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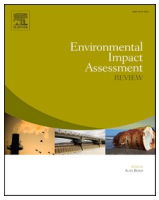

Missing steps in the assessment of the local economic impact of nuclear waste: The case of Italy

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ABSTRACT

The risk of adverse effects on local economies originating from the hosting of radioactive waste deep geological repositories and interim storage facilities has been only partially addressed in the literature. Most studies adopt the logic of economic multipliers and focus on benefits rather than potential costs. This may lead policymakers to adopt a biased perspective, as observed in Legislative Decree 31/2010 in Italy, where the process of planning an interim storage facility is underway. The article aims to critically discuss the logic of economic multipliers and contribute to the debate by shifting the focus towards the perspectives of risk perception, hedonic pricing, and willingness to pay. Such approaches, which have been adopted in studies on the effects derived from the transportation of radioactive materials, risks of nuclear incidents, and radiation releases at power plants, should inform citizens and can be useful in arriving at adequate and democratically agreed upon solutions. Their adoption would enable local communities to strengthen their awareness of potential negative socio-economic impacts deriving from such facilities.

1. Introduction

The 'nuclear power' option is back in vogue because of the ongoing energy crisis and pressing climate change. In the light of this renewed interest, it is worth discussing not only whether new nuclear power plants should be built but also how the resulting highly radioactive waste can be managed (Trontl et al., 2020; Bell and Macfarlane, 2022; Hilding-Rydevik, 2023; Smeddinck et al., 2022).

Almost 70 years after the start of the nuclear power age, only a few countries in the world have identified a viable solution for the siting of nuclear waste facilities (hereinafter, NWFs), such as deep geological and interim storage facilities (WNWR, 2019). Finland has been the first country in the world to decide on the final storage plan for its nuclear waste and is building a facility at Olkiluoto: Posiva Ltd. is already preparing to commission the repository in the coming years (Kojo et al., 2022; Vehmas et al., 2023). In 2022, the Swedish government granted the waste management company Svensk Kärnbränslehantering AB (SKB) a permit, in accordance with the Nuclear Activities Act, to build a repository in Östhammar and an encapsulation plant in Oskarshamn.

The policy decision about the siting of NWFs should be guided by a proper assessment of the implications for human health and the environment, on which experts still disagree (Ramana, 2018; Brunnengräber and Di Nucci, 2019; O'Mahony, 2021). Nonetheless, local communities are worried about socio-economic considerations too (Kojo et al., 2010; Di Nucci and Brunnengräber, 2017). The appraisal of the implications for the local economy from the siting of an NWF cannot be ignored and should be part of a democratic and participated decision-making process (Slovic et al., 1991; Flynn and Slovic, 1995; Lehtonen et al., 2020). Lack of awareness about socio-economic consequences can undermine citizens' participation (Sierra and Ott, 2022).

Most studies on the socio-economic implications of the hosting nuclear waste storage or disposal facilities adopt the logic of economic multipliers and focus on benefits rather than potential costs (Holm and Lindgren, 1997; Miller, 2010; Cabras and Mulvey, 2012; Fuentes-Saguar et al., 2017). This may lead policymakers to adopt a biased perspective as prompted, in the way we understand it, by the text of Legislative Decree 31/2010 in Italy where the process of planning an interim storage facility is underway. Sogin, the public company responsible for decommissioning Italy's nuclear plants and managing radioactive waste, focuses exclusively on the benefits and the resulting 'added value'. Sogin estimates that the construction of the interim storage facility and the related technology park (TP) will generate more than 4000 jobs per year

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for 4 years of construction: 2000 direct (internal and external) jobs, 1200 indirect jobs, and 1000 "induced" jobs. Then, during the operation phase, direct employment is estimated to account for an average of around 700 (internal and external) jobs, with about 1000 induced jobs. Accordingly, the facility and the TP represent a development opportunity for the hosting territory. The idea of complementing the interim storage facility with a TP would respond to the need for greater integration with the local community through activities that can strengthen the added value for the territory and the involvement of institutions, universities, associations, and local businesses (Cumo et al., 2016). The perspective provided by Sogin seems to be misleading and diverts attention away from the management of nuclear waste. Moreover, in the technical documentation there is no mention of the potential negative economic effects. All these elements make the approach adopted by Sogin questionable: the siting of an interim storage facility produces potential negative impacts not only to the natural, cultural, and historical heritage, but also to the real estate, agriculture, livestock farming, and tourism.

