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NUCLEAR ENERGY AGENCY
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Summary Record of the Third Meeting of the Ad Hoc Expert Group on "Cost of Nuclear Accidents, Liability Issues and their Impact on Electricity Costs"

NEA Headquarters, Issy-les-Moulineaux
3-4 June 2014

Contacts: Marco.Cometto@oecd.org and Alexey.Lokhov@oecd.org

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SUMMARY RECORD
OF THE THIRD MEETING OF THE AD HOC EXPERT GROUP ON

"COST OF NUCLEAR ACCIDENTS, LIABILITY ISSUES AND THEIR IMPACT ON ELECTRICITY COSTS"

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1. The third meeting of the Ad Hoc Expert Group on "Cost of Nuclear Accidents, liability Issues and their Impact on Electricity Costs" was held on the 3-4 June 2014 at the NEA Headquarters in Paris, France.

2. The agenda of the Expert Group meeting is available as an OLIS document [NEA/NDC(2014)10/REV1] and is reported in Annex 1.

3. Representatives from Belgium, Finland, France, the Republic of Korea, Switzerland, the United States and the United Kingdom, and the International Atomic Energy Agency (IAEA) attended the meeting. In addition to the nominated delegates, a consultant from Belarus and two observers from France and the Republic of Korea participated in the meeting. The representatives of Hungary, the Russian Federation, and the European Commission did not attend the meeting. The detailed list of participants can be found in Annex 2.

Day I

4. The meeting started with welcoming remarks by Ron Cameron (OECD/NEA, head of the Nuclear Development Division).

5. Marco Cometto (OECD/NEA) presented the structure and the current draft of Chapter 2 of the study "*Severe accidents in the history of civil nuclear power*" that currently includes the following major sections:

- Technology disasters;
- Nuclear hazards and safety measures:
  - Health effects of ionising radiation;
  - Radiological impacts of nuclear accidents;
  - Safety measures and countermeasures to reduce dose.
- Severe accidents in the civil nuclear power industry:
  - International Nuclear and Radiological Event Scale (INES);
  - TMI: *Description of the accident, evacuation and countermeasures, land contamination, health effects, economic data available;*
  - Chernobyl: *Description of the accident, evacuation and countermeasures, land contamination, health effects, economic data available;*

- Fukushima: *Description of the accident, evacuation and countermeasures, land contamination, health effects, economic data available*.

- Civil nuclear accidents in perspective;
- Discussion and conclusions.

6. Following the general presentation on Chapter 2, a detailed presentation on the estimates of the economic losses associated with Chernobyl was provided by Alena Nikalaenka (Belarus, NEA consultant):

i. Regarding the source term of the Chernobyl accident, it is estimated that the whole core inventory of noble gases, about 50% of I, and between 20% and 40% of Cs and Te was released directly to the atmosphere. The estimate for fuel material released to the environment is ~2-3.5% (3-6 t of fragmented fuel).

ii. Belarus was very severely affected by the accident at Chernobyl.

iii. In Belarus, the losses associated with the accident at Chernobyl were quantified on request of the Government of Belarus. These are the only official figures available for the losses associate with Chernobyl (no official figures from the Russian Federation and Ukraine).

iv. The economic losses are divided in the following categories:

- ***Direct losses*** – elements of national wealth lost: fixed and current production assets, social infrastructure and housing, as well as tangible components of natural resources (mineral, forest, land and water resources).
- ***Indirect losses*** – losses caused by disruption or cessation of production related to the accident.
- ***Loss of profit*** is a foregone economic loss due to the forced redistribution, underutilisation or modification of resource use (material, human, financial and natural resources), and due to structural changes in the economy.
- ***Additional losses*** are costs of mitigation and minimisation of the accident consequences, costs of maintaining adequate operation of various industries in the contaminated areas, including the establishment of safe living conditions for the population.

v. The results of the evaluation are converted to current USD without taking into account the purchase power parity (it should be noted that inflation in Belarus was very significant since 1991 and that the level of prices in Belarus is very low if compared to OECD countries).

vi. The official estimates (in current USD) state that the total loss due to the impact of Chernobyl on the economics of Belarus for the period 1986-2015 is about USD 235 billion, of which about USD 30 billion are direct and indirect losses, about USD 14 billion are loss of profit, and the largest contribution of USD 191 billion is attributable to additional losses.

vii. The losses to agriculture (part of the total loss of USD 235 billion) represent about USD 70 billion for the period of 1986-2015.

viii. Alena Nikalaenka presented the detailed estimates for the agricultural and agro-industrial complex, industrial sectors, environment, and health impact on the population.

ix. With respect to the health impact, she explained that the losses were subdivided in two categories: radiological (deterministic and stochastic) and stress-related. The stress-related component was estimated (based on expert judgement) as two times the loss associated with stochastic effects.

x. In conclusion, Alena stressed that:

- The estimates presented are the only available official estimates. They were performed in Belarus because the cost related to Chernobyl represents an important share of the budget of Belarus (e.g. the implementation of the Law on Compensations).
- In some aspects, it is challenging to understand the method used for the estimation (e.g. taking into account high inflation, devaluation of the national currency and conversion from Belarussian roubles to USD).
- It is impossible to compare losses in Belarus to those in Ukraine, the Russian Federation, and other affected countries, because of differences in the level of contamination, structure of the economy and the legislation, differences in approaches to mitigation and rehabilitation of the contaminated territories, etc.
- Agricultural production and business activities are possible in the areas with a significant level of contamination, but there is a cost for it.
- Health effects: stress-related factors are very important.

