SHARE

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D1.3: Definition of implementation qualifiers and instruments for implementation

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Abstract

This report is part of the SHARE activities in WP1 aimed at *establishing inventory of the relevant actors ensuring that the relevant spectrum of actors is addressed during implementation of the other WPs when establishing the roadmap, Developing the methodology for evaluating the stakeholders' needs, current available solutions and gap analysis. Definition of implementation qualifiers*.

This report shows the results of a desktop study carried out in order to define implementation qualifiers and instruments for implementation. The research was conducted through in-depth review of decommission activities, several expert meetings, multidisciplinary focus groups, and web-based workshops supported by Consortium and Expert Review Panel workshop reviews to consolidate and verify knowledge. Examples of implementation qualifiers are societal impact (e.g. new products, services and technologies; expected economic renewal and growth; and relevance for sustainable development and wellbeing, better protection of European citizens and the environment from harmful ionising radiation); actor-specific impacts (e.g. contribution to competences and skills development; capacity to improve performance; and improvement of national/international networks); scientific excellence (e.g. quality in science and technology development; innovation capacity); and financial. The map of the existing and potentially future qualifiers and instruments is in line with other activities conducted in other work packages of the SHARE project.

As one of the objectives of SHARE project is to identify existing and emerging innovative techniques and solutions for decommissioning employed across the nuclear industry to meet the current and future needs, the benefit of decommissioning solutions can be evaluated by “qualifiers” and the means of achieving these new solutions are identified as “instruments”. Overall, the combined set of qualifiers and instruments presented in this report provide some practical framing elements for a wide range of coordination and support actions (CSA) including, but not exclusively, those supporting the setting of Strategic Research Agenda (SRA).

In practise, the outcome of a gap/need analysis is formulated into a roadmap, where one assessment dimension can be the impact of the actions in societal, actor-specific, scientific or financial Impact Areas. Additionally, the qualifiers can be utilised in several ways e.g. 1) in project proposal phase as a checklist for the impact of proposed actions, 2) assessment of impact by the project funders or owners for self-funded technology or competence investments, and 3) research and educational institutes in order to advance knowledge through research on 4 different types of impact areas covered by qualifiers. An example would be for instance in item two of this list that the European Commission can use this document of qualifiers and indicators when evaluating future proposals in the decommissioning domain. An example for item three of this list would be for a university modernising the content of the post-graduate and short courses in topics that cover competences addressing qualifiers and indicators related to impact assessment in the decommissioning field. In both cases, the ultimate goal is to have better success in safe and efficient decommissioning, in these two examples by industrial technology impact or through competence development of qualified new staff entering the market

The content of this report is divided into Chapters. Chapter 1 presents the implementation qualifiers divided in different Impact Areas and Sub-Areas. Chapter 2 presents a high level overview of implementation instruments. Chapter 3 presents an example of the qualifier and instrument use in mapping needs.

The main objective of SHARE is to initiate and carry out collaborative actions in Europe and beyond to provide an inclusive roadmap for joint near future decommissioning research for stakeholders to improve safety, reduce costs and minimize environmental impact in the decommissioning of nuclear facilities, with commitment to:

- enhance confidence in the steps needed for the generation of knowledge on decommissioning and its safety, economic and environmental aspects
- encourage the future coordination of R&I addressing research topics strategically recommendable for financing in the next decades, to reduce overlapping work and produce savings in the total cost of R&I
- facilitate access to expertise and technology and maintain competences in the field of decommissioning and environmental remediation for the benefit of Member States and beyond.

Acronyms and Definitions

AI	Artificial Intelligence
AR	Augmented Reality
BD	Big Data
BIM	Building Information Modelling
CSA	Coordinated Support Actions
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EDTA	Ethylenediaminetetraacetic acid
FRMF	Free Release Measurement Facility
H2020	European Commission Horizon2020 program
Indicator	Parameter for which a topic is assessed
Instrument	Programs, policies or means of financing
KPI	Key Performance Indicator
KT	Knowledge Transfer
MS	Member State
NPP	Nuclear Power Plants
PPE	Personal Protective Equipment
PPP	Public-Private Partnerships
Qualifier	Quantitative or qualitative measure of impact
R&D	Research and Development
RIA	Research and Innovation Actions
SME	Small- and Medium-sized Enterprises
SRA	Strategic Research Agenda
TED	Tenders Electronic Daily
TRL	Technology Readiness Level

VR	Virtual Reality

1. Implementation Qualifiers

Decommissioning projects are multifaceted projects as illustrated in Figure 1-1. As such, implemented efforts (i.e. resources, R&D etc.) can have a rippling effect across the whole project and the quantitative and qualitative impacts of these efforts can be difficult to evaluate due to long time scales and numerous actors involved. “Qualifers” are defined as an item or property by which a change can be evaluated. Qualifiers can be broken down into four areas of impact, which include societial, actor-specific, scientific and financial. “Indicators” are the metric by which a qualifier is assessed, typically in reference to a change over time. They may also be referred to as Key Performance Indicators. It is preferred that indicators are quantitative or numeric, but in some cases they may also be only qualitative representing an impression or view of the situation (such as urgency, criticality, importance, riskiness, uncertainty). Examples of quantitative indicators are units of number of persons, time, volume, or monitory value. The availability of the information needed for the indicators may be challenging (e.g. private data held by companies, long time scales or delay in measurable impact). However, different avenues for information collection or modification of the indicators should be explored case by case. It can help when preparing a project or investment to have clear targets of the anticipated qualifiers and indicators, and then these should be tracked through the project duration. Examples of this would be to evaluate (positive) time savings when investing in a new process that is costly (negative) to understand the cost-benefit ratio. In such case, the qualifiers are time and cost, indicated in days and euros respectively. Use of pre-defined qualifiers and indicators at the start of the process helps evaluate the effectiveness of the implementation. The same can hold true when creating a gap analysis and/or strategic research agenda (SRA), where the qualifiers are used as basis for questions about the needs from various actors (e.g. companies, regulators, educators, society). The priorities for in the SRA are then described with respect for the associate qualifier to which the action will benefit.

