ISSN 1831-9424

European Commission

JRC SCIENCE FOR POLICY REPORT

Social impacts of nuclear closure and decommissioning

Guidance for assessment

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2023

Joint Research Centre

EUR 31312 EN

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC131260

EUR 31312 EN

PDF ISBN 978-92-76-59103-0 ISSN 1831-9424 doi:10.2760/410344 KJ-NA-31-312-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Gerbelova, H., Shortall, R.(s), *Social impacts of nuclear closure and decommissioning*, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/410344, JRC131260.

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Abstract

Nuclear closure and decommissioning is an inevitable process facing many EU member states, regardless of current policy. Several member states have also indicated that they will eventually phase out nuclear power completely in the longer term. Affected host communities will have to deal with social impacts, both positive and negative. The closure of such an important industrial facility may have major negative social impacts, especially in remote locations where nuclear power plants are the main source of local employment and income. Social impacts, however, have unique characteristics and tend to be neglected or inadequately accounted for in policy appraisals. Following the principles of social impact assessment (SIA), an internationally recognised framework, this study represents a guideline framework for future social impact assessments in affected communities.

We present examples of possible indicators for evaluating and forecasting social impacts of nuclear closure/decommissioning, which should be useful for both communities carrying out a local social impact assessment and policy-makers alike. We also provide advice for mitigation and enhancement strategies, monitoring plans, engagement approaches and reporting and governance arrangements that may be used by communities during the closure/decommissioning process.

Acknowledgements

We would like to thank Vaida Rukaite-Drazdove for her valuable contribution to this study via the case-studies. We extend our heartfelt thanks to those who helped organise the workshop, especially Ariane Liessens who did an excellent job of planning and facilitation. We thank Franck Wastin, Kaisa Simola and Anna Mengolini for their continued support of this research and the anonymous reviewers for reviewing this report. We are also extremely grateful to the participants of the workshop who gave up their valuable time to help us in our research.

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Executive summary

Regardless of the plans for nuclear energy at national level, each nuclear power plant (NPP) will eventually close and enter the decommissioning phase. If not properly managed, this may result in negative impacts for host communities. Since nuclear decommissioning projects are complex, involve many stakeholders at different scales, and are underpinned by uncertainty, it is especially important to consider social impacts, which tend to be neglected in socio-economic assessments due to their subjective or 'hidden' nature. It is therefore vital for the long-term prosperity of the community to pre-emptively identify possible social impacts to ensure the best outcome for the closure strategy. This study represents an initial analysis of the social impacts that may arise in host communities in EU member states, with the aim of providing guidance for localised social impact assessments (or similar undertakings) when they may occur and also to guide policy-makers on this topic.

Policy context

An economy that works for people is one of the European Commission priorities for 2019-2024([1]). Within this context, the effective implementation of the European Pillar of Social Rights is seen now more important than ever and greatly depends on the resolve and action of Member States, who primarily hold responsibility for employment, skills and social policies([2]). At the same time, the JRC Strategy 2030 calls for stronger anticipation culture to ensure a timely evidence for policies.

To support policy-makers and hosting communities in planning closure strategies, we present here insights into the key social impact assessment processes. The framework presented here allows for better understanding of social impacts emerging from the NPP closure and decommissioning on the hosting communities. An anticipated evaluation of the social impact will alleviate the industrial transition and enable prosperous growth of the affected community.

Key conclusions

Based on our analysis it is possible to draw some general conclusions regarding the social impacts of nuclear closure and decommissioning. However, it should be borne in mind that for every case the impacts and affected parties will differ, depending on local and national contextual factors. This implies that a full investigation of the impacts should always be done in each community, with the meaningful participation of affected stakeholders. With proper prior planning, the negative impacts can be mitigated and avoided and costs of the transition can be optimized. The closure of the NPP is only the beginning of a major structural change for the region and it should be perceived as an opportunity.

Main findings

Due to the age of the existing fleet in Europe, number of communities in the Member States are at risk facing NPP closure and decommissioning. Based on our analysis of case studies, literature and a workshop, we were able to identify key social processes and resulting social impacts for different phases of the NPP closure and decommissioning.

The closure of the NPP affects everyone in the community to some extent. In general, impacts on employment are considered the most important socio-economic impact. The NPP operator is often the major employer in the community and brought highly qualified workers and their families to the community. It has provided jobs, not only to NPP operation, but also to sub-contractors and indirectly associated activities induced by the consumption of the employees and their families.

It is important to note that many of the social impacts on workers are felt before the decommissioning itself begins. In particular, these are psychological issues of workers, personal and family income issues and management performance issues. All of these can cause distraction from normal activities, and thus reduce the safety culture, which is extremely important for the safe operation of the NPP.

However, not all impacts are necessarily negative. Some impacts may fluctuate over time and what initially seemed like negative impact may turn into an opportunity for something new. In this way, the closure of the

([1]) https://ec.europa.eu/info/strategy/priorities-2019-2024_en.
([2]) https://op.europa.eu/webpub/empl/european-pillar-of-social-rights/en/.

NPP offers prospects for the future economic development of the area. Highly skilled workers can attract new investors.

There may be also considerable interest for repurposing of the NPP site and taking advantage of the existing infrastructure. The presence of spent nuclear fuel at decommissioned power plants represents a significant and ongoing barrier to economic recovery and may cause concerns on safety of the temporary waste storage. On the other hand, waste processing ensures continuation of some business' activities on the site, which may be opportunity for the existing professional profiles of workers.

The dismantling of the facilities and the revitalization of the land also requires intensive transport of materials. It can create congestions, disrupt private and public transport and also brings a higher risk of traffic accidents, especially near schools and parks. In addition, higher air pollution, dust and noise can affect residents with medical preconditions, children and elderly people. On the other hand, the in-coming workers and drivers seek for specific local services, creating opportunities for local businesses.

The main aspiration for SIA is to mitigate the negative impacts and ensure that the project brings greater benefits to the community. For this purpose, we provide a list of possible mitigation and enhancement actions for the the most common impacts to the NPP project and to the hosting community in general. We also provide examples of indicators for some common impacts. Indicators serve as a mechanism to monitor the impacts and the progress of mitigation and enhancement actions.

For the success of the coping strategy, the NPP operator must work closely with local authorities and together they have the greatest responsibility over the monitoring of the transition process from the NPP closure towards the future development of the affected area. In the long run, the transition needs to promote the engagement with the local community to identify options to address potential negative impacts and ensure community cohesion.

In the SIA context, stakeholder engagement should go beyond simple informing or consultation, and rather use approaches that employ an inclusive and empowering democratic philosophy and involve members of the community in decision-making, in particular vulnerable and minority groups.

Establishing regular and standardised reporting will ensure that the area remains a safe place even after the NPP operator leaves the site and shows whether the continued development has a positive impact on the affected area.

Related and future JRC work

This report presents a first and tentative step to describing the social impacts of nuclear closure and decommissioning and aims to provide a guideline for assessing those impacts based on a desktop research and one workshop, mainly, with experts. Future research should involve additional participatory research, which should include more (and diverse) representatives from host communities using appropriate methods to capture local context, a plurality of viewpoints and at the same time empower citizens to design the future of their communities. Further research should also verify that any indicators produced are easily interpretable and communicable, crosschecked and compared with other data and across contexts.

Quick guide

After introduction to the topic, chapter 1 presents summary of perspectives for nuclear power in EU Member States and overview of the NPP hosting communities. In addition, the chapter introduces the Social Impact Assessment framework. Chapter 2 explains the approach followed in this study. Chapter 3 identifies the most common social impacts arising from the NPP closure and decommissioning and Chapter 4 presents examples of mitigation and enhancement strategies for those impacts and expands on indicators that serve to monitor the progress of changes over time. Chapter 5 provides insight into the stakeholder engagement and show examples of participatory methods used in social impacts assessment. Chapter 6 covers the reporting, governance arrangements and grievance mechanisms. In chapter 7 some additional recommendations for policy makers are briefly presented. Chapter 8 specifies limitation of this study and possible future work and chapter 9 closes the report with key findings.

1 Introduction

Nuclear power plant (NPP) closure and decommissioning projects (here shortened as nuclear decommissioning projects, NDPs) are especially complex because of their high costs and associated socio-economic and environmental impacts. They involve many stakeholder's activities at different scales, carry various uncertainties and are political sensitive (Invernizzi et al., 2017). They are also ethically sensitive because of ethical dilemmas e.g. related to intergenerational implications and the uncertainty of some risks (Taebi et al., 2012).

Along with technical, environmental or financial challenges, (Invernizzi et al., 2020) identify social and ethical challenges as one of the most important group of factors influencing the outcomes of NDPs. However, research on the societal aspects of nuclear decommissioning is still lacking (Perko et al., 2019) and socioeconomic impacts of plant closure are not well understood, which hinders effective policymaking (Nuclear Decommissioning Collaborative, 2020). Failure to mitigate social impacts can result in major hindrances to NDPs.

Two major challenges to NDPs arise from lack of acceptance from the public and personnel transition (Invernizzi et al., 2017). Personnel transition involves retraining employees, restructuring management, or creating alternative jobs or compensation strategies. This may lead to lower staff morale, lack of engagement and organisational problems. The community loses knowledge and human capital and workers may be forced to relocate. Resistance from the local community stems from fear, lack of knowledge, or low participation. Mitigation of these issues is important to ensure the closure and decommissioning runs smoothly.

Ensuring the ethical acceptability of NDPs will require taking account of the plurality of opinions and values of stakeholders through a bottom-up analysis of social concerns. Social Impact Assessment (SIA) provides a framework in which participatory and deliberative methods for assessing impacts on communities are applied.

The purpose of this research is to facilitate the monitoring of these possible impacts, which can help the NPP hosting communities to support their closure strategy and guide them through the transition process. The report does not attempt to carry out a full-blown social impact assessment, but aims to provide a preliminary assessment of socioeconomic impacts of nuclear plant decommissioning as well as guideline for assessing the social impacts of future closure and decommissioning projects. Addressing and analysing these impacts will ensure minimising the long-term adverse effects on the community and when a nuclear power plant announces its closure, all relevant activities are carried out in a safe, efficient and responsible manner.

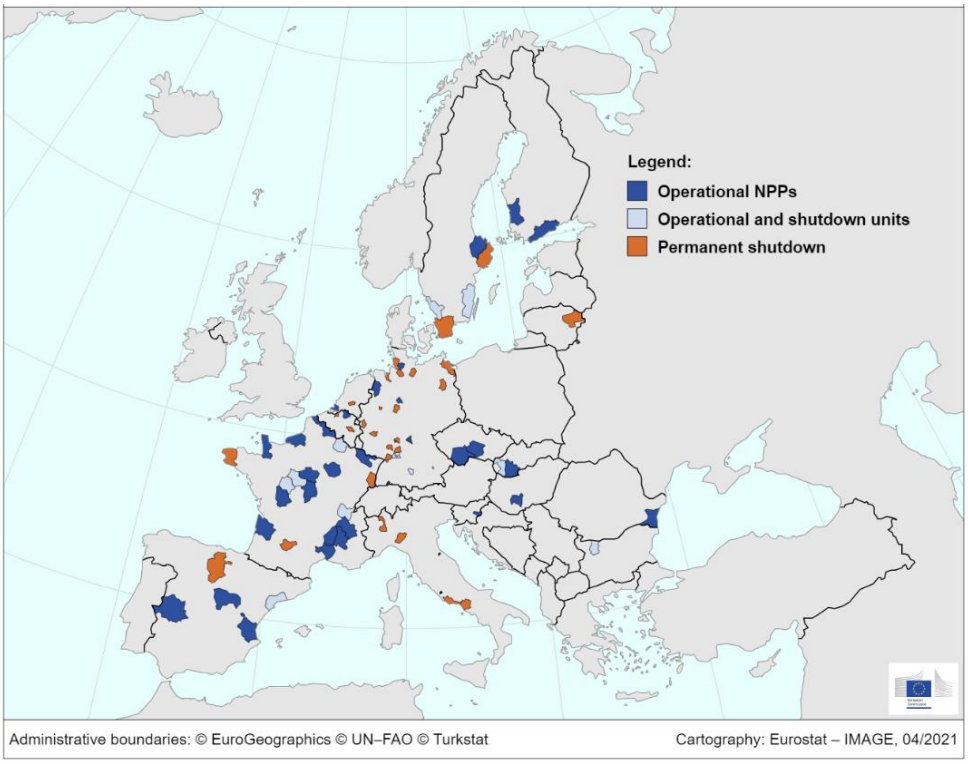
1.1 Overview of NPPs in the EU

Independently of the policy for nuclear energy at national level, each NPP will eventually close and enter the decommissioning phase. Even a country with nuclear expansion plans, can close the NPP in one site and build another elsewhere. The closure of such an important industrial facility, like the NPP, may have major social impacts on the hosting community. Especially in remote locations where nuclear power plants are the main source of local employment and income.

