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Optimisation: Rethinking the Art of Reasonable

Workshop Summary Report
Lisbon, Portugal
14-15 January 2020

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NUCLEAR ENERGY AGENCY
COMMITTEE ON RADIOLOGICAL PROTECTION AND PUBLIC HEALTH

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Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management and decommissioning, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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List of abbreviations and acronyms

AGES	Austrian Agency for Food and Safety
AI	Artificial intelligence
ANS	American Nuclear Society (United States)
APA	Portuguese Environment Agency
BfS	German Federal Office for Radiation Protection (Bundesamt für Strahlenschutz)
CEPN	Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire (France)
CRIEPI	Central Research Institute of Electric Power Industry (Japan)
CRPPH	Committee on Radiological Protection and Public Health (NEA)
CSN	Spanish Nuclear Safety Council (Consejo de Seguridad Nacional)
DOE	Department of Energy (United States)
DSA	Norwegian Radiation and Nuclear Safety Authority (Direktoratet for strålevern og atomsikkerhet)
EA	Environment Agency (United Kingdom)
EC	European Commission
EDF	Électricité de France (French electric utility company)
EPA	Environmental Protection Agency (Ireland)
FAO	Food and Agriculture Organization of the United Nations
HPS	American Health Physics Society
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
IPOLFG	Portuguese Oncology Institute (Instituto Português de Oncologia de Lisboa-Francisco Gentil)
IRPA	International Radiation Protection Association
IRSA	Icelandic Radiation Safety Authority
IRSN	French Radioprotection and Nuclear Safety Institute (Institut de Radioprotection et de Sûreté Nucléaire)
ISOE	Information System on Occupational Exposure
IST-CTN	Technological and Nuclear Campus, Technical Superior Institute, University of Lisbon (Portugal)
LNT	Linear non-threshold model
LSS	Life-Span Study
MnSOD	Manganese superoxide dismutase
NEA	Nuclear Energy Agency
NGO	Non-governmental organisation

NORM	Naturally-occurring radioactive materials
PWR	Pressurised water reactor
SSM	Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten)
QST	National Institutes for Quantum and Radiological Science and Technology (Japan)
US EPA	United States Environmental Protection Agency
WHO	World Health Organization
WPNEM	Working Party on Nuclear Emergency Matters (NEA)

Public and policy overview

The optimisation of protection, to keep radiological exposures as low as reasonably achievable (ALARA), taking into account social, economic and, more recently, environmental circumstances, has been central to radiological protection for decades. However, because of scientific uncertainty in understanding the biological effects of low doses of ionising radiation on human beings, other living creatures and ecosystems, and due to gaps in the knowledge of how ionising radiation might act on cell, tissue and whole organism biological functioning, precaution in regulation and application sometimes means that minimisation of dose has been substituted for a robust optimisation process. The objective of the NEA Workshop on Optimisation: Rethinking the Art of Reasonable was to discuss the nature and intention of optimisation of radiological protection, and to see how reasonableness should be interpreted and applied in practice.

While radiological protection optimisation is explicitly defined in international recommendations and requirements, its implementation in regulation and application remains quite varied. Workshop presentations and discussions showed that the objective of optimisation of radiological protection can be interpreted differently depending on the situation causing the need to consider radiological protection options. For example, optimisation of radiological protection in the context of a deep geological disposal site will address choosing containers and a site geology to manage exposures over tens of thousands of years, while optimisation of radiological protection addressing exposure to domestic radon will consider influencing personal behaviour. Such differences can promote a perceived image of uncertainty and lack of knowledge. These, combined with incomplete scientific knowledge, often result in radiological protection choices taking significant levels of precaution, to the extent of minimising exposures.

However, minimisation of radiological exposure is not the same as optimisation of radiological protection, because social and economic aspects need be taken into account. More importantly, situations causing the need to consider radiological protection options will generally be complex, multidisciplinary and multi-dimensional. Radiological risks will be only one of many different risks caused by the situation under consideration, and by the protection options being considered. Optimisation and reasonableness are informed by the scientific understanding of the risks involved but are case-specific, stakeholder-dependent, circumstance-driven judgements. By broadening the risk aspects being considered, beyond those caused by exposure to ionising radiation, the nature of the objective of optimisation of protection can evolve beyond the optimisation of radiological protection to the optimisation of well-being. To facilitate this evolution, the focus of the workshop was protection addressing well-being in the broadest sense. Thus, it is important to recognise that radiological protection is only one factor that should be considered when optimising overall well-being, and may, in fact focus efforts on radiological health risks to the detriment of other risks. In contrast, the goal of optimising well-being can focus overall protection solutions on the most serious issues, allocating resources in a more risk-prioritised fashion. This conclusion is consistent with several other reports and workshops organised through the NEA (see NEA, 2016; 2018; 2019).

Executive summary

The NEA Workshop on Optimisation: Rethinking the Art of Reasonable was attended by 86 experts from 22 countries, representing a wide diversity of nuclear and non-nuclear industries, and medical disciplines and communities (e.g. radiological protection, nuclear regulation, low dose risk research, industrial application, waste management, non-governmental organisations). The broad view of participants was that optimisation depends strongly on stakeholder involvement, which in turn depends strongly on trust. Achieving accepted and sustainable protection solutions can thus be long-term and resource intensive.

Optimisation of radiological protection is a fundamental principle of the international system of radiological protection, and is a tool that is widely used for radiological protection management. There has yet to emerge a common, practical understanding of what optimisation means, or what it is intended to achieve. And although there was general agreement that stakeholder involvement is a centrally important element for the identification of the optimal protection solution, without guidance addressing how safe is safe enough, protection solutions agreed by regulators, licensees, and directly and indirectly affected groups and individuals often seem to be working towards doses that are minimum, rather than radiological protection that is optimal. Discussions during the workshop focused on identifying elements of agreement, and on sharing experience.

Workshop participants identified several significant qualities of optimisation. Optimisation of radiological protection requires a process that engages key stakeholders, resulting in judgement that is informed by "radiological protection science" but that incorporates, and is often driven by, political, social, economic as well as ethical judgements. Optimisation is case-specific, and is thus heavily dependent on the prevailing circumstances. Cultural and community-related aspects are a significant part of the prevailing circumstances, and will play a large role in identifying the optimal radiological protection solution.

Radiological protection is needed when the prevailing circumstances are, in some fashion, radiologically threatening. However, the prevailing circumstances generally present risks that are far broader than their radiological aspects. The consequences of protection solutions can also cause risks. By prevailing circumstances, the workshop participants referred to any radiological, societal, economic, local, political, individual aspects, etc., that should be considered by decision-makers in choosing the optimal protection solution. The prevailing circumstances include such aspects as: **the physical context** of the situation (e.g. from where, when and how will/could radiological exposures occur; in what physical circumstances do exposed and potentially exposed individuals find themselves; what are the age and gender distributions of populations involved); **the economic context** of the situation (e.g. the cost of putting protection in place; the cost of not putting protection in place; the direct and indirect costs of the situation causing or potentially causing radiological exposures); **the societal aspects** of the situation (e.g. the pre-situation risk-perception of exposed and potentially exposed populations; the social effects that protective actions can cause on families, friends, societal functioning); and **the public health aspects** of the situation (e.g. radiological risks, psychological risks, lifestyle change risks). Radiological protection decisions will be influenced by these aspects. As such, in order to

truly identify the optimal radiological protection approach, all the diverse aspects of the prevailing circumstances need to be considered and commonly understood. The prevailing circumstances will frame the protection strategy and approaches that can be implemented, and will in fact drive the concerns of those affected or potentially affected. It should not be surprising that optimal radiological protection solutions can differ significantly from situation to situation, for example clean-up criteria for one site need not necessarily be the same as for another site. Such differences are, in general, a function of differing stakeholder judgements and different prevailing circumstances. An important aspect of reasonableness is that optimisation decisions should be customised; a one-size-fits-all approach is unlikely to serve the needs of the community and individuals impacted by the decisions.

