OECD Nuclear Energy Agency
International Atomic Energy Agency

ISOE

European Technical Centre

General Distribution
March 2018

ISOE INFORMATION SHEET

SURVEY ON THE VALUES AND USES OF THE MONETARY VALUE OF THE MAN.SIEVERT (IN 2017)

ISOE European Technical Centre - Information Sheet No. 61

In order to balance the costs associated with radiation protection options and their benefits in terms of exposure reduction the International Commission on Radiation Protection (ICRP) has suggested the use of cost-benefit or cost-effectiveness analysis in which the options benefits (or effectiveness) are given a monetary value, according to a monetary reference value of the avoided unit of exposure: *the monetary value of the man.Sievert*, often referred as the "alpha value".

Since the introduction of the concept in 1973, several surveys have been conducted through the ISOE network in order to collect the different alpha values used by regulatory bodies and nuclear utilities and plants, and also to gain information about its statute, role and uses.

The ISOE European Technical Centre (ETC) conducted a first survey in 1997-1998[1]. This survey has been updated in 2002[2] and later in 2009[3].

Almost 10 years since the last update, it appeared advisable to conduct a new survey.

[1] *ISOE ETC Information Sheet 18 – The Use of the Man-Sievert Monetary Value in 1997, 1998.*
[2] *ISOE ETC Information Sheet 34 – Man-Sievert Monetary Value Survey, 2002 Update, 2003.*
[3] *ISOE ETC Information Sheet 55 – Man-Sievert Monetary Value Survey, 2012 Update, 2012.*

1. Methodology

The survey has been conducted from May to July 2017 using questionnaires sent by email to selected ISOE contact persons. One questionnaire was designed for nuclear regulatory authorities and one for nuclear utilities.

Answers have been received from 21 countries (see Table 1 below)[4]. In 10 countries, only the nuclear regulatory authority has provided an answer. In 3 countries, only the nuclear utility/utilities or nuclear power plant (NPP) have provided an answer. Answers from both the nuclear regulatory authority and nuclear utility or NPP have been received from 8 countries.

Table 1. Answers received to the ISOE survey in 2017.

Country	Answers received from	
	Nuclear regulatory authority	Nuclear utility or Nuclear Power Plant (NPP)
Belarus	**X**	
Belgium	**X**	**X** (Electrabel, 7 NPPs)
Canada	**X**	
China	**X**	
Czech Republic	**X**	
Finland	**X**	**X** (Loviisa NPP)
France	**X**	**X** (Electricité de France, 58 NPPs)
Germany	**X**	
Japan	**X**	**X** (from 10 utilities [A])
Lithuania	**X**	
The Netherlands	**X**	
Republic of Korea		**X** (Korea Hydro & Nuclear Power, 25 NPPs)
Romania		**X** (Cernavoda NPP)
Slovakia	**X**	
Slovenia	**X**	**X** (Krško NPP)
Spain	**X**	**X** (Cofrentes NPP)
Sweden	**X**	**X** (Forsmark NPP; Ringhals NPP)
Switzerland	**X**	**X** (Leibstadt NPP)
Ukraine	**X**	
United Kingdom	**X**	
United States of America		**X** (from 70 NPP [B]; Exelon [15 NPPs]; Palo Verde NPP; Cook NPP)

[A] Chubu Electric Power Co., Chugoku Electric Power Co., Hokkaido Electric Power Co., Hokuriku Electric Power Co., Japan Atomic Power Co., Kansai Electric Power Co., Kyushu Electric Power Co., Shikoku Electric Power Co., Tokyo Electric Power Co. and Tohoku Electric Power Co. (representing 58 reactors, including 15 under decommissioning). Collected by the ISOE Asian Technical Centre.
[B] Set of data for 2015, provided by the ISOE North American Technical Centre.

The number of answers received directly from nuclear utilities or NPP reaches 12 but other data from the utilities of Japan have been collected by the ISOE Asian Centre, and a set of data has also been received from the ISOE North America Centre. In total, the survey represents the views of around 220 reactors in the world (around 50 %).

The data have been clarified (if necessary) and completed by additional emails exchange with the ISOE contact person.

