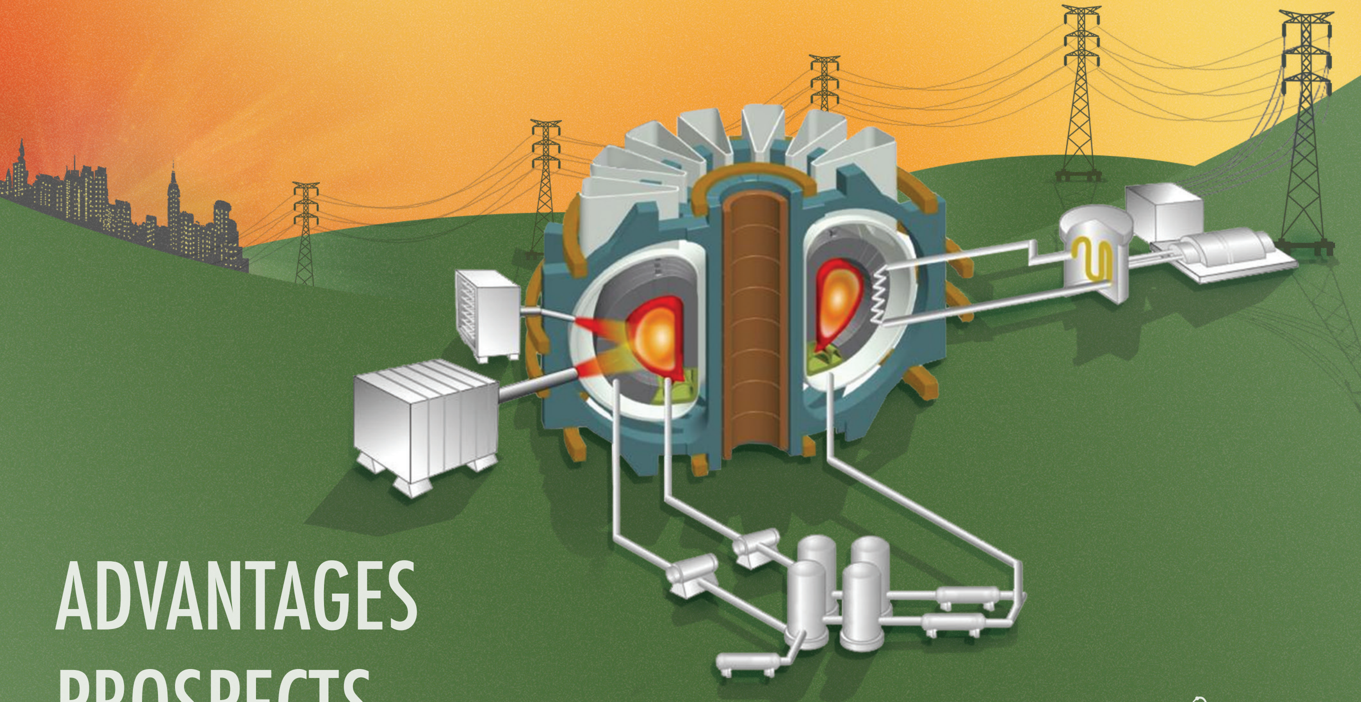
FUSION ENERGY

THE ROLE OF THE IAEA



ADVANTAGES
PROSPECTS
COLLABORATIONS

IAEA

IAEA

The International Atomic Energy Agency's mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

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Foreword

Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy

Aldo Malavasi, IAEA Deputy Director General and Head of the Department of Nuclear Sciences and Applications

The International Atomic Energy Agency (IAEA) is dedicated to helping all countries benefit from the peaceful, safe and secure use of nuclear science and technology in many fields, including energy production.

Fusion energy has the potential to become a virtually inexhaustible, safe, environmentally-friendly and universally-available energy source, capable of meeting global energy requirements.

Fusion energy has existed for billions of years shining benevolently upon the earth but mankind still has not managed to capture it in a controlled manner. To make fusion energy production a reality, enormous scientific and technical challenges still need to be overcome. The IAEA is leading international efforts to coordinate research in fusion technology by involving nuclear physicists, material scientists, nuclear data specialists, metallurgists, and plasma experts among others.

Since the early days of its inception, in 1957, the IAEA has supported nuclear fusion research. The IAEA Department of Nuclear Sciences and Applications and the Department of Nuclear Energy implement the IAEA's activities on nuclear fusion, under the guidance of the International Fusion Research Council, an IAEA advisory body with members from all parts of the world.

Big strides in understanding fusion energy science have been made. But more efforts with increased global collaboration, greater investment and coordinated research are required to make nuclear fusion energy production a reality. The IAEA continues to be at the forefront of these international efforts.

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Clean energy through fusion technology: A Sun on Earth

By Meera Venkatesh

A 'sunny day' or a 'sunny smile' is always welcome by all of us! Apart from brightening up our days, many of us recognise that the 'Sun' is the basis of life on earth. The incessant emission of energy and light from the Sun with an unending stock of fuel engenders, without exception, curiosity in thinkers and scientists. This is what excites global interest in fusion technology.

Fusion energy is attracting a lot of attention as the world's energy demands keep multiplying. The excessive dependence on fossil fuels and its impact on climate change due to carbon emissions are leading policy makers to consider fusion as a good option to explore.

