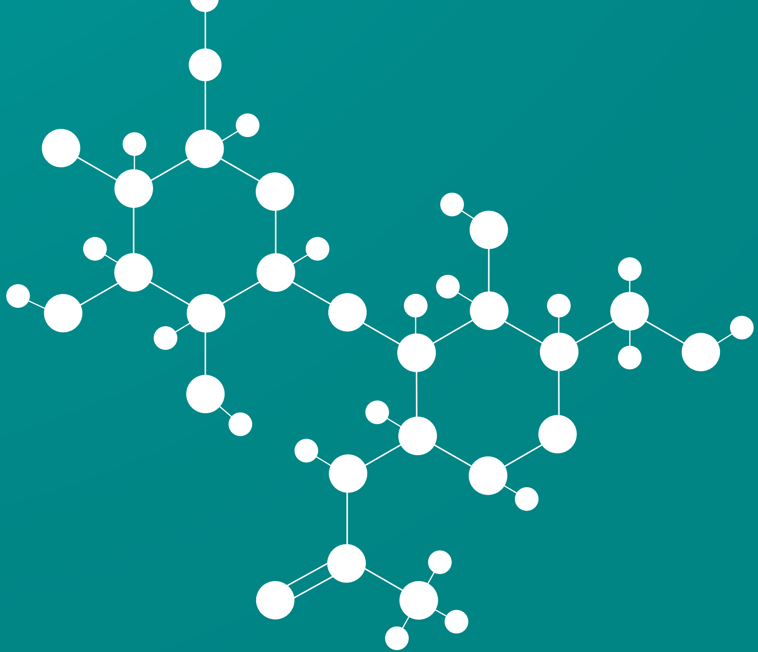
OpenMind BBVA

The Search for

Alternatives to Fossil Fuels



Sustainability NOTES | #3

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BBVA OPENMIND. THE SEARCH FOR ALTERNATIVES TO FOSSIL FUELS

Preface

Thanks to science, we know the risks posed by climate change and its causes. It is also thanks to science that we have more and more solutions to combat climate change. Within the scientific community, chemistry plays a particularly important role in the search for solutions. Many of the clean technologies used today, as well as a number of the products that contribute to the reduction of greenhouse gases, exist largely thanks to this branch of science. Chemistry is present in everything around us, although we are often unaware of it.

Precisely one of the objectives we pursue at **BBVA OpenMind** is to vindicate the essential role of science in the search for solutions to the great challenges facing the world, including the fight against climate change. It is in this spirit that the Sustainability Journals were born, this being the third issue, in which we compile, through interviews, the visions of great experts studying and working for a more sustainable world.

Greenhouse gases, especially carbon dioxide (CO_2), are the main culprits of climate change. This is what the international scientific community affirms. The burning of fossil fuels such as oil, natural gas or coal, which supply around 80% of the world's energy, releases tons of these harmful gases. According to UN figures, fossil fuels are responsible for more than 75% of total emissions. As a result, governments and companies around the world are strengthening their efforts to find ways to reduce these emissions and achieve the goals set out in the 2015 Paris Agreement. And science is a key tool to achieve this.

"Science is a key tool to reduce greenhouse gas emissions".

One of the solutions that has gained most prominence in recent years is renewable energies such as solar, wind and hydro, becoming for many a kind of Holy Grail in the fight against climate change. But will renewable energies be able to generate enough energy to meet global demand? The data would suggest not. At present, only 29% of electricity comes from renewable energy sources. Moreover, they still face a number of challenges, including climate dependency and storage.

"At present, only 29% of electricity comes from renewable energy sources. There is thus a need for further research into other alternatives".

There is thus a need for further research into other alternatives. One of them is fission energy. Although it is not a new energy source and generates a lot of controversy, science has also made great advances here. This energy could be a possible companion to renewable energies, at least until such time as the latter manage to resolve the challenges they face. There are also other technologies that until now seemed like science fiction, such as nuclear fusion, that can also play a role. Scientific advances in this field are very promising.

"We explore some of the lines of research that are seeking solutions to climate change".

Materials science is another branch of science that can provide great solutions to climate change, contributing to the development of new materials and products. One example is the conversion of plastic waste into fuel, with the aim of gradually replacing fossil fuels with less polluting alternatives.

In this chapter of the series, we take a closer look at some of these alternatives that are being developed. With experts such as Javier García, President of IUPAC, Ignacio Mártil de la Plaza, Professor of Electronics at the Complutense University of Madrid, Carlos Vázquez, PhD Researcher at Forschungszentrum Jülich, Germany and Member of Jóvenes Nucleares, Isabel García Cortés, researcher at CIEMAT and Marta Muñoz Hernández, Professor at the Rey Juan Carlos University, we explore some of the lines of research that are seeking solutions to one of the greatest challenges we face as a species: climate change. We would like to express our sincere thanks to all of them for their collaboration in this initiative.

Beatriz Rose
BBVA OpenMind Editor

The Role of Chemistry in the Fight Against Climate Change

INTERVIEW WITH:

Javier García

President of the International Union of Pure and Applied Chemistry (IUPAC), President of the Academia Joven de España [Young Academy of Spain], Rafael del Pino, Professor in Science and Society and Professor of Inorganic Chemistry at the University of Alicante.

Q

What role can chemistry play in the fight against climate change?

A

The origin of climate change lies in the greenhouse gas emissions that human beings produce, including CO_2 and methane. Chemistry has the ability to find alternatives that on the one hand, do not generate as much greenhouse gas, and on the other, use this waste, such as CO_2 or methane, to create a new economy, thus converting what is currently a problem of raw materials.

"The origin of climate change lies in the greenhouse gas emissions that human beings produce".

In recent years, we have seen fascinating discoveries in chemistry that make it possible to transform CO_2 into fuel with just water and sunlight, for example, or to transform CO_2 into molecules with a high added value. These new discoveries allow us to dream of circular chemistry in which CO_2 is integrated into cycles that are neutral from a climate change perspective.

Q

What is circular chemistry and how does it relate to the circular economy?

“Circular chemistry is a new way of understanding our relationship with the planet, so that everything we produce is designed to be reused”.

A

In order to make the circular economy possible, we have to be capable of recovering and reusing everything we produce. In order for this to be possible, we need new chemistry, new forms of production. Circular chemistry is precisely this - a paradigm shift: going from linear industry that extracts resources from the planet and transforms them into products with a high added value that are then sold, to a new chemistry in which sustainability is there from the beginning; chemistry in which molecules and processes are conceived and designed so that everything that is produced is easy to recover and reuse.

For example, in general, plastics are not currently conceived to be reused. Their structure does not contain any points that allow us to decompose them to recover the components and reproduce them. In recent years, we have seen truly spectacular advances in which a new generation of plastic has been designed whose structure contains breaking points so that once they have been used, they can be reassembled and recovered indefinitely. Today, what we do is simply recycle, giving new life to products that have not been conceived for reuse.

Therefore, circular chemistry is a new way of understanding our relationship with the planet, a new way of designing molecules and processes so that everything we produce is designed to be reused.

There is no circular economy without circular chemistry, without design on a molecular scale of everything we produce so that its reuse and recovery is as simple as possible. That is the priority: that they are designed and conceived for sustainability from the beginning. This implies a paradigm shift, a new way of thinking and of teaching chemistry. This way, we will make the dream of turning the industry of transformation into the industry of reuse possible.