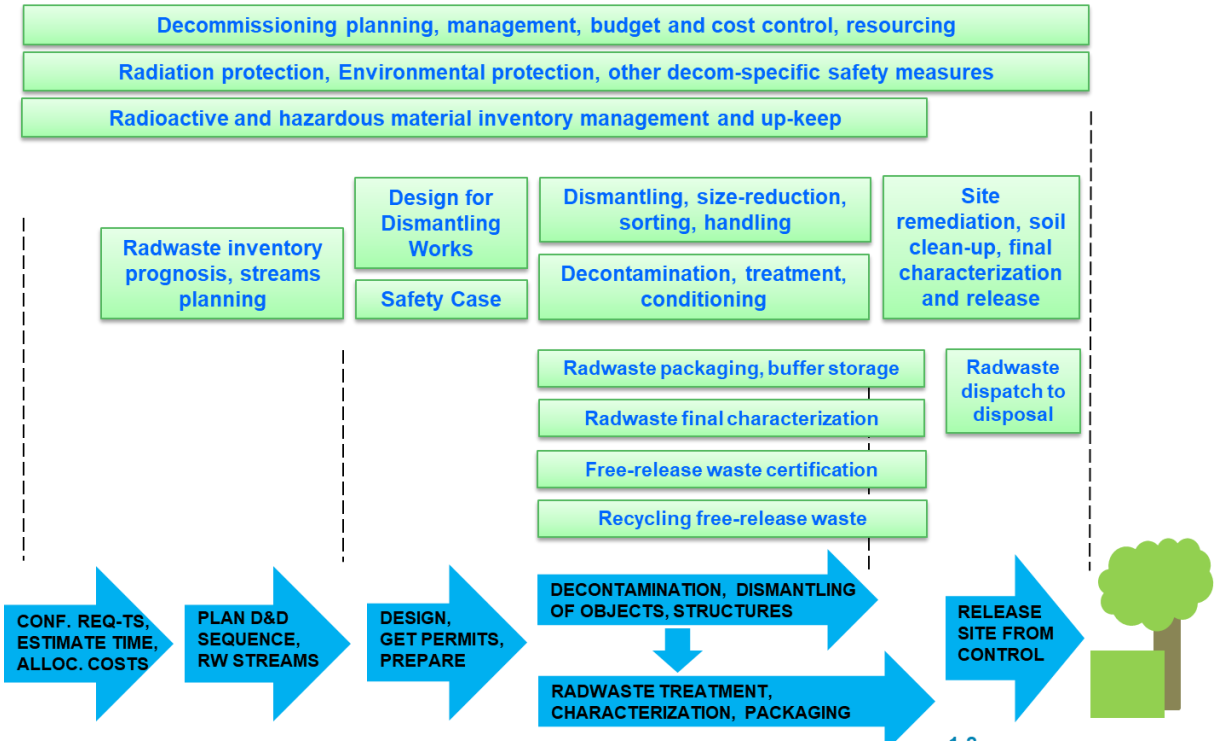

Figure 1-1. An example decommissioning project overview (modified) [1]

The rest of this chapter breaks down each of the four qualifier topics (i.e. Impact Area) into sub-areas for which the impacts can be measured. Each sub-area is described along with the suggested indicator, and in many cases give examples. Table 1-1 gives an overview of the Impact areas, Sub-areas, and Indicators covered in the following four sections.

Table 1-1. Qualifier overview.

Impact Area	Sub-Areas	Qualifier ID	Indicator
Societal	***Economic renewal and growth***	QL-01	*number of new companies registered*
		QL-02	*number of new persons employeed in a region, company or department*
	Protection of citizens and environment	QL-03	*percentage reduction of radioactive waste volumes between classes (HLW→ILW→LLW→VLLW)*
		QL-04	*percentage increase of exempt waste*
		QL-05	*percentage increase of material re-sold as recycled*
		QL-06	*percentage decrease in production of secondary waste streams (waste cleaning by-products)*
		QL-07	*percentage decrease in environmental accidents (i.e. waste chemical leaks or spills)*
		QL-08	*percentage decrease of human exposure accidents*
		QL-09	*percentage decrease of human occupational exposure*
	Public trust and confidence	QL-10	*rating percentage of public confidence in regulator in decommissioning oversight*
		QL-11	*rating percentage of public confidence in government in decommissioning policy*
		QL-12	*time/efficiency in moving from policy toward implementation and completion*

Actor-specific	***Processes, products and services***	QL-13	*number of new processes*
		QL-14	*number of new services*
		QL-15	*number of new products*
	Capacity to improve performance	QL-16	*percentage increase in efficiency of tasks*
		QL-17	*percentage decrease in time needed per task*
		QL-18	*percentage reduction in regulatory review time needs*
	Contribution to competences and skills development	QL-19	*number of new persons entering the workforce*
		QL-20	*number of persons completing training/certification*
		QL-21	*percentage reduction of accidents*
		QL-22	*number of services/tools available that address knowledge-management*
	Improvement of national/international networks	QL-23	*number of companies involved in research projects*
		QL-24	*number of companies involved in business partnerships*
		QL-25	*number of employees moving between companies/tasks/projects*
		QL-26	*number of cross-disciplinary actors within a project or research consortium*
Scientific	***Quality in science and technology development***	QL-27	*percentage efficiency in waste treatment methods*
		QL-28	*percentage efficiency in waste reduction methods (volume or mass reduction)*
		QL-29	*percentage efficiency in dismantling process*
		QL-30	*number of peer-reviewed scientific publications*
		QL-31	*number of chapters in scientific books*
		QL-32	*number of papers in conference proceedings*
		QL-33	*number of invited international guest lectures*
		QL-34	*number of capacity building or training programmes*
	Innovation capacity	QL-35	*number of patents filed*
		QL-36	*number of new spin-off initiatives*
		QL-37	*number of industrial companies co-financing research, technology development and innovation*
Financial	***Revenue and turnover***	QL-38	*number of new tender opportunities*
		QL-39	*monetary value (i.e. euros), percentage reduction or savings*
		QL-40	*monetary investment (i.e. euro) distribution between public-private*
	Sufficient investment	QL-41	*number of new tools/funding models*
		QL-42	*monetary availability for investing in company creation*
		QL-43	*monetary investment (i.e. euros) to funding schemes*
		QL-44	*number of available open-access facilities*
		QL-45	*number of temporary person exchanges between facilities/companies*

Qualifiers type 1: Societal impact

The first category of qualifiers addresses impacts to society, which can be viewed at a local, municipality, regional, country or EU level. The societal impacts address higher level area economics, perspectives of people, environmental protection and the overall trust and well-being of the society. They have overlaps to the other three categories as well.

1.1.1 Economic renewal and growth

Economic renewal and growth at a societal level covers a holistic approach to the region. These are also tied to the financial impacts described in Section Qualifier type 4 at a more detailed level, but at the societal level are measures of wider impact.

1.1.1.1 Companies (QL01)

Indicator = number of new companies registered

Increase in decommissioning will lead to an increase in the number of work force and services needed. Thus the availability of market potential for existing companies to expand their offering and new companies, at both the SME and large scale, to enter and expand in the market are high. Measurement of company growth are indicated by revenue, employees, turnover which are further described in Section Qualifiers type 4. Increase of companies registered often brings greater tax benefits to a region. This in-turn can impact the quality and availability of the societal public services in the area, such as health care, schools, roadways and infrastructure and public transport.

The number of companies entering the market can be assessed for instance by national trade association registries of active participants, number of new companies participating to industrial trade fairs, and number of companies and consortiums bidding to public procurement services. Examples of types and scopes of new companies could include demolition, cutting, heavy lifting/operations, recycling, safety equipment, digital modelling/simulation, economic estimation, etc.

1.1.1.2 Jobs (QL02)

Indicator = number of new persons employeed in a region, company or department

Linked to creation of new companies or expansion of existing companies, there is a need for greater work force and thus job creation. Increase of jobs leads to greater populations in local municipalities, and again also increased individual consumer spending and tax revenue for the region. As companies grow, they recruit or train for new positions. In many cases the job creation may actually be a competence development or training to adapt existing know-how to a new domain or department within the same organisation. For instance, an operating nuclear power plant facing closure and decommissioning will need to re-allocate much of its staff to new positions with an adjusted or re-tailored skillset. Typical new employee skill sets or job creation in decommissioning include civil engineering, material science, chemistry, environmental science, construction, surveying, monitoring, data management and economic forecasting. Example of decommissioning market growth is shown in Figure 1-2.

