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ISBN 978-92-95064-14-0

These transactions contain all contributions submitted by 7 December 2012.

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CIVIL SOCIETY

The European Commission Nuclear Safeguards Support Programme to the IAEA

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Abstract:

The IAEA bases its technical and scientific Programme on voluntary contributions from Member States. All these contributions constitute the IAEA Member States Support Programmes (MSSP). The European Commission Cooperative Support Programme (EC-SP) started in 1981 to support IAEA's activities in the field of nuclear safeguards. Since its beginning, the EC-SP has been operated by the European Commission's Joint Research Centre (JRC) and its institutes at Ispra-Italy, Geel-Belgium and Karlsruhe-Germany. EC-SP tasks provide technology and expertise in many technical areas related to the effective implementation of safeguards verification measures including the detection of undeclared materials, activities, and facilities. The paper details the main activities of the EC-SP in recent years in terms of the specific work as part of tasks with well-defined milestones and deadlines, training activities as well as the technical consultancy support to the many IAEA meetings and expert groups. The paper will describe how JRC technical activities contribute to the improvement of the implementation of Nuclear Safeguards and, in a wider view, to the implementation of nuclear non-proliferation policies.

Keywords: IAEA, Support Programme, EC-SP

1. Introduction

The European Commission Cooperative Support Programme to the International Atomic Energy Agency (IAEA) in the field of research and development in Nuclear Safeguards – EC-SP – was officially created on the 7th of May 1981 with an exchange of letters between Directors of the European Commission and the IAEA. Since then the EC-SP has been involved in more than 120 tasks in different technical and application areas of Nuclear Safeguards. In 2011, the EC-SP celebrated its 30th anniversary.

The EC-SP is an integral part the European Union's nuclear non proliferation policy [1]. Within the framework of the Euratom Treaty (1957), the European Commission's Directorate General for Energy (ENER) implements a European Union wide Regional System of Nuclear Material Accountancy and Control (RSAC). The Joint Research Centre – JRC, a sister Directorate General from the European Commission, provides, among others, the research, development and technical support to this RSAC and to the IAEA. JRC technical activities contribute to the improvement of the implementation of Nuclear Safeguards and, in a wider view, to the implementation of nuclear non-proliferation policies.

Beyond JRC and ENER, other European Commission services get inspiration from the EU non proliferation policy and regularly provide funding to IAEA specific projects. A good example is the EU support to the IAEA ECAS project – "Enhancing the Capabilities of IAEA Analytical Services" – from the Instrument for Stability. In such cases, the JRC, via the EC-SP, can provide the necessary scientific/technical assistance to the relevant Commission Services closing the gap between financing authority and the end-user.

This paper details the main EC-SP activities in the last 31 years of activities. It starts with some historical background and description of the current modes of operation, including the close collaboration with DG ENER, in charge of the implementation of the EURATOM treaty. The paper references some recent achievements of the EC-SP and ends with some discussion on current practices and future.

2. Historical Background

The IAEA was created in 1957, the same year as the Treaty of Rome (instituting the European Economic Community) and the EURATOM Treaty (instituting the European Atomic Energy Community) were signed. As a consequence of the EURATOM Treaty, an executive Commission of EURATOM (later merged into the Commission of the European Communities which later became the current European Commission) was mandated to implement the EURATOM Treaty, including all Nuclear Safeguards and verification measures.

In 1970 the Nuclear Non-Proliferation Treaty – NPT – entered into force and the IAEA received the mandate to create and implement an International Nuclear Safeguards regime.

Considering the technical character of Nuclear Verification methodologies, there was much technical collaboration between the IAEA and the European Commission's Joint Research Centre – which had been created in 1959 with the specific role of fostering joint European research in nuclear energy related matters.

After the creation in 1977 of the Member States Support Programme – MSSP, the European Commission joined the MSSP on the 7th of May 1981 with an exchange of Letters establishing a "formal Cooperative Support Programme between the IAEA and EURATOM in the field of Research and Development in Safeguards". The signatories were Messrs Sigvard Eklund, Director General of the IAEA, and Wilhelm Haferkamp, the German Commissioner for External Relations including Nuclear Affairs of the

Commission of the European Communities (President: Gaston Thorn).

The exchanged letters indicated that "… the programme will cover the following areas of R&D activity":

a) Surveillance and containment
b) Measurement technology
c) Training Courses
d) Information data, treatment and evaluations

3. EC-SP Modes of Operation

The European Commission's Joint Research Centre (JRC) operates the EC-SP. Two JRC institutes with a scientific and technical work programme in the field of Nuclear Safeguards are actively collaborating with the IAEA under the framework of EC-SP. These are:

- Institute for Reference Materials and Measurements (IRMM), Geel, Belgium
- Institute for Transuranium Elements (ITU), Karlsruhe (Germany) and Ispra (Italy) sites

The European Commission Directorate General for Energy – ENER, in charge of the implementation of the EURATOM Treaty, is kept informed about all IAEA requests as well as with the progress and implementation of current tasks. On a case by case basis, and whenever appropriate, ENER proposes trilateral collaboration schemes for the execution of specific tasks.

IAEA's Support Programme Coordination Group meets twice a year with the coordinator of the EC-SP and specific task officers for overall task review meetings.

3.1 Research and Development Tasks

The different meetings between JRC and IAEA staff contribute to a widespread dissemination of knowledge:

- JRC staff is aware about IAEA needs and orientations.
- IAEA staff learns about recent research activities, including new R&D results, laboratories, equipment, investments, etc.
- The regular MSSP coordinator meetings and IAEA R&D reports also contribute to this exchange of knowledge

These informal bilateral exchanges are beneficial as they contribute to bring together end-users and developers. Further, the good understanding of IAEA needs often influence future JRC multi-annual work programmes. On an annual basis, JRC's internal definition of work-programme objectives and deliverables for the different groups also reflect the current IAEA tasks.

3.2 Expert Meetings and Workshops

JRC staff, often together with colleagues from ENER, regularly participate to meetings, expert networks, workshops, etc. organised by the IAEA. These, again, contribute to a better understanding of IAEA needs in specific areas and are beneficial in looking ahead for future research avenues to be eventually implemented in forthcoming years.

3.3 Analysis of Nuclear Materials and Environmental Particle Samples – NWAL

The support to IAEA also includes the analysis of nuclear materials, of environmental particle samples, and the provision of reference/QC materials. These activities are performed in JRC laboratories in the frame of IAEA's Network of Analytical Laboratories (NWAL).

3.4 Scientific and Technical Support to EC Services supporting the IAEA

When other European Commission services support the IAEA, as part of the European Union non-proliferation policy, the EC-SP can be called to provide the necessary scientific and technical assistance to the relevant Services closing the gap between financing authority and the end-user.

Figure 1: H. Nackaerts IAEA Deputy Director General, Head of the Department of Safeguards, Y. Amano IAEA Director General, Y. Aregbe EC-JRC-IRMM and G. Voigt Director IAEA-SGAS at the groundbreaking ceremony for the new IAEA Nuclear Material Laboratory, Seibersdorf, 7 Sept. 2011.

3.5 Support to IAEA ECAS project

The European Union (EU) has affirmed that it will support international cooperation on technological infrastructure and networks necessary to verify the non-diversion of declared nuclear material but also the absence of illicit nuclear material and activities. The EU envisages supporting the ongoing efforts to strengthen IAEA's analytical capabilities with a contribution from the Instrument for Stability (IfS) to the expansion and modernisation of the IAEA Safeguards Analytical Laboratories (SAL) under the project of "Enhancing Capabilities of the Safeguards Analytical Services" (ECAS). On requests of EuropeAid Development and Cooperation (DG DEVCO) and the European External Action Service (EEAS) the JRC provides via the EC-SP technical/scientific advice for the EU donation for the new IAEA Nuclear Material Laboratory. The groundbreaking ceremony (Figure 1) was held on 7 September 2011 at the International Atomic Energy Agency

-Safeguards Analytical Laboratories –IAEA-SGAS, Seibersdorf.

3.6 Collaboration with other Support Programmes

Given the organisation of the European Union and the existence of the ESARDA association – focusing on R&D for Safeguards, it is considered positive to disseminate JRC current R&D activities for the IAEA to other EU Member States with an active MSSP.

Ten EU Member States participate at IAEA's MSSP: Belgium, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Spain, Sweden and the United Kingdom. These Member States are invited to participate at the EC-SP's Annual Review Meeting. In some cases, when discussing specific tasks or IAEA requests, it is beneficial to extend the discussion to other Support Programmes. This practice has been found useful both from the IAEA's perspective and from the participating MSSPs. Not only the discussions are richer, but it is also possible to better coordinate and focus on future efforts and initiatives.

Further to the above mentioned meetings, JRC researchers participate actively at ESARDA Working Groups. These working groups constitute a forum for technical discussions and contribute to a wide, scientific and technical knowledge base of Nuclear Safeguards. Participants to these working groups include ESARDA members as well as recognised observers. Within this context, both ENER and IAEA are represented in the working groups. As such, ESARDA working groups also contribute to the dissemination of the technical activities of many Support Programmes, including the EC-SP.

4. EC-SP Tasks

Since 1981, the EC-SP has been involved in as many as 122 tasks. Figure 2 shows the distribution of these tasks along the different Safeguards technical and application areas.

Figure 3 shows the evolution of the EC-SP along the years, ie, the distribution of its tasks in terms of the different technical and application areas. The graph compares the distribution of all 77 closed tasks with the current 45 active ones. Figure 4 shows the number of active tasks since 1981.

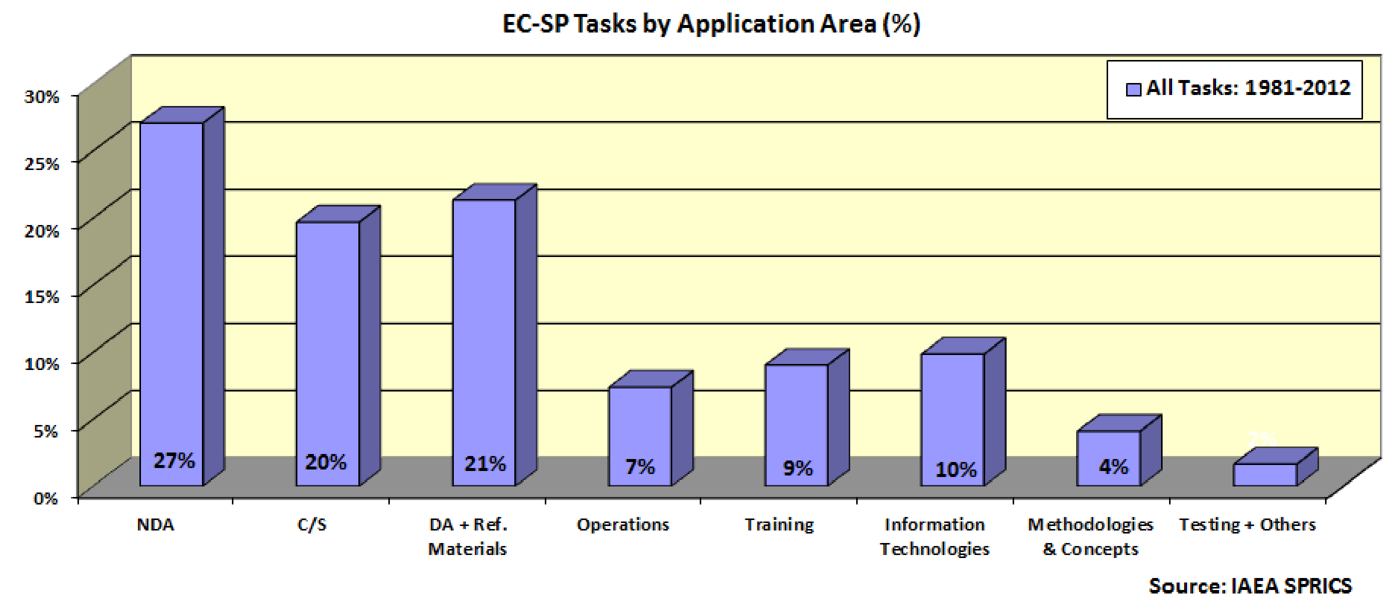

Figure 2: Distribution of EC-SP tasks for the period 1981-2012.

NDA: Equipment, Modelling and Measurements	7
Sealing, Containment and Surveillance	8
Analytical and Reference Techniques	6
IAEA Operations (e.g., JNFL, JMOX Projects)	7
Training	8
Information Technologies for Non-Proliferation	3
Concepts and Methodologies	4
Testing and Others	2
Total	45

Table 1: Distribution of EC-SP tasks in Autumn 2012

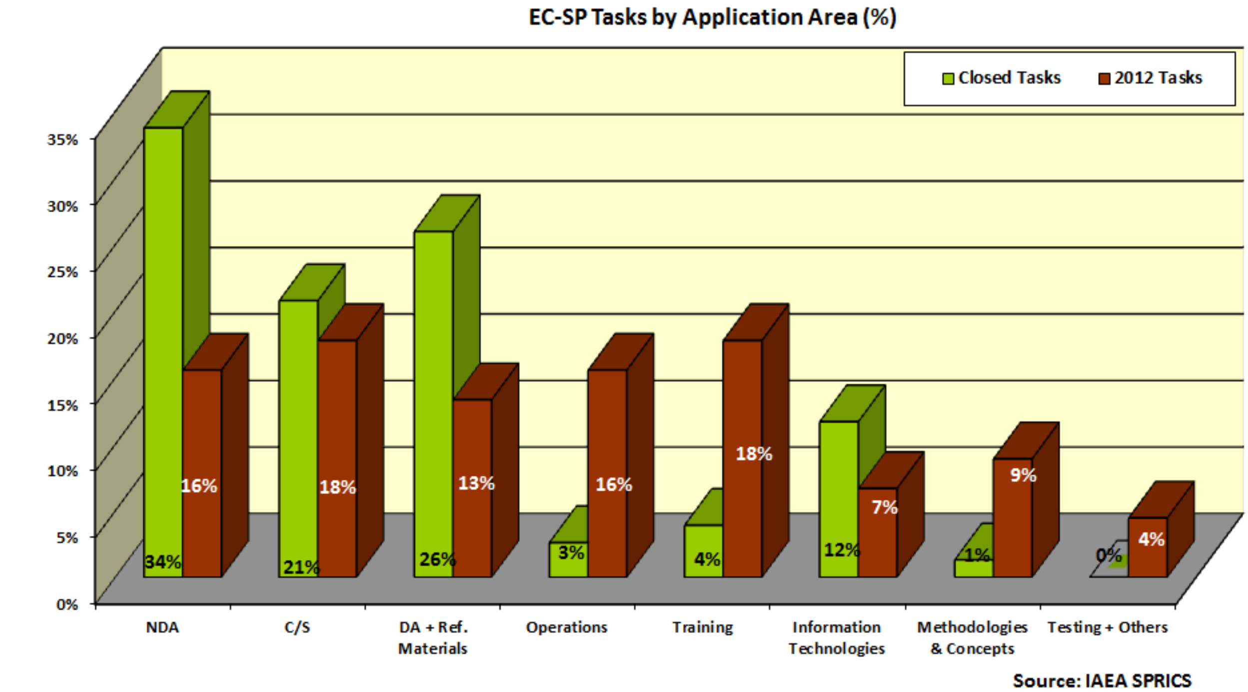

Figure 3: Distribution of EC-SP closed and active tasks for Safeguards technical and application areas

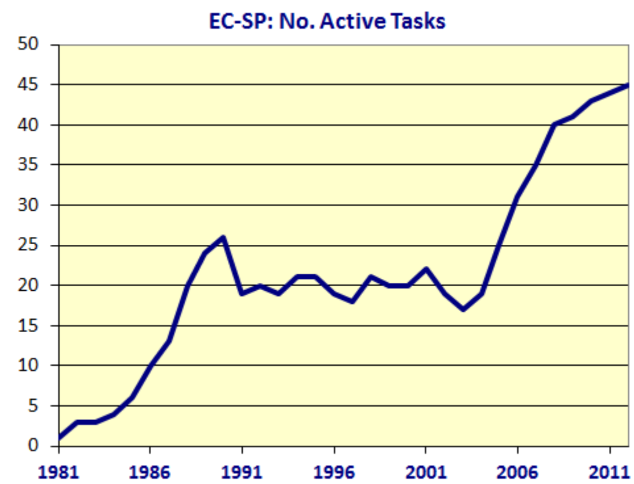

Figure 4: Number of EC-SP active tasks for the period 1981-2012.

From Figure 3 the following is observed:

a) The relative weights of tasks associated to Containment and Surveillance (C/S) and Information Technologies are relatively stable.

b) The relative weight of EC-SP tasks associated to traditional disciplines, such as NDA or DA, has decreased.

c) There is a substantial increase in tasks associated to IAEA operations and training.

d) There is also an increase in tasks associated to new activities, namely Concepts and Methodologies. Examples include: ASTOR Network of Experts for Safeguards in Geological Repositories, Novel Technologies, Acquisition Path Analysis, Safeguards by Design and Safeguards for Pyroprocessing,

A description of recent EC-SP technical achievements and task highlights can be found in [2]. Relevant references are included in Section 7.

5. Discussion and Conclusions

JRC's experience in operating the European Commission Support Programme, in line with the continuous collaboration with ENER, has been very positive. The franc and regular dialogue with both ENER and the IAEA led to a programme of applied research targeted to Nuclear Safeguards applications. This programme has produced and engaged into the technology transfer of several pieces of work with relevance to International Safeguards stakeholders.

In recent years, EC-SP contributions have expanded from activities in research and development in Nuclear Safeguards basic disciplines – C/S, DA and NDA, and now also include areas of operations and training. This is the natural evolution of product development, i.e., passing from laboratory prototypes to dedicated field instruments and measurement systems.

The EC-SP has kept in line with the new orientation of the IAEA in having "Safeguards which is fully Information Driven". Indeed, in the last six years there have been a few tasks paving the way and exploring new ways to acquire, process, analyse and integrate multi-lingual, multi-source, multi-timeframe information, including tools for the analysis of trade data.

In a domain as technical as Nuclear Safeguards, with a constant evolution of equipment and methods, training plays an important role to keep IAEA staff abreast of the new developments. Within the framework of the EC-SP, and for the last 31 years, JRC has made available its installations, laboratories, materials, expertise and know-how to the IAEA. There are tasks associated to long-standing training needs. Besides those tasks, other tasks often include a dedicated component of training, associated to the specific topic of the task.

The existence of a Support Programme creates, somehow, a sense of partial ownership in what concerns the implementation of International Safeguards. This makes politicians and decision makers more informed about IAEA Safeguards, its rules, modes of operation and technical requirements. This is specifically true for all the scientific and technical staff working in JRC laboratories who feel most gratified when they know that their work has successfully contributed to the continuous challenge in “raising the bar” in both Safeguards and Non-Proliferation issues.

Thirty years is a long period. The European Commission Cooperative Support Programme feels proud for all its past activities and achievements. The EC-SP wishes that the next thirty years are as successful and looks forward to increasing cooperation with the IAEA and its Member States Support Programmes.

6. Acknowledgments

The authors express their gratitude to all colleagues in ENER and JRC for their collaboration in the smooth implementation of the European Commission Cooperative Support Programme. In particular, a special word for all JRC task officers and other scientific and technical staff who play the important role of execution of the different tasks, as well as for having provided material for this paper.

A special acknowledgement is due to the previous EC-SP Coordinators Messrs. Marc Cuypers and Sergio Guardini who helped tracing back part of the history of the EC-SP.

The authors also acknowledge IAEA’s Support Programme Coordination team for the excellent relations and good discussions aimed at the continuous improvement and efficiency of the EC-SP.

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COMMUNICATING NUCLEAR DURING CRISES OR IN HOSTILE ENVIRONMENTS

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ABSTRACT

The aim of this paper is to show how to communicate nuclear topics in a hostile nuclear environment as present since many years in Austria.
The Austrian Nuclear Society did a three step approach to communicate with the public in 2010 and 2011.
The first step was a questionnaire distributed to a representative sample of the Austrian public in autumn 2010. The questions were all related to: "Why are the Austrians against nuclear power" [1] and it included a second intervention phase.
The second step was an information centre during the Fukushima accident. It resulted in approximately 1000 direct contacts with the Austrian public (phone, mail and personal talks). With over 150 interviews in TV and print media an even broader spectrum of the public was reached.
The last step and a result of the two previous ones, was the publication of a book in very basic nuclear language. ([3]) The book was requested by the public, and therefore written exactly for the broad public. Its major aim was to be informative on all nuclear related subjects, to educate and to be used as a tool to fight fears and prejudices against nuclear topics. Such a publication is the first of its kind in the German language area, and only few exist in other languages.
This paper shows how nuclear communication with the public is necessary and possible especially in a hostile environment or during crisis situations, such as the Fukushima accident.

1. Introduction and Motivation

This paper will demonstrate the importance of effective nuclear communication with the public, not only during crises but also in anti-nuclear environments. A part of this work will show how the lack of knowledge in nuclear topics encourages an anti-nuclear opinion.
Austria has not always been the anti-nuclear country it is today, but due to the Chernobyl catastrophe and Austrian politics opposition to nuclear programmes has increased.
Part of our motivation for researching this topic was to understand reasoning behind this anti-nuclear mentality and see if there are ways to change it.
The paper provides examples and best practices on how to supply the public with accurate information about nuclear topics, and also shows the success of this approach.

2. A three step approach for communication

2.1 Step one – a survey

The starting point of the three step approach to evaluate the opinion of the Austrian public about nuclear topics and provide them with the desired information commenced in autumn 2010. This first step consisted of an opinion poll that was delivered to 1022 people, representing the Austrian public. The poll "Position of the Austrians towards Nuclear Energy" was included in a study [1] which main purpose was to see if people would reconsider their opinion after an intervention.

The poll was divided into two parts, the first part included the questions about the Austrian opinion towards nuclear topics, and the second part contained questions about their nuclear knowledge.
For a second phase 150 out of the 1022 were chosen – the intervention. The choice of these 150 was made on a free will bases, maintaining a representative sample of the Austrian public. They received information about nuclear topics, either as an intervention text [2] or in the form of a personal talk to a nuclear expert. After this intervention phase, the subjects were asked to repeat the questionnaire so as to monitor their opinion change, 149 out of the 150 people handed this second questionnaire in.

2.2 Step 2 – communication during crises

While waiting for the results of this second phase, the Tohoku earthquake occurred. Knowing and fearing the media's response in Austria to a subject that is nuclear related, the Young Generation of the Austrian Nuclear Society decided to react as quickly as possible. The motivation is easily explained: We were aware that regardless of the severity of the accident in Fukushima, the media's response would not relate to all and therefore instigate panic and fear amongst the public. Our aim was to provide adequate and accurate information about the Fukushima accident, and thereby reassure the public. To illustrate the concerns about the overreacting media response, the following graph is shown.

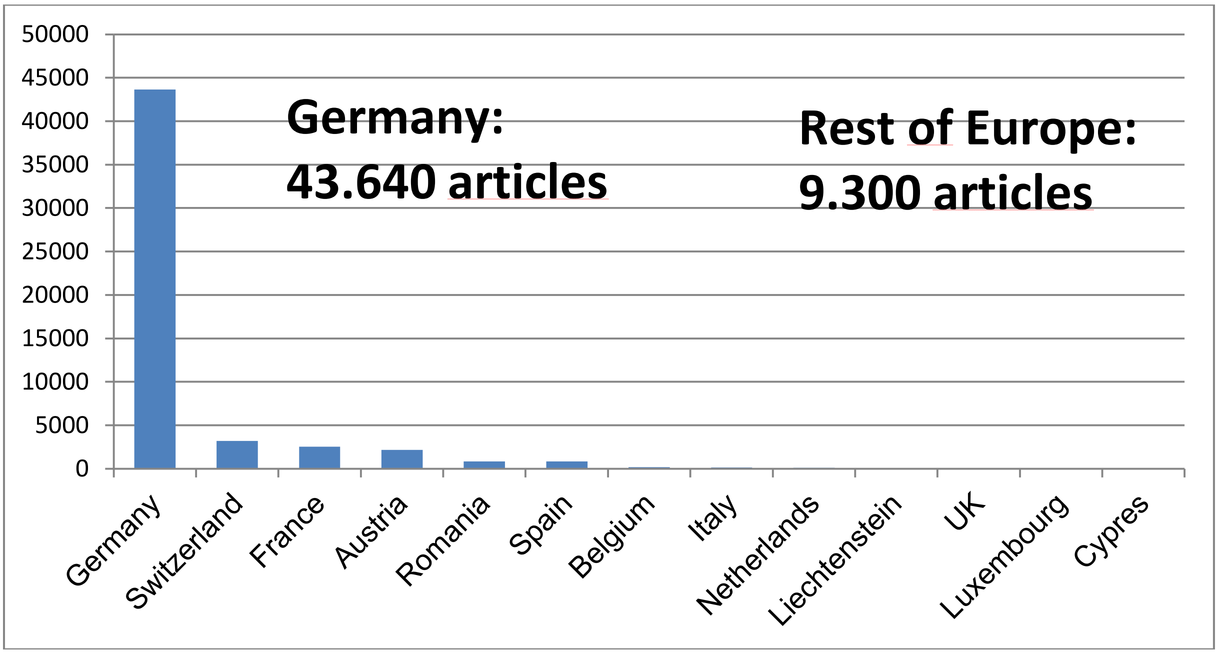

Figure 1: Distribution of newspaper articles in the first 3 weeks after Fukushima

The graph clearly illustrates that despite a distance of 8000 km the reaction in the German newspapers indicates that the accident happened next door and our and German lives were in danger.
The first step was the establishment of a media centre within the Institute of Atomic and Subatomic Physics in the Vienna University of Technology. Several phone lines were installed, as well as an e-mail address, with multiple accesses to it. With these two measures, the Austrian public was able to contact us directly, as the phone number and the e-mail address were provided to the media.
The information centre was in operation for three weeks, managed by 15 staff members and was usually open from 7am to 10 pm, including weekends. Two main functions were performed; the first one was the direct contact to the public receiving phone calls and/or e-mails. The second part was the new data and information analysis to brief our speakers for media interviews. The outcome is described in [4]. To summarize briefly: We received 800 e-mails and approximately 200 phone calls, as well as delivering over 100 interviews through the media, TV or radio.

