Fill in the title of your proposal below.

Title of the Proposal

Title of Proposal: **Licensing Safe & Small Accelerator Driven Module Reactors**

Acronym: **SSADMR**

The consortium members are listed in part A of the proposal (administrative forms). A summary list should also be provided in the table below.

List of participants

Partic. No.	Participant organisation name	Short name	PIC	Country
1 (Coordinator)	European Organisation for Nuclear Research	CERN	999988133	IEIO*
2	Centro de Investigaciones Energeticas, Medioambientales y Tecyhnologicas	CIEMAT	999614877	ÈS
3	Narodowe Centrum Badań Jądrowych	NCBJ	999506722	PL
4	Istituto Nazionale Fisica Nucleare	INFN	999992789	It
5	Hydromine Nuclear Energy S.a.r.l	HNE	917565681	L
6	Agenzia Nazionale per le Nuove Tecnologie, Energia e Sviluppo Economico	ENEA	999988521	It
7	International Thorium Energy Committee	IthEC	918008389	CH
8	Paul Scherrer Institut	PSI	999994923	CH
9		APPLUS		Sp
10		REZ		Cz

*International European Interest Organisation (IEIO)

Participant No. *	Participant organization name	Country
1 (Coordinator)		
2		

3		

* Please use the same participant numbering as that used in the administrative proposal forms.

1. Excellence

Your proposal must address a work programme topic for this call for proposals.

This section of your proposal will be assessed only to the extent that it is relevant to that topic.

1.1 Objectives

- *Describe the overall and specific objectives for the project, which should be clear, measurable, realistic and achievable within the duration of the project. Objectives should be consistent with the expected exploitation and impact of the project (see section 2).*

In the general stagnation context for the nuclear energy in Europe and in the Western world, Small Modular Reactors (SMR) have nonetheless gained a raising interest, as attested by the large variety of designs with distinct characteristics that have been presented even recently in several countries. Indeed, considering Carbon emission concerns and fossil fuels availability in the medium term, nuclear energy is looked as one of the realistic portfolio solutions to growing energy demand [1]. In this scenario, SMR may provide the possibility for deploying nuclear plants easier to install and less prone to severe accidents. The World Nuclear Association (WNA) foresees a large potential market for SMR, with many systems in operation by 2030. Hundreds of these systems could be deployed in China, according to the experts of WNA. However, as of today, the development and deployment of SMR's on the planet is at a very early stage. Just at the beginning of 2019, Canada has submitted a license application for its first SMR [2].

The enormous potential of SMRs rests on a number of factors:

- Because of their small size and modularity, SMRs could almost be completely built in a controlled factory setting and installed module by module, improving the level of construction quality and efficiency.
- Their small size and passive safety features make them suitable to countries with smaller grids and less experience of nuclear power.
- Their small size and passive safety features should allow to avoid the definition of an emergency zone or to limit it to the perimeter of the site.
- Size, construction efficiency and passive safety systems (requiring less redundancy) can lead to easier licensing compared to that for larger plants.
- Moreover, achieving 'economies of series production' for a specific SMR design will reduce costs further.

Therefore, a special role could be played by specific SMR meeting the most stringent requirements of safety, proliferation, waste management, and sustainability at the same

[1] (per esempio) International Energy Agency, Key World Energy Statistics 2016
[2] http://world-nuclear-news.org/Articles/First-Canadian-SMR-licence-application-submitted

time.

The most common definition of SMR, which is also the definition adopted by the SMR Regulators' Forum[3], is for a commercial system limited to 300 MWe. This quite broad definition has been complemented by another definition, that of the Micro Modular Reactor (MMR), limited to about 50 MWe. MMR units have been deployed, since the late '70, in remote areas of Siberia, to produce affordable electricity in a far-accessible environment. However, a large scale commercial deployment of SMRs is directly coupled to the economics of the technology and the licensing process is an important driver of these costs. Because the SMR have unique characteristics in terms of size and power but also because of novel features proposed that are largely unstudied from a regulatory perspective, a special attention must be dedicated to the Licensing Process (LP), that was historically developed for larger Nuclear Power Plants (NPP) and more in particular for PWR and BWR reactors.