The issue of the adverse effects on local economies from hosting NWFs is not adequately addressed in the public and policy debate, neither in Italy nor in many other countries. Such a limitation reduces the motivation of citizens and local communities to participate in planning and decision-making. Our purpose is to critically discuss the logic of economic multipliers and contribute to the debate by shifting the focus towards the perspectives of risk perception, hedonic pricing, and willingness to pay (WTP). Such approaches, which have been adopted in studies on the effects derived from the transportation of radioactive materials, risks of nuclear incidents, and radiation releases at power plants, should inform citizens and can be useful in arriving at adequate and democratically agreed upon solutions. Their adoption would enable local communities to strengthen their awareness of the potential socio-economic impacts deriving from NWFs.

The article is structured as follows. Section 2 provides a review of the economic literature. Section 3 summarises the economic analysis undertaken in Italy. Section 4 proposes to retune the public debate, introducing some missed steps. Section 5 concludes.

2. Theoretical background

The literature review was carried out in February 2022, updated in July 2023, following a standard content-centric procedure (Tranfield et al., 2003). No specific time limit was adopted. In the initial stage of study and exploration, the focus of the review was broad, since the aim was not to overlook any theoretical or applied perspective potentially relevant to the appraisal of the socio-economic effects arising from the management of radioactive waste. This choice was also justified by the fact that the implications for the local economy are sometimes only dealt with incidentally within works that address different research questions and interests. We also opted to place no restriction on the level of radioactivity of nuclear waste, even though the interest in a socio-economic perspective may be directly related to the magnitude of the risks to the environment and human health.

The search query used in the Scopus Elsevier database covered various combinations of keywords in titles, abstracts, and keywords as follows: "nuclear" OR "radioactive" AND "waste" OR "fuel" AND "repository" OR "disposal" OR "storage". The query was run on research documents published in journals belonging to social sciences and environmental science, as well as to disciplinary areas such as economics and business. The query, limited to research articles, book chapters, and books published in English, gave a total of 1097 publications.

The subsequent analysis, supported by text mining tools for the selection of research outputs focusing on socio-economic effects, cost-benefit analyses, and impact assessments on local economies, led to the identification of 75 relevant research outputs published from 1982 to 2023. Then, a detailed screening of the 75 articles was conducted, and 21 articles were selected as relevant to the present study. On the selected articles we performed a backward (that is, going backward by reviewing the documents cited by the 21 relevant articles) and forward (that is, going forward to identify unchecked related documents citing the eligible articles) review to collect further 34 research documents. At the end of the review, we counted 55 research outputs, excluding technical reports and documentation published by agencies, consultancies, and private corporations.

2.1. The economic multipliers approach

This section provides a critical perspective on the socio-economic effects deriving from NWFs.

Holm and Lindgren (1997) examine the population and employment growth induced by the construction of an NWF in Sweden. The model resembles a traditional demographic cohort model, combined with some assumptions regarding the interdependencies with the existing local economic system. The quantified impact on the local population and employment is appreciable albeit not sufficient to compensate for the long-term negative trends already existing in the area. The authors stress that the NWF is meant merely as an industrial investment programme and recognise that this is "a rather controversial but direct approach" (Holm and Lindgren, 1997: 28).

Economic multipliers still play a major role in studies on the impacts generated by the construction of new nuclear power facilities (NPFs). Accordingly, such facilities would generate positive direct and indirect effects on local economies (Cabras and Mulvey, 2012; Fuentes-Saguar et al., 2017). In a more recent work, Cabras and Mulvey (2012) put the issue as follows: "The negative impacts are often related to environmental externalities, such as issues concerning the disposal of nuclear waste, or to the population's exposure to risks connected to potential incidents, concentration of radioactive material, health, safety, etc. Conversely, the positive impacts are generally associated with the socio-economic opportunities in terms of potential investments, employment gains and level of economic leakage/seepage of resources to the local supply chain that the presence of a nuclear site could produce" (Cabras and Mulvey, 2012: 710). Fuentes-Saguar et al. (2017) consider the indirect economic impacts on the local economy generated by the decommissioning of an NPF. The authors use a linear model based on social accounting matrices that develops the traditional input–output approach by covering the effects exerted on other economic sectors. The results show that, if an NPF is decommissioned, there will be negative impacts in terms of employment and value-added generation (Bond et al., 2004). Surprisingly, by reversing the perspective, no reference is made to the potential indirect benefits that such decommissioning may generate for local businesses and the value of buildings and land.