[4] The detailed answers are available on the ISOE website (www.isoe-network.net) for ISOE Members only, under Activities > ISOE Working Groups > WGDA

2. The monetary value of the man.Sievert among nuclear regulatory authorities

2.1 Existence of a monetary value of the man.Sievert among nuclear regulatory authorities

In most cases (15 over 18), the nuclear regulatory authorities have reported that they are not using nor recommending a monetary value of the man.Sievert. The reasons reported by the regulatory authorities are listed below by order of frequency:

- The utility of the country has already introduced an alpha value in their organisation, so it is not necessary, nor useful for the regulatory authority to explore the subject. Some nuclear regulatory authorities have knowledge of the alpha values used by the utilities of the country and provided reference to these values.
- The determination and the use of the alpha value fall under the responsibility of the utility, who is in charge of the optimisation of the exposures of its employees.
- The process to establish an alpha value may be complex and questionable.
- The utilities generally spend more resources than the strict application of the alpha value will recommend.

Three nuclear regulatory authorities have reported recommendations about the use an alpha value:

- The British Office for Nuclear Regulation (ONR) recommends to use the framework lay down by the Health and Safety Executive (HSE) regarding the application of cost-benefit methodology to reduce occupational risks "ALARP" [5]. The monetary value recommended by HSE to prevent the occurrence of a cancer is 2.67 million £, hence around 3 million €. HSE introduced this monetary value in 2003, as well as an updating methodology based on the annual growth of the Gross Domestic Product (GDP) per capita. The ONR does not explicitly recommend to use a monetary value of the man.Sievert but precise that, if using one, it should be derived from the HSE value by using actual ICRP risk coefficients.
- The Slovak Public Health Authority (UVZSR) and the Czech State Office for Nuclear Safety (SÚJB) both reported a set of man.Sievert monetary values, varying with the level of average individual exposure and with the exposure situation (Table 2). The two systems are quite comparable and seem designed to cover as many exposure situations as possible, including public exposure. Although the categories and the numerical values are not fully identical.

Table 2. Set of alpha values set up by the Slovak Public Health Authority and the Czech State Office for Nuclear Safety.

Slovak Public Health Authority (UVZSR) set of alpha values	Czech State Office for Nuclear Safety (SÚJB) set of alpha values
– Exposure < 1/10th of annual dose limit: α = 33 €/man.mSv;	– Exposure < 1/10th of annual dose limit: α = 19 €/man.mSv;
– Exposure between [1/10th - 3/10th] of annual dose limit: α = 50 €/man.mSv;	– Exposure between [1/10th - 3/10th] of annual dose limit: α = 38 €/man.mSv;
– Exposure > 3/10th of annual dose limit: α = 200 €/man.mSv;	– Exposure > 3/10th of annual dose limit: α = 95 €/man.mSv;
– Occupational exposure between [20-50] mSv/year: α = 660 €/man.mSv;	– Occupational exposure in case of emergency: α = 95 €/man.mSv;
– Occupational exposure in case of emergency: α = 150 €/man.mSv;	– Exposure from natural source of radiation: *Not addressed*
– For medical treatment: α = 40 €/man.mSv.	– For medical treatment: α = 38 €/man.mSv
– Exposure from natural source of radiation: *Not addressed*	– Exposure from natural source of radiation: α = 19 €/man.mSv

[5] ALARP: As Low As Reasonably Practicable is the equivalent of ALARA in United Kingdom. This principle applies to all occupational risks, and in particular those from exposure to ionizing radiations. The cost-benefit analysis is presented on the HSE website: http://www.hse.gov.uk/risk/theory/alarpcheck.htm

But these are the only examples of values reported by nuclear regulatory authorities gathered by the ISOE's 2017 survey. Former surveys have gathered more values and some authorities that were recommending the use of alpha value in the past, do not recommend it anymore (ex. Canada).

2.2 Uses of the monetary values of the man.Sievert by nuclear regulatory authorities

The value reported by the ONR is not regulatory binding but rather a recommendation. Besides, this alpha value is linked with a generic cost associated to a cancer, so it is not specific to nuclear sector. It should be noted that in the last ONR publication for safety assessment of nuclear installation[6], the ONR states that cost-benefit analysis can be used in the demonstration of ALARP (and in this case, HSE recommendations with regard to the methodology should be followed) but cannot be "*the whole argument in the decision*".