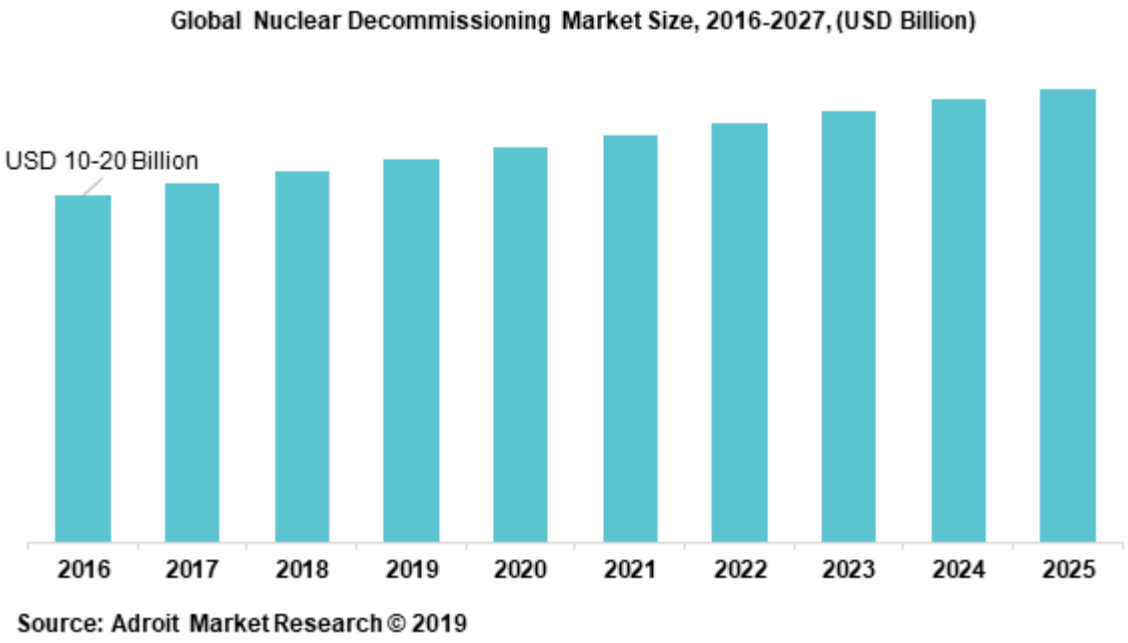

Figure 1-2. Decommissioning market forecast [2]

1.1.2 Protection of citizens and environment

Protection of citizens and environment is a core priority in decommissioning projects. Environmental considerations are also often key drivers for the public perception and acceptance in all nuclear related activities. In decommissioning activities, especially final disposal of high and intermediate level radioactive waste can be problematic if public trust and confidence is low.

1.1.2.1 Waste Volumes (QL03, QL04)

Indicator = percentage reduction of radioactive waste volumes between classes (HLW→ILW→LLW→VLLW)

Indicator = percentage increase of exempt waste

Incentives for efficient decommissioning primarily address optimisation of waste streams, so that a greater volume of waste can be free-released or can be disposed of in an easier class of repository, for instance at very low-level radioactive waste repository compared to medium level radioactivity. Improved procedures in waste classification enable more efficient and effective decommissioning processes. The waste classification (Figure 1-3) drives the reduction of the highest level of waste inventory. The drive for waste reduction addresses the conservation of environment and minimize the level of risk hazards. An example facility for pre-selection and free release measurements of nuclear facility wastes has been installed, tested and calibrated in CIEMAT Spain (i.e. Free Release Measurement Facility) within MetroDecom II project [3]. The indicator measurement is the percentage reduction (volume) of total waste per waste level classification (high, medium, low, very low) according to radioactivity.

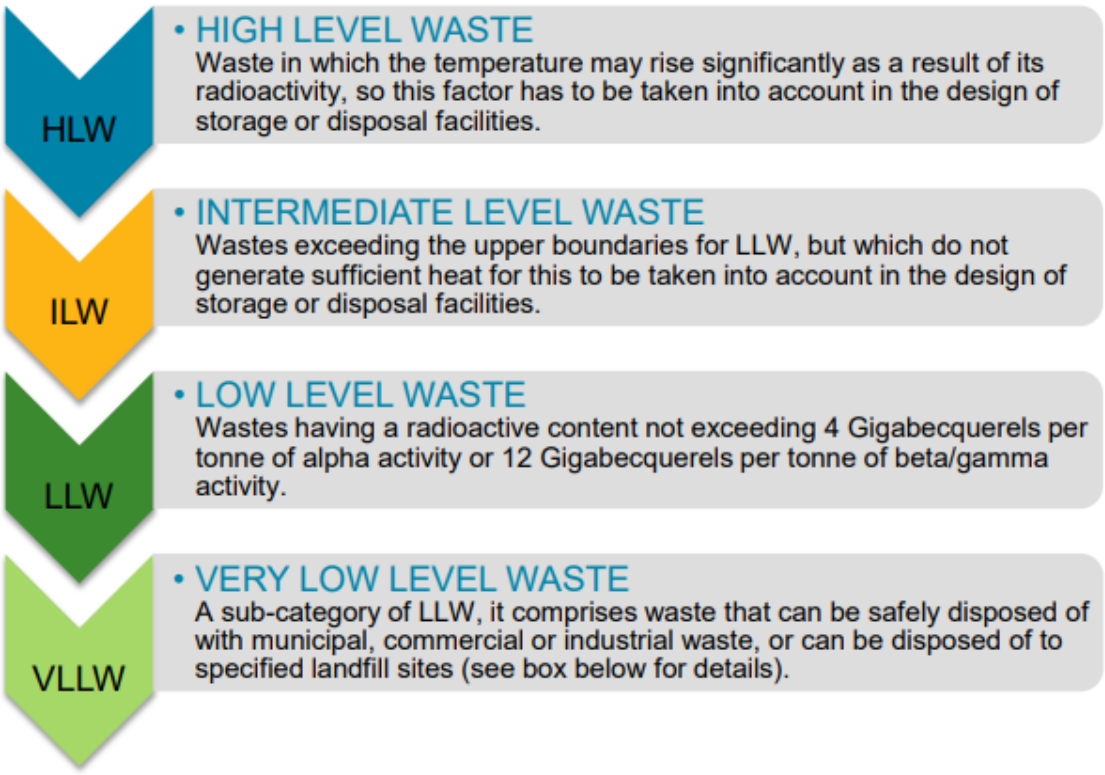

Figure 1-3. UK example of waste classifications, with target towards having greater volumes at lower levels than high levels [4]

1.1.2.2 Circular Economy (QL05)

Indicator = percentage increase of material re-sold as recycled

Waste hierarchy is a central theme for radioactive waste management. Figure 1-4 shows the waste management approaches according to environmental impact i.e. waste prevention is the most preferred approach and then waste minimisation, re-use, and recycling. The last approach, namely disposal, is left for wastes that cannot be managed using the more preferred approaches. For example. decommissioning produces large volumes of concrete waste, which can be re-used in industrial applications such as road construction fill. Any recycling of valuable resources, such as metals, benefits the circular economy.

Figure 1-4. Waste hierarchy of preferred approach [4]

1.1.2.3 Secondary waste (QL06)

Indicator = percentage decrease in production of secondary waste streams (waste cleaning by-products)

Secondary waste can contribute to a large percentage of decommissioning waste management. In addition to maintenance waste (i.e. used PPEs etc.), waste cleaning such as decontamination solutions/reagents/gels or laser peelings, produce contaminated by-products. For example, decontamination of large surface areas with water jetting causes large volumes of contaminated liquids and solids. These liquids can also contain complexing agents such as EDTA, which need to be taken into consideration in the radioactive waste management (i.e. waste acceptance criteria).