What could clearly be ascertained was that during the three week operation of the information centre, awareness of our existence was raised, and after one week of operation most Austrian media contacted the information centre to obtain information or asked us to check the articles for correctness before publishing such information. Our main data sources were the official statements by the IAEA, the Japanese authorities, as well as the Japanese media and our own measurements performed by staff members in Japan.
Our efforts at providing unbiased information were recognized not only by the Austrian media and public, but also by the Minister of Science and Research (Mrs. Beatrix Karl) who upon being informed about our work visited the information centre and the institute to acknowledge our initiative.

2.3 Step 3 – Preparing information to change the opinion

During discussions with the staff of the centre on how to retain and store the knowledge gained during our commitment for the information centre, we were contacted by a publisher who had analysed the public opinion and who recognised the need for a book, which would provide basic information about nuclear subjects. The outcome of this public opinion analyses arrived at the same time as survey study results back from 2010, which was a further indication that the right information can alter public opinion. (See below in Results and Discussion)
This was the final step: writing a book for everybody, providing them with simple and easily understood information about the Fukushima accident, the basic working principles of nuclear power and radiation, as well as discussions about renewable energies and the nuclear situation in our neighbouring countries. The book "Core question nuclear power – what happens if something happens" [3] was published in October 2011. It is one of the simplest and best ways to communicate with the public.

The three-step approach for communication during crises and in nuclear-hostile environments which began with the need analyses in a public opinion poll – at the same time trying to identify why Austrians are so strongly biased against nuclear technology, continued with the establishment of a public information centre during the Fukushima crises. This measure was taken to allow each and everyone access to unbiased information. The last step was the publication of a book - in layman's language – with the intend of educating the public and thereby providing them the opportunity to educate themselves about different nuclear topics.

3. Results and Discussion

There were two main outcomes of the first step: The Austrian public is generally wary of nuclear technologies, and this fear increases with age. Figure 2 shows the general fear of the Austrians, Table 1 indicates that the fear of nuclear technologies increases with age. Older people think more often that the risk of nuclear power is higher than the risk associated with other energy sources.

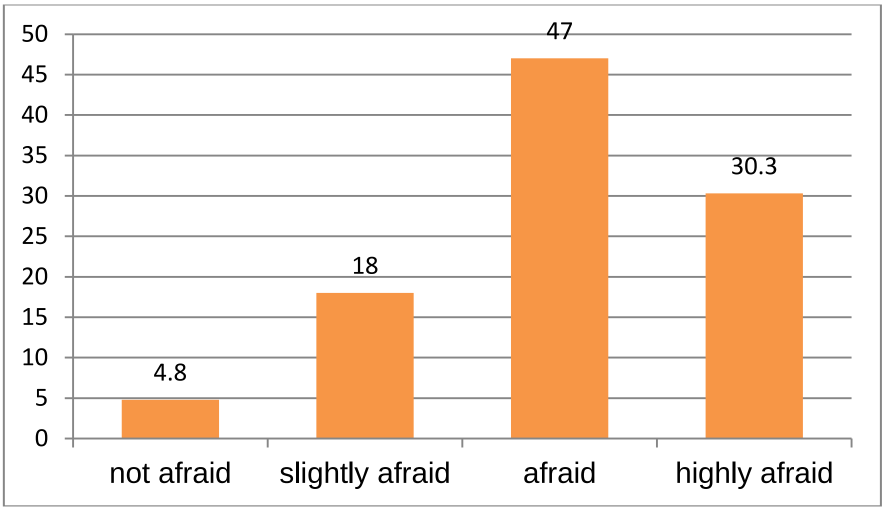

Figure 2: Shows the answers to the question: Are you afraid of nuclear technologies

	The risks of nuclear power are higher than those of other energy sources				
	age				
	to 25	**26-35**	**36-50**	**51-65**	**over 65**
true	63.1	68.4	77.1	87.6	84.3
not true	12.5	13.3	11.4	7.7	10.7
don't know	24.4	18.4	11.4	4.7	5.0
	100.0	100.0	100.0	100.0	100.0

Table 1 shows that the negative opinion towards nuclear topics increases with age

The other outcome of the first step is even more important. Figure 3 shows the opinion of the Austrians before the intervention as explained in the first chapter.

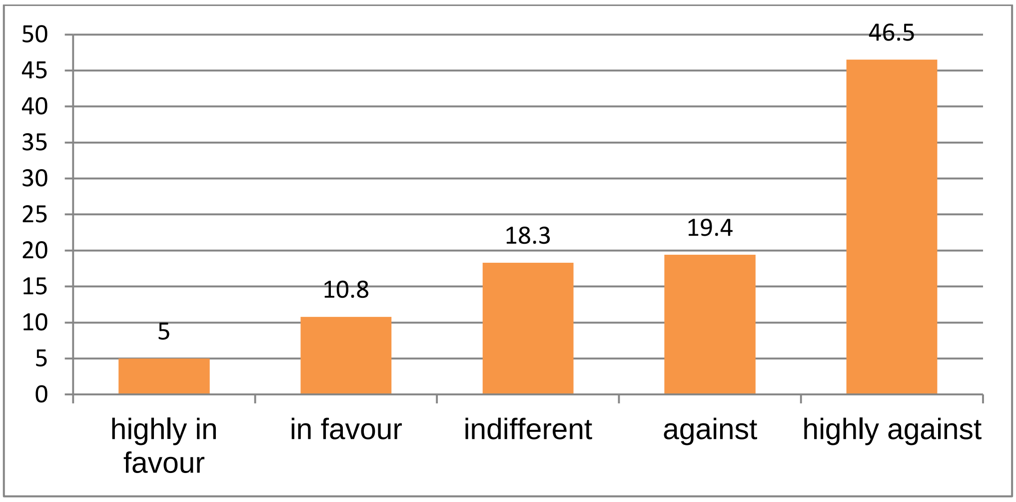

Figure 3: Displays the answer to the question: What is your general opinion about nuclear (before intervention)

Figure 4 shows the change to this question for the 149 people being a representative sample of the originally 1022 people interviewed altogether after the intervention:

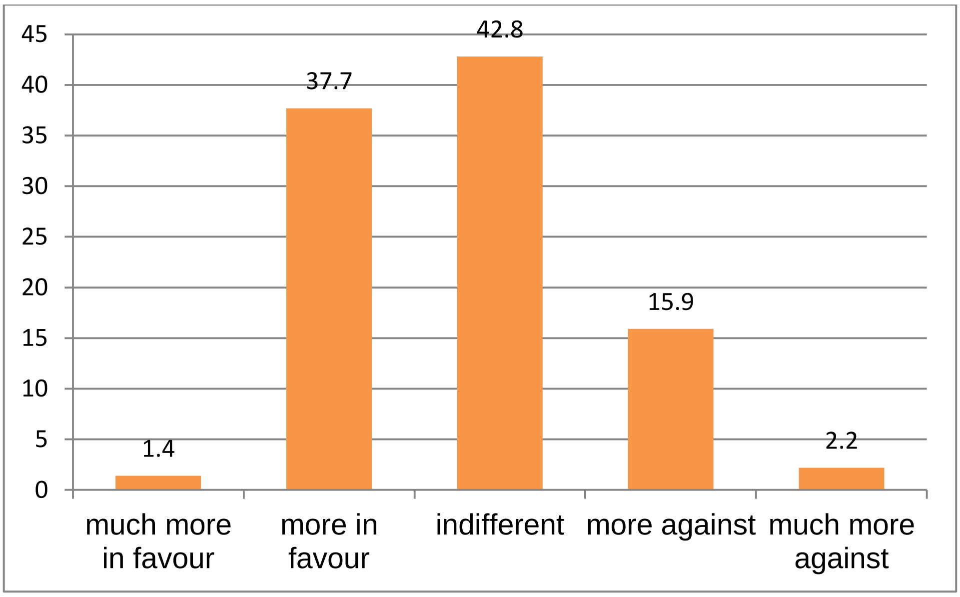

Figure 4: Opinion change after the written or oral intervention of the representative sample of 149 out of 1022 originally questioned people in percent.

It can clearly be seen that the intervention changed the opinion of almost all the participants. This indicated that our idea of providing information has had a positive effect.
The publication of the book triggered numerous discussions and it was reviewed in over 15 print media (including “Der Standard”). It was also nominated for the PIME award, was short listed, and finished in second place. With the advertisement of the book over the European Nuclear Society and its members, we also found a sponsor for the translation into English - the publication will be released in near future.
To conclude it can be said that even in environments like Austria, providing unbiased information will be appreciated by the public. The acceptance of nuclear technology will rise if the public is correctly informed. As nuclear technologies are a very complex matter, and not easy to understand for everybody, the right level of information must be provided – one best practice is the publication of a book.

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DEBUNKING NUCLEAR MYTHS

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ABSTRACT

For decades, the nuclear industry has been a target of negative campaigns that have not been addressed successfully by the nuclear community. Over time, the anti-nuclear movement has assembled an arsenal of mostly misleading or false arguments – effectively myths.

This paper analyses attempts of the pro-nuclear community to debunk such myths and finds them inadequate. The majority of articles addressing anti-nuclear arguments either originate in the academia/industry and are too technical for the general public or are written by journalists who lack theoretical background. No effort to approach anti-nuclear myths systematically and thoroughly has been identified during our research.

This paper aims to propose ideas on how to improve the current approach to anti-nuclear propaganda. Authors propose a framework that would allow specialists from the industry and academia to combine efforts with public relations specialists on systematically debunking anti-nuclear claims. Myths are to be collected and analysed by academia/industry specialists and then exposed to the general public by PR professionals. Clearly written articles tailored to the layman, with peer-reviewed scientific papers as supporting references, would aim to eliminate falsehoods from public discourse.

In conclusion, preliminary results of efforts in building cooperation between nuclear and PR professionals are presented.

1. Introduction

The field of power generation has always been a controversial one. Usage of fossil fuels is a common target for environmental activists, hydro power an occasional one, but nuclear power surpasses any other method of electricity generation in the amount of negative activism and criticism it attracts. Every industry has its share of accidents and environmental impact, and nuclear industry is no exception. But, given the public unfamiliarity with nuclear technology, those accidents produce nonreciprocal fear, [1]. This fear of the unknown makes the general public susceptible to anti-nuclear propaganda.

The anti-nuclear movement had some impressive results even before the now notorious Fukushima accident. Sweden, Italy and Austria are the best examples; Sweden held a referendum on nuclear power in 1980 in which over 70% of the voters opted for a fast phase-out of nuclear power plants, [2]. A referendum in Italy was held in 1987, with public opinion on nuclear power overwhelmingly negative, which led the Italian government to decide the very next year to phase out its nuclear power plants. The parliament of Austria decided in 1978 to ban nuclear facilities for 20 years - in this case without a referendum, albeit with full support of the general public. In 1998 this ban was renewed, again thanks to the overwhelming negative public opinion.

That anti-nuclear activism had crucial influence on the situation in Sweden, Italy and Austria is obvious. Matters got worse in the aftermath of Fukushima accident. The so called Nuclear Renaissance was almost stopped dead in its tracks, while anti-nuclear activism stepped up its activity considerably, [3].

The main tools of anti-nuclear activists are fairly common, often technically, ecologically and scientifically invalid arguments against nuclear power. This article inspects the nuclear industry's current efforts to confront those arguments and proposes new methodologies to effectively dismantle the anti-nuclear movement's arsenal of false arguments.

2. Approaching anti-nuclear arguments

A good deal of arguments that anti-nuclear activists use are either misleading or false, therefore we refer to those as anti-nuclear myths. How to efficiently approach the problem of these myths and activists that spread them is the main issue this article tries to address. For introductory analysis we find it helpful to divide anti-nuclear activists by their awareness of truthfulness of arguments they use. The motivation for this particular criteria of division is that this criteria significantly influences strategy of approach to those activists. Elementary logic, [4] teaches us that according to this criteria activists can be divided in exactly two groups:

1. activists who are aware that most of their arguments are false or misleading
2. activists who are not aware of that.

The second group of anti-nuclear activists - those who are not aware they use misleading arguments - can be educated, and in that respect they are no different than members of the general public with a negative stance towards nuclear energy. They can be approached using undisputable facts and ultimately convinced that the arguments they use are false.

The first group - those who are misleading the public intentionally – obviously cannot be reasoned with, so they should be engaged in debate and confronted with undisputable facts in public. That way the audience may hopefully become aware of what is reality and what is fiction.

In both cases, facts used while debating with anti-nuclear activists need to be undisputable. Using arguments for which there is even the slightest doubt leaves the pro-nuclear advocate open to the commonly used attack that he is using unproven or dubious claims. Therefore, it is essential that all pro-nuclear advocates are provided with a set of peer-reviewed arguments which cannot be disputed and are easily accessible for public reference.

2.1 Determining the truth

The scientific community has provided us with a methodology for determining undisputable facts – the scientific method. The scientific method is a method of procedure consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses, [5]. The scientific method is the best way yet discovered for winnowing the truth from lies and delusion, [6]. The scientific method satisfies the above stated criteria - facts confirmed by scientific method cannot be disputed.

The main practical applications of the scientific method are peer-reviewed scientific papers. Such papers are the main engine in the advancement of human knowledge and propositions confirmed through such papers are generally accepted as true. Therefore, our conclusion is that anti-nuclear myths should be debunked using peer-reviewed scientific papers.

Some anti-nuclear myths have already been directly or indirectly dealt with by the scientific community and what is left to be done is to compile a list of articles debunking a certain anti-nuclear myth. Some myths have not been appropriately addressed in peer-reviewed scientific literature, and those are still to be confronted with the scientific method.

2.2 Refutability of anti-nuclear arguments

It is, of course, not possible to refute all anti-nuclear arguments using the scientific method. It would be naïve to believe that all false anti-nuclear statements can be disputed by facts and logic. We believe statements used by anti-nuclear activists can be divided into four general groups according to their refutability:

1. vague statements
2. false statements
3. misleading statements
4. true statements.

First of all, some anti-nuclear statements are simply too vague; for instance, "Nuclear power is dirty" is a general statement which cannot be subjected to scientific scrutiny. It depends on the definition of the word "dirty" which is a subjective matter, therefore placing such a statement out of the domain of factual truth. We can never hope to disprove all anti-nuclear arguments simply because a significant proportion of them are by nature not disprovable.

We can, on the other hand, hope to disprove those anti-nuclear arguments which use factual statements. "Nuclear power emits more greenhouse gases per unit of produced electricity than natural gas powered plants", for example, is a factual statement. The truthfulness of this statement can be analysed with scientific apparatus and it can be determined beyond dispute if this statement is true or false. Not only is it possible to determine the amount of GHG that are emitted by nuclear power lifecycle, there in fact already exist several studies on this matter, [24].

There is also a third kind of statement which is true but misleading, such as, for example "Transportation of nuclear fuel emits greenhouse gasses". It is true that transportation of nuclear fuel emits GHG, but it has nothing to do with nuclear fuel. Emission of GHG by transportation is agnostic to the type of load it carries; therefore a transport of wind turbines and a transport of nuclear fuel both emit GHG. The statement in question can lead citizens to believe this to be a disadvantage of nuclear in comparison with other means of generation of electricity, while in fact all means of generation have this exact problem. Therefore, this is a factual statement which, although impossible to disprove, *can* be exposed as misleading.

Finally, some anti-nuclear arguments are entirely true. Statements like "Spent nuclear fuel remains dangerously radioactive for hundreds of thousands of years" are simply not disputable. As any other industry, nuclear has its inherent and factual risks and issues; most related to real-life implementation problems and often linked to aged technology or procedural errors. Such arguments should, for the sake of objectivity, be duly recognized and addressed. The general public should be educated to the fact that – as in any industry – on-going research and development already has in the pipeline solutions to current problems (e.g. new reactor designs, passive safety mechanisms or improved security procedures). In other words, the public should often be reminded of the nuclear horizon through popular science articles. Or more graphically, if one is building a new nuclear plant in 2012, one is most definitely not setting up a potential 1986 Chernobyl event, as is often the public image.

The public should also be made aware of the fact that if a problem has been identified in the past it has never since been ignored. One can easily learn a lesson from the aviation industry, which has done a very good job in explaining to the public how even tragic events from the past made today's air travel orders of magnitude more modern, safe and trustworthy. The nuclear industry still struggles to paint such a public image, although it objectively and historically paid a far smaller price in human life to achieve a similar, if not higher, level of reliability and positive disruptive potential. As important it is to disprove factually false arguments, it is equally important for the nuclear industry to shine spotlight on its trustworthiness, accountability and strict regulation, unrivalled in many other industries.

This line of reasoning can also benefit from the same peer reviewed processes and infrastructure that is outlined in this paper and most definitely needs to be part of a broader nuclear public relations strategy. However, of the four groups of anti-nuclear statements proposed here, only groups 2 and 3 are strictly disprovable with scientific fact, so the rest of this paper will focus on factual anti-nuclear statements that are either false or misleading.

There are a fair number of such factual statements that are used by anti-nuclear activists, and we hope to either prove them to be false or expose them as misleading. Efforts of the nuclear community to debunk nuclear myths cannot (and therefore will not) deter anti-nuclear activism, but they can prevent activists from freely using arguments which can be – through easily available and public reference – proved to be inadequate.

2.3 Presenting the results

Peer-reviewed scientific papers, while suitable for distinguishing facts from fallacies, are not suitable for communicating information to the general public. Communicating with the public is a discipline in its own right, usually called "public relations" (PR). Just as nuclear engineering has it specialists who are highly educated and trained in their profession, PR specialists have skills which are suitable for communicating with the general public.

For instance, it is quite obvious that if a journalist, an educator or a PR specialist decides to do research in nuclear technology, she or he will encounter serious obstacles because they are not a scientist – they lack theoretical background and are not trained to do scientific research (notwithstanding notable exceptions). The same stands for nuclear specialists doing PR work. Therefore, our conclusion is that the task of presenting these peer-reviewed scientific papers to the public should be done by technically oriented PR specialists, such as public relations experts, technical authors, popular science lecturers and journalists

There is little doubt about the form in which such material should be presented and distributed. World Wide Web is the obvious solution since it is ubiquitous; it is more far reaching than any other printed or electronic medium. Therefore we conclude that the results of any debunking efforts should be presented to the general public in the form of a web site.

3. Current situation

There already exists an abundance of pro-nuclear advocacy materials. Most nuclear sites and organisations provide some kind of advocacy material, be it pamphlets, posters or web pages. In the previous section we concluded that to effectively combat anti-nuclear myths there should exist a web page listing anti-nuclear myths which satisfies the following criteria: 1) it is debunking anti-nuclear myths using the scientific method; 2) it is presenting them with the help of PR specialists and 3) it is easily found and referenceable.

In this section we present results of our effort to inspect existing web sites that debunk anti-nuclear myths and analyse how they conform to above stated criteria.

It should be noted that our methodology was to simply search for web sites debunking anti-nuclear myths. We took into account only resources we were able to locate using Google Search. Comprehensive lists of myths or even lists of peer-reviewed scientific papers debunking anti-nuclear myths might already exist, but our inability to find them using intensive Google Search disqualifies them as unusable since they are effectively not publicly available or easily referenceable.

The only relatively comprehensive lists of debunked anti-nuclear myths that we found are at the websites of the Nuclear Energy Institute, [7] and the Canadian Nuclear Safety Commission, [8].

The list compiled by the Nuclear Energy Institute is titled “Myths & Facts About Nuclear Energy – Synopses of Common Myths About Nuclear Energy and Corresponding Facts That Refute Them”. This list is quite comprehensive: there are 46 myths debunked at the site. Entries are written in 4-5 sentences in language suitable for the general public and some include links to more information or even whitepapers and studies prepared, for example, at MIT or the University of Wisconsin. Although the work of the Nuclear Energy Institute is by far the best we found, we still find it lacking since NEI’s usage of undisputable references is sparse.

The Canadian Nuclear Safety Commission's list "Mythbusters" is a list of 34 anti-nuclear myths. More than half of the myths in this list (18 of 34) are filed under the section “Uranium mining and processing”. This is a very important topic in Canada, one of the world's biggest exporters of uranium, but is comparatively insignificant in European context since all of the mines in European Union accounts for less than 3% of EU’s uranium supply, [23]. Moreover, all 5 myths in the section Nuclear Power Plants are specific to Canada. Therefore, CNSC’s list, although one of the biggest found, is not very relevant in European context.

3.1 List sources and lengths

Apart from NEI's and CNSC's lists, resources dealing with anti-nuclear myths we found on the World Wide Web can mostly be arranged in two groups according to source:

1. articles in online versions of news magazines and on blogs
2. lists of myths on web sites of nuclear advocacy groups, industry web sites or web pages of pro-nuclear enthusiasts.

Lists from the first group were found in 3 online magazines: Washington Post, [9], Spiked, [10], Executive Intelligence Review, [11] and 2 blogs: [12], [13].

The half of the second group is made by lists composed by four pro-nuclear advocacy groups: American Clean Energy Resources Trust (ACERT), [14], American Nuclear Society (ANS), [15], Better Environment with Nuclear Energy (BENE), [16] and Nuclear Friends Foundation (NFF), [17]. The rest of this group are industry entities: Foratom, [18] and Emirates Nuclear Energy Corporation, [19] on one side and individual pro-nuclear enthusiasts, [20], [21] on the other side.

Most of the lists are 10 myths or shorter. The longest list – 20 myths - is at Foratom, [18]. Only 2 other lists are longer than 10 myths: BENE’s, [16], with 16 myths and the list compiled by Robertson, [20], with 13 myths. There are 4 lists with 10 myths: ACERT’a, [14] and ANS’s list, [15], the list published in Spiked Magazine, [10], and the list published on Al Fin Energy blog, [13]. All other lists are shorter than 10 myths.

3.2 Conclusions

Our analysis of lists at hand provided us with several insights.

Most of the lists were published by nuclear-related organisations. The content of those lists is mostly written in concise and up to the point language. Industry terminology is often used, so the reader is supposed to have at least a basic understanding of nuclear technology. Emphasis is put on facts and information transfer, not on diction and style.

Lists in the first group (published in news magazines or on blogs) are written in more general terms, with language aimed at the average reader. Language used shows more style but it is obvious that the content was written by people from outside of field of technical sciences.

Both articles on news portals and lists of myths on nuclear sites are mostly short (around 10 myths). Apart from NEI and CNSC's lists, we were unable to find a single comprehensive list of anti-nuclear myths with counterarguments given.

The counterarguments we were able to find are far from undisputable: almost none of the lists/articles we found link to primary reference literature. On the other hand, scientific journals and nuclear conferences are thriving with peer-reviewed papers discussing every aspect of nuclear power. For instance, on the 9th International Conference on Nuclear Option in Countries With Small and Medium Electricity Grids, among the topics were: Nuclear Energy and the Environment, Nuclear Safety Analyses, Nuclear Fuel Cycle, Radioactive Waste Management and Decommissioning, Emergency Preparedness, Liability and Insurance for Nuclear Damage, [22]. All of those topics included scientific papers discussing facts which are commonly used in debunking anti-nuclear myths.

We conclude that there is an obvious lack of cooperation between nuclear advocates and nuclear scientists. This is quite surprising, because in most instances people and organisations engaging in nuclear advocacy are in fact nuclear professionals themselves: members of the industry or the scientific community. But, our analysis clearly shows that results of nuclear research presented in peer-reviewed scientific papers are not used as references in articles dealing with anti-nuclear myths.

To solve this problem, we are proposing a creation of a dedicated hub where academic and industrial specialists with detailed knowledge of nuclear technology could interact with PR specialists with detailed knowledge of public relations. The recipe is simple: academia and the industry shall provide undisputable facts, PR specialists shall present them, and ultimately - journalists should hopefully reference them.

4. Proposed methodology

As can be seen from the previous section, web sites tackling the problem of anti-nuclear myths are sparse and their content is mostly unreferenced. None of the web sites we analyzed conformed to all three criteria we stated: no resources we found referenced any peer-reviewed scientific papers. Moreover, most resources were written 1) by journalists without in-depth understanding of nuclear technology or 2) by nuclear enthusiasts, without help from PR specialists.

In light of this conclusion, we propose creating a new web site which would conform to the criteria we stated in section “Approaching anti-nuclear arguments”. We propose a systematic approach to the problem of anti-nuclear myths: a web site which would contain an exhaustive list of anti-nuclear myths and proper debunking of each myth 1) using peer-reviewed scientific papers and 2) presented by PR specialists.

4.1 Preliminary work

The web site is to contain a list of publicly available anti-nuclear myths. For every myth some basic information should be collected, including:

- who is the original author of the myth (if that is possible to determine)

- which anti-nuclear studies or whitepapers support the myth
- a list of occurrences of the myth (in which publications, on which web sites is the myth mentioned).

After collecting basic information about a myth, the following step is to collect publicly available information challenging that myth. Existing popular articles such as those mentioned in the section on the current situation are to be collected and summarised. When this step is completed, every myth should have been challenged, but not necessarily debunked by scientific method at this point in time. This intermediate step is needed for two reasons:

1. collecting or writing peer-reviewed scientific papers is a time consuming process, so if this step is omitted, the web site we are proposing would be gaining useful content at a very slow pace, and
2. assembling a list of anti-nuclear myths and challenging them with publicly available information (without the scrutiny of scientific method) is still an achievement in itself.

As it is mentioned earlier, the only web sites giving a comprehensive list of analyzed anti-nuclear myths is the Nuclear Energy Institute's list of 46 myths and Canadian Nuclear Safety Commission's list of 34 myths. There are a considerable number of myths circulating in the anti-nuclear community, so improving on NEI's and CNSC's lists is certainly a step in the right direction. Also, NEI's list is written from the perspective of the American nuclear industry and CNSC's list is written from perspective of Canada's nuclear industry, so assembling a list from the European perspective would also be an achievement in its own right.

4.2 Debunking the myths

After collecting all publicly available information about myths, then the real work of debunking the myths by use of the scientific method can begin.

Every myth shall be addressed in two forms:

1. **reference article**: (list of) peer-reviewed scientific paper(s) debunking the myth
2. **popular article**: easily readable overview of the technical article intend for the general public.

The first step of debunking a myth shall be finding a peer-reviewed scientific paper explicitly debunking the myth in question. If such a paper is not found, the next step is to compile a list of peer-reviewed scientific papers debunking any part of the myth and writing an article which connects those papers into one meaningful whole. If the myth cannot be debunked in this way, the last step is writing a scientific paper explicitly debunking this myth and submitting it to the peer-review process by publishing it in a journal or on a conference. The end product of this process is what we labelled as the **reference article**.