Q

Do you think that industries and companies understand this new paradigm?

A

To continue producing the way we have so far is not an alternative. Production that is not conceived for reuse has brought us to the current situation, in which we not only suffer from climate change, but also an actual tsunami of single-use plastics. For companies, changing to a circular model is not only profitable, but also inexcusable because in the long-term, raw materials and the consequences of continuing to produce in a linear manner will make the entire system unsustainable.

Regulation can help to ensure this transition occurs. For example, the ban on the sale of single-use plastics in the European Union is forcing companies to innovate. The Spanish chemical industry is precisely the industrial sector that invests the most in innovation. It also generates 700,000 direct and indirect jobs, with an average salary of €38,000 and 93 percent open-ended contracts. Where there is more resistance is when it comes to investing in CAPEX to convert factories and processes in order to be able to produce differently. This is primarily due to high interest rates and the uncertainty in the market.

“For companies, changing to a circular model is not only profitable, but also inexcusable”.

Profitability can be conceived from two perspectives. In the short-term, it is to continue producing in a way that is geared toward margins for the coming years. Another is to consider the sustainability of the business, relations with consumers and with the planet over the long-term.

The companies that invest in sustainability will be more profitable because they are going to have a larger market of consumers, who are increasingly more aware. We are noting that the general public, and especially youth, are demanding that these changes are implemented as soon as possible. However, the urgency is not on the table clearly enough.

Q

You preside over the International Union of Pure and Applied Chemistry (IUPAC). **What are its main lines of research underway related to the fight against climate change?**

“E-waste ia a huge problem because we are generating a lot of waste due to our use and abuse of electronic parts”.

A

The IUPAC currently finances over 180 international projects in all branches of chemistry, some of which are very much focused on climate change and sustainability. I would like to point to an enormous project we are carrying out with other international organizations on a problem that we hear little about, but which is very important: electronic waste, or e-waste.

E-waste ia a huge problem because we are generating a lot of waste due to our use and abuse of electronic parts. Unlike other products, electronic parts are highly complex and practically unrecyclable. They contain a lot of chemical elements, some of which are very scarce, and are not designed to be recycled, which creates a severe problem.

In terms of climate change, we are addressing it from many perspectives. First, on an educational level. The IUPAC creates a lot of educational resources, beyond the chemical nomenclature and the periodic table. We currently have a large project underway on systemic thought to relate chemical concepts to their impact on the environment and humans' role in climate change. We want to incorporate sustainability into the way chemistry is taught from the beginning so that the new generation of chemistry professionals is aware and has the knowledge and skills they need to develop the circular chemistry I spoke about earlier.

In addition, we finance numerous research projects. Among the most interesting results I would like to highlight those related to the transformation of CO_2 into high added value molecules, CO_2 photoconversion molecules (directly converting CO_2 with sunlight, either photovoltaic or solar thermal) and the electroconversion of CO_2. In addition, thanks to the use of green hydrogen, we are going to see the possibility of hydrogenating CO_2 and turning it into all kinds of clean fuels that do not require fossil sources.

Another major project we are working on is to create new chemistry nomenclature - not for humans, but for machines so that artificial intelligence, machine learning becomes a reality in chemistry. To do so, computers must be capable of recognizing the molecules we describe in the millions of scientific articles that are available. The problem is that they don't understand because chemistry nomenclature was designed for humans, not computers. For this reason, we have created a new language called International Chemical Identifier, InChI, a code designed specifically for machines so that artificial intelligence becomes a reality in chemistry and helps us to accelerate scientific discovery, especially in the sustainability field.

"In the coming years that we will see chemical products whose manufacturing was at least partially designed by computers".

I would like to call attention to very recent research published this year in the journal Nature in which machines used artificial intelligence to identify synthetic routes to transform waste from the chemical industry into pharmaceutical compounds with a high added value. These synthetic routes are so effective that the authors of this research are testing them on a pre-commercial scale. In the coming years it is very likely that we will see chemical products whose manufacturing was at least partially designed by computers.

Artificial intelligence will also have a fundamental role in scientific discovery. Also in chemistry. Thus, we have to create not only a new language specifically for machines, but also standards when it comes to managing, communicating and sharing digital chemical information.

From the presidency of the International Union of Pure and Applied Chemistry, I can have an influence on the agenda of chemistry worldwide thanks to agreements with international organizations, and the IUPAC's financing capacities.

Q

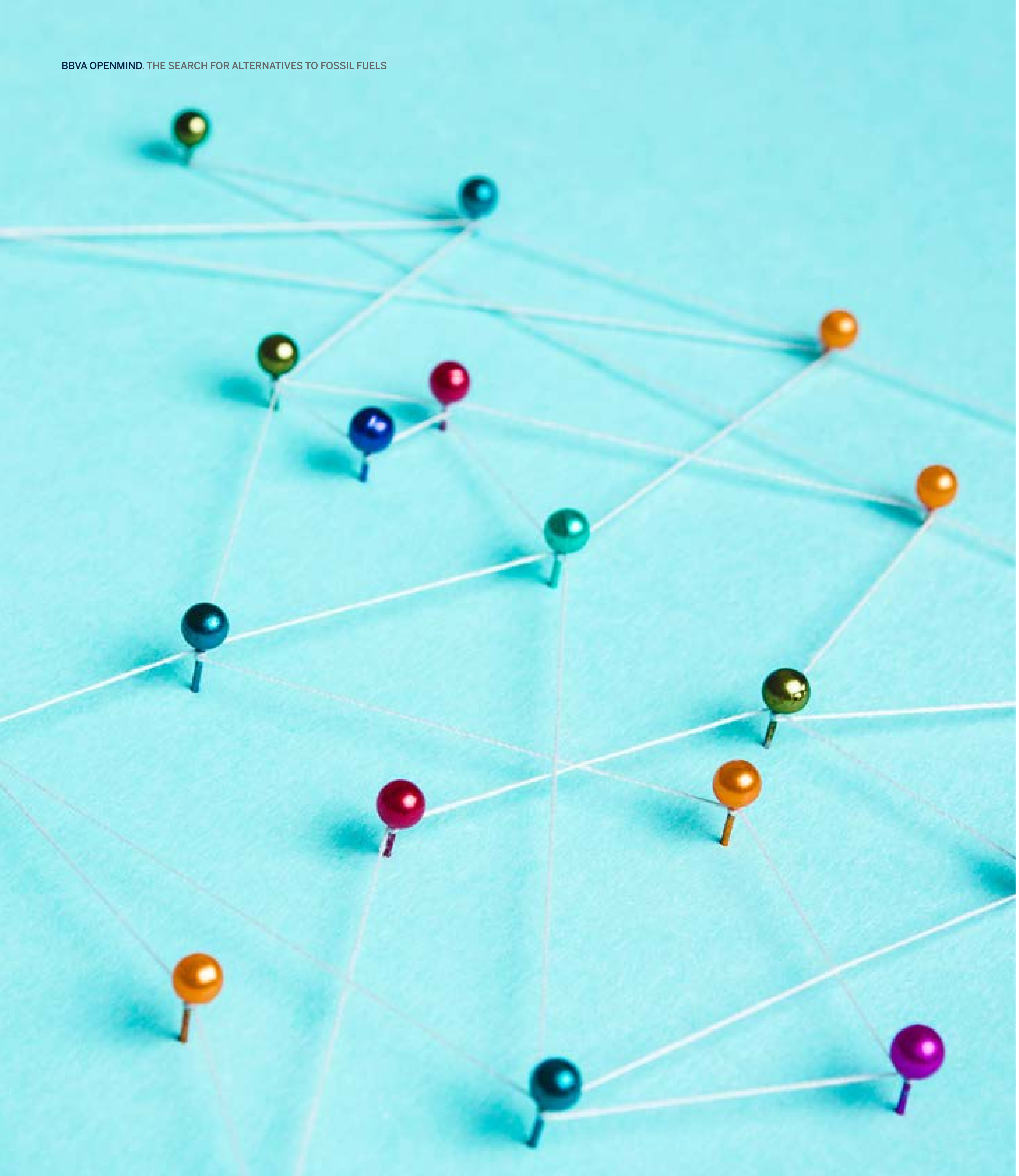
What steps should be taken to stop climate change?