The activity will be divided in two part for better develops the **Expected Impact of the NFRP-05**:

This action will allow the EU to establish a baseline for safety assessments and verification of existing and future SMR concepts during the following years. The safety demonstration could also provide support tools for SMR licensing process and to maintain highest standards in the EU's proposed concepts and designs.

Part 1 consider the existing SMR

Currently there are more than 50 SMR designs under development for different application. Three industrial demonstration SMRs are in advanced stage of construction: in Argentina (CAREM, an integral PWR), in People's Republic of China (HTR-PM, a high temperature gas cooled reactor) and in the Russian Federation (KLT40s, a floating power unit)[4].

The "ADVANCES IN SMALL MODULAR REACTOR TECHNOLOGY DEVELOPMENTS – IAEA 2018" *A Supplement to: IAEA Advanced Reactors Information System (ARIS) http://aris.iaea.org* will be the reference document for identify all the present SMR technologies. In particular, using the classification of table 1 of the reference, the following different categories of SMR will be analysed in the activity:

- Thermal reactors
  - WATER COOLED SMALL MODULAR REACTORS (land and marine base),
  - HIGH TEMPERATURE GAS COOLED SMALL MODULAR REACTORS
- Fast reactors
  - sodium cooled fast reactor (SFR),
  - heavy liquid metal-cooled (HLMC, i.e. lead or lead-bismuth) fast reactor
  - the gas-cooled fast reactor (GFR)
- Molten Salt SMRs) presents the SMRs that utilize molten salt fuelled (and cooled) advanced reactor technology.

The result of the analysis will put in evidence the safety and construction features of the 6 technologies proposed in the domain of SMR and underline the similarities and differences in relation to the needs of safety, fabrication, dismantling and operation. The aim is to emphasize the compatibility and the difficulties of each concept in relation to the current licensing procedures, such as defined in the

[3] SMR regulators Forum Pilot Project Report https://www.iaea.org/sites/default/files/18/01/smr-rf-report-29012018.pdf

[4] ADVANCES IN SMALL MODULAR REACTOR TECHNOLOGY DEVELOPMENTS – IAEA 2018

WENRA Report of Study by Reactor Harmonization Working Group RHWG March 2013 - Safety of new NPP designs. In particularity it will be identified if the are difficulties in application of the defence in dept as defined by IAEA INSAG 10 and modified by the WENRA report. Some safety authorities have a feeling of having to review the procedure for defence in dept, for example, the Canadian security authority says: "The CNSC is aware that designers of new reactor technologies, including SMRs, may propose alternative approaches to address the levels of defence in depth"[5]

Part 2 consider the future SMR concepts

For the future concept we consider the necessity of expand the targeted applications of SMR technology to the nuclear waste recycling domain. To this end the ADS type rectors have particularly performing characteristics. Some aspect as the residual heat removal, a fundamental safety faction identified in the beginning of the NFRP-05 call, the solutions will be the same as for critical SMR but for "confinement" and "control of reactivity" the solutions will be different (presence of the window for the confinement).

We consider that if "the way for robust science-based recommendations to decision-makers regarding SMR safety in the EU" should be defined, as demanded by the NFRP05, this way should integrate the ADS concept. Moreover, this position will reinforce EU's commercial prospects and competitiveness in this field.

For part 2, it will be necessary to develop a "conceptual design" of the ADS SMR, this development will be done in parallel to the part 1 so that when the conceptual design will be will be available (after 1 year?) the analysis of the ADS SMR in relation with the existing licensing reference will benefit from the results of the analysis of existing SMRs.

