This complexity was linked to the extensive timescales involved in RWM, which are 'not about our [time]scale, [but] about thousands, millions of years' (Participant focus group 1). Interestingly, these extensive timescales are not primarily linked by the focus group participants to technical challenges, but rather to governance challenges. Participating youngsters for example emphasized that our current administrative and geographical borders are insignificant in the longer term, that societies will inevitably and significantly change over time, and how preserving awareness about radioactive waste will prove highly complex and uncertain given these societal changes. This latter aspect was further discussed in one of the focus groups, where participants expressed views in support of awareness preservation for future generations to take informed decisions regarding the waste. This is in line with recommendations made by participants to a recent youth summit on radioactive waste management in Belgium, who recommended that information about geological disposal facilities should be preserved for future generations to facilitate informed decision-making (KBS Koning Boudewijn Stichting 2024b). One such decision could be the future retrieval of the waste from the disposal, for a variety of reasons. Retrievability (the possibility to take the waste out of a repository for at least a certain amount of time after its emplacement) has been brought forward in academia and policy-making as potentially enabling a higher level of intergenerational equity (Lehtonen 2010b; Shrader-Frechette 2000), at least under certain conditions, such as the preservation of memory about the disposed waste and the temporal framing of retrievability (cfr. Kermisch and Depaus 2024; Kermisch 2016). The topic also emerged during one of the focus group discussions, with proponents arguing how they don't 'understand why it's a point of discussion whether they can retrieve it or not', as they considered it 'logical that you should always be able to dig it back up if necessary', while others thought it would be 'comfortable if we just leave [the waste] there and simply can't reach it anymore' (Participants focus group 3).

In terms of tackling the complex challenge of long-term radioactive waste, various discussions emerged on the do-ability and desirability of different management options. Current legal and regulatory frameworks in Europe (and elsewhere) focus on the development of waste management strategies at a national level, with an emphasis on geological disposal as designated final destination for high-level long-lived waste (e.g. EU directive 2011/70/Euratom). Some youngsters voiced critiques on the idea of national approaches, and instead wondered whether 'we should […] bring all efforts together and find maybe a European and worldwide place to put the disposal' (participant focus group 1), although the do-ability of such international solutions in terms of siting and fairness was considered particularly complex. Again, this is in line with a recommendation made by participants at the youth summit on the management of Belgian long-lived radioactive waste, which states how 'the option of an international disposal should be taken into account' (KBS Koning Boudewijn Stichting 2024b: 36, translated from Dutch). Furthermore, a short discussion ensued in one of the focus groups on the extent to which current waste management strategies should be based on potential future developments and possibilities. Arguments were heard in favor of looking in more depth at how 'nuclear waste can be used to create more energy', while others instead stated that 'we should not rely on the theories and the things that are hypothetically possible, but we have to deal with what we know today'(participants focus group 1).

Survey results (Table A2 in Appendix) revealed general skepticism that geological disposal solves the issue of radioactive waste management. A one-way ANOVA test showed a small effect of age ($F(2,911)=5.90$; $p=0.003$), but the difference was mainly between the middle and the older age category, with the latter being more positive about geological disposal.

Furthermore, we found a main effect of age category on the agreement with the idea that future generations should be able to retrieve the waste (F(2,848)=5.10; $p = 0.006$). Younger respondents, agreed less ($M = 3.08$, SD = 1.13) compared to the middle age category ($M = 3.47$, SD = 1.08) ($p = 0.005$ in Tukey Post-Hoc test). While the agreement with the need for retrieval among young adults was also lower, on average, than among those from the highest age category, this difference was not statistically significant in the Post-Hoc tests ($p = 0.08$).