7. A first discussion was devoted to more general questions on the structure of the report, the balance of different sections and on the review process. Many experts asked the Secretariat on the process for reviewing the report. Given the nature of the report it was felt necessary to give a sufficient time for reviewing and carefully commenting the text, without having a too narrow deadline. Roh Hathlia (United Kingdom) expressed the need of carefully considering the relationship and links between the different chapters. In this respect, Chapter 2 is crucial for explaining the difficulties inherent in the project.

8. With respect to the presentation of Chapter 2, comments were made on the large volume of the chapter. Ralph Andersen (United States) and Anssi Paalanen (Finland) suggested shortening the section on health effects because it is partially out of scope of the study and keeping the detailed discussion in an annex.

9. Marco Cometto responded that in the current version only five pages are dedicated to the discussion of health effects of radiation, radiation protection models and their application to estimates of economic losses.

10. Stefan Hirschberg (Switzerland) underlined that there is no consensus on the relationships between dose and effects at low doses. When estimating health effects due to other energy sources such as fossil fuels, LNT-type relations are used. However, these standards are established for radiation protection and not for estimating losses due to accidents. Thus, it was suggested to present estimates using two different models in the report: LNT and linear with threshold.

    Ralph Anderson suggested adopting two or three possible methods and pointing out the impact on the results. This approach allows for illustrating clearly the implications of applying different relations/definitions and is currently adopted in the United States.

Roh Hathlia suggested using the LNT model since the choice of a threshold in the models would be arbitrary, even if considering differences in natural background (and the current regulations are even lower). Thus, there could be communication problems. Neil Higgins (United Kingdom) also indicated that the LNT model is based on a precautionary principle and he would be reluctant to choose a threshold that could be perceived as arbitrary particularly one that was close to or even above regulatory levels for normal operation.

In response, Ralph Andersen recalled that using LNT alone would be a departure from the current positions on the issue of the WHO, IAEA and UNSCEAR. He noted that all calculation steps are based on conservative approaches and was also concerned that adding conservatism to conservatism would progressively move result from a best estimate. The real question is the uncertainty (associated with the fact that there is no consensus on the dose-effect relationship at low doses) and considering both LNT and a relation with threshold allows this uncertainty to be captured. William D'Haeseleer (Belgium) suggested including this discussion in the report since it is useful for the audience, and to refer to the recommendations of the international organisations.

11. The Expert Group agreed to refer to different practices and to include both models (LNT and linear-with-threshold model), without making a specific recommendation on the model to be used. It was also agreed to avoid strong statements on the LNT model.

12. Ralph Andersen suggested removing the section with the description of the safety measures for reactors, in particular the discussion of the defence-in-depth, since it is out of the scope and the study should avoid being undermined by material that is not directly relevant to the report. The Expert Group agreed to remove the Box on Defence-in-Depth from the final version of report.

13. Roh Hathlia suggested considering moving the section on INES to the beginning of Chapter 2 or to place it in an annex.

14. Regarding the section on Chernobyl, Stefan Hirschberg suggested to complete the section on health effects with the data on leukaemia, as reported in the WHO report.

15. Geoffrey Rothwell (OECD/NEA) underlined the importance of avoiding double-counting while estimating the losses due to nuclear accident. It was suggested that the definition of categories used for estimates in Belarus (direct costs, indirect costs, loss of profit and additional costs) was not clear and could be redundant.

16. Several participants expressed comments on the very detailed presentation of economic consequences on Chernobyl. Stefan Hirschberg and Loreta Stankeviciute (IAEA) suggested highlighting the difficulties of identifying the economic losses due to the Chernobyl accident and to provide an explanation of why the study focuses on Belarus. It was recommended to shorten this section and move details to the Appendix.

    Also, there is some incoherence in the numbers presented that has to be removed. The methodology of the estimates should be clarified and explained in the report. Challenges and difficulties should be presented, together with the assumptions used to overcome them.

    Alexey Lokhov (OECD/NEA) noted that the objective of the Secretariat is to present the final results in this section in constant USD (if possible) and taking into account the purchase power parity changes in Belarus since 1991.

17. The balance between the descriptions of the three historical accidents (TMI, Chernobyl and Fukushima Daiichi) should be respected.

18. Finally, the Expert Group decided not to present comparisons between releases from accidents in civil nuclear and releases due to military tests.

19. In the afternoon, Ludivine Pascucci (France) presented the IRSN methodology for estimating the cost of a nuclear accident, based on the IRSN report "*Méthodologie appliquée par l'IRSN pour l'estimation des coûts d'accidents nucléaires en France*" that was published in mid-April 2014.

    Ludivine Pascucci indicated the need to have a global figure for the cost-benefit analysis, but also as an indicator of the overall consequences of a nuclear accident for decision makers, safety analysts and for crisis management. A global figure should be representative of the distribution of possible accident outcomes that covers several accident scenarios, the possible weather conditions, the geographical location of the site, the lifetime of the nuclear fleet as well as possible reaction of the public and of other key economic players.

    The IRSN considers that the median value of all modelled outcomes is the most appropriate indicator of the economic consequences of a nuclear accident, because the distribution of results is very wide and asymmetric. All possible economic effects should be taken into account, radiological consequences as well as economic consequences. The former are the results of several probabilistic calculations, while the latter are estimated through postulated scenario analysis.