It was noted that the objective of optimisation of protection is to achieve exposures that are as low as reasonably achievable (ALARA), environmental, societal and economic aspects being taken into account. This implies that considerations should broadly address prevailing circumstances, not only radiological risks. This also implies that the objective of optimisation of protection should be the overall optimisation of protection, the optimisation of "well-being", not simply the optimisation of radiological protection. The best "well-being" for both directly- and indirectly affected stakeholders can only be identified in the context of "the big picture", that is, a complex, multi-dimensional, multidisciplinary understanding of the prevailing circumstances. Well-being, as defined by the WHO, is not merely the absence of disease or infirmity. It is rather a combination of "all" aspects of life that lead to a state of complete physical, mental and social well-being in a given circumstance. In this context, the workshop participants noted that there are currently no tools or approaches to systematically balance such diverse aspects in the selection of the optimal protection solution. For example, sheltering and evacuation reduce radiological impacts, but can increase stress, psycho-social and economic impacts.

Multidisciplinary research (e.g. social sciences, humanities, technical sciences) is needed in this area to identify approaches to collectively and holistically address such diverse impacts on well-being. Optimisation of exposure is not necessarily the optimisation of well-being. Focusing on optimisation of protection in terms of well-being, including not only radiation-induced health risks, was seen as an effective approach to avoid focus on minimisation of exposure. A key factor in effectively achieving this is the need for trust between governmental decision-makers and the stakeholders who their decisions will affect.

Part of the general public tends to perceive radiological risks to be more serious, in an absolute sense, than they actually are as compared to other daily-life risks, and this was seen by some participants as a rationale for overly conservative radiological protection choices. The Linear Non-Threshold (LNT) model used to assess radiological risks was blamed by some workshop participants for generating public radio-phobia, because LNT suggests that any dose brings risk. The LNT model was questioned in terms of modern radiobiological understanding, which shows that cellular-, tissue- and organism-level protection mechanisms are far more complicated than a simple linear relationship would imply. Consequently it was claimed, by those opposed to the use of LNT as a risk management tool, that the use of LNT has caused conservative choices, for example large-scale evacuations, that provoked traffic accidents and deaths. In contrast to that, many participants viewed LNT as a practical protection model, not a scientific theory or hypothesis. The LNT dose-response model is neither able nor intended to reflect the complete mechanisms of cancer induction, but it continues to represent the increasing body of epidemiological data at low doses. One expert stated that it is the most parsimonious description of the available epidemiological data, and more importantly it provides a practicable basis for estimating the impact of radiological exposures for risk management purposes. Thus for the time being, the LNT model seems to be the most scientifically and practically reasonable tool for the management of radiological exposures. The community of radiological protection scientists continues to work to bring together the scientific insights from radiobiology and epidemiology into a unified framework that can be deployed by key stakeholders.

In conclusion, the workshop participants agreed that prevailing circumstances causing radiological and other risks / hazards are complex, multi-dimensional and multidisciplinary. The optimal protection solution should be selected based on a broad understanding of the prevailing circumstances – **the big picture** – and of the positive and negative consequences of each protection solution considered. Such a holistic approach, considering radiological, economic, societal, lifestyle, etc. aspects, was felt to be the most likely to optimise the well-being of populations directly and indirectly affected by circumstances and protection decisions. This is broadly in line with the current recommendations of the International Commission on Radiological Protect (ICRP), as documented in ICRP Publication 103 (ICRP, 2007), but emphasises the multidisciplinary, multi-dimensional nature of the complex circumstances to consider. It should therefore be expressed more clearly that: radiological issues may be only a small part of the overall risk vector; the complexity of such circumstances will generally require multidisciplinary input in order to identify the overall protection solution that delivers the best level of well-being; and the tools are needed to appropriately balance approaches to managing diverse risks.

This conclusion was based on a series of case study presentations addressing a broad series of different prevailing circumstances, and is also mirrored in the work of other NEA reports and workshops. For example, *Management of Radioactive Waste after a Nuclear Power Plant Accident* states: "More generally, it has been noted that the minimisation of one detrimental impact is always likely to result in something else detrimental not being minimised. Hence the need for a holistic view of optimisation, both as developed in radiological protection and as would be more widely understood by stakeholders" (NEA, 2016).

Taking a big-picture view of prevailing circumstances and a well-being approach to optimal overall protection is not a guarantee that protection solutions will meet the reasonableness concepts identified at the workshop. However the workshop participants suggested that such an approach would more holistically address stakeholder concerns, and would frame protection choices in a more complete picture of the situation. Presentations and discussions showed that there are still several interpretations of optimisation of protection, and that they are generally driven by the nature of the circumstances causing the radiological risks. This has led to confusion in regulatory and applicational discussions of how best to optimise, which have in many cases reinforced stakeholder mistrust. The workshop participants identified aspects that, if clarified and agreed, could improve this situation.

Workshop format

The NEA Workshop on Optimisation: Rethinking the Art of Reasonable was divided into seven sessions (see Annex), and was managed to encourage discussion. Focus was given to finding reasonable protection solutions in the various stages of the nuclear fuel cycle. Protection experience from other risk situations was also presented. Workshop conclusions were based broadly on the case study presentations illustrating approaches to optimisation of protection under various prevailing circumstances, e.g. building new nuclear-installations, waste management, normal operations, radon-exposure management, decommissioning.

Session 1: Welcome and introduction

These presentations provided a broad overview of the issues and questions of identifying the best protection solution under the prevailing circumstances, and summarised the previous and ongoing work in this area. The evolution of optimisation of radiological protection, focusing on exposure management, towards the optimisation of overall protection, focusing on well-being, was mentioned.

Session 2: Framework as it is today, evolution for the future

These presentations summarised international recommendations and European requirements provided a regulatory view of optimisation, as well as national approaches to stakeholder involvement.

Session 3: Practical approaches to the implementation of optimisation at nuclear facilities

Operators and implementers from nuclear power plants in operation, being planned or in decommissioning presented the approaches they use to identify optimal protection solutions, focusing on areas where, for various reasons, assumptions tend to err on the conservative side.

Session 4: Practical approaches to the implementation of optimisation in other circumstances

Regulatory authorities and implementers presented their experience in determining optimal protection solutions in emergency and recovery management situations, in medical exposure situations, in naturally-occurring radioactive materials (NORM) and radon-exposure situations, and in protection against contaminated food and drinking water.

Session 5: Breakout discussions

Meeting participants were divided into three groups to more intimately discuss and share their experience. Each breakout session was managed by a moderator, and supported by a rapporteur. Discussions were guided by a series of questions (see Annex), all addressed by each breakout.

In addition, following the presentation of breakout group discussion summaries, a panel of young professionals provided views on evolving approaches to working with stakeholders, including the use of artificial intelligence (AI) and social media.

Session 6: Stakeholder involvement and communication

Modern social science and various aspects of national and international experience in stakeholder involvement and communications were presented.

Session 7: What science is needed?

This session presented radiobiological and epidemiological evidence of the shape of the dose/response curve.

Conclusions:

The workshop Chair provided a brief list of preliminary thoughts on the workshop key results. The workshop hosts thanked speakers and participants for their active engagement in discussions.

1. Introduction

Over the past 15 to 20 years, the optimisation of radiological protection has gone from being just one aspect of the radiological protection system, to being a major focus of international recommendations. This is true of recommendations from the International Commission on Radiological Protection (ICRP), of requirements from the International Atomic Energy Agency (IAEA) and of Directives from the European Commission (EC). Because of this evolution, optimisation has become a more significant part of national regulations in many countries around the world. Doses should thus be kept "as low as reasonably achievable" (ALARA), taking into account both social and economic aspects. In practice, however, the optimal protection solution can be difficult to identify.