The values reported by SÚJB (and potentially UVZSR) are inserted in the national legislative framework[7], so the value is a regulatory data that the nuclear utility shall take into account[8]. The two regulatory authorities have experience in the use of the alpha values and provided examples: optimisation analysis (calculation for shielding material), in "*some activities with natural sources*" or to enlighten and evaluate a decision taken by the nuclear utility (the example was the decontamination of system). The two regulatory authorities insist that the alpha value is not the only criterion that is taken into account in their decision: the optimisation process cannot by only carried out by the means of quantitative methods and qualitative factors shall also be considered ("*previous experience in similar exposure situation*" is mentioned two times).

[6] ONR Safety Assessment Principles for Nuclear Facilities 2014 Edition (http://www.onr.org.uk/saps/saps2014.pdf), see § 15 *and seq*.

[7] For Czech Republic, the regulatory text is Decree 422/2016, section 7, § 6.
https://www.sujb.cz/fileadmin/sujb/docs/legislativa/vyhlasky/422_Radiation_safety_fin.pdf (18 Mb)

[8] It is not mandatory to perform cost-benefit analysis for all optimisation study, but if doing so, the values lay down in regulation are to be used (Decree 422/2016, section 7, § 8).

3. The monetary value of the man.Sievert among nuclear utilities and nuclear power plants

3.1 Existence of a monetary value of the man.Sievert among nuclear utilities and nuclear power plants

The monetary values of the man.Sievert reported by nuclear utilities or NPP are presented in Table 3, Figure 1 and Figure 2 for United States of America. For the sake of comparison, the monetary values in local currency or unit have been converted in €/man.mSv; using the July 2017 exchange rate[9].

Table 3. Monetary values of the man.Sievert reported by nuclear utilities and nuclear power plants in 2017.

Country	Utility or NPP	Alpha values (using local units)	Alpha values (in €/man.mSv)
Belgium	Engie - Electrabel	*No*	
Finland	Loviisa NPP	*No*	
France	EDF	**System of values** based on the individual annual exposure of the workers concerned by the investment: - [1-10] mSv/y: 650 €/man.mSv - [10-16] mSv/y: 1,300 €/man.mSv - [16-20] mSv/y: 1,800 €/man.mSv (up-dated in 2002).	*idem*
Japan	Chubu Electric Power Co.	*No*	
	Chugoku Electric Power Co.	*No*	
	Hokkaido Electric Power Co.	*No*	
	Hokuriku Electric Power Co.	*No*	
	Japan Atomic Power Co.	*No*	
	Kansai Electric Power Co.	*No*	
	Kyushu Electric Power Co.	*No*	
	Shikoku Electric Power Co.	*No*	
	Tokyo Electric Power Co.	**System of values** based on the individual exposure of the workers for the task under consideration: (used since 2015) - ≤ 1 mSv: 50,000 $/man.Sv - [1-5] mSv: 500,000 $/man.Sv - [5-10] mSv: 1,000,000 $/man.Sv - [10-20] mSv: 5,000,000 $/man.Sv - > 20 mSv: 10,000,000 $/man.Sv	System of values based on the individual exposure of the workers for the task under consideration: (used since 2015) - ≤ 1 mSv: 44.5 €/man.mSv - [1-5] mSv: 445 €/man.mSv - [5-10] mSv: 890 €/man.mSv - [10-20] mSv: 4,450 €/man.mSv - > 20 mSv: 8,900 €/man.mSv
	Tohoku Electric Power Co.	*No*	
Republic of Korea	KHNP	*No*	-
Romania	Cernavoda NPP	**Single value**: 570 €/man.mSv (up-dated in 2010).	*idem*
Slovenia	Krško NPP	**System of values** based on the collective exposure of the population concerned by the task: - < 50 man.mSv: 1,000 €/man.mSv - > 50 man.mSv: 2,600 €/man.mSv (2013 values).	*idem*
Spain	Cofrentes NPP	**Single value**: 5,000 €/man.mSv (up-dated in 2012)	*idem*
Sweden	Forsmark NPP	**Single value**: 10,000,000 SEK/man.Sv (2007 value).	Single value: 1,100 €/man.mSv
	Ringhals NPP	**Single value**: 11,300,000 SEK/man.Sv (2015 value).	Single value: 1,203 €/man.mSv

[9] Conversion were the following: 1 € = 1.12 US $ = 9.75 Swedish SEK = 1.087 Swiss CHF.