The age divide between youngest respondents and other age categories was present also regarding the need to monitor the safety of the disposal (F(2,991)= 5.08; $p$ = .0.006) and support expressed for implementing geological disposal as soon as possible (Welch's F(2, 218)=14.99; $p < 0.001$ applied due to unequal variances). Specifically, younger adults agreed less on the need to enable future generations to monitor the safety of the disposal, compared to those in the middle and highest age category (($p = 0.004$; respectively $p = 0.04$ in Tukey Post-Hoc test). Furthermore, younger adults also agreed significantly less that geological disposal should be implemented as soon as possible ($M = 3.12$; SD.=1.15) than respondents from the highest age category ($M = 3.66$; SD.=0.95; $p < 0.001$ in the Games-Howell test), whereas they had similar views with those from the middle age category. These findings can be interpreted in several ways. One possible interpretation is that the preference for a longer wait before implementing geological disposal suggests that youth are relying on future technological and scientific advancements. Such arguments were, for example, put forward by a small number of students in the youth trajectory of the recent national debate on geological disposal in Belgium (KBS Koning Boudewijn Stichting 2024b). This reliance on technological advancement could then reduce the perceived need for safety monitoring of the disposal. Alternatively, it may indicate that young people view radioactive waste management as generally safe, both in terms of current storage (leading them to feel there's no immediate need for disposal) and in terms of future disposal (resulting in a lower perceived need for future monitoring). Another interpretation could be that younger respondents are less interested in the issue of geological disposal overall, meaning they are less concerned with both safety monitoring and the urgency of disposal, or that they see RWM as the responsibility of older generations rather than theirs. Further research is needed to explore these findings in more depth and better understand the possible interpretations.

#### *4.2.1. Different roles in radioactive waste management*

In the focus group discussions, there seemed to be a clear agreement that experts should be trusted in the development and implementation of RWM strategies. In all four focus groups, participants expressed high confidence in the work and expertise of scientists and regulatory authorities when it comes to managing radioactive waste.

> Geological disposal, I do believe in it. I don't think only five people have been working on it. They're working on it all across Europe (Participant focus group 4)

In numerous instances during the focus groups, the work done by experts was considered as vital in RWM, putting these findings in line with recent recommendations made by students participating in a national debate on high-level long-lived radioactive waste in Belgium (KBS Koning Boudewijn Stichting 2024b). Interestingly, policy-makers and political processes were in such contexts sometimes referred to as a nuisance or potential threat to the 'scientific approach' which was considered to be the basis of the development and enactment of RWM approaches.

> The politicians and political decision shouldn't affect the site selection process, which should be 100% scientific (Participant focus group 1)

> There needs to be a good balance between politics and science, because with politicians, there's this economic aspect, like, oh yeah, we're aiming for profit or something. I don't know, I'm just saying something now. But the thing is, ultimately the scientists are right (Participant focus group 3).

Such statements at least partially inscribe themselves in a technocratic discourse on radioactive waste management, which situate decision-making in the realm of science, technology and engineering. The survey results align with this finding, as it shows that 82% of the young participants believe that a scientific experts committee should have a high level of involvement in decisions, which is a similar view as that of other age groups (see Table A3 in the Appendix). It is important to note, however, that, looking at broader publics, deliberative forms of decision making receive support also from a large part of young adults; for instance, 36% of the young respondents participating in the survey expressed a preference towards citizens having a high level of involvement in RWM decisions. It is this topic to which we turn in the next section.

***4.2.1.1. Citizen participation in radioactive waste management.*** An important distinction was made by focus group participants between different forms of citizen engagement in radioactive waste management, with a main distinction between transparency about and actual involvement in decision-making. Participants did agree that it is of high importance that citizens are correctly informed about RWM. Respondents remarked how they currently felt that they themselves, but also the public more generally, did not always receive sufficient information about RWM. A stronger focus on the subject in education but also in media was perceived as key in tackling this issue.

