Atoms for Peace and Development

Science and Technology for a Better and Safer World

Pasquale Ferrara
Rafael Mariano Grossi
Jeremy McNeil
Giorgio Parisi
and Wolfango Plastino

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Introduction

Pasquale Ferrara

The international scenario currently before our eyes is deeply concerning, with heightened international and regional tensions, and with the proliferation of nuclear weapons representing a major threat to international security.

In this respect, the system of safeguards represents a fundamental guarantee for our common security. Director Grossi can rest assured that in all relevant international fora, Italy will continue to promote the universalization of the Comprehensive Safeguards Agreements together with an Additional Protocol as the verification standard. Indeed, I wonder whether it would be possible to make the principles of the Additional Protocol a general norm of the international order: although this would now be very hard to accomplish, it is important that all responsible states continue to uphold this cornerstone of the non-proliferation architecture.

The non-proliferation and disarmament community is currently engaged in the preparation of the next Review Conference of the Non Proliferation Treaty (NPT), scheduled in 2020 and postponed due to the Covid-19 pandemic. In this regard, let me emphasize the importance that Italy attaches to the NPT: it remains the cornerstone of the global non-proliferation regime and the essential foundation for the pursuit of nuclear disarmament, as well as the basis for further development of nuclear applications for peaceful purposes. In our view, these three mutually reinforcing pillars are still perfectly valid today. We should use the remaining time in preparation of the Review Conference as an opportunity to build bridges between the State Parties and to assess the substantial progress achieved so far in the framework of this historic Treaty.

Our desire for a safer world for future generations underpins our efforts for effective progress on nuclear disarmament and non-proliferation. I am convinced that Article VI of the NPT provides a realistic legal framework to attain a world without nuclear weapons in a way that promotes international stability.

Our approach is based on the idea that the goal of a nuclear-weapons-free world can be reached gradually, with the involvement

of all relevant actors, through a series of concrete and progressive steps, and based on the principle of undiminished security for all.

In terms of concrete and effective measures towards this goal, Italy has always been a staunch supporter of the entry into force of the Comprehensive Test Ban Treaty and has always strongly promoted the start of negotiations for a treaty prohibiting the further production of fissile material for nuclear weapons or other explosive devices.

I would also like to stress the relevance of risk reduction, which can contribute to alleviating tensions and building the necessary trust and confidence, such as transparency and dialogue on nuclear doctrines and postures, military-to-military dialogues, hotline, "accident measures agreements" and notification of exercises, missile launch notifications and other data exchange agreements, consistently with the 2010 NPT Review Conference Action Plan.

This reflection on the NPT brings me to the current state of the Joint Comprehensive Plan of Action (JCPOA) on the Iranian nuclear programme. We believe that this agreement is an important element of global non-proliferation efforts and achievement of multi-party diplomacy, as endorsed by UNSCR 2231.

The JCPOA was agreed on to ensure that Iran's nuclear programme remained exclusively peaceful, in return for the comprehensive lifting of related UN, multilateral and national sanctions.

Preserving the JCPOA is therefore crucial, not only in terms of nuclear non-proliferation, but also for the security environment of the region. Therefore, the intention to return to the deal and to its full compliance stated respectively by the Biden administration and Iran are both highly welcomed. The new US approach marks also an extremely positive realignment between the two sides of the Atlantic on this crucial topic.

With the substantive discussions that will take place in Vienna, we are now on the right track, as this testifies that the only solution lies in diplomacy. Nevertheless, the road ahead is long and the end goal far from secured: at this critical juncture, all sides should refrain from any action that could increase tensions and derail this positive process.

In terms of challenges to the global non-proliferation regime, North Korea's nuclear and ballistic missile programmes remain an issue of serious concern. Pyongyang should undertake concrete steps towards a complete, verifiable and irreversible denuclearization, in view of a return to the NPT.

The global non-proliferation regime is under pressure also in relation to the threat posed by the proliferation of weapons of

mass destruction and their means of delivery to – and through – non-state actors.

Let me finally recall the need to recognize the changing nature of the existing threats, to react, adapt and step up our efforts at reinforcing the global non-proliferation regime. Risks may indeed arise from a variety of sources: states aspiring to possess nuclear weapons; non-state actors in search of "dirty bombs"; poor national legislation in place to prevent illicit trafficking of materials and dismantle proliferation networks, as well as from mismanagement and misuse of rapid development of science and technology.

I would like therefore to conclude this presentation by highlighting the importance of further analysis and research in the field of nuclear technology. In this respect, this event is an excellent opportunity for debate and analysis among international high-level experts and officials.

Technology and scientific innovation are essential for development. Nuclear applications offer enormous benefits in many areas of our lives, including health, agriculture, food production and energy generation, as well as in many sectors of industry.

In this respect, we commend the International Atomic Energy Agency's further advance along its pattern of "Atoms for Peace and Development" and its impressive work to ensure security and safety of nuclear activities around the globe, including to help countries achieve the goals of the 2030 Agenda for Sustainable Development.

Along this path, Italy is proud of its contribution to the technical cooperation fund of the Agency. Let me recall in particular the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, which is a driving force behind global efforts to advance scientific expertise in the developing world.

Finally, let me mention that each year a number of foreign researchers are hosted in our laboratories and medical facilities in the framework of fellowships financed under the Agency's technical cooperation fund. I believe that this research and academic aspect is a crucial component in confidence-building within the international system: compliance relies – *inter alia* – on the "human dimension", and we should learn to consider individuals involved in nuclear activities and their connected responsibilities as structural elements of the overall picture.