One factor that has made this identification difficult may be that societal interest in decisions addressing public health issues has greatly increased over time, and as a result stakeholder involvement has become a significant factor in decision-making. Yet, in the practical sense, it is not always obvious which stakeholders should be involved – and to what extent – in decision-making processes that identify and implement optimal protection. Neither is it evident who should decide what protection option to implement. In some circumstances, stakeholder involvement has resulted in the implementation of an optimisation decision that is in fact closer to dose minimisation than to the optimisation of protection.

1.1. Background

While it is generally well understood in the radiological protection community that the optimisation concept is not equivalent to minimisation – this is stated clearly in international recommendations such as ICRP Publication 103 (ICRP, 2007) – conservative choices nonetheless tend to be the norm in practice. This is partly driven by uncertainty in relation to the effects of low levels of radiation exposure. While epidemiological science and data suggest that the linear non-threshold (LNT) model fits well with existing human and animal exposure effects data, particularly at higher doses, exposures that epidemiologically show statistically significant, adverse health effects are nevertheless typically above the doses received by most radiation workers, and well above the doses experienced by the public. Biological studies of the effects of radiation provide some evidence that low doses may not lead to adverse effects (i.e. at the cellular level can at times lead to the up-regulation of detoxification processes), but at the same time studies have not yet fully explained complex cellular repair and damage mechanisms, and they cannot yet resolve the issue of what level of exposure can cause damage sufficient to cause adverse whole-body outcomes (e.g. solid cancer or leukaemia).

The precautionary principle is thus frequently evoked in the face of such uncertainty, which has in turn lead to conservative protection decisions, indicating that, as suggested by the LNT model, any exposure, no matter how small, carries a proportionate risk.

1.2. LNT issues

The LNT model is used by regulatory agencies around the world as the basis for the practical management of radiological exposure. Some experts feel that because the system of radiological protection makes use of the LNT model, and does not establish an exposure level below which it is "safe" (i.e. there is no risk), the reaction of the average stakeholder is one of fear because any exposure is in fact dangerous. For this reason, some experts feel that a threshold model, rather than the LNT model, would better address what they view as the fearful and overly prudent views of stakeholders.

The science behind radiological risk assessment continues to evolve, and the practical approach to addressing scientific uncertainty in risk assessment has continued to give rise to debate for many years. Radiological protection scientists continue to work to bring together radiobiological and epidemiological science into a more unified framework, but there has been no emergence of a clear regulatory model that would serve as an alternative to LNT.

A 2018 meeting organised by the American Nuclear Society and the American Health Physics Society (HPS) brought together radiological protection officials, epidemiologists, biological researchers and other experts from around the world to discuss the current scientific understanding of radiation effects and practical approaches to the implementation of optimisation. As discussed at that meeting, the assumption that any dose carries a risk has in many circumstances – including in waste management, clean-up end-state selection or the consideration of operational effluents – resulted in the choice of protection solutions focused on dose minimisation, and that can be viewed as extremely conservative in absolute terms. Whether resources are being used optimally has become a significant question, further demonstrating the need to develop a broadly accepted practical approach to how the exposure to low levels of radiation should be managed and regulated.

1.3. Prevailing circumstances

In the context of radiological protection decision-making, the prevailing circumstances refer to any aspects raised by key stakeholders that could or should be taken into account by the decision maker as part of the decision-making process. These of course include radiological aspects, but can also include economic, social, political and individual aspects, together representing the full, complex nature of the situation. It is in fact the prevailing circumstances that form the situational framework in which decision-makers will need to make choices.

Since many decisions are made by governments and regulators, engagement with stakeholders is an essential element in understanding how prevailing circumstances should be balanced with the desire to minimise exposure. In addition to radiological aspects (e.g. exposure scenarios, protection options, residual doses, dose distributions), decisions must reflect other public health risk factors, economic aspects and social aspects (e.g. community disruption and/or stress, social structure disruption).

For example, in post-accident situations the broader community will have views not necessarily based on scientific analyses, nor on governmental choices that have been made to indicate where the community is authorised to live, what it is authorised to eat and where it is authorised to work. These societal views cannot be ignored when decisions are being made. In addition to providing input into regulatory or governmental decisions, stakeholders will, in a practical sense, take actions based on their understanding of the situation – for example, members of the public affected by an accident situation may evacuate during an accident and later decide to return home when allowed to do so, or they may choose to move away permanently. Attempts should therefore be made to fully and broadly understand the prevailing circumstances as the decision-making process proceeds.

1.4. Decision-making

Radiological protection decisions involve a decision-making process that is informed by science but are based largely on a judgement as to which level of protection is "reasonably achievable". The science of radiological protection continues to evolve and advance, but it does not seem likely that it will quickly and definitively resolve the issue of whether or not any level of exposure can cause harm. The need to take radiological protection decisions nonetheless remains, and input is needed to help ensure that protection choices are indeed reasonable. In practice, taking a broad view of assessing and balancing responses to the risks associated with any particular prevailing circumstance can be very difficult to achieve.

1.5. Young professional participation

Today's young professionals will be tomorrow's radiological protection leaders. As such, their views of what is reasonable, and how this should be achieved in an increasingly digital society, are essential. The workshop programme thus included the active participation of young professionals, in particular during the case study breakout sessions.

1.6. Objective

Given the aspects discussed above, the objective of this workshop was to identify regulatory and practical approaches for assessing the radiological protection situation, and for developing, with appropriate stakeholder participation, the best radiological protection choices under the prevailing circumstances.

2. Summary of key points

The format of the NEA Workshop on Optimisation: Rethinking the Art of Reasonable led it to be a progression of considerations towards a series of overall conclusions. In order to assist the reader in following the logic of the conclusions section, this summary of key points has been laid out in the context of where presentations and discussions began, to give context to where presentations and discussions ended up.

2.1. Session 1: Welcome and introduction

This session established the flavour and direction of the workshop, laying out the problems and issues perceived to be associated with the optimisation principle, with its application, and with the use of the linear non-threshold (LNT) model. Perspectives were provided by: William D. Magwood, IV (NEA Director-General), Roger Coates (President of the International Radiation Protection Association [IRPA]), João Oliveira Martins (Regulatory Authority, Portuguese Environment Agency [APA]); and Mike Boyd (Committee on Radiological Protection and Public Health [CRPPH] Chair from the United States Environment Protection Agency).

It was noted that the science of the dose/response model is complex, and is currently very uncertain at doses relevant for occupational and public exposure situations. Questions as to the applicability of the LNT model of dose/response remain, and continued research is needed to reduce uncertainties. However, identifying the "best" protection option is not a scientific question, but is rather a judgement attached to the particular circumstances under consideration. To address this, experience of the CRPPH community has shown that social science and stakeholder engagement can be effective tools to determine the level of residual dose that is acceptable under specific circumstances. While stakeholder views and concerns can vary significantly depending on the circumstances, the process and elements needed to identify the optimal protection solution are broadly common to almost any situation. A key to successfully achieving accepted and sustainable protection solutions is focusing on the larger picture – with consideration of quality of life and other society benefits – not simply on radiological protection issues.

However, the tendency to choose conservative approaches to radiological protection remains. While optimisation of protection, and keeping doses as low as reasonably achievable (ALARA) is accepted as the controlling factor for exposures, there is not a common, practical understanding as to what these terms mean. It is thus important that this be corrected, taking an all-hazards approach as noted above. Radiation is often not the most significant hazard needing actions, but it often receives the most regulatory and stakeholder attention. Stakeholder engagement and the creation of a robust process for stakeholder input are thus an integral part of optimisation and ALARA, but graded, proportionate approaches should be established.