A

First, we need deadlines. The urgency should be a fundamental aspect when it comes to decision-making. We don't have time to waste.

Just as deadlines were moved up during the pandemic and all necessary resources were allocated, climate change needs this component of urgency.

Second, all actors need to be at the same table. We have to ensure that the solutions that scientists have reach the actors that have to implement them, such as the chemical or energy sectors, as well as those that have to finance them, the banks, and those that have to regulate them, the politicians. This is not what is currently taking place.



Third, science will give us the solutions, but it won't solve the problems for us. In order for these solutions to resolve the problem of climate change, political will is needed - not only from those in charge, but from all of us, the citizens and consumers. We can't expect science to solve our problems. Instead, we must solve the problems all together.

"Science will give us the solutions, but it won't solve the problems for us".

Fourth, and perhaps the most difficult to achieve is to have actual international cooperation in the fight against climate change. I am more pessimistic when it comes to this. The countries that have the financial capacity and technologies to decarbonize our economy have to share resources with countries that do not have them, as they need these resources to stop climate change. It is an issue of climate justice, but also an issue of intelligence. It is in all of our interests to adopt the technologies to produce energy in a more sustainable manner, and for that, financing is needed. Technologies and best practices must be shared. It is in everyone's interest.

Without international cooperation, there is no hope. On the one hand, it is an exercise of solidarity and generosity from those who have the means for those who do not. And on the other, binding commitments with well defined deadlines are needed. And of course, there must be a price on externality. The environmental cost of CO_2 emissions should be included in the price of products, and of course, polluting technologies should not be subsidized.

The Challenges of Renewable Energies

INTERVIEW WITH:

Ignacio Mártil de la Plaza

Doctor in Physics and Professor of Electronics at the Complutense University of Madrid.

Q

What are the main challenges ahead of us in the energy transition?

" If we want to decarbonize the economy, 100% of the enegy we consume must be electrical energy".

A

There are many challenges, but I would essentially highlight two: electrifying the economy and mobility.

Electricity is part of our daily lives. It is present in everything. For example, we are doing this interview by videoconference because there is electricity, our cell phones work because they have a battery that supplies electrical energy, lights work thanks to electricity, etc.

However, electricity represents only 15% to 25% of total energy consumption, depending on the country. If we want to decarbonize the economy, 100% of the enegy we consume must be electrical energy. Why? Because we can obtain it from sources that do not emit CO_2.

We still have a long way to go to achieve 100% electric power. This requires, on the one hand, electrifying a large part of industry and, on the other, electrifying transport, especially aviation and maritime transport. The challenge ahead is enormous.

Q

What role can renewable energies play?

A

Renewable energies play an essential role since, together with nuclear fission energy, they are the only ones that do not emit CO_2.

Renewable energies play an essential role because, together with nuclear fission energy, they are the only ones that do not emit CO_2. All renewable energies are needed, especially wind and photovoltaic, as they go hand in hand. In winter there is not so much sun but the wind blows, and in summer there is little wind but a lot of sun. One of the great evils always blamed on renewables is that they are intermittent and unpredictable, but if you look at the whole set of renewables as a single energy-producing element, those problems are drastically minimized. So we need both.

There is also talk of fission and nuclear fusion as other energy sources that could allow us to solve the problem of decarbonization. For me, however, they are not real alternatives. Nuclear fusion still has a long way to go before it becomes viable and profitable, both in terms of research and economics. And we don't have time to waste.

As for nuclear fission, it has been in the energy mix since the 1960s and has been stalled for a long time for several reasons, including safety and investment, both in terms of time and money. In the most optimistic case, it will take between 10 and 15 years to start up a nuclear fission reactor. This energy will never represent a higher percentage than it does today, that is, about four percent. It is a very small amount.

Q

What are the main challenges of renewable energies?

"We need to have efficient and cost-effective procedures that allow us to store energy at times when we are producing it but do not need it".

A

At this point, I am going to focus on wind and solar energy, both photovoltaic and thermoelectric.

We talked earlier about intermittency. Another big challenge related to this is energy storage. We need to have efficient and cost-effective procedures that allow us to store energy at times when we are producing it but do not need it. That, for example, is the main challenge for photovoltaics. As long as photovoltaic energy is not being used to decarbonize the economy, that is, to make an industry work, for a car factory, a large steel mill, or a cement plant for example, that energy that is being produced is either dumped into the grid or we lose it. We need to be able to store it efficiently.

There is a lot of talk these days about green hydrogen and other processes, although it remains to be seen in what timeframe it can be feasible. In the future it will be obtained with 100% renewable processes, it will be able to be stored and transported, but as of today this is not yet the case.

There is another challenge that has more to do with political than scientific issues. In this case I am talking specifically about Spain. On the one hand, we need the energy regulatory framework to be stable, i.e., it must not depend on the ups and downs of whoever wins or loses the elections. And on the other hand, we need to bet not only on self-consumption but also, and above all, on large plants, both photovoltaic and wind. Land is needed for this, and it must be done well.

Q

What lines of research are you currently working on in photovoltaic solar energy?

A

There are several lines of work, although the most important is to improve the efficiency of the dominant technology, which is silicon. Solar photovoltaic energy is completely efficient. It is almost at the very limit of what the theory predicts can be obtained and, according to the International Energy Agency, it is currently the cheapest way of producing electricity.

The problem is that silicon is reaching its theoretical limit, which is around 29%-30% efficiency. This means that out of 100 units of energy received from the sun, only 29 or 30 are transformed into electricity.

"There are several lines of work, although the most important is to improve the efficiency of the dominant technology, which is silicon".

Today there are laboratory solar cells that have an efficiency of over 27%, and there are photovoltaic modules on the market that are at levels of 24%. We are already very close to the efficiency limit, but we need more.

Why do we need more? Solar photovoltaic energy, like all renewable energies, is a low-energy density energy, i.e., to obtain a certain amount of energy you need many production units. Therefore, efficiency needs to be increased.

"Perovskite is a material that absorbs part of the solar spectrum much more efficiently than silicon".

This can be achieved by combining silicon with another solar cell to complement it. This is what perovskite does. Perovskite takes its name from a material, a rock, found in nature called calcium titanate (calcium, oxygen, and titanium) and is named after the Russian mineralogist Lev Perovski. However, the perovskite used specifically in solar cells is synthesized in the laboratory.