Lectio Magistralis

Rafael Mariano Grossi

In December 1942, on an old squash court beneath the stands of an abandoned American football stadium, an Italian scientist became the first person to light an atomic fire. In that moment, humankind harnessed the vast cosmic reservoir of energy in our sun and our stars.

The pioneering scientist was of course Accademia Nazionale dei Lincei's very own Enrico Fermi. Fermi laid the foundations of his famous experiment with the "ragazzi di via Panisperna" here in Rome.

As the inventor of the nuclear reactor and among the first to warn of its potential military use, Fermi knew that the energy he had unleashed could both harm and benefit us.

Towards the end of his life, he gave a lecture to a group of physicists. He told them: "What we all fervently hope, is that man will soon grow sufficiently adult to make good use of the powers that he acquires over nature".

In 1957, five years after Fermi made that statement, the International Atomic Energy Agency (IAEA) was founded and given a mandate to turn his "hope" into reality.

I have spent much of my adult life in the orbit of the IAEA. This has given me the privilege of seeing the Agency from several different angles: as an Argentinian diplomat; as a staff member, and now as its Director General.

The IAEA is a unique international organization, steeped in technical and scientific knowledge. Our hallways and laboratories echo with the conversations of scientists and public servants from every continent. We are a member of the United Nations family and partner with many of its Agencies. At the same time, we are autonomous. Ultimately, the IAEA answers to its 173 Member States.

Some of these states operate nuclear power plants, others do not; some are rich and others less so. Two wishes unite everyone we serve: the wish to live in peace, and the wish to benefit from the many life-enhancing applications of nuclear science and technology.

It is in meeting these wishes that the IAEA finds its mandate: "Atoms for Peace and Development".

Like a coin, the IAEA has two sides. On one side, we are the world's nuclear watchdog. We verify that states do not develop nuclear weapons. On the other, we are the facilitators of scientific and technical progress. We work to ensure that no community is left behind when it comes to benefiting from the safe, secure and peaceful uses of nuclear technology. We assist countries in healing their sick, boosting their crop yields, finding sources of fresh water, making oceans cleaner, and mitigating the consequences of climate change. The uses of nuclear are so wide ranging, that the IAEA alone helps countries achieve 9 of the UN's 17 Sustainable Development Goals.

To better understand where we are today and imagine what tomorrow might hold, I would like to take you on a journey back to the 1950s.

In Vienna, the wounds of war are still etched into the buildings. It is 1957, and the new home of the IAEA is just emerging from a decade of occupation by the war's victorious powers.

Here in Italy, things are looking up. The industrial miracle is producing everything from the most desired fashions to the Vespa. Federico Fellini and Sofia Loren are bringing Italian cinema to the world.

In Africa and Asia, countries are forging a new future, independent of colonial rule.

Technology is advancing. A new transatlantic cable enables better communication; the first computer comes to market; and jet aeroplanes herald intercontinental travel. In the Soviet Union and in the UK, the first nuclear power stations are producing electricity, and among nuclear scientists there is a sense of promise of further applications.

But, with the shock of the atomic bomb still fresh in people's hearts and minds, the spectre of nuclear conflict is casting a dark shadow over all this post-war potential.

To move confidently into the future, the world needs to find a way to prevent the destructive power of nuclear weapons while nurturing the technology's benefits for peaceful use.

It is in this context that the IAEA is founded, and 13 years later the Treaty on the Non-Proliferation of Nuclear Weapons, known as the NPT, will come into force.

For the past six decades, the IAEA and the NPT have made immense contributions to the safety and well-being of billions of people.

Were it not for this powerful international legal framework and the indispensable role of our inspections, we might well be living in the world the leaders of the 1950s and 60s feared would come to pass.

That the world is not permeated by nuclear weapons states, is a remarkable achievement. We should not take it for granted. As with other treaties and international institutions, the NPT and the IAEA rely on nations respecting international laws and norms. Today, the undermining of international laws and institutions; the closing of borders and the disregard for scientific and other facts, are serious challenges to peace.

Amid these obstacles, it is critical that the IAEA maintain its high level of credibility. To do this, we must remain steadfast in being firm and fair, especially in difficult situations.

Iran's nuclear programme is one of these challenges.

My team and I have maintained an open dialogue with Iran to verify, without bias, its nuclear programme. In the past months, we have worked tirelessly with Iran to ensure there is no break in the IAEA's collection of data while diplomatic negotiations towards an agreement between Iran and the five permanent members of the UN Security Council, plus Germany and the EU, continue.

This constructive and respectful approach does not mean we have shied, or will shy, away from telling the truth. We have made it clear that Iran has not yet answered our questions. And I have publicly stated my concern regarding this lack of clarity, especially as this ambiguity comes amid the backdrop of a continuously growing level of nuclear activity.

Also deeply concerning is the situation in North Korea. Satellite imagery indicates a reprocessing campaign may be underway. The situation is a cautionary tale of what happens when a country turns its back on established norms and its cooperation with the IAEA.

Even though inspectors cannot enter North Korea, the IAEA continues to monitor its programme and we stand ready to reengage. Every day we are reminded that diplomacy requires patience. This is true also in the IAEA's role in establishing a nuclear-weapons-free zone in the Middle East.

The process of establishing such a zone is, of course, led by the states in the region, and it is not easy. We will continue our consultations and engagement.

Over the past sixty years, our long-term goals of peace and prosperity have not changed. However, the political interests of nations have fluctuated amid constant geopolitical shifts, from the dawn and dusk of the Cold War, to terrorism and regional conflicts.