> I actually think [providing more information] is very important because it concerns things that we will carry with us for the rest of our lives and the next generations. I just find it strange that, for example, we learn a lot about history in school but not about this topic, which literally partly determines our future (Participant focus group 4)

> I mean, the media are supposed to speak about this important stuff, so maybe they should pick up the subject (Participant focus group 2)

Making information available and communicating transparently on the subject was considered as a prerequisite to have meaningful public debates and citizen participation on the subject. Again, this finding is reflected by recent recommendations made by youth participants to a national debate on high-level long-lived waste in Belgium, which highlight the importance of information to enable significant societal debate and advocate for various communication channels to spread information on the subject (KBS Koning Boudewijn Stichting, 2024b). However, a notable hesitancy was observed in the focus groups, especially among young individuals with no prior engagement with the topic, regarding citizen involvement in decision-making on radioactive waste management. The perceived lack of public knowledge and the high trust placed in experts led many young people to express reservations about involving citizens in all aspects of radioactive waste management.

> Regarding how to dispose of the waste… I don't think it is up to us to decide. You also would not tell a surgeon how they would need to operate on your heart because you think it is better, without having the proper education (Participant, focus group 4).

Interestingly, one young participant also shared feelings of anxiety about potentially being involved in decision-making on this issue. This anxiety stemmed from a sense of '*being thrown in a group of people who actually are working on* [the subject of radioactive waste management]' and realizing that your opinion as a youngster, despite being a self-proclaimed non-expert, would be given significant weight (Participant, focus group 3).

In addition to the perceived lack of expertise as a barrier to citizen participation, other arguments were raised that questioned citizen involvement in decision-making on radioactive waste management. One concern was a perceived disinterest among citizens in being involved in the first place.

> Between 60% or 70% of all the people that have access to the information for nuclear waste management they say 'I will have information about that, I will have the information about the current situation, and I'm OK with that. I don't need anything else' (Participant focus group 1).

Others doubted the intentions of those participating in the decision-making process, as they perceived that 'most people, when they give their opinion, are not necessarily [focused on] what would be the best, but more about what would be the best for themselves' (participant focus group 3). According to some, this also entails that participation processes and public debates 'could become a dangerous game of misinformation' (participant focus group 3).

And finally, there were some arguments voiced that indicated a skepticism towards the participation process and its added value in se. Such arguments doubted whether the voice of citizens would in the end change anything in the decision-making process, as final decisions were perceived to be taken elsewhere (e.g. by policymakers).

> To be 100% honest, even our participation there for me will not change anything to any waste management in the future. Because the decisions are taken at a state level, and not at scientific level or anything like that (Participants focus group 1).

In general, it thus seemed that the participating youngsters felt confident and also saw a clear need to climb the lower spurs of Arnstein's classical citizen participation ladder, but were much more divided and wary regarding how high this ladder should be climbed, and hence how much power should be attributed to citizens in RWM processes (Arnstein 1969). This was also reflected in the survey results.

As regards the desired level of involvement of different actors in decisions on a high-level radioactive waste disposal, younger adults indicated a significantly lower level of desired involvement for the national government compared to the middle and highest age category ($p = 0.035$; and $p < 0.001$ in Tukey Post-Hoc test).

As regards personal participation intention, younger respondents indicated less often that they would never agree to a radioactive waste disposal in their municipality and would protest against it (21.5%) than those from the middle (27.1%) and highest age category (27.4%) When looking at the participation intention of the other respondents, who indicated a desired involvement ranging from no involvement at all, up to partnership, we found that age category had a significant effect ($F(2, 737)=4.00$, $p = 0.02$). Specifically, the younger the age category the less is the intended involvement ($p = 0.04$ in Post Hoc-Test for category 1 vs. 2; and $p = 0.014$ category 1 vs. 3). Altogether (see also Figure 1) then survey results confirm that young people are less inclined to participate in radioactive waste decisions irrespective of whether they are in favour or not of the disposal.

Nevertheless, in most focus groups, voices were heard which did see -at least under specific conditions- added value in citizen involvement in decision-making. One participant for example remarked how it is first and foremost up to science to rationally approach the decision-making process, but if 'an unsolvable question, according to science, remains, […] you can solicit [citizens'] opinions' (Participant focus group 3). In other instances, siting was brought forward as a specific stage during the RWM process at which the voices of local citizens could and/or should be heard. As main reasons for promoting citizen involvement, youngsters referred to increasing confidence in the radioactive waste management process, and ultimately attaining acceptance of the chosen waste management strategy.