1.1.2.4 Environmental accidents (QL07, QL08)

Indicator = percentage decrease in environmental accidents (i.e. waste chemical leaks or spills)

Indicator = percentage decrease of human exposure accidents

In radioactive waste management (e.g. decommissioning waste management, legacy waste management), corrosion can increase the risk for waste leaks. Inproper storage of radioactive waste and failure of tanks and reservoirs can then cause wide spread environmental accidents and exposure of population. Therefore, innovations in package materials/packing techniques, enable safer packing and storage of radioactive wastes resulting in decrease of environmental accidents.

1.1.2.5 Occupational exposure (QL09)

Indicator = percentage decrease of human occupational exposure

Radiation safety is an overarching concept in keeping the occupational exposure to ionising radiation as low as reasonably achievable throughout the whole nuclear field. It is mirrored in whole spectrum of decommissioning processes starting from licencing/regulatory approval all the way to planning, execution and beyond. Comprehensive planning, exchange of experience, mock-up projects and

trainings enable efficient execution of critical decommissioning steps minimising the external exposure (e.g. removal of spent nuclear fuel or activated core components) and internal exposure (e.g. airborne contamination in biological shield cutting).

1.1.3 Public trust and confidence

Well planned, implemented and communicated decommissioning projects build trust and confidence of the public in the nuclear industry and actors in the decommissioning field. Procedures for public communication trust building can include good media coverage, open access to relevant documentation, dialogues processes, open hearings, workshops whereas trust and confidence can be measured with surveys, gallups etc. The public should be able to greate an understanding on decommissioning scenarios, technologies and processes involved, cost and schedule, risks and safety aspects, waste management with possibilities of recycling or routes to final disposal.

1.1.3.1 Regulator confidence (QL10)

Indicator = rating percentage of public confidence in regulator in decommissioning oversight

The regulator confidence is based on a dialogue with the public giving correct information through transparent and simple explanations. Additionally, transparent decision making processes conducted taking all concerns into account build trust and confidence. For example, stakeholder hearings give a platform for all national stakeholders (e.g. public, activist groups etc.) to have an impact in the processes such as decommissioning lisencing and environmental impact assessments. The dialogue also strengthens the engagement.

1.1.3.2 Government confidence (QL11)

Indicator = rating percentage of public confidence in government in decommissioning policy

The government confidence is based on adequate funding instruments, resources for independent research to support political decision making, support of regulator, and engagement at high political level and also internationally (i.e. EU and neighbouring countries). Additionally, as emphasised in the previous section, transparency is a critical component of government confidence too.

1.1.3.3 Policy efficiency (QL12)

Indicator = time/efficiency in moving from policy toward implementation and completion

Policy efficiency comes from good education, government official engagement with experts, efficient communication, accurate vision/roadmap, commitment of resources etc. Timely and efficient policy implementation includes determined and swift policy formulation and evaluation processes, including the *ex ante* impact assessment of new policies, as well as the *ex post* evaluation of old policies.

Qualifiers type 2: Actor-specific impact

The second category of qualifiers addresses Actor-Specific Impacts, which reflect individual company or industry advances. These qualifiers can include decommissioning processes, products and services, efficiency, as well as competences, skills and networks of people. These qualifiers are often the motivation for company investment to decommissioning, with the drive to be leaders in the decommissioning domain and strengthen their business position and market offering.

1.2.1 Processes, products and services

Linked to the Section 1 above, the creation or expansion of companies into the decommissioning market can also lead to new innovative tools that are offered on the market. The indicator can be evaluated by for instance by the number of new products, solutions or (non-physical) tools such as software systems and applications as well as sercvices. These are measured for instance by products and services advertised by a company within their web page, or product brochures. Examples of new tools could be reversed BIM models to efficiently plan the dismantling cuts of components.

1.2.1.1 Processes (QL13)

Indicator = number of new processes

Both new and existing actors in the field of decommissioning are in constant need for significant improvements or introduction of new processes, techniques and procedures for waste reduction, management and other related activities. This indicator focuses on the number of new processes creating a competitive advantage in terms of cost reduction or resource efficiency or production processes differentiation strategies. Examples of cost reduction and resource efficiency include a recycling plant for steel from dismantled nuclear facilities is at Marcoule, in France. This metal will contain some activation products, but it can be recycled for other nuclear plants. Studsvik Ab in Sweden and Energy Solutions in the USA recycle metals which can be released into general use. Examples of production process differentiation include industrial actors from other decommissioning fields (like oil and gas, fossile power plants and other big industrial complexies, even military sites) coming with their processes and experience into the nuclear decommissioning field.

1.2.1.2 Services (QL14)

Indicator = number of new services

A wide range of actors play either leading or supporting roles in the introduction of new services or the significant improvements of existing services in terms of their functionalities, specifications or characteristics. This indicator focuses on the number of new services linked to the execution, supervision or monitoring of decommissioning. The indicator also relates to new assessment services for the dismantling of nuclear facilities, as well as new software applications supporting safety and sustainability assessment activities. Some large actors combine all the necessary services into a single offering, sometimes including even waste management. But also in this case the new services in planning (e.g. 3D BIM model creation with laser scanners and drones), in execution (e.g. demolition using robots) or waste sorting and segregation (e.g. using the automated system proposed by NDA) can be identified. Services in decommissiog field include the decontamination process for large metal parts developed by Studsvik Ab in Sweden in 1980s. The Studsvik facility has a capacity of 5000 tn per

year. In 2009 Studsvik Ab opened similar facility in the UK near Sellafield. In 2016 EDF bought both facilities which demonstrates the proven status of these facilities in the market.

1.2.1.3 Products (QL15)

Indicator = number of new products

Innovative decommissioning actors often seek to introduce new or significantly improved tools/goods, artifacts, industrial machinery or physical infrastructures/tools into the market. This indicator focuses on number of new products or innovations that reached the development stages of the Technology Readiness Level (TRL) scales 7, 8 and 9, namely:

- Examples of product innovations at TRL-7 (i.e. system prototype demonstration in operational environment) include the robotics solutions demonstrated at the Sellafield site for inspection and handling of waste.
- Examples of product innovations at TRL-8 (i.e. system complete and qualified) include Manuela Manuela™ portable tool for the topographical and radiological mapping of nuclear facilities (market introduction in 2016 by Orano) and used until now successfully at several EDF sites.
- Examples of product innovations at TRL-9 (i.e. actual system proven in operational environment)

1.2.2 Capacity to improve performance

It is important to identify where the best opportunities exist to improve overall performance on decommissioning. Performance is measured by efficiency and lead time of tasks. Also time needed for regulatory review influences the overall performance.

1.2.2.1 Efficiency of tasks (QL16)

Indicator = percentage increase in efficiency of tasks

Efficiency measures the ratio of required input to the desired output. It can be quantified using costs, labour force, materials, energy, etc. Use of improved technologies and processes can reduce the required labour and minimize generation of secondary waste. This can take place for example using robotics for dismantling, sorting, packaging and cleaning. Increasing the efficiency levels when mixing human and robot interactions vary in case-by-case basis, especially when multirobot systems are put into operation with the expectation of working together with people as team. In such situations, efficiency can be increased by better training humans in the management of human-robot interactions, or by better programming multirobot systems to meet the needs of human operators or both.

1.2.2.2 Lead time (QL17)

Indicator = percentage decrease in time needed per task

Long lead times in nuclear industry, including decommissioning, makes this industry to differ dramatically from other industries which have been able to reduce the lead times considerably. Ways of reducing the time needed for each task would lead to a reduction in the lead times. Robotics, digital technologies, real-time data analytics and systems/processes automation are considerably reducing

the amount of time needed to identify, assess and allocate tasks to humans and robots, as well as to execute and complete those tasks. Furthermore, integrated IT solutions/systems are increasing the multi-tasking capabilities of humans and robots, thus helping to significantly reduce the time needed for tasks that may be independent from one another.

