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IFMIF-DONES as Paradigm of Institutional Funding in the Way towards Sustainable Energy

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Abstract: Although actions promoting sustainable energy production and consumption have been widely approached in the literature, the management of the big scientific projects devoted to these actions have not been considered as a matter of study from the perspective of sustainable development, but almost exclusively from the scientific or technical ones. Experiences all over the world are increasingly demonstrating that the impact of the project phase is more critical than expected. In this sense, the joint international research on clean and more efficient nuclear power, especially fusion, is currently focused on two large projects: ITER and IFMIF-DONES. Although ITER is step by step advancing, IFMIF-DONES still has a long way before it is actually implemented and its main target (the evaluation of the materials to build the future nuclear fusion reactors) is achieved. In this work, the different steps focused on IFMIF-DONES funding and management planning up to date are analysed and, departing from them, some key points on the future development of the project are proposed.

Keywords: sustainable energy; nuclear fusion; institutional funding; project management

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1. Introduction

Among the wide variety of problems mankind faces regarding the long route towards a fully sustainable development, energy production, consumption and management are major ones. The reason is that energy is not an isolated topic, but a total one with direct and transversal implications in many other aspects of economy, industry, research, environmental protection, legal affairs, etc.

Starting from the beginning of the energy chain, production is much more than a technical problem. Energy is not properly produced, but extracted and/or converted from some types to others according to our necessities.

The extraction of energy from some not very useful forms to others can be carried out by burning substances (coal, petroleum, gas, biomass) [1,2], or by producing and maintaining some kind of nuclear reactions (mainly, the fission of Uranium-235 and Plutonium-239) [3,4]. The extracted energy can heat fluids or gases for the direct use of this heat or produce movement directly used or to be converted into electricity.

In other cases, it is not necessary to extract energy, but just to convert some types into others. It is the case of solar radiation, which is produced during nuclear fusion reactions in the sun and reaching Earth in a more useful way, wind energy, which actually comes from the sun and is converted into electricity after moving generators, tidal energy, etc. In some cases, there is a third step in the chain of the conversions. It is the case of photovoltaic energy, where solar radiation produces quantum transitions and electricity.

In summary, the energy stored in atomic nuclei, as the potential energy of water, as chemical energy in wood, petroleum or coal, etc., is converted into movement (engines

for cars, planes or other moving devices), heat and/or electricity to power all kinds of electrical devices, heat up/cool houses [5,6] or light up lamps [7,8], among other finalities.

In the short summary of energy use, it has been mentioned that, within the sun, certain fusion reactions take place, which is what happens when different isotopes of hydrogen nuclei collide with such high energies that, in spite of the electrical repulsion, they stay together linked by the strong nuclear interaction. The use of hydrogen instead of heavy radioactive nuclei such as uranium and plutonium, is an advantage because waste management would be cheaper, easier and safer. Furthermore, the ease to obtain these nuclei, the low price of extraction and their almost unlimited abundance make the control of nuclear fusion a strategic objective to achieve sustainable, cheap and clean energy, which is one of the most urgent needs of mankind. Indeed, a deep analysis of the sustainable development goals [9] shows that the control of such a source of energy could remarkably contribute to the direct or indirect achievement of most of them. This would be the case of, at least, SDG 1 (no poverty), 2 (zero hunger), 3 (good health and well-being), 6 (clean water and sanitation), 7 (affordable and clean energy), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 10 (reduced inequalities), 11 (sustainable cities and communities), 13 (climate action), 14 (life below water) and 15 (life on land).

However, the extreme difficulty in controlling fusion reactions and extracting the released energy has not allowed this energy to be used to date. In Figure 1, the main milestones towards the commercial use of nuclear fusion are shown.