Meera Venkatesh
(photo: IAEA)

Enhancing clean energy production through fusion technology

Through extensive exploration using various tools, logical reasoning and ingenuity, scientists have proven that a seemingly simple combination of the nuclei of two very light atoms (tritium and deuterium — both heavier isotopes of hydrogen) spews out enormous amounts of energy. Such fusion of nuclei — or 'nuclear fusion' — has been a topic of great interest and intensive research since the 1920s.

"Harnessing commercially-viable fusion power is a very challenging endeavour, although fusion reactions have been successful during experiments and the technologies are continually evolving to address the challenges."

— Meera Venkatesh, Director, Division of Physical and Chemical Sciences, IAEA Department of Nuclear Sciences and Applications

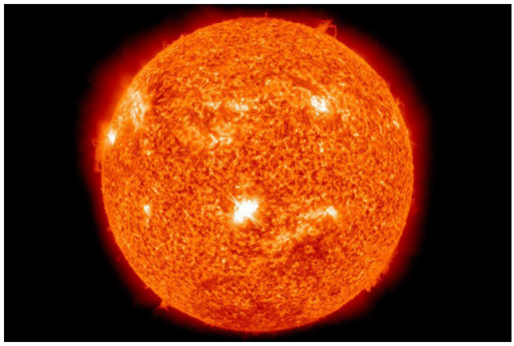
The signing of the Agreement that estabilished the ITER Organization
(photo: IAEA)

It is mind-boggling that the deuterium contained in 0.5 litre of ordinary water can provide enough energy for a single family house in Europe for a year, when properly fused with tritium in a fusion reactor.

But despite the apparent simplicity, harnessing commercially-viable fusion power is a very challenging endeavour, although fusion reactions have been successful during experiments and the technologies are continually evolving to address the challenges.

The difficulties facing fusion technology

Making commercially-viable fusion power a reality is fraught with serious technological challenges such as the ability to achieve temperatures exceeding 100 million degrees Celsius, 10 times higher than in the core of the sun, while confining the hot fusion fuel to the vessel within the reactor. Additionally, finding the right material to construct the fusion reactor, and developing the mechanism that will be used to extract and convert the enormous amount of energy that is produced, are among the other major challenges in the quest to produce electricity from fusion.



The Sun
(photo: NASA)

Making progress through international collaboration

To scientists, it was clear from the very beginning that success in using fusion technology would require international cooperation. At the second UN Conference on the "Peaceful Uses of Atomic Energy" in Geneva in 1958, discussion on nuclear fusion led to the newly created International Atomic Energy Agency (IAEA) being entrusted with the responsibility to lead the global collaboration. Five decades later the IAEA remains the natural home for fostering international collaboration in fusion research and development (R&D) through facilitating exchange of scientific and technical information. Supported by the dedicated community of fusion researchers in the small number of Member States, the Nuclear Fusion Journal was set up in 1960 by the IAEA to disseminate knowledge in this niche area of science. Today the journal is considered the main source of information about advances in nuclear fusion.

Status of the ITER construction site as at February 2015
(photo: ITER Organization)

Since 1962 the IAEA has also been organizing biennial 'Fusion Energy Conferences' (initially named Conference on Plasma Physics and Controlled Nuclear Fusion Research) to enable the dedicated fusion research professionals to periodically discuss developments and achievements. An International Fusion Research Council was also established to advise and provide guidelines to the IAEA Secretariat on matters relating to the Fusion R&D programme.

The fusion research community and the IAEA continue interacting closely on the development and evaluation of fusion-relevant basic data for nuclear, atomic and molecular interaction processes in fusion.

IAEA's role in international fusion endeavours

The impetus for the establishment of the international organization for fusion energy, ITER (International Thermonuclear Experimental Reactor) in 2006 came from discussions in IAEA forums that covered several initiatives for collaboration on an international fusion facility. The IAEA Director General is the depository of the ITER Agreement.

ITER, under construction in Cadarache, France, is the largest global scientific collaboration aimed at demonstrating the scientific and technological feasibility of fusion energy production. ITER and the IAEA signed a cooperation agreement in October 2008 to address key areas of common interest such as training, safety and security in nuclear fusion, as well as publications to reflect the work done at ITER.

Currently 35 countries are involved in the ITER project. In addition, individual countries are engaged in research for fusion to become a future source of energy. There is a growing expectation, especially in the fusion community that 'fusion electricity' would light the bulbs of their homes soon. While science and technology issues for fusion power are broadly agreed upon, the next steps to upscale the technology to practical use are still some distance away. Here, the IAEA plays a crucial role in bringing together all the Member States interested in fusion energy through the demonstration fusion power plant (DEMO) programme workshops. This workshop serves as a platform to facilitate collaboration in defining and coordinating DEMO programme activities.

The scientific community recognizes that the realization of fusion power reactors would be a landmark achievement, taking nuclear science and technology to another level.

Nuclear Fusion: An attractive form of energy for powering the world

By Antonio Botrugno, Mateusz Zarucki and Richard Kamendje

What powers the Sun and stars?

Despite the Sun being a remarkable 150 million kilometres away from the Earth, we still receive enormous amounts of energy from its radiation, which ultimately created and sustains life on our planet. Our forefathers sensed that there must be an "unusual" process inside the solar core that releases energy and powers the Sun even after billions of years. Today scientists have given this process a name: nuclear fusion.

Fusion occurs when two atomic nuclei come close enough to overcome their inherent electromagnetic repulsion. The product of this reaction is a heavier nucleus. The mass of this resulting nucleus is less than the combined mass of the initial nuclei. Einstein's famous $E = mc^2$ equation indicates that this mass difference is converted into energy. Because c in the equation is very large, the produced energy (E) per unit of reactant mass of material is roughly millions of times more than the energy released by typical chemical reactions, such as burning coal.