A useful approach that somewhat addresses these considerations is provided by the three-part justification process used for medical exposures. The first level is the justification of using radiation for diagnostic or treatment purposes in specific circumstances (e.g. a particular type of cancer). If the first level is deemed justified, then the second level is to justify the use of a specific procedure (e.g. CT scan, simple x-ray image, beam therapy) for treating a specific medical need. The third level involves justifying the specific use of radiation for a specific patient. This type of graded approach could be applied to optimisation of protection in public and occupational exposure situations, where the best protection solution should be determined, verified and demonstrated.

Finally, tying this loose framework together, the workshop participants broadly agreed that radiological circumstances are generally complex and multi-dimensional, and will drive the concerns of directly and indirectly affected stakeholders. The optimal radiological protection solution for a given prevailing circumstance is a judgemental choice, ideally informed by science that will maximise stakeholder "well-being" in a broad sense. This conclusion is reflected in several other NEA-organised workshops and reports (see NEA, 2016; 2018; 2019). In complex and multi-dimensional circumstances, the context of protection-option discussions, in any type of radiological situation (e.g. new build, normal operation, decommissioning or legacy management, radioactive waste management) should:

- come from an all-hazards standpoint (e.g. considering radiological, chemical, biological, physical risks);
- approach optimisation from a big-picture perspective (e.g. consider all impacts that prevailing circumstances may have, including public health, economic, social, structural, personal);
- assess the positive and negative consequences of all protection options under consideration (e.g. evacuation would reduce exposure, but may cause post-traumatic-stress-disorder);
- recognise that the aspects and processes needed to achieve accepted, sustainable protection decisions are relatively common to any prevailing circumstance.

To achieve protection solutions that are accepted and sustainable, and that optimise protection and well-being rather than simply reducing dose, this session suggested that experience has demonstrated the central importance of stakeholder engagement taking place in an atmosphere of mutual trust. Stakeholders must trust decision-makers, but decision-makers must also trust stakeholders. To create and sustain this mutual trust, it is important to build an equitable process in which stakeholders can discuss debate and prioritise reasonable optimisation solutions.

2.2. Session 2: Framework as it is today, evolution for the future

This section of the workshop programme carried on from the previous session by describing the status of international recommendations and requirements pertaining to optimisation of protection, how these are interpreted in regulation, and how they are implemented in practice. This session was chaired by Pedro Vaz (Instituto Superior Técnico, Portugal). Views were presented by Chris Clement (ICRP), Miroslav Pinak (IAEA), Javier Zarzuela (Spanish regulatory authority, CSN), and were discussed during a panel session moderated by Alan Waltar (American Nuclear Society, ANS).

As presented and, more importantly, as intended, the optimisation process aims to achieve a reasonable "compromise" with all stakeholders through a holistic approach that considers radiological and non-radiological issues. Key aspects of the ICRP's radiological protection system include, in the context of optimisation, descriptions of optimisation policy as a function of the type of exposure situation being addressed (i.e. planned, emergency or existing). The need to consider situations more broadly than radiation is clearly stated (i.e. keeping doses ALARA, social and economic aspects being taken into account) but the focus of the current system's recommendations remains on addressing radiological aspects. The IAEA's international requirements address standards for radiological protection and have a more applicational flavour. These requirements set radiological "must do" aspects of good practice using the precautionary principle in a graded fashion, and defining clearance levels below which there is generally no need for further regulation. Case-specific criteria where there is agreement that "enough has been done", if broadly agreed, could be taken as identifying the optimal protection solution (e.g. PWR refuelling collective dose < X man-mSv could be seen as enough). These are then interpreted, in the spirit of the ICRP recommendations, into national regulation.

From the practitioner's standpoint, the interpretation of recommendations and requirements in the application of national laws and regulations often reflects minimisation rather than a risk-informed graded approach. Risks from doses on the order of natural background, which represent a large fraction of occupational exposures, are too small and uncertain to estimate, and should be regulated as such. Exposures far below natural background, public exposures from nuclear power plant normal operations, from residual contamination after site clean-up, or from waste repositories, tend to be driven towards zero by industry peer reviews, and to a certain extent by regulatory reviews, often without regard for prevailing circumstances. Discussion of the evolution of radiological protection has focused on good judgement, fairness, practicability, moderateness, and ensuring or restoring trust. This should include a clear identification of the actual challenges, and active discussion with relevant stakeholders and decision-makers. A proactive process with stakeholders must be established, and should include such aspects as involvement, awareness development, empowerment and training in radiological protection culture. Although stakeholder involvement is to build reasonable decisions, based on reasonably realistic assessments, excessive precaution will work against this objective.

2.3. Session 3: Practical approaches to the implementation of optimisation at nuclear facilities

This section of the workshop programme was dedicated to the views of the nuclear industry, and addressed practical approaches to the implementation of optimisation at nuclear facilities. This session was chaired by Marilyn Kray (ANS President, United States). Presentations were made by Marilyn Kray, Guy Renn (ISOE Chair, EDF Energy UK), Gilles Ranchoux (EDF, France), Takatoshi Hattori (CRIEPI, Japan), and Bernt Lorenz (nuclear power plant operations, Germany). Discussion was moderated by Antone Brooks (Washington State University, United States).

Presentations highlighted the tendency in the nuclear industry to encourage progressive, incremental dose reduction efforts, even where radiological risks are demonstrably negligible. Especially for low dose level works, the main basis for dose optimisation is operating experience, with the adoption of controls that are deemed to be best (normal) practice. For high dose level tasks, more technically advanced protection means are usually put in place according to radiological risk assessments. However, the thresholds delimitating a high dose level task from a medium or low high dose level task are a left to the discretion of each operator according to technical feedback and/or the social or regulatory context. Exposed workers are increasingly aware of different protection solutions, have access to an internet of ideas, and may demand particular dose reduction measures irrespective of their cost benefit. Workers with critical skills have a strong negotiating position. An objective of radiological protection is that radiological risks should be fully integrated in the global risk assessment at the same level as the other conventional risks. To achieve this, quantitative dose optimisation is used in a graded fashion but there is no consistent consensus as to when doses can be considered fully optimised.

This is particularly true in terms of clearance of materials from radiologically controlled areas. Regulators may sometimes require the operators to apply a very conservative clearance process to gain public acceptance. In light of reasonableness, a graded approach should be applied in clearance regulation. It should be noted that radiation exposure on the order of 10 µSv per year presents only a negligible health risk, and this should be understood by the public and the regulators. The inclusion of nuclear and radiological educational programmes for children at appropriate ages should enable the general public to have a more factual and reasonable perception of radiation effects and related health risks. In general, support of such efforts requires a global consensus on dose-based regulations that are sufficiently protective of all members of the public. These standards should be in a form readily understandable by stakeholders to allow them to make their own decisions, for example regarding a response to a radiation accident. To facilitate this, it was suggested that outreach teams should be sent to areas affected by radiation related events to provide factual information of the associated risk, or lack thereof, in the affected area.

Views of some from industry suggested that the evolution of the system of radiological protection has, over the past 30 years, resulted in unnecessary confusion and overly restrictive norms. There is no “fair and consistent resource allocation”. If the philosophical background of radiological protection does not evolve, especially of the ALARA-principle/optimisation, there is great risk of continued confusion, ignorance and mistrust. Consensus on a lower border of protection, the so-called de-minimis-values, below which additional radiological protection measures are no longer warranted, would be useful.

2.4. Session 4: Practical approaches to the implementation of optimisation in other circumstances

This session of the workshop was designed to be complementary to session 3, addressing optimisation in areas other than the nuclear fuel cycle. The session was chaired by Shaheen Dewji (Texas A&M University, United States). Presentations were given by Matthias Zaehringer (WPNEM Chair, Bundesamt für Strahlenschutz [BfS], Germany), Joana Santos (Health Technology School, Coimbra, United Kingdom), Ciara McMahon (Environmental Protection Agency, Ireland), Maria Perez (WHO) and Lavrans Skuterud (DSA, Norway). The discussion was moderated by Thierry Schneider (CRPPH Bureau, CEPN, France).