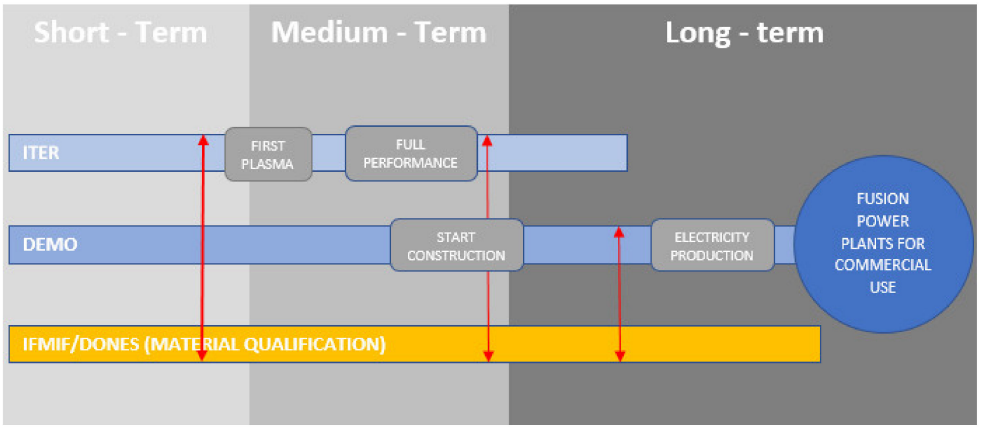

Figure 1. Fusion roadmap. More information in EUROfusion website [10].

Among the main difficulties regarding the safe and profitable control of energy from nuclear fusion are the very high temperatures necessary for the hydrogen nuclei to pass the electrical repulsion barrier and fuse, and the neutrons resulting from such a fusion that would cause damage to the reactor materials, because they cannot be stopped with magnetic fields.

After the long and successful operation of the "Joint European Torus" (JET) [11], the main experiments to overcome these difficulties were the "International Thermonuclear Experimental Reactor" (ITER) [12] and the "International Fusion Materials Irradiation Facility DEMO Oriented Neutron Source" (IFMIF-DONES) [13,14]. The latter consists of a deuterons accelerator that produces fusion-like neutrons after the collision of deuterium nuclei with a lithium cascade. The neutrons, at about 14 MeV, are used to irradiate and study their effects on different material candidates for the construction of the DEMOnstration Power Plant (DEMO), the last experimental reactor before the commercial use of fusion, which is expected to be built around the 2040s of the XXI century.

With an initial budget of 700 MEUR [15], IFMIF-DONES will likely be built in Escúzar (Granada, Spain), where the preparatory works have already started. It is expected to become the most important scientific installation ever in Spain and its economic, social, environmental impacts are supposed to be very remarkable at a local [16,17] and global [9,18]

level, which proves the potential of this project as a path towards the achievement of several sustainable development goals (SDG). However, the management of such a project is also very complex with three main players: the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT, Spain), the University of Granada (UGR, Spain) and, since 2021, the IFMIF-DONES Consortium.

In this work, several aspects related to the economical and organizational aspects of the IFMIF-DONES project are presented and analysed in order to give a better idea of one of the main milestones in the path towards clean and sustainable energy. Hopefully, it can be useful for other projects in this or near fields in order to make the first forecasts and applications for funding.

2. Materials and Methods

An extensive revision of the agreements, calls, competition processes, main milestones and granted funding projects related to IFMIF-DONES was carried out. Given the qualitative perspective of this work, which describes the development of an unique project, expected to serve as a guide for future projects in different areas, the sources for this revision were mainly of two different natures, the first one being bibliographic, including laws, administrative resolutions, and institutional websites. On the other hand, the day-to-day experience of such a large project, where political, administrative and technical eventualities can happen, was a worthy source for this work, pretending to become a guide of learned lessons and a model for other future projects on experimental facilities for research on sustainable energy.

Once the different funding sources were identified, a deep analysis of the different budgets, work packages, funding conditions and final reports was performed.

The methodology used depended on factors such as an administration or international body granting the funds or the status of the project (finished or currently ongoing).

In the following section, the main milestones concerning funding were presented and analysed.