The economic multipliers perspective is common to other energy fields, such as renewables and non-renewables, and has been discussed critically (Glasson, 2017; Glasson et al., 2022; Collard et al., 2023). In our view, the limitation of the above approach is evident, and this limitation should be taken into consideration by the local communities in their decision to host an NWF: the siting of such a facility produces potential negative impacts on the natural, cultural, and historical heritage, the real estate, and some economic activities, such as agriculture, livestock farming, and tourism.

The above biased approach has been adopted in reports and documentation about NWFs produced by agencies, consultancies, and private corporations (IAEA, 2002; OPG, 2011, 2013; Cadence Economics, 2018; ANDRA, 2023). It should be acknowledged that, at times, a more coherent framework has been outlined (AECOM, 2011; Radioactive Waste Management, 2016). Although the negative socio-economic implications are mentioned, it is difficult to find extensive and thorough discussion. Often the justification that is found in the documentation is that, at a preliminary stage, it is not possible to determine in detail the likely extent and nature of socio-economic consequences as they depend on the characteristics of the host community and local economy. Hence, only a list of potential effects, both positive and negative, is outlined

along with possible measures to enhance and/or mitigate the overall impact (Posiva, 1999, 2008).

2.2. Some relevant theoretical perspectives

The first, albeit incomplete, attempt to adopt a more balanced perspective is proposed by Hamm et al. (1984). The authors provide an embryonic analysis of the impacts of siting a deep geological repository in a rural area on several dimensions: economic, demographic, public service, and fiscal. This includes both positive and negative effects. Very few studies published since this first work adopt a similar balanced perspective on the resulting economic effects. White et al. (1994) look at the economic impacts of the deep geological storage at Yucca Mountain, Nevada, and focus on tourism in Las Vegas and Clark County, emphasising that the negative effects on Nevada's economy could be strong. Along the same line, negative effects on the image of areas hosting NWFs are recognised by Easterling (1992, 1997), Slovic et al. (1993, 2012), Bassett et al. (1996), and Avolahti and Vira (1999).

This limited focus on the negative economic implications in the literature happens even though people adequately perceive the potential economic consequences. Kojo et al. (2010) study the siting of a deep geological repository in Finland and collect data to understand what residents believe to be the impact of an NWF. The results show that many of the respondents anticipated that the facility would have a negative effect on the "image" of the area and on the activities connected to nature around the repository. Kim and Park (2017) perform a structural equation model to analyse the determinants of local acceptance of the location of spent nuclear fuel repositories. Concerning the economic dimension, the authors find that the siting of such a facility might generate a negative image and lead to economic losses.

NWFs may evoke a wide variety of negative images that affect the perception of risk (Slovic et al., 2012). The facility and the associated negative imagery could, over time, become representative of the area in which it is located.

Easterling (1997) reviews the studies commissioned by the Nevada Nuclear Waste Project Office to estimate the economic impact of a deep geological facility in Nevada. The analysis finds that effects on tourism occurred for some repositories but not for others, and the conclusions emphasize the potential for negative effects: "In other words, when people think of the prospect of visiting Las Vegas, the repository will become one of the images that comes to mind. The theory assumes that this image will be highly aversive for the typical individual, and as such, will reduce the decision maker's preference for visiting Las Vegas" (Easterling, 1997: 637). Slovic et al. (1993) make a comprehensive attempt to estimate the negative effects from nuclear waste. The authors investigate the potential impacts of the proposed repository at Yucca Mountain on tourism, retirement and job-related migration, and business development in Las Vegas and Nevada. Adverse impacts are expected to result from perceptions of risk, stigmatisation, and socially amplified reactions to "unfortunate events": major and minor accidents, discoveries of radiation releases, evidence of mismanagement, attempts to sabotage or disrupt the facility, and so on. According to the authors, the risk that intense negative imagery associated with the facility could cause significant harm to Nevada's economy is strong. Conversely, Metz (1994) stresses that the claim that economic losses could derive from such repositories is not corroborated in empirical studies.