It is our aim to reach out to a wider academic and industrial community in order to create partnerships with institutions and individuals which can help us in finding and/or writing quality reference articles. The amount of primary literature in the field of nuclear technology is vast and limited resources available to the authors of this paper are insufficient to handle it. That is why any effort to debunk a meaningful number of anti-nuclear myths has to be a collective effort of the pro-nuclear community.

The reference article, because of the nature of language used in scientific papers, is not suitable for usage in the general public domain. Therefore, the second step of debunking a myth shall be presenting the reference material to the general public in the form of a **popular article**. In this step, PR specialists such as public relations experts, technical authors, popular science lecturers and journalists transform the reference article to a form easily understandable by the members of general public, using plain language, sound and correct analogies and reducing the technical terminology to a more common level. The reference article is therefore simplified and presented by people who do not need to have in depth understanding of nuclear technology, but who do have in depth understanding of language and/or public relations, psychology, argumentation and debate skills, etc. We can be reasonably confident to expect that such a popular article will generate the greatest possible effect by being as understandable to the layman as possible.

5. Nuclear-myths.org

Efforts to realize a project described in the previous section are well under way. A web site was created at the address http://www.nuclear-myths.org/ and all needed infrastructure was set up. The preliminary work described in section 4.1 of this paper is currently underway: myths are being collected and organized, together with publicly available information challenging the myths. The results of this work are to be presented at the European Nuclear Conference 2012 in Manchester, at which point the web site will be opened to the public.

5.1 Plans for the future

After finishing the preliminary work and unveiling the web portal at ENS 2012, our plan is to start contacting members of the academia and industry professionals around Europe, and find those willing to engage in the project to build an exhaustive database undisputably of debunked anti-nuclear myths. After a sufficient number of myths is debunked, articles will be translated into selected languages and offered to national nuclear societies for usage in pro-nuclear advocacy and education.

6. Conclusion

Continuous strengthening of anti-nuclear movement over time implies that efforts of nuclear advocates are insufficient. While not all anti-nuclear statements are disprovable, some can be show to be false or misleading. One of avenues that could be taken to improve industry resistance to attacks from anti-nuclear camp is by debunking some anti-nuclear myths using peer-reviewed scientific papers and then presenting results of this debunking with aid of PR professionals. In this paper we presented an idea of a web site to which any anti-nuclear activist, journalist, politician or member of general public can be referred to if he cites any of anti-nuclear myths. We hope that nuclear-myths.org is a serious step in direction of realising that idea.

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THE INTERNATIONAL PROJECT ON INNOVATIVE NUCLEAR REACTORS AND FUEL CYCLES (INPRO)

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ABSTRACT

The IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was established in 2000. INPRO cooperates with Member States to ensure that sustainable nuclear energy is available to help meet the energy needs of the 21st century. INPRO is part of the integrated services of the IAEA provided to Member States considering initial development or expansion of nuclear energy programmes. By October 2012, INPRO membership has grown to 38 members. INPRO is currently implementing four major projects: 1) National Long Range Nuclear Energy Strategies, 2) Global Nuclear Energy Scenarios, 3) Innovations and 4) Policy and Dialogue. Activities underway during the 2012–2013 biennium are discussed, including the INPRO Collaborative Projects SYNERGIES and ROADMAPS, the INPRO Dialogue Forum, the INPRO methodology and transportable nuclear power plant studies. INPRO's strategic vision for the development of the Project to 2017 is outlined.

1. Introduction

The IAEA fosters the peaceful use of nuclear power by supporting existing and new nuclear programmes around the world, catalysing innovation and building indigenous capability in energy planning, analysis, and nuclear information and knowledge. The IAEA provides integrated services to Member States on nuclear power and fuel cycle through the Planning and Economic Studies Section (PESS), the Integrated Nuclear Infrastructure Group (INIG) and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO). These integrated services include: 1) helping Member States to make knowledgeable decisions on energy supply options with the help of energy planning so they can independently chart their national energy future (PESS), 2) assisting Member States in building the necessary institutional and technical infrastructure for the initial deployment of nuclear power (INIG), and 3) assisting Member States in assessing proposed nuclear energy systems holistically from a long-term strategic perspective (INPRO).

1.1 About INPRO

The IAEA's International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) was established in 2000 as a flagship project, through an IAEA General Conference resolution with the goal of ensuring a sustainable nuclear energy supply to meet 21st century needs. To achieve this, INPRO brings together nuclear technology holders and users to consider innovations in nuclear reactors, fuel cycles and institutional approaches that underpin national and international strategies leading to sustainability.

INPRO plays an important role through fostering a broader understanding of the future development of nuclear energy from national, regional and global perspectives. It achieves this through evaluation of innovations in nuclear technologies and institutional arrangements and national nuclear energy system assessments (NESA). INPRO has over 11 years of success as a collaborative international project, with continuously increasing membership and regular acknowledgment in General Conference resolutions. The three pillars of its activities are: the INPRO methodology, INPRO Collaborative Projects and the INPRO Dialogue Forum.

1.2 Membership and joining INPRO

INPRO is a membership-based project, guided by a Steering Committee, in which INPRO Members are represented. The INPRO Group in the IAEA's Department of Nuclear Energy coordinates activities with IAEA Member States that have joined the project. INPRO is primarily funded through extrabudgetary contributions. By October 2012, 37 IAEA Member States and the European Commission were INPRO Members (see Fig 1).

IAEA Member States and recognized international organizations can join INPRO. Benefits of membership include: 1) international cooperation facilitated by INPRO, 2) full access to INPRO tools, models, publications, expertise and member network, 3) participation in the INPRO Dialogue Forums and in Collaborative Projects, 4) results and findings of studies and 5) contribution to the future planning of INPRO through representation in the Steering Committee.

The **membership application process** includes three steps: 1) the Head of the national organization responsible for nuclear energy, or the international organization, submits a written request to the IAEA Deputy Director General for Nuclear Energy, announcing interest in joining INPRO as a Member; 2) agreement on the participation mode is reached through consultations; and 3) the Member State or international organization is officially recognized as an INPRO Member.

Fig 1: History of INPRO membership

1.3 INPRO participation, Steering Committee and international collaboration

There are several modes of participation in INPRO. A Member can: 1) provide extrabudgetary financial contributions, 2) provide cost-free experts to work in the INPRO Group at the IAEA; 3) perform a national nuclear energy system assessment using the INPRO methodology, or 4) actively participate in INPRO Collaborative Projects. The INPRO Steering Committee meets regularly to review progress and provide guidance. Every two years, it endorses the INPRO Action Plan which defines future tasks and priorities.

Owing to the cross-cutting nature of INPRO, close and effective cooperation with other IAEA programmes is emphasized, ensuring exchange of information and cooperating on topics of common interest. INPRO is also collaborating with other international initiatives and institutions, the Generation IV International Forum, the International Science and Technology Centre, the Organization for Economic Cooperation and Development's Nuclear Energy Agency, the World Nuclear Association and the European Sustainable Nuclear Energy Technology Platform.

1.4. INPRO's added value and Development Vision 2012–2017

INPRO has several unique strengths. It provides reference scenarios for sustainable regional and global nuclear energy development. It also assists Member States directly in the development of national long range nuclear energy strategies. Moreover, it provides information on technical and institutional innovative approaches. The INPRO Dialogue Forum offers an established mechanism through which nuclear technology holders and users can jointly consider global nuclear energy sustainability and nuclear energy innovations.

The INPRO Development Vision 2012–2017 presents the view on how INPRO contributes, consistent with the IAEA Nuclear Energy Basic Principles, to global nuclear energy sustainability. In its *Medium Term Strategy* for 2012–2017, the IAEA envisages a focus on areas where it can have a unique impact. INPRO's holistic approach enables it "to facilitate collaboration among interested Member States in the joint development of evolutionary and innovative nuclear energy systems" [1]. INPRO's activities are centered on the key concepts of global nuclear energy sustainability and development of long range nuclear energy strategies (see Fig 2).

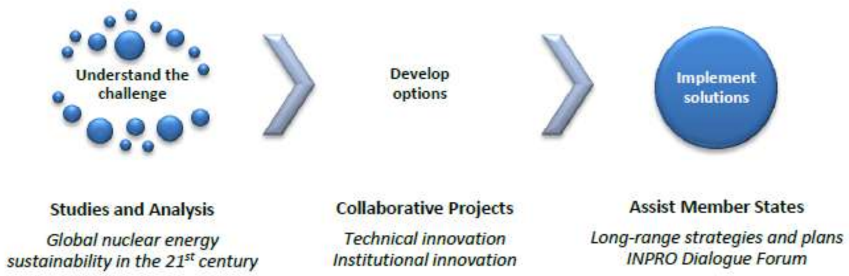

Fig 2: Global nuclear energy sustainability and INPRO's contribution

INPRO seeks to broaden the understanding among Member States of the challenges involved in achieving global nuclear energy sustainability. It achieves this through various means including technical assessments that help to promote the contribution of nuclear energy as part of broader UN goals for sustainable development in the 21st century. It also seeks to develop a shared understanding of options that enhance sustainability through collaborative studies of proposed technical and institutional innovations. INPRO publishes findings that assist its members and the broader Member State community so they can take optimal advantage of anticipated innovations and of international collaboration in their national long range nuclear energy strategies and development.

2. Developing long-term nuclear energy strategies

2.1 Initial considerations

Energy planning aims at ensuring that decisions on energy demand and supply involve all stakeholders, consider all possible supply and demand options, and are consistent with overall national sustainable development goals. The concept of sustainable development encompasses three interdependent and mutually reinforcing pillars: social development, economic development and environmental protection, linked by effective government institutions.

The IAEA assists Member States in capacity building in national and regional energy system analysis and planning, so they can independently draft their national energy strategies. Depending on a country's indigenous resource endowment, sustainable development objectives and social acceptance factors, the energy system analyses may or may not include nuclear energy in its future energy mix. The IAEA offers a set of computer models to develop potential and plausible projections of energy demand and corresponding supply mixes. The INPRO methodology supports holistic nuclear energy system assessments. Long range and strategic planning for energy system evolution including nuclear energy requires a sound understanding of technology evolution and innovation, economic development, environmental constraints and social acceptance. Adopting a nuclear power programme has intergenerational implications and obligations extending well beyond 100 years [2].

When addressing nuclear energy strategies, we define a strategy as being a plan of action conceived to achieve a particular goal. The strategic focus lies beyond the goal of a single nuclear power plant and it is centred on the medium- to long-term. A nuclear energy strategy covers the whole nuclear energy system over many decades. A nuclear energy system may eventually include all facilities of the nuclear fuel cycle from mining/milling, conversion, enrichment, fuel fabrication, electricity generation or other energy products, through to final end states for all wastes and permanent disposal of spent fuel and/or high level waste, and related institutional measures including legal frameworks and related regulatory bodies. In planning terms, a strategy covers the whole nuclear energy programme, i.e. all projects.

In many countries, particularly where the energy economy is a fundamental role of government, there is a structured hierarchy of national planning documents, often linked to the national development plan. In countries with so-called “deregulated” or “liberalized” energy economies, nuclear development is driven by a complex interplay of financing resources, regulatory structures and government sponsored R&D programmes. In those cases, the government’s role is to affect and maintain fair business and financial practices, safeguard the public and environment and indirectly stimulate strategic outcomes through targeted incentive programs of various sorts (e.g. tax incentives, finance guarantee programs and other approaches). Under those circumstances, nuclear energy decisions and implemented portfolios are owned and organized by private or public-private enterprises.

2.2 Importance of long-term strategies

Why are long-term nuclear energy strategies important?

Because the characteristic times of drivers and implications in society, technology, resources and economics are also long-term.

According to INPRO’s definitions, a nuclear energy system is sustainable in the long-term if it can operate at least until the end of the 21st century. Long-term nuclear energy strategies are important, as opposed to short-term strategies, for several reasons:

***Long-term* policy considerations are key drivers of nuclear energy.** Examples include environment, competing fuel supplies, expected energy demand and security of energy supply. Environmental considerations, including climate change, are long-term phenomena of 50 to over 100 years. Economic availability of competing fossil fuels is envisaged for a period of 20 to 100 years. Global and national population growth and economic growth, with associated increases in energy intensity, are estimated two generations ahead, i.e. over 50 years. The ultimate energy security objectives are long-term national and international value propositions. Nuclear energy, as part of a sustainable base-load energy supply, can help meet those objectives.

Nuclear energy has a *long-lasting* technical infrastructure lifetime. For instance, one nuclear power plant requires 15 years of planning, financing and construction; it operates for 40 to 60 years (or longer), and decommissioning and waste management may take over 15 years. A full nuclear energy programme extends over 100 years. Therefore, a country which adopts nuclear power makes a long-term commitment, spanning several generations and accepts consequences that could extend well beyond a century (unless long lived wastes are exported). By considering long-term issues related to institutional measures, such as legal and regulatory frameworks, human resource development, the role of national industry, political commitment and public acceptance, a country can develop an enhanced understanding of the required actions to maintain a sustainable nuclear power programme. Dealing with nuclear waste as defined in the INPRO methodology enables a country to develop a better understanding of the long-term commitment associated with its waste management obligations and the available options to reduce the burden on future generations [3].

Becoming a 'welcome member of the nuclear family' takes *considerable time*. This is a soft factor, but one of the most relevant ones. In the nuclear sector, many issues need to be considered in advance. Trust, governmental agreements and reputation are only some of the issues to be considered.

National sustainable development plans are *long-term* policies. Education, urbanization, agriculture, industrialization and health policies are conceived for periods of over 50 years. For example, pension policies may be envisaged for more than 100 years. Industrial and infrastructure development plans are envisaged for 15 to 30 years. Also, the building or transferring of nuclear knowledge, human resources and education plans are made for 15 to 40 years.

***Long-term* strategies are required because of the large investment volumes.** In this process, the whole nuclear energy system envisioned needs to be considered. The typical payback time is several decades per operating unit and there is a high risk of large stranded investments which needs to be taken into account. Considerations about how to optimally "pool the risk" over decades are important for the host economy.

Finally, implementation of technical and institutional innovation requires *decades* of effort. Ensuring the sustainability of nuclear energy needs both technological and institutional innovative approaches. Technology innovations are being pursued nationally or through international initiatives, such as Generation IV International Forum and the European Sustainable Nuclear Energy Technology Platform. INPRO contributes to, and complements these efforts. However, these technical innovations, such as Generation IV reactor designs need between 20 to 40 years in order to be deployed. Institutional arrangements are an important part of the nuclear energy system, including bilateral or multilateral agreements, treaties, national nuclear legislation and regimes, safety standards, new regulatory and licensing approaches, and international conventions. Deploying new reactor designs may require innovative institutional approaches, in particular for transportable small and medium-sized nuclear power reactors.

3. Status of INPRO projects

3.1. Project 1: National long range nuclear energy strategies

For 2012–2013, the INPRO Action Plan identifies activities in four INPRO projects, on the basis of: 1) guidance from IAEA General Conference Resolutions, 2) guidance from the INPRO Steering Committee and 3) in line with the IAEA's Programme and Budget for 2012–2013. The objective of Project 1 is to assist Member States in building national long range nuclear energy strategies and in long range nuclear energy deployment decision-making through the INPRO methodology and other tools [4].

The **INPRO methodology** identifies a set of basic principles, user requirements and acceptance criteria in a hierarchical manner as the basis for the assessment of the sustainability of a nuclear energy system. If these are met, the nuclear energy system represents a sustainable energy source. If not all components are met, a nuclear energy system may still represent a useful energy supply system, but may need to change and evolve to become improve sustainability over time. The results of a nuclear energy system assessment could be used to help frame a policy debate or serve as technical guidance. INPRO has a holistic approach to assess nuclear energy systems in seven areas: economics, infrastructure, waste management, proliferation resistance, physical protection, environment and safety of reactors and nuclear fuel cycle facilities (see Fig 3).

Fig 3: Structure of the INPRO methodology

A **nuclear energy system assessment (NESA) support package** has been developed and continuously reviewed and enhanced. Six national assessments have been completed: Argentina, Brazil, India, and Republic of Korea (as technology developer) and Armenia and Ukraine (as technology users). A multinational assessment (the ‘Joint Study’) has been performed by Canada, China, France, India, Japan, Republic of Korea, Russian Federation and Ukraine [5]. The results are documented in IAEA publications [6, 7]. In 2012, four further INPRO members are conducting or have initiated NESAs using the INPRO methodology.

In 2011, **Belarus,** a nuclear ‘newcomer,’ completed a two-year review of its planned nuclear energy system with support from the Russian Federation. The assessment consists of the first two nuclear power plants expected to come into service in 2016 and 2018 and the associated waste management facilities. It is an exemplary assessment for ‘embarking countries’ because of its full scope covering all INPRO assessment areas.

The Atomic Energy Committee of **Kazakhstan** requested IAEA support in conducting an assessment of existing and potential nuclear power technologies. The main aim of this assessment is to confirm that Kazakhstan’s strategic plans to develop nuclear power are focused on ensuring the availability of adequate energy resources for sustainable development. It is planned to perform a full scope NESA.

A NESA in **Ukraine** was initiated in 2011. It aims to define the potential role of nuclear energy and model various options for nuclear energy development, as well as undertake a limited scope assessment, focusing on economics, infrastructure and waste management. The final report of this project is expected in 2013.

Indonesia is planning to include nuclear power in its energy mix to strengthen the country’s energy security and mitigate climate change. The NESA will serve as a foundation for the national nuclear energy agency (BATAN) to assess the planned national nuclear energy system, i.e. fuel cycle facilities for the front end (mining/milling, conversion, fuel fabrication) and back end (waste management, potential spent fuel export or repository), with several options regarding the reactor types. Indonesia started the assessment in 2012, with a limited scope to familiarize the team with the approach and available tools. In 2013, a full scope NESA activity is planned.

A **2nd edition of the INPRO methodology** is planned. The objective is to revise and update the INPRO methodology and to publish it as an IAEA report. The two main tasks are: 1) to technically update the INPRO Manual and 2) to revise and enhance the INPRO methodology [8]. A draft White Paper dated July 2012 was presented to the 19th SC meeting and a consultancy meeting will take place in November 2012 at the IAEA [9].

The concluded **Collaborative Project (CP) PRADA** (*Proliferation Resistance: Acquisition/Diversion Pathway Analysis*) focused on the development of methods for identification and analysis of pathways for the acquisition of weapons-usable nuclear material, and on the evaluation of proliferation barriers. It concluded that the robustness of barriers is an integrated function measured by determining whether the safeguards goals can be met. The **new CP PROSA** (*Proliferation Resistance and Safeguardability Assessment Tools*), a follow-up project, will develop a coordinated set of Generation IV International Forum/INPRO tools, identify the interface of the Proliferation Resistance and Safeguardability assessment tools of both methodologies and examine their validity.

The completed **CP ENV** (*Environmental Impact Benchmarking Applicable for Nuclear Energy System under Normal Operation*) developed among others a benchmark of methodologies for the ranking of radio-nuclides in terms of human health related impact. As a follow-up project, the **new CP ENV-PE** (*Environmental Impact of Potential Accidental Releases from Nuclear Energy Systems*) aims at providing a framework to assess radiation doses and related risks to human health caused by potential radioactive releases during an accident in a nuclear power plant.

3.2. Project 2: Global nuclear energy scenarios

The objective of Project 2 is to develop global and regional nuclear energy scenarios, on the basis of a scientific-technical analysis, that leads to a global vision on sustainable nuclear energy development in the 21st century.

The natural abundance of thorium in comparison to uranium, its chemically inert nature, superior thermal conductivity and advanced neutron characteristics make thorium based fuel cycles attractive. The **CP ThFC** (*Further Investigation of the U^{233}/ Th Fuel Cycle*) was concluded in 2010. This INPRO study investigated the potential role of thorium in supplementing the uranium–plutonium fuel cycle under several scenarios that assumed a significant increase in the use of nuclear energy in the world. While thorium fuel fabrication and irradiation experience cannot yet be considered as commercially 'mature', there is sufficient knowledge and experience today for a technically feasible implementation of a 'once through' thorium fuel cycle [10].

The **CP FINITE** (*Fuel Cycles for Innovative Nuclear Energy Systems based on Integrated Technologies*) provides an overview of technically feasible and economically sound advanced and innovative nuclear fuel and fuel cycle options. Existing national strategies and technologies for the fuel cycle back end, planned evolution, and corresponding databases will be analyzed through realistic scenarios of nuclear energy demand. This on-going project will be concluded soon.

The **CP GAINS** (*Global Architecture of Innovative Nuclear Systems based on Thermal and Fast Reactors including Closed Fuel Cycles*), completed in 2011, addressed technical and institutional issues to develop a global architecture for sustainable global nuclear energy in the 21st century. The project developed a framework, including a methodological platform, performed sample studies and indicated potential areas for application of the GAINS framework for the dynamic assessment of a transition to future sustainable nuclear energy system. This project has shown that the sustainability of nuclear energy system will be easier to achieve on a global scale if technology users and suppliers collaborate effectively. The final project report has been approved for publication in the IAEA Nuclear Energy series and is currently in print. The draft report is available on the INPRO website. A follow-up project (SYNERGIES) was launched in 2012 [11].

The **new CP SYNERGIES** (*Synergistic Nuclear Energy Regional Group Interactions Evaluated for Sustainability)* will quantify the benefits and issues of collaboration among countries in transitioning to a globally sustainable nuclear energy system and identity the transition scenarios which offer a 'win-win' strategy for both, technology holders and users. The objective is to identify and evaluate mutually beneficial collaborative architectures and the driving forces and impediments for achieving sustainable nuclear energy systems by applying and enhancing the analytical framework developed in the GAINS project. The SYNERGIES project is implemented in coordination with the Planning and Economic Studies Section, the Integrated Nuclear Infrastructure Group, the Nuclear Power Technology Development Section, the Division of Nuclear Fuel Cycle and Waste Technology, Department of Technical Cooperation and the Department of Nuclear Safety and Security of the IAEA. Representatives of 23 IAEA Member States and International Organizations participate in this project.

The **new CP ROADMAPS** (*Roadmaps for a Transition to Globally Sustainable Nuclear Energy Systems*) will start in 2013. The proposed 'umbrella' activity will integrate the outputs of several INPRO activities to develop roadmaps, i.e. flowcharts of the actions/scope of work/timeframes and drivers for particular stakeholders, needed for a transition to globally sustainable nuclear energy system. The global R&D review and new infrastructure data will be used as input for modelling of possible transition scenarios from the current fleet of reactors and nuclear fuel cycles to a future globally sustainable nuclear energy system, for which the analytical framework (codes, data and scenarios) developed in GAINS and SYNERGIES may be used.

3.3. Project 3: Innovations

The objective of Project 3 is to investigate innovations in selected nuclear energy technologies and related R&D and in innovative institutional arrangements to be deployed in the 21st century and to support Member States in pursuing such innovations. The following CPs have been completed: **COOL** (*Investigation of Technological Challenges related to the Removal of Heat by Liquid Metal and Molten Salt Coolants from Reactor Cores Operating at High Temperatures*), **AWCR** (*Advanced Water Cooled Reactor Case Studies in Support of Passive Safety Systems*), **PGAP** (*Performance Assessment of Passive Gaseous Provisions*), **DHR** (*Decay Heat Removal System for Liquid Metal Cooled Reactors*) and **SMALL** (*Implementation Issues for the Use of Nuclear Power in Small Countries*).

Two new CPs are considered in this area: **RISC** (*Review of Innovative Reactor Concepts for Prevention of Severe Accidents and Mitigation of their Consequences*) and **LOADCAPS** (*Load Following Capability in Innovative Designs*). A report on the study "*Legal and Institutional Issues for Transportable Nuclear Power Plants*" (**TNPP**) presenting some options for deployment of transportable factory fabricated modular small and medium-sized reactors and considering legal and institutional challenges connected with the possible deployment of such kind TNPPs is expected to be published in early 2013. Under the 2012–2013 Programme, the following activities are planned: 1) Transportable Nuclear Power Plants II - Case Study on Factory Fuelled Small and Medium-sized Reactors and 2) Investigation of options for a new international project on fast reactors, fuel cycles and materials R&D.

3.4. Project 4: Policy and Dialogue

The objective of Project 4 is to provide guidance and policy coordination to Member States, coordination with other international organizations and initiatives and to bring together technology holders and users to share information on long range nuclear energy system strategies, global nuclear energy scenarios and technical and institutional innovations. The main activity in this project is the INPRO Dialogue Forum on Global Nuclear Energy Sustainability.

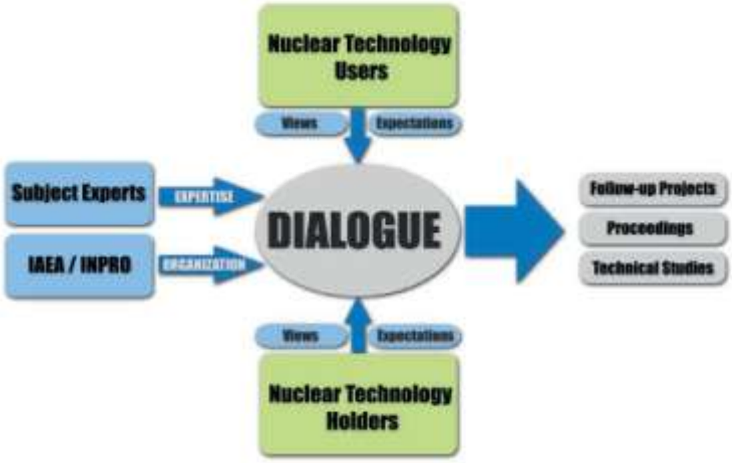

Fig 4: Schematic illustration of the INPRO Dialogue Forum

The **INPRO Dialogue Forum on Global Nuclear Energy Sustainability** brings together technology users and holders from all interested IAEA Member States so that technology holders can better understand the needs and concerns of technology users and users can better understand the possibilities and limitations of technology holders associated with the development and deployment of innovative nuclear energy system (see Fig 4). The INPRO Dialogue Forum is open to all IAEA Member States and involves a variety of stakeholders, including governments, national and international organizations, regulators, vendors, operators and researchers. All Dialogue Forums have been supported by the IAEA Technical Cooperation programme. This facilitates the participation of developing countries and allows them to engage in discussions on global nuclear energy sustainability otherwise not possible.