Country	Utility or NPP	Alpha values (using local units)	Alpha values (in €/man.mSv)
Switzerland	Leibstadt NPP	**System of values** based on the individual annual exposure of the workers concerned by the investment: - [1-10] mSv: single value equal to 300 CHF/man.mSv - [10-20] mSv: alpha value is increasing linearly up to 3 000 CHF/man.mSv (at 20 mSv).	**System of value**s based on the individual annual exposure of the workers concerned by the investment: - [1-10] mSv: single value equal to 273 €/man.mSv - [10-20] mSv: alpha value is increasing linearly up to 2,730 €/man.mSv (at 20 mSv).
United States of America	From 70 NPP	**Single value** from 5,000 $/person.rem to 40,000 $/person.rem depending on the plant	**Single value** from 446 €/man.mSv to 3,570 €/man.mSv depending on the plant
	Cook NPP	**Single value:** 32,632 $/ person.rem	**Single value:** 2,014 € /man.mSv
	Exelon	**Single value for the plant**[10], based on the INPO ranking, which depend on the plant collective dose[11]: - 1st quartile: 20,000 $/ person.rem - 2nd quartile: 40,000 $/ person.rem - 3rd quartile: 60,000 $/ person.rem - 4th quartile: 80,000 $/ person.rem	**Single value** for the plant, based on the INPO ranking, which depend on the plant collective dose[9]: - 1st quartile: 1,780 €/man.mSv - 2nd quartile: 3,560 €/man.mSv - 3rd quartile: 5,340 €/man.mSv - 4th quartile: 7,120 €/man.mSv
	Palo Verde NPP	**Single value**: 33,000 $/ person.rem (updated end 2011)	**Single value**: 2,739 €/man.mSv (updated end 2011)

3.2 Observations with regard to the monetary value of the man.Sievert among nuclear utilities and nuclear power plants

The analysis of the answers leads to the following observations:

- Most of the nuclear utilities and NPP who answered the survey have introduced and are using a man.Sievert monetary value (or a set of values). However, nuclear utilities in Belgium, Republic of Korea, Finland and the majority of Japanese's nuclear utilities have not introduced the concept in their organisation. In Japan, only TEPCO has set up a set of values, which applies only for Fukushima-Daiichi NPP.

- When the concept is used, it can be a single alpha value (around half of the answers) or a set of alpha values (the other half of the answers).

- The **single alpha values** goes from 446 €/man.mSv to 5,000 €/man.mSv ; hence more than a factor 10 between the lowest and the maximum values. The mean value is 1,540 €/man.mSv and the median value is 1,200 €/man.mSv. At first thought, it is remarkable that the array of values is quite large, considering that the estimated risk associated with one man.Sievert is the same.

[10] Exelon is using a hybrid system mixing a system of alpha values (the alpha value is increasing with the level of collective dose) and single alpha value (only one value applies at plant level). The reported situation for Exelon is detailed in the table below.

Alpha value	Plants
20,000 $	Braidwood, Byron, Calvert Cliffs, Clinton, Dresden, Gina, Limerick, Nine Mile Point 2, Oyster Creek, Peach Bottom 2, Quad Cities
40,000 $	-
60,000 $	-
80,000 $	La Salle, Nine Mile Point 2, Peach Bottom 3, Three Miles Island

[11] "*INPO* Collective Radiation Exposure Index *is calculated every year for each NPP by adding external and internal doses received during the last two outages and work during operation for the last 24 months; the sum is divided by 2 to have the value for one year. All the NPP can then be ranked according to their radiation protection results (1st quartile etc.). Exelon uses a base monetary value of 20,000 $/man.rem, which is then multiplied by the INPO quartile ranking to achieve the actual monetary value for engineering modification of the unit. This allows to give more financial resources to unit which have a higher historic INPO ranking. Duke Energy is adopting a similar formula. In addition, some units may have introduced specific monetary value, that is why Cook NPP (in the 1st quartile) prefers to use a 32,632 €/man.rem value)".*
(These additional precisions have been provided by D.W. Miller, Cook NPP).