3. IFMIF-DONES: Financial Sources and Implementing Frameworks

The financial sources of IFMIF-DONES were described, and their policies to fund the project through the main players, as well as the way they are performing this, were presented and analysed. This task was carried out in the following subsections, source by source.

3.1. EUROfusion

The European Consortium for the Development of Fusion Energy (EUROfusion) was established in 2014 to unify the efforts of the fusion research bodies from 25 European Union member states, including the United Kingdom, Ukraine, and Switzerland. It supports and funds fusion research activities on behalf of the European Commission's Euratom Program. It is currently composed of 30 research organisations, with approximately 150 affiliated entities, including universities and companies [10].

The EUROfusion budget (Table 1) presents an idea of the importance of this body and the international interest on fusion development.

Table 1. EUROfusion overall budget for the period 2014–2020.

TOTAL FUNDING	**2014–2020**	**1,234,100,000.00 EUR**
EURATOM H2020		678,800,000.00 EUR
STATE MEMBERS FUNDING		555,300,000.00 EUR

After the completion of the EUROfusion budget for 2020, and due to the situation generated within the COVID-19 pandemic, the commission considerably decreased the

funds earmarked for the project in a readjustment aimed at providing more funding for COVID-19-related programmes and actions.

Since January 2018, the University of Granada (UGR) is one of the affiliated entities aforementioned as the Third Party of CIEMAT, in order to efficiently execute the actions aimed at the implementation of the IFMIF-DONES facility, which was the target of this work. The EUROfusion tasks related to IFMIF-DONES, where CIEMAT and UGR are involved, were included in two main work packages (WP) as listed below.

3.1.1. WP26: Early Neutron Source Definition and Design (WPENS)

For the construction of the DEMOnstration Power Plant (DEMO), that is expected to be the last prototype before the commercial future reactors after the decade of the 2050s, the qualification of the materials that could be used in the construction of the critical parts is essential.

Therefore, a neutron source capable of mimicking the conditions that might be encountered in DEMO and, thus, in future fusion reactors, is needed in order to irradiate test materials and establish the most suitable ones, since the neutrons originated in the fusion reactions might, inevitably, collide with this first wall, exposing the materials that form it under very severe radiation conditions.

The objective of WPENS is to advance with engineering designs of the IFMIF-DONES facility which, in principle, aims to cover the DEMO's needs. The design and development of some prototypes of several components that will be part of the installation in the next five years are also included. Some of its key milestones are:

- Technical review on the accelerator and target;
- Concept design selection;
- Selection of site (Escúzar is the most probable location to be selected);
- Design and qualification R&D;
- Start of construction;
- Commissioning and start of operation.

All of these key milestones were framed and planned to be achieved as part of an overall roadmap, in which the other projects were framed as part of a whole, all of which were co-ordinated to achieve power generation for commercial use by magnetic confinement fusion.

3.1.2. WP30: Education (WPEDU)

The targets of EUROfusion programs, regardless of IFMIF-DONES, go beyond strictly technical issues, and foresee the training of future fusion scientists through PhD and pre-PhD programmes. In this framework, the WP30 aims to have a direct impact on the development of human resources expected to be necessary in the short and medium-term for the research and development of the fusion industry.

Therefore, direct support is being provided to doctoral and pre-doctoral programmes at European technical institutes and universities in order to guarantee the acquisition of expertise in subjects mainly related to engineering and physics applied to fusion.

This programme also intends to support students from universities established in countries with little experience in fusion research. For this purpose, students must spend a minimum of 6 months in a host centre, although they would continue to be linked to their university, and funds would be allocated to help provide these universities of provenance with the necessary infrastructures for research in this field. The doctoral thesis of these students would be jointly supervised by their home university and the host centre.

3.2. European Regional Development Fund (ERDF)

The ERDF aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions. This is going to be achieved by focusing on some priority areas, strongly related to sustainable development [19]:

- Innovation and research;

- The digital agenda;
- Support for small and medium-sized enterprises (SMEs);
- The low-carbon economy.