It is a material that absorbs part of the solar spectrum much more efficiently than silicon. If we combine, in a structure we call a tandem, a silicon solar cell on the bottom and a perovskite solar cell on top, the perovskite absorbs the most energetic part of the solar spectrum and, at the same time, lets through the less energetic part that will be absorbed by the silicon. In this way, we combine the best of both worlds.

In the laboratory, solar cells with this tandem structure have achieved an efficiency of 31%-32%, compared to the 27% efficiency of silicon alone. And at the semi-commercial level there are tandem modules with an efficiency of 28%, compared to 24% for silicon.

In no more than two or three years there will be commercial silicon and perovskite tandem modules with efficiencies of 30%-32%. That is the efficiency of a nuclear power plant or a gas-fired power plant.

Q

Can these efficiency levels be increased in the future?

A

If we compare the advances in silicon and perovskite efficiency, we can certainly increase this efficiency.

Silicon solar cells emerged in the late 1950s and had an efficiency of 15%. Today they have an efficiency of 26%. In other words, their efficiency has doubled in 70 years.

If we analyze perovskite, the first solar cell appeared in 2009 and had an efficiency of 4%. Today, perovskite cells alone, without silicon, reach an efficiency of 26%. With this data, imagine what can be achieved in the next five years.

Apart from efficiency, another great advantage of laboratory-synthesized perovskite is that the chemical elements of which it is composed (carbon, hydrogen, nitrogen, lead, etc.) are very abundant in nature. The drawback is that precisely one of these elements, lead, is highly toxic. Hence, one of the lines of work in the field of perovskites is to find an alternative to lead that allows the same levels of efficiency to be maintained. It has been tried to be replaced by tin, but so far, the results have not been very promising.

Q

Can solar panels be recycled?

A

Today, recycling is one of the biggest businesses emerging from the renewable energy world. Currently, 90% of the components of silicon solar cells are recycled. And in a few years this figure will reach 100%.

Silicon photovoltaic solar energy uses very abundant and non-toxic chemical elements. On the one hand, silicon, which is the second most abundant chemical element in the earth's crust after oxygen. On the other hand, aluminum, which is the third most abundant element in the earth's crust. It also uses silver, which, although not as abundant as the previous elements, is also abundant. Finally, it also incorporates very small amounts of other elements such as phosphorus or boron, which are also abundant. In short, all its elements are abundant and not very toxic, which makes recycling much easier.

Q

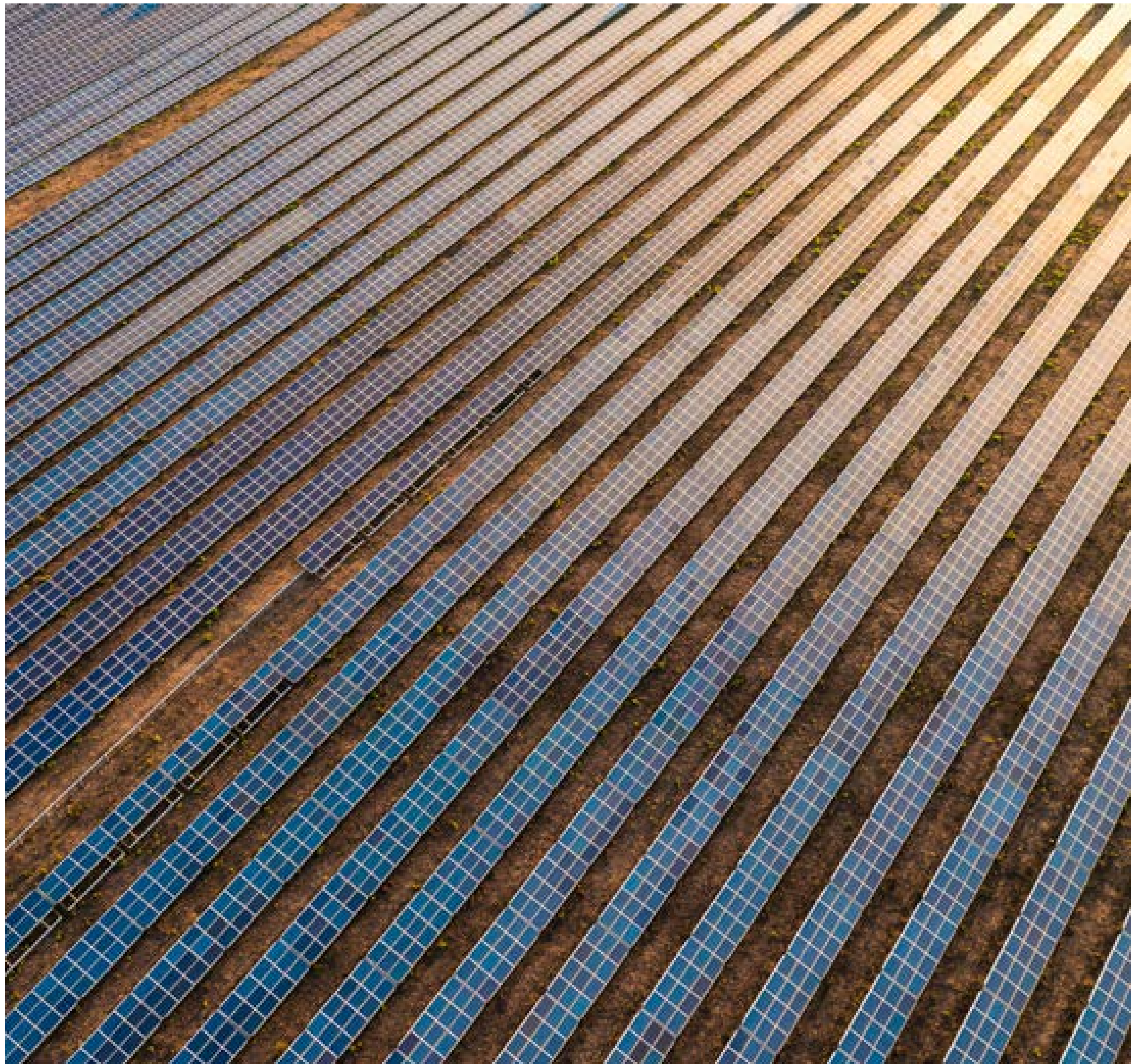
Will renewable energies completely replace fossil fuels in the future?

A

This is a big debate. Many people doubt that it is possible to achieve a 100% renewable mix throughout the planet. Today there are countries like Iceland that have achieved this, but of course, it is a country with few inhabitants and spectacular geothermal energy. Achieving this at a global level is a huge challenge. But we have no choice but to move in this direction, even if neither we nor our children will ever see it.

> "Many people doubt that it is possible to achieve a 100% renewable mix throughout the planet".

Another of the great challenges of any energy transition is that investments in energy are very long-term investments, i.e., the inertia of energy systems is enormous. Transforming an energy mix is a very long and slow process because the investments are very large, and their amortization is also long.



Nuclear Fission - A Necessary Technology In Energy Transition

INTERVIEW WITH:

Carlos Vázquez Rodríguez

PhD Researcher at Forschungszentrum Jülich, Germany and Member of Jóvenes Nucleares

Q

What is fission energy and what advantages does it have over other energy sources?

"A nuclear reactor, is a "machine" capable of controlling a fission reaction, in which an enormous amount of heat is released, and converting this heat into electrical energy".