The different numeric between the countries can be explained by the use of different methodologies to calculate the alpha value and also differences in the national economic conditions (considering that economic indicators like GNP per capita are sometimes a basis to calculate the alpha value).

But even within the same country, the alpha values can be quite different from one utility or plant to another. In the United States of America, the alpha values range from 446 €/man.mSv to 3,570 €/man.mSv (see Figure 2). This is because the methodology used by most American NPP to establish the alpha value is also partly based on plant-specific conditions such as the INPO ranking (ex. Exelon fleet, see footnote 9) or salary conditions and local dose constraint (ex. Palo Verde NPP[12]).

Finally, given all the rationales used to estimate the alpha value, is it not so surprising that the reported single alpha values are distributed over a large interval.

- A **system of alpha values** is based on a mathematical model where the monetary value is increasing with the level of exposure. Historically, these models that have been introduced[13] to allow spending more financial resources in order to reduce together the collective dose, the dispersion of the individual doses and giving priority to the most exposed individuals.
  In the survey, several systems are reported, where the monetary value increases:
  - with regard to the individual dose:
    - mean annual individual dose for the workers concerned by the radiation protection investment (Leibstadt NPP, EDF);
    - or individual doses to be received for the task under consideration (TEPCO).
  - Or with regard to the collective dose:
    - the collective dose of the NPP (Exelon);
    - or the collective dose of the task under consideration (Slovenia).

  Compared to the single alpha value case described above, the interval of reported values is bigger because the values are also depending of the intervals of exposure (that may be different both in terms of values and/or in terms of nature ex. individual vs. collective) when the single alpha values apply irrespective of the level of exposure.
  Indeed, the interval of values goes from 44.5 €/man.mSv up to 8,900 €/man.mSv and it is not relevant to calculate a "mean" alpha value in this case. When considering only the maximum alpha values of the ranges of values, the mean is 2,730 €/man.mSv.

- Some of the rationales used to evaluate the alpha values are varying with time, such as the radiation protection indicators of the plant and the economic conditions, leading to the possibility to update the alpha values regularly. Hence it could be seen from the survey that some values have been updated recently when other are older.

[12] Palo Verde NPP reported using the following formula: $\alpha = S + (T+B/2)/D$ where:
- Where S is the "basic" alpha value recommended by the nuclear regulatory authority (2,000 $/man.rem);
- T is the annual training cost for an employee (3,093 $/man per year);
- B is salary and benefit for an employee (118,200 $/man per year), divided by 2;
- D is the local dose constraint (2 rem/year hence 20 mSv/year).

This formula have been introduced in 1984 and updated five times considering the salary conditions (from 8,500 $/man.rem in 1984 to 33,000 $/man.rem in 2011).

[13] Historically, these models have been introduced by National Radiation Protection Board (NRPB) in the United Kingdom (1981) and Nuclear Protection Evaluation Centre (CEPN) in France (1996).