A synthesis of part 1 and part 2 will be developed for complying with the NFRO-05 scope:

"this action should bring tools for assessment of specific present and future SMR technologies and provide a set of their safety specifications and requirements in line with the EU directives. Focus should be also given to set up basic safety objectives for future SMRs licensing process."

ADS presentation:

Already at the end of the '90 at CERN Nobel Prize C. Rubbia proposed the concept of Energy Amplifier (EA), an Accelerator Driven System (ADS) able to produce energy by impinging a proton beam on a spallation target enclosed in a subcritical reactor. ADS can offer the possibility to test concepts (e.g. innovative fuel types and construction materials) to be applied in innovative commercial reactors in a safe manner, being the system controlled by the accelerator. The ADS status-of-art project is MYRRHA, which adopts a linac for the accelerator. An assessment of world efforts on ADS can be found in [111]. An ADS with a layout conceived as a specific SMR test stand, is to be considered a novel and innovative concept, that could produce a paradigm shift when the originality of the SMR features, combined with those of the accelerators, are considered collectively. These features include, but are not limited to:

- Small power and compact architecture usually (at least for Nuclear Steam Supply System and associated safety systems) employing passive concepts. Therefore, there is less reliance on active safety systems and additional pumps, as well as AC power for accident mitigation.

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[5] Small Modular Reactors: Regulatory Strategy, Approaches and Challenges - Discussion paper DIS-16-04 - Canadian Nuclear Safety Commission (CNSC) 2016

- Lower power leading to reduction of the source term as well as smaller radioactive inventory (smaller reactors).
- Modularity and small size allow having several units on the same site.
- Lower requirement for access to cooling water – therefore suitable for remote regions and for specific applications such as mining, desalination.
- Ability to remove reactor module or in-situ decommissioning at the end of the lifetime.
- The accelerator (providing by spallation the neutrons necessary to breed the fission reaction in a subcritical core) can be shut off in a fraction of a second, eliminating the major risks related to the criticality operation.

SMRs in general, and of course ADS SMRs as well, have not yet been licensed (except, as of today, the SK SMART 300 MWe reactor) or widely analyzed by regulators. We think that the future of nuclear energy depends on the capability of the forthcoming systems to cope with the concurrent issues of safety, proliferation, cost, waste production and management. Acceptability by the public is a requirement contemplated as a mandatory review step in the usual LPs and policy decision is the normal initiation phase of all LP. A system layout that is not able to address convincingly all the above reported issues will not pass these barriers. For these reasons we want to provide tools for the assessment of a realistically deployable innovative technology able to confront the necessity of improvement in safety and security with the cost issues and with the waste reduction, and providing a set of safety specifications and requirements, in line with the EU directives. Indeed, the management of spent nuclear fuel requires safe storage and disposal. As a consequence, dealing with its long-term radiotoxicity is a key challenge. In about 60 years of nuclear power plants activity, Europe has been accumulating a large stock of radioactive waste that may pose issues of safety, security, proliferation, environmental challenge and societal concern. As shown in Fig. 1, by IAEA Data Waste Counter [111], today over 400,000 tons of spent fuel have been discharged all over the world, out of which about one third in Europe, and the problem will only increase in magnitude in the coming years, despite the decreasing number of nuclear plants in Europe. In addition, as it is more apparent in the USA, the unduly long delay in providing definite management solutions to nuclear waste imposes financial risks to operators and governments which may render nuclear energy less competitive and thus might remove a significant CO2-free emitting energy source for the future. Geological disposal is today's technological paradigm, being the only actively pursued option for spent fuel or High Level Waste (HLW) management. However, this option raises strong concerns in the public opinion on the ability to guarantee a safe and secure system for the extremely long period during which nuclear wastes must be isolated (200,000 years or longer). Indeed, none of our political or social institutions have been stable over a period of 1,000 years, therefore it is not obvious how to ensure that a stable monitoring and safeguarding system can remain in place as long as necessary. Moreover, geological disposal of radioactive waste requires a series of careful analyses projecting the site geo-chemo-physical evolution into the future for millennia. Last but not least, it is ethically questionable whether we have the right to burden future generations with the potential risks posed by nuclear wastes if we do not make our best efforts to minimize them. Therefore, accelerator physics and nuclear science together need to enable alternative technological options in this area to provide an acceptable societal solution to the problem. A fully sustainable nuclear energy system should further reduce the waste burden in volume and in longevity by minimizing the presence of long-lived radiotoxic isotopes in the waste to be disposed of and thus by incinerating these long-lived isotopes in transmutation systems. Partitioning the waste to separate the long-lived isotopes and transmuting the latter in dedicated systems, is a viable solution on a human time scale, morally acceptable, technically feasible, and possibly also economically more sustainable. At the moment the most advanced ADS technological development whose final aim is the nuclear waste transmutation is represented by the MYRRHA project. We want to leverage on the achievements of this project, and at the same time to support its on-going LP. To target its aim, and notably its scientific and technological breakthroughs, SSADMR is broken down into a number of interdisciplinary and concrete objectives addressing every aspect encompassed by the ADS SMR concept and to its licensing.