Lessons addressing optimisation in emergency management, medical exposures, radon, food and drinking water, and post-Chernobyl recovery were discussed. These non- nuclear power plant areas presented quite varied circumstances, yet resulted in similar issues and best practices.

In general, the objective of optimisation is somewhat unclear. For some time, optimisation of radiological protection has been driven by the LNT model. However it is clear that radiation detriment, as defined by ICRP, in the dose region generally being addressed for worker and public exposures is extremely uncertain. This, along with the inherent complexity and unfamiliarity of radiological risks for most affected stakeholders, significantly complicates communications. Exposure situations are further complicated by the fact that other risks than radiation exposure are generally present (e.g. chemical hazards, physical hazards). Further, protection choices may, themselves, cause other risks (e.g. psychological issues, traffic accidents, social issues). Although optimisation involves finding the best protection under the prevailing circumstances causing the radiological risks, the multiple risks that may be associated with a given set of circumstances and possible protection approaches are difficult, if not practically impossible to compare. For example, the evacuation of populations in the event of a nuclear or radiological accident would reduce exposure, however such evacuations generally provoke significant levels of psychological risks, may cause traffic accidents, may have significant economic impacts on affected regions, etc. The objective of optimisation (e.g. exposures that are as low as reasonable achievable, avoiding chemical and physical hazards, reducing costs, limiting social disruption, avoiding psychological trauma) is difficult to identify in such a complexity of risks and benefits. Importantly, there are currently no tools to support the balancing of risks and benefits that decision-makers would strive to make when identifying the best protection solution to address as many risks as reasonably possible.

One tool that was identified as important in such decision-making circumstances was a national strategy, and relevant benchmark criteria, both of which would assist in communications with stakeholders. Both strategy and benchmarks should be developed with input from stakeholders in order to best facilitate achieving protection approaches that are accepted and sustainable.

However, all of these considerations were seen within a framework of stakeholder involvement. This includes elements such as: identifying the aspects of most concern to stakeholders so they can be perceived to be addressed; utilising stakeholder local knowledge so that protection solutions function efficiently; identifying the group most at risk so that the level of protection fits the circumstances; providing technical expert support in affected areas; etc.

A central issue is the need to establish a trusted relationship between decision-makers and affected stakeholder groups. Ideally, this should be the case before there is a need, and ideally decision-makers should be prepared to listen to and respond to stakeholder concerns. Such a trusted relationship is needed so that a shared understanding of the risks and benefits of the circumstances being addressed can be established

2.5. Session 5: Breakout discussions

This session of the workshop had the specific objective of eliciting the views of as many participants as possible regarding commonalities and differences among the different circumstances addressed during the workshop. Each of three breakout groups was invited to discuss any or all the case studies presented in Sessions 3 and 4 (e.g. nuclear power plants under normal operation; nuclear power plants under decommissioning; nuclear or radiological emergency management; nuclear or radiological recovery management; post-accident food and drinking water management; radiological waste management; legacy waste management; and naturally-occurring radioactive materials (NORM) and radon management). The objective of breakout discussions was to identify:

- What could change: Practices, regulations, science application, etc.? Today? Tomorrow?
- Which aspects should be considered, discussed and balanced in different prevailing circumstances?

- What is needed for more broad-based decisions?
- How should risk transfers be addressed, e.g. worker to public, worker to environment?

As support for discussions, the following prompting questions were given to each breakout group:

- Who are the stakeholders that need to be involved, in some manner, in decision-making processes so as to identify and implement optimal protection?
- Who is the decision maker?
- What type of concerns are stakeholders likely to have with regard to the prevailing circumstances and residual exposures following the implementation of optimal protection solutions?
- What regulatory requirements impact the identification and implementation of optimal protection solutions?
- Where are protection options, aspects, criteria or other factors most likely to be conservative in nature?
- What type of approach(es) to stakeholder engagement would best address stakeholder concerns?
- What aspects of identifying and implementing optimal protection solutions are likely to support achieving accepted, sustainable decisions?

An obvious yet significant conclusion reached during the breakout sessions is that radiological protection is only one of the components of optimal protection. If the concern is "Am I safe?", then a message only in terms of dose would be insufficient. "Safe" is a subjective judgement, not a number. To establish a common understanding of agreed and sustainable protection decisions, an effective process to engage stakeholders, and stakeholder dialogue are essential. Dialogue involves listening, seeking to understand the underlying real concerns rather than making assumptions about people's issues. To achieve this, interaction with stakeholders should be on a continuous basis in order to gain confidence (trust). The focus of interactions should be on building good relationships rather than on providing information. The skills needed to effectively dialogue and interact with stakeholders are based on social science, which should be integrated into the university radiological protection degree programmes.

Although stakeholder involvement was addressed more in detail in session 6, following the breakout sessions, it is an important element of decision-making process in any prevailing circumstance and was a significant part of breakout discussions. It was noted that stakeholder involvement is not a consensus effort. Rather, it is a process that should be established in planning for or in reacting to a circumstance with radiological protection implications. The extent and nature of stakeholder involvement in decision-making should be clearly expressed from the start. Communications and dialogue should not be seen as selling a solution, and should show respect for, and incorporate (to the extent possible) stakeholder views. It should have a continuity with politics, be layered in time and space, and should result in decisions being taken at the right time. While it is clear that the decider decides, the extent to which the decider is responsible for resolving all aspects of a situation is not inherently clear. For example, is the decider responsible for assuring "value for society"?

Uncertainty was seen as a key driver of conservatism. Avoiding high consequence – low probability circumstances tends to be integral to protection choices. Both regulators and licensees tend to act on the conservative side, such that there is a discontinuity between theory and practice: optimisation tends to be applied as minimisation. Many types of pressure push regulators and licensees to the conservative side: political/legislative views; industry peer reviews; public/NGO pressure; uncertainty; and continuous improvement. A truly graded approach is needed, exploring different protection options from an all-hazards view rather than simply comparing risks.

In terms of criteria to be used, it was noted that while numbers do count, they do not drive fear, and they are rarely decisive. Caution should be used when setting criteria (site, design, function), because strict criteria can restrict optimisation choices. In some circumstances there is probably a generic, residual-dose status below which everyone would agree that no further dose reduction is necessary. This could be the case for smaller practice where a detailed optimisation process is not relevant, but optimisation should clearly be used in complex situations.

A key point of discussion was the importance of framing radiological protection decisions in the context of "The Big Picture". All the cases discussed (e.g. nuclear power plants under normal operation; nuclear power plants under decommissioning; nuclear or radiological emergency management; nuclear or radiological recovery management; post-accident food and drinking water management; radiological waste management; legacy waste management; and NORM and radon management) showed complexity well beyond radiological protection issues. Individuals and groups affected by a radiological circumstance will be concerned for their overall well-being, not just for their radiological risks. However, radiological risks often tend to provoke the highest priority concerns among affected stakeholders. Experience among breakout participants suggested that stakeholders did not spontaneously consider all the levels of risk and benefit beyond radiological aspects. This significant finding of the workshop can be expressed as follows:

– Complex circumstances are multi-dimensional, and require a multidisciplinary approach to identify the optimal protection solution. Accepted, sustainable protection decisions will address circumstantial risks, protection measure risks and benefits, and the consequences that actions, and non-actions will bring with regard to affected-stakeholder well-being.

In view of the potentially long duration of radiological circumstances, the workshop organisers felt it important to highlight the views of young professionals, who will replace those more experienced but retiring radiological protection professionals. Knowledge management will thus be an important issue to tackle, using new approaches to communications such as web-based information or discussion fora. A "crowd sourcing approach", generally using social media to exchange views, in this case could be used to gauge the views of affected or potentially affected stakeholders, and to work with them to address their concerns. In view of the easy accessibility and global availability of electronic communications, management choices are necessary. Organisationally, either staff is allowed (encouraged) or not to use social media to express views. The organisational choice made will build or discourage trust in decision-makers, and ownership in the process and outcome.