The execution of the ERDF funds for IFMIF-DONES is being carried out during this first phase following two parallel lines of tasks: CIEMAT tasks with co-funding from the Spanish Ministry of Science, Innovation and Universities, and UGR tasks, with co-funding from the Regional Government of Andalusia (Consejería de Economía, Conocimiento, Empresas y Universidad).

3.2.1. Line Spanish Government—CIEMAT

On June 2019, CIEMAT submitted an application for ERDF co-financing funds under the "IFMIF-DONES site preparation activities and implementation of related laboratories (DONES PRIME) within the multiregional operational programme 2014–2020" to the General Office of Science Policy Coordination, dependent on the Spanish Ministry of Science, Innovation and Universities.

After the request's approval, an agreement for the execution of the project between the Ministry of Science, Innovation and Universities and CIEMAT was signed, which implied, among other aspects, the anticipation of the Ministry of the funds corresponding to the ERDF co-financing (budgetary line 28.06.463B.821.10 from the General State Budget 2020, extended budget of 2019, Table 2) at a 0% interest rate and reimbursable till 31st December 2023, as well as that the actions to be carried out to be implemented in the Escúzar municipal district of Granada.

Table 2. Total funding CIEMAT.

GRANT					
BUDGET LINE	2020	2021	2022	2023	**TOTAL**
Assistances and technical support					**1,100,000.00 EUR**
Labour costs					**15,000,000.00 EUR**
Various					**200,000.00 EUR**
TOTAL					**16,300,000.00 EUR**
ERDF FUNDING 80%					**14,000,000.00 EUR**
NATIONAL FUNDING 20%					**2,300,000.00 EUR**

All actions were planned to be carried out on a plot of land of about 100,000 m^2 located in the Metropolitan Industrial and Technological Park ceded by the Town Council of Escúzar (Figures 2 and 3).

Figure 2. Geographical location of the Metropolitan Industrial and Technological Park (Escúzar, Granada, Spain).

Figure 3. Upper view of the plot where IFMIF-DONES was foreseen to be built.

Among the actions to be carried out in the framework of the DONES PRIME, some of them were typical ones in constructive projects, with added attention to seismic hazards (studies of seismic activity, permanent installation of seismometers and accelerometers, seismic isolation studies for the main building, topographical surveys of the overall site, geotechnical studies of the first construction area, geotechnical surveys of the overall site).

After these first steps, the planning was as follows:

- Urbanization of the plot of land of approximately 1.000 m^2 and supply of services.
- Design and construction of three buildings.
- Building 1 (6.000m^2 approx.): Administration and visitors' centre. It is planned to be the place where the design and construction team will be located, housing all the auxiliary and administration staff.
- Building 2 (1.300 m^2 approx.): Once the operation phase begins, it shall be used as a spare-parts warehouse; during the construction phase, it is to be used as an auxiliary building for materials storage, among others.
- Building 3 (140 m^2 approx.): Access control and security personnel to be located in this building.

The agreement signed established a period of implementation for these actions that expires on 30 June 2023 (which may be extended if necessary until 31 December 2023).

3.2.2. Line Regional Andalusia Government—UGR

On October 2019, a Transfer of Nominative Allocation (TAN19) from budget item 1400 17 000 G/54A/74104/00 A112306060E0 2019000323 was granted to the University of Granada to finance the actions intended to promote the candidature of Granada. On December 2019, the University of Granada was notified of a resolution for the transfer of 1,750,000.00 EUR, representing the starting point for the actions the University of Granada is to carry out in order to boost Granada's candidacy.

The lines that were expected to be covered by this grant were the following:

Research, Training and Mobility Programme IFMIF-DONES

The purpose of this training programme is to recruit candidates with a university degree or PhD to be formed in international research centres and laboratories that are currently developing actions related to IFMIF-DONES so that, in the future, they can perform their work in the facility obtaining very valuable training and, at the same time, acquiring knowledge transferable to the project.