Inside the Sun, gravity resulting from its mass enables adequate conditions for fusion reactions to naturally occur. On Earth, complex techniques and advanced technologies are being used to reproduce similar conditions in a reactor that will eventually deliver electricity into the grid. The goal of building a power plant based on controlled nuclear fusion has proven to be one of the greatest challenges in modern science and technology. For over 50 years scientists and engineers have been pioneering ways of harnessing fusion energy on Earth.

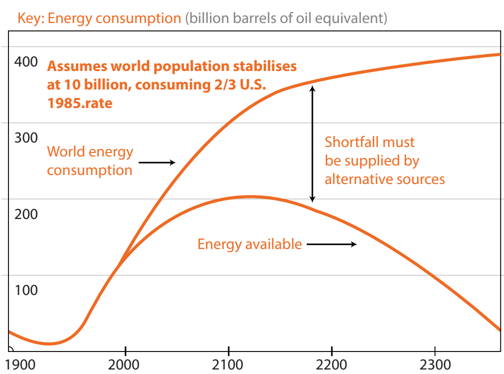
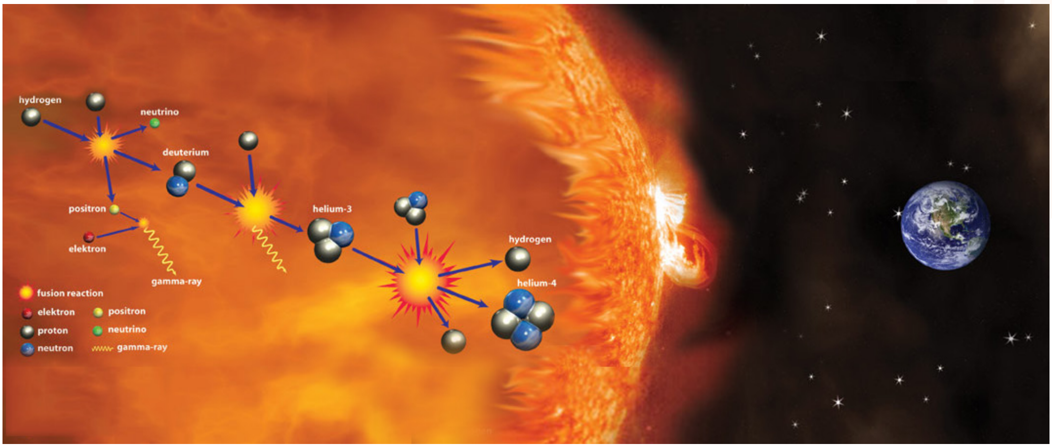


Figure 1: World energy supply and demand
(source: World Energy Council)



Nuclear fusion powers the Sun
(source: ITER Organization)

Fusion potential in future energy demand

A stable, sustainable, and environmentally sensible energy supply is the driving force for socio-economic development. Access to energy is indirectly related to living conditions and life expectancy.

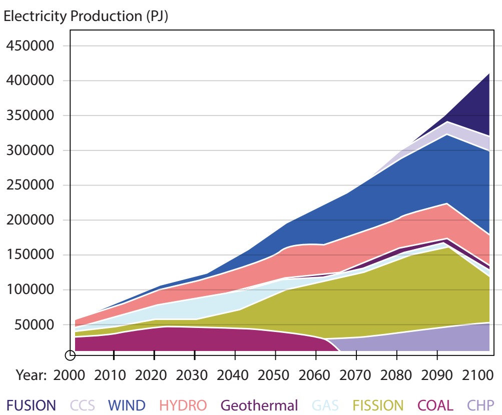


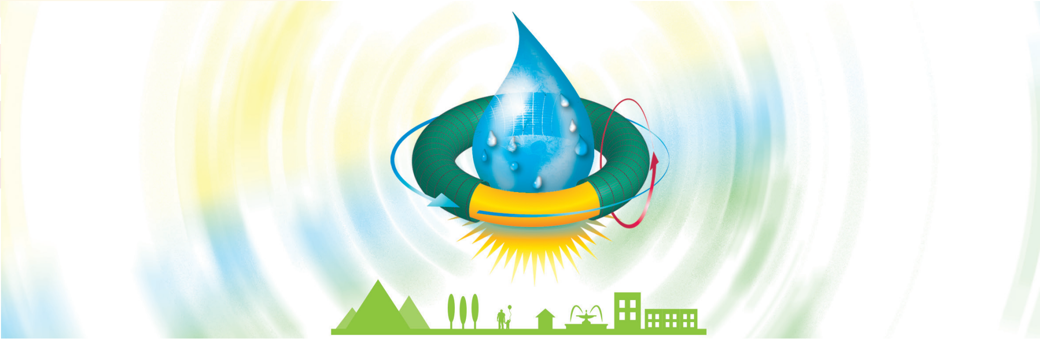
Figure 2: Energy scenarios until 2100 from EFDA-TIMES model
(source: www.euro-fusion.org)

Energy consumption and demand are constantly growing with the increasing world population and rapid technological development. It's likely that in the next 30 to 40 years, fossil fuels will still dominate the energy market, but energy experts and economists predict that the gap between fossil fuel supply and demand will continue to grow wider as time passes (see figure 1). Fusion energy has the potential to provide a more efficient, safe and clean solution to the global energy problem. The long-term energy scenario from the EFDA-TIMES model (see figure 2) shows that fusion energy has the possibility to play an important role in the world's energy mix in the second half of the 21st century. Fusion energy can contribute to fill the gap between energy demand and supply. According to estimates, it could account for about 20 per cent of the world's energy market in 2100.