The first two INPRO Dialogue Forums were held in 2010 and focused on 1) socioeconomic and macroeconomic factors, proven technology and safety approaches for innovative nuclear energy systems and 2) multilateral approaches to nuclear energy deployment with focus on institutional challenges. The third Dialogue Forum was held in 2011 on 3) common user considerations for small and medium-sized reactors. In 2012, two Dialogue Forums took place. The fourth Dialogue Forum focused on 4) drivers and impediments for regional cooperation on the way to sustainable nuclear energy systems. The fifth Dialogue Forum and the first to be hosted by a Member State took place in August 2012 in Seoul, Republic of Korea and focused on 5) global nuclear energy prospects in the post-Fukushima Era.

4. Conclusion

Since its inception in 2000, INPRO has provided added value to its members and to the larger Member State community through active engagement in projects of immediate interest to the sustainable development of nuclear energy. INPRO provides this value through services to INPRO members including training in nuclear energy system assessment (NESA) using the INPRO methodology; by providing a mechanism for direct member collaboration on technical projects of mutual interest including long-term strategic studies on the development and analysis of global sustainable nuclear energy systems; and through topical Dialogue Forums that are open to all IAEA Member States and to recognized international organizations. In each case where applicable, opportunities to promote responsible interaction between technology holder and user communities is encouraged. This approach benefits the international community by increasing the prospects for forming strategic partnerships that promote shared and coordinated sustainable nuclear energy development goals.

INPRO's activities are part of the integrated services the IAEA offers to Member States at different stages of development of their nuclear power programmes so that they can use nuclear energy in a safe, secure and reliable way. These services also include energy planning and support to countries developing new nuclear energy programmes. INPRO focusses specifically on strategic nuclear energy issues and the long-term perspective to help achieve sustainable outcomes. The necessity of taking a 'long range view' is inherent in the nuclear technology endeavour: timescales of environmental consequence of carbon and other emissions, remaining abundance of competing economic fossil fuel resources, length of technology lifecycles and infrastructure commitments, level and length of effort required to develop sophisticated nuclear institutional cultures and human resource base and other long-term propositions, directly drive and influence nuclear development. In the broad sense of the global nuclear energy endeavour (from cradle-to-grave), the nuclear technical lifecycle eclipses even large conventional hydropower development. INPRO emphasizes the long term perspective when assisting its nuclear newcomer members with NESA projects. Building even a single nuclear power plant implies a century of commitment to infrastructure, institutions and education and, in most cases, well beyond that time frame. In the case of a large nuclear economy, a few centuries of technical/institutional commitment are implied. INPRO will continue to provide services to its members and the larger interested community and has a Development Vision in place through 2017 to direct its mission scope.

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WHAT LIES BEHIND THE CLAIM FOR TRANSPARENCY ?

Nathalie Guillaume, Communication division CEA (France)

Everybody talk about transparency nowadays.
The basic meaning of transparency could be summarized as openness. If you are transparent enough, your topic could be seen and known by everybody. Then it would just be a question of mind aptitude, organization and communication ?
But the word carries on other subtle meanings. For example, when somebody is called "transparent", you don't even notice him, as he is so lacking in personality.
On the other hand, in movie industry, transparency is a technique which helps to create illusion through false film set.
So nothing to do obviously with the world of nuclear!

When we look closer, we notice that two sorts of people use the term of transparency. Some politics or institutions use it and some NGO's either. But what about the general public ? What are the French people waiting for?
Tranparency often appears to be a claim. But is it a claim for more understandable information ? Or a claim for more truth? Is it a question of attitude, providing more external visibility, access to comprehensive information ? Of a question of trust ? Do people believe that nuclear lacks ethics ? Is there a morality issue in this claim? What is the general public waiting for as regards information from the nuclear actors? Is the topic connected to wider issues ?

"Nuclear accident: always a man-made one"

The monthly scientific journal "La Recherche" published an article on October commenting on the results of a Japanese independent inquiry commission about Fukushima. The title was: "Can /or may nuclear be transparent ? ". The article didn't answer its own question. But indeed the Fukushima accident was definitively described as "a man-made accident", although caused by a huge earthquake and an hellacious tsunami. Indeed, even during ordinary times, we ourselves often tend to be apologetic. But how is the general public feeling about this?

To tackle more deeply these issues, the CEA (French atomic and alternative energies Commission), has launched a qualitative survey on last summer*.
Indeed, through qualitative surveys, you can collect people own words, their representations; the methodology (group discussion with a professional “host”) is well adapted to explain attitudes (rational as well as irrational ones), to understand them more deeply, to gather some qualitative information that you cannot get through quantitative surveys (based on interviews on samples).

Trust and the claim for transparency

Investigating on transparency lead us to study the basis of trust. The following answers only work as regards France, since the question of trust is a very cultural one.

What is the most frightening in general?
Violence, illness, crisis, pollution (especially the new types we cannot monitor: electromagnetic waves come in first, followed by the risks connected to the big food industry, and big chemical industry). The risks brought by aspartam, asbestos, palm oil, paraben, bisphenol … are worrying ones.
Nuclear as a risk doesn’t appear during the first round of conversation.
The closest risks are major worries, that is to say, whatever comes from food, can give cancer, all that can be disseminating, and cannot be managed.
These are different from the “faraway risks”: major oil pollution, wastes in general.
Nuclear wastes appears then in the wording. Especially as regards the future of our children.
“We master only what has already happened. But the wastes we don’t master them” noticed a participant.

Fear tempered by nationalist attitudes
Nuclear risk is considered to be a faraway dangerous risk, but well managed. National pride appears to be prominent to soothe the possible fear. Indeed, there are few topics left for national pride at the moment in the country. Nuclear “savoir-faire” is one of them. Since “we are the first, we master the risks”.
Do people trust the State? It depends on the topic. As regards nuclear, it is definitely “Yes”.

Mistrust lead by disbelief in industry
One great asset for nuclear in France is surely that it is a state-owned industry.
State cares and fixes it. Anyway, “nuclear is so dangerous that it is impossible not to care about it. And if you care, you master”, mentioned one participant.

**Ipsos/CEA (*July 2012- *a qualitative group organized in Paris).*

On the other hand, people are very reluctant towards industry; the world lobby is only used by the group, for big private corporations, such as food industry and chemicals.

Nuclear acceptance: a strong relationship with knowledge

The nuclear world is a spot of high level experts, with their own language, high schools, codes, networks (*cf. qualitative survey on the image of nuclear- Ipsos /CEA September 2010*). It is a unique world gathering nuclear operators, experts, controllers, high civil servants, part of the same family.

In France, as in every country, the level of education, as well as position in society, is a driving force to nuclear acceptability.

A methodology point has to be noticed: all the working-group participants had a minimum level of education, which could orientate their comments on the risks.

The poor scientist is trustworthy

In general people trust experts: that is to say, first of all, scientists, doctors (while mistrust towards drugs is growing), NGO'S (needed to give balanced information on nuclear but not really trustful) and teachers*.

A good trustworthy scientist is the poor one, who stands apart from industry.

The need for information has evolved

The amount of information on nuclear has never been so bulky.

People's consciousness of nuclear risks has raised. But they definitively make a difference between the Chernobyl information times and nowadays.

On the other hand some participants of the study mentioned that "now that we have talked a lot about safety and accidents, they (the authorities) will really take care". So it is a good point.

What breeds trust and mistrust in France ?

No hesitation about it among the participants of the study, what builds trust is:

- Creating rules, norms, legal requirements.

-Even if the participants are aware that they don't really understand what the figures mean, with no comparisons available, the existence of norms are comforting.

How to be transparent ?

What is required to be called "transparent"?

-First of all is "traceability". Feedback of experiences is prominent for people.

- Recognizing mistakes (mea culpa).

-Then admitting the risks. Explaining how we can manage them.

**Ipsos/CEA annual barometer -November 2012*

-Telling all about budgets, tests, refurbishing…
-Developing arguments on advantages and drawbacks, so as people are able to choose (some quoted the drugs' explanatory leaflets).
-Avoiding one voice communication on advantages.

-On the other hand, some participants also expressed the needs to be reassured, as a part of a transparency process: they want to know that everything has been evaluated.
-Since transparency is "Truth", it is not always comforting.
(Some of them appeared not really keen on knowing everything). They had rather trusting government). Too much transparency is not always good (it might be a way to get rid of responsibility).
-Most of them want explanations on what will happen (with milestones, timetable…).
-They need to know the historical part, and what may be the future.
-Finally, they claim for comparison with other countries.
That is to say: getting a viewpoint to understand.

Who could be transparent for them ?
-Maybe an independent NGO.
-Some laboratories.
-Some governmental controllers.

Who couldn't ?
-A private company definitively couldn't (oil companies, chemicals are quoted)
If the question is asked about nuclear:
-The nuclear industry at large is said to be transparent.
-But on the other hand all that is related to nuclear is unclear, impossible to understand.

What about "Transparency" in social media ?
Social media are usually a place where political expression is active, and where opposition to nuclear is fairly developed.
The participants praised social media and internet as the voice of the People.
However, they are dubious about the quality of information found there.
They don't really trust what they can find there.

In conclusion, no real claim for transparency, or no strong mistrust about nuclear appeared through this qualitative study, thanks to the strong links with public authorities and the historical pride about nuclear in France. However a strong challenge on messages, attitudes in communication is facing us: recognizing errors when necessary, without any guilty feeling.

HOLISTIC AND INTEGRATED ANALYSIS OF NUCLEAR ENERGY FOR A SUSTAINABLE ENERGY SUPPLY

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ABSTRACT

This study aims to provide a holistic analysis and evaluation of the nuclear energy system in terms of technical, environmental and economical aspects. The generation of nuclear electricity adopting advanced LWR is compared with readily available fossil and renewable energy systems. The nuclear technology system over the entire life cycle is analysed. Similarly, fossil based electricity generation systems and renewable energy systems are analysed in the same way. The different technologies are then classified according to the way the emissions affect the environment. Afterwards, the levelised electricity generation costs of the technologies are calculated and the external costs resulting from the release of emissions are internalized. Subsequently, the total costs of the different energy technologies are calculated and compared. Furthermore, the interdependencies between different parts of the energy system are analysed using an energy system model. For this purpose three different scenarios from German-European perspectives with a uniform European target of climate control are determined. All scenarios take into account the interrelation between German and European energy system. The current national and European energy policy and its technology-related objectives are examined in two scenarios. They differ merely in the life time of existing nuclear power plants. In the third scenario no technology-related objective is considered. The result of the technology-related analysis shows that, compared to other technologies, nuclear energy has the lowest total cost (ca. 53 $€_{2007}$/MWh). Only a rise in investment costs and mining of low grade uranium move the position of nuclear energy costs to the middle zone. The consideration of severe accidents of nuclear power plant has in monetary terms only negligible influence on the total costs of nuclear energy. The total-cost comparison reveals that, in general, the difference in total-cost is ascribed to the internalisation of external costs of up to 30 $€_{2007}$/MWh for fossil-fuel technologies, while to higher investment costs of up to 200 $€_{2007}$/MWh for renewable energy. The key findings from the integrated assessment of the nuclear technology in the European energy system model can be summarised as follows: due to the reduction of greenhouse gas emissions (by 80 % in 2050 compared to the year 1990), the use of low-carbon technologies increase. The results of all scenarios show that the share of nuclear power in electricity generation will be at least at the same level as today. In all three scenarios, the external costs decrease compared to today's level.

1. Introduction

Following the accidents at the Fukushima Daiichi nuclear facility, Germany reviewed its nuclear policy and the Bundestag passed a law that mandates a total phase-out of nuclear power by 2022. However, the European Commission believes that the safe use of nuclear power continues to be an option for the decarbonisation of energy supply. In light of the merging energy market in Europe, all decisions of neighbour countries are relevant to national energy systems. Therefore, the future role of nuclear power should be considered at European level. The major reasons for rejection and support of nuclear power in Europe are the concern of the contribution of nuclear energy to decarbonisation, the different assessments of the risks of nuclear accidents and the perception of nuclear power in ecological, economic and social aspects.

This study has two main objectives. The first is to conduct a holistic analysis and assessment of the nuclear energy on the basis of a direct comparison with fossil and renewable technology systems in technical, economic and ecological aspects. The second objective is to analyse the role of nuclear energy played in greenhouse gas reduction in the European energy system.

2. Methodology and Approach

In accord with the definition of weak Sustainability, derived from the concept of sustainable development by the Brundtland Commission /WCED 1987/, the relative sustainability is measured using an environmental-economic approach. The Enquete-Commission of the German parliament concluded that total costs (sum of private and external costs) are an appropriate indicator to account the overall resource consumption. Thus the total costs are a suitable measure for the assessment of the relative sustainability of different energy technologies and systems. Another approach to quantify the relative sustainability is the multi-criteria decision approach. Both approaches, the total cost approach and the multi-criteria decision approach, are often used to access the relative sustainability (see /Schenler et al. 2009/, /NEEDS 2005 – 2009/ und /Markandya 2010/). The workflow and structure of this study follow the processes shown in Figure 1. Based on the comprehensive analysis of different energy technologies, an integrated analysis of nuclear energy is conducted on the assumption of a uniform greenhouse-gas-reduction-goal. The integrated analysis aims to determine the full costs of the energy system through three different scenarios.

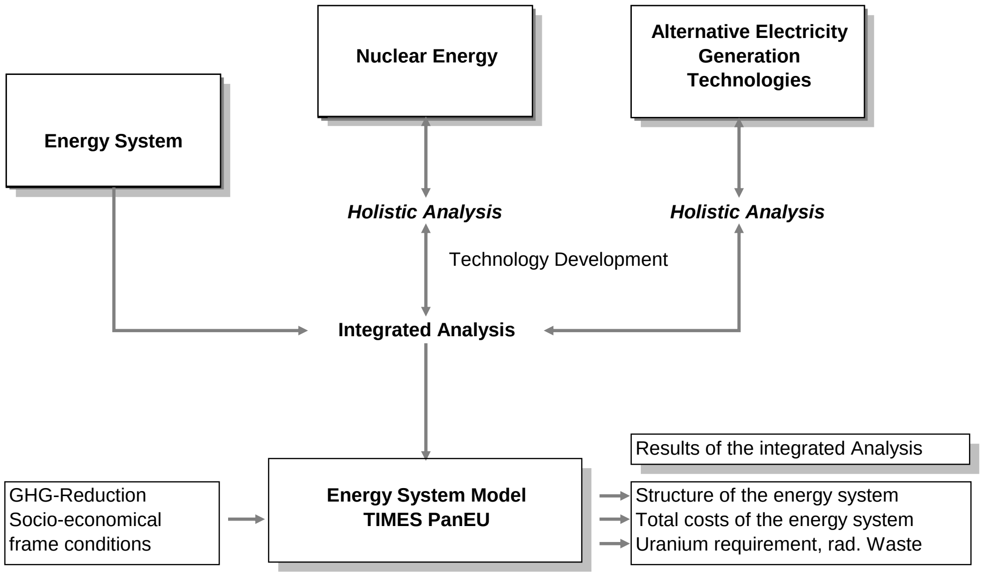

Figure 1: Schematic representation of the holistic-integrated structure

Holistic Analysis

The holistic analysis is a methodology for quantifying the levelised utilisation of resources and the environment as well as the levelised costs of energy systems. It is Based on a full scope Life Cycle Assessment (LCA) (incl. risk assessment), that provides an evaluation of energy supply options with regard to resource, health and environmental impacts. The health impacts and environmental damages, arising from air pollution, cause economic losses which are not accounted for in electricity prices (so called external costs). The sum of the external costs and the levelised power generation costs make up the total costs.

Due to increasing environmental awareness, various LCA`s of energy technologies were done over the last decades. In view of the greenhouse gas effect and the scarcity of resources, the LCA of energy systems focussed on the greenhouse gas potential and the cumulative energy demand. Since the 1970s a number of studies that addressing the greenhouse gas effect and the cumulative energy demand of nuclear energy were published (see also /Sovacool 2008/, /Weisser 2007/ und /Wissel et al. 2007/). Nearly all studies demonstrate that nuclear energy has low cumulative greenhouse gas emissions and low cumulative energy requirements. However, only a few studies took further environmental aspects (e. g. air pollution, waste arisings) into consideration. Until now, no advanced reactor design and prospective dynamics of the nuclear fuel cycle in the field of LCA of nuclear energy technologies have been studied.

The holistic analysis consists of three different levels. The primary level is the parametrised LCA (LCA-Methodology to modify assumptions and technical settings by parameters) of the nuclear energy system. The parametrised LCA are applied to investigate different variants in the nuclear process chain and the impact of prospective frame conditions. Exemplary results of the LCA are environmental impacts and the waste. The emissions of e. g. SO_2, NO_x, PM, Radionuclides are responsible for a higher concentration of air pollutions in the atmosphere and thus also for detrimental health impacts and environmental damage. The external costs resulting from impacts on human health, agricultural crops, biodiversity losses and building materials are monetary quantifiable by dose-response models. The primary level of the holistic analysis ends with the quantified external costs of the nuclear energy system. A model is then developed for the primary level.

The second fundamental level of the holistic analysis is to calculate the levelised power generation (private) costs. The power generation costs are calculated by using the Net Present Value (NPV) methodology over the complete process chain of the energy systems.

The third level of the holistic analysis is the assessment of severe accidents of nuclear energy. The risk calculation of the severe accidents is computed using the simplified methodology from the Paul Scherrer Institute[1]. The risk assessment is based on existing Probabilistic Safety Analysis (PSA). An estimation of the damage is conducted and is interpreted in physical and monetary terms.

In the fourth and last part of the holistic analysis, the different costs are summarized.

In order to make the results of analysis comparable between (third generation) nuclear energy system and other energy systems, the analyses of the selected energy technologies (advanced fossil based energy and renewable energy) are carried out in the same way. In this way, the comparison can be carried out under the same well-specified conditions and the relative sustainability of the technologies can be measured.

Holistic-integrated Consideration by an energy system model

The national European energy systems of the EU-27 are integrated in the pan-European energy market with homogenous energy and climate objectives. In 2008, the European Commission published a climate and energypackage, known as the “20-20-20” targets. The package aims at reducing the EU’s greenhouse gas emissions by 20% in comparison to 1990’s level, reducing the final energy consumption by 20 % and increasing the share of renewable energy in gross final energy consumption to 20%. Consistent with all this energy and climate policy targets of the EU-27, plus the national targets and policies (e. g. nuclear policy) of all the European states, the role of nuclear energy is considered in the integrated analysis. The integrated analysis is performed using a technology-based energy system model TIMES PanEU, a multi-regional model, that defines each country in Europe as a region. The objective function of the model is a minimization of the total discounted system costs over the time horizon from 2000 to 2050. A perfect competition among different technologies and paths of energy conversion are assumed in the model. The TIMES PanEU model covers, on country level, all sectors connected to energy supply and demand. For example the supply of resources, the public and industrial generation of electricity and heat, the industry sectors, commercial, households and transport. The technology-oriented character of this energy system model allows a consideration of the future structure of the energy system, the primary energy consumption (incl. uranium requirement), the radioactive waste production and the total costs of the energy system. TIMES PanEU considers interactions between the supply and demand sectors of the energy system. Up to 2050 the different technology development paths are comprehensively analysed and considered in the integrated analysis.

3. Holistic Analysis of Nuclear Energy

The holistic analysis of the nuclear energy refers to the baseline of the electricity generation by an advanced reactor (EPR: net power 1.600 MW_{el}, efficiency 36 %, availability 85 %/a). Due to the long life time of the nuclear power plant, various developments in the nuclear fuel cycle must be considered in the holistic analysis (e. g. grade of the uranium ore, types of uranium mining). Furthermore, expected technology developments at each stage/process of the nuclear fuel cycle and dynamic development of the background system (up to 2050) are analysed. Following the baseline analysis, this study determines further different variants of the nuclear energy system for mapping prospective developments.

[1] See also: CETP /Eliasson 2003/, NEEDS /Burgherr et al. 2008/ and SECURE /Burgherr et al. 2011/.

The LCA results derived from the baseline nuclear energy system shows that most of the emissions in the air arises from the nuclear fuel cycle, and more than half of the total demand for material and energy resources is devoted to the power plant. Radioactive emissions in the life cycle of the nuclear energy system are mostly from indirect emissions of the nuclear fuel cycle. External costs of the baseline case are less than 2 €/MWh_{el}. The variant with low grade uranium has the highest emissions and the external costs can increase up to threefold.

The levelised costs of generating electricity (excluding external costs) amount to 51 €/MWh_{el} (baseline). About 65 % of the levelised costs are capital costs and 20 % variable costs (incl. costs of the nuclear fuel cycle). The remaining costs are fixed cost for the power plant.

The consequences and economic effects of severe accidents of an advanced nuclear power plant are estimated by a simplified methodology of offsite consequences. The methodology is based on the program MACCS (Melcor Accident Consequence Code System) that calculates offsite risks for defined radionuclide groups. The risk is the product of the extent of damage and the probability of occurrence. The low probability (<10^{-6} per annum) of a severe (nuclear third generation) reactor accident, despite the possible high economic consequences

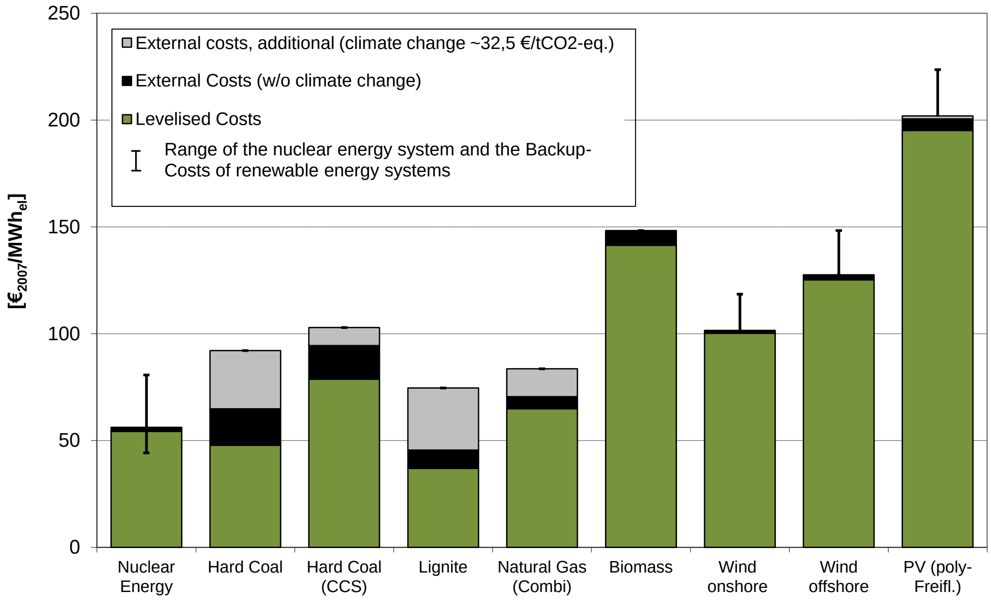

Figure 2: Total cost of nuclear power and other technologies

When the three cost components are assimilated into the total costs, it reveals that the total costs of nuclear power generation in the amount of 53 €/MWh_{el} are most affected by capital costs, which further suggests that discount rate, annual availability of the plant and investment costs have the most significant influences on the full costs.

In order to thoroughly evaluate the total costs of the baseline and of the different variants of the nuclear energy system, the obtained results of total costs are compared with other energy technologies. The comparison of the generation (private) costs of the energy technologies and the cost benefit of power generation by nuclear and lignite are shown in Figure 2. Taking into account the external costs, the fossil based power generation technologies are more expensive than nuclear energy significantly. Wind energy and nuclear energy have the lowest external costs, but the power generation costs are two times higher than by nuclear. On the contrary, the sum of the levelised power generation costs and the external costs of solar energy (photovoltaics) are many times greater than by the conventional options.

Considering the intermittent supply of wind and solar energy, , the additional costs for backup technologies to ensure system stability are also considered. They have however only little impact on the results. The range of backup costs and external costs of nuclear power are as well illustrated in Figure 2.

4. Integrated assessment of nuclear energy in the energy system

In line with the European 20-20-20 targets and the EU´s long-term emission target of reducing greenhouse gas emissions by at least 80 % until 2050 (relative to 1990), three scenarios are developed. The first and second scenarios are closely oriented to the current energy policy and differ merely in the life time of the nuclear power plants. In the reference scenario, current German and European energy policy are assumed (e. g. Germany´s energy transformation, nuclear phase out in Germany, Switzerland and Belgium). The second scenario, first alternative scenario, refers to the pre-Fukushima situations, with life time prolongation of nuclear units in several European countries. In the third scenario, second alternative scenario, no technology-related restrictions are assumed.

The results of the scenario analysis of the first two scenarios show, that the generation of electricity in Europe increases by up to 15 % to 3,800 TWh in 2050 compared to 2010. The nuclear share is projected to decrease by 7 % compared to the current level. However, most of the generated electricity in Europe comes from wind energy and nuclear in 2050. In the long-term, the share of renewable energy in electricity generation increases to about two-thirds of the European annual electricity generation. Due to the greenhouse gases reduction target, the fossil based power generation decreases steadily. The German electricity generation decreases about 19 %, against 2010. In comparison to these scenarios, the demand of electricity in the second alternative scenario, i.e. without technology-related restrictions, is significantly higher. Key growth driver of the electricity production is the cost-efficient electricity generation by nuclear energy. The cost-efficiency production of electricity has impact on all energy sectors and a share of the renewable energy production is substituted by nuclear generation. By comparison with the reference scenario, the arising of radioactive waste in Europe increases by about 1.7 times in the second alternative scenario.

The changes in electricity structure and fossil fuel input, as a result of a more cost-efficient CO_2-mitigation strategy in the two alternative scenarios, lead to lower cost of electricity production up to 2030. The differences in the average electricity generation costs can be mirrored by comparing the changes in the overall total system costs among the various scenarios. The two alternative scenarios have lower private and external system costs until 2030 compared to the reference scenario (total cost differences in Europe: 50 and 640 bn. €; in Germany: 18 and 156 bn. €). It can be concluded that the costs in the second alternative scenario is lower, because all options for a cost-optimisation production structure are considered. Further it reveals that the Gemany´s energy transformation lead to an even more increase of energy system costs in Europe than in Germany.

5. Conclusion

In comparison to existing studies, new innovative aspects are considered in the holistic analysis of the nuclear energy system. The scenario analysis confirms that nuclear power plays a key role in the European energy system in future and can contribute to a cost-efficient energy supply.