- The objective of the SSADMR proposal is to analyze the Licensing Process (LP) applied to a special, innovative type of system; the Accelerator Driven Small Modular Reactor (ADS SMR).
    - Conditions for achievement:
- We want to demonstrate that harmonization of engineering aspects, manufacturing and accompanying certifications can standardize the LP , thereby facilitating the licensing of ADS SMR, which, together with its economies of scale, could make it more attractive for industry. The final aim of this study would be to facilitate efficient progression of regulatory activities for licensing general types of SMRs.
    - Conditions for achievement:
- Being the LP layout-specific, because inherently linked to the specific project characteristics and to the targeted applications, we want to present a specific, innovative and safe ADS SMR concept, and apply to this a generalized approach, in order to advance standardized plant projects for authorization of construction and operation of the modular nuclear installation. The targeted applications of the concept we propose are including, but not limited to, energy production, and nuclear waste transmutation.
    - Conditions for achievement:
- We want to define the magnitude of risks embedded in the specific ADS SMR, with the aim of applying a graded approach to determining the level of regulatory control.
    - Conditions for achievement: prepare a plan with harmonized methods for reviewing safety cases
- We want to define criteria that allow for ADS SMR “generic site” prescriptions, and “generic engineering project”, in order to fully exploit the modularity concept also for similar SMR projects, identifying what factors are associated with facilitating international licensing of SMRs.
    - Conditions for achievement: ensure competence building and transfer of knowledge on ADS and SMR

- We want to define the authorizations for construction, operation, decommissioning for a generic ADS SMR.
    - Conditions for achievement:
- Education, training, communication and dissemination are additional objectives
    - a) Training of young researchers within the project by schools and workshops on specific topics
    - b) Documentation, communication and dissemination of the results, addressing the directly concerned community involved in the nuclear waste disposal safety case and a broader scientific community.

Therefore, our vision, in a time horizon at the middle of the century, is that the ADS SMR system can help the redevelopment of nuclear industry, not only competing on the traditional energy market, but also replacing retiring coal-fired power plants in countries where regulations are banning coal, and advancing niche applications, for example in remote or isolated areas or islands that require small-sized units and in which electricity produced with non-nuclear sources of power has high costs, or water desalinization. To quantify the potentiality of the market, Nuclear Energy Insider estimates that just in USA replacing coal power plants (that shall have to be shut down in any case), offers a market opportunity of 30 B$.[6]

Once the concept engineering features (modularity, reactor / safety system integration, sub-grade installation etc.) will have demonstrated technical and economic capabilities, the principle will be more easily escalated to multi-unit installations allowing for the cost-efficient deployment of SMRs able as well to cope with a vision that surpasses the current paradigm of “burying the waste”, by the use of a new technology that provides a workable contribution to solve a worldwide problem, and that at the same time helps to increase the social acceptability of nuclear industry.