Fusion energy: a range of advantages

Limitless availability of fuel

One of the main advantages of fusion energy is its enormous natural supply of inexpensive fuel. This results in a virtually inexhaustible energy source, having the potential to supply large amounts of energy for thousands of years. Current fusion reactor designs use deuterium and tritium as fuel, both being heavier forms of the element hydrogen. Deuterium is extracted inexpensively from water, whereas tritium will be produced inside the reactor



Fusion energy: A small amount of water contains enough deuterium to produce large quantities of clean energy
(Antonio Botrugno)

from lithium. Lithium is relatively abundant on the Earth's crust and can be easily extracted from rocks. These elements are more evenly distributed around the world.

Environmentally friendly: no greenhouse gas emission, minimal long-lived radioactive waste

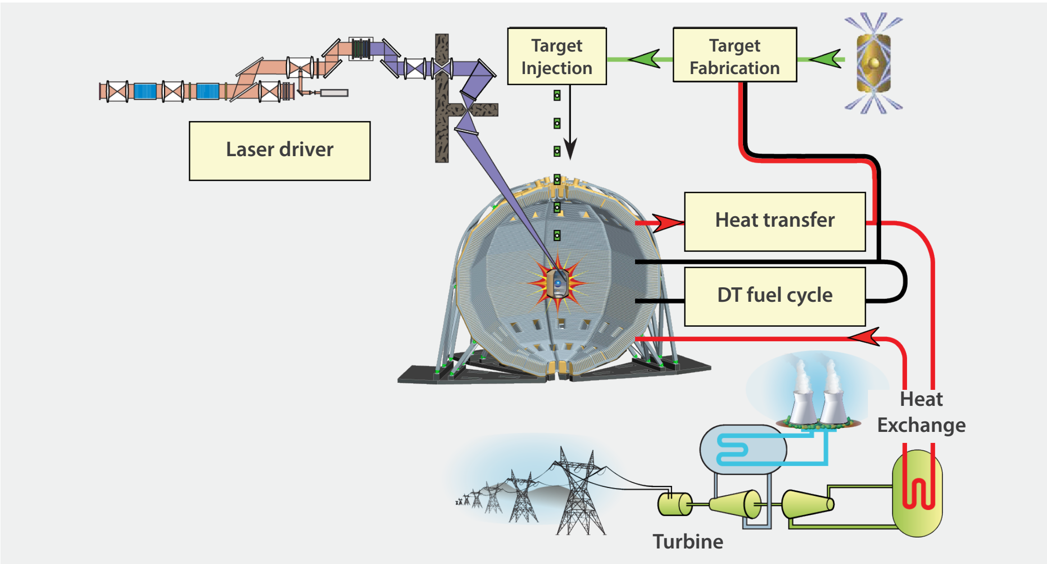
Fusion represents a clean source of energy. In fact, deuterium is a stable isotope of hydrogen, while tritium is a low radioactive material and its inventory is very small as it is produced in a controlled manner inside the reactor for immediate consumption. Moreover, while the fusion products are stable, there are minimal long-lived radioactive products resulting from neutron bombardments of the reactor components' materials. These long-lived radioactive products will be safe to recycle conventionally within 100 years.

Intrinsically safe fusion reactor operation

Within a fusion reactor, the sensitive temperature-pressure balance requirement for reactions to occur makes it easy to stop the process of energy production almost instantly, as part of safety shutdown procedures. At a single instant there would only be enough material in the reactor to produce energy for a few seconds. Therefore, even in the event of a loss of coolant or power-failure, there is no danger of runaway processes caused by uncontrolled chain-reactions, avoiding the possibility of major accidents.

International cooperation to shape the future of fusion

To perform nuclear fusion in a controlled manner has been the focal element of various research groups across the world. The next step is the experimental facility under construction, known as the International Thermonuclear Experimental Reactor (ITER), an international project with seven members: China, India, Japan, South Korea, the European Union, the Russian Federation and the United States. ITER is being built in Cadarache, in the south of France. It is the world's most advanced and largest fusion experiment, representing a remarkable demonstration of how international collaboration can be beneficial for peaceful purposes. ITER is designed to achieve a fusion power gain of at least 10 and produce in excess of 500 MW of fusion power. It will also test key technologies necessary for a fusion reactor. With ITER under construction, the worldwide magnetic fusion programme is in a transition to one that is increasingly focused on the production of fusion energy on an industrial, power plant scale. Many countries are independently developing programme plans and initiating new research and development activities leading to a demonstration of fusion energy's readiness for commercialization (DEMO).



Principle of laser inertial fusion energy, one of the schemes to harness fusion energy on Earth
(source: Lawrence Livermore National Laboratory)

Collectively these plans and activities comprise a world "DEMO Programme," even though there is no single or coordinated view of the roadmap to DEMO construction. Resolving DEMO scientific and technical issues and facility requirements is of common interest, even if the emphases and priorities vary from nation to nation. Thus there is substantial scope to add value through international cooperation. Against this backdrop, the IAEA has established a series of DEMO programme workshops to facilitate international cooperation on defining and coordinating DEMO programme activities.