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POSTER:

NUCLEAR AND CIVIL SOCIETY

NUCLEAR MYTHOLOGY

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ABSTRACT

Scientists who worked on Manhattan project criticality tests named them “Dragon Experiments”: they were “tickling the tail of the dragon”. This fascination for mythic animals went on as reactors were named *Dragon* (Winfrith) or *Phenix* (Marcoule), a German waste treatment installation was called *Fafnir,* a famous dragon, and *Melusine* was the first reactor on the Grenoble site.

A phoenix was a logical choice for a breeder reactor, a mythical animal that regenerates again and again from its ashes. But this image was not strong enough to avoid the scares generated by the presence of plutonium together with sodium. With plutonium, we somehow missed our chance: as we all know, it was named from the planet Pluto. It could have been a good choice because Pluto was the god of all natural ground resources, be it minerals or plants. But it was also associated with infernal deeper forces. Thus a US politician once said: I*f there ever was an element that can be associated with hell, it is plutonium*.

But dragons? It is a positive symbol in China, with multiple aspects, e.g., the year of the dragon is favourable for large projects. In Europe, it is a dangerous beast in most legendary tales, symbol of bad things that glorious saints must kill, as George or Michael did. Do Greenpeace activists dream that they follow their example when they fight nuclear developments? Always prompt to use strong images, they carried along rivers and streets, a Nessie type monster called MOX during their demonstrations against plutonium recycling. Ukrainian children after the Chernobyl accident have drawn devouring dragons, but for others, dragons are often friendly in their children’s books. I like most *L’histoire d’un gentil dragon rouge* by Max Velthuijs. The terrible dragon is tamed by an intelligent scientist and thus it blows its powerful flames into a boiler, producing heat and electricity for the whole town. Everybody thus loves the beast.

We have to find such symbols to familiarise nuclear activities for European populations. Could we “launch” Nukie, a friendly dragon, as a mascot for our activities?

1. Naming fissile materials

Sometimes events that are not at all related to your subject have a long term influence on its development. It was the case when Klaproth discovered uranium in 1789. Planets have all been named after ancient Roman gods, themselves inherited from Greece. At the time Klaproth discovered his new substance, the British astronomer Herschel, born in Hannover, had recently observed a new planet. But it is J.E. Bode, director of the Berlin observatory in those days, publisher of an Astronomisch Jahrbuch every year, who chose the name. After Saturn, identified with the Greek god Cronos, there was some logic to choose his father **Ouranos**, that can be written **Uranus** in German and was taken as such in other languages. Klaproth, a great admirer of this astronomical discovery, decided to name the metallic substance he found after the planet, thus uranium. But Ouranos is not really a nice god. Son of Gaia, he personifies the Sky, apparently considered as a source of fertility. But at the same time, he had dozens of terrible children with Gaia, among them Titans and Cyclops. She finally was bored of being so frequently “covered” and asked one of the Titans, her son Cronos, to castrate his father. Although we could plead that uranium is the son of Gaia and thus should be considered a nice material, if we insist on mythological aspect these sinister family stories might become better known! Uranium minerals were appreciated by collectors because they glowed in the dark but it is only more than a century later that the fissile properties of uranium were discovered.

Another naturally fissile material, thorium, also received its name from a god, but a Germano-Scandinavian one. It was J.J. Berzelius who identified this material in 1829. He chose to name it thorium after the god **Thor**, again a terrible one, travelling around the world in a chariot pulled by two stinking billy goats, master of lightning, symbol of violent strength but also of fertility and the protector of humans. Again we can think of him with mixed feelings.

At Berkeley Radiation Laboratory, when a team of scientists among which Mac Millan and Seaborg, discovered other fissile materials, they continued to name some after the planets: neptunium and plutonium. Seaborg and Wahl, his assistant, identified element 94 on February 23, 1941; they created them using the 60-inch cyclotron and an uranyl nitrate hexahydrate target .The team discussed names (1) : *ultinium, extremium, pandemonium,* but they decided to continue the order of planets and the last one available was Pluto, thus plutonium and they choose to abbreviate it Pu and not Pl.

This choice was probably not the best one if we consider its impact on the public image: although the god **Ploutos or Pluto** means the rich, and is associated with all the resources that the ground can provide, it is its connection with the Greek god Hades and infernal forces that people remember. A US senator once said that if there ever was a material that can be associated with hell, it is plutonium. We could just as well say that the name is perfect for a material that could provide wealth and energy for thousands of years.

But it seems that we are faced with the same attitude that the media have with news: good news is no news. It is not the virtues of the gods that gave their names to our fissile materials and especially for plutonium that are remembered, it is their tragic fate that is put forward.

2. From alchemy to the original sin

The discovery of radioactivity has a lot of similarities in people's imagination with the work of alchemists. The scientists themselves realised that. This is how Weart describes it (2):
Rutherford and Soddy found, for example, that radioactive thorium, atom by atom, was gradually turning itself into radium. At the moment he realised this, Soddy recalled, "I was overwhelmed with something greater than joy – I cannot very well express it – a kind of exaltation." He blurted out, "Rutherford, this is transmutation!" "For Mike's sake, Soddy" his companion shot back, "don't call it transmutation. They will have our heads off as alchemists". But the next moment, Rutherford was waltzing around the laboratory, booming out "Onward Christian Soldiers". Already at the instant, the new science was born, it could stir strong emotions.

This was the discovery of natural radioactivity ; later on, Pierre and Marie Curie isolated a number of naturally occurring radioactive elements. Their daughter Irene and her husband Frederic Joliot really realised the dreams of the alchemists when they obtained radioactive nitrogen from boron. As we mentioned above, Seaborg and his team could generate a nearly non existent material, plutonium, using Lawrence's cyclotron and the appropriate target. Such actions stimulate the imagination of artists, novelists and the film industry. A typical example is Mohlitz's engraving *La découverte du plutonium* : it looks as if a solitary Seaborg has worked in a fantastic environment, surrounded by mysterious phials and all sorts of skeletons. Skeletons have been connected with radioactivity since the beginnings of radiography. But they were present also early in the arts as in Melies' film *Les rayons Rôntgen*, where a man walks behind the machine screen and his skeleton walks on alone.

But very soon what impressed their imagination the most was the power that might be released. Thus famous stories were published, telling how ambitious men supported by mad or greedy scientists would dominate or destroy the world with some sort of scientific devices. From Anatole France *L'île des pingouins* (1908) and H.G Wells *The world set free* (1914) to J.B Priestley *The Doomsday men* (1938), the stories are numerous. Wells dreamed that the use of an atomic bomb – he is the first to have used this word – would enforce a pacific world. But already in 1921 he wrote: *The dream of "The World set Free", a dream of highly educated and highly favoured leading and ruling men, voluntarily setting themselves to the task of reshaping the world, has thus far remained a dream.(3)* Thus Apocalypse might result from the ambition of Doomsday men.

And indeed, such a major destruction had never been done before by a single instrument, and it was the first widely known result of atomic discoveries. Ending WWII, the three apocalyptic explosions impressed the world population forever. This "original sin" would remain in most people's mind as a mark of infamy on any nuclear research. In the very early morning in Nevada's desert on July 16, 1945, the scientists themselves were deeply moved when they observed Trinity's explosion. Oppenheimer expressed his feelings with reminiscences of an epic saga from India: *If the radiance of a thousand suns were to burst into the sky, that would be like the splendour of the Mighty One,* but he also felt: *I am become Death, the shatterer of worlds.* Carson Mark, one of the researchers who had participated in the theoretical calculations, wondered if the "explosion sphere" would ever stop growing ... General Farrell thought (4) that it was a blasphemy to manipulate forces until then left to the Mighty One. Religious and mythical feelings rush back in the presence of such a monstrous phenomenon.

3. Nuclear installations, gods and dragons

During the Manhattan project, the first attempts in Los Alamos to create a temporarily critical mass of fissile materials – be it with slugs of uranium or semi-spheres of plutonium – were called by the scientists "tickling the tail of the dragon". The dragon was dangerous and during those years, it killed two scientists.

But it seems that nevertheless, scientists loved legendary animals and mythical gods, especially in Europe. The French CEA gave their names to many of its nuclear installations. Some choices had obvious origins like Siloe, a pool type research reactor: Siloe was a bathing pool in Jerusalem at the time of Jesus. But why did they decide to name another Osiris, a god that reigns over the dead? And a copy of this reactor, thus named Osirak, was sold and built for the Iraqis. Israël hated it so much that they bombed it. Why Melusine, in 1958, the first of its pool type reactors, a fairy with a snail or a fish tail (the legend is not clear on that subject ...)?

After a series of musical choices for the reactors connected with the fast breeder programme – Harmonie, Masurca, Rapsodie – they turned again to the great myths for their prototype power plant: Phenix. It had its logic as this animal comes back to life from its ashes. The Phenix reactor had its enemies but its overgrown descendant Superphenix provoked furious opposition leading to memorable battles.

The French were not alone in selecting such names: in Belgium, the underground galleries in the Boom clay, under the nuclear research centre in Mol were named Hades. A certain logic again for an underground test lab that would provide the information to define and guarantee the feasibility of geological storage to keep indefinitely highly radioactive wastes which are in peoples' minds dangerous whatever the packaging. Extending this research under European auspices, they named the interest group Euridice. Great! She never came out of the Inferno, even with the help of her lover Orpheus. This name must be taken as a guarantee that those wastes will stay underground for ever !

Other countries loved dragons; I do too ... A German company named a waste treatment installation Fafnir, after the famous dragon that Siegfried had to fight. In England in 1962, the UKAEA started a high temperature gas cooled reactor in Winfrith, simply called Dragon. It was run as an OECD/NEA project, burning coated particles. Even the Nuclear Decommissioning Authority loves to play with such symbols: when this reactor was dismantled and virtually empty, NDA titled its *Stakeholders newsletter:* "Winfrith's DRAGON loses its fire."

No wonder that nuclear opponents or fiction writers represent nuclear activities as dangerous dragons. In one of the first James Bond film, Dr No lives on an island that is supposedly inhabited by a dragon which in reality is a nuclear reactor. Nearly 50 years later, Professor David Phillips, president of the British Royal Society of Chemistry *blamed the film for casting a long-lasting shadow over the image of nuclear (.?..) nuclear technology being presented as a "barely controllable force for evil" (5).*

Greenpeace designed a very aggressive Nessie type dragon to represent MOX. They carried it along the river near the Belgonucleaire MOX fuel plant in 1992 during demonstrations against the extension of the plant. They later obtained cancellation of this project (using legal arguments, not the dragon!). They used it again in the streets of Huy when they tried to prevent loading of MOX fuel into the Tihange reactor. They did not succeed. When in Saskatchewan (Canada) people resisted a big-corporate plan to mine uranium, they claimed: "Nuclear dragons attack".

It is a dragon made of US Pershing and Russian SS20 missiles that St George kills on New York's UN grounds, a sculpture named "Good Defeats Evil", created by the Russian artist Zurab Tsereteli. Novels abound with nuclear dragons; *Nuclear dragon* tells the story of a fusion reactor explosion, *Legacy of dragons* is about a supposedly lost World War II atomic bomb, *The tail of the dragon* narrates a CIA conspiracy against its own government. A recent puppet show in the Cité des Sciences in Paris and in other places, represented nuclear power as a dragon that must be slaughtered. Non-fiction titles also use the dragon symbol. *Slaying the nuclear dragon* is about nuclear disarmament dynamics in the XXIst century. *Feeding the nuclear dragon* was the title in 1995 of a description of developments of the nuclear industry in China by the Canadian campaign against nuclear development at a time when AECL signed a Memorandum of Understanding with China National Nuclear Corporation. This year, two Chinese authors titled their paper *on the prospect and potential of cross-Strait cooperation on nuclear security, Taming the dragon. (6)*

4. Taming the dragon?

This is also the question I ask in the book I am preparing, probably published this winter, *Dompter le dragon nucléaire ? Réalités, fantasmes et émotions dans la culture populaire.* I insist on the importance of dreams and images. If representing nuclear energy as a dragon seems so evident to so many people, why shouldn't we follow and make use of this symbol? After all, *this legendary monster appears as a primordial force, coexistent with the emergence of the world (7).* It was scary in the old days when numerous saints and heroes had to kill them. By the way, does Greenpeace and its friends feel like being St George or St Michael when they fight nuclear activities? But today, dragons are mostly part of folklore activities. In children books they are seldom scary and always end as the best friend of the children, sometimes even as their pet animal.

After all, dragons have some positive analogies with nuclear power plants: as already mentioned dragons symbolise primal forces as nuclear chain reactions are. They usually stay underground, in deep caves. Initially in Europe we did install our nuclear plants deep in the hills, for example Chooz (in the north of France, nearly in Belgium) where nobody objected to plant A's presence – which was not the case for the big ones later outside. Possibly we should at some time go back to the "âge des cavernes" to satisfy people's anxieties and to resist terrorists and planes crashes. If he wants to work with a dragon, the tamer must learn its behaviour and should use patience and not violence. He should never turn his back to the animal. It is the same with a nuclear plant, you have to pay attention at all times.

In Max Velthuijs *Le gentil dragon rouge*, the enormous animal terrifies the town. He burns the nearby forest, resists the action of the fire brigade, carries away the cage in which they try to trap him. Nothing works to tame it until a learned professor has the good idea to build a steam engine in which the gentle dragon can blow his flames. It provides heat and electricity for the whole town and everyone is happy and thankful. Isn't that the story we would like to tell about our activities? Would a nice Nukie, yet to be drawn, not be a good symbol of nuclear energy? Is it too naïve a suggestion? Let's try …

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ROLE OF STRATEGIC TRADE CONTROL IN EUROPEAN AND INTERNATIONAL NUCLEAR NON-PROLIFERATION EFFORTS

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ABSTRACT

In the international efforts against proliferation of WMD, the area of strategic trade controls holds a crucial place. This has been recognized since the establishment of COCOM during the Cold War, of the Nuclear Suppliers Group in the 70's and the other export control regimes. More recently, the role of sub-national networks became evident with the analysis of the A.Q. Kahn network, its operational modes and partners. Strategic trade control is also at the heart of UNSCR-1540. The European Union (EU), legal framework for the control of dual-use (DU) items and technologies was thoroughly revised in the mid 1990's resulting in the first integrated dual-use control list derived from the international export control regimes. The "EU dual-use control list" became an international reference attached to EC Regulation 1334/2000, which was later recast as EC Regulation as 428/2009 and its more recent amendments.
A key issue for an effective strategic trade control is the technical competence required in all phases (industry, licensing, enforcement, prosecution). Also the analysis of trade flows and transactions are of utmost importance. Besides reviewing the overall issues and measures in place, this paper will describe the contribution of the Joint Research Centre of the European Commission to support the EU stake-holders.

1. Introduction

The area of strategic trade controls holds a crucial place for strengthening global efforts for WMD risks mitigation. This has been recognized since the establishment of COCOM during the Cold War, of the Nuclear Suppliers Group in the 70's following the Indian test and the other export control regimes. More recently, the Pakistani proliferation programme, DPRK's test and the analysis of the A.Q. Kahn network, its operational modes and partners stressed the role of sub-national networks

For these reasons this topic is also at the heart of the resolution of the 2004 Security Council of the United Nations 1540 (UNSCR 1540) [1] as a response to the threat to a global peace and security that could raise from the proliferation of chemical, biological, radiological and nuclear (CBRN) weapons of mass destruction (WMD). The UNSCR 1540 calls upon all UN member states to implement a set of measures to combat illicit and criminal activities including transfer or misuse of controlled commodities, by putting in place at national level appropriate legislations with an efficient enforcement. It provides guidance for national implementation and it is the first international regulation for a universal control of strategic trade. The so-called "1540 committee", which is structured in working groups and groups of experts, reports to the Security Council on the implementation of the resolution in the member states through monitoring and strengthening the different undertaken initiatives in line with the required measures [2]. The Committee uses matrices, which are built from information provided from each country according to the operative paragraphs of the resolution, to organize information about the implementation monitoring and also as a reference tool for identifying assistance priorities that a country may require from the technical perspective or others. The 1540 Matrix gives a quick and wide picture on the status of the global

(UN member states) implementation of the resolution which would help identify countries or regions that would necessitate further assistance from other donors such as the EU.

The international export control regimes are the Zangger Committee [3], Nuclear Suppliers Group [4], the Australia Group [5], the Wassenaar Arrangement [6] and the Missile Technology Control Regime [7]. The regimes are non-binding agreements setting guidelines including lists of controlled strategic items which are periodically reviewed to address the evolving WMD proliferation threats. Controlled items are also listed in the Schedules of the Chemical Weapons Convention.

2. Strategic Trade controls

2.1. General Export Control Framework

As shown in Figure 1 an efficient export control must be maintained by at least five pillars which are legal, licensing, customs, awareness and sanctions. The two first pillars regard laws that have to be applied as a legal frame based on the regulations in force and requirements for licensing for export. The third pillar regards the effectiveness of the control when the goods come to be exported which relies on trained customs aware of related risks and consequences. Export control awareness arising should make in evidence the role of the export control in mitigating threat of WMD and should concern not only state authorities but also the industry dealing with sensitive technologies a and the academia. Finally, reliable enforcement must be in place and severe sanctions must be executed when pronounced for non-conformity with export law.

Fig 1: illustration of the five pillars that support an efficient export control framework

2.2. The EU export control framework

As set out in the EU security strategy [8] and the EU WMD strategy, export control is a key barrier against WMD proliferation. An overview of this regulation underlining the main issues and challenges of its harmonised implementation within the EU member states is reported [9].

The European Union (EU), legal framework for the control of dual-use (DU) items and technologies was thoroughly revised in the mid 1990's resulting in the first integrated dual-use control list ("EU dual-use control list"), derived from the international export control regimes' lists. The "EU dual-use control list" became an international reference attached to EC Regulation 1334/2000, which was later recast as EC Regulation as 428/2009 [10] and its more recent amendments (EU Regulation 388/2012 [11]. Other additional restrictive measures including also dual-use items, target like Iran through EU Regulations 961/2010 [12], 267/2012 [13], and North Korea 329/2007 [14] and 2012/635/CFSP [15] (graphite material).

EU Regulations are directly applicable in the EU Member States. Their implementation through national laws is national competence and duty. The EU provides support to this, through a variety of instruments and initiatives, both inside and outside Europe.

The EU Customs Code and its security amendments set the framework for enforcement.

2.3. The role of the European Commission

Various Commission's policy making Directorate Generals (DGs) such as DG Energy, DG Trade, DG DevCo or DG Taxud are in charge of different files related to the fight against proliferation of WMD.

The implementation of the EU regulation 428/2009 by EU member states is closely followed by the European Commission DG TRADE through the "Art. 23 Coordination Group" meetings, where Member States report on the regulation implementation issues and status. The Council's Working Party on Dual Use meetings deals instead with amendments, to be co-decided by the European Parliament. These relate e.g. to the technical annexes and country specific control lists.

The JRC provides support to some activities of the Policy DG's. Its capacity building in the field of export control is closely guided by the requirements for a full and efficient implementation of the EU Regulation 428/2099 and amendments in all the EU member states. The Nuclear Security Unit of the Institute for Transuranium Elements of the Joint Research Centre, European Commission, based in Ispra (Italy), has progressively developed expertise in the field of export controls of DU items and technologies to support DG TRADE.

2.4. EU issues

Several instruments and initiatives are put in place by the EU to facilitate and ensure a harmonized implementation of the regulation within the EU member states. It is worth underlining that due to the common market within the EU, the export control regulations must be implemented at the same standard in each of the member states. This would prevent any loophole from a member state in which the regulation would have not been fully implemented and enforced making consequently export control efforts of other member states inefficient. However not all EU member states have the same means to implement their export control systems, which provides a challenge to the full enforcement of the process. This is even more difficult when including also challenges as transit, transshipment, brokering and intangible transfers. Moreover, some EU MS are not members to all Regimes, which limits their access to information.

The implementation of the export control regulations relies on the availability of technical assistance in a broad range of competences, which may lack in some EU member state. The technical assistance could be the identification of a commodity among large numbers of items and technologies listed in the controlled lists of the regulations and what that commodity it is needed for.

3. JRC Technical support activities

JRC provides technical assistance to DG Trade, which is in charge of implementing and amending the EU Regulation 428/2009. Thanks to its wide competence in numerous fields spread in seven research institutes, the JRC is the main structure inside the Commission able to tackle such diversity of items and technologies that are listed for instance in the annex I of the regulation. Under the mentioned collaboration with DG Trade, the JRC is attending and contributing to the different technical meetings of the Nuclear Suppliers Group and the Australia Group Regimes regarding respectively nuclear and biological related DU items and technologies. In fact, the EU is full member of the Nuclear Suppliers Group regime while observer in the Australia Group regime.

Furthermore, the JRC is operating and contributing to the EU Dual-Use Pool-of-Experts, which aims to provide non-binding advise to the licensing authorities of the member states on a wide range of technical issues in either commodities rating or end-use plausibility. The assistance requests are submitted to the point of contact of the pool-0of-experts which is managed by the JRC.

The expertise is gathered internally to the EC from JRC and ENER as well as from identified national experts. The pool-of-experts recently entered into force and is expected to play an increasing role for a harmonized implementation of the export control regulations within the EU member states without burdening the national authorities. Figure 2 summarizes the pool-of-experts operating concept.

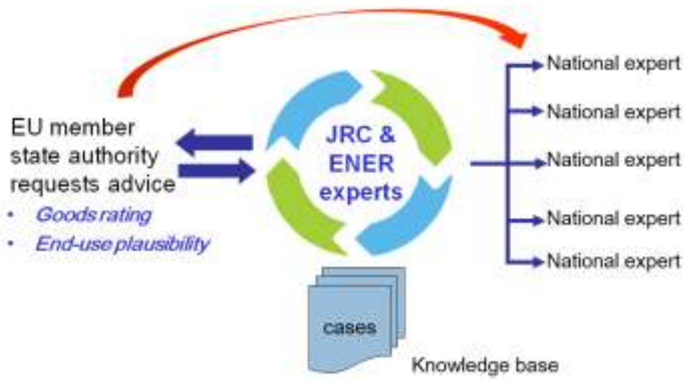

Fig 2: Operation concept of the EU export control pool-of-experts

As the security has an international dimension, EC has developed several long term initiatives such as the Instrument for Stability and the recently launched CBRN Risk Mitigation Centres of Excellence for which DG DevCo is responsible [16]. Also in these initiatives, export control is addressed, executed mainly by the German BAFA on behalf of the European Commission. The JRC contributes as a provider of technical assistance for outreach activities at either national or regional levels. In this context, JRC is playing a role for enhancing interactions with projects of a similar nature financed by other donors. The collaborations with donors enhance effectiveness of the engagements and provide an overview on all planned and ongoing projects in a beneficiary country or region to avoid duplications of efforts among the donors.

The JRC collaborates with the different US departments dealing with the export control programs by establishing regular dialogues on respective experience exchange and best practice sharing. Recently a new EU-US working grouping on export control and building capacity is established on purpose to extend and strengthen cooperation in this field.

4. JRC Capacity building and research activities

Beside the assistance that the JRC is providing to others DGs, an important activity regards capacity building and networking as a key for establishing a robust knowledge platform to support export control of DU items and technologies for inreach and outreach. Within the collaboration with US DoE NNSA, JRC has organized several export control seminars and workshops which have been attended both by EU and non-EU states including industrial groups. These events have addressed topics of relevance such as DU commodity identification, tangible and intangible technology transfers and internal compliance practices. The later topic, which concerns the exporting industry, is considered as a quality label for the export procedures. These events fit in both the awareness raising and the licensing pillars of the export control.

JRC ITU nuclear security unit has undertaken research activities regarding some sensitive steps of the nuclear fuel cycle such as uranium enrichment being investigated from the export control perspective. This for instance concerns the laser isotope separation which includes several techniques such as those based on atomic or molecular vapours of uranium as feed material. The laser isotope separation concept is not specific to uranium enrichment, it can in principle also be applied for enrichment of elements others than uranium provided that the know-how and the suitable well-tuned lasers are available [17]. It is under development for enrichment of isotopes for research, industry or nuclear medicine applications. The laser isotope separation technology is expected to grow not only in the nuclear field such as the recent licensing of the Global Laser Enrichment Corporation in US (SILEX) [18], but also in other fields as mentioned above. As this sensitive technology is subject to spread, new approaches are required both for nuclear safeguards inspectors and for the reinforcement of the export control of the related technologies and components, to mitigate proliferation risks.

5. Trade analysis in support to IAEA safeguards and export controls

Following the disclosure of undeclared nuclear programs in Iraq and DPRK, the IAEA sought to use sources of information in addition to State declared information to derive indicators of possible undeclared safeguards-relevant activities [19]. Such new sources include trade-related information. JRC has surveyed and catalogued open sources on import-export, customs trade data [20] and developed tools for their use in safeguards [21]. Tests on the use of these data by the IAEA suggest safeguards relevance along the following lines [19]:

- Support the IAEA State evaluation process and improve understanding of a State's nuclear programme – Trade information on exports can support the assessment of a State's nuclear related industrial capabilities. Data on trade flows between States can be used to understand their international cooperation. Understanding mining-related activities can be improved by using data on the exports of raw materials and semi-finished products. Data on imports and exports of nuclear materials and equipment may also provide information on the development of the nuclear fuel cycle in general.
- Verify import and export declarations made by States under Additional Protocols (APs), article 2.a.(ix) [22] – Trade data can prove useful to identify flows of raw material subject to safeguards. Trade categories (of the Harmonized System [23]) appear to be less specific than control/safeguards categories, but precise enough to be determined as safeguards-relevant. The identification of shipments of some AP Annex II equipment may represent a greater analytical challenge.
- Identifying indicators of activities to be safeguarded or to be declared under APs, article 2.a.(iv) [22] – In this context it is foreseen that trade data can be used to verify hypotheses about the absence of undeclared activities. Commodities to serve as indicators and methodologies then need to be identified on a case by case basis and in a hypothesis-specific way.

The same trade data sources are finding application also in support to the implementation of export control policies for dual-use items in the European Union [24].
As mentioned above the EU single market and the consequent free movement of goods within the EU territory makes it necessary to harmonise the controls of the export of dual-use items in 27 Member States. Harmonisation means same rules and a consistent implementation across Member States both in licensing and customs controls. To date there are no official data on the trade of dual-use items. It is therefore difficult to assess progress towards an effective EU export control 'system' because of its distributed nature.
Statistical trade data of customs origin can be used to estimate extra-EU trade flows of dual-use items. Since these data refer to export-controlled items through non-specific descriptors, they provide though only upper bounds of the real dual-use trade. Still using these data can prove useful to *profile* the European dual-use trade. Which items are traded the most, towards which destinations? And: which items are *not traded* or are exported only in limited quantity? This profiling exercise can simplify the picture of the export of dual-use items which *a priori* (i.e. before seeing any data) is complex given the very high number of items listed for controls. Trade data can aid focusing the attention where required.