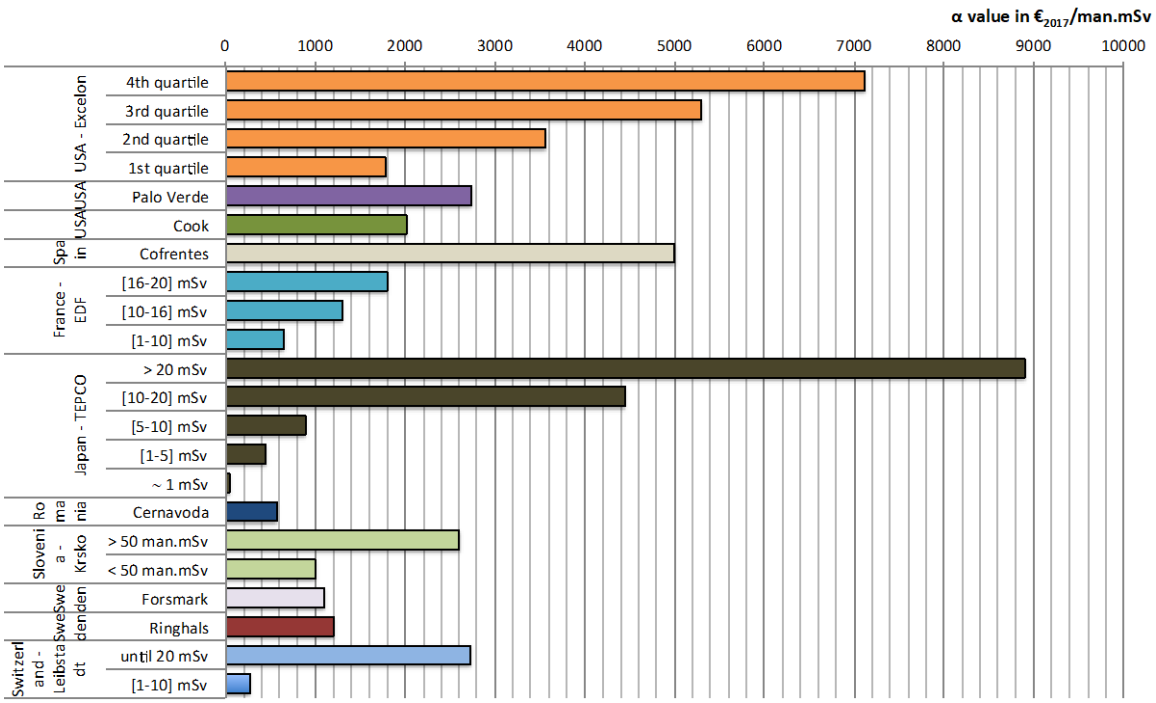

Figure 1. Monetary values of the man.Sievert reported by nuclear utilities and nuclear power plants in 2017.

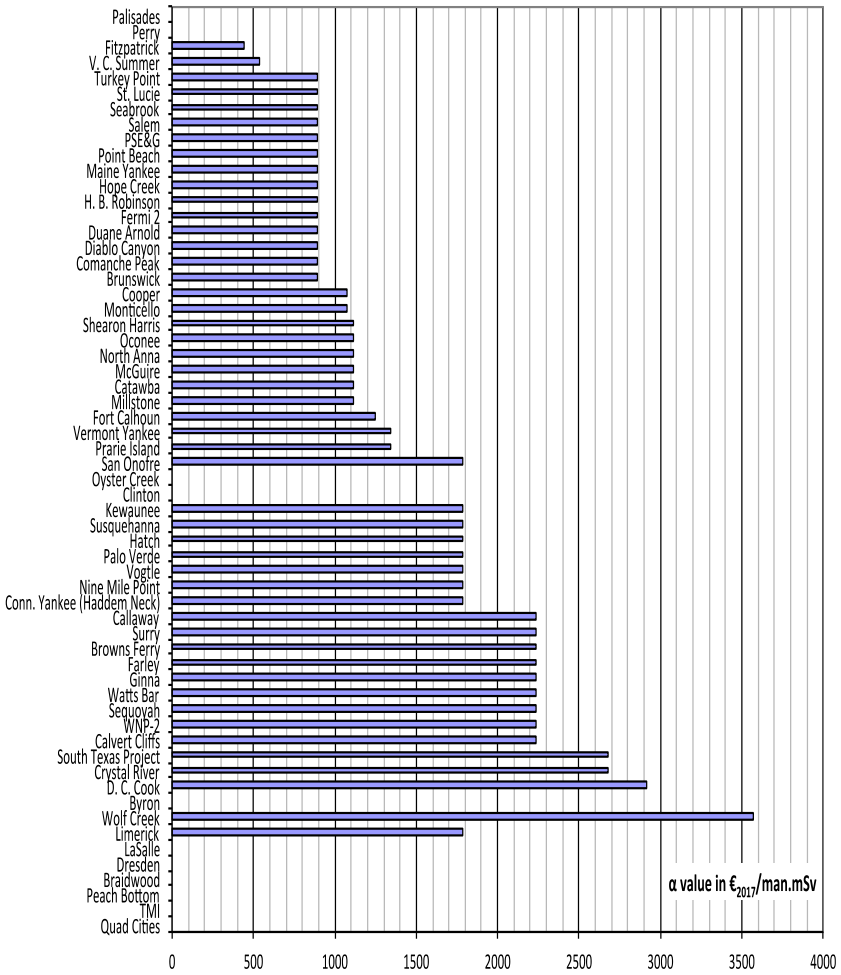

Figure 2. Monetary values of the man.Sievert reported by nuclear power plants in the United States of America (2015 data)