Ultimately, the success of ITER and demonstration plants would introduce the world to an 'Age of Fusion', where a significant part of humanity's energy needs is covered by a virtually inexhaustible, safe, environmentally-friendly and universally-available resource. The IAEA will keep playing a key role during this exciting period where significant advances in fusion energy are imminent.

Fostering progress towards commercial fusion energy

By Ralf Bernd Kaiser, Richard Kamendje and Sehila M. Gonzalez de Vicente

As the premier event in the area of thermonuclear fusion research and technology, the IAEA's biennial Fusion Energy Conference (FEC) series has a long history of making possible the interaction of key stakeholders in a collaborative spirit to advance the understanding of this field of nuclear science and bring the prospect of commercial fusion energy closer to reality. Commencing in 1962 as a conference on "Plasma Physics and Controlled Nuclear Fusion Research", it has accompanied international fusion energy endeavors from the beginning, since the declassification of nuclear fusion research.

The challenge of creating a 'star' — a fusion power plant — here on Earth was to become clearly visible with each edition of the conference — a trademark for international collaboration in fusion research. The race was on to collectively demonstrate tangible advances in the field as expectations in various parts of the world were high to be able to build a first fusion power plant within a decade or so. Over the last 50 years research in fusion energy has seen formidable and sustained progress with gradual, promising increases in the triple product. The triple product is a measure of a device's ability to contain enough hot fuel (which is held in the form of a highly ionized gas known as plasma). It is defined as the product of the plasma density (number of particles per unit volume), temperature and confinement time. Since the 1960s, the fusion triple product has almost doubled every two years, a rate of increase comparable with the well-known progress in computing known as Moore's Law, which states that the processing speed or power doubles every two years (see figure 1).

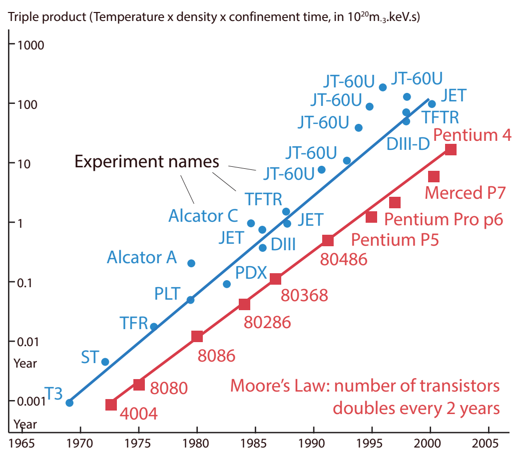


Figure 1: Progress in the fusion triple product compared with another high tochnology field
(source: Fusion Physics, IAEA published book)

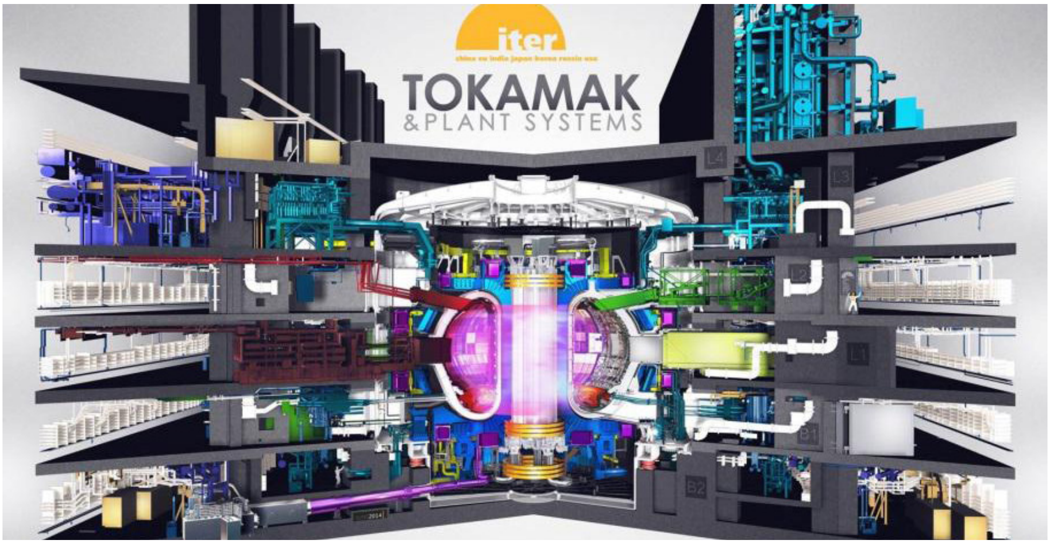


Figure 2: Cut away diagram of the ITER device being built in Cadarche, France
(source: ITER Organization)

Fusion energy conference 2014 in Saint Petersburg, Russian Federation
(photo: IAEA)

The establishment of the physics and technical basis for next step fusion devices such as the International Thermonuclear Experimental Reactor (ITER) (see figure 2) with the potential for upscaling to a power plant, represents tangible progress witnessed and documented through the series of conferences. In recent years the conference has evolved, serving as a platform for sharing the results of research and development efforts that are being shaped by the need to demonstrate the technological feasibility of fusion power production, extraction and conversion under practical and economically attractive conditions. In doing so, the conference helps to pinpoint global advances in fusion theory, experiments, technology, engineering, safety and

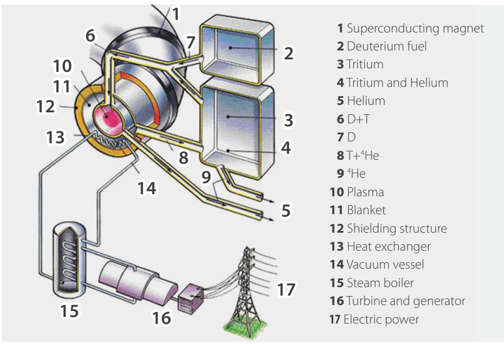


Figure 3: Diagram of how a fusion power plant would create power in electricity
(source: blogs.longwood.edu)

Ralf Kaiser, Section Head, IAEA Physics Section
(photo: IAEA)

socio-economics. More importantly, the FEC aims to set these results against the backdrop of the requirements for a net energy producing fusion device and a fusion power plant in general, and thus, contributes to defining the way forward for this technology.