    In terms of radiological consequences, the IRSN has defined two source terms, corresponding to a severe and a major accident; releases are based on PSA level 2 studies from IRSN (corresponding to median values of $5 \cdot 10^{15}$ and 10^{18} Bq of aerosols). For each source term, the IRSN compute several sequences as a function of the meteorological conditions during the releases and computes the median cost.

    Concerning the economic consequences, she gave a detailed description of the methodological hypothesis for image costs in tourism and for the impact on the fleet of nuclear reactors.

20. Hans Maertens (Belgium) asked why it was decided to take the median value as a relevant parameter: in his view there is not a clear motivation to prefer it to the mean or the mode. Neil Higgins, Marie-Anne Plagnet (France) and Geoffrey Rothwell expressed their concern on possible double-counting in calculating induced effects with the IRSN methodology.

21. The Secretariat presented the progress made on Chapter 3 (methodology) and underlined the open questions. Marco Cometto presented the structure of the chapter and the different estimation perspectives (involving different types of losses) that have been considered by the Expert Group:

    i. The *accident preparedness and management perspective;*
    ii. The *potential liabilities and compensation perspective;*
    iii. The *total social cost perspective.*

    Marco Cometto noted that a clearer and more focused definition of the "total social cost perspective" would be beneficial for the study. He also gave an outline of the current categorisation (see table below) of losses and presented some difficult points requiring further clarification.

    Finally he presented some generic methodological issues which require a separate analysis. After the presentation, the Expert Group discussed the different points raised by the Secretariat.

22. With respect to the definition of different estimation perspectives, Jan Horst Keppler (OECD/NEA) indicated that an "externality" or "social cost" is not a cost (well-defined) that the market somehow

has forgotten. It is a range of impacts of different firmness, some of which are certainly legitimate to be internalised, others which are much more uncertain. Certain externalities should exist as their cost of internalisation would be higher than their cost. Other "externalities" are already internalised through the liability system. He noted that the Chicago school maintains for that reason that no welfare-relevant externalities exist. The argument is not universally accepted but it is far more pertinent than it sounds. One possible way to get around this conundrum is to group externalities into categories of different firmness and political legitimacy.

23. Ludivine Pascucci and Jan Horst Keppler supported the idea of adding a short general discussion on environmental and irreversible losses and indicated that there is a vast literature that has already treated this subject. Stefan Hirschberg indicated that loss of biodiversity should be also considered although it is very difficult to quantify in monetary terms.

24. Concerning the "monetary valuation of human life" all experts agreed that the use of a willingness-to-pay (WTP) approach is preferable to the use of human capital (HP). Stefan Hirschberg recalled that the ExternE project recommended to use VOLY and DALY (disability-adjusted life year) instead of VSL. Neil Higgins noted that there is not a good reason to prefer VOLY to VSL (they are intimately related and equally flawed).

    Ron Cameron concluded that the report should present and discuss the various approaches, and indicate the impact of the choice of approach on the final results.

25. Concerning the presentations of the "uncertainties in physical and economic estimates", the Expert Group already indicated in previous meetings that the different cost elements should be presented with the associated uncertainties.

    Hans Maertens suggested that the ideal solution is to provide the maximum information possible to the reader and thus provide the average, mode and median together with an interval of estimates.

    Jan Horst Keppler and Seung-Su Kim (Republic of Korea) recommended to make a clear separation between physical and economical estimates and to make a clear distinction between risk and uncertainty. Seung-Su Kim also noted that some causes of uncertainty, such as the reaction of the government, can be controlled, while others, such as the weather conditions, cannot be.

    Anssi Paalanen also indicated that some reactions of the authorities can be predicted a-priori, while others are of more political nature and can be only observed a-posteriori.

    Ludivine Pascucci recalled that the modelling uncertainties in the computer codes are quite large and suggested to present the results by steps (first physical and then economic estimates). The uncertainties associated with economic costs (image costs, cost of the electricity production system) are not larger than the uncertainties associated with radiological costs. Radiological costs account for only one part of the total cost of the accident, sometimes only a minor part as is the case for limited off-site releases (radiological costs represent in this case about 20% of the total cost of the accident). A decision of prevention taken on 20% of the total cost of the accident will for sure be a wrong decision; that's why a sound economic estimate should cover all the costs. Economic costs are the result of postulated scenario based on the careful study of historic data. They can be estimated a priori and should be accompanied by an in-depth qualitative discussion on the hypotheses, the methods and the results of the evaluation.

    Alysia Bone (United States) expressed the view that the study should clearly indicate that there are some impacts that can be quantified and others that should be discussed only in a qualitative way.

Neil Higgins summarised the discussion indicating that the study should provide for each cost component a range of possible outcomes and quantify this range.

26. Regarding the issue of "discounting of cash flows" associated with loss estimates, Stefan Hirschberg recalled that the issue of discounting was extensively discussed in the ExternE project and it was very difficult to reach a consensus among experts. The study adopted three different discount rates (0%, 3% and 6%) for all effects but decided not to discount health costs.

    Some experts noted that different discounting choices would have a limited impact on the cost since most of the economic burden happens in the early years after the accident.

    The majority of the group supported the choice of using a non-zero discount rate in the study, and to use a unique value to avoid unnecessary complication.

    Geoffrey Rothwell summarised the position of the Expert Group by suggesting the use of the social discount rate in the analysis (3% real).