Some literature focuses on the impact that NWFs and the transportation of highly radioactive waste have on real estate. Negative effects are found on both residential and commercial properties (Gawande and Jenkins-Smith, 2001; Gawande et al., 2013). The standard hedonic model of house pricing takes the distance from the waste transportation route to the repository as a regressor, in addition to further control variables. Again, it is the public perception of the nuclear risk that causes the change in the price of real estate (Folland and Hough, 2000). Gawande and Jenkins-Smith (2001) use data on 9432 property sales in South Carolina to model the effects of the (highly publicised) transportation of spent nuclear fuel to a storage facility at the Savannah River Site. The results show that, in high-density urban areas, property values have declined substantially. Similarly, Gawande et al. (2013) assess whether 13 years of accident-free nuclear waste transportation still affects the market valuation of properties along the route. They find that the negative impact continues in the long term.

The literature published since the Fukushima accident focuses on estimating how much consumers would pay to reduce the risk of radiation exposure (Aruga, 2017; Matsumoto and Hoang, 2020; Wakamatsu and Miyata, 2021). Many studies find that consumers differentiate between food products from affected and unaffected regions, even when they are informed that the contamination risk in the regions is the same (Tajima et al., 2016; Wakamatsu and Miyata, 2017). Tajima et al. (2016) test the change in market prices using monthly panel data on the price of six types of fresh vegetables from each of the 47 Japanese prefectures traded in the Tokyo metropolitan central wholesale market from January 2006 to March 2015. The results show that the price of vegetables grown in Fukushima prefecture fell by 10–38% after the disaster compared with counterfactual estimates in the absence of perceived radioactive risk. This effect persisted over the next 3 years, even after radioactivity detection tests had been passed successfully. Wakamatsu and Miyata (2017) observe that seafood from Fukushima and adjacent prefectures was considered lower than that originating from other regions. The authors argue that the reason lies in the reputational damage that affected local producers and retailers, even though seafood from Fukushima were safe enough. The authors conduct an experiment to measure the impact: respondents were willing to pay 94 yen less for seafood when it came from Fukushima, and prices in Miyagi and Ibaraki, adjacent to Fukushima prefecture, were 50–60 yen lower than for other domestic products. Aruga (2017) observes a reduction in the prices of seven agricultural products following the Fukushima accident. The author uses the contingent valuation method to derive the WTP for agricultural products (rice, apples, cucumbers, beef, pork, eggs, or shiitake mushrooms) from the regions near the NPF and identify influencing attributes. Interestingly, the survey contained the following question: "Are you willing to buy [A] from a region 100 km away from the nuclear plant if the discount rate of this product was [x]% compared with the product from a region 300 km away from the [NPF]?" (Aruga, 2017: 681). Initially the discount percentage was proposed to be zero. Then it was increased by 10% to a maximum of 60% if the consumer answered "no" to the previous question. If the respondent continued to answer "no" to the proposed discount percentages, up to seven subsequent questions were asked until the discount percentage reached 60%. Conversely, if the respondent answered "yes" to a certain discount percentage, no further questions were needed. Although more sophisticated and consistent approaches can be found in the literature, such as the multicriteria analysis methods (Munda, 2004; Diaz-Maurin et al., 2021), we emphasize the feasibility and intuitiveness of the hedonic pricing and WTP methods. They allow the implications on the local economy to be highlighted through simple and direct reasoning, representing a first concrete step towards participatory and shared decisions by the host local community.

3. The socio-economic analysis behind the Italian interim storage facility

3.1. Direct and indirect benefits

This section summarises the economic approach adopted in Italy. According to Sogin, the interim storage facility would produce direct and indirect benefits for local communities. The economic analyses carried out by Sogin are available in Sogin (2020a, 2020b, 2020c).

As required by Legislative Decree 31/2010, Sogin has drawn up a proposal of benefits, divided into:

- employment benefits and

- benefits to individuals, businesses, and local authorities in the area.

In accordance with the provisions of article 27, paragraph 2, letters f) and h) of the above Decree, Sogin provides a preliminary assessment of the employment prospects that will derive from the interim storage facility and TP:

i) benefits linked to the activities carried out for the management of the facility (direct employment benefits),
ii) benefits generated in the economic system through the production chain by suppliers involved in the activities linked to the NWF (indirect employment benefits),
iii) benefits generated by the increase in economic activity in the area, not directly linked to the facility but thanks to the facility (induced employment benefits).