The fact that newer communications tools are in general "second nature" to young professionals was discussed as a distinct advantage. Young experts' experience can bring "a fresh eye" to more seasoned issues, and can contribute to building "the big picture" view to any circumstances. Machine learning and predictive analytics can help to better understand reasonable actions in radiological protection situations. Aspects such as email filtering, computer vision, speech recognition, handwriting recognition, economics and medical diagnosis could be fruitfully addressed.

2.6. Session 6: Stakeholder involvement and communication

This session of the workshop focused specifically on stakeholder involvement and communication issues. The session was chaired by Charlotta Fred (Swedish Radiation Safety Authority, SSM). Presentations were given by Thierry Schneider (CEPN, France, CRPPH Bureau), Paul Locke (Johns Hopkins University, United States) and Ted Lazo (CRPPH Secretariat).

By this time in the workshop there was general agreement that the framework elements of the radiological protection (RP) system used to identify optimised protection and accepted and sustainable protection decisions will be driven largely by stakeholder assessment of prevailing circumstances. The optimal radiological protection solution for a given prevailing circumstance is a judgemental selection of what best addresses stakeholder concerns, and maximises stakeholders' well-being. To achieve this, stakeholders need to have a vision of "the big picture", that is, what makes up their well-being, e.g. radiological considerations, and other social, economic, societal, personal prevailing circumstances. The role of the RP is to establish a fair and sustainable process to engage key stakeholders, and to help stakeholders appreciate all relevant aspects of a situation, both individual-specific and generic, and the implications of possible protection choices. To achieve this, stakeholder trust in the source of information is essential. Local and long-term engagement is important to building trust: "To be trusted, you must communicate successfully. To communicate successfully, you must be trusted." There is a need to engage with the younger generation, help build a local constituency, assure adequate resources to support communications, and institutionally recognise that situation complexity requires big-picture focus.

Risk can be quantified, but risk acceptability in a given prevailing circumstance is based on case-by-case judgement. Risk communication is a long-term, dynamic, evolving, multi-step, multi-dimensional, socially and technically complex, and resource intensive activity. NGOs and local stakeholders have specific and varying local knowledge and understanding, such that dialogue with stakeholders should be institutionally required for regulators. To facilitate communications, a simple and visual radiation exposure scale could be a useful tool. Social media is another key tool, and can help to identify possible concerns in advance, but can be resource intensive.

Reasonableness is a way of calibrating (balancing) the factors that go into the optimisation process so that the optimisation of radiological protection aligns with optimal protection. This can include such diverse aspects as economics, social factors, and ethics and values. Risk communication is one way of obtaining some of the information needed to undertake the balancing and calibration that is required (i.e. prevailing circumstances and the big picture). In such circumstances, data matters, but other factors, especially trust, might matter more. Thus going into a risk-induced circumstance, listen first and exchange information. Use stories, not statistics, whenever you can. Recognising that Risk = Hazard + Outrage, and that Communication = Process + Substance will assist in prioritising preparedness and implementation actions.

2.7. Session 7: What science is needed?

The final session of the workshop addressed the issues of scientific uncertainty and the exposure management tools that should be used. This session was chaired by Werner Rühm (Helmholtz Center Munich, Germany). Presentations were given by Antone Brooks (Washington State University, United States) and by Dominique Laurier (IRSN, France).

The workshop was organised such that the scientific understanding of the possibility of solid cancer and leukaemia induction due to low dose radiological exposure was not specifically addressed in terms of reasonableness in radiological protection decisions. However, recognising the importance of scientific uncertainty in the application of a precautionary approach, it was agreed to present scientific views on the current level of scientific understanding.

The fact that a large part of the general public tends to perceive radiological risks to be more serious than they actually are was seen by some participants as a significant cause of overly conservative radiological protection choices. The LNT model used to assess radiological risks was identified by some participants as generating public radio-phobia, because LNT suggests that any dose brings risk. Participants broadly agreed, however, that fear is not driven by numbers.

The LNT model was questioned by some participants in terms of modern radiobiological understanding. Single hit theory, whereby one hit of DNA can result in cancer, has been overtaken by evolving understanding of cancer-generation complexity. In some circumstances low doses can stimulate the immune system, increase DNA repair and upregulate many other protective mechanisms. Aspects such as glutathione, manganese superoxide dismutase (MnSOD), apoptosis, metabolic pathways, and bystander effects show the complexity of cellular responses to radiation exposure and their ability to address such insults. Dose-related cellular response mechanisms suggest that there may be a dose threshold for some cellular responses, although it is not known whether or not a dose threshold exists for organism end points such as cancer and leukaemia.

Beyond these considerations, it was suggested that society must learn from its experiences and consider ALL the consequences of actions to balance residual risk and regulatory actions – a graded approach. Risks can be increased by dose minimisation and similar protective actions that may in some cases outweigh the calculated protection gained. Some participants saw the deaths and societal disruption caused by evacuation and sheltering during the Fukushima Daiichi Nuclear Power Plant accident as an example of this. Some participants expressed the view that science has demonstrated that the risks from radiation have been and continue to be overestimated, and that fear partly generated by irresponsible use of collective dose, ALARA and LNT risk calculations are detrimental to optimal decision-making for improving human health and welfare. A few participants suggested that science and experience suggest that a threshold model, rather than an LNT model, should be used to assess the risks, and benefits (i.e. hormesis) of exposure to low levels of ionising radiation.

But while radiation biology highlights the complexity of cellular mechanisms, epidemiology highlights the biologically and statistically significant human-health risks due to low dose exposures. There has been reinforcement in the last decade of the epidemiological evidence of some excess risk of some cancers after low dose (< 100 mSv) radiation exposure. Although some recent studies have suggested evidence of curvilinearity (e.g. Grant et al. 2017, or more recently Little et al. 2020), participants broadly agreed that evidence remains in favour of linearity, and no evidence of a general threshold has been reliably demonstrated. Recent epidemiological results support non-threshold linearity as the most plausible dose-response model at low doses. There are still uncertainties and lacks of knowledge (internal exposures, modifying effect of sex, age and time since exposure, variation between cancer sites…), but additional results from various epidemiological studies are expected in the near future.

It was stressed that the LNT model is a practical, radiological protection model, not a scientific theory or hypothesis. The LNT dose-response model is not able to reflect the complete mechanisms of cancer induction, nor any other model at this point, but the LNT model continues to represent the increasing body of epidemiological data at low doses. It is the most parsimonious description of the available epidemiological data, and it provides a practicable basis for estimating the impact of radiological exposures for risk management purposes. The view was expressed that the LNT dose-response model is not overly protective at low doses. An LNT model is also used outside of the radiation field: a linear non-threshold relationship is considered for assessing risk for many chemical carcinogens (chemicals, diesel exhausts, heavy metals, alcohol, etc.) (US EPA, 2005). Thus for the time being, the LNT model seems to be the most scientifically and practically reasonable tool for the management of radiological exposures.

3. Conclusions and the way forward

Reasonableness is a case-specific, stakeholder-dependent, circumstance-driven judgement, informed by the scientific understanding of the risks involved, and best built in an atmosphere of trust between the decider(s) and affected stakeholders brought together in a fair and sustainable process in which prevailing circumstances can be discussed and balanced. Workshop presentations and discussions highlighted that the optimisation of exposure is not synonymous with the optimisation of radiological protection. Optimisation of exposure has often led to a narrow focus on radiological protective measures, and to residual exposures that are minimised rather than optimised. Optimisation of overall, well-being based protection is inherently broader than optimisation of exposure, and is focused on addressing all the relevant aspects of the big picture. The broad, multi-dimensional, multidisciplinary status of stakeholder well-being is the objective of optimisation in any circumstances. To achieve an optimal state of well-being requires:

- the development of a broad and common understanding of the prevailing circumstances and the hazards they present;
- an assessment of radiological and other risk protection options and of the consequences each protective measure might cause;
- a set of tools to compare and balance different risks and benefits that the prevailing circumstances and protective measures might cause;
- an equitable and sustainable stakeholder involvement process to listen to concerns, to incorporate local knowledge and expertise into situational resolution, and to effectively communicate with relevant stakeholders.