27. The Expert Group also discussed the issue of taking into account risk aversion. Stefan Hirschberg recalled that risk aversion is real, but its quantification is extremely controversial and prone to a lot of manipulation. He also noted that it is almost only discussed in the nuclear field, which puts nuclear in an unfair position with respect to other technologies. His suggestion was to discuss the concept of risk aversion in a qualitative way but not to monetise it. This position was also supported by the majority of the Expert Group (Jan Horst Keppler, William D'Haeseleer, Anssi Paalanen and Hans Maertens).

    Some disagreement with this view was expressed by Ludivine Pascucci who recalled that risk aversion exists and should be discussed and monetised. Valuing the risk as its expected value denies the (public) decision maker the right to express his preferences regarding this risk. Catastrophic risk is different from usual risks: for low probability high cost events, there is no mutuality; liability schemes do not cover the full costs of the accident should this risk materialise; hence, a large part of the cost would necessarily be transferred to the State. Confronted with low probabilities high cost events, the decision maker could prefer to spend more money on the prevention of the accident than its expected value to avoid a far larger loss should the accident occur.

    The group arrived to a consensus that risk aversion should not be integrated in the cost estimation. However it should be presented, together with the cost figure of an accident and the associated probability, in the analysis.

28. Finally, the group reached an agreement on the decision to not sum the cost categories, but provide each value separately, and discuss the categories that can only be evaluated qualitatively.

29. In summary, it was agreed to make the following changes in subsections (listed below) of the "generic issues" section of Chapter 3:

    i. Subsection "Defining a monetary value of human losses and injuries":

        - Different approaches (HC, WTP/WTA, VOLY, VSL, etc.) should be discussed.
        - One approach should be used in the practical evaluation (e.g. WTP, VOLY) and the impact of the choice of other approaches should be assessed.

    ii. Subsection "Compensations and economics transfers";

iii. Subsection "Uncertainty in physical and economic estimates":

- Discussion of different types of uncertainties: some are known and can be quantified and some are unknown and should be discussed qualitatively/using postulated scenarios.
- Results should be presented as an interval (representing the quantifiable uncertainty) with estimate(s) of the average.

iv. Subsection "The long lifetime of impacts and the choice of the appropriate discount rate":

- The role of discounting and the potential impact on the results should be discussed.
- For the modelling purposes, 3% real discount rate will be used for all categories of losses.

v. Subsection "Risk aversion":

- The risk aversion will be discussed, but not monetised. The final results in Chapter 4 will be presented as consequences, probabilities, and expected loss (i.e. the reader will have the opportunity to use their own risk aversion factor).

vi. Subsection "Is it possible to have a single-figure estimate of losses due to nuclear accident?":

- The estimates of losses will be presented separately, and categories will not be aggregated in one figure.
- A discussion on cost-benefit analysis (in which aggregation may be required) will be added.

vii. Following the suggestion by Ludivine Pascucci, a subsection with generic discussion on environmental losses will be added.

Day II

30. Stefan Hirschberg summarised Day I, noting that good progress was made and the group reached a consensus in many areas.

31. Ximena Vásquez-Maignan (OECD/NEA) presented the draft material for Chapter 5 of the study in which a review of existing third party liability regimes will be provided, together with a discussion on insurance and alternative forms of financial securities, and historical nuclear accidents from a legal viewpoint.

32. Ralph Andersen raised a question regarding the nature of the international initiatives supporting a global third party nuclear liability regime. He specifically wanted to know how these initiatives could be related with the current study.

33. Ximena Vásquez-Maignan explained that the first initiative was taken under the auspices of the IAEA, which encouraged its member countries to adhere to one of the existing conventions. In addition, there have been some bilateral initiatives taken, such as the declaration by the US and France inviting States to adhere to one of the revised liability convention (she commented that there are still some countries party to the old Vienna regime), and a similar French-Russian declaration. Regarding the position of the NEA, the matter was discussed at the last Steering Committee meeting, which encouraged, as a

first critical step, to adhere to one of the enhanced nuclear liability regimes and to adopt consistent legislation if they have not already done so.

34. Ximena Vásquez-Maignan underlined that a global nuclear liability regime is beneficial for all the stakeholders i.e. victims, operators as well as suppliers. From the suppliers' perspective, such a regime would increase nuclear trade since there would be a greater legal certainty provided by the liability principles, such as the principle of exclusive liability of the operator.

35. From the perspective of victims, there would be a clear legal procedure if all States have similar nuclear liability regimes. For example, if nationals of a non-nuclear State suffer injury from a nuclear accident, in the absence of any specific nuclear liability law or convention regime (such as in Austria), they will seek a remedy under their national tort law; additionally, the competent court may be the national courts of the State where damage was suffered. In such a case, the victim may face difficulties in enforcing a court decision that would be favourable to him/her. It is clear that such a situation could be significantly challenging for all the stakeholders. She underlined that the revised Paris Convention expanded its geographical scope to provide remedies for victims located within non-nuclear States as well.

36. Roh Hathlia commented that the present study is covering on-site and off-site costs as well as immediate, medium and long-term costs of a nuclear accident. However, the nuclear liability regimes only cover off-site costs. He shared his concern that due to the nature of nuclear liability regimes there would be possible gaps in the structure of this report. According to him, even though some of the off-site costs could be raised up to billions of dollars there has not been discussion regarding how to fully address the off-site costs.

    Additionally, he underlined that disproportionate time and efforts have been devoted to the topic of compensation under third party nuclear liability regimes, because this issue in fact only deals with certain elements of a wider range of cost categories related to a nuclear accident. According to him, many members of the NEA Nuclear Law Committee also share similar concerns and these should be taken into account during the development of the report.