1.2.2.3 Regulatory review (QL18)

Indicator = percentage reduction in regulatory review time needs

Regulatory reviews are one of the most important processes causing the very long lead times in nuclear industry. Using advanced technologies and software (like BIM/Digital twin approach) could allow integration of the regulatory review as a parallel process to the planning and design phase. Another important driver of efficiency and time reductions in regulatory reviews is 'standardisation'. For example, European regulators have a long tradition in the development of standardised Safety Reference Levels (SRLs) for decommissioning and nuclear waste management processes. Compliance with such SRLs and other IEC and non-IEC safety standards can help to reduce regulatory review time needs.

1.2.3 Contribution to competences and skills development

Safe and efficient nuclear decommissioning requires a complex and diverse range of skills and competences. The length of programmes requires consideration not only of the current availability of skills and capabilities but how they might be sustained over lengthy timescales. New skilled and competent people are needed to replace the senior highly skilled workforce as many workers approach retirement age. These implementation qualifiers measure how different solutions and choices influence the availability of well-educated and competent workforce devoted to safe decommissioning.

1.2.3.1 Workforce (QL19)

Indicator = number of new persons entering the workforce

There is a strong competition in Europe between the different technology sectors for competent and skilful workers entering the labour market. Therefore, the number of persons hiring to nuclear decommissioning work indicates people´s appreciate the potential of these companies. The automation, digitalisation and robotisation waves are transforming nearly all industries, including those in the nuclear sector. As a result, the workforce supply and demand are increasingly shaped by new needs for IT competences and skills, which is likely to continue increasing the number of IT consultants and managers entering the workforce.

1.2.3.2 Training and certification (QL20)

Indicator = number of persons completing training/certification

Developing of training and education at national and the EU level requires collaboration across countries. Training and capacity building programmes also improve national and international networks, while reinforcing EU level competence in decommissioning that would have relevance outside of Europe, and this could enhance competitiveness of Europe in global decommissioning projects. Overall, by increasing the number of trained and certified workforce Europe will also improve

the capacity to improve performance. A well-trained workforce will help to increase efficient of tasks, reduce the time needed per task and at the same time ensure compliance with safety standards, thus contributing to reduce regulatory review time needs.

1.2.3.3 Reduction of accidents (QL21)

Indicator = percentage reduction of accidents

Reducing accidents is often the result of multiple interconnected interventions. In highly regulated sectors such as the nuclear waste and decommissioning industry, compliance with safety standards, protocols and procedures is key to the reduction of accidents. However, the main reason for accidents to happen are the lack of effective monitoring processes, poor adaptation and mitigation strategies to changing conditions, lack of early response mechanisms, as well as the lack of foresight competences and culture to anticipate, assess and timely manage possible short-medium-to-long-term risks.

1.2.3.4 Knowledge-management (QL22)

Indicator = number of services/tools available that address knowledge-management

The uptake of virtual reality (VR), augmented reality (AR), Big Data (BD) and Artificial Intelligence (AI) is pushing for improved knowledge management based on these and other technologies. Similarly, there is an increasing need to understand the role of organizational cultures in knowledge management, which often translates into the introduction of new solutions accelerating the absorptive capacity of individuals and teams within an organisation or company.

1.2.4 Improvement of national/international networks

National and international networking activities bring multiple benefits to both research and business communities. Some of the commonly known benefits of networks is their ability to support knowledge transfer (KT) through multiple channels (e.g. internships, collaborative/contract research, licensing, publishing, etc.) and for a variety of reasons (e.g. exploring new ideas/opportunities, mapping common needs and gaps in terms of resources and information, etc.). In the context of promoting actor-specific impacts, research networks, business networks, as well as the role of mobility and multidisciplinary have been considered of particular relevance for the mapping of qualifiers and related indicators.

1.2.4.1 Research networks (QL23)

Indicator = number of companies involved in research projects

A growing number of companies are actively participating in research projects either as full partners, subcontractors, observers or as case studies in the piloting or demonstration of research and innovation solutions, especially in the context of some research-driven public-private partnerships (PPPs) (see also Section 2.3).

1.2.4.2 Business networks (QL24)

Indicator = number of companies involved in business partnerships

Companies often seek for partnerships with other companies with the same value generation network either as suppliers, purchasers or distributors of products and services. In decommissioning it is typical

that large companies create full-service decommissioning offerings using technologies from high-tech companies and services by companies dedicated to industry services.

1.2.4.3 Mobility (QL25)

Indicator = number of employees moving between companies/tasks/projects

Knowledge transfer is often linked to the mobility and mutual-learning that happens when employees from one company move to other companies and undertake different tasks or projects.

1.2.4.4 Multidisciplinarity (QL26)

Indicator = number of cross-disciplinary actors within a project or research consortium

Knowledge generation, especially about the future (e.g. challenges, risks and opportunities) requires an increasing combination of expertise, evidence and creativity, often blended with the help of interactive and participatory processes involving a wide range of stakeholders from multiple disciplines.

Qualifiers type 3: Scientific impact

The third category of qualifiers addresses Scientific Impact, which reflects technical and innovation issues associated with decommissioning. These qualifiers are often the items most associated with academic and/or research and development projects, where metrics are physical improvements.

1.3.1 Quality in science and technology development

The high quality achievements in science and technology are often a result of several years of research efforts requiring intra- and multidisciplinary collaborations. As such, short projects may not be able see the scientific impact during the project duration. However, in the decommissioning field, the overall projects cover years and even decades and thus, the R&D can be developed, published and utilised during the project duration. Collaboration and publishing is key for the scholarly conversation and impact in scientific community. Quality indicators to assess publication, research quality and impact are journal credibility, journal impact factor (i.e. statistical measure to compare journals in a given field published yearly in Journal Citation Reports), and citation counts / H-Index.

1.3.1.1 Waste Treatment and Waste Reduction (QL27,QL28)

Indicator = percentage efficiency in waste treatment methods (ratio of the mass of segregated part to the original mass of radioactive waste)

Indicator = percentage efficiency in waste reduction methods (volume or mass reduction)

The scientific research carried out in waste treatment (e.g new chemical agent for metallic cleaning) and waste reduction (e.g high temperature HIP, gasification etc.) gives input in understanding of fundamental level reactions. These results, in turn, are reflected in new technologies with higher efficiency (e.g lower reagent use, lower amount of secondary waste etc.) and better value to cost ratio in decommissioning processes.

1.3.1.2 Dismantling Process (QL29)

Indicator = percentage efficiency in dismantling process (time and resources needed for the dismantling process)

Utilisation of technologies, such as uptake of BIM linked robotics and use of training simulators, widens the set of decommissioning tools resulting in more time and resource efficient dismantling processes.

1.3.1.3 Scientific Publications (QL30, QL31)

Indicator = number of peer-reviewed scientific publications

Indicator = number of chapters in scientific books

Scientific publications include a wide range of research outputs often classified into the following categories: primary – including original research articles, some government and case study reports; secondary – such as text/edited books and articles providing systematic summaries or reviews of primary research; tertiary – aimed at listing or repackaging existing information and knowledge. This indicator focuses on the number of primary publications in journals such as Analytica Chimica Acta, Energy Policy, Environmental Impact Assessment Review, Environmental Research Letters, Materials

Today, Nuclear Engineering and Design, Renewable and Sustainable Energy Reviews, among others. The indicator can also include the number of secondary publications, for example, chapters in (edited) books by respected publishers such as Springer Nature's books and eBooks.