In coming decades, the pace of geopolitical and technological change is unlikely to slow. It will be vital that the IAEA remains strong throughout.

Member states are wise to keep supporting our work, financially, by helping strengthen safeguards, security and safety norms, and by furthering the scientific collaborations that help us support peace and prosperity around the world.

A robust regime of safeguards, including Additional Protocols, is essential. The Additional Protocol strengthens the IAEA's safeguards mandate. Without it, what inspectors can do is limited. A little like a man looking for his keys under a lamp post, not because he dropped them there, but because this is the only illuminated place on the street, it is not good enough for the IAEA to look for nuclear activity only where a member state declares it is. The Additional Protocol gives inspectors the authority to search thoroughly, thereby more confidently being able to reassure the world that no nuclear materials are unaccounted for, nor have any been diverted. The international community granted the IAEA this authority after the revelation in 1991 of the extent of Iraq's hidden weapons programme.

A similarly important lesson came a decade later amid the September 11 terrorist attacks in the United States. These made clear to the world that the threat of nuclear proliferation had changed since the 1950s. With the spread of nuclear material across all continents and the rise of non-state actors, it was high time to sharpen the international focus on security.

The Convention on the Physical Protection of Nuclear Material and its 2005 Amendment make it legally binding for countries to protect a wide range of peaceful nuclear material wherever it is located, whether in facilities, in transit or in storage. Through peer reviews, shared databases, and training, the IAEA assists countries across the world in meeting that obligation. We help them understand how to keep their nuclear material safe and secure, whether it is located in a hospital treatment room, at a power plant, or in a university laboratory. The amendment also provides for strengthened international cooperation. Italy plays an important role in this. For example, it funds the International School of Nuclear Security, organized by the IAEA and the International Centre for Theoretical Physics in Trieste. Our 10th session was held last month, updating early-career professionals from developing countries on the latest in nuclear security.

Nuclear safety and nuclear security are closely related. Without them, nuclear will not be able to deliver on its beneficial potential. Today, we have a strong international safety culture in no small

measure because of the lessons we learned from the Chernobyl accident. International conventions and a robust network of cross-border cooperation exists, with the IAEA at their centre. Principles to guide countries in their implementation of these objectives, further strengthened that safety culture following Fukushima. This is important, not only for those countries pursuing nuclear power programmes, but also for those, like Italy, that have decided to decommission their nuclear power reactors.

Globally, nuclear power plants provide around a third of our low-carbon electricity. Nuclear energy is here to stay. Countries in Asia and even in the oil-rich Middle East are looking to it to meet their growing energy needs. More than 50 reactors are under construction and 27 countries are actively considering, planning or embarking on a nuclear power programme. The IAEA is helping many of them lay the legal, organizational, human and technical foundations that will allow them to fulfil their ambitions in a safe, secure and efficient way.

Because every time a nuclear power plant replaces a coal mine, the world can breathe more easily – quite literally. Today, 8 million people a year die because of the health effects of fossil fuel emissions.

With the technical challenge of long-term nuclear waste disposal having been overcome by sites like Finland's Onkalo repository, experts have concluded there is no science-based evidence to suggest nuclear does more harm to human health or the environment than other green technologies backed by the European Union.

Of course, each country has its own unique circumstances, and each chooses its own energy mix. But if we are to reach net-zero emissions anywhere close to 2050, the world will need to harness all available low-carbon energy sources. The Intergovernmental Panel on Climate Change models four pathways to achieving our critical 1.5°C degree goal. These require nuclear power generation to increase between 59% and 501%. This projection by leading international environmental scientists is higher even than the IAEA's top estimates.

It is clear that we will have to come up with new technologies across all low-carbon solutions. In nuclear, for example, Small Modular Reactors (SMR) could offer an option for smaller electricity grids, including those in developing countries. If SMRs are used to produce hydrogen, we could reach tough-to-decarbonize sectors, including transport and industry. Further in the future, tangible progress in fusion will bring with it the prospect of safe, reliable and abundant carbon-free energy. In all of these cases, the IAEA is laying the groundwork to contribute to their safe development and deployment.

If we are to hand this world to the next generations better than we found it, we must invest in science.

Newspaper headlines may tend to focus on our safeguard work, but many countries join the IAEA because they want our help in safely applying nuclear science and technology to a myriad of peaceful endeavours. The following specific examples illustrate the IAEA's unique mandate.

The SESAME international research centre in Allan, Jordan is a notable achievement in which the IAEA is involved. Countries in the Middle East with deep political differences came together to build the facility at whose heart is a synchrotron light source allowing scientists from across the Middle East and beyond to collaborate, teach and advance nuclear science. These days, as the conflict in Gaza rages on, this example reminds us of what can be done when scientists work together.

Whereas the SESAME project was a long time coming, my next example shows just how quickly the IAEA can move in a crisis. Over the past year, we have done our part to help fight the Covid-19 pandemic. To date, the agency has sent RT-PCR testing kits to 128 countries, enabling the testing of more than 28 million people.

While we were mounting the largest emergency response operation in our history, we were also devising a coordinated, long-term initiative to combat the reoccurring challenge of viral outbreaks like that of Covid-19. Zoonotic Disease Integrated Action, the IAEA initiative we call ZODIAC, is nuclear's contribution to helping developing countries spot zoonotic diseases and stop them from spreading. The programme builds on decades of experience and is an example of the IAEA joining partners, such as the World Health Organization, the United Nations Food and Agricultural Organization, and the World Organization for Animal Health, under the "One Health" approach to soothe and to cure, and to rebuild communities.