Currently, several research and development programmes are being initiated around the globe to address the challenges associated with producing fusion electricity from the products of the fusion reaction — the high energy neutrons. Methods being pursued to do this involve slowing down the neutrons in a lithium blanket, which in turn heats water to drive steam turbines in a conventional way (see figure 3). Efficient heat extraction and conversion technologies within a reliable/maintainable and safe system are among the key issues of worldwide interest.

As a forum that brings together many generations of scientists, engineers and leaders with a wide spectrum of knowledge and expertise, the FEC strives to promote excellence in scientific achievements. In fact, the IAEA's annual Nuclear Fusion Prize is awarded during the FEC to recognize seminal scientific contributions to the advancement of fusion.

As the largest IAEA conference besides its General Conference, the FEC will remain a key player in the evolving global fusion programmes that are increasingly focused on developing plans to demonstrate the production of electricity.

Widening awareness on fusion science and technology: IAEA publications

By Sophia Jane Le Masurier

The IAEA's publishing programme has played a significant role in the dissemination of information to its Member States. The first technical books were issued in 1958 and, since then, the IAEA has established itself as a leading publisher in the nuclear field. It now publishes over 100 titles annually, ranging from case studies to international safety standards.

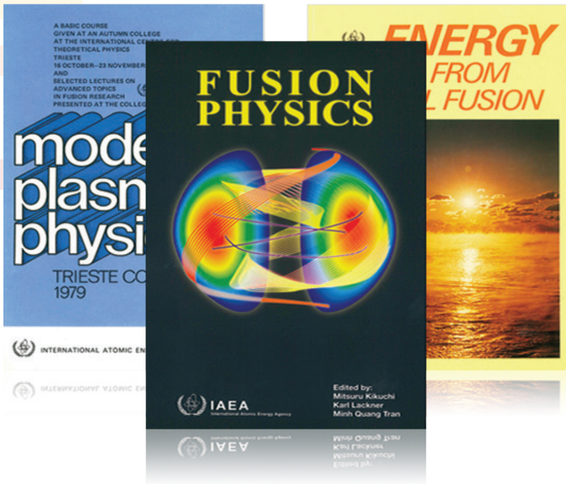
In the area of fusion, and in tandem with the IAEA's technical activities, the publishing programme has supported Member States in the following ways: dissemination of research results; assistance and information provision to researchers; facilitation of international collaborative activities such as the International Thermonuclear Experimental Reactor (ITER); documentation arising from technical meetings and conferences; and the provision of educational resources, including textbooks and training courses. The publications offer an unbiased and authoritative source of information. They are driven by developments in the field and by the changing needs of Member States.

Dissemination of Research

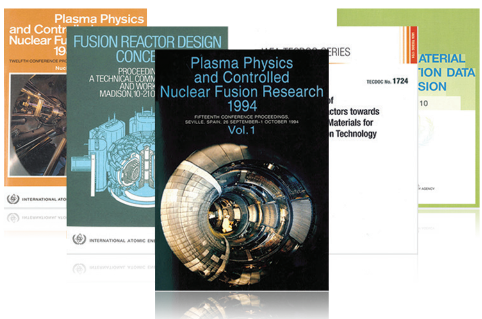
Nuclear Fusion

One of the most important contributions that the IAEA's publishing programme makes in support of fusion research is the provision of a high quality, peer reviewed forum. The journal Nuclear Fusion was launched in 1960. It is now the most frequently cited journal in the field.

Nuclear Fusion is steered by an international board of eminent scientists, who give direction on content and policy. It facilitates communication between research groups worldwide, disseminating results



and concepts and aiding collaboration. The journal now regularly receives submissions from over 30 countries and its geographical balance reflects the significant body of work being done globally in fusion. Every major advance in fusion has been reflected in the journal's published articles.



Conference and workshop publications

The IAEA has an active programme of conferences, project meetings and workshops. The results from these are captured in a range of publications, from full proceedings to final reports of IAEA coordinated research projects. Papers from the flagship biennial IAEA fusion conference have been published in various forms, and create an ongoing record of research progress.

Education

The IAEA has always assisted Member States' efforts in the arena of education, knowledge sharing and training by providing appropriate materials for researchers, students and educators. It has ensured the involvement of leading individuals in fusion and facilitated knowledge transfer. The recent 1200 page graduate text, Fusion Physics, with its broad coverage of fusion topics, is an example.

International collaboration

Arguably, the most strategic contribution of IAEA publications in fusion has been in support of large international projects. The global collaboration in fusion that became ITER was preceded by the experimental power reactor study, International Tokamak Reactor (INTOR), which had been pursued under the auspices of the IAEA. The IAEA published a series of publications arising from the INTOR workshops. The IAEA has supported the ITER endeavour from its inception and through its founding as an independent international organization; and as part of this support has published a number of ITER-related publications. The importance of publications to the enterprise is indicated by the 2008 cooperation agreement between the two organizations which makes specific reference to, among other things, cooperation on publications.