To gain insights into the topic, we firstly reviewed lessons learnt from different host communities across Europe which have faced NPP closure and analyse the socio-economic impacts on the hosting community. As we can see in Figure 1, last year there were 31 NUTS3 (Nomenclature of Territorial Units for Statistics) classification level regions with host permanently closed NPPs.([3])

([3]) There are three notes we would like to mention for a proper reading of this map. Firstly, the figure presents only NPPs in operation and permanently shut down. However, there are others regions with NPPs under construction or in planning phase. Secondly, some shut down NPPs are sealed and not decommissioned. Lastly, this map indicates in light blue colour regions which may have already shut down at least one of the unit of the existing NPP.

Figure 1. NUT3 regions hosting operational and permanently shut down units.



Source: Own elaboration on data from PRIS([4]).

Due to the age of the existing fleet in Europe, this issue will touch a relatively large number of hosting communities in the medium term. Therefore, we collected information on the currently operating NPPs and their future plans according to national perspectives. Table 1 presents the different trends for nuclear energy in EU countries. While some countries continue to build new units, others, such as Germany, Spain and Belgium plan to phase out nuclear power in the relatively near future.

Table 1. National projection for nuclear power capacity (MW) until 2050 in the EU based on the IAEA country profiles.([5])

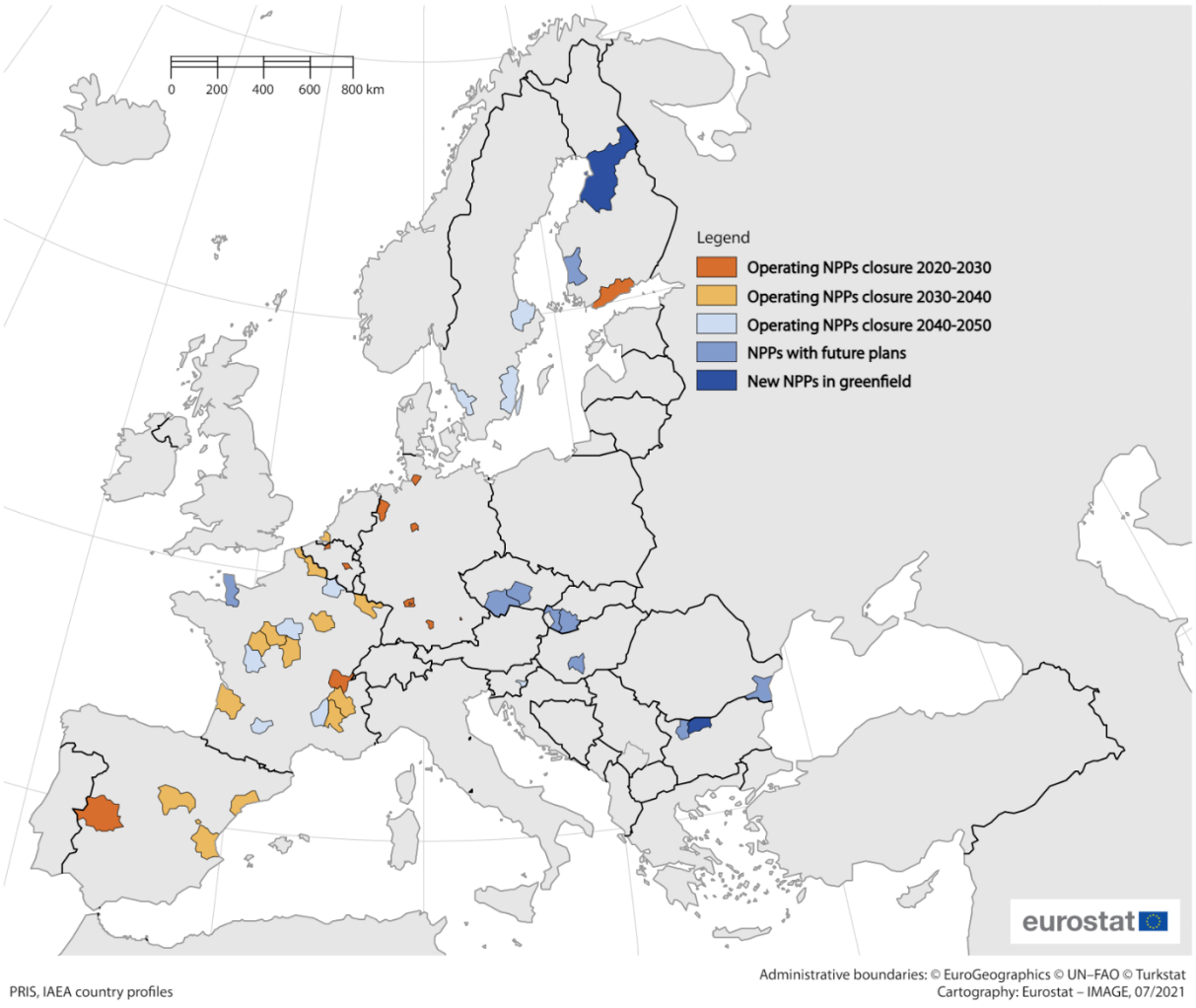
Belgium	5942				↓
Bulgaria*	2006	2006	2006	3240	↑
Czechia*	3934	3934	2984	4184	→
Finland	2794	4780	3000	3000	→
France	61370	53080	11560	1630	↓
Germany	8113				↓
Hungary	1902	4302	2400	2400	↑
Netherlands	482	482			↓
Romania	1300	2090	1440	1440	→
Slovakia	1837	2080	2080	2080	→
Slovenia*	688	688	688	1000	↑
Spain	7121	5104			↓
Sweden	6882	6882	4820		↓
	2020	2030	2040	2050	

(*) Assumption: all planned and proposed capacity will be built in 2050.

([4]) https://pris.iaea.org/PRIS/home.aspx.
([5]) https://cnpp.iaea.org/pages/index.htm.

We also analysed regions hosting those NPPs. Figure 2 presents regions under the NUTS3 level hosting an operational or under construction power plant and their planned closures. The planned closures we estimate those NPP that have no further plans or proposals for construction of new NPP or extension lifetime of the current one. This indicates that planning the NDP strategies is relevant topic for EU regions, independently of the national plans for nuclear power in each member state. At some point they will need tackle the closure their facilities and propose new activities to keep the regional economy alive.

Figure 2: Projections of closure of NPPs at hosting NUTS3 region levels.



Source: Own elaboration.

Our mapping in Figure 2 could potentially help to define regions to be included in further analysis. See *Box* 1 for more detail. The impact assessment analysis requires a good factual knowledge of the studied regions to understand the main socio-economic variables that affect the activities of the local nuclear industry, such as involved stakeholders, employment, business activities and interrelationships between economic sectors. This report offers a general guidance to social impact assessment and does not analyse any particular case. *Box 1* includes some proposed criteria that may influence which regions to include in further analysis.

Box 1: Criteria for regions at high risk for negative impacts of nuclear closure and decommissioning.

Answering these questions could help to identify which regions are potentially at "higher risk", i.e. having no experience with decommissioning, and therefore requiring more effort to develop a coping strategy.

- What is the age of the existing NPP and estimated timeframe for the closure (end of the lifetime)?
- Is the region in a country that projects continued operation of nuclear for production of energy (future plans for possible construction) or phasing out?
- What can be learned from the previous closure of units of the NPP?
- Does the country have recent experience with decommissioning?
- Is the decommissioning in a neighbourhood region?
- What is the size of the NPP (to see the magnitude of e.g. employment)?
- How is the supply chain characterised (i.e. diversity of business, locations, profitability in recent years)?

1.2 Assessing social impacts using the Social Impact Assessment (SIA) framework

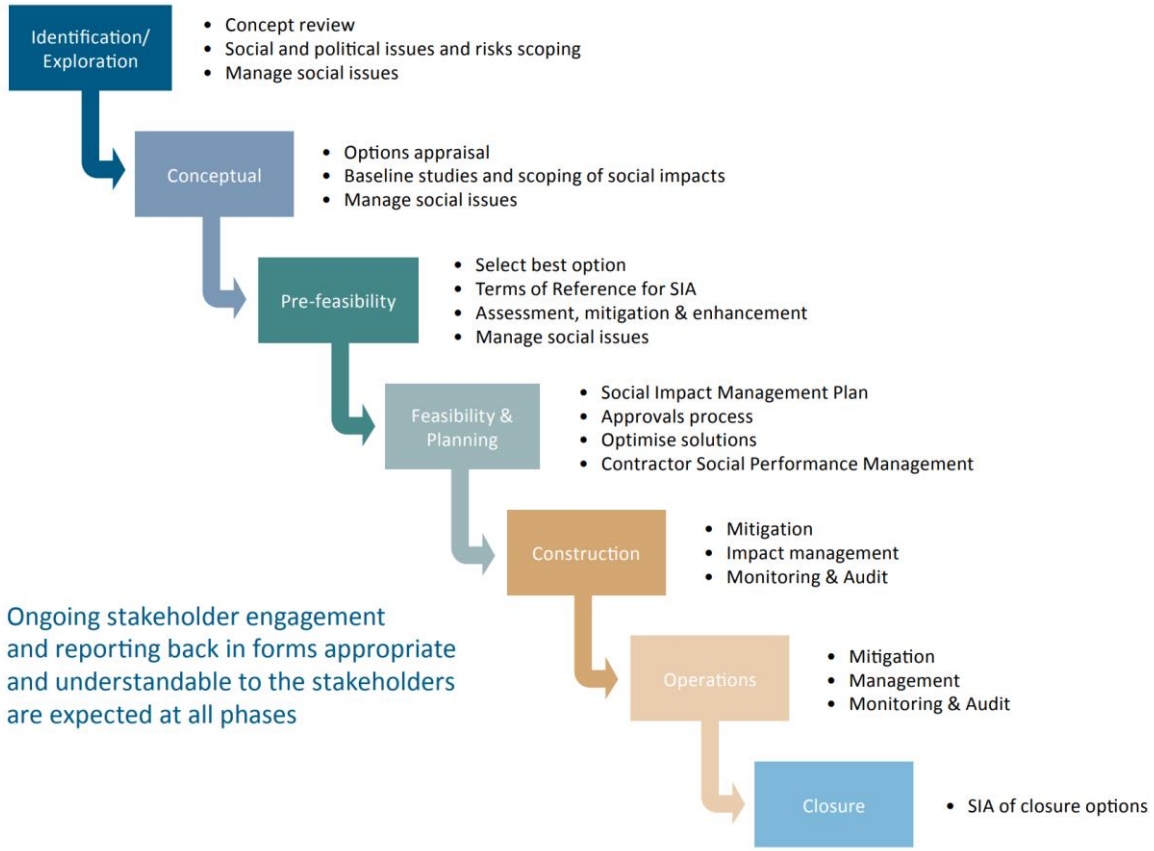
According to the International Association for Impact Assessment (IAIA), social impacts may be conceptualised as changes to one or more of the following (Vanclay, 2002):

- People's way of life: that is, how they live, work, play and interact with one another on a day-to-day basis;
- Their culture: that is, their shared beliefs, customs, values and language or dialect;
- Their community: its cohesion, stability, character, services and facilities;
- Their political systems: the extent to which people are able to participate in decisions that affect their lives, the level of democratisation that is taking place, and the resources provided for this purpose;
- Their environment: the quality of the air and water people use; the availability and quality of the food they eat; the level of hazard or risk, dust and noise they are exposed to; the adequacy of sanitation, their physical safety, and their access to and control over resources;
- Their health and wellbeing: health is a state of complete physical, mental, social and spiritual wellbeing and not merely the absence of disease or infirmity;
- Their personal and property rights: particularly whether people are economically affected, or experience personal disadvantage which may include a violation of their civil liberties;
- Their fears and aspirations: their perceptions about their safety, their fears about the future of their community, and their aspirations for their future and the future of their children.