The host centres in which the participants are to be trained, and with which the University of Granada has signed agreements in 2021 for this specific purpose, are the National Institutes for Quantum and Radiological Science and Technology (Japan), the

Karlsruhe Technological Institute (KIT) (Germany) and the Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) (Italy).

Research Labs

This grant also covered the costs of research staff and equipment for 2020 and 2021 for both the Virtual Reality (VR) Laboratory for remote manipulation tasks in DONES, which currently involves four junior researchers and one semi-senior researcher (data from November 2021), and the Control Systems Laboratory to interact with the previously developed "Linear IFMIF Prototype Accelerator" (LIPAc) in Rokkasho (Japan). On November 2021, this second laboratory was staffed by four junior researchers, two semi-senior researchers and one post-doctoral researcher.

The VR laboratory was responsible for the setting up of virtual reality simulators for remote manipulation maintenance and replacement operations in the DONES environment. Two levels were implemented in this phase:

- Level 1 Simulation OFf–LIneVIRtual (SOFLIVIR).
- Level 2 Simulation ON–LIneVIRtual (SONLIVIR).

Among the most remarkable equipment stands out a haptic feedback device that enabled experimentation with highly immersive interfaces to perform remotely controlled maintenance tasks in IFMIF-DONES (Figure 4).

Figure 4. Haptic feedback device Virtuose 6D TAO.

In the LIPAc laboratory, an emulator of the LIPAc control centre in Japan was set up for remote operations and a model of the IFMIF-DONES control system was implemented in order to be able to operate as its Digital Twin.

One of the most remarkable equipment comprised a robotic arm allowing control strategies and suitable interfaces to be optimised for future operators in charge of the maintenance of IFMIF-DONES.

The construction of a facility was also scheduled to serve as a hydrological laboratory for sustainable drainage systems consisting of 1 × 1 m plots, for permeable paving and green roofs, with a base raised about 70 cm above the ground and auxiliary facilities on the IFMIF-DONES site next to the existing meteorological station.

The extension of these activities is to be funded in the following years 2022–2023 through the SN 21–23 grant.

Technical Office's IT Equipment and Staff Formation

The rest of the grant was completed mainly with the acquisition of computer equipment for the newly created Technical Office, design software licenses for the installation planning and training courses for the Technical Office staff.

ERDF Exceptional Grant (SN 21–23) 2021–2023

The remaining amount (EUR 12,250,000.00) to make a total of EUR 14,000,000.00 to be financed by ERDF is currently being reviewed, taking into consideration the budget report submitted by the University of Granada to the Regional Ministry of Economic

Transformation, Industry, Knowledge and Universities (General Secretariat for Universities, Research and Technology) on 30 July 2021.

The following actions divided into work packages were planned to be carried out under this funding line.

IFMIF-DONES/UGR Research Centre

This centre is to be set up on a 4500 m^2 plot of land located next to the accelerator facility (Figures 5 and 6). This line covers everything from the acquisition of the plot of land to the project design, project management and construction of the building.

Figure 5. Upper view of the plot where IFMIF-DONES/UGR Research Centre is expected to be built (in blue).

Figure 6. Infographics IFMIF-DONES/UGR Research Centre.

With a total built-up area of 3500 m^2, the facility shall be used for research activities linked to the particle accelerator.

Among others, it is to feature a cleanroom, a laboratory for structural materials characterisation and a 1400 m^2, 20 m high bay for the assembly of prototypes (some of them expected to have a scale of 1:1) and remote manipulation experiments.

Acquisition of Adjacent Plots for Auxiliary Buildings

It is planned to purchase plots neighbouring the main site with an approximate surface area of 35,000 m^2 to be used as temporary facilities during the construction phase and to host laboratories or start-ups during the operation phase.

DONES Components Prototypes

The design and construction of different prototypes of critical components within the installation was conceived to verify the viability of these, as well as to test their operation in different scenarios, including incidents that may occur during the operation phase and, allowing the behaviour of these components to be known in advance. Some prototypes selected for their complexity and relevance were to be funded within this work package.