Sogin estimates that, in the construction phase, the total employment benefits may exceed 4000 units per year (of which 2000 are direct internal and external jobs, 1200 are indirect jobs, and 1000 are induced jobs). These numbers seem to be in excess compared to the UK experience, according to which the estimated number of jobs for the construction of a geological disposal facility (which is a rather more complicated and costly project) is an expected average of 2000 (direct) jobs in any given year over a time span of about 175 years (Nuclear Waste Services, 2022).

In the next (operational) phase, lasting 40 years, direct employment is estimated at an average of about 700 employees, including internal and external ones, with induced employment that can increase to about 1000 jobs on average. In the phases of the closure and monitoring of the repository, which will last over 300 years, Sogin estimates that the decrease in jobs can be offset by the start-up of research activities in the TP thanks to the presence of prepared facilities and logistical services in operation as well as an induced workforce of high-level and experienced professionals.

Sogin forecasts that an increasing share of jobs will be offered to residents of the surrounding areas, who will be able to develop specific know-how through the training activities in the TP. Sogin formulates the above estimates based on the preliminary planning and a comparison with similar facilities in other countries.

3.2. Economic compensation

Sogin specifies that other countries in which NWFs are being built have adopted a system of direct and indirect benefits as compensation for using a portion of land for a long period of time and a reward for the local communities. In accordance with Legislative Decree No. 31/2010, the area that will host the NWF and TP will receive a monetary contribution based on the agreement between local authorities and Sogin.

Based on the provisions of article 27, paragraph 2, letter i), Sogin proposes economic compensation and monetary rewards to enhance the commitment of local communities and "protect" the value of the buildings, land, and local economy. Table 1 shows, for each stage of the project, the aims and objectives of the direct benefits, the underlying rationale, the beneficiaries, and the legal framework.

As shown by international experience, Sogin emphasises that the added value that the TP will bring to the surrounding area extends beyond direct benefits and employment and will represent an opportunity for long-term development. According to the NEA (2007), the definition of added value needs to be specific to each site and local community, and has to be developed in consultation with local stakeholders. Therefore, it seems that Sogin did not adopt the suggested perspective, by which the implementation of an added value approach or a community benefit package must be dependent on the context and guided by the overall perception of interested stakeholders, such as local communities, but also the media and non-governmental organizations (Lehtonen and Kojo, 2019). Nonetheless, it should be stressed that the added value perspective has not always been implemented correctly in practice for the difficulties in combining different stakeholders' interests and needs at each stage of the process (Elam and Sundqvist, 2006; Kojo and Richardson, 2019).

According to Sogin, the facilities will generate:

- benefits deriving from the increase in economic activities as a function of the adaptation and enhancement of the facility (e.g., transport routes) and services (e.g., water, gas, sewerage, and digital networks) in the area hosting the facilities,
- benefits deriving from the presence of the facility, such as the expected increase in the local population and in the economic development of local activities and services.

4. The economic analysis of NWFs: Missing steps

4.1. The impact on the local economy

Technical report A) deals with the TP, although attention should have been paid to the repository and its implications for health, the environment, and the economy. The transport, management, and storage of highly radioactive waste may exert negative effects on the local economy, especially on agriculture (crops and livestock) and tourism, not to mention property prices.

Such negative economic effects cannot be ignored: if the perceived risk and the related image resulting from the presence of a highly radioactive waste repository were negative, it would be reasonable to expect deleterious implications for the demand for local products (vegetables, fruit, meat, eggs, etc.) and tourism services and hence (indirectly) a negative impact on the employment in the area.

Technical report B) focuses on estimating the effects that the facilities will generate for new jobs, a large number of which, at least in Sogin's view, could be offered to residents. According to Sogin, the construction phase will begin after the executive plan and should last 4 years. The number of jobs for this phase is estimated using an "employment factor" expressed in terms of 8–11 jobs per million euros invested. As a result, an average annual total number of employees, both internal and external, is indicatively 2000.