There are many medical uses of nuclear technology beyond combating zoonotic diseases. Cancer is a big one. Through nuclear medicine and therapy, the IAEA has been working hard to open access to life-saving pharmaceuticals, equipment and knowledge to countries that lack them. The projected increase in cancer cases over the coming decade will be distributed unevenly. The number of new cases is forecast to rise more than 80% in low-income countries, double the rate richer countries will experience. Today, cervical cancer kills more than 300,000 women every year – nine out of ten of them in low- and middle-income countries. Many of these deaths would be preventable if it weren't for the fact that

people living in nearly 70 countries, 28 of them in Africa, still do not have access to radiotherapy. Setting up a cancer centre is not an easy task, which is why the IAEA has helped countries such as Zambia on their journey to do so. For many public professionals and policy-makers, the agency serves as a key resource for learning and sharing best practices, and to ensuring these life-saving treatments are available and carried out safely and effectively.

The next examples I would like to give are of nuclear science offering solutions to the challenges of climate change and pollution that go well beyond decarbonizing electricity production.

For farmers in Vietnam, for example, radiation processing turns casava root starch polymers into water-absorbent pellets, which are used to help irrigate rubber plantations. In Latin America, Asia and Africa, IAEA experts help countries use ionizing radiation to breed new crop varieties so famers reap harvests that can better survive droughts and disease and offer higher nutritional value. This not only boosts yields, but also conserves water and reduces the need for pesticides and fertilizer. From Afghanistan to Argentina, the IAEA helps communities use isotopes to trace and assess the availability of fresh water, allowing them to use this precious resource prudently. Isotopes also allow scientists to trace microplastics across the oceans, and through the food chain from the bellies of shrimp to those of fish to ours. This means governments can rely on accurate information as they seek to overcome an increasingly global problem. Of all the plastic we have used to date, 70% is already waste. Less than 10% has been recycled, with much of the rest eventually landing in our waterways. One of the problems is that plastic is difficult to recycle, and here too, nuclear techniques can help, in this case by breaking down long and complex polymers. Like a discarded plastic bottle washed onto a distant shore, many challenges do not respect national borders. The IAEA enables scientists and professionals to reach across their borders to share their experiences and data. A powerful example of this comes in a rather small body – that of the Mediterranean fruit fly, one of the world's most destructive agricultural pests. The IAEA helps many countries eradicate the medfly by using radiation to sterilize males. In the Middle East, this little insect flies without challenge across borders and through military no-fly zones. But it met its match when Israeli, Palestinian and Jordanian policy-makers, scientists, farmers and technicians came together and – aided by the IAEA – used the sterile insect technique to eradicate them. The agency has adopted the same approach to help Senegal and other countries combat the deadly tsetse fly.

In these endeavours, member states receive our assistance on the ground, at our laboratories near Vienna and in Monaco, and at the conferences and training events we host and facilitate. Knowledge like this is shared through our virtual platforms and reports, and through our partnerships with research facilities around the globe.

In all we do, we seek to empower the people we serve, and this is especially true of women. I am determined we do our part to boost the number of women benefiting from and participating in nuclear science.

The American physicist, Leona Woods, was the only woman in Fermi's team that built and experimented with the world's first nuclear reactor. There are far too many women scientists who have received far too little credit for their important work.

I opened my remarks with Enrico Fermi, and as I approach the end of them, I want to name some of the women scientists who worked around Fermi's time. Their contributions in many cases were not only important to science, but also to him.

- Tatiana Ehrenfest-Afanaseva, who together with her husband laid the foundations of statistical mechanics and statistical thermodynamics.
- Emmy Noether, who solved problems key to the theory of relativity and whose mathematical formulations, including those surrounding the principle of the conservation of energy, contributed to our understanding of physics.
- Marietta Blau, the first physicist to show that proton tracks could be separated from alpha-particle tracks in emulsion.
- Irène Joliot-Curie, whose work offered an important clue for the discovery of the neutron, and who discovered induced radioactivity.
- Lise Meitner, who discovered radiationless atomic transitions and later discovered nuclear fission. Her mastery of experimental physics underpinned and facilitated some of the most important scientific advances made by her fellow scientists, including Fermi's nuclear reactor.
- Ida Tacke Noddack, a chemist, who suggested that the radioactivity Fermi observed resulting from neutron bombardment of uranium might be caused by disintegration of the uranium nucleus into several heavy fragments. Had Fermi taken note, he would have sooner understood the process we now know as fission.
- Maria Goeppert Mayer, who proposed the nuclear shell model of the atomic nucleus.

My hope is that young scientists will research these great scientists' discoveries and take inspiration from their perseverance and determination. And that we more senior leaders will remember the equally vital contribution women and men make in helping us achieve our goals.

Today, it is our job to clear the path of women scientists of their historical and current obstacles. This is why I launched the Marie Skłodowska-Curie Fellowship, whose inaugural group of 100 women fellows is already receiving financial support to study for their Master's degrees in nuclear subjects around the world.

We have come a long way since the hopes and fears of the mid-1900s led to the IAEA's founding. As you can perhaps tell, I am fiercely proud of this unique organization's accomplishments and of the work its women and men continue to do every day. But we cannot do it alone. In closing, I want to thank the Accademia Nazionale dei Lincei for the great honour of being with you in this magnificent setting today. And I want to thank Italy, its policy makers and its scientists, for helping the IAEA to make Fermi's hope a reality. I call on all of us to redouble our efforts to use wisely, justly and always peacefully the incredible power he and the women and men who worked alongside him unleashed 80 years ago.