As a framework to these requirements, discussion pointed out the importance of understanding cultural aspects in identifying the optimal protection solution. The workshop participants also noted that social media provides stakeholders with a tool to "learn from their peers". Stakeholders also want to learn from experts, whose support is thus vital to achieving well-informed stakeholder understanding. As such, there is a need for "teachable moments" where stakeholders can find expert assessments. Monitoring social media, to be aware of and prepared to address such issues can contribute to being a trusted source of valid information.

Although taking in the big picture, the well-being approach is no guarantee that overall protection solutions will be reasonable. Workshop participants suggested that such an approach would more holistically address stakeholder concerns, and would frame overall protection choices in a more complete picture of the situation. Presentations and discussions showed that there are still several interpretations of optimisation of overall protection, and that they are generally driven by the nature of the circumstances causing the radiological risks. This has led to a misunderstanding in discussions of regulatory approaches and their application as to how best to optimise -- which have, in many cases, reinforced stakeholder mistrust. The workshop discussions, however, identified aspects that, if clarified and agreed, could improve this situation.

Prevailing circumstances presenting radiological risks should be understood holistically, as complex, multi-dimensional, multidisciplinary situations in which radiological risks are only one of potentially many risks. This should be reflected in international recommendations and requirements, outlining radiological and non-radiological, situational and decisional aspects to consider in regulation and application.

There is a need to develop a new, internationally agreed understanding of optimisation of overall protection and its objective, beyond just radiological protection, focusing on achieving optimal well-being. This should include broad and institutional discussions on how "reasonableness" is understood, and on processes to identify "reasonable" overall protection decisions.

The process for developing optimised overall protection, and the elements that should be considered, include aspects that need consideration in any circumstances. Some situation-specific elements and the consequences of radiological protection decisions will depend on prevailing circumstances. These common and case-specific elements of optimisation of overall protection should be identified.

Numeric criteria can be both useful and problematic. Discussion should be organised to identify what types of numeric criteria that are useful for the regulation and application of optimisation, and on approaches to agree on numeric and other decisional criteria.

In order for decision-makers to appropriately identify the best overall protection solution under the prevailing circumstances, tools need to be developed for balancing the diverse risks and benefits that prevailing circumstances present, and that the consequences of protection solutions might cause.

Risk communication should be recognised as an important process during which key stakeholders exchange ideas, discuss prevailing circumstances and calibrate potential solutions with the goal of enhancing well-being. An equitable and sustainable process much be established to create and maintain trust and confidence. Communication tools, such as a simple, visual radiation scale, should be developed to facilitate addressing stakeholder concerns.

The objective of this workshop was to identify areas where a broader vision of the prevailing circumstances, and of the implications of protection decisions, could facilitate a more widely accepted, sustainable and reasonable path forward for circumstances that require radiological protection decisions. It is hoped that the results of this workshop will support the evolution of the current radiological protection framework as a tool to help achieve optimised well-being.

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Appendix 2: Workshop programme

Day 1: 13 January 2020

Time		Topic	Speaker
09:00		**Session 1: Welcome and introduction** The Nuclear Energy Agency (NEA), the CRPPH and the host organisation(s) will welcome participants. • NEA welcome: William D. Magwood, IV • Portuguese Minister of Health (TBD) • Portuguese Minister of Science and Technology (TBD) • Portuguese Minister of the Environment (TBD) • CRPPH welcome: Mike Boyd	
10:00	1	**How safe is safe enough?** Optimisation is a question of finding the best radiological protection under the prevailing circumstances. This science-based judgement will depend on many aspects and will be very case-specific. Regulators, licensees, elected officials, non-governmental organisations (NGOs) and members of the public often have different judgements under such circumstances. This presentation will discuss the various aspects of these considerations, and will lead to discussions on how to improve the situation. Discussion	NEA Director-General William D Magwood, IV
10:30	2	**Where we are now?** The topic of reasonableness is currently seen as extremely relevant for all branches of radiological protection, and has been discussed in several national and international fora. These discussions have been summarised by the International Radiation Protection Association (IRPA), whose President will present the status of discussions. Discussion	IRPA President Roger Coates
10:50		**Break**	
Time		**Topic**	**Speaker**
11:20	3	**Portuguese regulatory authority** Optimisation is in many cases a regulatory issue. In non-nuclear countries such as in Portugal, optimisation in the use of medical radiation is a key topic, as discussed in this presentation. Discussion	João Oliveira Martins - Regulatory authority, Portuguese Environment Agency (APA)

11:40	4	**Reasonableness: A practical overview** The Workshop Chair will present the context of this meeting, noting the work that has been carried out by the NEA Committee on Radiological Protection and Public Health (CRPPH) and the key issues that have been identified, and outlining the objectives and expected outputs of the meeting. Discussion	Mike Boyd - CRPPH Chair - US EPA
12:00		**Lunch**	
13:30		**Session 2: Framework as it is today, evolution for the future** This session will present various aspects of the decision framework as it exists today for radiological protection circumstances, and the direction of the evolution that is developing as a result of implementation experience. Approaches to identifying and addressing relevant aspects will be discussed, as will the emerging direction moving forward. Chair: Pedro Vaz: Instituto Superior Técnico, Portugal	

Time		Topic	Speaker
13:40	5	**Recommendations and rationale** This presentation will discuss how the international system of radiological protection describes the principle of optimisation, and how it should be understood and implemented. Feedback to the International Commission on Radiological Protection (ICRP) will be discussed, as will the various radiological protection criteria and the rationale for their numerical values (e.g. dose limits, dose constraints, reference levels, clearance and exemption levels). Discussion	Chris Clement - ICRP Scientific Secretary
14:00	6	**Standards** This presentation will discuss how the International Atomic Energy Agency (IAEA) Basic Safety Standards (GSR Part 3) and related safety guidance documents describe the principle of optimisation, and how they recommend that the concept and its application should be understood and implemented. Discussion	Miroslav Pinak - Section Head: Radiation Safety and Monitoring, IAEA
14:20	7	**Regulation** This presentation will discuss the Spanish regulatory approach to the optimisation of protection, and how national-level regulations implement radiological protection criteria in the context of optimisation. Discussion	Javier Zarzuela - Sub-Director of Operational Radiation Protection, CSN, Spain

14:40	8	**Stakeholder involvement** This presentation will discuss how stakeholder involvement is managed in radiological protection decision-making, and how this can affect radiological protection choices. It will also examine the social and economic aspects of such decisions. Discussion	Andy Mayall - CRPPH Bureau - Environment Agency, United Kingdom
15:00		**Break**	
Time		**Topic**	**Speaker**
15:20	D2	**Discussion of the radiological protection framework** A moderated panel and audience discussion of these presentations will focus on the overall framework of optimisation decisions and on which aspects will drive the identification of the optimal protection solution. Moderator: Alan Waltar past President, American Nuclear Society (ANS)	
16:00		**Session 3: Practical approaches to the implementation of optimisation at nuclear facilities** This plenary session will have a series of case studies, each representing very different prevailing circumstances and each raising different stakeholder concerns, protection options and decision consequences. Each case study will present what is meant by "optimal protection" for that circumstance, will address the relevant aspects considered when identifying optimal protection solutions and will discuss where conservatism may affect the reasonableness of agreed solutions. Chair: Marilyn Kray, ANS President	
16:10	9	**Overview of optimisation issues in the United States** This presentation will give a high-level view of issues affecting choices of optimal protection solutions in various circumstances in the United States Discussion	Marilyn Kray - ANS President
16:30	10	**Operational nuclear power plants** This presentation will discuss how regulations and other protection-optimisation considerations are interpreted at operational nuclear power plants when making radiological protection decisions, including such aspects as economics, image and trust. Discussion	Guy Renn - ISOE Chair - EDF Energy UK