The next "operational" phase will last about 40 years. Around 700 people will be needed to manage the site in the first 15–20 years, distributed as follows: 271 employees in the disposal area of the NWF, 177 in support services, 95 in quality, safety, and security, 62 in the

Table 1
Quantifying direct benefits.

Phases	Legal framework	Indicative rationale	Beneficiaries	Aims and objectives
Authorisation–Construction	Law No. 239/2004	One-off as a percentage of the total estimated investment	Local authorities involved as a percentage established by law	Information activities and involvement of stakeholders in the authorisation process, independent verifications, and socio-economic development of the area
Operation	Law No. 368/2003	Progressively increasing, up to about 15 million euro/year: annual update by the CIPE	Territorial entities concerned as a percentage established by current regulations	Control activities on facility operation and independent verifications; socio-economic development of the area

Source: Sogin (2020).

storage area, and 60 in the research area of the PT.

Based on the above considerations, 150 employees will be involved in the last phase, in which will occur the dismantling of all the facilities, the removal of high-level waste to its final location in a deep geological repository, the subsequent dismantling of the high-level waste storage complex, and the construction of a multilayer cover. An average of 100 people will be needed for site management, 50 of whom will work for the TP. Overall, in the last phase, about 250 employees per year are expected.

Once the operations at the NWF have been completed and the cover has been built, the monitoring phase will begin, with a duration of 300 years. The activity in this last phase will consist of managing the site safely, including surveillance and control services for the facility, research and development in the TP, and general services. Sogin estimates an indicative number of employees around 100.

The effort to detail how many jobs will be required, as well as the time frame, is appreciable. However, we need to estimate the direct impact on the resident workers who can effectively be employed in the project. Moreover, we should quantify the negative impacts on the local economy, which may reduce the indirect employment benefits (point ii above). If a positive (direct) effect on new jobs can be expected, what will be the net effect on the employment if the image associated with the repository puts the production of local goods and services at risk?

Technical report C) envisages the chance of adopting compensatory measures to protect the local businesses on the one hand and the value of buildings and land on the other. In this document, Sogin introduces the concept of compensation and thus seems to imply a negative impact. Nonetheless, the kind of negative impact is not specified. A non-trivial issue concerns the measurement of the expected negative effects. As one moves away from the repository, there will be fewer risks to health, the environment, and the local economy. The quantification of the risk (and the related compensation) must be correlated with the distance from the NWF (Kojo and Richardson, 2009).

4.2. Risk perception by local communities

The magnitude of such impacts could be realised using regional profiling and surveys (Kari et al., 2010; Litmanen et al., 2010). The former consists of circumscribing the local communities that are likely to be affected by the proposed facility and gathering data about the labour force, education, the industrial structure, and social well-being (Sjöberg, 2009; Kojo et al., 2012). The surveys involve asking residents questions. Socio-economic factors play an important role in forming the public opinion, and surveys should be used to gather insights into the public opinion and prepare action plans aimed at changing the public attitudes towards the subject of interest (Bergmans et al., 2008; Trontl et al., 2020). A possible survey may include a simple and straightforward question as follows: "For each of the following statements, please tell me whether you totally agree, tend to agree, tend to disagree, or totally disagree with it:

1. The siting of an NWF near your home would have effects on the environment and health.
2. The siting of an NWF near your home would have negative effects on the environment and health.
3. The siting of an NWF near your home would have effects on the local economy.
4. The siting of an NWF near your home would have positive and negative effects on the local economy.
5. The siting of an NWF near your home would have negative effects on agriculture, livestock farming, and tourism.
6. The siting of an NWF near your home would have negative effects on property values."

Such a survey would provide a rough measure of the perceived risk. The answers may help to identify a proxy for the impact of the facility on the local economy and focus on those issues that are of most concern. However, one point must be emphasized: companies and authorities in favour of the project might be unwilling to carry out such a survey, because asking would be likely to prompt concerns that otherwise might stay dormant.

It is possible to identify two possible scenarios or outcomes of the survey. Table 2 summarises a combination of the possible answers with respect to three economic dimensions:

- A. Net direct impact on employment in the NWF and TP (which includes the assessment of direct effects on new jobs in the NWF and TP),
- B. Indirect/induced positive effects on employment outside the NWF and TP,
- C. Net impact on local economic activities (agriculture, livestock farming, tourism) and property values $\geqq 0$ (which accounts for positive economic effects and concerns about negative economic effects).