Social impact assessment (SIA) as a practice emerged around the same time as environmental impact assessment (EIA) in the 1970s, and diverged into its own separate practice as a remedy to what was then seen as a failure of EIA to sufficiently capture social issues (Vanclay et al., 2015). Social impact assessment is defined as including "*processes of analyzing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment*" (Vanclay, 2003).

The SIA is relevant to all project phases over the whole lifetime of the project (Figure 3). The identification and exploration of the social issues should be done before planning and construction of any project. However, this is not always the case. Many existing and operating industrial projects do not undergo such an assessment. Most of the existing industrial SIAs focus on the construction and operational phase. However, we believe that the closure of facilities such as NPPs also warrants similar attention. With proper prior planning, the negative impacts can be mitigated and avoided and costs of the transition can be optimized. The closure of the NPP is only the beginning of a major structural change for the region and it should be perceived as an opportunity.

Figure 3. Phases of project where SIA is applicable.



Source: Vanclay (2015).

The International Association for Impact Assessment (IAIA) (Vanclay et al., 2015) describes SIA as being comprised of four phases, which allow for an ex-ante appraisal and ex-post monitoring of projects:

1. Understand the issues: this phase requires understanding the proposed project and key social issues, identifying the likely impacted communities and stakeholders designing participatory or deliberative spaces for com- munity members to understand and evaluate the project impacts and contribute to planning.
2. Predict, analyse and assess the likely impact pathways: this phase involves determining the impacts or social changes that are likely to result from the project alternatives, including cumulative impacts.
3. Develop and implement strategies: this phase involves identifying ways to address or mitigate negative impacts and enhance benefits. Strategies to help communities cope with change may be developed. Agreements with communities on impacts and benefits are made.
4. Design and implement monitoring programs: this phase involves developing indicators to monitor change over time, with the participation of stakeholders. A social management system is implemented.

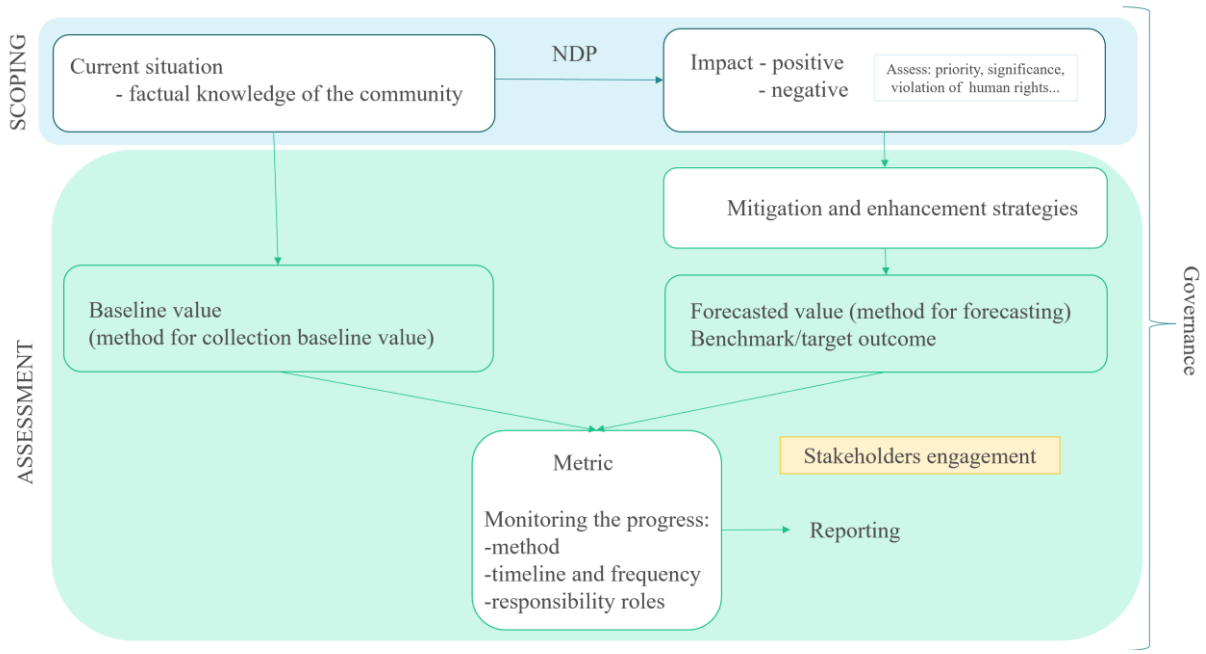
As an overarching framework, SIA includes the assessment of socially relevant aspects such as: aesthetic impacts (e.g., landscape analysis), archaeological and cultural heritage impacts, community impact, cultural impacts, gender impacts, health and mental health impacts, impacts on indigenous rights, psychological impacts or resource issues (access and ownership) (Vanclay, 2003). Diverse methods may hence be used in SIA, and can originate from sociology, anthropology, demography, development studies, gender studies, social and cultural geography, economics, political science and human rights, community and environmental

psychology, or other social research methods. According to the principles of SIA, appraisals should be as much as possible participatory, and engage communities in decision-making, e.g. through the use of deliberative approaches (Esteves et al., 2012). Section 5 provides more details on some engagement and participatory methods that may be used.

2 Methodology

There are different possible approaches for managing social impacts. Social impact assessment is an internationally recognised framework for measuring and managing social impacts. Figure 4 describes the framework we follow in this report. A good knowledge of the community and the identified social potential impacts defines the scope of the assessment. Once the social impacts are identified they need to be monitored and addressed. To identify the effects of the closure on the hosting community, the framework requires i) baseline values, including the identification of methods how to collect these values; ii) forecasted values with the impact, including the method how to forecast the values (i.e. quantitative modelling, experts inputs, scenario analysis, stakeholder workshops); and iii) the desired/benchmark value or vision of the preferred future. The changes and progress are monitored over time using different indicators. Different enablers and actions are also established to address the impacts. Note that SIA is iterative process. Therefore, the effect of the applied mitigation and enhancement strategies needs to be reported. The monitoring method, monitoring timeline and frequency and responsibility for the monitoring also need to be defined. The entire process needs to be well governed and transparently communicated via reporting. Finally, to achieve the best results, participation and engagement of the stakeholders and community members through the whole process should be maximised.

Figure 4. SIA framework.



Source: Own elaboration.

In this report, following the general principles of SIA, we carry out an analysis of the potential social issues that may occur (corresponding to the first steps of the SIA process, Figure 4). Our analysis is based on a targeted review of the literature from relevant international organisations on the topic of nuclear closure and commissioning, a number of exemplary case studies and a stakeholder workshop. In the exploratory workshop, we collected inputs from a small group of stakeholders, mainly experts, during a limited time-period (half-day workshop).

Experiences from historical case studies can help to identify the common factors when estimating the social impacts. In this regard, we have carried out an in-depth analysis of three case studies, Fessenheim in France, Ignalina in Lithuania and Philipsburg in Germany, and included this in a related conference paper (Gerbelová & Drazdove, 2021). As we refer to this publication through this report, we include the main results in Annex I of this report for the reader's convenience. We chose these three particular case studies based on data availability and for reasons of language. We could observe that each host community has its own experience and challenges. Yet, we were able to derive some lesson learnt which we consider important and refer to them across this report.

We also organised a half-day online exploratory workshop with seven stakeholders with expertise in the social management of nuclear decommissioning and community representatives with direct experience in nuclear decommissioning. The workshop was organised around four predefined activities, where participants drew on their own experience and perspectives.

In the first activity, we asked participants to complete an empathy map which helped them to think from the perspective of the key community members impacted by NDPs. This exercise was done from the perspective of three community members: plant worker, family of the plat worker and municipality member. In the second activity, participants were asked, based on their expertise or experience, to identify the social impacts from the perspective of a community facing the potential closure of NPP. In the third activity participants grouped the identified impacts into themes agreed in a group discussion. The fourth activity involved the development of selected social impact indicators. Together with the participants, we identified possibly metrics for the chosen impacts, as well as methods to measure progress. These included qualitative and/or quantitative metrics to measure progress or change in each social impact

The participatory setting of the meeting ensured the sharing best practises and enhanced networking. For further details of the workshop and its outputs, please see our conference paper (Gerbelová & Shortall, 2022). We also present the most important results of the workshop in Annex II. For example, see the identified social impacts by the participants and their categorization according to themes.

3 Identifying social impacts of nuclear closure and decommissioning

The closure and decommissioning of NPP is a multi-step process, which will take several years and can be divided into three phases (OECD Nuclear Energy Agency, 2002):

- The announcement of the closure and preparation for the cessation;
- Decommissioning, which involves dismantling the facilities and proper disposing of any radioactive material;
- Remediation of the surrounding area, which enables safe reuse of the site for other nuclear, industrial or general purposes.

Each phase includes several activities that can have different social impacts. Therefore, their assessment is a complex process. In this chapter we identify and analyse key impacts that should be considered in the design of recovery plans.

To a certain extent, the experience is similar to any other industrial transition. For many years, the operation of the NPP provided a financial privilege to the area. For example, in Fessenheim, France the region received a total of 47.1 million euros, including 2.1 million from property tax in 2016 (see Appendix I for more detail). After closure, the hosting community becomes a less attractive place to live and work as a result of phase-out of the NPP and related direct and indirect services. In some cases, the closure of such a large employment site leads to out-migration and could lead to a complete collapse of the community.

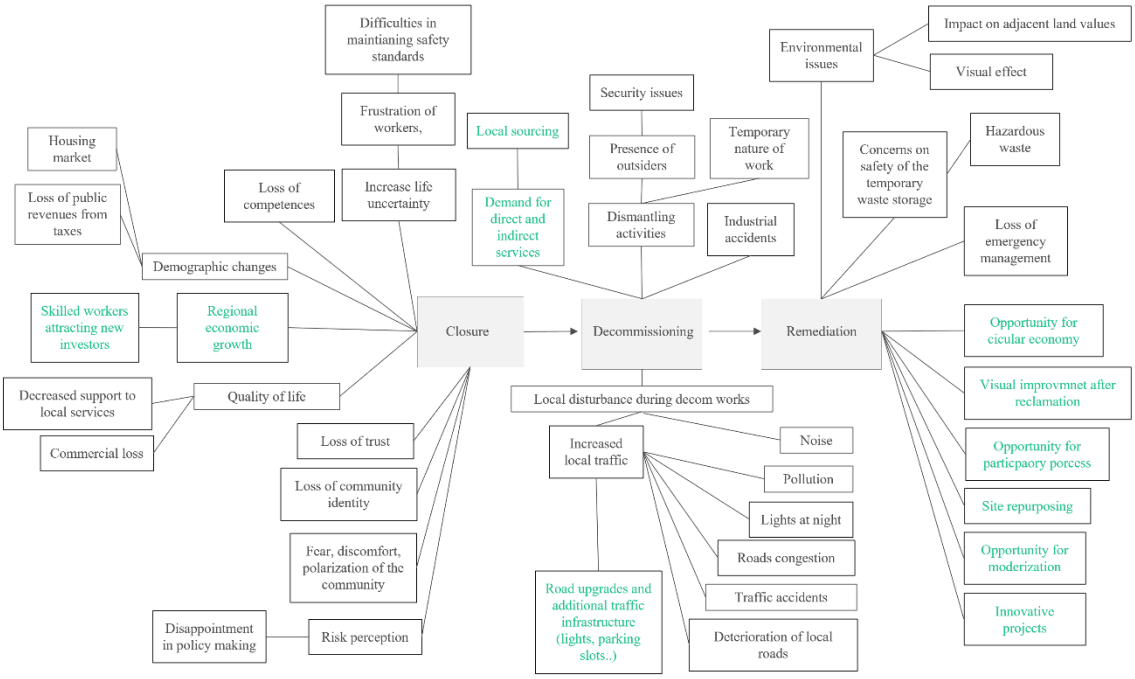
A specific feature of NPPs is the composition of employees. They are high-skilled and high-paid workers. In addition, NPPs are located in remote areas and therefore, the inflow of workers and their families into relatively small towns has certainly increased the local population. NPPs create jobs not only related to its operation but also in sub-contractors' companies and indirectly associated activities. This creates a sense of community pride and keeps the local economy vivid. The high standards of living of the workers brings a substantial income to the region in property taxes and other revenues.