> I think it can be interesting to involve people because you are less likely to oppose things that you really understand. When you just hear 'waste', your reaction might be: oh, no. But if you know what it is about, you feel more like you can participate in the discussion and that it is valuable (Participant focus group 4)

Such reasoning is in line with dominant instrumental approaches to citizen participation in RWM, which have been extensively described (e.g. Lehtonen, 2010b; Lidskog and Sundqvist 2004; Strauss 2010). Substantive or normative rationales for citizen involvement -which respectively emphasize improved decision quality through diverse perspectives, and democratic legitimacy (cfr. Fiorino 1990)- were not explicitly discerned by our focus group participants.

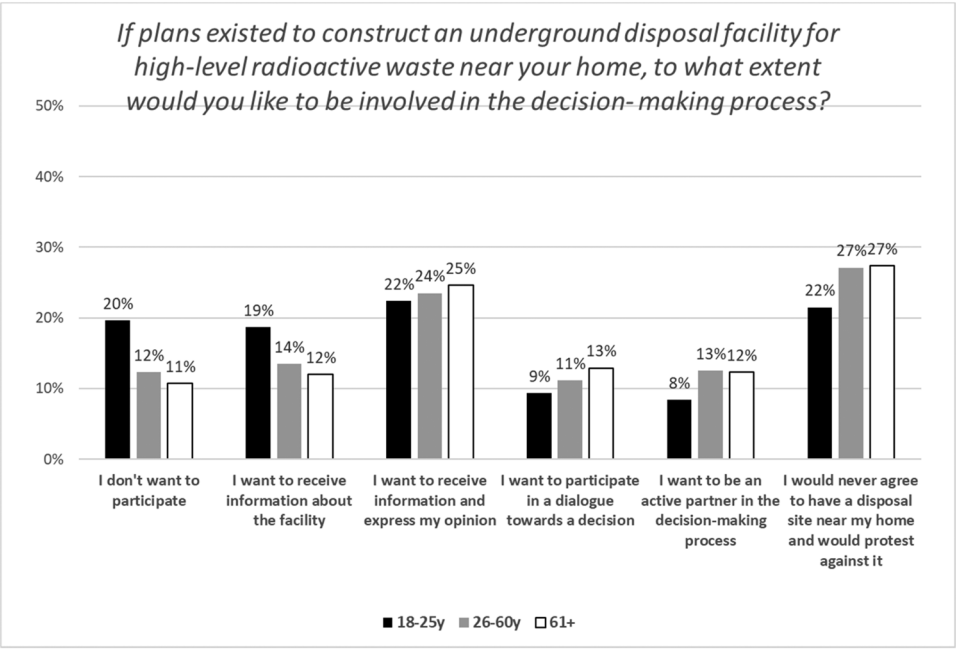


**Figure 1.** Participation intention ($N = 1060$).

***4.2.1.2. Enabling youth participation.*** As a final topic in the focus groups, participants turned to the issue of youth involvement, and how to potentially increase the presence of this demographic group in RWM participatory processes. First, it should be noted that a critical voice could be heard in one of the focus groups which questioned the maturity of youngsters to express well-founded opinions on the subject: 'to have a good opinion, maybe we can, they must wait until [they are] 20, 25 [years old] (Participant focus group 1). In line with discussions about citizen participation more broadly, some participants shared a feeling that 'the majority of the youth could be only wanting some information without participation: they only want to know what is the status quo, what is done right now, what is the law, what is going to be the future, and then they are fine' (Participant focus group 1). If, however, (some) young people would be interested in joining -and the voluntary participation of over a 100 youngsters in a recent youth summit on Belgian radioactive waste management is a clear indication of such interest (KBS Koning Boudewijn Stichting 2024b)-, it was considered important that such involvement would be enabled more strongly than is currently done in various national contexts. Main reasons for enabling the involvement of youth, were found in ideas that young people can offer fresh perspectives and views which are not to be found among older demographics, that early involvement would enable also participation at later stages in life, that youth will be 'stuck' with the waste for a long time still, and -as recognized in all focus groups- that youth involvement entails an investment in the future, as responsibilities need to be passed from one generation to another.