1.3.1.3 Conferences (QL32)

Indicator = number of papers in conference proceedings

Conferences provide an excellent opportunity to share and learn from recently implemented or ongoing strategies, instruments and technological/scientific developments as well as common challenges faced by policy, business, research and civil society actors.

1.3.1.4 Education Lectures (QL33, QL34)

Indicator = number of invited international guest lectures

Indicator = number of capacity building or training programmes

Building competences and skills on state-of-the-art technologies, practices and developments is key to promote excellence and achieve desirable impacts from ongoing and future activities. This qualifier focuses on two indicators: the number of invited international guest lectures to share knowledge and the number of capacity building or training programmes boosting individual and organisational absorptive capacities.

1.3.2 Innovation capacity

In an increasingly competitive, uncertain and sometimes rapidly changing world it is becoming imperative for firms and other organisations, including government, research and civil society actors, to play an active role in innovation activities. To do so, the development of innovation capacity both to introduce new products, services and processes to the market and to develop in-house solutions that to boost excellence and impact benefiting an organisation and society in general. Many indicators can be linked to the innovation capacity, however patenting, spin-off from existing companies and open innovation practices have been suggested as of particular relevance for the qualifiers related to scientific impact.

1.3.2.1 Patenting (QL35)

Indicator = number of patents filed

Protecting the IP of inventions and technological solutions of procedures through patents is one of the ways to securing a competitive advantage in some industries. While there is also plenty of literature about the mixed impacts of patents on innovations, those who argue in favour of patents focus on their positive impact in terms of increasing the economic returns of investments in research and development (R&D). Taking this perspective in mind, this indicator will measure the number of new patents filed.

1.3.2.2 Spin-off from existing Companies (QL36)

Indicator = number of new spin-off initiatives

Spin-off companies emerged from successful alternative or new activities, technologies, processes, products and services developed within an organisation or company. The operations of spin-off companies are often independent from the parent company, however the licensing of some technologies or access to common networks may also be expected.

1.3.2.3. Open innovation (QL37)

Indicator = number of industrial companies co-financing research, technology development and innovation

There is an increasing interest to promote higher levels of participation of the private sector in collaborative research and innovation initiatives, as well as coordinated actions promoting technology development and transfer to/from public initiatives at national and EU levels. This indicator focuses on the number of industrial companies co-financing research, technology development and innovation. Examples of these innovation initiatives are the Sellafield challenges and the competitions for innovative solutions run by Innovate UK, in conjunction with the Nuclear Decommissioning Authority, Sellafield Ltd and Magnox Ltd.

Qualifiers type 4: Financial impact

As noted in Section 1 on qualifiers of Societal impact, a driver of impact is related to company and job growth. These have more detailed or specific indicators of direct Financial Impact in this section of the fourth qualifier type. Qualifiers are addressing business, offering solutions and funding schemes. Table 1-2 shows an example characteristics of ecosystem types addressing the relationships, actors and roles. It should be noted that from the society point of view, finally a successful and optimal decommissioning system will require fewer financial resources. Meaning the market will be highly competitive.

Table 1-2. Characteristics of ecosystem types [5]

	Business Ecosystems	**Innovation Ecosystems**	**Knowledge Ecosystems**
Baseline of Ecosystem	Resource exploitation for customer value	Co-creation of innovation	Knowledge exploration
Relationships and Connectivity	Global business relationships both competitive and co-operative	Geographically clustered actors, different levels of collaboration and openness	Decentralized and disturbed knowledge nodes, synergies through knowledge exchange
Actors and Roles	Suppliers, customers, and focal companies as a core, other actors more loosely involved	Innovation policymakers, local intermediators, innovation brokers, and funding organizations	Research institutes, innovators, and technology entrepreneurs serve as knowledge nodes
Logic of Action	A main actor that operates as a platform sharing resources, assets, and benefits or aggregates other actors together in the networked business operations	Geographically proximate actors interacting around hubs facilitated by intermediating actors	A large number of actors that are grouped around knowledge exchange or a central non-proprietary resource for the benefit of all actors

1.4.1 Revenue and turnover

Individual company growth or performance in the decommissioning market is measured by their annual financial reporting, as turnover and revenue in euros and growth in percentage change over time. A company's growth indicates their success in penetration and delivery in the market. The company's growth is also tied to their success in demonstrating high quality services, tools and success in delivery. The accumulation of many companies entering the market and good performance is linked to the societal impact (Section 1).

1.4.1.2 Market Potential (QL38)

Indicator = number of new tender opportunities

The financial impact from decommissioning can be evaluated by assessing the opportunities on the market for companies to offer their services. The availability of tendering opportunities in the public and private sector per year is an indicator of the market potential. Tendering opportuties can be evaluated by total number of open opportunities, volume of the tenders (euro), duration of the work scope (months, years) and size of the awards. A company's performance can be indicated by the number of new offers (or euro volume offered) that are evaluated as opportunities or submitted per year.

Examples of tracking market potential for decommisisioning opportunities and offers are for instance the public procurements on the European TED (Tenders Electronic Daily) system found at https://ted.europa.eu/TED. TED is the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurement.

The EC has explained the number of opportunities increasing at a steady rate over the last decade and an estimated future forecast of significant needs for additional decommissioning expertise due to the evolution of the NPP fleet, as shown in Figure 1-77.

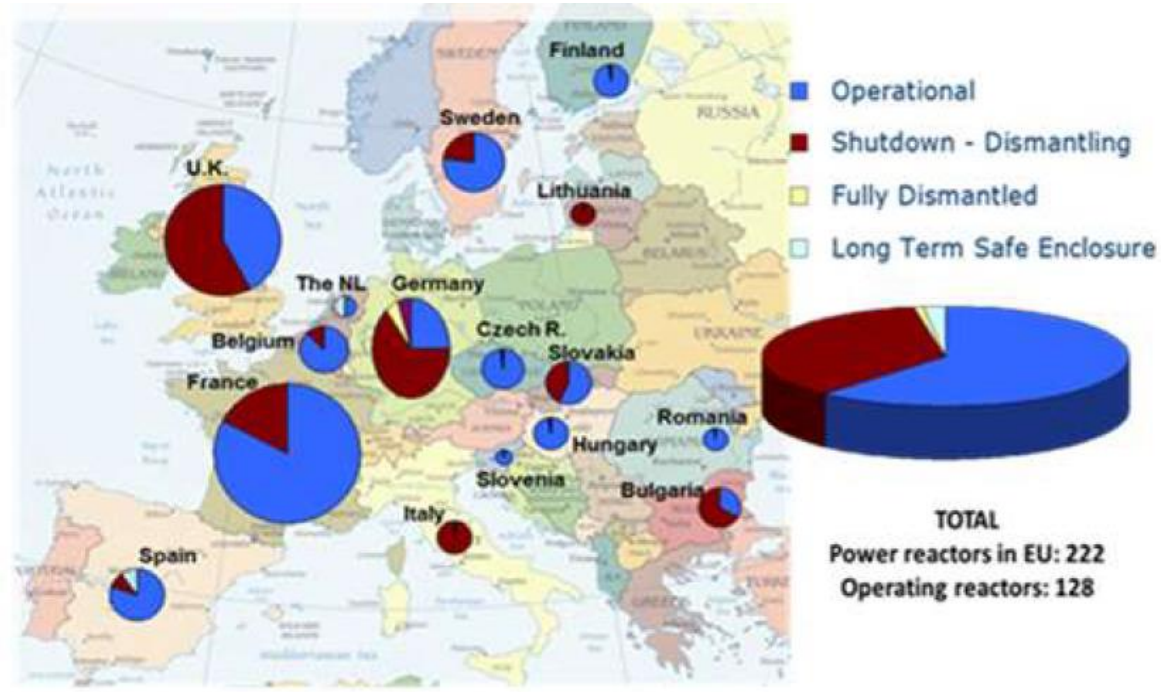

Figure 1-7. European Decommissioning market, status of nuclear power plants [6].