In the table, "+" shows a prevailing positive attitude (i.e., if you totally agree or tend to agree with it), while "-" indicates a prevailing negative attitude (i.e., if you tend to disagree or totally disagree with it). To simplify, we assume that indirect and induced effects on employment necessarily go hand in hand with the presence of direct effects, taking their sign (positive or negative). Hypothetically, 10 possible scenarios, each with a different combination of positive and negative attitudes, exist: five of these are highly unlikely given the low probability that the construction of a new facility would generate a non-positive effect on direct employment. For such a reason, these are not shown in Table 2.

The other five scenarios are all possible, clustering into two different outcomes: scenario 1 and scenario 2. In the former, in which the direct, indirect, and induced employment effects are expected to be positive, the local community should be inclined to host the facility based on economic considerations (scenario 1). On the other hand, for all other scenarios citizens should be more careful when assessing the economic impact (scenario 2). In this case, a prudent analysis is essential to negotiate compensatory measures that are more congruent with the economic damage caused, if perceived as such by respondents, and that adequately account for the potential negative implications for the local economy.

The negotiation and definition of compensatory measures will follow the phase of identification of the eligible areas, and the local community can arrange to arrive prepared at the negotiation table with a comprehensive framework of the expected socio-economic effects. Some modelling approaches could be adopted to understand the links between economic activities and identify the overall impacts. Quantitative methods are regional input–output analysis, integrated modelling, and computable general equilibrium modelling. These methods require considerable amounts of data. Input–output analysis is a commonly used technique, while the other two methods are more sophisticated.

Sogin identifies several eligible sites for the NWF. The province of Viterbo (in Lazio) is the area with the highest density of potential sites, listing 22 potentially suitable areas out of a total of 67. Of the 22 areas,

Table 2
Expected economic effects – possible scenarios.

		Scenario 1	Scenario 2
A.	Net direct impact on employment in the NWR and TP	+	+
B.	Indirect/induced positive effects on employment outside the NWR and TP	+	+
C.	Net impact on local economic activities (agriculture, tourism) and property values $\geqq 0$	+	-

Legend: "+" stays for a prevailing positive attitude; "-" stays for a prevailing negative attitude.

seven have the highest scores of eligibility: five are in class A1 (potentially eligible areas with maximum score) and two are in class A2 (potentially eligible areas with a 'good' score). In the province of Viterbo, 14 municipalities are involved. The municipality with the highest number of eligible areas is Tuscania (with eight areas), followed by Canino (five), Montalto di Castro (five), and Arlena di Castro (four). Some of these areas show a very strong inclination towards agriculture, livestock farming, and tourism.

The facilities will occupy on an area of 150 ha, of which 110 will be dedicated to the repository and 40 to the TP. The special concrete containers (modules), which will enclose the metal containers with the radioactive waste inside, totalling about 78,000 cubic metres of radioactive waste, will be placed inside 90 reinforced concrete constructions (cells). The facility will receive waste for several years and store it until it is no longer radioactive.

If we look at data on the local economy of Viterbo, we can gain a basic understanding of the possible negative implications. In the province of Viterbo, agriculture is the main economic resource, with the production of vegetables, fruit, olives, wine grapes, sugar beet, cereals, and potatoes. The manufacturing sector is characterised by a high incidence of traditional processing (foodstuffs, textiles, clothing, and the extraction of quarry minerals, such as kaolin, fossil flours, and siliceous sands) and prevailing medium and small-sized industrial concentrations, except for the industrial district of Civita Castellana (ceramics). The service sector is underdeveloped, but tourism activities emerge in Montalto di Castro, Tuscania, and Tarquinia, with increases pre-Covid in agritourism activities, hiking tourism (Acquapendente, Bagnoregio, and Montefiascone), and "food and wine" tourism.

5. Conclusions

The purpose of the article was to provide a critical analysis of the economic approach adopted in the literature on the local socioeconomic impacts of hosting a nuclear waste storage or disposal facility, and to suggest the introduction of alternative methods focusing on risk perception, hedonic pricing, and WTP.