Looking to the future, the IAEA will facilitate knowledge dissemination in relation to demonstration power plants (DEMO) and beyond.

Responsive to changing requirements

The IAEA endeavours to ensure that its information provision is agile and highly responsive to the evolving needs of the user communities. The topicality of the publications in fusion complements on-going activities worldwide. For example, the scope of research papers published in the IAEA journal Nuclear Fusion has changed over time. Earlier articles concentrated on plasma physics and the necessary conditions for fusion. Later, discussion on engineering issues, machine concepts and the results from a proliferation of machines were published. Another example would be that throughout the years, IAEA activities, which result in special journal issues, proceedings volumes and technical reports, have always addressed issues of contemporary research interest. Current concerns on fusion materials and technology have therefore resulted in various IAEA publications, such as Applications of Research Reactors towards Research on Materials for Nuclear Fusion Technology, TECDOC 1724.

Impact

Whilst the impact of the IAEA's contribution to knowledge dissemination through its fusion publications is difficult to quantify, measures such as the number of citations and the traffic to the online publications give an indication of worth and utility. There were 236 000 downloads of Nuclear Fusion articles in 2014, and according to the 2015 Journal Citation Reports®, the journal achieved a very high impact factor. The book, Fusion Physics, remains among the top 10 most popular online IAEA books.

Through its publications, the IAEA provides continuity and an unbiased, international forum. With its close links with the fusion community, it ensures relevance and topicality of information.

IAEA's collaborative networks: Fostering intellectual diversity and efficiency in fusion development

By Richard Kamendje and Sehila M. Gonzalez de Vicente

As a complex field of research and technology, expertise developed by fusion scientists and engineers is as diverse as there are multiple schools of thought and different approaches to address the challenges on the way to a fusion power station.

However, there are leading ideas and pioneering concepts representing breakthroughs that have proven to substantially expand the frontiers of fusion research and development and define mainstream lines of investigation. A landmark example is the tokamak concept (see figure 1), a fusion device using a toroidal vacuum chamber for fuel containment and magnetic fields to confine the fuel particles away from the chamber walls (this is what is often referred to as the magnetic bottle). Since the invention of the tokamak and the construction of the first machine in 1954 in the former Union of Soviet Socialist Republics (USSR), more than 200 such devices have been built and operated globally. The tokamak is the most advanced magnetic confinement fusion concept and currently the best choice for next step devices such as the International Thermonuclear Experimental Reactor (ITER) and beyond. While currently larger and larger tokamak devices are the focus in order to address reactor-relevant physics and technology issues, there is still the need for smaller machines to conduct complementary investigations. As a matter of fact, small fusion devices offer a number of advantages: they are flexible and cheap to operate and therefore allow a variety of dedicated investigations including testing new ideas and technologies.

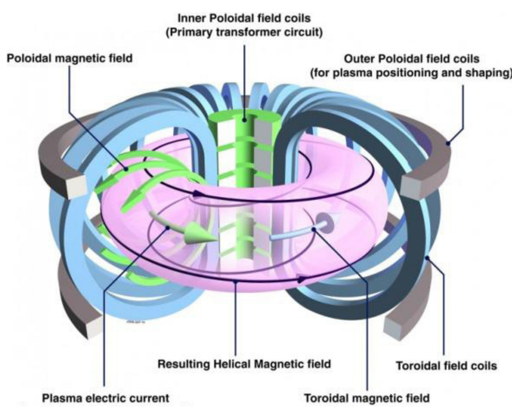
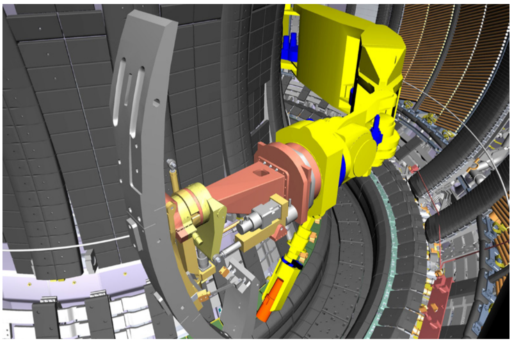


Figure 1: Diagram illustrating the tokamak principle: arrangement of magnetic field coils and the resulting magnetic field that confines the plasma
(source: www.euro-fusion.org)



Fusion pioneers to use of remote handling technology for maintanance purposes
(source: www.euro-fusion.org)

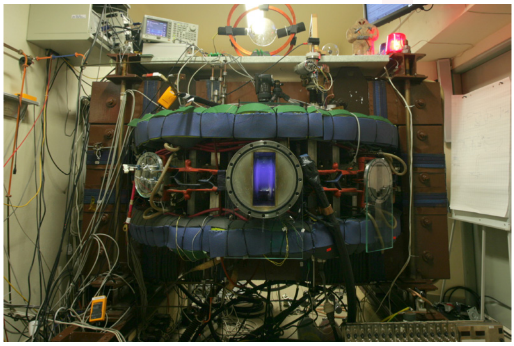


Figure 2: The GOLEM tokamak at the Czech Technical University in Prague with a cryostat testing high temperature superconducting coils during IAEA Joint Experiments, for the first time on a tokamak (photo: Vojtech Svoboda)

Global collaboration to find solutions

Streamlining the contribution of the dozens of small fusion devices around the world to mainstream fusion research is one the areas where the IAEA plays a key role. Through its coordinated research activities, several networks of small fusion devices have been established and are being successfully used to enable an integrated approach in the quest for solutions to the targeted outstanding issues. For instance, joint experiments are organized within the networks that gather experts from various institutions to exploit the capabilities of a given machine, thereby increasing intellectual diversity and maximizing the scientific output of the said device. A good example of such collaboration is when experts from private companies and research institutions in the United Kingdom, the Russian Federation and the Czech Republic tested, for the first time in history, the use of high temperature superconductors coils on the GOLEM tokamak (the oldest operating tokamak in the world) at the Czech Technical University in Prague (see figure 2).