Another specific factor is the presence of spent fuel at decommissioned power plants, which can represent an obstacle to site redevelopment. In the short term, new opportunities will arise in the vicinity rather than directly on site (Nuclear Decommissioning Collaborative, 2020). On the other hand, the decommissioning phase may temporally offset the economic losses. It is important to identify the expected impacts and possible opportunities for community economic development in advance, engaging with all stakeholders and creating the knowledge base for the community.

Based on our analysis of case studies, literature and a workshop, we were able to identify key social processes and resulting social impacts for different phases of the NDP. Figure 5 depicts a result of a brainstorming over the possible social impacts and causes. In the middle the three phases of the NDP are presented as 'closure', 'remediation' and 'decommisioning'. A hierarchy of activities and impacts arising from each of these phases are shown. Such mind map might help track the ideas and later to be reflected on in further analysis. Note, we do not present an exhaustive list of social impacts. Nevertheless, we try to represent, to our best knowledge, the key social impacts on the project and on the community as whole. The figure also shows potentially positive impacts in green.

The Nuclear Decommissioning Collaborative differentiates between socioeconomic impacts of plant closure and plant decommissioning (Nuclear Decommissioning Collaborative, 2020) in the following sub-chapters we describe the impacts in each phase.

Figure 5. Mind map of the social impacts of the NDP.

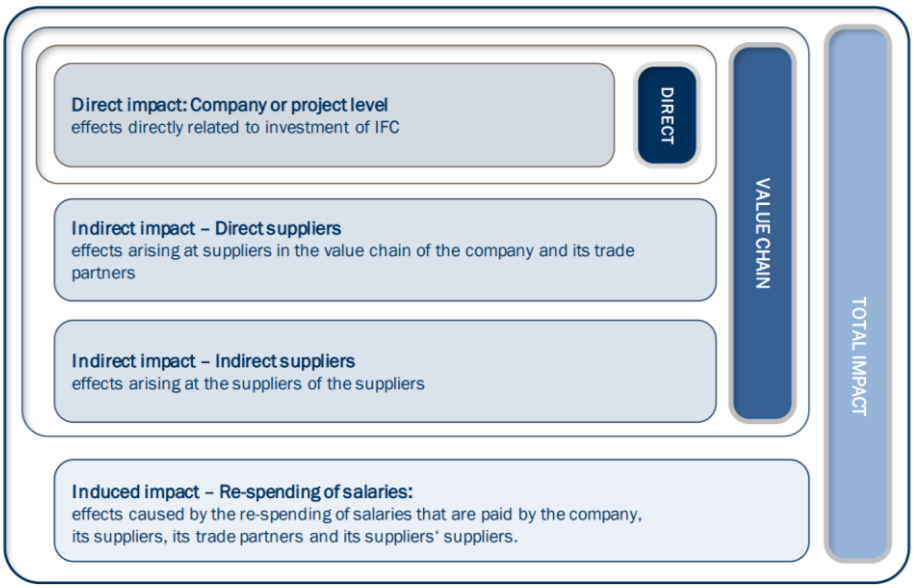


Source: Own elaboration.

3.1 Impacts of NPP closure

The closure of the NPP affects everyone in the community to some extent. In general, impacts on employment are considered the most important socio-economic impact. The NPP operator is often the major employer in the community and brought highly qualified workers and their families to the community (International Atomic Energy Agency, 2008b). It has provided jobs, not only to NPP operation, but also to sub-contractors and indirectly associated activities induced by the consumption of the employees and their families. Figure 6 shows various impacts level of the total employment.

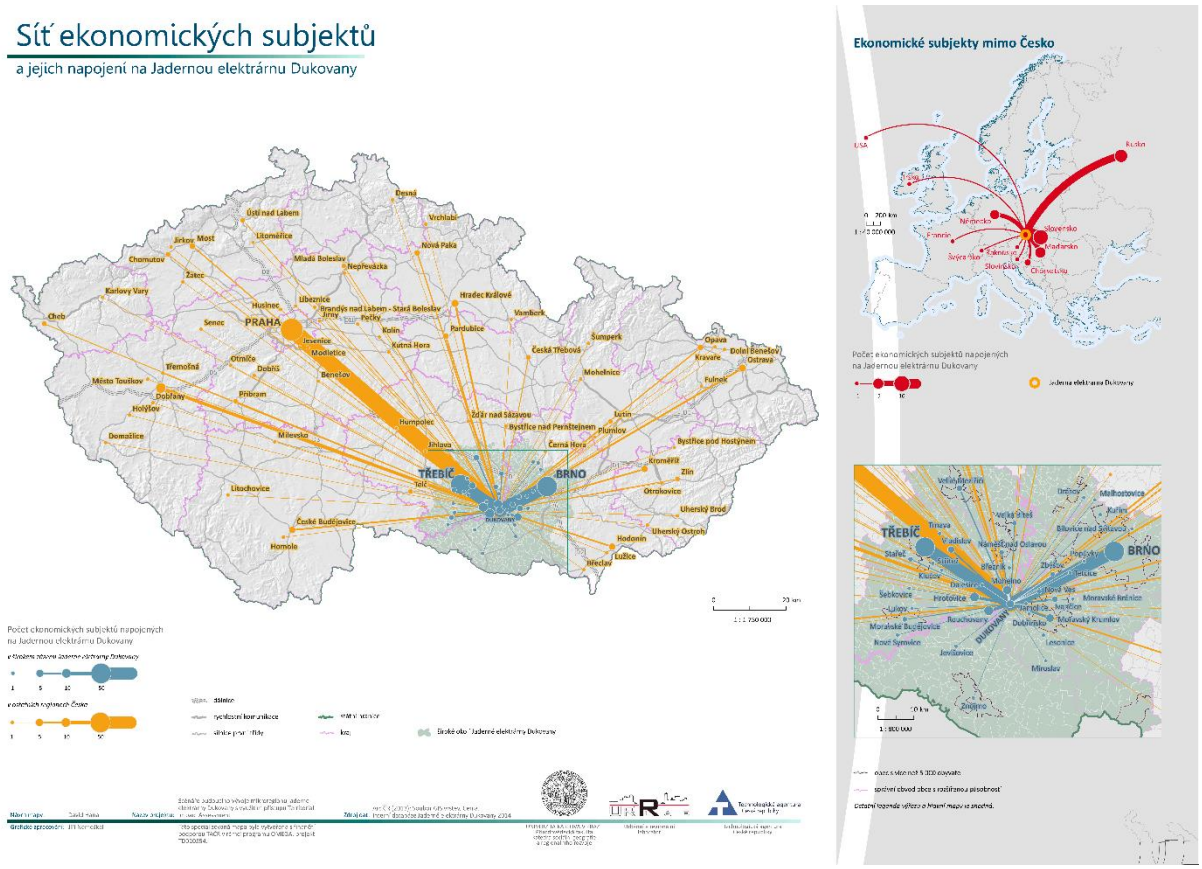
Figure 6. Different levels of the impacts on employment according to International Finance Corporation (IFC).



Source: Redqueen (2017).

The operation of the NPP has contributed to the economic prosperity of the community and provided a substantial income. Figure 7 shows an example of the supply chain of the Czech NPP Dukovany. Different business sectors are connected with the main activity to varying degrees. Therefore, it is difficult to estimate the magnitude of the impacts and it will depend on the potential for business diversification of each company. The figure also shows the wider reach of the potential impacts beyond the local community. However, this report focuses primarily on the hosting community and therefore these impacts are considered out of the scope.

Figure 7. A network of economic entities connected to the Dukovany NPP.



Source: https://www.atlasobyvatelstva.cz/cs/dukovany.

The closure may result in the loss of essential services and support to local amenities, such as schools, hospitals and public transport. The outmigration can affect the housing market (Bauer et al., 2017). Overall, there is a potential risk of loss of community trust and failure to manage public opinion if decisions are not well communicated and transparent (Perko et al., 2019). Funding insecurity may also cause stakeholders to worry (Hirose & McCauley, 2022).

The closure also results in the loss of public revenue coming from the taxes paid on working activities, taxes paid on the annual income of employees and other public revenues such as those re-injected into the local economy, for example in the real estate market.

The workers at NPPs are impacted by the transition, both positively and negatively. Work continues for a few years prior to decommissioning but some workers may have trouble adjusting to a new job description (Hirose & McCauley, 2022). It is important to note that many of the social impacts on workers are felt before the decommissioning itself begins. In particular, these are psychological issues of workers, personal and family income issues and management performance issues (International Atomic Energy Agency, 2008b). Fear, perceived risk, lack of knowledge or lack of public participation can result in avoidance and resistance by the workforce (Perko et al., 2019). Some stakeholders may perceive intergenerational risk, e.g. risk for future generations from waste disposal (Hirose & McCauley, 2022). Furthermore, community polarization can occur

due to disagreement arising from the interests of different groups (Collaborative, 2020), or differing perceptions of risk (Perko et al., 2019).

It is possible that workers are under increased stress or feel frustrated after the announcement of the NPP closure due to the uncertainty about their personal and family future. They are also concerned about moving away. All of these factors can cause distraction from normal activities, and thus reduce the safety culture, which is extremely important for the safe operation of the NPP. With the gradual decrease of human resources at the facility workers may feel unappreciated or undervalued for their skills.

Note that not all impacts are necessarily negative. Some impacts may fluctuate over time and what initially seemed like negative impact may turn into an opportunity for something new. In this way, the closure of the NPP offers prospects for the future economic development of the area. Highly skilled workers can attract new investors. However, it is possible that the newly created jobs will have a lower level of remuneration. There may be also considerable interest for repurposing of the NPP site and taking advantage of the existing infrastructure. The presence of spent nuclear fuel at decommissioned power plants represents a significant and ongoing barrier to economic recovery and may cause concerns on safety of the temporary waste storage. On the other hand, waste processing ensures continuation of some business' activities on the site, which may be opportunity for the existing professional profiles of workers (see example of Fessenheim, France in Annex I).

The assessment should evaluate the post-project use of infrastructure and human capital in accordance with local development plans and priorities. It is important to identify further opportunities in the surrounding and to provide targeted support for the structural change. The transition process takes several years and the lack of a solid recovery plan can reduce the prosperity of the region and increase the recovery costs.