1.2 Relation to the work programme

- *Indicate the work programme topic to which your proposal relates, and explain how your proposal addresses the specific challenge and scope of that topic, as set out in the work programme.*

For SMRs, the safety-by-design can be enhanced by the subcriticality of the system (we should give some justification for the statement and, on the other hand, I would not contrast the safety of the SMRs to that of the SMR ADSs. The call considers the SMRs promising in terms of safety. I would play on complementarity thanks to the elimination of waste, ...) The use of

[6] http://www.nuclearenergyinsider.com/smr/pdf/USSMRUtilityMarket5.pdf

proper passive safety systems activated by force of nature (gravity, conduction, convection, i.e.) represents the second level of safety. In ADS the spallation technique is the efficient way to produce high neutron flux by externally supplying neutrons into the reactor. In this way, including the low inventory of radioactive materials in respect to larger NPP, as well as the capability of the accelerator to very rapidly shut the beam off, thereby interrupting the nuclear chain reaction, the ADS SMR can set a benchmark in the nuclear safety standard. The safety-by-design, reducing the probability of accidents and mitigating the consequences, produces a system which is simpler, safer, cost effective and, in principle, easier to-be-licensed. The long operating experience (OPEX) accumulated singularly on the main components of the ADS SMR reduces uncertainties and mitigate risks. In fact, accelerators technologies are deployed since almost a century, with operating data available in terms of safety, availability and reliability. Even if it is not obvious that a smaller reactor means a shorter technical assessment (the time to complete the review is influenced by the time needed to confirm that the proposed safety and control measures meet regulatory requirements), for the subcritical reactor the demonstration of safety in support to the application for authorization is expected to be easier, for example, because of the response to abnormal conditions.

Requirements for SMRs may be site-specific and also legislation dependent, and therefore the regulatory and legal requirements in different countries can jeopardize one of the main features of SMR: exportability. Moreover, the precise legal authority and role of regulatory body is not the same in all States. . But even if requirements cannot be harmonized between different States due to legal structure differences, acceptance of common methodologies can facilitate the use of one regulator's conclusions to inform another's technical assessment work, which would reflect into time and cost savings. This would include for example the use of common mechanical design codes, personnel and process qualifications, materials and analysis requirements, and a QA system that includes design change management. Standardization is a key factor for SMR, because factory production is one of the distinctive features of this type of systems, differentiating it from the existing nuclear supply chain. Indeed, the SMR business model has been assimilated to the production of nuclear engines for ships. The SSADMR project should be highly standardized, which implies that the possible vendor must find an appropriate balance between standardization and customization demands. In addition, any rework should be avoided because it disturbs the assembly process. Finally, all components/parts/kits required for ongoing work should be available at due time because any delays will affect the production of the entire plant and not only one unit. An important challenge for the factory assembly of SMRs is nuclear regulation. While all of the safety features of SMRs could be addressed generally within the existing regulatory framework, there are issues that must be resolved. In particular, current regulatory practices might not be fully compatible with a factory assembly model, especially if the assembly process is automated. Regulators must adapt their methods of work to test the units to the greatest extent possible at the assembly stage and reduce the potential for rework. For the successful deployment of SMRs, a new approach to licensing should be developed to allow factory-based manufacturing and serial deployment. It might require strong co-ordination not only between regulators but also between manufacturers. On the other hand, full factory assembly of SMR units will allow large savings in manufacturing costs.

Many factors are influencing the SMR market. According to NEA [7], among the several factors influencing the SMR market need to be included the nuclear regulatory barriers and the public attitude towards nuclear power. In the case of an ADS, we should add to the challenges the skeptic attitude towards this specific industrial applications of the accelerator technology, which is sometimes in our opinion wrongly perceived as a research domain-centered activity. We believe that SSADMR can deal with all these challenges at the same time, by targeting basic safety objectives able to support future SMRs licensing processes. This will be done in particular by complementing the choice of the accelerator layout with a careful component and system reliability analysis. Moreover, the close interaction in the Consortium among designers, typical manufacturers of specific components (magnets for example, or spallation target) and regulators will allow examining various approaches and possibilities, providing more realistic results.