We argue that to assess the socioeconomic effects on the local community what matters is not only the 'real' risk, but also its the perception: the perceived risk is often higher than the real one. For such a reason, we must acknowledge that the way in which this perception is formed is crucial, and this is where methods such as WTP and hedonic pricing can play an important role. We should be prepared for all possible repercussions, whether they are immediate, remote, or even irrational. In the short term, following the hosting of the facility, citizens may perceive the area as 'risky', opt for products and locations elsewhere, give up their holidays in the area, or forego the purchase of a property near the repository. Uncertainty surrounding the health and environmental implications amplifies anxieties and worries and increases the expected impact on the economy. Additionally, we may expect that some distant adverse events (e.g., an accident with radiation leakages at an NPF thousands of kilometers away) may generate negative implications for the economic activities carried out in the area hosting the NWF.

An increasing number of studies focus on the assessment of the impact that the siting of deep geological and interim storage facilities, as well as the transport of radioactive waste, has on property values, helping to realize the potential socio-economic implications that could arise for the local community. Negative effects have been found on both residential and commercial properties. Again, it is the public perception of the nuclear risk that may cause the change in the price of real estate (Folland and Hough, 2000; Gawande et al., 2013). In high-density urban areas, property values have declined substantially, and negative impacts persisted in the long term (Gawande and Jenkins-Smith, 2001).

Similarly, a growing body of literature employs models aimed at estimating WTP, which is the maximum amount of money an individual is willing to pay to purchase something, such as food produced near an NPF or NWF (Tajima et al., 2016; Matsumoto and Hoang, 2020; Wakamatsu and Miyata, 2021). Models aimed at measuring WTP inquire about the effects originating from a major event, such as an accident at an NPF or the beginning of operations at an NWF. Consumers differentiate between food products from affected and unaffected regions, even when they are informed that the contamination risk in the regions is the same (Tajima et al., 2016; Wakamatsu and Miyata, 2017). The decrease in price for the 'affected' regions could be higher than 10%, and the effect persists over a time span of a few years, even after radioactive detection tests had been passed successfully. This shows that the reputational damage in some cases is difficult to erase. Finally, the decrease in the price of goods and services produced and offered locally is inversely proportional to the distance from the NPF or NWF (Aruga, 2017).

Despite several methodological and empirical issues that may arise with these methods (Kuminoff et al., 2010; Small and Steimetz, 2012), the above approaches help articulate the underlying reasoning. Additionally, it is helpful that only a few intuitive operational steps are needed to conduct an assessment of the expected negative effects on the local economy. Such approaches should inform citizens and can be useful in arriving at adequate and democratically agreed-upon solutions. Their adoption would enable local communities to understand the potential negative socio-economic impacts deriving from NWFs.

The economic analysis provided in Italy for the public consultation refers mostly to the economic benefits that would arise from the location, construction, and operation of the NWF and its associated TP. There is no mention of the potential risks and negative effects perceived by consumers and tourists and no discussion of the possible reduction in the WTP for goods produced locally and services offered near the NWF. The potential negative impacts on property values have been neglected too. Such a condition appears to be the outcome of two converging forces: the limited attention given in the literature to the costs and negative impacts of hosting an NWF, as extensively discussed above, and the inherent difficulties in conducting such an assessment at an early stage in the process of selection of eligible areas. Nevertheless, neither of the reasons should justify uninformed choices and decisions that could adversely impact the ability of local communities to actively participate in informed debate and decision-making on NWFs.

Even if it is not possible to determine in detail the extent and nature of socio-economic effects originating from the hosting of NWFs, as they depend on the location of the facility, it is important that citizens have as broad a knowledge basis that they can draw upon when considering the impacts of facility siting. This is also the prescription in the guidelines by the International Atomic Energy Agency (IAEA, 2014) and the Institute for Environmental Protection and Research (ISPRA, 2014). ISPRA (2014) affirms that the selection, among the potentially eligible areas, of the sites (which, in the IAEA recommendations, correspond to the 'Area survey stage – site screening phase') should take the socio-economic aspects into consideration.

A framework for the appraisal of potential effects, both beneficial and adverse, needs to be identified in advance and explicitly, along with a series of generic measures that could be adopted to enhance or mitigate the overall impact. A more detailed, location-specific assessment could be carried out in more advanced stages of the process, also distinguishing the effects for each phase of the life cycle of the facility. The frame must be made available soon so that local communities and interested stakeholders can contribute data and economic interpretation, helping to understand the objectives and nature of the compensatory measures.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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