3.2 Impacts of the decommissioning phase

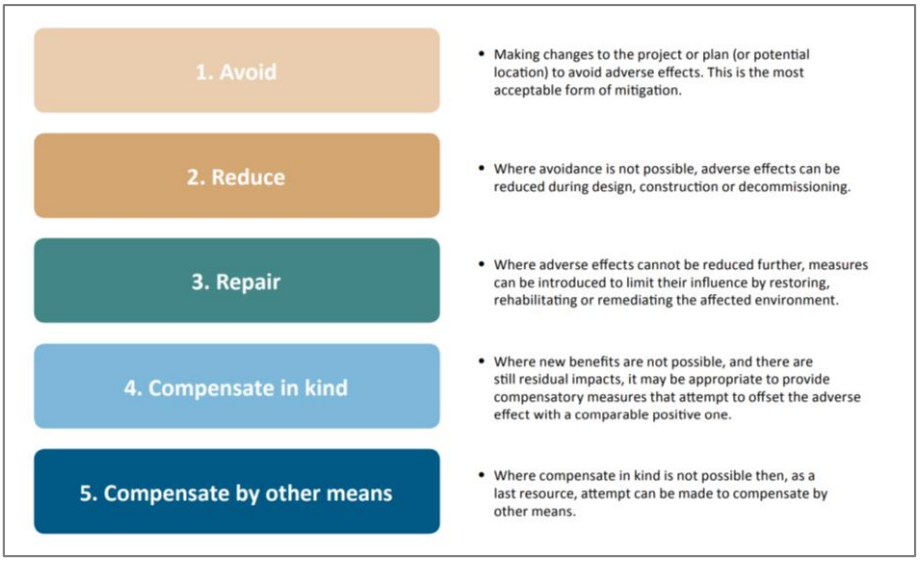
Decommissioning ensures the continuation of specific local businesses activities in the community and can partially offset the negative social impacts. Although the dismantling of the facility, waste treatment and reclamation may take several years, these activities are of a temporary nature which might be of greatest concern to employees. A sufficient number of employees is required to ensure safe plant operation through the processes of decommissioning and the waste recovery process. For example, the experience of Philippsburg, Germany shows that NPP operator maintained all workers at the site for the dismantling, interim storage facility and new projects developed on the site (see Appendix I). However, different skills and reassignment to a new job position may be required. Learning and adapting can be challenging. Many of carried out works are one-of-kind tasks. Moreover, part of the dismantling processes are carried out in highly contaminated and radiation areas. The process also produces other hazardous materials, such as asbestos, acid or lead (International Atomic Energy Agency, 2008a). Stakeholder dissatisfaction may also arise due to unmet expectations or worries of increased risk due to limited financing (Perko et al., 2019).

Another challenge for the hosting community can be the presence of additional workers for the dismantling. Similar to the construction phase, the dismantling activities affects the local community in particular by constraining public infrastructure and services and disrupting their routines and common space (NT Inquiry, 2017). Given the predominantly male inflow, women could be vulnerable. The dismantling of the facilities and the revitalization of the land also requires intensive transport of materials. It can create congestions, disrupt private and public transport and also brings a higher risk of traffic accidents, especially near schools and parks (NT Inquiry, 2017). In addition, higher air pollution, dust and noise can affect residents with medical preconditions, children and elderly people. In particular, residents close to or on the road to decommissioning activities may experience high visibility of heavy-vehicles giving the impression of industrialisation of the landscape, noise disturbance and widespread use of lights at night (NT Inquiry, 2017). On the other hand, increased heavy traffic can accelerate the modernisation of local roads and incentive the upgrade infrastructure. If well designed, the community can benefit from such improvements in the long-term. The inflow of workers also offers an opportunity to improve public other services. The in-coming workers and drivers seek for specific local services, creating opportunities for local businesses. In addition, local employees and businesses should be preferably engaged in decommissioning activities.

4 Mitigation and enhancement actions

The main aspiration for SIA is to mitigate the negative impacts and ensure that the project brings greater benefits to the community (Vanclay & Franks, 2015). There are different ways to mitigate negative impacts, some having a very simple solution, others requiring extra effort. However, it is important to analyse all the negative impacts and define the mitigation strategies to address them. Figure 8 presents the hierarchical structure for mitigation actions. Every project also brings opportunities for benefits to the community and these should be enhanced. The main purpose of the evaluation of the mitigation and enhancement strategies is to show the value for the community and thus obtaining the so-called "social licence" to operate the project. Without a social license, the resulting lack of trust, delays, or higher costs, can eventually jeopardise the whole project.

Figure 8. Mitigation hierarchy for addressing potential negative impacts.



Source: Vanclay & Franks (2015).

Strategies for each mitigation and enhancement action must be clearly defined and show how the negative impacts will be overcome. In Table 2, we propose some mitigation and enhancement strategies for the most common impacts to NDPs. Note that these are just examples of recommendations for the project stakeholders, however. In practise the mitigation and enhancement strategies will depend on the particular context and will have to be thoroughly assessed involving all relevant stakeholders.

Table 2. Examples of proposed mitigation and enhancement actions for NDP (own development based on IPIECA/OGP, 2013, International Atomic Energy Agency, 2008a, 2008b).

Loss of employment	• Develop human resources plan • Implement individual carrier guidance for the affected employees • Offer training system and consultation service
Frustration of affected employees	• Communicate plans clearly, transparently and timely • Consult about personal preferences of employees and their ideas • Ensure common understanding of the vision and plan • Offer continuity of employment where the circumstances allow • Promote employment for the employees' family members • Facilitate promotions, trainings and complaints mechanisms
Mistrust in the	• Effective management of social media

community	• Ensure proactive communication before and throughout the decommissioning process • Establish a vision involving the community members and ensure its implementation • Focus on building confidence and trust • Ensure a participatory approach
Loss of business activity	• Identify businesses at potential risk • Create a technical support group to assist affected businesses in their recovery plans • Establish an individual human resources support for affected employees • Focus on employees whose loss of employment leads to poverty • Support creation of new business activities • Monitor local skills and professions
Economic development	• Develop a strategic plan for the future development of the community • Identify local supply and service opportunities to keep sustainable economic benefits and provide incentives for innovation • Review synergies between growing and declining sectors • Attract new investors taking into account local professions and skills • Provide targeted trainings to enhance new skill requirements • Facilitate the mapping and monitoring of rising opportunities, and govern the local citizens' engagement
Increased influx of workers	• Identify required changes in demand for local services • Protect the safety and health of employees, contractors and the general public • Increase security measures close to the project site
Increased heavy-vehicle traffic	• Forecast heavy-vehicle traffic volume • Assess used roads and possible alternative routes • Identify a road infrastructure that may require upgrades • Provide necessary extra safety road measures • Ensure competent drivers and provide safety briefings for all drivers entering the project site
Increased demand for local services	• Identify additional required local services • Provide training and a technical support to promote the recruitment from local community
Upgrading of infrastructure	• Identify possible infrastructure improvements and assess the plan to implement it with the decommissioning project
Loss of pubic revenues	• Develop a strategy for retaining the employees in the area • Evaluate funding options to accelerate the area's development
Visual and noise effect	• Maintain appropriate distance from homes, businesses and other community areas • Optimise the transport of materials • Install noise and visual barriers
Environmental impacts	• Plan solid waste management with focus on reuse, recycling and circular economy • Use good practices for land reclamation • Ensure adequate training of personnel in waste categorization, waste treatment and familiarity

	with sustainable values • Communicate the environmental assessment to the public
Industrial accidents	• Ensure maintenance of all safety measures • Enhance safety measures • Ensure qualified and well-trained personnel • Prepare emergency plan • Ensure awareness of the emergency plan to residents in proximity of the project site and local emergency units
Radioactivity	• Ensure appropriate training of employees through the different phases of the decommissioning process • Ensure adequate training for contractors • Introduce protective equipment for the employees • Monitor regularly the radiological levels of the workers and surroundings • Maintain emergency plan

Indictors of social performance serve as a mechanism to monitor the impacts of the NDP and the progress of mitigation and enhancement actions. Indicators allow monitoring changes over time in quantitative or qualitative terms. See Annex II for some examples of indicators we developed. The monitoring plan presents how the impacts will be monitored over time. This helps to track the performance and evaluate whether targets are met or additional measures need to be applied. Table 3 presents examples of indicators and monitoring methods for some common NDP impacts. However, as for the whole SIA process, all relevant stakeholders should be involved in drawing up the monitoring plan and the plan also must clearly define responsibilities for the monitoring, as well as its timing and frequency.

Table 3. Examples of indicators and monitoring method (own elaboration).

Impact	**Indicator**	**Monitoring method**
Loss of employment	Number of employees	Company records
	Unemployment rate	Local statistics
Loss of business activity	Financial indicators of local businesses (e.g. turn-over rate)	Financial register database
	Household income and % households below poverty line	Citizens' surveys and statistics
	Rate of out-migration	Local statistics
Economic development of the area	Territorial development plan present	Meeting with local stakeholders
	Evidence of area revitalisation	Implementation of action plans
	Number of jobs created	Company records, statistics
	Production of liquid and solid waste – circular economy	Company' records
Increased influx of	Number of contracted employees	Company records

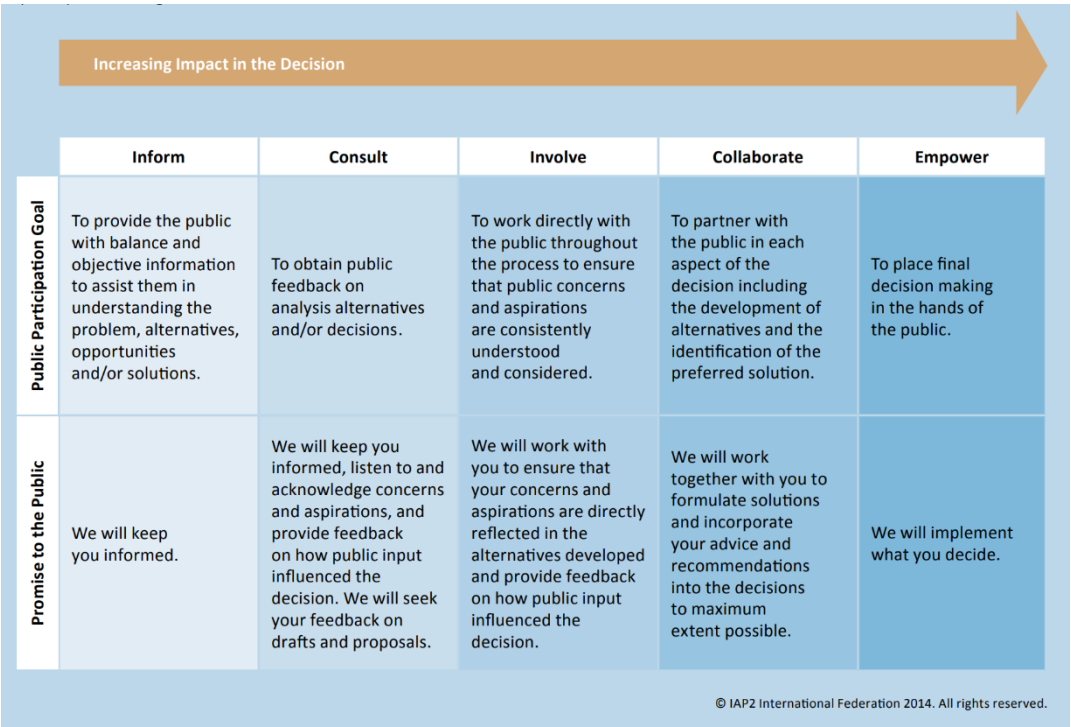
workers	Reports on crime and violence	Police records
Increased heavy-vehicle traffic	Air quality and noise, congestion	Traffic, air pollution and noise sensors
	Indicators of road condition	Road inspections
	Number of accidents	Police records
Demand for employment and services	Number of public services (schools, nursery, medical care)	Statistics and meetings with stakeholders
	Unemployment rate	Statistics
Loss of pubic revenues	Taxes to the authorities	Governmental records
	Public investments	Statistics, governmental records
Visual and noise effect	Perimeter of affected residents	Meetings with the local authorities and project experts
	Level of noise	Noise sensors
Industrial accidents	Number and gravity of accidents	Company accident and incident records
	Number of exposed workers and residents	Records of the NPP medical service and experts
	Post-evaluation of accidents	Interview with workers
Radioactivity	Level of radiation	Measuring radiation level, sensors
	Number of affected workers	Medical records

5 Community participation and engagement

Stakeholder engagement is an important aspect of social impact assessment. Stakeholders can be defined as *"persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and/or the ability to influence its outcome, either positively or negatively."* Therefore, local communities or individuals in host communities of NPPs are stakeholders, including their *formal and informal representatives, national or local government authorities, politicians, religious leaders, civil society organizations and groups with special interests, the academic community, or other businesses* (IFC, 2007). According to the principles of SIA, stakeholder engagement and associated feedback should be carried out from the early stages of a project (Figure 3) and carry on through until the closure/decommissioning stage (Vanclay et al., 2015). E.g. the identification of likely social impacts, the development of social impact management plans, operation of monitoring plans and decommissioning plans should all involve participation of the affected stakeholders.