In this context, one application of statistical trade data analysis is the estimation of dual-use trade flows to inform the design of Union General Export Authorisations [24]. Other possible uses of trade analysis include assessments related to the application of sanctions.

6. Conclusion

The export control of DU items and technologies complements nuclear safeguards and security systems and the strategic trade control in general is playing a crucial role for European and international nuclear non-proliferation efforts. In this context, the EU Regulation 428/2009 incorporates in a structured manner in its annexes all DU items and technologies from the various multilateral export control regimes. The implementation of this legislation is a national competence and duty, and EU provides support to this, through a variety of instruments and initiatives, both inside and outside Europe. This paper summarized the technical assistance that the JRC is providing successfully to the customer DGs responsible for the strategic trade and for a harmonised implementation within the EU member states. Meanwhile through collaborations with research organisations, the JRC is undertaking research activities to face new challenges in the export control of dual use items and technologies including trade flow analysis.

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WHAT DRIVES PEOPLE'S (NON)ACCEPTANCE OF NUCLEAR ENERGY? RESULTS FROM AN EMPIRICAL RESEARCH IN BELGIUM

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ABSTRACT

Higher knowledge has long been hypothesized as leading to better acceptance of nuclear energy, but in the last years other factors such as risk perception and trust in nuclear risk governance were also recognized as key elements. While stakeholder involvement is now fully recognized as a key element of nuclear energy acceptance, there are still questions about the impact of higher knowledge.

This paper investigates the relation between knowledge about the nuclear domain, risk perception of nuclear risks and confidence in the management of nuclear technologies on the one hand, and attitude towards nuclear energy and opinion about nuclear energy, on the other hand. It also studies the factors that are pleading in favour or against nuclear energy. The study is based on empirical data from a large scale opinion survey in Belgium between 25/05/2011 and 24/06/2011. The population sample consisted of 1020 respondents and it is representative of the Belgian adult population (18+) with respect to gender, age, region, province, habitat and social class.

Our results show that confidence in the safe management of nuclear technologies is a driving factor for people's acceptance of nuclear energy, higher confidence leading to higher acceptance. The correlation between knowledge and attitude/opinion towards nuclear energy is statistically significant, but rather low, showing only a weak effect of knowledge on attitudes or opinions about nuclear energy. A weak effect is also observed for risk perception of nuclear risks, lower risk perception leading to a somewhat more positive attitude / opinion about nuclear energy.

In the study we also highlight the main factors that are pleading in favour or against nuclear energy and we show that these factors are the same, both for people who are pro and against nuclear energy, even if the strength of the relations varies among the two groups.

1. Introduction

Understanding people's risk perception and attitude towards nuclear, as well as "*communicating with civil society on the issues at stake and associating the public with decision making"* have long been recognized as essential for the future of nuclear energy (OECD, 2002).

People's attitude towards nuclear energy has evolved during time. In early 50's and 60's nuclear power was believed to be the cheapest form of electricity production (Whitfield et al., 2009), abundantly available ("too cheap to metre", ibidem) and "a magical panacea" (Weinberg, 1992, p.1) in the technology field. However, around the years 70's, and especially after the nuclear accidents at Three Mile Island (1979) and Chernobyl (1986), public attitude changed drastically, due to concerns related to safety of nuclear installations, disposal of radioactive waste and lack of trust in nuclear governance (Whitfield et al, 2009), and later on, concerns about the possible misuse of nuclear technologies for malevolent purposes (e.g. Turcanu et al, 2011).

In the decade preceding the accident in Fukushima, increasing positive attitudes towards nuclear energy were observed again, this period being sometimes referred to as the “nuclear renaissance”. Whitfield et al (2009, p. 425) was noting in 2009 that nuclear energy "is fit, it is safe and it is back". In the context of the growing concern for the reduction of greenhouse gases emissions and given the two decades without major accidents, nuclear energy was reconsidered as a "viable energy option again" (ibidem).

The accident in Fukushima in 2011 has caused a serious shift in public attitudes towards nuclear energy, as shown by several opinion polls, and this not only in Japan, but also in other countries around the world (Asahi Shimbun 2011, Ramana 2011, Ipsos MORI 2011). The disaster in Fukushima led to intense political discussions and even to decisions to phase out nuclear power in short time after the accident, as it happened for instance in Germany.

Psychological studies inform us that attitudes influence and are influenced by beliefs (Fishbein and Ajzen, 1975) and that knowledge of a person's beliefs about an object and his evaluations of the object's attributes allow predicting his/her attitude towards the object. A good insight into people's attitude towards nuclear energy can be thus facilitated by the study of people's beliefs about the related risks and benefits.

In particular, the psychometric theory shows that risk perception of modern technologies (e.g. nuclear technology) is influenced to a great extent by the psychological characteristics of risks (familiarity, dread, immediate vs. late effects, etc.). These factors explain risk perception beyond the classic components of harm and probabilities of occurrence. For instance, the perception of a risk as an involuntary hazard, with catastrophic potential and delayed consequences and being an unknown risk lead to lesser acceptance of the related technology (Slovic 1992, Fischhoff 1995, Sjöberg 2002). Sjöberg (2000) also suggested that risk perception is partly influenced by what is seen as "tampering with nature". His study revealed that risk characteristics such as disaster potential, tempering with nature and unfamiliarity with the risk were the main explanatory factors for the risk perception of a potential nuclear accident such as the Chernobyl accident. In the same perspective, our study investigates the influence of several risk characteristics on the attitude/opinion about nuclear energy.

Risk research studies in the past suggested "*a very strong impact of emotional processes on risk attitudes, which in turn is supposed to imply that these attitudes are rigid and unchangeable*" (mentioned in Sjoberg, 2003). However, as pointed out earlier in the paper, public attitudes with respect to nuclear did change several times in the last decades. The study by Sjoberg (2003) on radioactive waste could provide some explanations; in the mentioned research the expected severity of consequences was found to be more influential on policy attitudes than emotional reactions (e.g. fear and anxiety). From the same study, the substitutability of the (nuclear) technology came also out as an important factor with regards to nuclear policy attitudes.

Whitfield el al (2009) found that higher trust in the institutions responsible for nuclear governance led to reduced risk perception of nuclear power and that higher trust and lower risk perception predicted a more positive attitude towards nuclear energy. Also in the chemical industry, a study by Huang et al (2013) suggests that public acceptance of risks could be predicted by: self-evaluated personal knowledge about the chemical industry, perceived effects of accidents related to the chemical industry, perceived benefit obtained from the chemical industry, and trust in the government’s risk management abilities, the latter being the most influential factor.

Our research aims to investigate the relation between attitude/opinion towards nuclear energy and three characteristics of risk, i.e. knowledge about the nuclear domain, confidence in the management of nuclear technologies, as well as risk perception of an accident in a nuclear installation. It also looks in detail at the arguments that are seen as pleading in favour or against nuclear energy and it identifies how these arguments change among different population groups. In particular, it investigates if these arguments differ depending on the opinion about nuclear energy. The study is based on empirical data from a large scale opinion survey in Belgium, collected in the third month after the accident in Fukushima, between 25/05/2011 and 24/06/2011.

2. Data collection

Since 2002 the Belgian Nuclear Research Centre SCK•CEN conducts periodical large-scale (N > 1000) public opinion surveys among the Belgian population. The sample of people interviewed is representative of the Belgian adult population with respect to province, region, and level of urbanisation, gender, age and professionally active status. The large sample size of the survey allows highlighting general trends and conducting detailed analysis of subgroups of the population. The first edition of this survey was set up in collaboration with IRSN (France), a number of common questions allowing comparisons between the responses in the French and Belgian population.

Alongside recurrent issues such as perception of various risks, confidence in risk regulators or opinions about the use of nuclear energy, the SCK•CEN Barometer surveys include detailed research sections on topics such as emergency planning (2002), food safety (2006), communication (2009), stakeholder participation and information processing (2011).

In 2011, for the fourth edition of the SCK•CEN Barometer (Turcanu et al, 2011), the research focused, among others, on the changes in public attitudes towards nuclear energy and the main associations behind peoples' favourable or unfavourable attitude towards nuclear energy after the accident in Fukushima. Data were collected using CAPI (Computer Assisted Personal Interviews), as it provides good access to data and the possibility to immediately access intermediate results. This method entails personal interviews taken by a professional interviewer at the home of the respondent, with answers directly recoded and stored on computer hard disk. The field work was carried out between 25/05/2011 and 24/06/2011 by a market research company (ASK) with professional interviewers. The interviews were carried out in Dutch or in French language, according to the preference of the interviewee. A quality control of the data was done both during the interviews, as well as at the end of the field work.

3. Method

3.1. Measurement of the different variables

3.1.1 Attitude towards nuclear energy

Consequently, attitude towards nuclear energy was first assessed through a number of general questions on which the respondents had to state their agreement or disagreement degree (see Table 1).

Please state how much you agree or disagree with the following statements:	***Answering categories***
In general, I believe that the benefits/ advantages of nuclear energy outweigh the disadvantages.	*1. Strongly Disagree* *2. Disagree* *3. Neither agree, nor disagree* *4. Agree* *5. Strongly Agree* *9. Don't know / no answer*
The reduction of the number of nuclear power plants in Europe is a good cause (item inverted).	
Nuclear power plants endanger the future of our children (item inverted).	

Table 1 Attitude towards nuclear energy

A factor analysis performed on the three items discussed above (Principal Axis Factoring) resulted in one factor with eigenvalue larger than 1, accounting for 64% of the variance in the data. The reliability of the scale constructed with the three items is $\alpha=0.72$, indicating a reliable scale. A higher value on this scale represents a more positive attitude towards nuclear energy.

3.1.2 Opinion about nuclear energy

Opinion about nuclear energy was measured by a direct question on whether the respondent was in favour of nuclear energy or not. The answering scale ranged from "1=totally in favour" to "5=totally against". A lower value on this scale represents thus a more positive opinion.

3.1.3. Knowledge about the nuclear domain

A number of 17 exam style items were employed to assess the general knowledge about the nuclear domain. The questions used were selected and adapted from: i) Eurobarometer surveys (e.g. Eurobarometer 271 of 2006 and Eurobarometers 324 and 297 of 2008); ii) previous editions of the 2009 SCK•CEN Barometer (Van Aeken et al. 2007) and; iii) discussions with experts. Table 2 summarises the questions asked and the results obtained.

Items assessing knowledge about nuclear	**Answering categories**	**Correct answers [%]**	**Incorrect answers [%]**
What do you think about the following issues:			
Is a dirty bomb the same as an atomic bomb?	*1. Yes 2. No 9. Don't know / no answer*	48% (No)	25%
Will exposure to radiation always lead to contamination with radioactive material?		31% (No)	59%
Is radioactive waste exclusively produced by nuclear power plants?		61% (No)	27%
Which percentage of electric power in Belgium *do you believe* is produced in nuclear plants?	*1. Less than 25 % 2. Between 25-45% 3. Between 45-65% 4. More than 65 % 9. Don't know / no answer*	34% ("Between 45-65%")	51%
***Please indicate whether the following localities have a nuclear power plant (rotated)*:**			
Doel	*1. Yes 2. No 9. Don't know / no answer*	80% (Yes)	10%
Hasselt		82% (No)	5%
Tihange		82% (Yes)	10%
Namur		82% (No)	5%
Lier		78% (No)	7%
Which of the following sectors makes use of nuclear technology?			
production of electricity	*1. Yes 2. No 9. Don't know / no answer*	97% (Yes)	1%
medical sector		89% (Yes)	6%
food industry		29% (Yes)	59%
textile industry		28% (Yes)	56%
What do you think about the following statement: is it true or false?			
There exists a plan to ensure the protection of the population in case of a nuclear accident.	*1. True 2. False 9. Don't know/ no answer*	74% (Yes)	15%
Please answer the following questions (rotated):			
Radioactive waste is collected and treated	*1. Separately from other wastes 2. Together with the other waste 9. Don't know/no answer*	87% ("Separately from other waste")	5%
Radioactivity can be directly measured:	*1. With special equipment 2. It cannot be measured 9. Don't know/no answer*	91% ("With special equipment")	3%
The measurement unit for radioactivity is:	*1. Becquerel 2. Hertz 3. Metres/second 9. Don't know/ no answer*	53% (Bq)	13%

Table 2 Knowledge about the nuclear domain

3.1.4. Confidence in the management of nuclear technologies in Belgium

A number of questions in the survey enquired about the respondents' confidence in the management of nuclear technologies.

<table>
<tr><th>Please state how much do you agree or disagree with the following statements:</th><td rowspan="6">1. Completely disagree
2. Disagree
3. Neutral
4. Agree
5. Completely agree
9. Don't know / no answer</td></tr>
<tr><td>Nuclear reactors in Belgium are operated in a safe manner</td></tr>
<tr><td>There is insufficient control by authorities of the safety in nuclear installations in Belgium</td></tr>
<tr><td>I believe that in Belgium radioactive waste is stored in a safe manner.</td></tr>
<tr><td>The transport of radioactive materials is not safe.</td></tr>
<tr><td>I feel well protected against risks from nuclear installations</td></tr>
</table>

Table 3 Confidence in the management of nuclear technologies

A factor analysis performed on the items regarding confidence in the safe management of nuclear installations resulted in one factor with eigenvalue larger than 1, accounting for 56% of the variance in the data. The reliability of the scale constructed with the five items is α=0.80, which indicates a reliable scale.

3.1.5 Risk perception of nuclear risks

Risk perception of nuclear risks was assessed with the following question: 'How do you evaluate the following risks for an ordinary citizen of Belgium'. The items used to measure nuclear risks were 'radioactive waste', an 'accident in a nuclear installation' and 'a terrorist attack with a radioactive source'. A 5-point answering scale was used for each item, ranging from 1='very low' to 5='very high'. Factor analysis was conducted on the three risk perception items and resulted in a single factor, accounting for 74% of the variance in the data. The reliability of the constructed scale was α=0.82, and thus again a reliable scale. A higher value on this scale represents a higher risk perception.

3.1.6. Factors seen as pleading in favour or against nuclear energy

Next, the respondents were given a list of issues and were asked to state whether they considered these as factors pleading in favour or against nuclear energy (see Table 4).

<table>
<tr><th>Concerning nuclear energy in Belgium, several aspects are continuously being discussed. In your opinion, do the following factors plead against or in favour of nuclear energy?</th><th>Answering categories</th></tr>
<tr><td>Transparency of nuclear industry</td><td rowspan="10">This factor pleads:
1. Strongly against nuclear energy
2. Rather against nuclear energy
3. Neither against, nor in favour of nuclear energy
4. Rather in favour of nuclear energy
5. Strongly in favour of nuclear energy
9. I don't know/NA</td></tr>
<tr><td>Safety of nuclear installations in Belgium</td></tr>
<tr><td>Nuclear waste</td></tr>
<tr><td>Possible misuse of nuclear technologies by terrorists</td></tr>
<tr><td>High energy production from small number of sites (2 in Belgium)</td></tr>
<tr><td>Nuclear energy makes us dependent on large multinationals</td></tr>
<tr><td>Nuclear energy helps our national energy independence.</td></tr>
<tr><td>Costs of electricity produced in nuclear power plants.</td></tr>
<tr><td>Low CO_2 emissions during electricity production in nuclear power plants.</td></tr>
<tr><td>Reliability of energy supply by nuclear power plants in Belgium.</td></tr>
</table>

Table 4 Arguments in favour or against nuclear energy

4. Results

4.1 Descriptive analysis

4.1.1 Attitude towards nuclear

The opinion on whether *"the reduction of the number of nuclear power plants in Europe is a good cause"* has been measured in all SCK•CEN Barometers since 2002. The percentage of respondents agreeing with this statement decreased from 66% in 2002 to 51% in 2006, respectively 47% in 2009. In 2011 the trend has changed: 61% of respondents agreed with this statement, which is comparable to the year 2002, before what is sometimes referred to as the "nuclear renaissance".

The negative switch in the attitude towards nuclear energy was observed also with the statement *"in general, the benefits of nuclear energy outweigh the disadvantages"*. In 2011, 30% of the respondents agreed or strongly agreed with this statement, compared to 44% in 2009; and 39% disagreed with this statement in 2011, compared to 26% in 2009.

Regarding the possible negative effects of NPP's on future generations ("*nuclear power plants endanger the future of our children*"), the results in 2011 were very similar to those obtained in 2009 (and 2002): 49% of the respondents agree or strongly agree with the statement, while 23% disagree or strongly disagree and 24% undecided. Only a minor increase in the percentage of respondents agreeing or strongly agreeing with this statement could be observed as compared to 2009.

4.1.2 Opinion about nuclear energy

A clear change towards a more negative opinion about nuclear energy could be noticed in 2011, as compared to 2009. In 2009, the opinions about nuclear energy in Belgium were rather balanced, with a slightly higher number of respondents in favour (32% pro, 24% against nuclear energy) and a large number of people undecided. In 2011, there is a clear switch: only 18% of the respondents are in favour of nuclear energy, whereas 45% are against. It could also be noticed that, similarly to 2009, more than one third of the respondents (35%) did not take a clear stand as regards nuclear energy.

4.1.3 Risk perception of nuclear risks

The questions related to risk perception showed an increase in the number of people having high or very high risk perception for all three items investigated (accident, terrorism, waste), compared to 2006 and 2009 (see also Turcanu et al, 2011). For instance, for an accident in a nuclear installation 34% of the respondents in 2011 had a high or very high risk perception, compared to 20% in 2009 and 17% in 2006. In 2011, 39% had a low or very low risk perception of an accident in a nuclear installation, compared to 53% in 2009 and 62% in 2006. For radioactive waste, 41% of the respondents in the 2011 survey had high or very high risk perception, vs. 33% with low or very low risk perception.

4.1.4 Knowledge about the nuclear domain

Knowledge about the nuclear domain in the Belgian population remains limited. Most respondents know the location of the nuclear power plants in Belgium and the general questions regarding the emergency plan and the radioactive waste were also answered correctly by most respondents. However, only one third of the respondents knew the correct range of the nuclear energy in the total energy mix, and 26% overestimated its importance. Basic knowledge of radiation protection is missing in the general population; for instance, almost 60% of the respondents think, mistakenly, that exposure to radiation will always lead to radioactive contamination. While the use of nuclear technologies for the production of electricity and in the medical sector is well known, the knowledge about its use for other purposes (e.g. in the food sector for sterilisation by irradiation) is rather limited.

At the same time, almost all respondents know that radioactivity can be measured with special equipment, but only half of them know the correct measurement unit.

4.1.5. Confidence in the management of nuclear technologies

As regards risks from nuclear installations, the question on the perceived feeling of safety revealed that 34% of the respondents feel well protected (vs. 43% in 2009 and only 18% in 2002), while 40% feel unsafe (vs. 28% in 2009 and 56% in 2002). While this shows more concern in the population as compared to 2009, this is expressed at a considerably lower level than in 2002.

At the same time, 43% of the respondents think that nuclear reactors in Belgium are operated in a safe manner, while 20% disagree with this statement.

Opinions are divided concerning the control of the safety of installations, the transport of radioactive material and the storage of radioactive waste in Belgium. 38% of the respondents think that there is sufficient control of the safety of installations, whereas a similar percentage of the respondents (34%) think that there is insufficient control. Similarly, 34% think that the transport of radioactive materials is safe, while 39% think that it is unsafe; and 38% think that there is sufficient control by authorities on the safety of nuclear installations in Belgium, while 35% think the opposite, i.e. that the control is not sufficient.

4.1.6 Factors pleading in favour or against nuclear energy

A closer look into the possible motivations of people's opinions and attitudes towards nuclear energy is provided by the items depicted in Fig. 1. Results show that the main factors pleading in favour of nuclear energy are the low CO_2 emissions - with 52% of the respondents having the opinion that this factor pleads in favour or strongly in favour of nuclear energy -, followed by the energy independence (47%) and the reliability of energy supply (45%).

The main factors that are considered to plead against nuclear energy are clearly the radioactive waste and the possible misuse of nuclear technologies: respectively 76% and 69% think these are negative aspects of nuclear energy that plead against its use for electricity production.

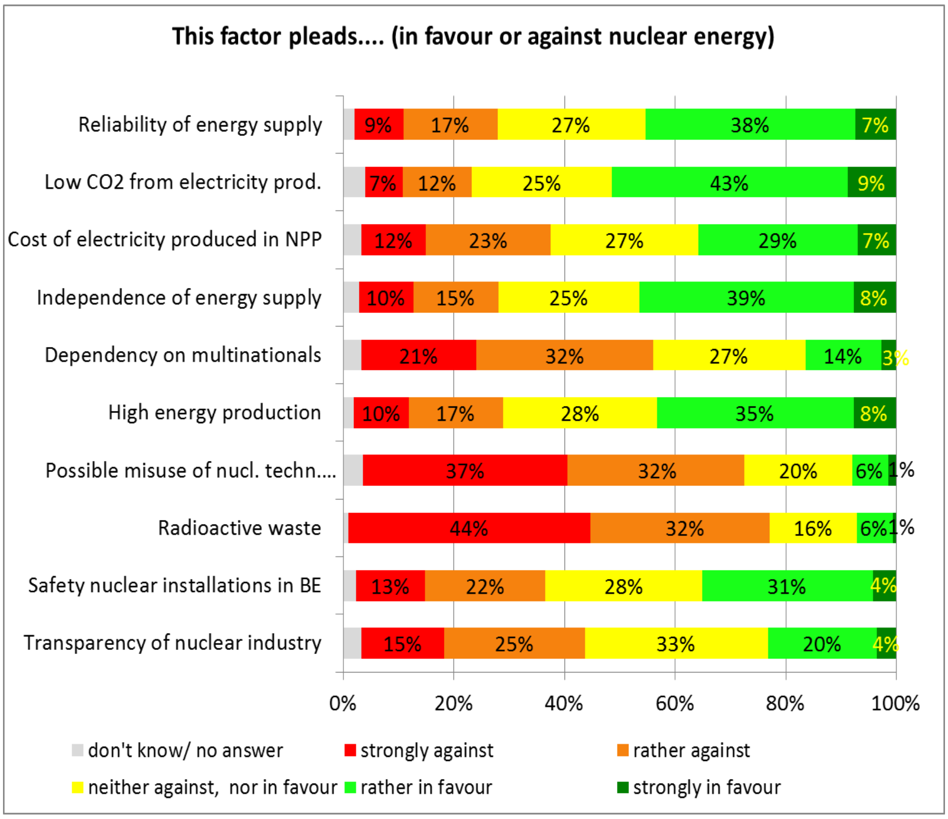
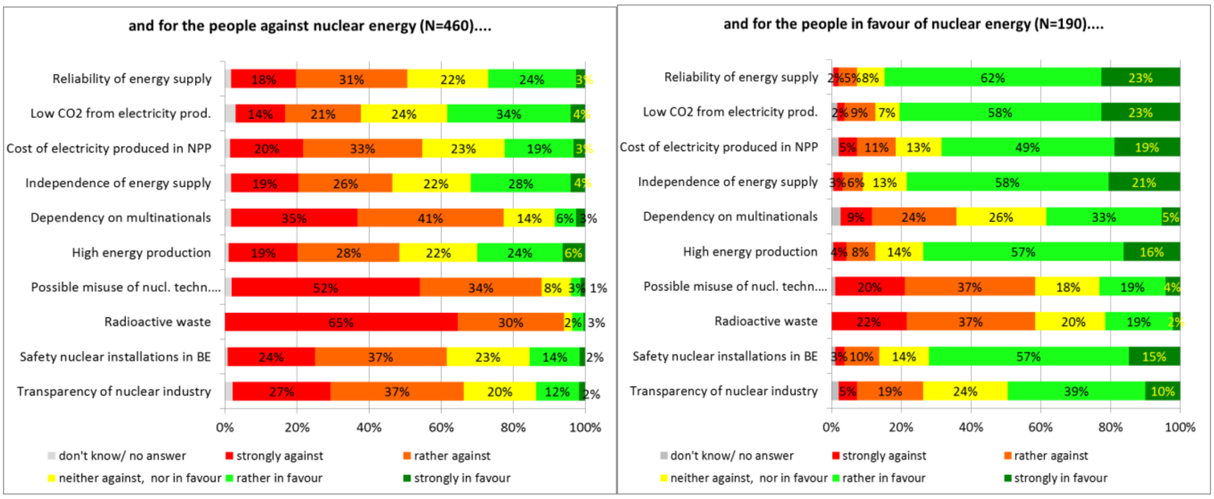


Fig. 1 Factors pleading in favour or against nuclear energy, N=1020

Prior to the accident in Fukushima, in 2010, a European opinion poll showed (Eurobarometer 324, page 52) that the highest risks associated with nuclear safety were considered to be the lack of security against terrorist attacks, the misuse of radioactive materials and the disposal of radioactive waste. Our study showed that these concerns remained the same after the accident in Fukushima, as shown in our study.



a) b)

Fig. 2 Factors in favour/against nuclear energy for a) people against nuclear energy; b) people in favour of nuclear energy

Figure 2 presents a similar analysis, but this time for two separate population groups: those having a negative opinion about nuclear energy (Fig. 2a), respectively those having a favourable opinion about nuclear energy (Fig. 2b). Despite the different opinions concerning nuclear energy, the factors seen as the most negative are the same. The positive factors are also similar, except that the reliability of energy supply has a higher influence on those in favour of nuclear energy.

4.2. Influencing factors for the attitude towards and opinion about nuclear energy

The study of the correlations between the attitude towards and the opinion about nuclear energy, on the one hand, and knowledge about the nuclear domain, risk perception of nuclear risks and confidence in the management of nuclear technologies, on the other hand, revealed that the latter is most strongly correlated with attitude towards nuclear and opinion about nuclear energy (see table 5).

Variable	Spearman's rho	1	2	3	4	5
1	Confidence in management of nuclear technologies (high score= high confidence)	1.000				
2	Attitude towards nuclear energy (high score= positive attitude)	.595**	1.000			
3	Knowledge index	.126**	.125**	1.000		
4	Risk perception of nuclear risks (high score= high risk perception)	-.301**	-.213**	-.065*	1.000	
5	Opinion about nuclear energy (1= totally in favour… 5=totally against)	-.527**	-.709**	-.137**	.183**	1.000

* p<0.05; ** p<0.01; *** p<0.001

Table 5 Correlations between studied variables (Spearman's rho)

Knowledge and risk perception are also correlated with attitude / opinion about nuclear energy: a higher knowledge and a lower risk perception are somewhat more often found among people with a positive attitude or having a favourable opinion about nuclear energy.