> Management of radioactive waste will need to continue for a long time, so you always want to, yes, find a way to engage young people to ensure that generation after generation remains involved (Participant focus group 3).

At the same time, it was also remarked how youth involvement cannot be considered as a means to access the voice of 'future generations'. While it is important to involve youth, this will need to be done with each new generation, as current youngsters 'don't represent [all] the future generations' (Participant focus group 2). Additionally, warnings were voiced of 'youth-washing' participation processes, by involving some youngsters or youth organizations

in the waste management process, and subsequently portraying them as 'the' voice of the next generation. Key attention should therefore be given to the empowerment of (willing) participating youth. It is through empowerment and making sure that young people 'have the feeling that [they] have the power to change something or to influence something' (Participant focus group 1), that genuine interest and engagement in the topic can be enabled.

On a more practical level, our focus group participants proposed a range of potential means and initiatives that could further facilitate youth involvement. They argued that as a first step, stronger investments should be made in providing information on RWM, adapted to the lifeworld and reference frames of young people. Especially the means of information provision need to be more tailored towards youngsters, for example by integrating it in education and school curricula, or using digital tools and media, such as social media, YouTube videos, or games.

> So maybe in schools, you can have game materials around [RWM], or an online game, in order to already raise interest in elementary school. In this way, you already know something about nuclear waste and don't have to find out about it only during high school or something. (Participant focus group 4)

Also low threshold recreational activities and spaces could offer a route towards informing youth, e.g. in the form of small 'lab experiments' to familiarize yourself with radioactivity, or having accessible information centers. In the context of the latter, multiple references were made to the Belgian visitor and information center Tabloo—a collaboration between the Belgian waste management organization ONDRAF/NIRAS and local communities in the context of a surface repository for low- and intermediate-level short-lived waste (www.tabloo.com). This finding should be understood in the context of the FSC workshop, during which all focus group participants had visited this visitor and information center.

> Because [Tabloo] is a place where you can meet some people, also experts, it's a place you can go with your child, if you are a parent, to do something on Sunday. It is also a place where you can just eat. It's good, because it is a place where you can go and learn something without being bored by the thing […]. You have to find a sneaky way to teach it (Participant focus group 2).

Regarding other forms of engagement, setting up dedicated participatory structures targeting young citizens was considered as a viable way to facilitate their involvement. The implementation of 'youth councils', as is currently already experimented with in Germany (cfr. NEA 2023), was brought forward as an option. Particularly the siting process was considered as a vital stage to involve youngsters in decision-making, and having a legal requirement to develop a youth council was considered a potential route. An attention point for some would however be that such a youth council should not 'isolate' youth in the decision-making process, but rather that youngsters are integrated to the same extent as other age and stakeholder groups. The extent to which participatory structures are representational of general population demographics was highlighted as an attention point.

> It should be integrated on the same eye level with all the stakeholders inside a procedure. But for access to information, access to nuclear waste management, then the youth council could be a key role model (Participant focus group 1).

Focusing more on awareness, participants in two focus groups pointed out that structures for future engagement with the topic of radioactive waste could be established through the development and facilitation of rituals, traditions and cultures around the subject. Referencing the persisting traditions of and interest in religion, youngsters hence considered that similar structures could keep the topic of RWM alive over generations. As such, these participants unknowingly inscribed themselves in older argumentations on the use of traditions and rituals in radioactive waste awareness preservation (see e.g. Sebeok 1984).