37. Lastly, he proposed that Chapter 5 should not be located after Chapters 3 and 4 because their numbers in relation with the costs of a nuclear accident appear at odds. In comparison, the liability amounts in Chapter 5 would seem inadequate and it could raise additional challenges. In order to avoid it, he proposed to narrow down the content of Chapter 5 into a brief analysis of the current liability system. In addition, it would clarify the fact that nuclear liability costs are a small sub-set of nuclear accident costs.

38. William D'Haeseleer asked whether "unlimited liability" was taken as a legal term or not. He also wondered if there would be a possibility to claim compensation from a parent company of a nuclear installation operator for the excess damage. According to Ximena Vásquez-Maignan, under the principle of the "corporate veil", a parent company cannot be held liable for the legal consequences of the acts of its subsidiaries unless there is proof that the parent company was in fact directly managing the business of the subsidiary, such that the subsidiary was not in fact an independent, separate company. Piercing the corporate veil is possible under very rare circumstances and strict legal requirements. However, she commented that few States, such as Sweden, provided under their national legal systems the possibility for a parent company to be held liable for its subsidiary.

    William D'Haeseleer also asked if there would be any legal difference if the operator is State owned and whether the State could be held accountable in case of an accident.

39. Ximena Vásquez-Maignan explained that this is entirely up to the legal system of a state. In principle, liability of a State-owned company acting as a private entity, such as EDF in France, cannot be attributed to the State.

40. When discussing the legal aspects of the Fukushima Daiichi accident, the difficulty in distinguishing the damage due to the nuclear accident from that resulting from the tsunami or earthquake was addressed. Ximena Vásquez-Maignan explained the approach undertaken to make the distinction and added that according to the last guidelines issued in December 2013, TEPCO was obliged to indemnify the loss of properties of the evacuated persons who were living within the parameters of the restricted zones, when the properties were damaged by the tsunami or earthquake, because they could not return to take the necessary actions to mitigate or repair the consequences of the natural events. The compensation was based on a percentage of the value of the properties.

41. Stefan Hirschberg considered that the State intervention and third party liability compensation beyond the conventional regimes (i.e. for non-nuclear damage) are not generally considered as internalised costs, since they are subject to the occurrence of an accident which is why they are not pre-determined factors. Referring to alternative financial security possibilities to guarantee liability amount, he wanted to know whether there is an ongoing discussion to create a new financial mechanism for this purpose.

42. Ximena Vásquez-Maignan answered that according to her knowledge there is no available alternative scheme other than those mentioned in her presentation (i.e. insurance, mutual, operators' pooling systems and corporate alternatives, such as captive insurance companies).

43. Following a brief discussion regarding internalisation and externalisation of costs, Ron Cameron referring to the earlier comments of Roh Hathlia in the matter of restructuring the content and repositioning of Chapter 5, suggested that nuclear liability regimes be described in an annex of the Report. He proposed that Chapter 5 only covers information about the range and types of risks and includes a description of the regimes applicable to other hazardous industries as well. Lastly, he proposed that the role and implementation of nuclear liability regimes in case of a nuclear accident should only be briefly and factually covered within Chapter 5.

44. Alexey Lokhov presented draft Chapter 4 of the study in which examples of practical applications of the methodology of estimating losses associated with nuclear accidents (presented in Chapter 3) will be provided.

    In Chapter 4, the methodology is applied as a high-level estimate to three hypothetical nuclear accidents in two different OECD countries[1]. The purposes of this work are:

    i. To clarify the different steps involved in the estimation of the economic consequences of a nuclear accident and to illustrate with practical examples the methodology presented in Chapter 3.

    ii. Show the uncertainties involved in the estimates of physical and economic impacts of a postulated nuclear accident as well as the importance of local circumstances (geographical location, weather condition, season, timing of the releases, etc.) on different categories of cost.

1. France (IRSN) and UK (PHE) have agreed to perform scenario calculations to be included in Chapter 4.

iii. Attempt to identify the key cost drivers in the case of a nuclear accident, and the possible actions and measures to mitigate it.

Regarding the choice of appropriate source terms and pattern of releases, it was stressed that they must be presented with estimates of probabilities, and be based on detailed calculations of accidental sequences.

It was suggested to take the following source terms corresponding to:

- A scenario with bypass of containment → "Severe accident with significant off-site releases".
- A scenario containment failure →"Severe accident with limited off-site releases".
- A scenario with controlled and delayed releases (e.g. through filters, etc.) → "Severe accident with controlled and filtered releases".

There are publically available detailed source terms. The preferred choice of the Secretariat is the report by the US NRC *State-of-the-Art Reactor Consequence Analyses (SOARCA) Project Volume 2: Surry Integrated Analysis Office of Nuclear Regulatory Research*, NUREG/CR-7110, Vol. 2, Rev. 1, August 2013. The scenarios "Unmitigated ISLOCA" and "Unmitigated LTSBO" from that report are suitable for the needs of the study.