Sharing knowledge and training

In addition to exchanging scientific information, the networks of small fusion devices are also being used to exchange equipment, tools and personnel. As an example, materials samples to be tested in a prototypical environment were prepared by one institution in Germany and distributed free of charge to more than a dozen other participating institutions in various IAEA Member States to conduct similar tests and contribute to a database of properties.

Another key contribution of the networks relates to capacity building through education and training of the next generation of fusion scientist and engineers. This is particularly important as the transition in fusion research and development towards increased technology activities represents an expansion of the traditionally required expertise.

A collaborative approach

A Network of devices addressing fusion-related physics and technology issues

IAEA provides atomic and nuclear data to Member States for fusion technology

By Julie Sadler

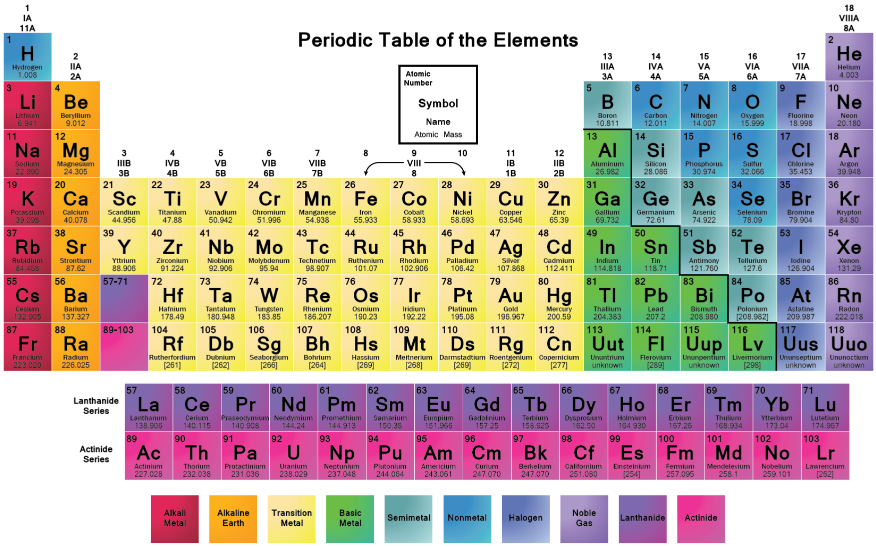
The great deal of research that has been carried out over the last six decades has ensured that the world is that much closer to making nuclear fusion power plants a reality. By sharing atomic and nuclear data, the IAEA is aiding the nuclear fusion research community to analyse plasma experiments for nuclear fusion and to further develop the design of fusion-based power plants and assess their operational behaviour.

In connection with the data efforts, the IAEA organises meetings with scientists in order to facilitate the exchange of information about nuclear, atomic and molecular processes and to coordinate future data development projects.

"Member States can use the Nuclear Data Section (NDS) databases for example, in connection with nuclear fusion experiments or in their plasma physics laboratories. Beyond the existing experiments they are used in connection with the design of future devices and concepts," said Bastiaan Braams, Head of the Atomic and Molecular Data Unit, IAEA Nuclear Data Section.

"Member States can use the Nuclear Data Section (NDS) databases for example in connection with nuclear fusion experiments or in their plasma physics laboratory. Beyond the existing experiments they are used in connection with the design of future devices and concepts."

— Bastiaan Braams, Head of the Atomic and Molecular Data Unit, IAEA Nuclear Data Section



Periodic table of the elements
(source: www.sciencenotes.org)

Collecting, establishing and maintaining the data

The IAEA Nuclear Data Section works with four main strands of data: atomic, molecular, nuclear and plasma-material interaction. Atomic data relate to the electrons in atoms, such as excitation (change of electron energy) or ionization (electron loss); molecular data refers to molecules that interact with electrons or ions; nuclear data relate to the interactions of a particle, such as a neutron or a proton, with the nucleus of an atom; and finally plasma-material interaction data relate to the effects of exposing a surface to fusion plasma.

The collected data is maintained within internationally approved databases, such as numerical databases that mainly contain data for cross-sections of various collision processes, and bibliographical databases that contain indexed references to literature on atomic, molecular and nuclear processes in fusion devices.

The evaluation of data is very complex and it is a topic of active research. "Evaluating the data is a big problem," said Braams. "Since the IAEA is not a research establishment, NDS relies on outside expert opinion and advice to assess the quality of the data and to provide uncertainty estimates. We have lots of data for which the accuracy is not well known" he added.

Bringing nuclear fusion experts together

In connection with its efforts to make the available data as accurate as possible, the IAEA also acts as a communication facilitator by bringing scientists and experts from many countries together to exchange information, to identify critical issues and to transfer specific knowledge for nuclear fusion data development projects.

"The data that we supply is also available online, cost-free and without any login requirements. They are openly available to Member States and for that matter to non-Member States. We don't make a distinction," said Braams.

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