While potentially relevant to target young citizens, dedicated structures such as 'youth councils' might face challenges in attracting youth and next generations. Rather than setting up

dedicated frameworks or organizations for youngsters (Dickson-Hoyle et al. 2018), and in line with broader literature on shifts in citizen participation (e.g. Dalton 2008; Hooghe and Oser 2015), some respondents therefore suggested that information and participation activities could be linked to existing institutions and participatory structures which make it easier to reach youth. School is an obvious institution in this context, and examples were given of existing participatory structures in educational institutions, such as student councils or school parliaments, which could put the topic of RWM on the agenda and provide opportunities for students to voice their opinions. According to our respondents, this could take the form of dedicated thematic weeks in school, focused on broader themes such as 'long-term thinking', in which RWM can be integrated. Linking the topic of radioactive waste more strongly to various disciplines and educational tracks in higher education was considered as another possible way to bring the topic closer to the lifeworld of youngsters, e.g. in the form of Master thesis topics - not only in engineering or science education, but also in social science, graphic design or arts. Beyond school, also youth clubs such as scouting groups were mentioned as an existing structure in which youth can be brought into contact with the subject of radioactive waste management. Finally, also the existing political voting process was mentioned as a participatory structure through which youngsters could potentially have their voice heard on the subject, e.g. in light of a referendum on siting a waste repository. For all these structures and initiatives, a key point of attention will be the empowerment of youth, hence finding ways to actually make their inputs count in the governance process (cfr. Brickle and Evans-Agnew, 2017).

Moreover, for the topic of radioactive waste to find its entrance in these existing participatory structures, it needs to be made relevant for youth.

> You have to find a way to put… it's hard, but to put nuclear energy or waste in their daily lives, and how it could be useful right now (Respondent focus group 2).

This could be done by linking it to topics which are directly of relevance to their lives, in the form of specific effects and interests.

> I think it kind of comes down to, if I get to co-decide which one, then I also want to know what the effects of my choice are. So what would that mean for me? If I choose this, then what would that mean for me? (Respondent focus group 3)

A very concrete topic which was brought forward in this light, was the interest youngsters have in their future employment. Some respondents emphasized a perceived need to connect various waste management strategies to the potential effects these could have in terms of future employment opportunities and responsibilities.

> In the end it's always professionals who have to maintain [the radioactive waste repository], I think. […] How does [the waste disposal] affect the jobs which are going to be there? (Respondent focus group 3)

Another way of attaining relevance, would be to connect the topic of radioactive waste management to broader societal issues that youngsters care for or that (will) affect them in one way or another. Here, broader discussions about energy provision or climate change came to mind.

> In the end it is a question about scales between first defining a way of life, energy needs for the society, which will be found in an energy mix that we can do, or choose, which redefines the waste management. In each aspect there are decisions to be made. […] When you go down the scale it is going to be more and more technical. And maybe if you start with the less technical stuff you can maybe catch their interest there, so they can see the whole picture, see how everything is important in the end, and maybe try to engage them this way. (Respondent focus group 2)

> Maybe in the final year of secundary school, some kind of workshop-week [can be organized] […] about long-term thinking and ethical questions, and radioactive waste management could be integrated in it (Respondent focus group 4)

## 5. Discussion

In this article, an analysis is presented of youth perceptions about radioactive waste, youngsters' attitudes towards participation in the management of this waste, and ways in which such participation could be facilitated. Findings highlight how young adults did not seem to differ from older age groups in terms of their risk perceptions of radioactive waste, and their knowledge about current radioactive waste management (which seems rather low). In the focus group discussions conducted in this study, youngsters demonstrated a high perceived need for experts (scientists, authorities) to be involved in the decision-making process, while sometimes sharing doubts about or a low confidence in the role of policymakers and citizens. This was also reflected in personal participation intention which was somewhat lower than those of older age groups. Nevertheless, as shown by the survey results, there is also support for citizens' involvement in decision making on radioactive waste management, including more interactive forms of participation.