Time		Topic	Speaker
16:50	11	**Decommissioning** This presentation will discuss how regulations and other protection-optimisation considerations are interpreted at nuclear power plants under decommissioning when making radiological protection decisions, including such aspects as economics, image and trust. Discussion	Gilles Ranchoux - EDF
17:10		**Short break**	
17:30	12	**Graded approach to uncertainty in compliance with clearance levels** This presentation will discuss how large volumes of slightly contaminated material can be released in an efficient manner under clearance procedures. Discussion	Takatoshi Hattori - CRIEPI
17:50	13	**From optimisation of exposure to optimisation of protection** This presentation will discuss various issues faced by nuclear power installations in operation and under decommissioning when working to identify the best worker and public protection, while optimising rather than minimising exposure. Discussion	B. Lorenz R. Brunner - Lorenz Consulting
18:10	D3	**Discussion of optimisation of protection for nuclear power plants** This will be a moderated discussion of these presentations, focusing on the practical and operational aspects that affect optimisation decisions, on which aspects will drive the identification of the optimal protection solution, and on which aspects can increasing push solutions towards conservatism. Moderator: Tony Brooks, University of Washington, United States	
18:30		**End of first day**	

Day 2: 14 January 2020

Time		Topic	Speaker
09:30		**Session 4: Practical approaches to the implementation of optimisation in other circumstances** This plenary session will present a series of case studies, each representing very different prevailing circumstances, and each raising different stakeholder concerns, protection options and decision consequences. Each case study will define what is meant by "optimal	

		protection" for that particular circumstance, address the relevant aspects considered when identifying optimal protection solutions, and discuss where conservatism may affect the reasonableness of agreed solutions. Chair: Shaheen Dewji, Texas A&M University	
09:40	14	**Emergency management** This case study will discuss aspects to be considered when making optimisation decisions regarding urgent protective measures. The focus will be on the processes used to achieve accepted, sustainable solutions for protective actions. Discussion	Matthias Zaehringer - WPNEM Chair
10:00	15	**Medical exposure** This case study will discuss aspects to be considered when making optimisation decisions regarding patient and worker protection in medical exposure situations. The focus will be on the processes used to achieve accepted, sustainable solutions for protective actions. Discussion	Joana Santos - Professor, Health Technology School, Coimbra

Time		Topic	Speaker
10:20	16	**NORM and radon** This case study will discuss aspects to be considered when making optimisation decisions regarding the management of NORM and radon situations. The focus will be on the processes used to achieve accepted, sustainable solutions for protective actions. Discussion	Ciara McMahon - EPA, Ireland
10:40	17	**Radionuclides in food and drinking water (WHO)** This case study will discuss aspects to be considered when making optimisation decisions regarding the post-accident management of food and drinking water. The focus will be on the processes used to achieve accepted, sustainable solutions for protective actions. Discussion	Maria Perez - WHO
11:00		**Break**	
11:30	18	**Recovery management** This case study will discuss aspects to be considered when making optimisation decisions regarding post-accident recovery. The focus will be on the processes used to achieve accepted, sustainable solutions for protective actions. Discussion	Lavrans Skuterud - DSA, Norway

11:50	D4	**Discussion of optimisation of protection for other circumstances** This will be a moderated discussion of these presentations, focusing on the practical and operational aspects that affect optimisation decisions, on what aspects will drive the identification of the optimal protection solution, and on what aspects can increasingly push solutions towards conservatism. Moderator: Thierry Schneider, CRPPH Bureau, CEPN, France	
12:30		**Lunch**	
Time		**Topic**	**Speaker**
14:00		**Session 5: Breakout discussions** Participants will break into three groups to hold discussions, each addressing a series of questions. Each breakout discussion will address all the case studies presented in Sessions 3 and 4. The objective of breakout discussions is to identify: • **What** could change: Practices, regulations, science application, etc.? Today? Tomorrow? • **Which** aspects should be considered, discussed and balanced in different prevailing circumstances? • **What** is needed for more broad-based decisions? • **How** should risk transfers be addressed, e.g. worker to public, worker to environment?	Breakout session discussions
15:30		**Break**	
17:00		**End of second day**	

Day 3: 15 January 2020

Time		Topic	Speaker
09:00	D5	**Breakout topic plenary summary: Decisional aspects to be considered in radiological protection situations** The Rapporteurs for the breakout sessions will briefly present the results of discussions. This will be followed by a panel discussion of young radiological protection experts, who will present views on what aspects they consider to be the most significant in decision-making situations. "Modern" approaches used to dialogue with stakeholders and to understand their views and concerns will be a focus of discussions.	

		Moderator: Nicole Martinez, Clemson University Panel Members: - Sylvain Andresz, Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire (CEPN, France) - Momo Kurihara, National Institute for Quantum and Radiological Science and Technology (QST, Japan) - Franz Kabrt, Austrian Agency for Food and Safety (Ages, Austria) - Amir Bahador, Kansas State University, United States, - Jorge Borbinha, Technological and Nuclear Campus, Technical Superior Institute, University of Lisbon, (IST-CTN, Portugal)	
10:30		**Break**	
11:00		**Session 6: Stakeholder involvement and communication** Stakeholder involvement and communication are key aspects of decision processes for the optimisation of protection. This session will discuss approaches to dealing with stakeholder situations such that decisions will be scientifically and situationally informed, so as to be accepted and sustainable. Chair: Charlotta Fred, Swedish Radiation Safety Authority (SSM) Chair: TBD	
11:10	19	**Risk communication** The results of the NEA Stakeholder Involvement Workshop on Risk Communication will be presented. Discussion	Thierry Schneider - CEPN, CRPPH Bureau

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11:30	20	**Communicating with stakeholders: Key elements** This presentation will discuss the science of social interactions needed to identify and implement optimal protection solutions, and approaches to help ensure that protection decisions are taken in an informed framework. Discussion	Paul Locke - Johns Hopkins University
11:50	21	**CRPPH stakeholder involvement experience** The NEA Committee on Radiological Protection and Public Health (CRPPH) has, since the early 1990s, studied and addressed the involvement of stakeholders in radiological protection	Ted Lazo - CRPPH Scientific Secretariat

		decisions. This presentation will summarise the pathway and current status of the committee's thinking on this important topic. Discussion	
12:10		**Lunch**	
13:30		**Session 7: What science is needed?** The science behind the reactions of living cells, tissues, organs and individuals to ionising radiation interactions is far from fully understood. This session will briefly summarise what science currently says about the shape of the low dose response curve, and will provide suggestions as to what further studies are needed to better understand the dose/response curve. Chair: Werner Rühm, Helmholtz Institute, Germany	

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13:40	22	**Is there or is there not a threshold?** The radiation biological science behind threshold and hormesis theories will be presented, highlighting the direction that further research should pursue to help show either the generic nature of this low dose response, or its applicability in some but not all exposure situations. Discussion	Tony Brooks - Washington State University
14:00	23	**Is LNT sufficiently supported scientifically?** The LNT hypothesis has been used for some time as a practical tool for the management of exposure to ionising radiation. This presentation will discuss whether or not radiation biological science is sufficiently supportive of LNT to continue its use as the basis for radiological protection regulation and application. Discussion	Dominique Laurier, - IRSN
14:20		**Conclusions** • Communication strategy • Areas for further consideration • Suggestions for future ICRP recommendations	Mike Boyd - CRPPH Chair - US EPA José Venancio - IPOLFG
14:40		**End of workshop**	