Different levels or intensity of stakeholder engagement, ranging from informing to empowerment are possible and it is important to differentiate between them. The International Associate for Public Participation (IAPP) provides a useful guideline for the different levels of participation (Figure 9). While participation of affected communities is a statutory requirement in most countries, the level of participation required is often considered inadequate and not in line with SIA principles. In the SIA context, stakeholder engagement should go beyond simple informing or consultation, and rather use approaches that employ an inclusive and empowering democratic philosophy and involve members of the community in decision-making, in particular vulnerable and minority groups.

Figure 9. Levels of public participation.



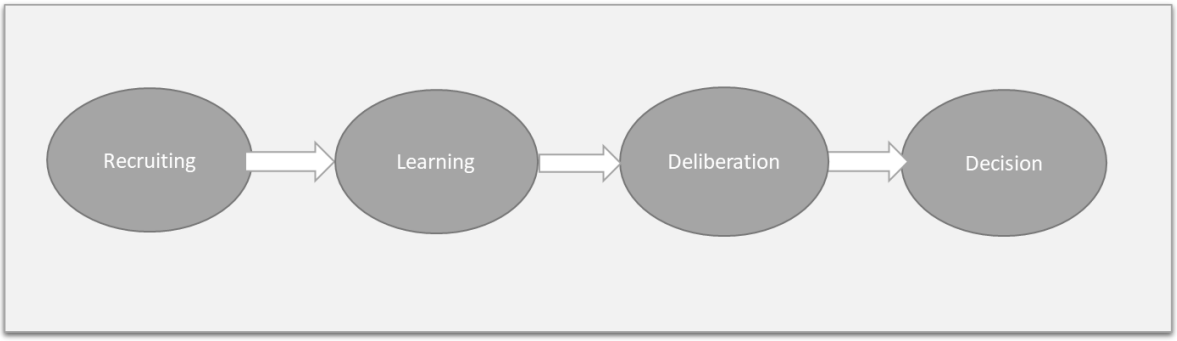
Source: IAP2 Public Participation Pillars([6]).

Deliberative methods are particularly relevant in this regard (Vanclay et al., 2015). Deliberative methods usually include four main phases (Figure 10): recruiting, learning, deliberation and decision (Shortall, 2020). The OECD provides a guide for the use of deliberative processes for citizen's participation in public decision-making, differentiating between participatory and deliberative processes. Participatory methods and deliberative methods can be distinguished by the type of participation, the numbers of participants and how

([6]) https://cdn.ymaws.com/www.iap2.org/resource/resmgr/communications/11x17_p2_pillars_brochure_20.pdf.

participants are selected (Carson & Elstub, 2019; OECD, 2020). Participatory methods encompass a diverse array of opportunities to participate for large numbers of people with varying levels of citizen empowerment, whereas deliberative methods involve smaller groups but require in-depth discussion, reflection and exchange of views. Deliberation requires that participants become well-informed about a topic, which requires a learning phase. While deliberative methods usually involve stratified random selection of participants, participatory methods often allows for self-selection of participants (OECD, 2020).

Figure 10. Main stages of any deliberative approach.



Source: Own elaboration.

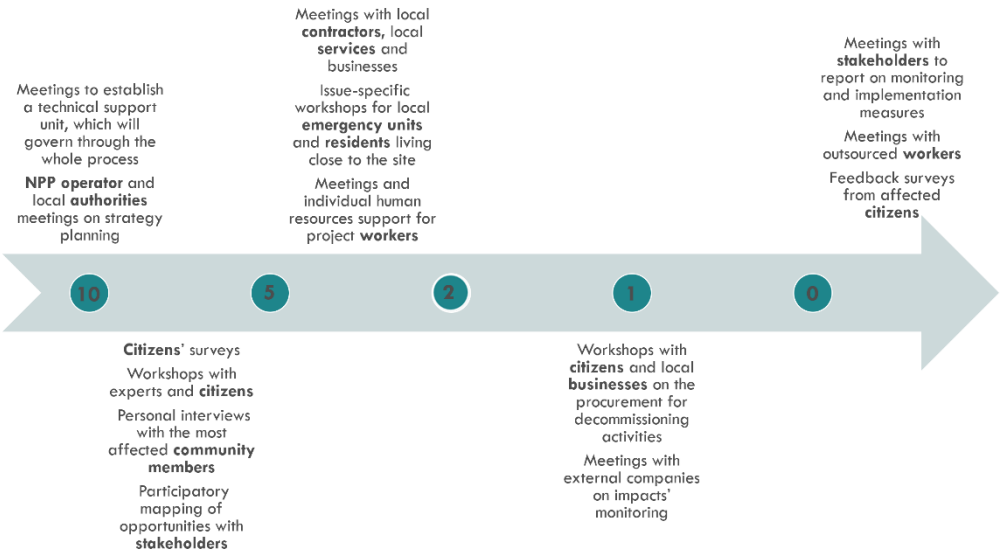
Some examples of the use of participatory methods used in SIA, and the level of participation they provide are shown in Table 1. Please note that this is not an exhaustive list, and that there are many possibilities for participatory methods.

Table 4. Examples of participatory methods used in SIA according to IAP2 level of participation.

Inform	**Consult**	**Collaborate**	**Empower**
Open house/open day	Community consultation	Co-creation workshop	Consensus conference
Public hearings, meetings	Vulnerable groups interviews	Citizen's dialogue	Citizen's assembly
Trainings	Focus group	Collective negotiation process	Joint projects/ventures and partnerships
	Community workshop		

Figure 11 shows an example stakeholder engagement plan showing various engagement activities carried out during the years prior to the NPP closure. An early planning is crucial for successful outcome of the project.

Figure 11. Proposal of stakeholder engagement plan.



Source: Own elaboration.

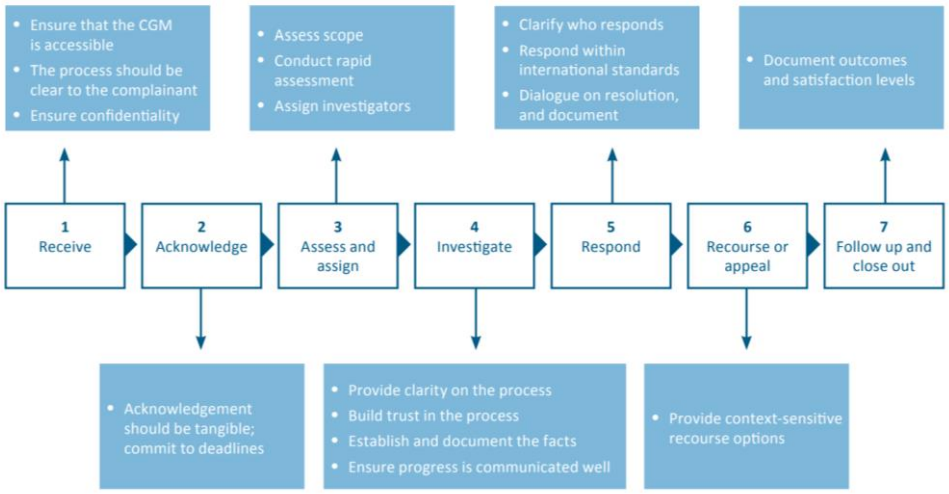
6 Reporting, governance arrangements and grievance mechanisms

The NPP operator must work closely with local authorities and together they have the greatest responsibility over the monitoring of the transition process from the NPP closure towards the future development of the affected area. In the long run, the transition needs to promote the engagement with the local community to identify options to address potential negative impacts and ensure community cohesion. Establishing regular and standardised reporting will ensure that the area remains a safe place even after the NPP operator leaves the site and shows whether the continued development has a positive impact on the affected area.

The monitoring plan shall be developed in a participatory way and must indicate the allocation of governance and oversight over the monitoring, the monitoring frequency and how the results of the monitoring are going to be reported (Vanclay & Franks, 2015). The monitoring plan must also set out clearly the responsibilities and timelines of contracted parties, such as those monitoring the air, soil and road traffic, and set out the role of public services such as schools, medical and emergency services. Additionally, the NPP operator and the relevant regulatory body must to ensure that all activities are carried out within the regulatory framework and comply with all safety standards. The results of monitoring and measurements shall be publicly available.

The grievance mechanism serves as the possibility to redress any concerns and complaints. It shall be used to record any complaints before, during and after the closure and decommissioning activities. The grievance mechanism must be accessible to all community residents, projects employees and all related stakeholders. To do so, they need to be informed about this possibility, in the first place, and be aware of the process (see Figure 12). All records must be confidential and processed with fairness and trust. The body in charge of the grievance mechanism shall assess the issues of concern and propose solutions to them. The outcome is communicated back to the complainant and, depending on the outcome, the complaint is closed or further dealt with. If the grievance mechanism is well managed, it increases the trust of the community to the project and reduce business risks.

Figure 12. Steps in processing a grievance.



Source: Vanclay & Franks (2015).

7 Limitations and future work

In this report, we present an overview of possible social impacts that may occur during the NPP closure and decommissioning process. We carry out this analysis with the intention of providing a guidance for similar assessments at the project level or policy level. We also provide advice for the ongoing management and monitoring of social impacts for the whole closure and decommissioning process, in accordance with current SIA principles.

Our analysis is based on a review of the literature from relevant international organisations on the topic of nuclear closure and commissioning, a number of exemplary case studies and a stakeholder workshop. In the exploratory workshop, we collected inputs from a small group of stakeholders, mainly experts, during a limited time-period (half-day workshop).

Our presentation of social impacts and indicators is therefore based on our own interpretation of literature and case studies and the outputs of the expert workshop represent the opinion of a small group of experts. Community members themselves have not been directly involved in identifying social impacts in this report. As such, this is a starting point for the development of social impact indicators and does not represent an exhaustive list of social impacts of nuclear closure and decommissioning.

In the future, we will carry out additional qualitative research to further validate our findings on the social impacts of nuclear decommissioning and closure, and the associated indicator development. Future research should involve a participatory approach, which should include more and diverse representatives from host communities. This is needed in order to ensure a balanced perspective of the social impacts that are important for communities to take into consideration, as well as to further verify the proposed indicators. Since social indicators are context-specific and sometimes subjective, in this report we only aim to provide a framework and suggestions for indicators, which should always be validated by stakeholder input in each case. Further research should also verify that the indicators are easily interpretable and communicable.

8 Recommendations for policy makers

It is important to understand the relevance of the possible social impacts arising from the NPP closure and include their assessment in all levels of policy-making. The closure of the NPP is only the beginning of a major structural change for the region and it should be perceived as an opportunity. Most importantly, the closure announcement and the coping strategy should be developed well before NPP closure and involve all related stakeholders.

The closure decision is by the national policies; whereas, the impacts are strongest at the community level. Therefore, the collaboration across the different governmental levels is crucial. The governing body can provide certain supports, such as technical assistance, capacity building, offer trainings and reskilling, support for R&D and incentives for creation of new businesses. This can be based on open call for projects with priority ideas and possibility of funding. The primary focus should be on economic activities to support and secure employment for the local people as well as ensuring their well-being. Citizens should be involved and engaged in the different process through the whole SIA.