The summary of scenarios and releases proposed to the study, and their comparison to generic source terms S1, S2 and S3 is provided in the table below:

Scenario	Integral release fractions by chemical class									Release time	
	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La	*start*	*end*
Severe accident with significant off-site releases	98.27%	1.97%	0.01%	15.40%	13.14%	0.02%	0.28%	0.00012%	0.00002%	12.8 h	48 h
Severe accident with limited off-site releases	80%	0.08%	0.08%	0.6%	2.30%	0.0015%	0.01%	0.002%	0.0001%	45.3 h	72 h
Severe accident with controlled and filtered releases[2]	~100%	~0.001%	~0.001%	~0.15%	~0.001%	less 10^{-4}%	~0.001%	less 10^{-4}%		>24 h	
Generic S1	80%	40%		60.7%	8%	2%			0.3%	Few hours	
Generic S2	75%	5.5%		3.25%	5..5%	0.5%			0.08%	>1 day after	
Generic S3	75%	0.35%		0.9%	0.35%	0.03%			0.005%	Delayed release	

One can see that the "Severe accident with significant off-site realises" scenario is close to S2 with much more iodine (five times more) and less caesium (~2 times).

The scenario "Severe accident with limited off-site realises" is close to S3 with four times less caesium.

The US NRC representatives contacted the NEA and expressed concerns about the use of source terms from the Surry NPP in other situations (even of similar design) because source terms are site- and plant-specific.

[2] See discussion below in the presentation by Michel Ciais.

Thus, the NEA Secretariat proposes to "anonymise" the source terms from the above report, and remove all mention of Surry and the US NRC.

45. Michel Ciais (France) presented the source term of the third scenario "Severe accident with controlled and filtered releases", produced by EDF for a large LOCA with filtered releases, in which:

- The core begins to melt one hour later (all emergency systems fail);
- Containment pressure increases up to 5 bars;
- The containment is vented (24 hours or later after the beginning of the accident);
- The vent is a filtered vent (sand filter) with an filtering efficiency of:
    - 1/1000 on aerosols;
    - 1/10 on molecular iodine.
- The activity released to the environment in mass fraction of core inventory is estimated to be of the following orders of magnitude:
    - Noble gases: ~ 1 (100%);
    - Iodine: ~ 1.5 10^{-3} (0.15%);
    - Aerosols (Cs, Sr, Rb, Ag, Cd, Br, Mo, Sb, Te): some 10^{-5} (some 0.001%);
    - Other aerosols: less than some 10^{-6} (some 0.0001%).

The radiological consequences of such releases are expected to be the following:

- In the short term (7 days) : evacuation in a 5-km radius and Iodine prophylaxis in a 10-km radius;
- In the medium to long term :
    - Temporary relocation may be necessary up to a 2-km radius within the first year;
    - Food commercialisation and consumption ban in a few tens of km with a rapid decrease due to iodine disappearance: only 30 km after one month.

The economic losses are expected to be the following:

- Health costs: no short- or long-term effects, health monitoring for 10-20 thousand people;
- Countermeasures costs:
    - Evacuation: about 10 000 persons for 7 days, 2 000 persons for 1 year;
    - Food restrictions: Food ban on a 30-km radius for 1 year.
- Decontamination costs: small area to be decontaminated since 99.9% of Caesium releases are filtered;
- The impact on the economy is expected to be under the liability regime provisions and on a par with the amounts available under the revised Paris and Brussels conventions;
- Costs on-site potentially covered by the insurance of the nuclear operator (decontamination, dismantling, loss of assets):

- The order of magnitude of decontamination costs is similar to TMI costs for decontamination;
- Loss of the plant and temporary loss of production for the two-unit plant.

46. Marie-Anne Plagnet added that such a scenario is considered a maximum realistic scenario by the operators in Europe (and presented in the position paper by ENEF).

    Stefan Hirschberg indicated that the third scenario presented above is worth including into the study. However, it should not be presented as the "maximum realistic scenario" in terms of releases, as done in the ENEF position paper, because it depends on the cut-off on probabilities.

47. Alysia Bone further clarified the position of the US NRC with respect to the use of source terms inspired from the SOARCA report for Surry NPP in the United States.

    In particular, she indicated that including economic estimates in the report is problematic in that it removes attention from the methodological part (Chapter 3) and attracts attention to numbers in Chapter 4. Thus, the readers could miss the key element of the study which is the internationally agreed methodology of loss assessment. The NRC is also concerned that the detailed quantitative results could be misinterpreted and misused.

48. Stefan Hirschberg recalled that one of the strong points behind the source terms from SOARCA is the probabilistic calculations (PSA level 2) that allow putting these releases in a risk perspective. Using generic source terms (without probabilities) would lead to misuses and misinterpretations. He also confirmed that the case studies are intended to illustrate the methodology and show the sensitivity of the results to different conditions and assumptions.

49. Ron Cameron indicated that the present study was commissioned by the NEA Nuclear Development Committee (NDC), and that the scope (approved by the NDC) included providing examples of quantification of losses. Also, a bare methodology without examples of application would be unsatisfactory. In addition, there are benefits in testing the methodology since it provides feedback and allows improving it by refining the definitions.

50. Roh Hathlia suggested putting the scenario analysis in the annex. On this issue, William D'Haeseleer indicated that OECD/NEA has already experienced (with success) scenario analysis on politically sensitive issues, for example in the recently published study "*Economics of the back-end of the nuclear fuel cycle*". William suggested using figures from the SOARCA study (with some rounding) without an explicit reference to the study. Stefan Hirschberg suggested that a range of probabilities for sequences considered could be derived from the literature.

51. Anssi Paalanen raised the issue of selecting scenarios, in particular of considering scenarios with very low probability (e.g. 10^{-8} events/year) and severe consequences, like for the sequence with containment bypass. He expressed the concern that the general public does not fully understand the low probability and thus the attention would be drawn on highly unlikely and very costly scenarios: he suggested choosing scenarios that have higher probability of occurrence.