A

Let's start with a common saying: Energy is neither created nor destroyed, it is transformed. There are different ways of transforming energy into electrical energy, for example by transforming wind speed or the radiation that reaches us from the sun. We also have several "machines" that transform heat into electrical energy. A nuclear reactor, for example, is a "machine" capable of controlling a fission reaction (whereby the nucleus of an atom is split in two), in which an enormous amount of heat is released, and converting this heat into electrical energy.

Heat can be generated by burning fossil fuels, burning biomass, or using nuclear fission. The concept of energy density, i.e., the amount of energy we can extract, is very useful in understanding the differences between nuclear fission and other ways of generating heat.

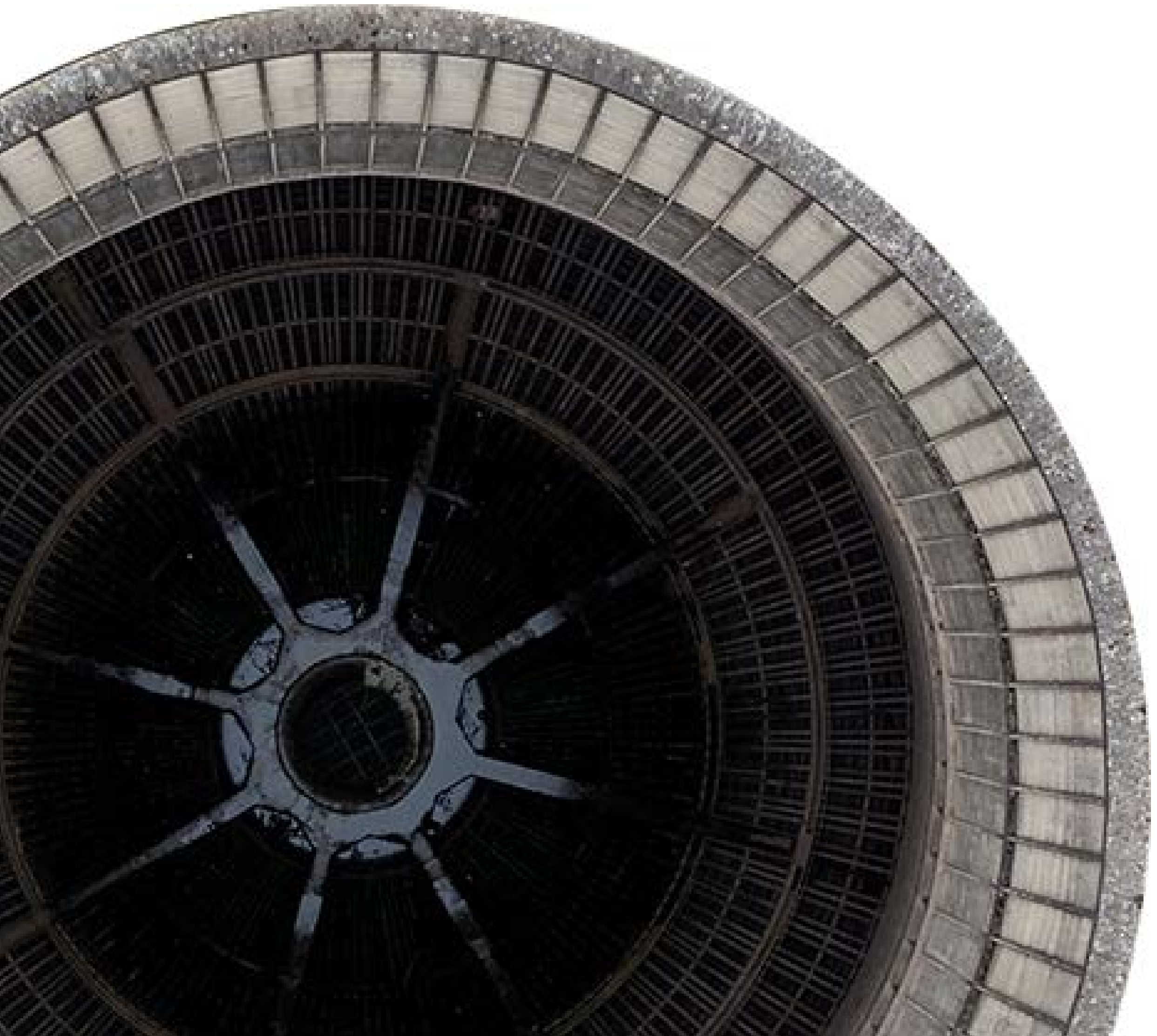
Nuclear fission has a much higher energy density than all the others. We can extract much more energy through nuclear fission than, for example, the burning of fossil fuels. How much more? Well one pellet of nuclear fuel, which is the size of a finger, contains as much energy as a ton of coal. By analyzing the high amount of energy released by a nuclear fission reaction, we can understand many of the advantages of this technology.

In the case of Spain, for example, only 7 GW of the almost 120 GW of installed power correspond to nuclear energy. Well, with this limited percentage (less than 6%), and thanks to its ability to generate electricity for more than 90% of the year's hours, nuclear power plants have been producing 20% of the country's electricity for more than 10 years. The ability to produce continuously is the great advantage of nuclear energy over renewable energies, which depend on weather conditions. For the sake of illustration, wind energy generates similar amounts of electrical energy with almost 30 GW installed, 25% of the total power.

Another advantage of nuclear fission, which it shares with renewables, is that it is a clean process in the sense that it does not produce greenhouse gases, which are responsible for climate change. These technologies are undoubtedly the ones that should replace coal and fossil gas in our system.

"Thanks to the enormous energy density of nuclear fission, it would be feasible to store fuel without depending on any external country".

Finally, another great advantage of nuclear energy over fossil fuels lies in energy security, a term that has been on everyone's lips for months. Thanks to the enormous energy density of nuclear fission, it would be feasible to store fuel without depending on any external country. In fact, we could store nuclear fuel for twenty years of operation of all our nuclear power plants in the space of a soccer field. This is neither technically nor economically feasible with fossil fuels such as coal, gas, or oil. Hence the current energy crisis. Being much less energy dense, we cannot store enough of these fuels to cover our needs, which necessitates continuous purchasing and importing of fossil fuels.



Q

Despite all these advantages, nuclear energy has a reputation for being unsafe and generating hazardous waste. **How dangerous are nuclear power plants?**

"Spanish nuclear power plants are repeatedly placed among the highest rankings of the safest nuclear power plants in the world".

A

Nuclear energy, given its energy density and the fact that it has so much controlled energy concentrated in such a small space, has obvious potential risks. Obviously, these potential risks must be controlled, and undoubtedly, the public, and even more so us technicians, must demand the highest safety standards from the nuclear industry.

As a technician who is very demanding with the safety standards of our plants, proof of which is that I have decided to dedicate my life to studying them, I can confirm that our nuclear power plants meet the highest safety standards we should require of them. In fact, Spanish nuclear power plants are repeatedly placed among the highest rankings of the safest nuclear power plants in the world.

It is difficult to develop in so short a space an adequate justification for what I have just said, but it is important to put the “problem” of safety in perspective. What is the health impact of the alternative to assuming the potential risks of nuclear energy? Well, the air pollution associated with the use of fossil fuels causes several million deaths each year, according to the World Health Organization.