Pre-PhD Training Programme

The development of a training programme for pre-doctoral students to develop lines of research related to the particle accelerator, having one person as their doctoral thesis director in charge from CIEMAT and another from the University of Granada.

In addition to the line foreseen for the payment of researchers' salaries, each line of research requesting is to be rewarded with a maximum of EUR 15,000.00 upon the submission of a budget and justification, to cover students staying in other centres, fungible material, cost of publication and dissemination of the results obtained, etc.

The following thirteen lines of research were selected until April 2021:

- Sensitivity analysis of the diagnostics in the irradiation area.
- Characterisation of the materials (getters) to be used in the impurity traps.
- Development of a beam diagnostic based on radiofrequency receivers for the control of the beam profile in the target.
- Development of an expert system for predictive maintenance in IFMIF-DONES and the intelligent estimation of spare parts.
- Design of a radiology laboratory taking into account the uniqueness of the DONES facility.
- Preliminary design of a computerised axial tomography laboratory.
- Design, construction and dynamic characterisation of impurity traps for a liquid lithium loop.
- Study of the hydrological parameters of different types of sustainable drainage systems (SuDS).
- Study the different families of precursor interstitial clusters formed in irradiated Fe by ab initio calculations.
- Research and development of advanced materials for the interceptive monitoring of the very high-intensity and power beam profile in IFMIF-DONES.
- Modelling of the STUMM (Start-up and Monitoring Module) sensors.
- Simulation of the possible entry of air or water into the accelerator cavity, and of the abrupt rupture of the sealing of the vacuum chamber of the target.
- Use of graphene as a coating for the development of a system for the extraction of tritium from liquid lithium in the IFMIF-DONES purification circuit.

RV/LIPAc Labs

The activities carried out by the VR and LIPAc laboratories already described in the TAN 19 were continued and the costs for the years 2022–2023 are to be covered by this grant.

Regarding the VR laboratory, the implementation of a third level of functionality and complexity of the simulations is foreseen in this upcoming phase (Level 3 Simulation ON-Line de MIXted, SONLIMIX).

Concerning the LIPAc laboratory, in this phase, the LIPAc mirror room is to be set up and an experimental prototype developed to enable the demonstration of how some different systems work.

In summary, Table 3 shows the funds distribution of this package for the University of Granada's tasks. As shown, it is more detailed than Table 2 due to the different nature of the task to develop.

On 14 September 2019, the General Secretariat for Universities, Research and Technology of the Andalusian Regional Government agreed to grant a nominative subsidy for running costs under budgetary line 1400010000 G/54A/44104/00 01 in the amount of 262,500.00 EUR.

These activities were conceived in parallel to those already being carried out within the framework of EUROfusion and of the DONES-PreP project (see Section 3.3) for the constitution of an international consortium to manage the IFMIF-DONES facility.

Table 3. Total funding, Universidad de Granada.

GRANT	TAN 19	TAN 19			
		SN 2021–23	SN 2021–23	SN 2021–23	
BUDGET LINE	**2020**	**2021**	**2022**	**2023**	**TOTAL**
Land purchase	0.00 EUR	1,373,000.00 EUR	0.00 EUR	0.00 EUR	**1,373,000.00 EUR**
Fixed assets		1,153,556.96 EUR	4,070,000.00 EUR	4,628,600.00 EUR	**9,852,156.96 EUR**
Various		174,400.00 EUR	280,200.00 EUR	85,200.00 EUR	**539,800.00 EUR**
Labour costs	25,052.38 EUR	257,871.78 EUR	294,400.00 EUR	162,600.00 EUR	**739,924.16 EUR**
Educational budget		458,709.60 EUR	895,159.28 EUR	141,250.00 EUR	**1,495,118.88 EUR**
Operating costs					**2,300,000.00 EUR**
TOTAL	25,052.38 EUR	3,417,538.34 EUR	5,539,759.28 EUR	5.017.650,00 EUR	**16,300,000.00 EUR**
ERDF FUNDING 80%					**14,000,000.00 EUR**
NATIONAL FUNDING 20%					**2,300,000.00 EUR**