The closure plans should prepare for the changes in the number of employees and evaluate their professional skills. A sufficient number of employees is required for the decommissioning. However, the employees may fear the temporary nature of this engagement. A personalised human resources care is considered as best practice in the preparation for the professional transition.

The collection of data for the SIA can represent a major challenge when targeting a smaller geographical scope. Therefore, it is extremely important to work in collaboration with the local authorities and representatives of the hosting community. Additionally, local authorities have the possibility of direct interaction with the involved businesses and have knowledge of the local conditions and expertise, which can facilitate the mapping and monitoring of upcoming opportunities, and govern the local citizens' engagement. All decisions taken should be participatory and inclusive.

9 Conclusions

In this report, we provide a description of the EU member states that are likely to face decisions about nuclear closure and decommissioning and we give an overview of the possible social impacts (negative or positive) that may arise as a result. Social impacts are often neglected in policy appraisals. The social impact assessment (SIA) framework provides valuable guidance for assessing social impacts for project, plans and policies. We apply the principles of social impact assessment to take the first step in identifying some of the important social impacts of nuclear closure and decommissioning. Our presentation of the social impacts is not intended to be exhaustive and is based on our insights from literature, case studies and an expert workshop. We also provide guidance on how such social impacts could be monitored using indicators, as well as possible governance arrangements.

Sharing experiences between communities facing a similar transition is valuable for planning. The lessons learnt from communities in one country may be transferable to others, however local contextual factors will need to be considered e.g. plant size, location, decommissioning strategy, etc. Since social impacts are context specific, further participatory research is required in order to properly clarify social impacts, in particular at the local level. Regardless of the project, the earlier social impacts are incorporated into plans for closure and decommissioning, the more chances that the benefits for the community can be enhanced and the negative impacts mitigated. Mitigation actions can avoid, reduce, repair or compensate negative impacts. Following best practices for the management of social impacts, as laid out in this report, can help to make the most of available opportunities for enhancing community benefits.

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List of abbreviations and definitions

EIA	Environmental Impact Assessment
EU	European Union
IAEA	International Atomic Energy Agency
IAIA	International Association for Impact Assessment
IAPP	International Associate for Public Participation
IFC	International Finance Corporation
IAIA	International Association for Impact Assessment
NDP	Nuclear Decommissioning Project
NPP	Nuclear Power Plant
OECD	Organisation for Economic Co-operation and Development
PRIS	Power Reactor Information System
SIA	Social Impact Assessment

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Annexes

Annex 1. Review of case studies

The results presented here are part of the conference paper Gerbelová & Drazdove (2021) and are repeated here for the reader's convenience.

A1.1 Fessenheim, France

Nuclear energy makes a predominant part of the French energy mix providing 70% share of the electricity production (European Commission 2021a). However, by 2035, the national energy plan foresees a reduction to 50% (European Commission 2021b) To begin with, the Fessenheim NPP (FNPP) closed its first unit by the end of February 2020 and the second by the end of June 2020 (Électricité de France 2019). France has another 56 reactors of the same type, of which 12 is reaching 50 years of operation by 2035 (International Atomic Energy Agency 2021). This raises a great opportunity for FNPP to be a pioneer in the prospect of decommission in France. In the coming years it will allow for the pooling of engineering, operating and maintenance resources and sharing important lessons applicable to all sites.

The FNPP is located in the Haut-Rhin of the Grand Est region, eastern France. Since the start of its operation in 1977, the territory around Fessenheim has remained dependent on the socio-economic activities associated to the NPP. Its operation provided a financial privilege to the area for many years without the need of exploring diversified solutions. In addition, the FNPP has made a significant contribution to the local taxes. In 2016, the region received a total of 47.1 million euros, including 2.1 million from property tax. The Fessenheim town alone, with a population of 2389 inhabitants, receives around 6.6 million euros per year (France Bleu 2018). Therefore, as in any other region where a NPP is shut down, the area around Fessenheim now raises questions about the local economy and jobs.

The French company EDF (Electricité de France) assumes full technical and financial responsibility for the decommissioning of all its nuclear power plants. Under EU State aid rules, EDF received compensation in 2020 as a result of the early closure of the FNPP of almost 400 million euros (Nuclear Engineering International 2021). In addition, up to 2041 there will be subsequent payments to compensate for any loss of earnings (Électricité de France 2019). The amount allocated will be used for dismantling operations of the FNPP and to support projects for the green growth of the region (France Bleu 2020a). The decommissioning of the power plant will start by 2025. Until then, EDF will prepare the facilities for dismantling and strengthen support for its employees.

In 2020, the FNPP employed 760 EDF employees and approximately 300 employees in service companies (Électricité de France 2021a). In 2025, the number should be reduced to 60 employees in charge of dismantling activities and around 100 service providers (Électricité de France 2021b). EDF has therefore put in place a system allowing each employee a personalized care in preparation for the professional transition (Électricité de France 2021c). In one year, they found a solution for 80% of employees. However, most of them opted for relocation to other EDF production centres and only a quarter of the employees plan to join EDF's local projects (BFM Business 2021).

To continue benefitting from the local employment and supporting the economic development of the territory, the region presents a number of projects that allows for creation of new jobs. The first forward-looking plans focus on the prosperity of the industrial site around the NPP and the nearby river port. The proposal also includes site reconversion into a techno-centre for the dismantling of nuclear reactors and recycling low-level radioactive metal (The regional Government Gran Est Region 2019). Such a project would use the existing technical skills and alleviate the saturation of waste storages implied by the closure of many reactors in France in future. The location of the NPP close to the border with Germany also allows for Franco-German cooperation, such as a planned photovoltaic project in Réguishem, which is expected to be operational in 2022 (Tecsol 2020).

The region is committed fully substituting energy production from FNPP with renewable energy production and energy savings. In this context, the State will mobilize 250 million euros in aid over 20 years (France Bleu 2019). This is the first time in France, when the call for tenders for renewable energies was limited to a specific territory. Potential energy transition projects take into account renewable electricity production (solar, wind, small and large hydro) and heating alternatives such as geothermal network or biofuel plant (Larochelambert 2019). This plant is expected to start operating in 2024 and to create 350-700 full-time positions (France Bleu 2020b). The ongoing energy transition also strengthens the tradition of the local chemical industry, as the development plan presents a semi-industrial pilot of the methane cracking for

hydrogen production. Finally, the planned program for the future of the Rhine territory also takes into account sustainable mobility, agriculture and investments in the required infrastructure (Larochelambert 2019).

While all the above-mentioned projects seem promising, their implementation will take several years. An overall transition plan will still to be defined in a coherent manner, including its coordination and funding. The local government criticizes the lack of anticipation of closure, as the first initiatives were launched only in 2018, and fears the consequences for local jobs when EDF staff leave and until new opportunities emerge (France Bleu 2020c).

A1.2 Philippsburgh, Germany

As part of its energy transition, known as "Energiewende", Germany targets to reduce its greenhouse gas emissions by 80 to 95% in 2050 compared to 1990 levels (Renn & Marshall 2020). To achieve this, priorities lie in the coal phase out, large-scale expansion of electricity generation from renewable sources, upgrades in transmission grid infrastructure and energy efficiency. At the same time, German policymakers decided to phase out all nuclear power following the Fukushima accident in 2011. Eight reactors were immediately shut down and the remaining reactors are being phased out by 2022. Replacing fossil fuels and nuclear power with renewables has transformed many sectors affecting a number of businesses and employees in the country with the largest energy market in the EU.

Overall, the "Energiewende" can bring many socio-economic benefits. The renewable energy sector has become a major growing industry and has created more jobs than was lost in the traditional energy industry (Clean Energy Wire 2018). However, there have been particular challenges that may be important to raise within the context of this study. For example, the "Energiewende" framework strongly supports energy community projects across the country. However, their presentation to local communities requires careful planning. There were examples of intensive opposition that managed stopping a wind farm project (Reusswig et al. 2016). This shows how sensitive the topic is and that a relatively small community can influence the feasibility of the project.

The anticipated transition planning is a key instrument supporting regional policy in its structural changes. Unexpected measures can have negative socio-economic impacts of a larger magnitude. This can be seen from the example of German NPPs, which closed immediately after the Fukushima accident in 2011. Local employment has decreased significantly and house prices fallen largely compared to regions maintaining operational NPPs (Bauer et al. 2017).

The last shut down reactor in Germany was the Unit 2 in Philippsburg in the end of 2019 (Energie Baden-Württemberg 2021). The Philippsburg NPP (PNNP) is located in the southern federal state Baden-Württemberg, which has an important history in the nuclear sector. There are three NPPs with altogether five units, two interim storage facilities, the former reprocessing plant in Karlsruhe, the European Joint Research Centre in Karlsruhe, facilities of the Karlsruhe Institute of Technology and the Siemens educational reactor (Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg 2021).

Out of the five nuclear power units, only Neckarwestheim II continues to operate, others are decommissioned. The permanent closure strategy for Philippsburg 2 therefore benefited from the experience gained in the closure of all surrounding sites. For example, the local energy company responsible for the operation, decommissioning and dismantling of the PNPP, Energie Baden-Württemberg (EnBW) Kernkraft GmbH, launched an early public communication in Philippsburg and neighbouring municipalities in 2014 Energie Baden-Württemberg Kernkraft GmbH 2018). The evolving discussion, including the main public dialogue event in 2016, concerned not only the plans for dismantling existing infrastructure, but also the re-use of the site and the construction of new facilities. This concerns in particular (i) the temporary on-site storage of waste; (ii) the residual material processing centre; and (iii) a converter to be built at the site of the recently demolished PNPP cooling towers, which will serve as a substation in the south of the next 340 km long direct current line bringing electricity from northern Germany (Transnet BW 2015).

These projects ensure that the location maintains its economic development without interruption. According to the EnBW Kernkraft GmbH, all employees, accounting for around 700 people, continue at the PNPP for the dismantling process. In addition, the Philippsburg area requires additional qualified workers through recruitment channels such as decontamination specialists, equipment mechanics or radiation protection specialists (Step Stone 2021).

A1.3 Ignalina, Lithuania

The Lithuanian Ignalina Nuclear Power Plant (INPP) closed its two units in 2004 and 2009. The closure of the RBMK-1500 nuclear power plant was a condition to join the EU. The premature closure of the only NPP, which supplied 80-85% of the energy needs, has significant national and local impacts (Poskas 2009).

Both the plant – starting its operation in 1983 and 1987, units 1 and 2 respectively – and the town (former Sniečkus, now Visaginas) were established to integrate Lithuania into the All-Soviet Union economic structures via the energy supply system. The specific characteristics of the town were specific mono-industry, high living standards and ethnic composition (mostly Russian-speaking migrants, Lithuanians as a minority). Over the years, it was a story of success and the forerunner of socialism. Following the declaration of Lithuanian independence in 1990, the town became a place of tension and uncertainty (Baločkaitė 2010). The impact of the INPP extends beyond Visaginas, in 2002 the government officially established an INPP region, with a total of 2839 km^2 consisting of municipalities Visaginas, Ignalina and Zarasai (Lietuvo Respublikos Vyriausybės nutarimas dėl Lietuvos Respublikos Ignalinos atominės elektrinės regiono sudarymo 2002).

The shutdown and subsequent decommissioning of the INPP were of unprecedented nature and represented for Lithuania an exceptional financial burden disproportionate to the size and economic power of the country. The EU financially assists Lithuania in decommissioning and in addressing the consequences of the closure of the INPP (Council regulation 2021). In addition, the region has its responsible authorities: Ignalinos NPP Regional Development Council (Regiono plėtros taryba), decision taking body and INPP Regional Development Agency (Regiono Pletros agentura), decision implementing body, responsible for implementing socio-economic projects in order to minimise the consequences of the closure of the INPP.