Research participants in focus groups further emphasized the need to be informed and to gain awareness on the topic of radioactive waste management, while being more hesitant towards any 'higher' levels of engagement. During focus group discussions, respondents therefore highlighted ways in which awareness raising could be facilitated among young people, although many of such facilitators could also enable a stronger voice for youth in decision-making processes on RWM. While some suggestions entailed the development of dedicated participatory structures -e.g. youth councils-, it seemed like most respondents considered that youth participation would benefit from a stronger alignment with and integration in existing lifeworlds, interests and participatory structures of youngsters. Schools were an obvious context, but also youth clubs and online communities were suggested. In general, digital tools such as social media and (online) gaming were considered as particularly appealing to younger citizens, hence enabling information provision to and participation of this demographic group.

These findings align with broader literature on youth participation in environmental matters, which shows that participation builds critical capacities and empowers young people as active contributors to sustainable development (Dickson-Hoyle et al. 2018; Rexhepi, Filiposka, and Trajkovik 2018). Digital participation, mixed digital and physical formats, and gamification are particularly effective for involving young adults (Rexhepi, Filiposka, and Trajkovik 2018). Grassroots participation, alongside formal structures, can also be valuable for youth leadership and capacity building (Dickson-Hoyle et al. 2018). It is vital to complement formal participatory structures in radioactive waste management with integrated, bottom-up initiatives that align with youths' interests and lifeworld. Additionally, it is crucial that young people see their contributions are heard and impactful, underlining the key importance of empowerment.

The current study responded to a need for dedicated research on youth involvement in radioactive waste management. This study offers a step towards gaining a better understanding of (the current lack of) youth participation in radioactive waste management, by attaining insight in how young citizens perceive radioactive waste and its management, their potential role in this management, and what factors could facilitate their involvement and the involvement of their peers. It found empirical evidence that -at least in the studied context- young citizens seem to be less inclined to participate in decisions on RWM, a finding which has already been experienced in practice in different national initiatives which struggle to attract young people. Moreover, focus group discussions brought to light various ways in which youth could be better targeted and involved in RWM, deviating from more 'traditional' participatory structures which have been set up in different RWM programs. Gaining this understanding is of key importance for the representation of various age groups in current debates and decisions on radioactive waste, and for the continuation of participatory initiatives across generations. It demonstrates the need to complement existing participatory structures in radioactive waste management -which are often focused on physical meetings and longer engagement over time- with initiatives focused on more short-term, episodic or digital forms of engagement. Of

course, this paper is only one step of many still to take, both in terms of broadening the gained insights and deepening them. It for example remains to be seen to what extent the findings presented in this paper represent generational/cohort effects, and hence will 'stick' to people as they age, or whether they are rather specific to particular age groups, and hence youths' perspectives and attitudes will shift as they grow older. We therefore hope our work can inspire both future research on this topic and the implementation of attained knowledge in practice.

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## Appendix Details on quantitative analysis

**Table A1.** Survey items radioactive waste management.

| Item | Answering options |
|---|---|
| Risk perception | |
| How do you perceive the potential risk to your health within the next 20 years from each of the following sources?<br>• Radioactive waste | 1. No risk at all<br>2. Very low<br>3. Low<br>4. Moderate<br>9. High<br>9. Very high<br>9. Don't know / no answer |
| Knowledge | |
| What do you think happens at this moment with high-level radioactive waste in Belgium? | 1. Buried underground<br>2. Burned<br>3. Stored on surface<br>4. Recycled<br>9. Other<br>9. Don't know / no answer |
| Attitudes | |
| To what extent you agree or disagree with the following statements?<br>• Geological disposal solves the issue of high-level radioactive waste.<br>• Future generations should be able to retrieve the waste from the geological disposal installation.<br>• Future generations should be able to monitor or measure the safety of geological disposal.<br>• In Belgium, we should implement geological disposal for high-level radioactive waste as soon as possible. | 1. Strongly Disagree<br>2. Disagree<br>3. Neither agree, nor disagree<br>4. Agree<br>9. Strongly Agree<br>9. Don't know / no answer |
| Participation | |
| In your opinion, to what extent should the following actors be involved in the national decision-making process concerning geological disposal as the final destination of high-level radioactive waste in Belgium?<br>• The national government<br>• The regional government<br>• The local government<br>• The nuclear safety authority<br>• Non-governmental organisations and associations<br>• The radioactive waste manager<br>• A scientific experts committee<br>• Citizens | 1. Not at all<br>2. To a limited extent<br>3. Moderate amount<br>4. To a large extent<br>9. Completely<br>9. Don't know / No answer |
| If plans existed to construct an underground disposal facility for high-level radioactive waste near your home, to what extent would you like to be involved in the decision-making process? | 1. I don't want to participate<br>2. I want to receive information about the power plant to be decommissioned<br>3. I want to receive information and express my opinion<br>4. I want to participate in a dialogue towards a decision<br>9. I want to be an active partner in the decision-making process<br>9. Don't know/ no answer |