1.4.1.3 Reduced Liability (QL39)

Indicator = monetary value (i.e. euros), percentage reduction or savings

As the decommissioning services and offering become more mature and common practice, the risks associated with their delivery become less. Repeated offering and delivery of routine tools and practices mean more accuracy in forecasting the techniques to use, schedule and budget. Thus companies procuring and also deliverying the decommissioning have lower liabilities or uncertainties. This helps reduce the costs of decommissioning. Reduced liability can be seen in contractual terms as well as in dispute resolution (for instance number of litigations, value (euros) of litigations). Reduced liability also can be indicated within a company's financial balance sheets, as it can result in higher or lower profit margins at the completion of decommissioning tasks or projects.

1.4.1.4 Funding Schemes (QL40)

Indicator = monetary investment (i.e. euro) distribution between public-private

The level of maturing of decommissioning across Member States and internationally between countries is varied. The funding scheme for handling the costs associated with decommissioning are varied between the Member States, often as a hybrid between governmental/public financing and private funding from the nuclear power plants. The waste management funds of each country are varied based on how funds are collected, reinvested and used over time for decommissioning.

An indicator of decommissioning maturity can be linked to the distribution of funding (euros per year) between public and private funds. The change in time for who is financing a specific project can indicate the maturity of a program or country to handle the decommissioning at a different level. The financial impact to the public for decommissioning can be tied to governmental or industry taxation,

i.e. associated with cost of electricity. This indicator assists in understanding the independence from public or tax-payer costs associated with decommissioning.

1.4.2 Sufficient investment

In order for the market to progress, it is expected that there shall be adequate funding for decommissioning from both the public and private sector. It is also necessary to have investment in supporting infrastructure and facilities that enable development of technologies and competences.

1.4.2.1 Funding Models (QL41)

Indicator = number of new tools/funding models

There should be a variety of tool and funding models deployed at both public and private sector levels to advance decommissioning activities. The assessment of the various mechanisms to facilitate progress on a project or national decommissioning project is subject to qualitative interpretation.

1.4.2.2 Start-up and Company Creation (QL42)

Indicator = monetary availability for investing in company creation

Related to the earlier scientific and actor-specific qualifiers of spin-off companies (QL36), it is also necessary to have financial means for investment in new companies or start-ups. The financial investments can be from growth funds, governmental bodies or companies that are actively pursuing subsidiary growth daughter-companies. These actions then in-turn benefit the company and job creation, within the societal qualifiers (QL1, QL2, QL14).

1.4.2.3 Research and Development Financing (QL43)

Indicator = monetary investment (i.e. euros) to funding schemes

Domestic and international financing for research and development to advance decommissioning technologies and innovation will aid many of the other qualifiers identified above through this Chapter. Research and development via public financing such as the European Commission's Horizon2020-Euratom program aims at accelerated solutions that can be widely deployed by member states.

1.4.2.4 Facility Access (QL44, QL45)

Indicator = number of available open-access facilities

Indicator = number of temporary person exchanges between facilities/companies

Enhancement of the decommissioning process requires external facilities that are used for material and structural evaluation of the NPP components. Investment for infrastructure facilities used to compliment decommissioning is beneficial for improving the industry. Open-access facilities that are operated for shared utilisation can facilitate greater improvements to decommissioning technologies and aid wider competence development.

2. Implementation Instruments

This chapter provides linkage to where the qualifiers and indicators of Chapter 1 can be utilised. The presented implementation instruments are a high level overview whereas Deliverable 3.3 will address the implementation instruments in depth. Implementation of decommissioning actions falls to both public and private sectors, at local (domestic) and on the international market. Figure 2-1 shows an example of EU funded projects related to decommissioning as of 2020. There are also networks to facilitate exchange of information on decommissioning to serve various purposes. These items are shortly described in the next subsections. In all items, the social, financial, actor-specific and scientific qualifiers described in Chapter 1 can be applied where relevant to evaluate the impact of the planned activity. It is the juristriction of the implementor (and/or funding body) to assess which importance or priority of various qualifiers that are utilised to compare suggestions of varying work plans or consortium.

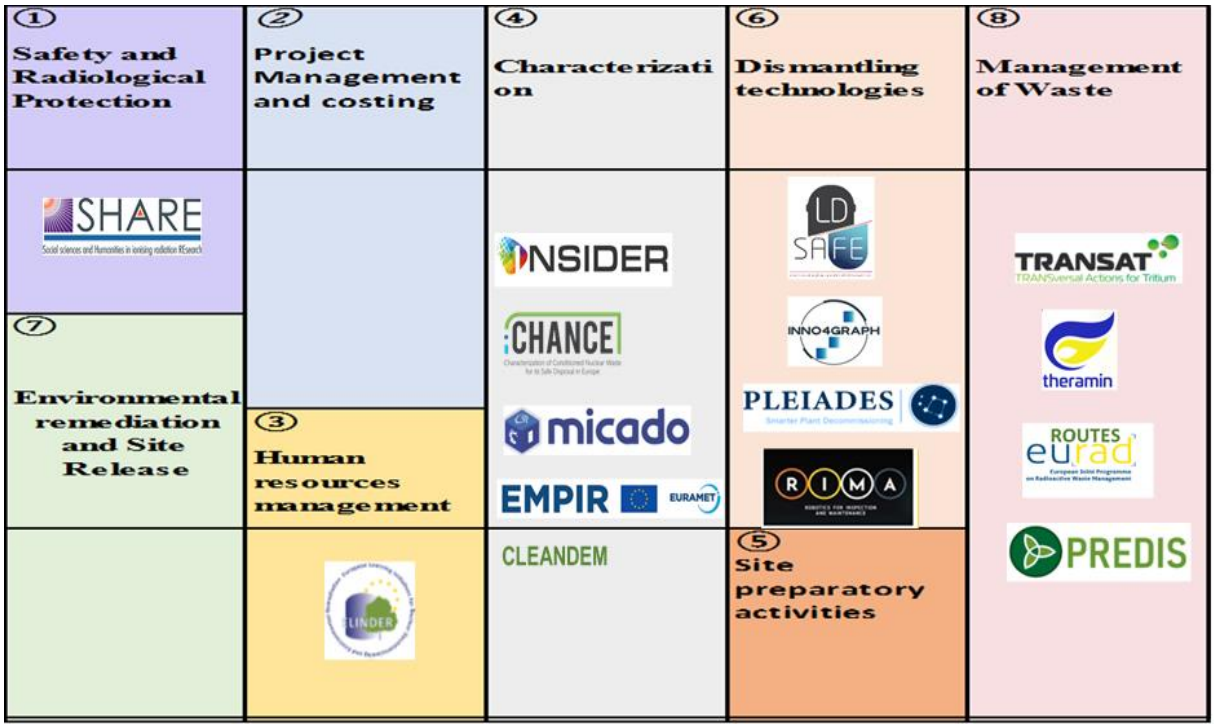

Figure 2-1. EU funded projects delated to decommissioning as of 2020 [7].