52. Stefan Hirschberg noted that the selection of accidental scenarios took into account this concern and the group did not select the accident with maximum possible consequences.

53. It was agreed to continue discussions with the US NRC on the source term issue.

54. After the general discussion of the structure and approach of Chapter 4, Neil Higgins and Ludivine Pascucci presented preliminary results of modelling of the scenario "Severe accident with significant off-site releases" (inspired from the ISLOCA sequence from the SOARCA report).

    It should be noted that these results were produced using the internal methodologies of PHE and IRSN, and **not the NEA methodology** being developed within the framework of the present study (discussed above and provided in draft Chapter 3).

55. Neil Higgins presented the preliminary modelling results for the scenario "Severe accident with significant off-site releases" for a generic PWR in a representative location in England (east coast).

    The release pattern (based on the NRC assessment of a ISLOCA release at the Surry NPP, the consequences of an emergency period of ~48 hours from the initial alarm) was repeated 950 times sampling 5 years of meteorological data to create the PSA results.

    The preliminary losses (quartile values) results were described (for two weather models used: ADEPT and NAME).

    Discussion of the current assumptions of the modelling:

    - The modelling did not consider on-site losses or the direct/indirect loss of GVA from the closure of the power station.
    - Relocation is triggered for annual doses of 50 mSv or above. Lower thresholds are being calculated and the consequences of a phased response considered. The worst of the range of accidents modelled will then incur larger business losses and population displacement than currently triggered.
    - Transport costs have not been considered or the practicality of moving large numbers of people in a short time.
    - Iodine distribution limited to 240 km from site.
    - No animals are culled and food disposal costs have not been considered.
    - Two decontamination options are applied in built-up areas depending on housing density and effectiveness.
    - Capital losses of business buildings, plant and transport machinery included.
    - Accommodation costs included, including capital losses.
    - Losses from the tourism sector to the national economy are only assessed on the basis of supply limitations – the direct restrictions placed on tourist based industries.
    - The main gap in the analysis: the current modelling only considers supply limitations in the tourism sector when demand is likely to have the largest effect. It is difficult to estimate the fall in demand from freely transferable discretionary spending. Considering historical events as a guide to future behaviours is fraught with difficulty as many factors may conspire to alter the expected number of tourist arrivals.

56. Some questions were raised on the modelling of agricultural losses and food bans, on decontamination measures and relocation.

57. Neil Higgins responded that the food ban was modelled by excluding the products from the supply chain (using limits from EU regulations) and that decontamination costs have been taken into account.

Regarding relocation, modelling results indicate that the areas contaminated are generally sparsely populated and that the majority of restrictions will only be required for comparatively short time periods.

With respect to the global impacts on the economy, the current modelling is applicable to the whole of the UK with the economy recovering quickly by moving production to non-contaminated regions.

Neil Higgins added that the health effects are estimated using the WTP approach and take into account both morbidity and fatalities. However, no costs of health monitoring are quantified.

58. Ludivine Pascucci presented the preliminary modelling results for the scenario "Severe accident with significant off-site releases", for a typical PWR NPP located in-land in France.

    An ISLOCA-type release in France would typically feature thousands km² of contaminated territories, hundreds km² of exclusion zones, and thousands of refugees.

    In the median case (variability takes into account only the weather conditions) it would cost about EUR 350 billion.

    This figure is below the IRSN estimate for the "major accident" (different source term) for which the estimate was EUR 450 billion. However, the estimate is consistent with historic costs of nuclear accidents (Chernobyl, Fukushima Daiichi).

59. The discussion that followed concentrated on the uncertainty issues. Indeed, the difference between "favourable" and "unfavourable" cases only takes into account the variability of the weather conditions.

60. Several participants expressed concerns that the largest contribution (more than 75% in the median case) to the total cost was attributed to "soft" costs (e.g. image costs) for which the uncertainty is large, but not taken into account. These costs are evaluated using postulated scenarios.

61. Michel Ciais and Alena Nikalaenka asked what criteria were used in the modelling for food bans. Ludivine Pascucci responded that for this modelling a value of 100 Bq/kg was used.

62. The Expert Group discussed the title of the final publication. The title "**Estimation of potential losses due to nuclear accidents**" was agreed.

63. The next meeting of the Expert Group is scheduled to 11-12 December 2014 at the NEA headquarters in Issy-les-Moulineaux.

Annex 1. Agenda of the Third Meeting of the Ad Hoc Expert Group on "Cost of Nuclear Accidents, Liability Issues and their Impact on Electricity Costs"

DAY I
Welcome and introductory remarks
Self-introduction of experts *(all)*
Adoption of the agenda *(all)*
Current status of the study *(Alexey Lokhov,* NEA*)*
Presentation of draft Chapter 2 "Severe accidents in the history of civil nuclear power" (*Marco Cometto*, NEA)
"Economic losses related to the Chernobyl disaster in Belarus", (*Elena Nikolaenko*, NEA consultant)
Discussion of draft Chapter 2 "Severe accidents in the history of civil nuclear power"
Presentation and discussion of the IRSN methodology (*Ludivine Pascucci*, IRSN)
Presentation of draft Chapter 3 "Approaches to estimation of potential losses due to nuclear accidents" (*Marco Cometto and Alexey Lokhov*, NEA)
Discussion of draft Chapter 3
Remarks from the Co-chairs
DAY II
Summary of day I *(Co-chairs)*
Presentation and discussion of draft Chapter 5 "Question of funding nuclear liability" (*Ximena Vasquez*, NEA)
Presentation and discussion of scenarios for Chapter 4 (*Secretariat*)
Presentation of scenario "Severe accident with controlled and filtered releases" (Michel Ciais, EDF)
Preliminary modelling results (*Neil Higgins,* PHE)
Preliminary modelling results (*Ludivine Pascucci*, IRSN)
Discussion of the preliminary modelling results
Discussion of the title of the final publication
Any other business