1.3 Concept and methodology

(a) Concept

- *Describe and explain the overall concept underpinning the project. Describe the main ideas, models or assumptions involved. Identify any inter-disciplinary considerations and, where relevant, use of stakeholder knowledge. Where relevant, include measures taken for public/societal engagement on issues related to the project. Describe the positioning of the project e.g. where it is situated in the spectrum from 'idea to application', or from 'lab to market'. Refer to Technology Readiness Levels where relevant. (See General Annex G of the work programme);*

- *Describe any national or international research and innovation activities which will be linked with the project, especially where the outputs from these will feed into the project;*

The conceptual and traditional scheme of an ADS is shown in fig. 1 (from [8])

[7] https://www.oecd-nea.org/ndd/pubs/2016/7213-smrs.pdf

8 R. Cywinski, A. Herrera-Martínez, G. Hodgson, and et.al, "Towards an Alternative Nuclear Future," The Thorium Energy Amplifier Association (ThorEA), 2009

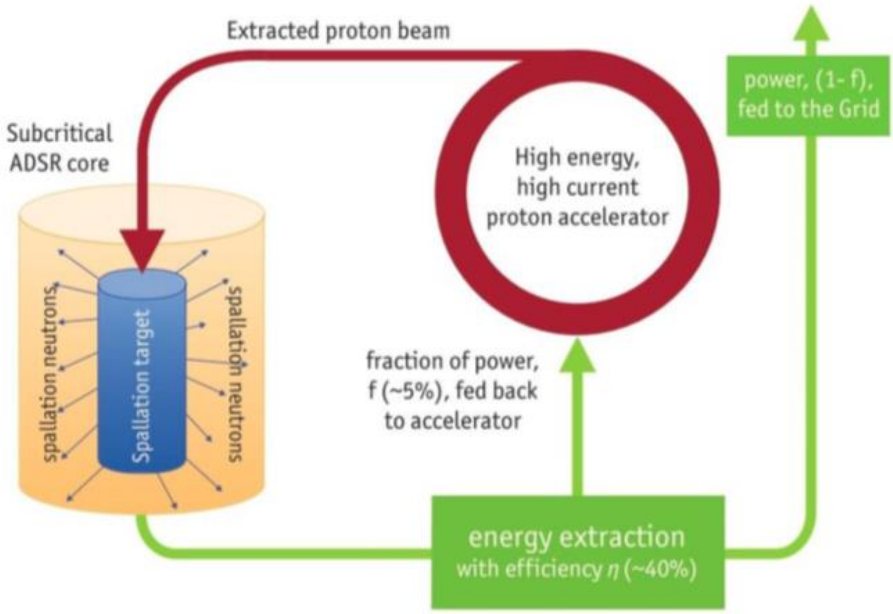

Fig 1. ADS conceptual scheme

The ADS SMR concept stems from the combination of particle beam accelerator technology and compact nuclear reactor technology. The benefits of this combination multiply the advantages of the single SMR in terms of safety, cost, and environmental impact. Because the LP has been individuated as a barrier to the deployment of SMRs in general, and therefore of ADS SMR as a consequence, we want to analyze the LP for the SSADMR system with the aim to advance the concept to a realistic approach.