2.1 Public funding

For public sector, cooperative activities on decommissioning, for some decades there have already been technology development and networks at the European level to advance cooperation and innovation. These can be topics falling with research and innovation actions (RIA) and coordinated support actions (CSA) with programs such as Horizon2020-Euratom [8]. It is anticipated that these will also continue in the future, for instance in the next Framework program. The direction of the Euratom directives for nuclear safety and management of spent fuel and radioactive waste is based on Member State needs.

Within public sector financing, the European Commission also funds contracts via the European Bank for Reconstruction and Development (EBRD) [9] for assisting decommissioning of nuclear facilities and equipment in Lithuania, Bulgaria and Slovakia associated with their entry to the European Commission. Since 2014 the EU co-financing has been concentrated on safety challenges of the decommissioning [10]. Such opportunities are available via public procurement, for instanced via the EC's Tenders Electronic Daily (TED) portal [11].

At a national level, each country may also have funding instruments to facilitate advances in decommissioning processes and services. These are handled by for instance governmental ministries, academic funding bodies or business development bodies to promote technologies, offerings or competences.

2.2 Private funding

Individual companies responsible for nuclear facilities such as power plants and radioactive waste storage also solicit assistance for decommissioning. Companies or owner groups can directly procure or order services via invite only. In such cases, it can be beneficial for companies offering such services to be listed within databases showing their availability. An example of this would be the Nuclear Energy Buyers Guide [12].

2.3 Networking

Companies and groups interested in cooperation in the decommissioning domain are active in a variety of platforms. Together they serve as routes for:

- working groups, to address specific challenges or topics
- develop position papers, to influence policy and actions
- exchanging information and expert resources, including competence development
- partnering for development of technical projects and potential commercial contracts
- transfer or co-development of technology.

Membership to the groups can be via invite, appointment or membership fees. The networks may also utilise the qualifiers and indicators of Chapter 1 when discussing the priorities of activities. Examples of key networks for decommissioning include groups such as:

- International Atomic Energy Agency (IAEA) [13]
- Nuclear Energy Agency (OECD-NEA) [14]
- World Nuclear Assocation [15]
- European Nuclear Society [16]
- Sustainable Nuclear Energy Technology Platform (SNETP) [17]

3. Example of Qualifiers and Instruments use in mapping needs

The qualifiers presented in previous sections can inform the identification of instruments supporting the systematic mapping of research, education, innovation and regulations needs (Figure 3-1). This work would require further analysis of the need for *today's instruments* (i.e. policy and funding mechanisms/tools that are consolidated or consolidating as effective in helping to respond to concrete needs), short-to-medium-term *instruments* (i.e policy and funding mechanisms/tools that are emerging or promising) and long-term instruments (i.e. policy and funding mechanisms/tools that are still in "wish lists" but without any concrete actions to materialise them). In practise, the defined need/gap (e.g. where the gap is, what is missing) can be further assessed with needs in Research, Education, Innovation and Regulation in order to fill the gap. Such needs can be identified through structured consultations (such as the SHARE Survey) or with the help of more systematic 'critical issues analysis' supporting 'action roadmapping'[18]. Table 3-1 presents an example matrix focusing on one hypothetical need arising from the SHARE survey.[1] The matrix presents first the gap/need and then suggests what is needed in Research, Education, Innovation and Regulation in order to fill the gap with the corresponding qualifiers. However, further brainstorming is required for in depth analysis and will be the basis of the activities in Work package 4 and Deliverable 4.1 and 4.2.

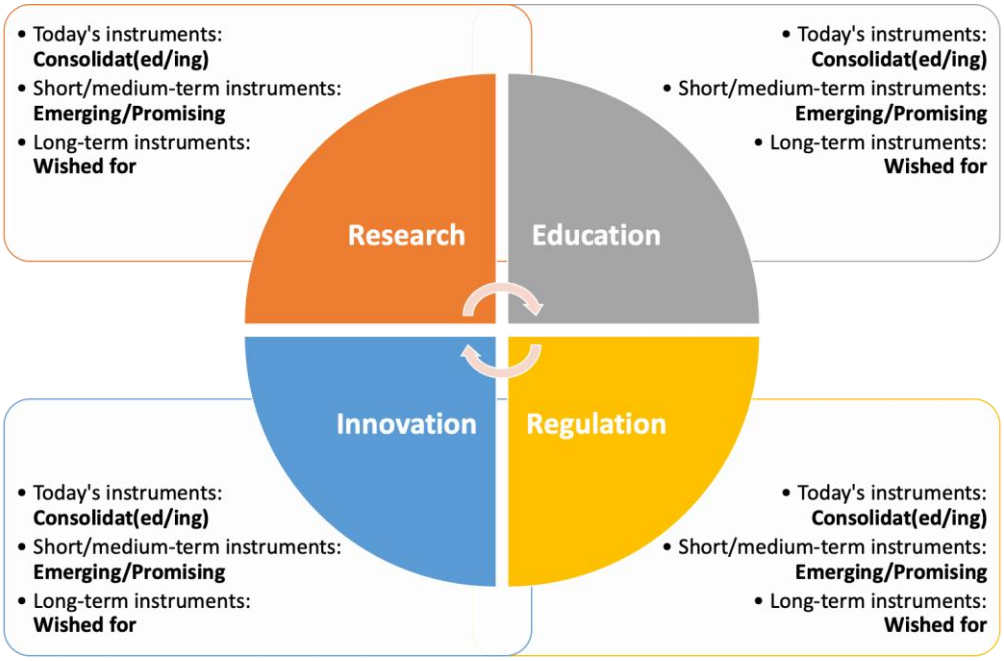

Figure 3-1. How qualifiers are associated with current and future instruments.

[1] D2.3 Report on analysis of preliminary results from the questionnaire

Table 3-1. A hypothetical example matrix on how to fill the gap in Research, Education, Innovation and Regulation, with respect to qualifiers and funding instruments as described in Chapters 1 and 2

Gap/need SHARE survey Q63 "Characterisation methods and technologies to identify subsurface contamination" Question translated to a hypothetical example: Need to characterise subsurface alfa emitters in-situ			
How to fill the gap		**Qualifiers**	**Instrument**
Research	R&D projects on development of in-situ alfa emitter technologies able to characterise subsurface contamination.	Scientific impact area: Number of peer-reviewed scientific publications (QL-30), Number of papers in conference proceedings (QL-32)	Public (e.g. EU) and private (e.g. instrumentation company)
Education	Promotion of radiation measurement technology development in education in order to attract people on the field.	Actor-specific impact area: Number of persons completing training/certification (QL-20) Scientific impact area: Number of invited international guest lectures (QL-33), Number of capacity building or training programmes (QL-34)	Public funding (e.g. IAEA)
Innovation	New technology solution to characterise subsurface emitters in-situ.	Actor-specific impact area: number of new products (QL-15) Scientific impact area: Number of patents filed (QL-35), Number of new spin-off initiatives (QL-36), Number of industrial companies co-financing research, technology development and innovation (QL-37)	Private funding (e.g. instrumentation company)
Regulation	Tax reduction for companies investing in R&D.	Financial impact area: Monetary investment (i.e. euro) distribution between public-private (QL-40)	Private funding (e.g. instrumentation company)

With this example, there is the linkage between how qualifiers, indicators and instruments are utilised together. These can be deployed in the SHARE project when formulating the gap analysis and strategic research agenda activities, but hopefully are also well utilised by many other actors when planning programs and investment strategies in the future. The implementation of this type of process of transparent, quantitative key performance indicators helps ensure the impact of the work and assessment of benefits for all parties in the short- and long-term through decommissioning processes.

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