We are not aware of the abrupt and radical change we need to achieve if we are to do without fossil fuels, from which we get 90% of the energy we consume. This will be an even greater challenge if we are to get rid of fossil fuels without nuclear energy. We need all clean sources of energy generation; we cannot do without any of them.

Q

What waste does a nuclear power plant have and how is it managed?

"If we take Spain, the high-level waste generated by all of the country's nuclear power plants over the more than 40 years they have been in operation would fit into five Olympic-size swimming pools".

A

90% of the waste produced by a nuclear power plant is very similar, in terms of radiotoxicity, to that generated by a hospital, industrial facilities, or other radioactive elements that are present in our daily lives. They are not a cause for concern. The complex management is for the remaining 10%, the high-level waste. This is basically spent fuel from nuclear power plants. This type of fuel has two major problems. On the one hand, it is highly radiotoxic, so it must be well confined and controlled. On the other hand, its radiotoxicity lasts for tens of thousands of years, so this waste must be managed in the very long term.

However, this waste will cease to be radioactive at some point, unlike other toxic wastes produced in various chemical industrial processes, which will never cease to be radioactive. What's more, the volume of this waste is tiny, much smaller than that of these other toxic wastes. So much energy is extracted with such a small amount of fuel (again highlighting the importance of energy density) that the amount of remaining waste is minimal. If we take Spain, for example, the high-level waste generated by all of the country's nuclear power plants over the more than 40 years they have been in operation would fit into five Olympic-size swimming pools.

Therefore, in terms of volume, they are not a problem, nor is their management, since the technologies we need to control and manage these wastes exist.

Today, the big problem in waste management is the inability to reach social and political consensus when deciding on an optimal waste management strategy. This is not the case in some countries such as Sweden or Finland, which have more advanced citizen participation processes than in other countries such as Spain. A definitive solution, called deep geological storage, is already under construction there. Technicians have determined that these territories are geologically optimal for the construction of definitive storage facilities because they can ensure that they will be completely protected from any layer of the biosphere for tens of thousands of years.

If there is one thing that both nuclear and anti-nuclear scientists should agree on, it is that the waste that has already been produced must be managed safely and appropriately. This lack of consensus is the main barrier to implementing a definitive solution; it is neither a technical nor an economic problem, as the European Commission acknowledged in the report that gave rise to the inclusion of nuclear energy as a transitional technology in the Green Taxonomy.

Q

What are the main challenges facing nuclear power and how are they being addressed?

"One of the main challenges is to complete projects on time and within budget".

A

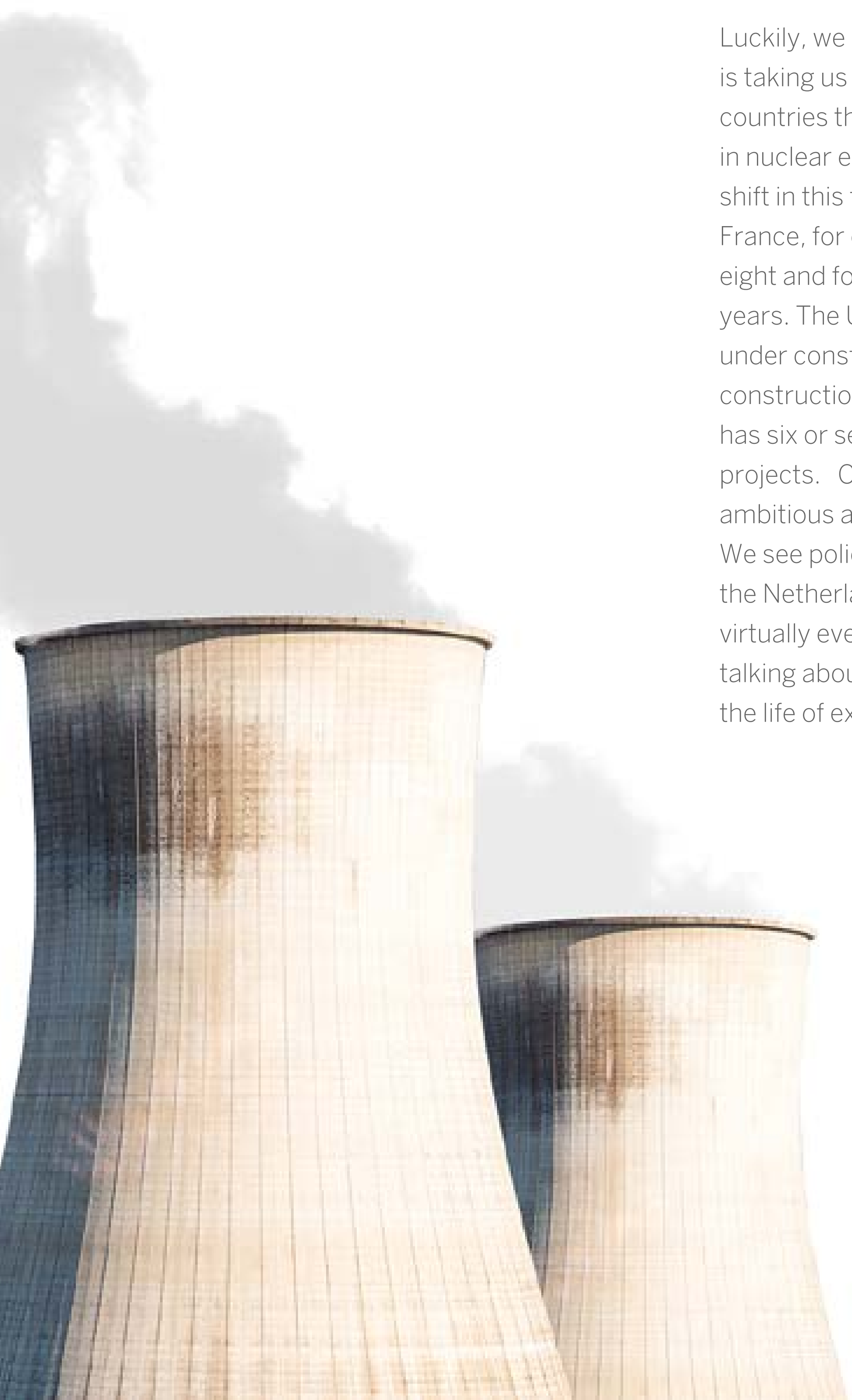
One of the main challenges, especially in the West, is to meet the construction deadlines for new nuclear reactors. The last few projects that have been built have had long delays, resulting in huge cost overruns. On average, or median to be more precise, the construction time for a reactor is between seven and eight years. However, in the West there are some that have taken up to 15 years to build while in countries like China they take six years, meeting all safety standards. The same is true in South Korea. Therefore, construction delays are not an intrinsic issue of technology, and the big challenge for the West is to complete projects on time and within budget.

One of the other great challenges facing nuclear energy is the “bad” reputation that you mentioned in an earlier question. However, if we objectively assess nuclear energy, we can see that it has all the characteristics that we would be looking for in a new energy to carry out the energy transition (clean, continuous energy, and with high energy density). If it were not for all that heavy “baggage”, that bad reputation and social opposition in certain countries, all the investors in the world would be wagering everything to solve the main challenge of nuclear energy, namely, reducing its costs. They have been doing this for almost 30 years for solar and wind power, which, although too expensive in the past, are now the most competitive thanks to the continued investment in them.

"One of the other great challenges facing nuclear energy is the bad reputation and social opposition".