The main components of the SSADMR system are: accelerator, subcritical core and spallation target. The requirement of subcriticality of the reactor implies that during operation the neutrons necessary to sustain the fission must be continually supplied to the core. This is done by the accelerator, producing proton impinging on the spallation target. For each of the system components technology benchmarks are available and diverse solutions for the layout exist. More than 40,000 accelerating machines are deployed today in the world, with applications as diverse as medical therapy and diagnosis, manufacturing processes (EB-welding, n implantation, radioisotope production…) and research (particle physics, synchrotron radiation, material science…).- Based on such widespread applications and the available long duration OPEX data, we can consider the corresponding technology scenario to be mature (although continuously and fast developing towards more and more innovative solutions). In the process of producing neutrons from an accelerator-based spallation neutron source, the accelerator plays an important part in the facility to achieve the maximum number of neutrons. SSADMR will investigate an accelerator of the cyclotron type, because its relative compactness enhances the characteristics of a SMR, which by definition needs to be size effective. The experience of operating for 50 years the PSI cyclotron, world record in its power class, and the experience of design, construction and operation of the Large Hadron Collider at CERN, the largest circular collider in the world, will be relevant to define requirements of safety and reliability for the SSADMR accelerator. The reactor core of a SMR can be considered a simplified, scaled version of the equivalent NNP. Spallation is the process of producing neutrons by causing particles from an accelerator to impact a heavy metal target.

In order to achieve the highest rate of neutron production, the target material of the spallation process has to be composed of an element which has a high atomic number along with a reasonable thickness. It is widely understood that the reaction between heavy nuclei and highly energized incident protons can produce a large number of neutrons with a wide spectrum of neutron energy, which makes this method ideal for minimization of nuclear wastes. Neutron multiplicity, defined as the number of neutrons per incident particle (n/p), is a crucial parameter for showing the performance of applications of an accelerator driven neutron source. Neutron multiplicity is a function of beam energy and target materials, linearly dependent on the target mass number (in the range $12 < A < 238$) and slowly increasing with incident proton energy (in the range $0.2 < E < 2$ GeV).

The average number of neutrons is approximately given by

$$\langle n \rangle = (0.0803 + 0.0336 \ln E) A$$

where E is the incident proton energy in GeV and A is the target mass number. This formula provides 10 % accuracy or better for $A \geq 40$ [9].

The spallation target we will consider is based on liquid Lead Bismuth metal eutectic (????), for reason of experience and OPEX accumulated (MEGAPIE[10] was using the same technology, and MYRRHA will be adopting this technology as well).

For the SSADMR system, we will produce a reference layout and, at the same time, we will produce the requirements and safety documentation that are demanded for a full LP. It will be a sort of “dummy exercise” of licensing, calibrated and proof-checked on a valid layout, because the LP is concept-dependent, and because safety-by-design is part of the process. To get the most out of the project and making the exercise realistic and useful it is necessary to include all design aspects, from the starting point, that otherwise will be hidden in the folding of the documentation.

SSADMR will interface with the MYRRHA community in SCK, as well as with the community of nuclear engineers and scientists in CERN, PSI, CIEMAT, ENEA and INFN.

The licensing process requires for the applicant to submit a detailed demonstration of safety, which is reviewed by independent regulators, according to the national applicable laws. It should be responsibility of the regulator to provide guidance, safety objectives, criteria and the format of the documents to be produced (generally a Safety Analysis Report, SAR). For this reason, and also in consideration of the innovative type of plant for which few regulatory experiences are existing, we deem necessary to work according to a well defined stakeholders scheme, where the regulatory functions shall interface with the technical counterparts and

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[9] J. Cugnon, C. Volant, and S. Vuillier, “Nucleon and deuteron induced spallation reactions,” Nucl. Phys. A, vol. 625, no. 4, pp. 729–757, Nov. 1997.

[10] G. S. Bauer, M. Salvatores, and G. Heusener, “MEGAPIE, a 1 MW pilot experiment for a liquid metal spallation target,” J. Nucl. Mater., vol. 296, no. 1–3, pp. 17–33, 2001.

with the implementing actors, and where the public and policy makers also have a definite role. An early involvement of regulators in a process like this depicted is critical to prevent delays. Our partner Applus will mirror the regulator action, providing the guidance and steering the exercise process.

According to the Hierarchy of safety standards for innovative reactors, prepared in the frame of the SARGEN-IV project, as reported in fig 2 [11], it will be necessary to ensure that the safety standard of LEVEL I, II and III are fulfilled already before submission of SAR.