Discussion*

Rafael Mariano Grossi, Jeremy McNeil, Giorgio Parisi, and Wolfango Plastino

Wolfango Plastino: *Should nuclear energy be a part of the energy mix that moves us onto a more environmentally sustainable path? If so, what are the kind of activities that would move nuclear power higher on the climate change agenda?*

Jeremy McNeil: I am an ecologist who works on the effect of climate change on agricultural and natural ecosystems, and obviously any form of energy that will reduce the production of greenhouse gases, such as nuclear energy, is in my mind something that we should seriously investigate. Like everything else, though, it comes at a cost, and there are benefits and there are disadvantages, and we have to look at those. And while nuclear plants do not produce greenhouse gases, there is the whole question of radioactive waste that we have to deal with. In Canada, of course, this has been a very active area of debate, and there are two possible approaches: one is the deep geological disposal, whereby the waste is put very deep into the ground in areas that are extremely solid, and thus the probability of leakage is reduced, particularly as they have developed multi-barrier approaches. There is always the question, as this waste lasts for thousands and thousands of years, of what might happen: could they leak? And as a result, there is another group that is taking an above-ground approach, and it has basically been called "rolling stewardship", whereby the responsibility passes from one generation to the other; the argument for that is that science and technology might develop a means by which we can actually reduce the dangers of radioactive waste with future development.

In my mind, to be honest, it's extremely important that we look at alternatives. Of great importance for us as scientists is the

* The text below is the full transcript of the Round Table that followed the *Lectio Magistralis* by H.E. Rafael Mariano Grossi, Director General of the International Atomic Energy Agency.

question of education. We have the data, we mustn't just believe that because we believe something, everybody else will, as well. We must have an open dialogue between scientists and politicians; we must work with agencies such as Professor Grossi's. We really need to make sure that the public understands. And I think that this is an important role that academics and academies can play. We have serious problems with climate change, and nuclear energy is obviously one of the potential solutions that we must investigate at great length, but with transparency, and by presenting both the benefits and the disadvantages.

Giorgio Parisi: The use of nuclear energy in the future is a highly controversial point. I have discussed it with many friends and with many fellows of the Academy, and the viewpoints are quite different. The difficulties in finding a common viewpoint also arise because there are many different issues which are interwoven here. There are not only environmental issues, but there are economic issues and societal issues; we also have problems with the import/export of developing countries that should be taken care of. And then, as President McNeil was also saying, we have the problem of the relation between science and society in education, which should be taken into account.

Let me present some personal considerations, since it's clear that I certainly can't speak here in the name of all academics, because there are many different opinions. I am very convinced that, as we know, from what we have seen from Chernobyl and also from the Japanese accident, most of the damage that is done by nuclear plant reactor incidents happens in the vicinity of the reactors. They say up to one hundred kilometres – certainly, more than one hundred kilometres, the damage is very minimal. But the regions that might be at twenty, thirty kilometres are also the most likely to be evacuated, at least in a very serious accident. Therefore, this type of damage, which is very serious, is proportionate to the population around the centre.

We have been very lucky in the past; the populations around Chernobyl and also around the Fukushima reactor were not as high-density as the Val Padana. Therefore, as far as the possible damage in proportion to the population, we can say more or less that the benefits do not strongly depend on the region where they are constructed – especially if you think of it from the ecological point of view; for carbon reduction, it is region-independent. Of course, if you want to transport energy, it is clear that you would like to have reactors near to populated regions, but of course this includes very high costs. I think that in countries like Italy, Belgium,

the Netherlands and some regions also of China and India, the construction of reactors should be avoided, because these are the worst places to construct reactors if you look at the ratio between benefit and risk.

As Professor McNeil was saying, there is a serious problem in the whole world regarding long-term management of radioactive waste. There are so many unsolved problems. For example, there is no final decision for the long-term, permanent deposit of waste in the United States. The Yucca Mountain Project failed, a similar project in salt mines in Germany failed, and so of course we can have nuclear waste for hundreds of years, for thousands of years. We know how to control it. But it is unclear where we can put it, in a place where we can forget it – not for the rest of the universe, but at least for ten or a hundred or a thousand years, or something like that.

One other problem that makes difficult large-scale construction of nuclear plants – and I am not discussing a single or a few cases, but large-scale construction, since if you don't have large-scale construction, it will impact very little, in a marginal way on CO2 – is that nuclear energy is an extremely complex technology to import from abroad. Many developing countries may not be able to construct safe reactors themselves – I don't mean reactors in general, which is easy, but latest-generation safe and stable reactors – the reason being that the technology must be imported from abroad. And this is something that would have some weight in the technological independence of the country; for it's clear that if a country becomes dependent on outside intervention, this goes in the wrong direction, because it is very important that developing countries become, as far as possible, economically independent from others.

Even developed countries should become independent, in some cases. I remember there was a shortage of masks in Italy and in many other countries, because we were dependent in the same way on other countries for the construction of masks and similar individual protection. So it's clear that economic independence is very important.

And I think that one kind of action that should have the highest priority is energy-saving actions. Energy-saving actions are very important. One of the places where you can save an incredible amount of energy is in ecologically friendly building. We have a huge amount of energy that goes into heating – this depends on the country, of course; not so much in Africa; but even in Africa, if you want to have the same level of life as in the developed countries, you will have a certain amount of air conditioning in

the future. Now if you start to put air conditioning in a place with bad insulation, it will bring a lot of waste, so I think that improving insulation of buildings will be extremely important. And insulation technology made by local development will strongly contribute to the local economy.