This is why the other great challenge for nuclear energy is communication, education, talking and interacting directly with the general public and politicians to highlight our capabilities and show how useful and essential nuclear energy is in the fight against climate change.

Luckily, we are seeing an international trend that is taking us in that direction. There are many countries that are starting to invest very seriously in nuclear energy and there has been a clear shift in this trend over the last five years or so. France, for example, is planning to build between eight and fourteen reactors over the next fifteen years. The United Kingdom has two reactors under construction and has just approved the construction of two more. The United States has six or seven very advanced modular reactor projects. China, India and Russia have had ambitious active nuclear plans for decades. We see policy changes in South Korea, Japan, the Netherlands, Sweden, and Poland. All in all, virtually every major economy in the world is talking about building new reactors or extending the life of existing ones.



Q

Are the reactors being built today very different from those built 50 or 60 years ago? Has the technology evolved a lot?

"Today's designs are designed to overcome the challenges of conventional reactors".

A

It's very impressive. I like to call it the nuclear power of the 21st century.

Today's designs are designed to overcome the challenges of conventional reactors that we have been talking about during this interview. For example, today's nuclear power plants generally always operate at maximum power, and in the coming years they will need to be made more versatile. In the case of Spain, for example, we will be able to produce virtually all our electricity with solar energy in the middle of the day during the summer. That is why we will need nuclear power plants to adapt. The new reactors are designed for this.

On the other hand, the energy transition is not just about electricity. We need to decarbonize each and every process we do. And in heat production, for homes and for industries, we have an even bigger challenge than electricity. There are many sectors that are much more difficult to decarbonize than electricity. The new reactors are designed for this.

Reactors are being designed to produce hydrogen. China already operates reactors to produce heat for industrial processes such as steel production or other processes that emit a lot of CO_2. Work is also being done on reactors to desalinate water in places where there is no potable water or on transportable reactors to bring electricity to remote places that do not have established power grids, which Russia has already achieved in Siberia with its famous floating reactor.

There are even reactors at advanced stages of development designed to reduce radioactive waste management times from tens of thousands of years to just a few hundred! Not only that, this process, referred to as transmutation, can generate more fuel than is consumed. In practice, this would make nuclear energy a renewable energy, which is why it is attracting such high-profile investors as Bill Gates.

Ultimately, technological advances in nuclear energy have the potential to provide solutions to many of the major challenges of the energy transition.

Q

What role should nuclear energy have in the international energy mix in the future?

A

Renewable technologies should lead the way in the energy transition. They have to be the protagonists of the changes we have to make in the way we generate and consume energy. But nuclear energy also has a role to play. There is no doubt about it.

Renewable energies need some kind of support, at least for the next 30 or 40 years or until there is a technology disruption that allows us to produce energy continuously, without depending on climate conditions, or to efficiently store the huge amounts of energy we consume on a daily basis. And this support must be provided by nuclear technology.

"Renewable energies need some kind of support, And this support must be provided by nuclear technology".

Achieving decarbonization by 2050 is key to the future of the planet. The challenge of meeting our emissions reduction targets is so great that it would be unwise to ignore any of the low-carbon technologies available to us. For more than 40 years, nuclear has been generating a high percentage of the planet's clean energy, and it must continue to do so.

Present and Future of Nuclear Fusion

INTERVIEW WITH:

Isabel García Cortés

Doctor in Physical Sciences and Researcher at the National Fusion Laboratory of the Energy, Environmental and Technological Research Center (CIEMAT).

Q

What is nuclear fusion and how does it differ from nuclear fission at nuclear power plants?

“Nuclear fusion consists of the union of two nuclei of light elements to obtain a heavier element, which also releases a large amount of energy”.

A

Both nuclear fission and nuclear fusion are energies that come from the nucleus of atoms, which is why we call them ‘nuclear.’ They differ in that fusion obtains energy through the union of two nuclei, while fission involves the splitting of a heavy nucleus into two lighter nuclei.

The fission of a nucleus of a heavy element of the periodic table releases a huge amount of energy, as we know from the nuclear fission power plants across the planet. However, nuclear fusion consists of the reverse process, i.e., the union of two nuclei of light elements to obtain a heavier element, which also releases a large amount of energy.

The fusion process is the driving force of all stars in the universe. The Sun, for instance, produces so much energy because fusion reactions are continuously taking place there. The heat that reaches the Earth and fuels life here arises from the fusion of nuclei of hydrogen atoms forming helium atoms. Fusion research aims to simulate the Sun's processes in a controlled manner on Earth for use as a new energy source. This could supply an answer to humanity's growing demand for energy consumption.

Seventy years ago, when the search for this energy source began, researchers looked precisely at the processes in stars. However, something that seems simple in stars turns out to be one of the biggest challenges we face today.

Q

What are the pros and cons of nuclear fusion versus nuclear fission?

A

I should say the main drawback of fusion versus fission is that we don't have it up and running yet. There are no fusion reactors supplying power like fission power plants do. It's also much more technologically challenging. Given what we know today, a fusion power plant will be far more technically complex than a fission power plant.

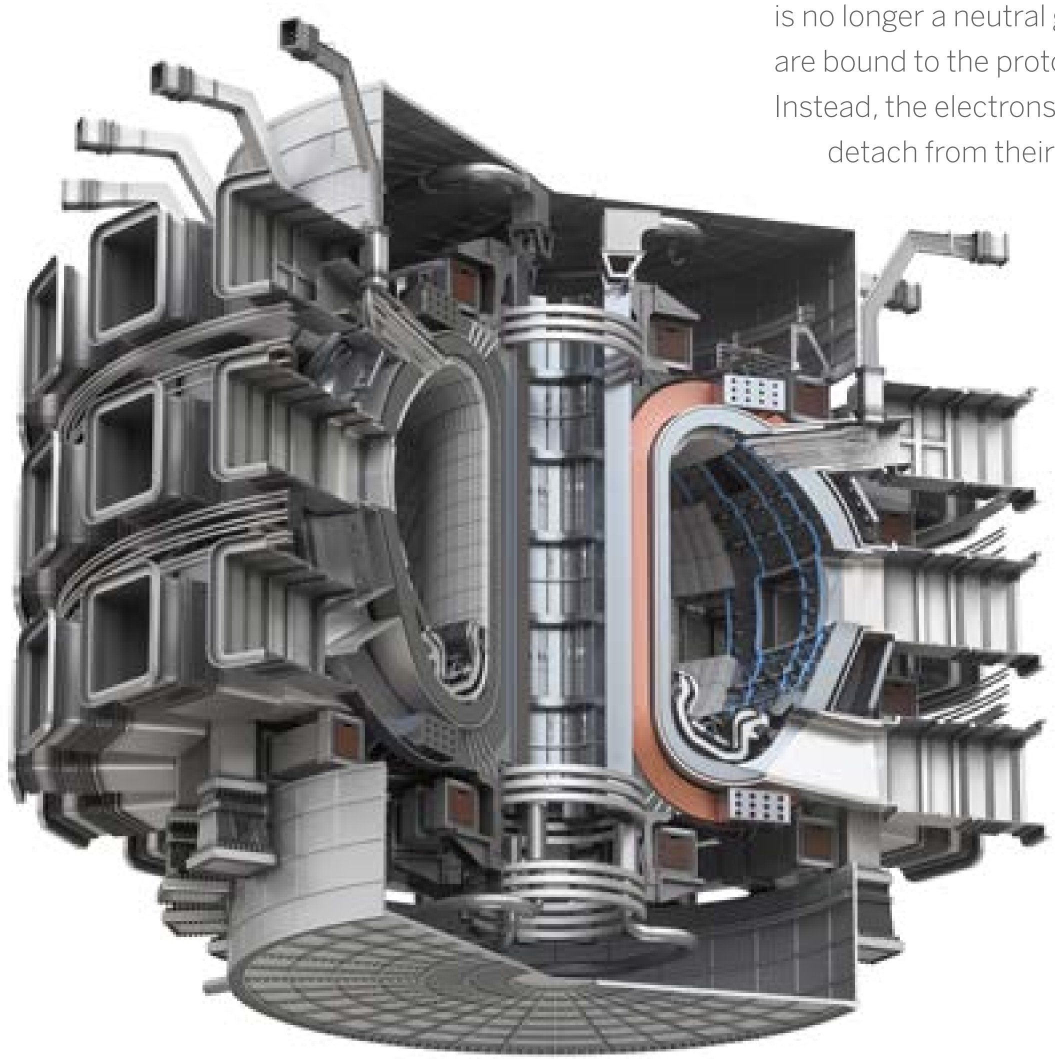
But fusion also has many things going for it. To begin with, it's fueled by hydrogen, which is easily found in nature. On the face of it, we would have inexhaustible fuel. Moreover, nuclear fusion doesn't involve chain reactions. In magnetic confinement reactors, for example, processes continue only if there is a magnetic bottle that keeps them stable and away from material surfaces. If we switch off the magnetic field, the reactions stop and the fuel cools down and ends up as a harmless hydrogen gas. There are no chain reactions, unlike fission, where the process can be hard to control.