The site of the plant should be adapted for economic activity, re-use of buildings and infrastructure. The plan is to achieve the "green field" by 2038. For this purpose, 1800 employees still worked at INPP on 1 January 2021 (State Enterprise Ignalina Nuclear Power Plant 2021). However, the European Court of Auditors doubt that this number is adequate, and there is still no detailed staff plan covering the entire decommissioning process, which has been significantly delayed (European Court of Auditors 2016).

Despite all efforts to soften the sub-sequences of decommissioning of the INPP, the aftershock increased the energy prices, unemployment increased, trades were disappearing, and the emigration level increased (Gaigalis 2013). Over the past 20 years, the INPP region has lost around 1/3 of its population and has a higher unemployment rate and lower entrepreneurship rate compared to the country's average (Ignalinos atominės elektrinės 2018, Lietuvos regionai 2019). However, it is possible that the immediate negative impact on the region has been caused by more factors than the mere closure of the INPP, such as the global economic crisis. Some mitigating measures against poverty and social exclusion have certainly been implemented before joining the EU. However, access to the European Structural and Investment Funds has increased the capacities of the region (European Parliament 2019). The recovery task has additional challenges due to the multinational composition of the regional community (i.e. 43 nationalities in Visaginas) and the social exclusion of target communities. The municipalities of the region openly refer to these challenges and seek to address them through formal planning Visagino miesto vietos veiklos grupė 2021.

Although there are still socio-economic challenges in the region, progress has been made and efforts are slowly showing trends of recovery. For example, the number of small and medium-sized enterprises increased to 2156 in 2021 compared to 1930 in 2011 (Official Statistical Portal 2021). At national level, Lithuania's energy transition policy is on track with visible success (International Energy Agency 2021). After the closure of the INPP the energy had to be imported. Currently, Lithuania imports 70% of its electricity, while bioenergy is taking the lead in domestic energy supply. Most Lithuanian co-generation (combined production of heat and power), district heating and residential heat switched from natural gas to biomass. The Lithuanian liquefied natural gas terminal in Klaipėda has significantly reduced the country's dependence on direct gas imports from the Russian Federation, which is a declared political priority for the government. The terminal also improved gas market integration and lowered gas prices in the region.

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Annex 2. Measuring social impacts of nuclear closure and decommissioning

The results presented here are part of the conference paper Gerbelová & Shortall (2022) and are repeated here for the reader's convenience.

A2.1 Identifying social impacts

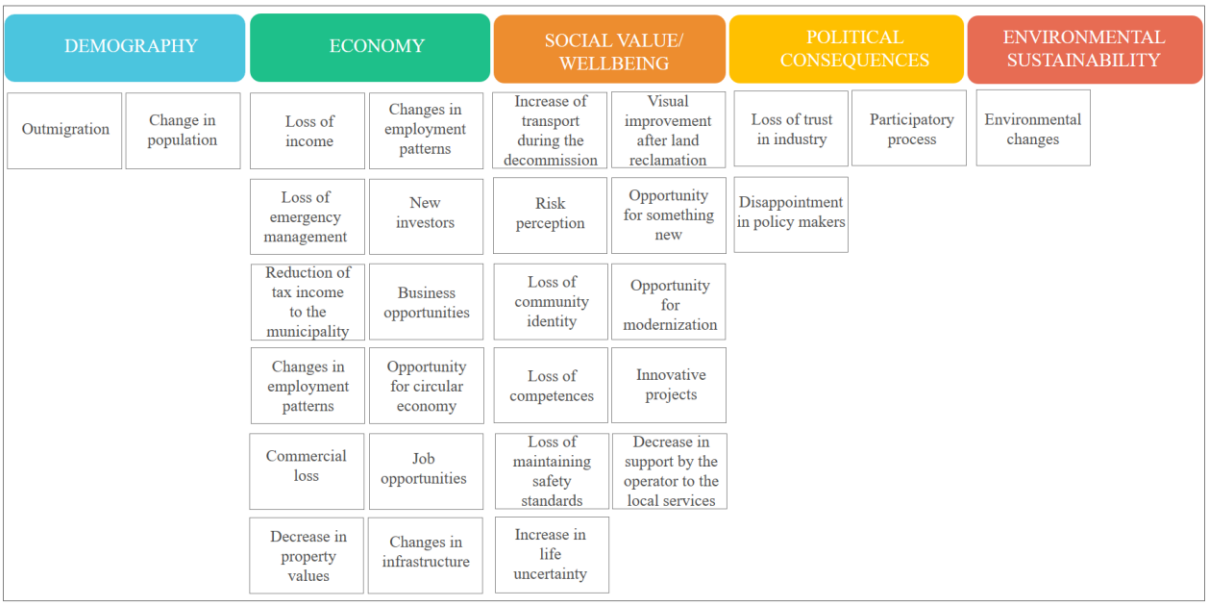
In the first part of the workshop, participants identified the most relevant social impacts according to their experience. The social impacts discussed related to impacts of the project in particular on workers and on the community in general. Participants reported some positive impacts leading to opportunities and benefits for the community, negative impacts that should be reduced or mitigated, as well as impacts with uncertain outcomes, which may potentially evolve in both directions (positive and negative) or fluctuate over time.

For example, one of the identified impacts was population change. The population may be reduced if there is no further economic development in the area. There is a risk of the departure of the employees and families of the NPP and the closure of all directly and indirectly related business activities. It is therefore crucial to continue to ensure local employment and to support the economic development of the region. The implementation of new projects will take several years and may create a gap after the departure of the NPP staff and until new opportunities arise. This shows how important it is to monitor the progress of change over time and to develop appropriate measures accordingly.

A2.2 Grouping social impacts into themes

Having set out the social impacts, we asked the participants to group them into themes in order to provide a better structure for future discussion. Figure A1 summarises the social impacts discussed in the workshop and their distribution into five proposed categories. Participants easily divided social impacts into two themes: *Economy* and *Demography* without much discussion. The themes *Well-being* and *Political Consequences* were discussed at more length because some of the impacts were considered relevant to more than one theme. The last theme identified was *Environmental Sustainability*. Although environmental impact assessment is usually carried out separately, the workshop participants still mentioned it here because environmental change by default affects society and, according to the participants, is of great concern to the community. A distinction was made between sustainability in general, which covers all three economic, environmental and social dimensions, and environmental sustainability. However, the participants argued that nuclear power plants are one of the most sustainable ways of generating electricity and that potential future projects in the area could in fact have higher environmental impacts. A representative of local authorities pointed out that the future site development plan must provide for an economic development project with less environmental damage than the current NPP.

Figure A1: Discussed social impacts categorized according to themes.



Source: own elaboration

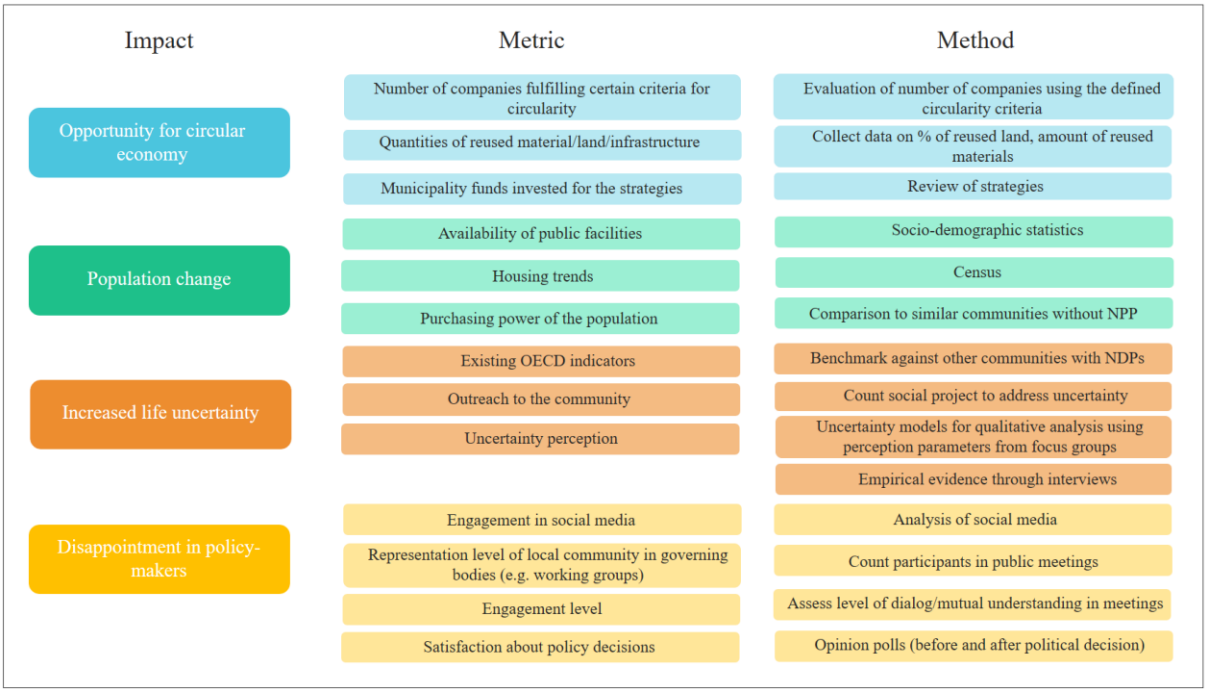
Interestingly, participants agreed that, in their experience, radiation exposure to the local population was not a major problem and the host community perceives that there is no longer a risk of exposure with the closure of the NPP. Only operational staff are aware that they may be exposed to an increase in radiation pollution during the decommissioning process. Local representatives recalled the need to maintain radiological risk management until the site is fully rehabilitated. The only specific health problem that was briefly addressed

at the workshop was the decrease of the health condition of the community and the stress caused by a possible lower quality of life.

A2.3 Proposing indicators for selected impacts

Figure A2 summarises the outcome of the final exercise, where participants proposed indicators for four selected social impacts. The first impact discussed was an *opportunity for the circular economy*. One of the proposed indicators was the number of new businesses meeting certain circularity criteria. The criteria could be measured by the amount of material reused and/or by means of ecological footprint indicators or using other environmental impacts. An important argument is that the analysis should distinguish between long-term and short-term effects. It is important to consider this in the monitoring plan and to define the frequency and duration of each measurement. Another indicator for measuring opportunities for the circular economy could be a regular review of a municipality's budget to see how many companies use the incentives for the development the pre-defined circular economy criteria.

Figure A2: Proposed indicators with metrics and methods for chosen social impacts.



Source: own elaboration

Possible indicators for *population change* were relatively straightforward, as many data are already available in statistics, such as age structure, availability of public facilities, household incomes or the purchasing power of the local population. However, participants noted that a good interpretation of the data is important. For example, local authorities observe a trend that housing prices are falling with outmigration. However, lower housing prices are an opportunity for young people. Their influx may counterbalance the trend, but the structure of the population may be different.

On the social impact of *increased life uncertainty*, participants suggested a comparison with progress in the well-being of other communities (as a benchmark) with the NDP using existing indicators developed by the Organization for Economic Co-operation and Development (OECD). Another point raised was the use of experience gained from other NDP communities or measuring outreach to the community by analysing the number of social projects aimed at reducing uncertainty. Participants also had an interesting debate on how to measure the perception of uncertainty and concluded a possible combination of qualitative and quantitative methods. For example, focus groups could formulate community perception parameters on uncertainty, which could then be used in scientific uncertainty models, and combine with empirical evidence based on surveys.

The last social impact discussed was *disappointment in policy-makers*. The first idea for measurement was an analysis of social media to see community engagement and views. Participants drew attention to the

difference between participation and an active role in decision-making and suggested also counting the active representation of the municipality in governing bodies such as working groups. The quantitative number of staff in the meetings could be complemented by a qualitative evaluation of the dialogues and mutual understanding at the meetings. Another indicator proposed was the measurement of improvements in the community's perception of policy decisions. This could be done through surveys carried out before, during and after the implementation of a decision. This would allow policy makers to reflect the results of surveys and seek better progress to the satisfaction of the community with their decisions.

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