3.3 Users and uses of the monetary values of the man.Sievert within nuclear utilities and nuclear power plants

Several respondents have declared that internal reports can document how to use the alpha value, but this is not systematic (around half of the answers of those that have introduced an alpha value). The most frequent reported users are – by far – the Radiation Protection Department, followed by the other Departments and then top level management

The frequency of use is generally 1 to 10 times a year, sometimes less (once a year) and never more than 10 times a year. This leads to suppose that the alpha value is used for important decisions and not on a day-to-day basis. The reported examples of use (listed by order of frequency) confirm this statement:

- Large-scale modification ("*large/important projects*" is a common wording) such as:
  - the installation of a microfiltration system in the Reactor Primary Circuit,
  - the removal of by-pass lines or the renewal of parts of the waste system,
  - the installation of Steam Generator platform lane,
  - or the replacement of the reactor vessel closure heads.
- Chemical decontamination of systems and circuits.
- Power reduction of the plant.
- Building of new facility, with radiation protection impact (installation of a detritiation facility).
- Priorisation of modifications for the long term.

The reported examples confirm that the alpha value is only used for important decisions, both from economical and operational point of view. One has reported that the alpha value cannot be applied for optimisation of 'low' exposures.

In practice, it is reported that the Radiation Protection Department are using the alpha values when performing optimisation study and prepare arguments for the decision that will be taken at a higher hierarchical level. To this regard, there is a consensus to declare that the alpha value is a precious tool to provide more objectivity and transparency in the decision-making, because the impacts of the project have to be quantified and put into perspective through a formalized process.

According to the examples that have been provided, the alpha value is generally used to evaluate one option (from a radiation protection point of view). In this case, the outcome will be on the decision to implement or not the given option ('go/no go output'). But some examples show that the alpha values can also be used for more open questions such as establishing priorities among several projects or defining the extent of the decontamination perimeter ('ranking output').

It is commonly highlighted that the alpha value is not the only support for the final decision and that it is encompassed in a much broader process. The alpha value is "*one item of the optimisation analysis*", "*one of the tools*" that help in the decision or only one "*additional information among other factors*" and is not uncommon that some projects are implemented, even if the reference value is exceeded. Some of the other factors that are used in the decision have been reported and show great variety:

- Diminution of contamination, source term and dose rate in the area.
- Work environment, time and number of maintenance over time, etc.
- Reactor safety or reactor availability.
- Industrial safety of the workers.
- Financial resources available.
- Legislation
- "*And many many others*".

SYNTHESIS

In this survey, only a few nuclear regulatory bodies have explicitly referred to an alpha value. There is a consensus to say that the use of the alpha value is mainly the nuclear industry concern. For the regulatory bodies who have introduced the concept, the alpha value has different status: it is a recommended use (UK), or has a regulative statute (Czech Republic and Slovakia).

- A large proportion of the nuclear utilities and NPP who answered the survey have introduced and are using an alpha value.
- A first group is using a single alpha value (mainly utilities from the USA) when the second group is using a set of values, increasing with the level of exposure of the workers under consideration (expressed either in collective dose of the plant or the task considered, or in mean individual dose of the workers concerned by the investment or individual dose of the task).
- Variations in terms of methodologies to establish the alpha value, economic conditions, plant radiation protection indicators and level of exposure (for set of alpha values) drive different alpha values, who range from 44.5 €/man.mSv to 8,900 €/man.mSv. As a result, inter-comparison should be made with caution.
- The alpha value is generally applied 1 to 10 times a year, mainly for important projects with impacts in radiation protection, financial, operation, etc. From this survey, Radiation Protection Department are the first users as to document for decision that will be taken at higher level. Decisions can be of 'go/no go' or 'ranking' types.
- The concept is recognized to provide objectivity and transparency in the decision process. But, whatever the output, it is commonly said that the optimisation process cannot be restricted to the use of the monetary value of the man.Sievert: this is only one tool used in a much broader context and to be considered with other decision criteria.