Rafael Mariano Grossi: This is a fascinating debate. What we hear from President Parisi, and especially from certain comments by Dr. McNeil, is that what's really important here is to have a debate with full transparency, where the discussion is based on scientific fact and information, and not on ideological aspects. One feels sometimes that around the issue of nuclear energy – in particular in some parts of the world, in Europe for example – there is a lot of emotion, and a lot of positions that are based on beliefs, but sometimes not so much on scientific information.

As I said, I do not consider myself a nuclear lobbyist, but the reality of the world is that nuclear energy in the world is growing. It's not diminishing. So I think we should talk about things as they are. And why is this happening? Are people jumping irresponsibly into activities that they should not be doing? I don't think so. What we see is that for many, many countries – for a number of reasons, including some relating to energy independence, for example in Eastern Europe; for diversification of energy matrices, like in the Arab world; the necessity of facing the ambitious goals of decarbonization, in countries which are consumers of coal, like China or India – for a variety of reasons, what we see is an increasing trend. And I would quote, not the representative of a nuclear utility, but the Intergovernmental Panel on Climate Change, which, as many of you must know, is a group of distinguished scientists from all over the world. Having studied the current trends and evolution in terms of decarbonization and energy in all of their projections and the different models that they have established to get to a decarbonized global economy, nuclear is part of it. The issue is how much nuclear you have, or if you have any. There are some countries that are not going for it; as I was saying, forty-two countries at the moment have embraced it. And by the end of the decade, there might be around fifty. So what we are saying is that this is a growing trend.

What's important here – and I think that Professor Parisi was mentioning some of these issues – is that we have adequate answers to the safety operation of nuclear power plants, including waste, where, from our perspective, the problem is more of social acceptance than of technical lack of answers. Because the answers are

there. A few months ago I was on the island of Onkalo in Finland, where half a mile underground you have an incredible feat of engineering, and a deep geological nuclear repository is ready for licensing. So the issues of waste are also there, and the cases that we know are of course debated. And rightly so. In democracies, these things should be debated, and all the information should be set before the public to reach an informed decision.

So, from the perspective of the IAEA, what are we trying to do, how are we trying to contribute? In two ways. First of all, by ensuring through the safety standards that we administer all over the world that there is a lowest common denominator. There are some countries that have highly developed and sophisticated safety structures. Some others, less so. What we want is to make sure through the IAEA that everybody has at least the minimum required levels.

This is one thing. And the other thing is, when working with countries – especially those newly acceding to nuclear energy – to make sure that they do everything as they should, and work within and with the international community through the commissions and committees on safety standards that we have, in order to ensure that whatever they do, it is done in a way that is beneficial, and beneficial to all.

Wolfango Plastino: *There are regional concerns regarding the water disposal from the Fukushima Daiichi nuclear power plant as it may affect the water environment in that part of the Pacific Ocean. Are those concerns well founded?*

Rafael Mariano Grossi: It's an excellent question, because this is one of the topical issues of the day. As many of you know, around the stricken nuclear power plant, the water that has been used to cool off the stricken reactors has been accumulating, and the Japanese government has arrived at a decision to dispose of it through controlled discharges of treated, processed water. And there are concerns, mainly expressed by some regional, coastal countries: China, the Republic of Korea, some other South-East Asian countries, and even by Japanese people. I was myself in Fukushima; I was talking to the fishing associations and groupings and journalists, and of course there are concerns. You ask in your question, Wolfango, whether these concerns are justified. I would say these concerns are legitimate. Every concern has to be taken seriously and with due respect. Because these people need to be

reassured that if anything is done, it will be done in a way which will not be harmful to the environment.

In terms of what we do, the IAEA has been working with Japan ever since the accident took place. And in particular, in this case, I discussed these matters in Japan with the then Prime Minister, Shinzo Abe, a year and a half ago, and I proposed to him that whatever was to be done, could be done with the IAEA. And I took the liberty, as head of an international organization, to suggest to him that they should avail themselves of our assistance – not because Japan needs any assistance in undertaking this, but simply because the international community needs a neutral, third-party with the technological ability to monitor whatever is going to be done there, through a process – a process that will take place before, during, and after the discharge of this water.

Of course, the water can be made acceptable to the environment, and, as those who are knowledgeable say – and I suppose Dr. McNeil, you are an environmentalist, you must know this – there are methodologies to get rid of the radionuclides, in particular the caesium and strontium, and also a number of other radionuclides that are present in this water before it is released, so that whatever is released is not contaminated, radioactive water. It's water that may contain some tritium. People have also been asking, why can't we do this only after tritium has been taken out of these volumes of water? And we also have been looking into this, to give people an idea – because again we have to inform, we have a responsibility to inform. In this 1.2 million tonnes of water, there are sixteen grammes of tritium; and this tritium will be disposed of after treatment, and in volumes that are reduced, because this water is not going to be released all of a sudden, as if one opened the floodgates; it's going to be done over the course of decades. You heard me well: decades. Maybe thirty years, or maybe even more. So it's going to be done in such a way that you have a function of volume of water, an amount of tritium, and the comparison with activities that are being carried out.

You know, effluents are a reality of industry, let alone nuclear industry. In any activity, there are effluents. So what we do is try to ensure that whatever we put back into our environment is not harmful, is not doing any damage to the fish, to the marine sediment, or to the water itself. This is what we are going to do. It's going to be a complex operation – one of the most complex operations that the IAEA is going to be undertaking – but we have started already. And also let me say – because this is also about acceptability, this is also about taking the right political decisions – I have set up a task

force at the IAEA where our experts will be joined by a select group of top scientists, like the Accademia Nazionale dei Lincei, coming especially from the countries that are expressing concerns, so that we will show, as far as possible, that we have an operation that is scientifically sound, politically honest and transparent.