A further analysis using linear regression (see Table 6) confirmed that confidence in the safe management of nuclear technologies is the most influencing factor.

	Dependent Variable: Attitude towards nuclear		Dependent Variable: Opinion about nuclear energy	
	Model 1 (N=925)	**Model 2 (N=840)**	**Model 3 (N=989)**	**Model 4 (N=870)**
Independent variables	**Std. Beta (Sig)**	**Std. Beta (Sig)**	**Std. Beta (Sig)**	**Std. Beta (Sig)**
(Constant)	-.378 (0.006)	-.604 (.605)	3.852 (0.000)	3.673 (0.000)
Knowledge index	0.090** (0.005)	.019 (.492)	-.110*** (0.000)	-.063* (.031)
Risk perception of nuclear risks	-.210*** (0.000)	-.050 (.084)	.167*** (0.000)	.026 (.394)
Confidence in management of nuclear technologies	*Not used*	.591*** (.000)	Not used	-.508*** (0.000)
Adjusted R^2	**0.05**	**0.37**	**0.04**	**0.27**

Table 6 Regression models for attitude towards and opinion about nuclear energy

Table 6 shows that confidence in the management of nuclear technologies moderates the influence of knowledge and risk perception of nuclear risks on attitudes towards and opinion about nuclear energy. In models 1 and 3, where the confidence in the management of nuclear technologies was not used, both risk perception and knowledge had a significant influence on attitude towards, respectively opinion about nuclear energy; a lower risk perception and a higher knowledge seems likely to lead to a more positive attitude or opinion. However, the explanatory power of these models is much lower than the one of models 2 and 4, where confidence in the management of nuclear technologies is entered as a potential predictor. The role of these risk perception and knowledge is completely (Model 2) or partially (Model 4) taken over by the confidence in the management of nuclear technologies in the final models, and yields a significantly higher explanatory value of the regression models.

5. Conclusions

First, our paper has shown that the increasing positive attitude towards and opinion about nuclear energy observed in the previous decade has changed. Indeed, attitudes and opinions towards nuclear energy are clearly less positive than before the Fukushima accident, even though they remain slightly less negative than before the "nuclear renaissance".

Our analysis has then highlighted the main factors that are pleading in favour (low CO_2, emissions, energy independence, and the reliability of energy supply) or against nuclear energy (radioactive waste and the possible misuse of nuclear technologies). It has also shown that these factors are the same, both for people who are pro and against nuclear energy, even if the strength of the relations varies among the two groups.

Finally, our study has investigated the relations between, on the one hand, attitude towards nuclear and opinion about nuclear energy and, on the other hand, knowledge about the nuclear domain, confidence in the management of nuclear technologies, and risk perception of nuclear risks. The results of this study show that higher knowledge about the nuclear domain and lower risk perception of nuclear risks are likely to lead to a more positive attitude towards nuclear or a more favourable opinion about nuclear energy. However, the explanatory power of knowledge and risk perception on attitude/opinion towards nuclear energy is rather low. The confidence in the safe management of nuclear technologies is most strongly correlated with attitude / opinion than knowledge and risk perception of nuclear risks and comes out as the most important factor explaining the attitudes towards and the opinion about nuclear energy.

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MEDIA ATTENTION TO NUCLEAR ACCIDENTS: FUKUSHIMA AS A CASE STUDY

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ABSTRACT

This research seeks to capture and explain media reporting about the nuclear accident in Fukushima and makes a link from media reporting to the public policy debate. The nuclear energy program debate in media articles is analysed and the use of collective memory in media reporting about the Fukushima nuclear accident is identified.
The study is based on content analysis of two quality newspapers in Belgium, one in Dutch language, the other in French language. The data base consists of 260 articles published in the two months after the Fukushima nuclear accident and 34 articles published in the two weeks of the first (one year) commemoration of the accident. Every article was coded by two independent coders for each language group.
The results clearly demonstrate that journalists linked the nuclear accident in Japan with other domestic or international issues. The Fukushima nuclear accident was frequently used as a starting point for the discussion about nuclear energy policy and the future of nuclear energy. In addition, the Fukushima nuclear accident was presented in the media in the light of the Chernobyl nuclear accident.

1. Introduction

Mass media and journalism play a progressively important role in contemporary nuclear emergency situations. Public policy scholars often accentuate the key role of crises in explaining policy change (Sabatier and Jenkins-Smith, 1997, Nohrstedt,2011). When mass media report intensively about a certain topic, the people receiving the media information consider this topic as important (McCombs and Shaw 1972, Cohen 1985). Moreover, numerous studies from political and risk research established strong correlations between media and public priorities (For overview: McCombs and Shaw 1993). Although nuclear accidents are mostly not directly experienced, but rather learned through media reporting, they have a strong impact on the public opinion and often lead to political discussions about the use of nuclear energy for power generation (Boomgaarden and de Vreese, 2007).
In nowadays societies, risk-related information is a prevalent type of information distributed or produced by the mass media and is frequently a subject of journalism. Journalists represent, interpret, and construct reality (Rupar 2010). In doing so they often make use of the collective memory. Several studies on journalism reporting have examined the relationship between media and memory with focus on historical analogies drawn between present and past events (Volkmer, 2006; Barnhurst, 2003; Zelizer, 2004; Edy & Daradanova, 2006; Robinson, 2009). The findings of these studies confirmed that present factors tend to influence journalistic recollections of the past, and past factors tend to influence, or distort, journalistic experience of the present.
However, much empirical work still remains to be done in order to explain the influence of collective memory, of crisis-induced policy outcomes and of the link between media reporting and policy changes (agenda-setting), especially in the context of a nuclear accident.

A stream of research has tackled the agenda-setting power of the mass media (Edwards and Wood 1999; Soroka 2002) indicating that the influence of media coverage on the political agenda is contingent (Van Aelst and Walgrave, 2011). Sometimes political actors follow the media stream, while sometimes they do not seem to bother about media coverage. Still, after the Fukushima nuclear accident the researchers are trying to answer questions like: "*Is Chancellor Angela Merkel responsible for the turn in German energy policy, or was the shift caused by journalists*?"(Kepplinger and Lemke 2012).

In the present research we looked to the relevance of the Fukushima nuclear accident in the Belgian press in the first two months after the accident and to the relevance of the accident in the press during the first commemoration of the accident. We seeked to determine what was the main concern of media discussions. We expected that the attention to the Fukushima nuclear accident will alternate from the attention to the accident itself with the attention to domestic and global issues (*H1*). In addition, we hypothesised that the discussion in the media will be linked to the nuclear energy program (*H2*). Moreover, we expected that the collective memory about the Chernobyl accident will linked to the accident in Fukushima and the public policy related to nuclear energy programmes (*H3*). Energy was expected to be the most conflicting topic both in articles published in the first two months after the accident, as well as in the articles related to the first commemoration of the Fukushima nuclear accident.

2. Method

The media articles related to the Fukushima nuclear accident published in two largest quality Belgian newspapers De Standaard and Le Soir are analysed. The articles included in the analysis were published during two months after the Fukushima nuclear accident (period between the 11th of March, 2011 till the 11th of May, 2011) and in the two weeks of the first commemoration of the accident (period between the 3rd of March, 2012 till the 18th of March, 2012). The news articles were downloaded from the press data base Mediargus, and were obtained through a data base search using the words 'Fukushima' and 'nuclear' in the case of the first two months after the accident, respectively the word 'Fukushima' for the period of the one year commemoration of the accident. The final data base consists of 260 articles published in the two months after the Fukushima nuclear accident and 34 articles published in the two weeks of the first commemoration of the accident. The articles were published in either Dutch or French language, depending on the newspaper.

Every article was coded by two independent coders for each language group. In case of disagreements, the master-coder decided the final code based on a discussion. The inter-coder reliability was calculated with Krippendorf's alpha coefficient.

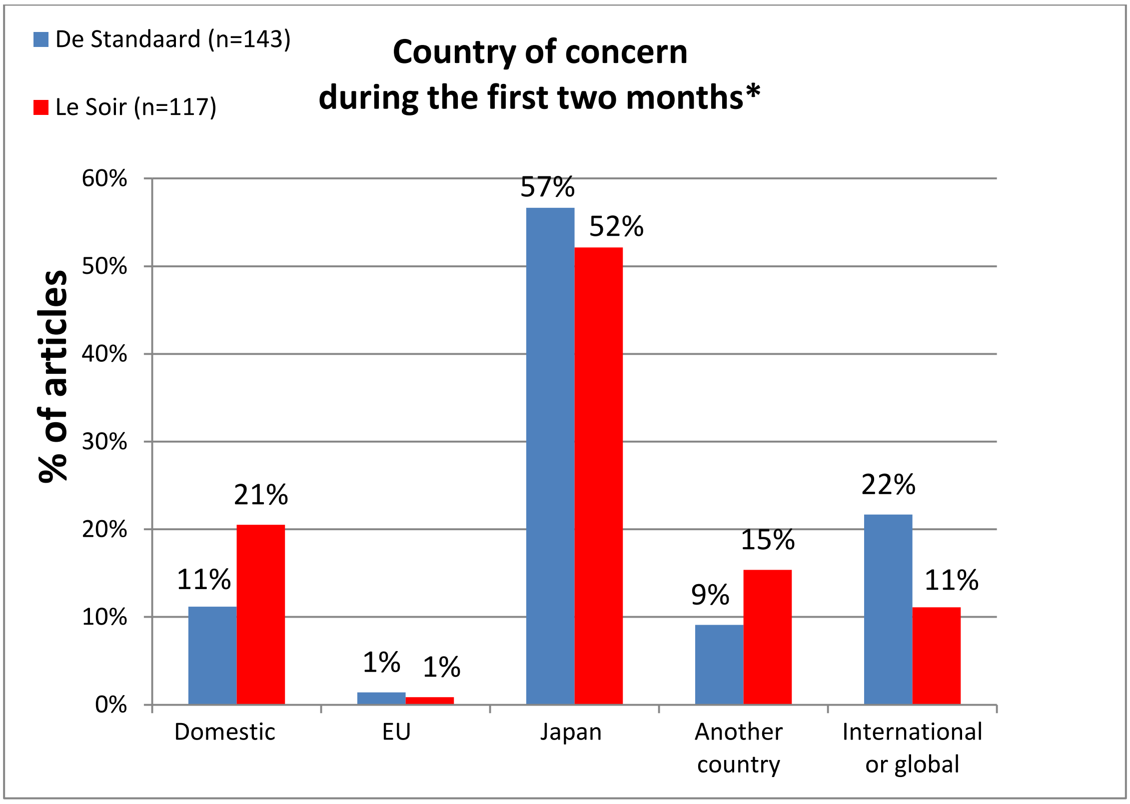
3. Results

3.1 The Fukushima accident as a domestic and international concern

The relevance of the accident in Japan for the newspaper articles analysed was assessed by the identifying whether the article was concerned mostly about the accident itself (events in Japan), the related topics in Belgium (domestic issues), issues related to the European Union, issues relevant to another country or issues of international or global concern.

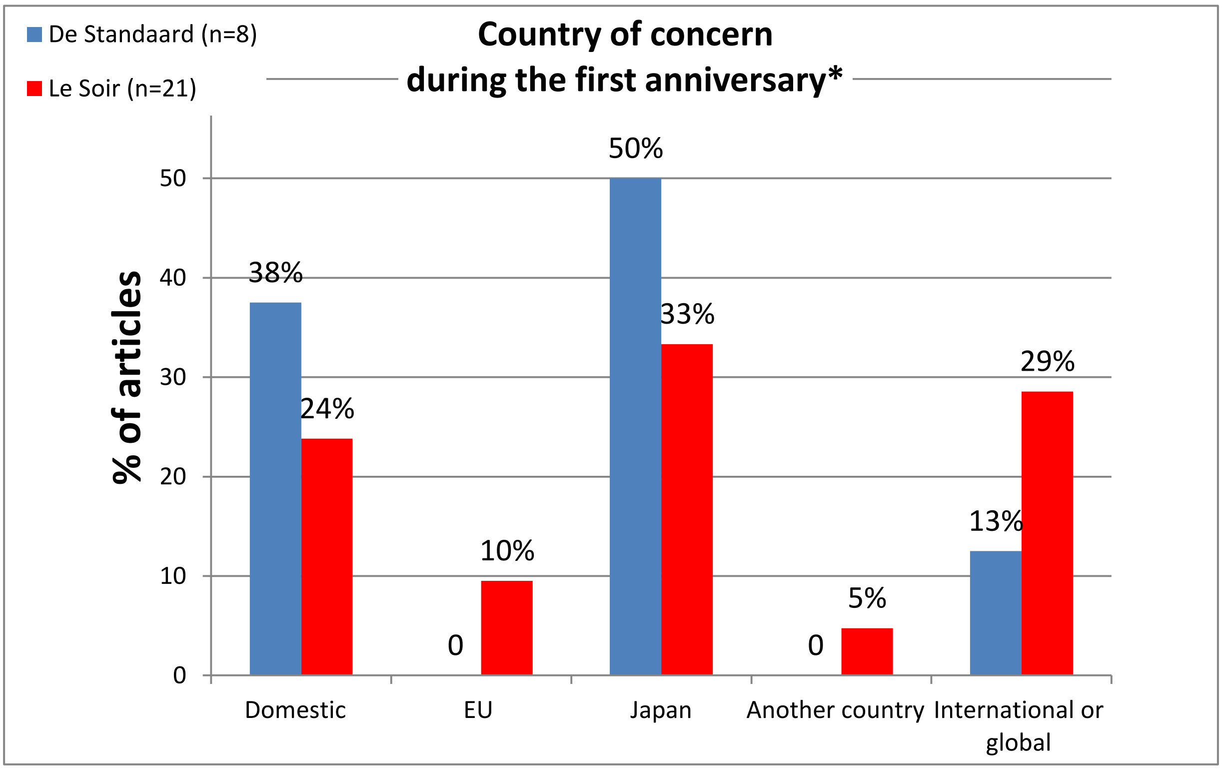
Figure 1 shows that the two Belgian newspapers mainly dedicated their attention to the situation in Japan itself the first two months after the accident: 55% of the articles were directly related to the events in Japan. However, 45% of the articles published in the first two months were focused on a topic that was not directly related to the accident in the Japan. 15% of the articles focused on the domestic relevance of the

accident and 17% on the relevance of the accident internationally or globally, e.g. the future of nuclear energy worldwide.
There was an obvious switch in the media coverage one year later, during the first commemoration of the accident (Figure 2). The analysis shows that the domestic, international or global influence of the Fukushima nuclear accident became even more important. Although 38% of the articles were still directly related to the events in Japan, the main concern of 28% of the articles was a domestic issue, e.g. the nuclear reactors in Belgium. In addition, the international or global issues became important in the media reporting - 24% of the articles on average were related to international or global issues. It is interesting that the Belgian media analysed did not discuss the nuclear accident in Japan in the context of European Union, but rather in the context of a particular country of the E.U. in the first two months after the accident. For instance Germany and German political decisions related to the future of a nuclear energy program were regular topics in the Belgian press. It seems that the European context of the accident became slightly more important in one of the two newspapers analyzed during the first commemoration of the accident.
From the findings we can conclude that journalists linked the nuclear accident in Japan with -domestic or international issues. This became even more evident during the first commemoration of the accident. The journalists published a big share of the articles in which the Fukushima accident was used only as a starting point for a discussion about a domestic or international issue.



*Intercoder reliability: De Standaard = 0.92, Le Soir = 0.98

Figure 1: Country of concern during the first two months



*Intercoder reliability: De Standaard = 0.97, Le Soir = 0.91

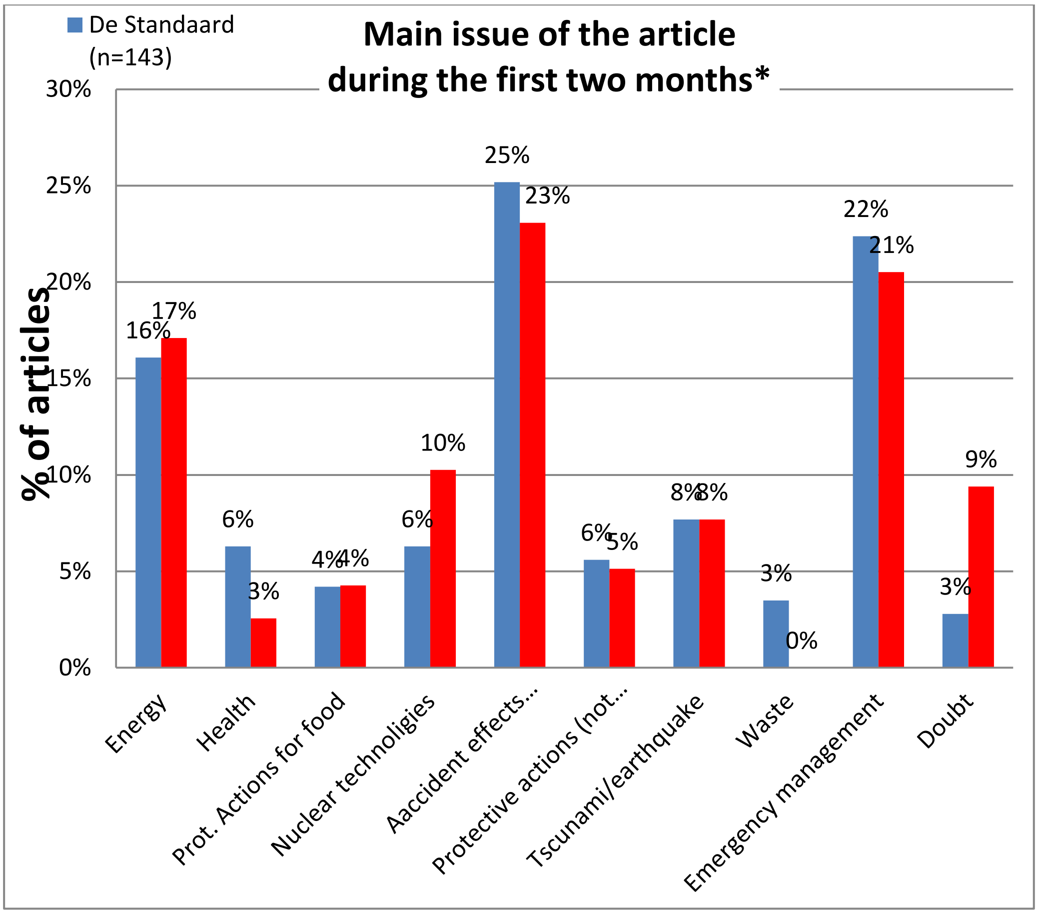
Figure 2: Country of concern during the first commemoration

3.2. Future of nuclear energy as a main topic in the media discussion

The accident effects and the emergency management were the main topics in the journalistic discussions in the first two months after the accident (see Figure 3). Almost every second article published in these two months reported about accident's effects other than health or food. They were reported about different aspects of radioactive contamination (land, sea, inhabited areas) and about protective actions, for instance decontamination, evacuation and sheltering. The in-depth analysis of the evolution of the topic during the weeks following the accident shows that media focused their attention on multiple topics at the beginning of the accident; yet, the diversity of topics within media attention decreased with time and became limited to energy.

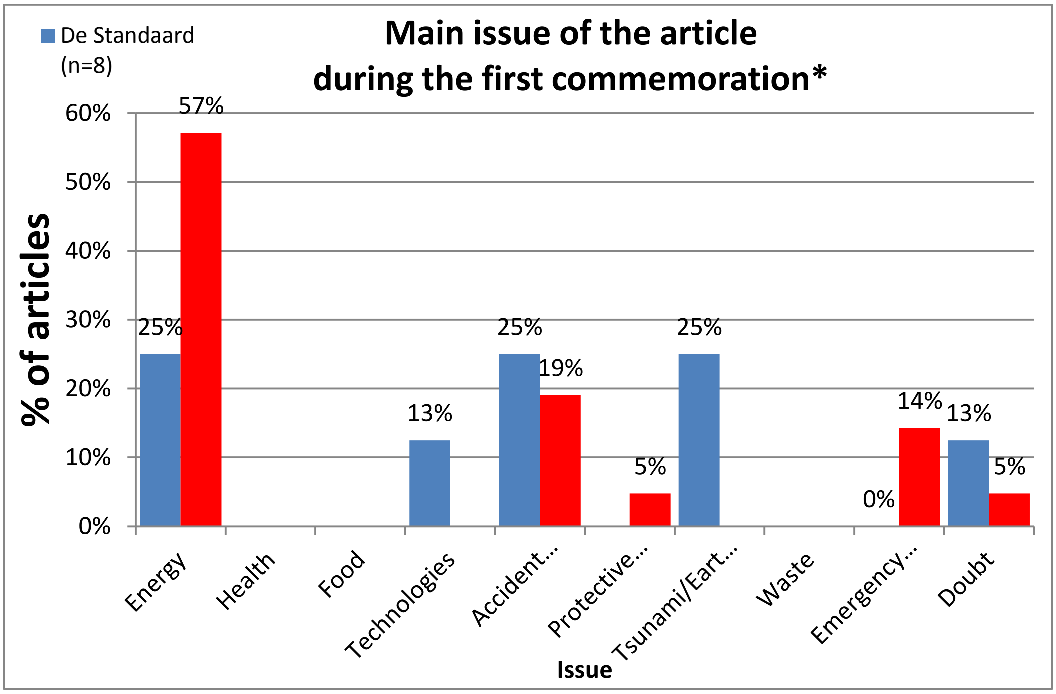
One year after the accident, during the first commemoration, the energy topic became the most discussed topic in the media articles mentioning the accident in Fukushima (see Figure 4). For instance, almost 60% of the articles published in Le Soir discussed the energy issues in relation to the Fukushima nuclear accident. The second most frequent topic (19%) were the accident effects that were unrelated to health or food: contamination, radioactivity, economic impact, material damage and disturbance of everyday life.

Although the media coverage of the topics in the newspapers analyzed was similar during the first two months after the accident, we can notice a drastic difference in the media coverage, especially related to energy topic, one year after the accident. The different media coverage and space given may indicate the diverse editorial policies of the two newspapers as regards nuclear energy.



*Intercoder reliability for Energy: De Standaard = 0.70, Le Soir = 0.95

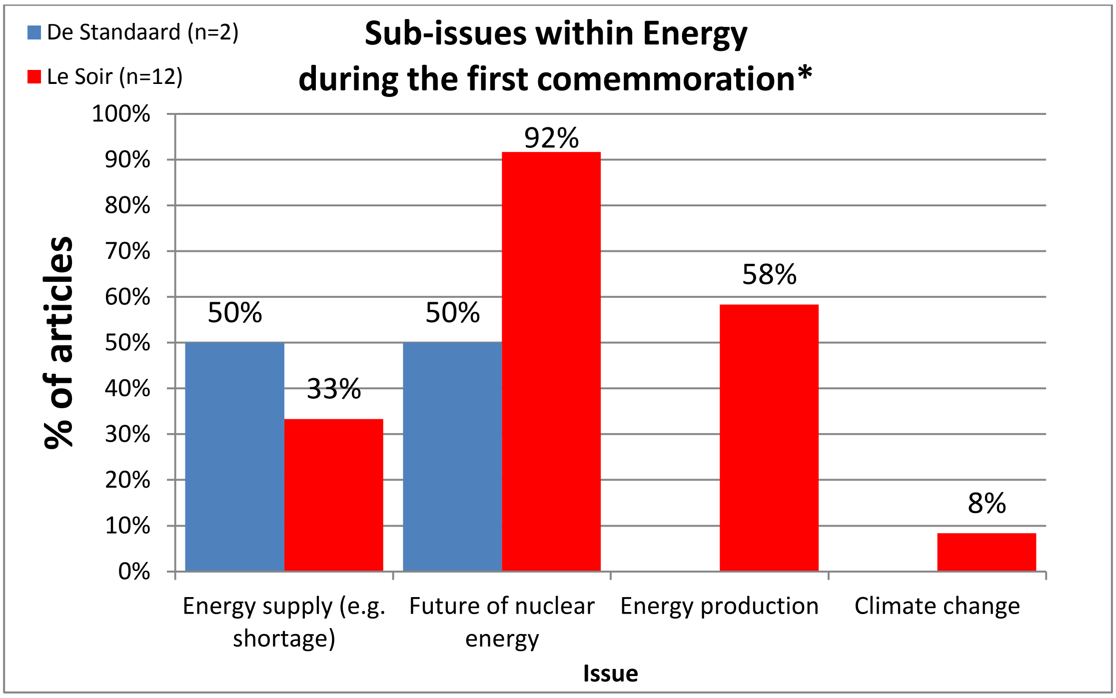
Figure 3: Main issue of the article during the first two months after the accident



*Intercoder reliability for Energy: De Standaard = 0.96, Le Soir = 0.97

Figure 4: Main issue of the article during the first commemoration of the accident

Since the issue of energy was revealed as the most frequently covered one, while the attention to the energy issues increased with a time, we analyzed the content of the articles published one year after the accident in more depth.
In the comparison between the two newspapers we should keep in mind that De Standaard had just 2 articles where 'Energy' was the main issue, while Le Soir published 12 articles discussing energy as a main issue. However, the most discussed topic related to the Fukushima nuclear accident in both newspapers was the future of nuclear energy.
Figure 5 suggests that the future of nuclear was a frequently covered aspect in articles that had 'Energy' as main topic (91% for Le Soir, and 50% for De Standaard). In Le Soir, energy production is the second most covered sub-topic in the context of energy (58,3%) while it is not once mentioned in De Standaard. Le Soir mentioned every sub-topic at least once, while De Standaard only mentioned two of them, also just once.
To conclude, more than ninety percent of the analyzed articles related to energy discussed the potential exit from the nuclear energy programme and the moratorium. In general, nuclear accidents can have an influence on public policy. The influence of the Chernobyl accident was highly investigated and the influence on the public policy was confirmed by many researchers (Triandafyllidou 1995, Lindner 2000, Cantone et al. 2007). Public policy scholars often accentuate the key role of crises in explaining policy change (Nohrstedt, 2011). Thus the Fukushima accident became a stimulator for political actions as a consequence. Moreover, according to our analysis of the two newspapers having different editorial policy related to the nuclear energy, the journalists writing about the Fukushima nuclear accident, primarily discussed the future of nuclear energy in order to confirm their own editorial policy.