Annex 2. List of participants

Belgium

William D'HAESELEER
Director
University of Leuven Energy Institute
KU Leuven
Celestijnenlaan 300
B-3001 Leuven (Heverlee)
Tel: +32 (0)16-32 25 11
Fax: +32 (0)16-32 29 85
William.Dhaeseleer@mech.kuleuven.be

Hans MAERTENS
Expert Risk Manager Structured Products
Belgian Debt Agency
Kunstlaan, 30
BE-1040 Brussels
Tel: +32 2 574 71 97
hans.maertens@minfin.fed.be

Finland

Anssi PAALANEN
Fortum, Nuclear Safety Assurance
POB 100, FI-00048 FORTUM
Keilaniementie 1, Espoo
Tel: +358 400 597866
anssi.paalanen@fortum.com

France

Michel CIAIS
Direction de la Stratégie et de la Prospective
Électricité de France (EDF)
43 rue Kleber
92300 Levallois-Perret
Tel: +33 1 82 24 86 19
michel.ciais@edf.fr

Ludivine PASCUCCI
Institut de radioprotection et de sûreté nucléaire (IRSN)
31 av Division Leclerc
92260 Fontenay-aux-Roses
Tel: +33 158 35 92 48
Ludivine.Pascucci-Cahen@irsn.fr

Marie-Anne PLAGNET
Industrial Production Division
Électricité de France (EDF)
1 Avenue du General de Gaulle
92141 Clamart Cedex
marie-anne.plagnet@edf.fr

Korea, Republic of

SunKab PARK
Manager
Nuclear Policy Team
Technology Policy & Planning Department
KHNP (Korea Hydro and Nuclear Power Co., LTD.)
Tel: +82 2 3456 2355
Fax: +82 2 3456 2359
sk1994@khnp.co.kr

Seung-Su KIM
Principal Researcher
Nuclear Policy Research Department
Management and Economic Analysis Team
Korea Atomic Energy Research Institute (KAERI)
1045 Daedeokdaero, YuseongGu
Daejeon 305-353

Tel : +82 42 868 2721
Fax : +82 42 861 7521
sskim5@kaeri.re.kr

Switzerland

Stefan HIRSCHBERG (Co-chair)
Head
Laboratory for Energy Systems Analysis
The Energy Departments
Paul Scherrer Institute
CH-5232 Villigen, Switzerland

Tel: +41 56 310 29 56
stefan.hirschberg@psi.ch

United Kingdom

Roh HATHLIA
Assistant Director
Office for Nuclear Development
Department of Energy and Climate Change
55 Whitehall
London SW1A 2EY

Tel: +44 (0) 300 068 5901
roh.hathlia@decc.gsi.gov.uk

Neil HIGGINS (Co-chair)
Public Health England (PHE)
Centre for Radiation, Chemical and Environmental Hazards
Chilton, Didcot
Oxon, 0X11 0RQ

Neil.Higgins@phe.gov.uk

United States

Ralph ANDERSEN
Senior Director
Radiation Safety & Environmental Protection
Nuclear Energy Institute (NEI)
1201 F Street, NW, Suite 1100
20004 Washington DC, United States

Tel: +1 202 739 8111
Fax: +1 202 533 0101
rla@nei.org

Alysia G. BONE
Rulemaking Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission

Alysia.Bone@nrc.gov
Tel: +1 301 415 1034

International Atomic Energy Agency (IAEA)

Loreta STANKEVICIUTE
Energy Economist
Planning and Economic Studies Section (PESS)
Department of Nuclear Energy (NE)
International Atomic Energy Agency (IAEA)
Tel: +43 (1) 2600-22777
l.stankeviciute@iaea.org

OECD Nuclear Energy Agency (NEA)

Ron CAMERON
Head of Nuclear Development Division
Tel: +33 (0) 1 45 24 10 60
Ron.CAMERON@oecd.org

Marco COMETTO
Nuclear Energy Analyst
Nuclear Development Division
Tel: +33 (0) 1 45 24 11 38
Marco.COMETTO@oecd.org

Jan Horst KEPPLER
Senior Adviser
Nuclear Development
Tel: +33 (0) 1 45 24 10 65
Jan.KEPPLER@oecd.org

Alexey LOKHOV
Nuclear Energy Analyst
Nuclear Development Division
Tel: +33 (0) 1 45 24 10 62
Alexey.LOKHOV@oecd.org

Geoffrey ROTHWELL
Principal Economist
Nuclear Development Division
Tel: +33 (0) 1 45 24 10 69
geoffrey.ROTHWELL@oecd.org

Ximena VÁSQUEZ-MAIGNAN
Senior Legal Advisor
Nuclear Law Division
Tel: +33 (0) 1 45 24 10 32
Ximena.VASQUEZ@oecd.org

Consultant

Alena NIKALAYENKA
Scientific Practical Centre of Hygiene
220012, Akademicheskaya str. 8,
Minsk, Republic of Belarus
Tel : +375 29 311 51 40
nikolaenko67@gmail.com