Jeremy McNeil: I think the most important point, as Director General Grossi indicated, is transparency. People have concerns, and their concerns should be addressed, and in a very transparent way.

Obviously, he addressed the question of removing contaminants. As an ecologist, there's one other thing that we need to think about: what is the temperature of the water that is being released, and what is the relative volume and the area that might be affected? Now, that might sound silly, but as water doesn't change temperature as rapidly as air does, if you're releasing water at a much higher temperature – and that could be two or three degrees – than the ambient temperature, this can have an effect on the food chains, and as a result it could have a local or a broader effect. It may affect the growth of algae blooms; a slightly higher temperature may cause the proliferation of diseases that are present, like viruses that might be present in seafood. Now, the relative importance of that is going to be, as I said, decided by the temperature difference, and the amount of water being released relative to the volume that it's being released in.

Much of this can actually be mitigated by previous experience, because, as was mentioned earlier, this whole idea of effluents being put out into water systems is not new. I remember, a number of years ago, there was a very large factory that was producing aluminium, and they were taking water out of the lake, using it in the factory, and then putting it back in at a much higher temperature, which then caused problems with the ecosystem. Well, they said, "We have to control this", so what they ended up doing was actually building a series of greenhouses, and the hot water was pushed through, the heat was taken out, allowing them to grow vegetables during the winter, in an area where this normally couldn't happen, so they were available locally. And only then the water, at a temperature which was very close to the normal temperature, was returned. In that way they mitigated the problem.

So again, the science is available to address the questions that are being raised. We as scientists must work with politicians, we must work with the general public, and make sure that everything is presented in such a way that they understand that their concerns have been listened to and that there is science that can be applied to help mitigate problems.

Giorgio Parisi: What has been said is very important. It's very important that all these kinds of concerns are addressed. There are concerns related to radioactivity, there are problems related to the temperature of the water. But I believe that the fact that the IAEA is going to monitor all these activities is extremely important, because transparency is unusually important in this situation, since people often do not trust governments. I don't say that they have any reason to mistrust governments, but it's a fact that many people do not trust even their own governments, or the governments nearby; so, to have an international agency that is going to monitor this situation, to check that all the radioactive heavy nuclei have been filtered out, that only a small amount of tritium will remain, is extremely important. Because if only tritium remains in a small amount, it's clear that there is no environmental danger, except as far as water temperature is concerned and so on. And this can be addressed. If there were heavy nuclei insertion, that would be a completely different story, and it is crucial that an independent observer – not only an observer, but an independent team of scientists, led by the IAEA – is overseeing the situation. If IAEA is overseeing this activity, I am completely confident that everything will go well.

Wolfango Plastino: *Can you please highlight the initiatives to promote peaceful uses of nuclear science and technology to extend their reach across the globe, especially to developing countries?*

Giorgio Parisi: This is an extremely important issue, and as has already been said by Ambassador Grossi, one big issue is the treatment of cancer. Cancer has to be treated. There are many things that can be done with cancer, and one thing that is extremely important with cancer is some kind of radiation therapy. Radiation therapy is something that may completely change the outcomes of some kinds of cancer from negative to positive, or it might allow patients to gain many years, and it's clear that it's missing in many countries. So this is something that must be seen to. And also another important programme – of course, it is only for a small minority of people – is proton therapy. This therapy is an extremely sophisticated way to cure cancer, and it should be used only for a small number of cancers that are resistant to radiotherapy, or in some regions near the brain, or other regions where you can't use radiotherapy. And it's clear that even people in developing countries must have access to this type of therapy. Proton therapies are very expensive, but they include the construction of a small

accelerator, and this will be very important also at an educational level, since you have to train people on site that are able to do these kinds of things.

The other problem that I think is also as important as the treating of cancer is cancer diagnostics. Something like positron emission tomography. This can be done only if you produce, on the spot, a few kilometres away from the place where you implement this type of diagnostic tool, various types of reactive elements. Also scintigraphy, since all these types of diagnostic tools, which are crucial to see whether or not you have metastases, where they are and so on, have to be done with a very short half-life. You can have a combat bomb or some long-life radioactive elements for standard radiotherapy, but if you want to use positron emission tomography, you must produce the elements on the spot, and this is also very important. This is a very sophisticated technology that must be imported, and people in the country must learn to use it.

Rafael Mariano Grossi: I'll try to be brief, because I think you brilliantly explained things that we're actively working on: nuclear medicine, radiotherapy, diagnostics, theranostics, and the new trends. The agency is not only trying to give the hardware, but we are also working on capacity building. We are training the people. This is what needs to happen. The same applies as well to some of the areas I mentioned before, like plastic pollution, like food security with crops, with plant breeding and genetics.

We have a technical cooperation programme which is at the moment helping more than one hundred and forty countries. One hundred and forty countries are benefitting in one way or another from the work we are doing, which we are carrying out in the IAEA.

There is one thing I want to say. We more or less know the scientific areas, as we have mentioned. The problem is of course the vastness of the needs, and the expectations that are there, which require redoubled effort. And it is obvious that the meagre budgets of international organizations – for example, I have the budget of a small police force in a medium-sized city in Europe or even in Latin America, and we are doing non-proliferation work, we are doing a variety of things – is a fact of life. So this is why we are trying to reach out also to the private sector. We are reaching out to regional development banks, because these needs are there. And funding is not going to be reaching those who need it just because of the force of the market. We will have to be active and proactive in doing these things.