3.3. European Commission through the European Strategy Forum on Research Infrastructures (ESFRI)

The European Strategy Forum on Research Infrastructures (ESFRI) is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach [20]. After being included in ESFRI, IFMIF-DONES was granted a funding of 4,246,325.63 EUR for the project called DONES Preparatory Phase (DONES-PreP) for 27 months (1 October 2019–30 December 2021). It handled various aspects of the IFMIF-DONES project which, due to the international dimension of it, were quite complex and required a high level of coordination between all parties involved.

The IFMIF-DONES facility was submitted by Spain to be included in the ESFRI Roadmap 2018, a proposal that was endorsed by the ESFRI Forum, resulting in the project being included in the roadmap, considering both the Spanish technological and research capacity, as well as the clear commitment of the institutions at the local (Granada), regional (Junta de Andalucía) and state (Government of Spain) level.

The DONES-PreP participants included several partners, which were listed below:

- Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, Spain.
- United Kingdom Atomic Energy Authority CCFE, UK;
- Commissariat à l'énergie atomique et les énergies alternatives, CEA, France;
- Empresarios Agrupados Internacional S.A. EAI, Spain;
- Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, ENEA, Italy;
- Instytut Fizyki Jądrowej Polskiej Akademii Nauk, IFJ PAN, Poland;
- Istituto Nazionale di Fisica Nucleare, INFN, Italy;
- Institute of Plasma Physics and Laser Microfusion, PPLM, Poland;
- Instituto Superior Tecnico, IST, Portugal;
- Karlsruhe Institute of Technology, KIT, Germany;
- OnGranada, Spain;
- Ruđer Bošković Institute, RBI, Croatia;
- Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire SCK CEN, Belgium;
- Universidad de Granada, UGR, Spain;
- Warsaw University of Technology, WUT, Poland;
- Centre for Energy Research, EK, Hungary.

In parallel, the projects also had some observers:

1. Centro para el Desarrollo Tecnológico e Industrial CDTI, Spain;
2. École Polytechnique Fédérale de Lausanne EPFL, Switzerland;
3. EUROfusion, EU;
4. Fusion for Energy F4E, EU;

5. Ministerio de Ciencia, Innovación y Universidades. Secretaría General de Coordinación de Política Científica, MCIU, Spain;
6. National Institutes for Quantum and Radiological Science and Technology, QST, Japan;
7. Nuclear Physics European Collaboration Committee, NuPEcc, EU;
8. Sociedad Española de Técnicas Neutrónicas, SETN, Spain;
9. Junta de Andalucía, JdA, Spain.

Concerning the work to be conducted, the activities of the preparatory phase were divided into 10 work packages:

1. DONES-PreP Project Management—Lead participant: CIEMAT;
2. Communication—Lead participant: UGR;
3. Evaluation of DONES Governance—Lead participant: RBI;
4. Evaluation of DONES Legal Framework—Lead participant: CIEMAT;
5. DONES Financial Approach—Lead participant: CIEMAT;
6. Preparation of the Structural Funds Applications—Lead participant: UGR;
7. Health, Safety and Environmental Studies—Lead participant: CIEMAT;
8. Other Complementary Experiments and Upgradeability—Lead participant: IFJ PAN;
9. Support Facilities and Exploitation of Results—Lead participant: RBI;
10. Consortium Agreement Preparation—Lead participant: CIEMAT.

From the above-listed activities, it was clear that for DONES preparation was essential to coordinate and provide a general framework for the project in terms of legal aspects which affected it, as it was necessary to establish a common legal basis that observed the specific regulations of each country involved, which is why a continuous check and update is necessary, as well as permanent contact with the authorities of every country involved in order to obtain a document that serves as a reference standard for the installation and operation phases.

Another important aspect of the preparatory phase was the dissemination of the project, with special emphasis on the area in which the installation is to be located, as well as surveying opinion to find out the degree of acceptance and knowledge of the population about the project, which was a critical factor for the optimum achievement of the project.