*The coders could select one or more sub-issues within each issue
**Intercoder reliability for Future of nuclear energy: De Standaard = 1, Le Soir = 1

Figure 5: Sub-issues within the “Energy” during the first commemoration of the accident

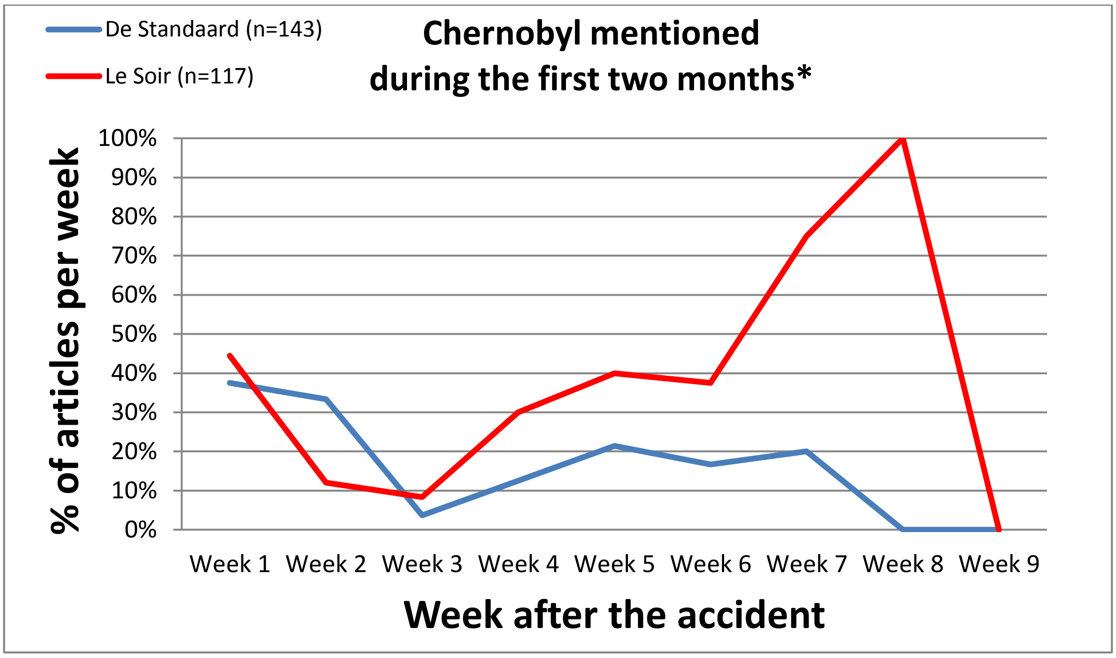
3.3 The Fukushima nuclear accident in the light of the Chernobyl accident

The journalistic production of news is in many cases subject to the influence of collective memories. These refer to the shared pool of information held in a group of people and are widely available in the public sphere. In this research we traced back the influence of the collective memory on the Chernobyl accident on the media reporting about the Fukushima nuclear accident.

The results of the media analysis of the articles published in the first two months after the accident reveal a strong influence of the past on the reporting about a present nuclear accident. Although the nuclear accident in Chernobyl had different characteristics than the accident in Fukushima it has been taken as a reference in the media almost every day.

Figure 6 presents the relative numbers: the percentage of appearance of the word "Chernobyl" in all the articles related to the Fukushima accident published in the two newspapers in the first nine weeks after the accident. We found out that the word "Chernobyl" was significantly more often mentioned in Le Soir than in De Standaard during the two months after the accident. The frequency of referring to the Chernobyl accident in the two newspapers showed increasing differences between the two newspapers with time after the accident; the largest difference in frequencies was observed in week 8, when the world remembered the 25th commemoration of the Chernobyl accident. From Figure 6 it is clear that the journalists of Le Soir referred to both nuclear accidents in the same article.

This trend in referring to the Chernobyl accident is even more significant in the articles published one year after the accident, discussing the first commemoration of the Fukushima nuclear accident. The newspaper Le Soir mentioned the word Chernobyl in more than 38% of the articles discussing the first commemoration of the Fukushima accident, while De Standaard did not refer to the Chernobyl accident at all.

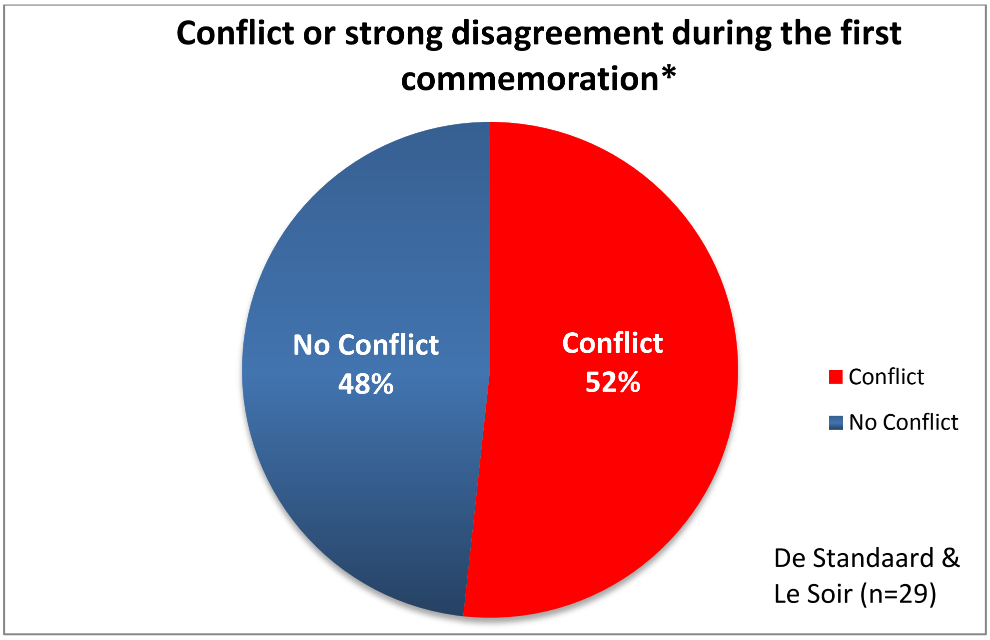


*Intercoder reliability: De Standaard = 1, Le Soir = 1

Figure 6: Chernobyl mentioned in the articles during the first two months after the accident

3.4 High presence of conflicts in the media reporting about the Fukushima

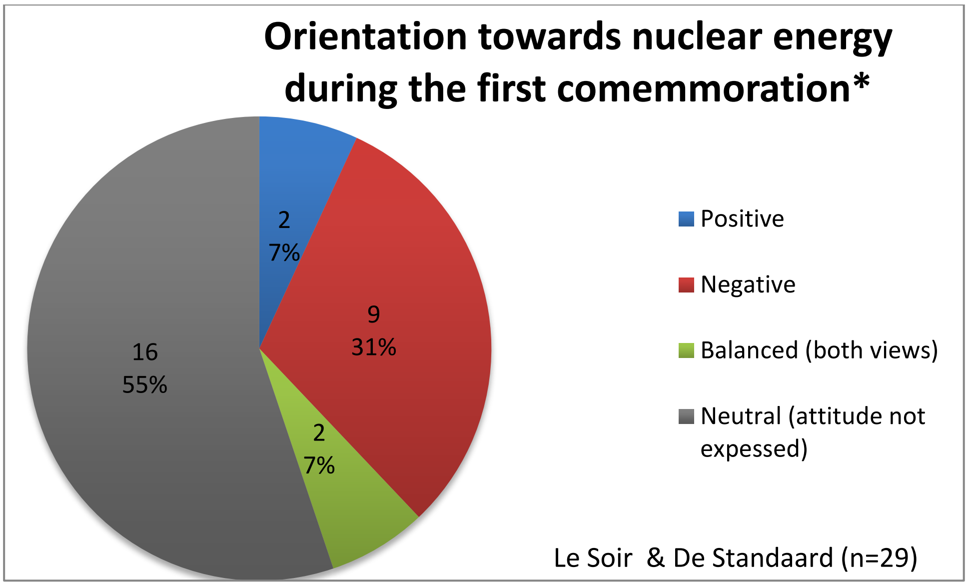
The role of thumb in journalism is that a conflict or disagreement increase media attention. Media articles containing a strong conflict are generally considered worthy to be published (Rupar 2010). One of the main points in our study was to identify the existence of conflicts or disagreements in media reporting about the Fukushima nuclear accident. Conflict stories involved a conflict between people/groups/parties/countries. Such stories contained an explicit mentioning of the fact that there was disagreement about the issue (e.g. nuclear energy, emergency management, monitoring). This disagreement was expressed in words (e.g. contradictory positions or claims) or in deeds (e.g. protest, stigmatization).
Based on the media analysis we can confirm that also the reporting about the Fukushima nuclear accident in a first two months presented conflicts and strong disagreements between the experts, political actors, emergency managers, action groups (see Figure 7). Conflicts were presented in every third article (32%). One year after the accident, during the first commemoration, conflicts became even more visible in the press, being presented in every second article. Yet, again drastic differences among the two newspapers were identified: 62% of the articles in Le Soir and 25% of the articles in De Standaard reported about a strong disagreement or a conflict.



*Intercoder reliability: De Standaard = 0.88, Le Soir = 0.90

Figure 7: Conflict or strong disagreement during the first commemoration of the accident

An additional analysis of the articles reporting a conflict or strong disagreement revealed that the future of nuclear energy was the most conflicting topic in media reporting during the first commemoration of the Fukushima accident. In the articles where the attitude towards nuclear energy was expressed (nuclear energy is good or bad), most of the articles (31%) were negatively oriented towards nuclear energy, with journalists presenting mostly views and arguments against nuclear energy (Figure 8).



*Intercoder reliability: De Standaard = 0.85, Le Soir = 0.90

Figure 8: Orientation towards nuclear energy during the first commemoration of the accident

4. Conclusions

In the present research we looked in to the relevance of the Fukushima nuclear accident in the Belgian press in the first two months after the accident and during the first year commemoration of the accident. The results show that media attention to the Fukushima nuclear accident alternated from attention to the accident itself to domestic or global issues. This became even more evident during the first commemoration of the accident. The journalists published a big share of the articles, where the Fukushima accident was used frequently as a starting point for a discussion about a domestic or international issue.

We also investigated if the discussion in the media was linked to the nuclear energy policy. The analysis confirmed that the future of nuclear energy came increasingly in focus with time, becoming the most important topic during the first commemoration of the accident.

Moreover, we expected that the collective memory about the Chernobyl accident will be linked to the accident in Fukushima and the public policy related to nuclear energy programmes. The results of this study showed that the references to Chernobyl were numerous, the articles discussing Fukushima mentioning also the accident in Chernobyl. With regards to this aspect, the analysis also revealed differences in the editorial policies of the two newspapers analysed.

Conflict was often reported in the articles discussing the accident in Fukushima, which shows that a nuclear emergency is a highly conflicting topic.

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THE COLLABORATIVE PROJECT ON THE EUROPEAN SODIUM FAST REACTOR AND ITS PROLIFERATION RESISTANCE EVALUATION

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ABSTRACT

The collaborative project on the sodium fast reactor (CP-ESFR) is an international project where 25 European partners develop R&D solutions for a European Sodium Fast Reactor concept. The Project is funded by the 7th EU Framework Programme and covers topics such that the fuel, the fuel element and the fuel cycle, the safety concepts, the reactor architectures and components and the balance of plant. Within the sub-project 3, dedicated to safety, a task, addresses proliferation resistance issues. In the paper some of the core features and the so called working horses, for a loop and a pool Sodium fast reactor concept are presented, by highlighting those more relevant for the proliferation resistance aspects. Some of the activities carried out in the project for its proliferation resistance evaluation are then illustrated, in particular those related to material type considerations on the possible diversion targets.

1. Introduction

The collaborative project on the sodium fast reactor (CP-ESFR) is an international project where 25 European partners develop R&D solutions for a European Sodium Fast Reactor concept [1]. The Project explores aspects related to the main design aspects of the system, with particular focus on the core features. Within sub-project 3, dedicated to the system's safety concepts, a dedicated task led by JRC-ITU, with contributions of EdF, ENEA and AREVA, addresses proliferation resistance issues. The objective of this task is to make considerations on the resistance to nuclear proliferation of a Sodium Fast Reactor design. The Generation IV International Forum (GIF) Proliferation Resistance & Physical Protections (PR&PP) Evaluation Methodology [2] has been chosen as the general framework for this work, complemented by punctual aspects of other evaluation methodologies and studies. In particular, some of the indications contained in the International Atomic Energy Agency (IAEA) International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) PR assessment manual [3] have been considered to make Material Type attractiveness considerations on the core options under investigation by the CP-ESFR analysts. This paper will first briefly illustrate some aspects of the ESFR design relevant to proliferation resistance and then will present selected aspects emerged by the analysis carried out.

2. Aspects of the ESFR design relevant to proliferation resistance

Two concepts of 1500 MWe reactors called "Working Horses" have been proposed in the context of CP ESFR: a pool type and a loop type design. For both designs, two core options are proposed: one with U and Pu oxide fuel and the other with U and Pu carbide fuel. For both carbide and oxide cores, the inner and outer fuel regions have different Pu mass content in order to flatten the core power shape. The reactor architectures and the core of the working horses are shown in Fig 1.

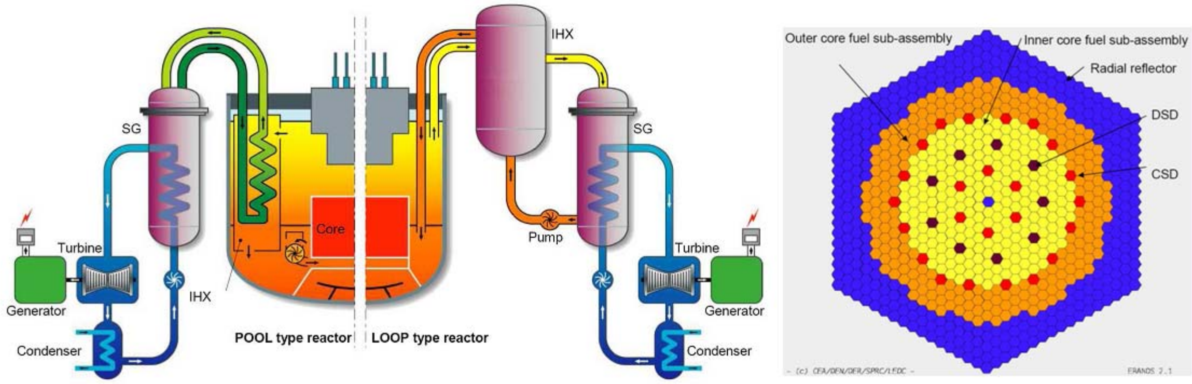

Fig 1. Schematic diagram of reactor architectures of the two ESFR working horses [4] and the SFR core with oxide fuel, no blanket case. [5]

The systems could be used for minor actinide management (MA), either in homogeneous or heterogeneous mode. Homogeneous MA management basically consists in replacing part of the uranium of the fresh fuel elements with minor actinides (4% MA), while heterogeneous MA management considers that an additional ring of fuel assemblies (FA) is added with respect to the specified 'Working Horse' core [6]. These additional ring assemblies form the radial blanket. Fresh radial blanket assemblies, when present, are always composed of depleted UO_2 (80%) and MAs (20%). The group investigated the possibility to perform MA management only for the oxide core.

3. Proliferation resistance evaluation framework

The GIF PR&PP Evaluation Methodology framework [2] is illustrated in Fig 2.

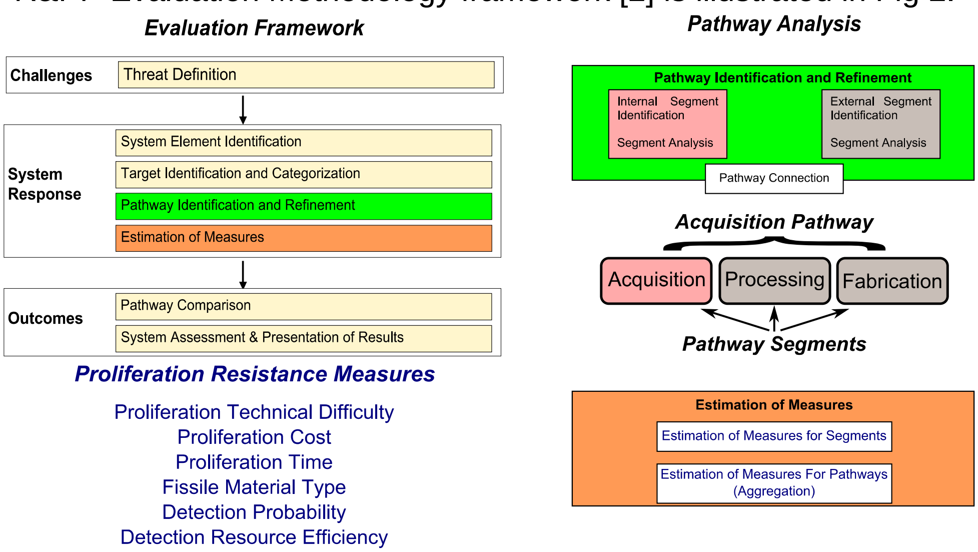

Fig 2. The GIF PR&PP methodology framework

The GIF defines proliferation resistance as “that characteristic of an NES that impedes the diversion or undeclared production of nuclear material or misuse of technology by the Host State seeking to acquire nuclear weapons or other nuclear explosive devices”[2]. The threats to be considered according to the methodology are 1) *Concealed diversion,* 2) *Concealed production of nuclear material,* 3) *Breakout* and 4) *Production in clandestine facilities*.

A full PR evaluation of the systems design was beyond the scope of the project. The GIF PR&PP methodology framework has been used to decompose the system into system elements and to identify potential diversion targets. The analysis then focused on the aspects that were considered to be more relevant for the project, i.e. targets characterizations in terms of nuclear material attractiveness for a proliferator, Safeguards by Design (SbD) considerations, high-level considerations on the four above-mentioned threats. Although the in vessel fuel handling systems of the reactors are different for pool and loop reactor types, both designs share the same conceptual system elements, shown in the left hand-side part of Fig 3. The right hand-side of Fig 3. shows the possible diversion target types (in red) corresponding to all the cases simulated for the oxide and carbide cores by the other project partners [6], [7].

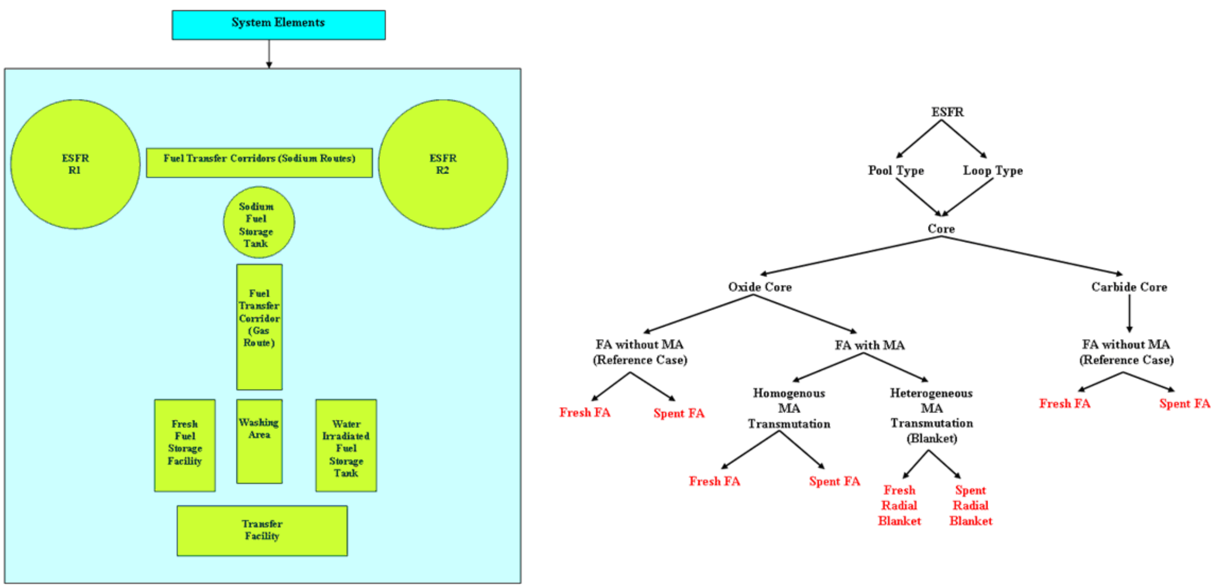

Fig 3. ESFR system elements and possible diversion targets in different cases

To analyse the nuclear material attractiveness of the identified diversion targets, several literature studies have been reviewed and applied. The following paragraph illustrates the outcome of the material type analysis performed by applying User Requirement 2 of the INPRO Proliferation Resistance (PR) manual (The attractiveness of nuclear material and technology in an INS for nuclear weapons programme should be low) [3].

4. Material type analysis according to INPRO PR UR 2

User Requirement [UR] 2 of the INPRO PR manual provides 3 indicators and related evaluation parameters (EP) for the attractiveness of Nuclear Material [3]. Fig 4. shows the quantification of nine of them when applied to the ESFR possible diversion targets.

	EP2.1.1 Material type/ category						EP2.1.2 Isotopic composition						EP2.1.3 Radiation field					
	VW	W	M	S	VS	MT type	VW	W	M	S	VS	Pu-239/Pu (%)	VW	W	M	S	VS	Dose (mGy/hr)
Fresh oxide FA	■					UDU				■		47.76		■				173
Fresh carbide FA	■					UDU				■		47.76	■					145
Fresh oxide FA with 4% MA	■					UDU				■		47.76				■		3330
Spent oxide FA		■				IDU		■				62.41					■	4.13E+06
Spent carbide FA		■				IDU		■				62.96					■	4.63E+06
Spent oxide FA with 4% MA		■				IDU		■				58.82					■	3.86E+06
Spent Blanket with 20% MA		■				IDU				■		48.57					■	2.29E+06

UDU: Un-irradiated Direct Use Material
IDU: Irradiated Direct Use Material

	EP2.1.4 Heat generation rate						EP2.1.5 Spontaneous neutron gen. rate						EP2.2.1a Mass of an item (kg)					
	VW	W	M	S	VS	Pu-238/Pu (%)	VW	W	M	S	VS	(Pu-240+Pu-242)/Pu (%)	VW	W	M	S	VS	Mass of one item (kg)
Fresh oxide FA		■				3.60		■				40.35				■		500 - 750
Fresh carbide FA		■				3.60		■				40.35				■		500 - 750
Fresh oxide FA with 4% MA		■				3.60		■				40.35				■		500 - 750
Spent oxide FA		■				1.94		■				30.37				■		500 - 750
Spent carbide FA		■				1.37		■				30.22				■		500 - 750
Spent oxide FA with 4% MA		■				6.68		■				29.50				■		500 - 750
Spent Blanket with 20% MA				■		37.79		■				13.47				■		500 - 750

	EP2.2 No. of items for SQ						EP2.2.3 No. of SQ (material stocks or flow)						EP2.3.1 Chemical/ physical form					
	VW	W	M	S	VS	No. of SQ in FA	VW	W	M	S	VS	No of SQ in NES	VW	W	M	S	VS	Form
Fresh oxide FA	■					3.45	■					>100			■			Pu compounds
Fresh carbide FA	■					2.90	■					>100			■			Pu compounds
Fresh oxide FA with 4% MA	■					3.45	■					>100			■			Pu compounds
Spent oxide FA	■					4.83	■					>100				■		Spent Fuel
Spent carbide FA	■					2.52	■					>100				■		Spent Fuel
Spent oxide FA with 4% MA	■					5.26	■					>100				■		Spent Fuel
Spent Blanket with 20% MA		■				0.83		■				69.72				■		Spent Fuel

Fig 4. Comparison of the cases with respect to nuclear material attractiveness study in INPRO UR2. Very Weak (VW), Weak (W), Medium (M), Strong (S), Very Strong (VS).

Fig. 4 shows that the “Spent Blanket with 20% MA” dominates or equals the other targets in all the considered indicators, making it nominally the least attractive nuclear material target in the system. This would seem to hint at the fact that the heterogeneous transmutation of minor actinides in the radial blanket would not pose additional diversion hazards. In addition, the possibility to recycle minor actinides in the blanket instead of recycling them in fresh fuel elements would avoid incurring in “safeguardability" issues for the fresh fuel elements [8]. On the other hand, it has to be noticed that the presence of a radial blanket would open up potential misuse scenarios that might worsen the overall PR of the reactor core.

There is no substantial difference between diversion targets in the oxide and the carbide options. The only indicator that scores differently is the radiation field for fresh oxide and fresh carbide fuel assemblies. The difference stems from the different amount of nuclear material available inside the elements, but this difference (173 mGy/h vs 143 mGy/h) has no real life impact.

In the case of homogeneous minor actinide management, the minor actinides are added to the fresh fuel. As can be seen from the indicators, this leads to a difference in the quantification of the radiation field indicator related to the fresh fuel targets. In this case the difference is substantial and points at a higher difficulty in handling MA-bearing fresh fuel. It has to be noticed that the presence of MA in the fresh fuel assemblies might have negative impacts on the safeguardability of these items, as the current verification activities might be hindered by the strong radiation emission of the actinides (for additional details on this aspect see [8]).

5. Conclusions

This paper presented selected aspects of the CP-ESFR proliferation resistance evaluation, the evaluation framework and then some outcomes stemming from the application of User requirement 2 of the INPRO PR manual. In summary:

- Both loop and pool type working horses share the same core configuration. Although being item facilities and therefore not posing particular problems in terms of safeguards accounting and reporting, liquid sodium is a hostile environment and an opaque coolant that makes the verification of the sodium-immersed nuclear inventory more problematic than in typical LWRs.
- The addition of MA to the fuel and/or blankets might have proliferation resistance and safeguardability implications that need to be thoroughly assessed adopting a systemic point of view.
- For a diversion strategy there is no big difference in terms of material type attractiveness between the oxide and the carbide fuel assemblies.
- Blanket assemblies (where present) could be composed by depleted uranium or by more complex mixtures. Irradiated blanket assemblies could have a relatively low burn-up and, depending on the initial mixture, may contain weapons-grade plutonium. The addition of MA to the blanket mixture strongly affects the irradiated assemblies' plutonium isotopic composition.

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