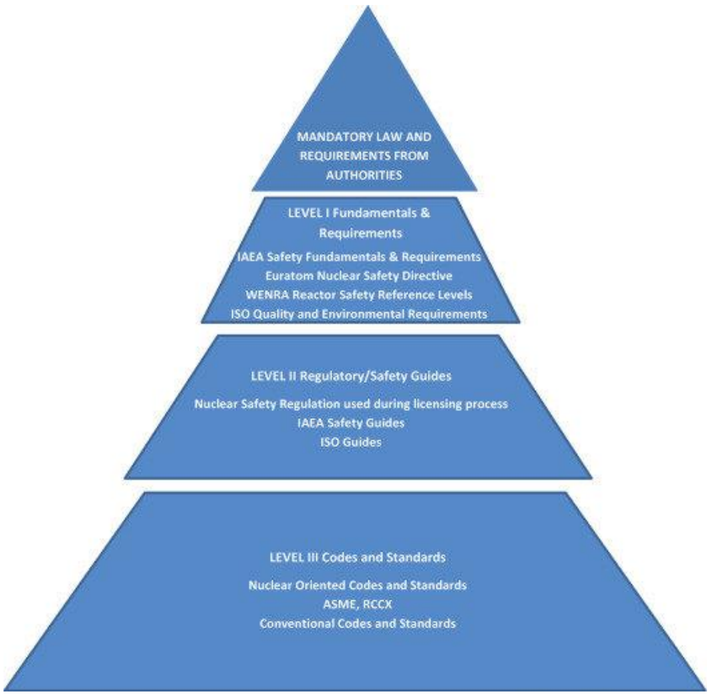

Fig 2. Hierarchy of safety standards for innovative reactors.

Well before the submission of the licence application, it would be also requested for the regulators to meet with the licensees, the designer and with the prospected operator. The Consortium will prepare, under supervision of Applus, our "internal regulator", the documentation according to the general structure of the SAR:

1- General Design Aspect, safety objectives and engineering design requirements
2- Design of systems, structures and components
3- Reactor, reactor coolant and connected systems
4- Accelerator and beam losses
5- Spallation target and window, qualification and experimental data.
6- Safety features
7- Decay heat removal system
8- Containment system
9- Habitability system

[11] Sargen-IV: Consideration on the possible content of the safety analysis report for innovative ESNII reactors – Nuclear Engineering and design 300 (2016) 453-466

10- Instrumentation & control
11- Electric power and power conversion system
12- Radioactive waste management and Radiation protection

Site characteristics, operational conditions, human factors engineering and management systems, which are also normally included in the SAR, will only be treated on general terms, because either are geography dependent, or depending on experiences of the specific operator, that, at this moment, is not defined and not part of the work.

1.2 Ambition

2. Impact

2.1 Expected Impact

2.2 Measures to maximise impact

2.2.1 Dissemination and exploitation of results

2.2.2 Communication activities

3. Implementation

3.1 Description of work — Work packages, deliverables and milestones

3.2 Management capabilities

3.3 Management structure and procedures

3.4 Risk management

3.5 Consortium/ Clusters as a whole (where applicable)

3.6 Resources to be committed

PART B. I

⚠ **For a proposal to be considered as complete, the applicant(s) should fill in the following table templates:**

1. **Table 3.1.a – List of Work Packages**
2. **Table 3.1.b – Work Package Descriptions**
3. **Table 3.1.c – Work Package Effort**
   An excel template is provided in the "Partner(s) Application/Proposal Template" package made available to the applicant(s) via the submission system

4. **Table 3.2 – List of identified critical risks and the mitigating measures foreseen**
5. **Table 3.3 – Total Eligible Costs breakdown per Work Package**
   An excel template is provided in the "Partner(s) Application/Proposal Template" package made available to the applicant(s) via the submission system