**Table A2.** Means and standard deviations for variables measuring attitudes towards geological disposal of radioactive waste.

| To what extent you agree or disagree with following statements (1 = strongly disagree to 5 = strongly agree) | Age category | N | M | SD |
|---|---|---|---|---|
| Geological disposal solves the issue of high-level radioactive waste | 1 | 92 | 2.37 | .96 |
| | 2 | 533 | 2.37 | 1.11 |
| | 3 | 289 | 2.64 | 1.07 |
| Future generations should be able to retrieve the waste from the geological disposal installation | 25 y or younger | 89 | 3.08 | 1.13 |
| | 26–60 y | 495 | 3.47 | 1.08 |
| | 61y or older | 267 | 3.37 | 1.09 |
| Future generations should be able to monitor or measure the safety of the geological disposal: | 25 y or younger | 103 | 4.15 | .93 |
| | 26–60 y | 576 | 4.41 | .74 |
| | 61y or older | 315 | 4.36 | .71 |
| In Belgium, we should implement geological disposal for high-level radioactive waste as soon as possible | 25 y or younger | 82 | 3.12 | 1.15 |
| | 26–60 y | 452 | 3.29 | 1.07 |
| | 61y or older | 275 | 3.66 | .95 |

**Table A3.** Perceived need for the participation of different actors in decisions on the destination of the high-level waste in Belgium.

| In your opinion, to what extent should the following actors be involved in the national decision- making process concerning geological disposal as the final destination of high-level radioactive waste in Belgium? (1 = not at all; 5= completely) | Age category | N | Mean | Std. Dev. |
|---|---|---|---|---|
| The national government: | 25 y or younger | 103 | 3.68 | 1.00 |
| | 26–60 y | 563 | 3.94 | 0.98 |
| | 61y or older | 314 | 4.10 | 0.95 |
| The regional government | 25 y or younger | 101 | 3.46 | 1.00 |
| | 26–60 y | 561 | 3.49 | 1.09 |
| | 61y or older | 314 | 3.68 | 1.04 |
| The local government | 25 y or younger | 103 | 3.41 | 1.01 |
| | 26–60 y | 565 | 3.41 | 1.14 |
| | 61y or older | 311 | 3.64 | 1.05 |
| The nuclear safety authority | 25 y or younger | 105 | 4.39 | 0.80 |
| | 26–60 y | 567 | 4.31 | 0.79 |
| | 61y or older | 315 | 4.43 | 0.64 |
| Non-governmental organisations and associations | 25 y or younger | 100 | 3.27 | 1.07 |
| | 26–60 y | 550 | 3.30 | 1.09 |
| | 61y or older | 301 | 3.35 | 1.13 |
| The radioactive waste manager | 25 y or younger | 104 | 4.04 | 0.94 |
| | 26–60 y | 571 | 4.03 | 0.93 |
| | 61y or older | 314 | 4.14 | 0.87 |
| A scientific experts committee | 25 y or younger | 105 | 4.23 | 0.87 |
| | 26–60 y | 573 | 4.32 | 0.77 |
| | 61y or older | 321 | 4.41 | 0.67 |
| Citizens | 25 y or younger | 104 | 3.16 | 1.11 |
| | 26–60 y | 569 | 3.19 | 1.07 |
| | 61y or older | 310 | 3.31 | 1.07 |