Jeremy McNeil: Obviously, one has heard all of the related issues for medicine. Because of my own field in entomology and working with insects within the context of food security, I would bring a little more detail into the whole idea of insect control.

We were very reliant on pesticides for many, many years; the idea was basically, if we have a problem, spray. And more and more we became aware of the ecological impact, which was very negative in many cases. So we've been working for more than half a century in the area of developing a much more integrated approach, called "integrated pest management", where one uses natural enemies, one uses resistant plants, and one of the other areas is what's called the "sterile male technique" that Director General Grossi actually mentioned in his plenary lecture.

In this case, there's a mass-rearing facility where you rear millions and millions of a given pest, and the males are sterilized using radiation, and then are released into the natural population, at a density that is way higher than the natural population – let's imagine, a hundred to one. So the probability of the female mating with a sterile male is much higher than with a regular male. And in doing this over several generations, you will end up decreasing the population.

Now, that requires an infrastructure, large facilities where you can do the radiation under proper controlled conditions. It has to be a species which is easily reared, which is not always the case with major pests. And so for use particularly in developing countries it will be absolutely necessary that we provide the needed infrastructure to help, and also the capacity building, even on the basis of science. There are a number of stellar examples of where this actually worked, but there are failures, as always, and it will only work under certain conditions. If you have an enormous, enormous population you won't be able to physically rear that many insects, to produce the overabundance of sterile individuals. In species that move over very large distances, you can have a problem, so you need to know that. Another is, do the females mate more than once? And in that case, this is very different from species that only mate once, because if they mate with a sterile male, physiologically females may be able to recognize this, and then re-mate multiple times.

So there is the potential there, we can use it; but again, it is the surveillance and transparency as it relates to the actual utilization, and the education so that people can move forward on this. But it has potential, and given the whole question of food security under the conditions of climate change, this is something that we really do have to work on.

Wolfango Plastino: *How can the main international actors, including international organizations, contribute to addressing the challenges related to nuclear proliferation posed by North Korea, and how can they manage the situation in the context of safeguard activities in Iran?*

Jeremy McNeil: The Director General has very much covered this, and this is really a major question of diplomacy. Along with IAEA, there are many other organizations that are working in the direction of inhibiting, and preferably stopping, nuclear proliferation. I think at the level of organizations like national academies, we need to work together with umbrella organizations, for example both the Accademia Nazionale dei Lincei and the Royal Society of Canada are members of IAP (Interacademy Partnership), we are both members of the Science 7 Group and the Science 20 Group, and it is through collaborations like this that we should be working, developing dialogues, and providing evidence-based information. We need to be building bridges rather than walls. And in this case – through transparency, providing information, talking with the other organizations that have the same goals as us – we will be able to educate and work with those other organizations that can help locally educate the general public. Because the whole question, as all of us have repeated before, comes down to transparency, and providing evidence-based and at-arms-length information, as we move forward to try to limit or eliminate these possibilities.

Giorgio Parisi: I fully agree with Professor McNeil, and I believe that education is a very important issue in this game. Collaboration between academies is very important, and I think that what is crucial, both in the case of North Korea and also with Iran, is to develop scientific ties with these two countries.

One major success story, for example, is the SESAME electron accelerator which is being constructed in Jordan, if I am correct, to which many regional countries are contributing. Among them are certainly Israel and Iran, and I remember that Italy also made some kind of contributions. Of course, this may be more difficult to do with North Korea, but I think that one should perhaps start with scientific collaborations, scientific exchange with people from North Korea, with the rest of the world – maybe on biology if they don't want to collaborate on nuclear facilities – and I think that would also be something that we should do, that we should not suppose that a student coming from North Korea or Iran to Italy to study is a dangerous terrorist.

I think that we should open up to scientific exchange, and academics may play a very important role in facilitating a scientific exchange with these countries, because scientists tend to trust one another. This is the meaning of the title of this series, Science Diplomacy, which Wolfango Plastino suggested. And I think that this starts also with scientific exchange among countries. This is something that should be strongly developed.

With Iran, this is somewhat possible; North Korea, not. But one may start to do something of this kind, maybe start to have exchanges regarding ecology with North Korea, or something else if they don't want to share certain things that may be too sensitive.

Rafael Mariano Grossi: I think there's (of course not surprisingly) a lot of wisdom in what Professor McNeil and President Parisi have just said.

I would retain two ideas from this. First of all, when it comes to non-proliferation, we have to recognize first that this is a reality, that it can happen; secondly, that you can best tackle this kind of thing through a family of efforts, rather than unilaterally applying certain restrictive measures. Limitations are necessary, and there are treaties and conventions, and the safeguards which we carry out work. This has to be, and is, constantly improved, because technology evolves, because the proliferator may be looking for alternative ways to do what they want to do.

There is also the very important point of intangible proliferation, in the sense of the passage of knowledge. And of course, we need, as an international community, cooperation in science, and academies of course are at the heart of this work. So, as I was saying, what we need to do is something that, at the end of the day, and when we are talking from a place of humanity like this, is quite simple to understand, and it's something at which human beings can and should excel: dialogue. Listen to each other. Cooperate. Do it with eyes wide open, but with a good disposition.

And I think that with this kind of approach, the chances that we catch whatever should be caught, but at the same time we allow the flow of knowledge and good will without problems, is possible. It's not impossible, certainly.

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