3.4. In-Kind Contributions from International Partners Involved

Although the ownership of the facility is to be held by the Spanish Consortium composed by the General State Administration (Ministerio de Ciencia e Innovación) and the Regional Government of Andalusia (Consejería de Economía, Conocimiento, Empresas y Universidad), the development and implementation of this singular scientific and technical infrastructure in Spain is to, undoubtedly, require in-kind contributions from the partners involved in the project. The participating countries are to sign contracts with the industrial agents in their respective countries to directly provide the components necessary for the development of the facility; thus, not depending on the fluctuations in the value of the currency of each country and thereby ensuring that part of the investment reverts to the economic operators in their country.

This type of in-kind contribution has already been carried out in important and complex projects such as ITER in France. However, prior exhaustive planning of not only a technical, but also a legal nature, is necessary, since, given the international nature of the project, there might be different legislative spheres, requiring the establishment of a common framework to establish the conditions for these in-kind contributions to be carried out in an efficient manner.

4. Overview and Discussion

The path towards a profitable and sustainable control and commercialization of fusion energy has been full of obstacles since the theoretical comprehension of nuclear fusion in the 2030s of the XX century. In spite of the colossal efforts and remarkable advances, the full control of fusion is, nowadays, still at least two decades ahead. The extreme conditions of nuclear fusion, only possible in star cores, are so difficult to reproduce that we must solve

two main problems: the control of plasmas at temperatures of about 100 million Kelvin, currently progressing with advances with regards to superconducting magnet technology, and the control of neutrons resulting from the fusion reactions.

In order to advance in the development and implementation of new technologies for these problems, it is necessary to build large and very expensive experimental installations that, in spite of their impact from the economic perspective, are expected to have very positive turn-overs, since they are essential milestones in the journey to clean, safe and almost unlimited energy that mankind requires in order to go on progressing according to the Brundtland principles of sustainable development and the achievement of the SDG.

In this framework, the "International Fusion Materials Irradiation Facility DEMO Oriented Neutron Source" (IFMIF-DONES) is to be the key to determine the materials to build the fusion reactors capable of surviving the damages due to neutron irradiation.

The first steps for its construction have already been taken in Escúzar (Province of Granada, south of Spain), a poorly developed area that is expected to experience a strong boost in terms of incomes, employability for young people and contribution to the development of the whole region where it is located.

However, the actual implementation of such an extremely complex project presents several features that are the target of this research. On one hand, the financial needs (around 700 Million EUR) make it necessary to have different funding sources. At this stage of the project, most of the budget came from the European Commission or its subsidiary bodies through different programs. Some of them are directly related to the development of the region, whereas some others have a more technical background and are oriented to the solution of concrete problems of the facility.

On the other hand, the National and Regional Governments of Spain have also contributed with European funds and with their own funds. Even other European governments are considering in-kind contributions, which demonstrates the clear will of the institutions to advance in IFMIF-DONES and, consequently, in the pursuit of more sustainable energy.

The sustainable management and coordination of these funding, as well as the complexity inherent to the project, is an essential key for its success and the global advance through the path of sustainable development. These items were the target of the present work.

As potential limitations of this work, it is necessary to remark that the novelty of IFMIF-DONES, a facility whose target and specificity has no precedents, could lead to changes in the execution and budgetary policy of the funding bodies, especially the National and Regional Governments in Spain and Andalusia, respectively. It means that some lines analysed could suffer variations needing updates in future works on this project. Another limitation came from technical eventualities of the project, leading to changes in the design, building and implementation of the facility with the consequent impact on the funding that could also change the current lines here described.

In summary, great progresses frequently demand large experimental facilities whose project and implementation are very complex. In this article, the main sources for the implementation of IFMIF-DONES were presented and analysed. The strengths and weaknesses presented in this work should help to successfully culminate the project and also to approach other challenging installations in other parts of the world.

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