Finally, the waste generated by nuclear fusion is of medium or low activity, unlike the waste from fission power plants, which lasts for hundreds or even thousands of years. However, let's not forget that fusion energy is also nuclear. Therefore, it will require waste supervision and management following the regulations established by the competent nuclear authorities.

> "A fusion power plant will be far more technically complex than a fission power plant".

Q

How does a fusion reactor work?



A

In a magnetic confinement fusion reactor there are several basic procedures. The first procedure involves the fusion process itself, in the fuel container. In our case the container resembles a large hollow doughnut where a vacuum forms to ensure that no other element that is in the air enters and thus only the hydrogen is acted on.

Once the vacuum arises in our chamber, we need the fuel. We introduce hydrogen in gaseous form. We will need to heat it so that the nuclei will fuse. For this to happen, the fuel needs to be at hundreds of millions of degrees. We must raise the temperature of the gas in the chamber until it is no longer a neutral gas, in which the electrons are bound to the protons and the nucleus. Instead, the electrons (negatively charged) detach from their positively charged nuclei and form a 'plasma.' This plasma is our fuel. Plasma, an ionized gas at extremely high temperature, is the fourth state of matter.

Finally, we set up magnets that generate a magnetic 'bottle' that confines the plasma (as an ionized gas, the particles will follow the magnetic field lines).

This prevents the plasma from approaching the walls. These steps require the use of sophisticated technology in the latest generation reactors. For example, we use superconducting coils to achieve stronger magnetic fields and more effectively trap all the particles and keep them away from the container walls. The development of superconducting coils is one of the scientific breakthroughs that have come to the aid of fusion technology.

Once all this is set in motion and continues long enough, the particles begin to coalesce and the reactions begin. In addition to supplying power to the grid, the heat given off by the process can heat the plasma itself. The heating systems needed to start the reactions become unnecessary.

There are many experiments underway that help us toward an advanced understanding of what fusion reactors could be like, but the fact is that there is still no prototype fusion reactor in operation. The ITER (International Thermonuclear Experimental Reactor) aims to prove that such a reactor can supply enough energy to counteract the energy expenditure involved in igniting fusion reactions. This is an international project that in 10 years' time should give answers to this and many other questions on the road to the design of a commercially viable reactor.

Q

What is ITER? What is it for?

> "It's an international partnership of 35 countries that seeks to answer the big questions of fusion".

A

ITER is the big dream on the road to fusion. When I started in fusion research many years ago, there was already talk of ITER. The project has evolved from a simple and unambitious machine to what it is today: a large-scale project that brings together myriad systems that push the limits of technology.

It has had its ups and downs, in step with the cost of fossil fuels. Fusion energy research really took off with the oil crisis of the 1970s. Then, with oil becoming cheap, investment in fusion petered out and research has progressed more slowly. The same has happened with projects such as ITER.

ITER is currently well advanced, however. It's an international partnership of 35 countries (the 27 countries of the European Union, Switzerland, the United Kingdom, China, India, Japan, South Korea, Russia and the United States) that seeks to answer the big questions of fusion, such as whether controlled fusion is viable as a stable energy source. The fact is, we know that fusion reactions do happen, but we also need to know if we can control them in a stable and predictable way. We cannot have plasma instabilities in the many systems needed for the plant as this would fail to ensure the desired continuity in the power supply.

ITER is not a commercially viable reactor, but it is necessary to understand and decide on a safe pathway to a fusion power plant.

ITER. Provence, France.

Q

What are the main difficulties in creating a fusion reactor?

"The most effective reactions, which would lead us to have energy more easily, are those of deuterium and tritium".

A

There are many challenges. For many of them, we won't have an answer until ITER is operational.

For example, I said earlier that we use hydrogen. But in reality hydrogen comprises three different elements: hydrogen, deuterium and tritium. Hydrogen has no neutrons in its nucleus, while deuterium has one and tritium has two. The most effective reactions, which would lead us to have energy more easily, are those of deuterium and tritium. We can easily get deuterium from seawater, but tritium is much harder to come by. It's half-life is only nine years, and it must be produced initially in a fission power plant. We need to have it available to start fusion reactions in ITER and future reactors.

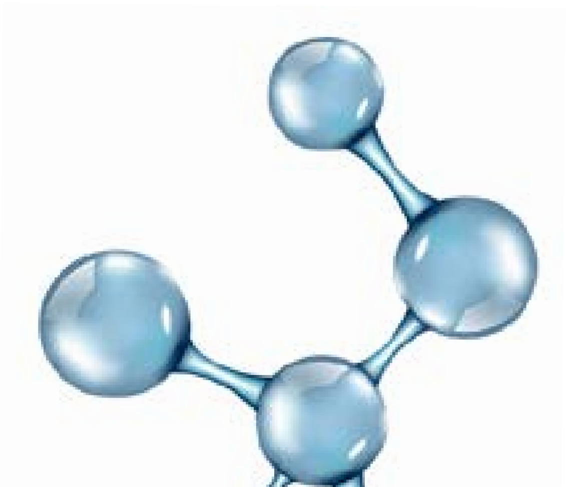
During reactions, a tritium atom plus a deuterium atom results in a helium atom plus a high-energy neutron, which gives up its energy in a lithium mantle on the first wall of the vessel. The lithium in the mantle, reacting with the neutron, yields tritium again, which we will need to be capture and redirect back into the plasma to continue fueling the fusion reactions. Therefore, for fusion to be commercially workable, tritium must be recycled. And the process of capturing that neutron in the special materials of the first reactor wall is what we will put to the test in ITER.

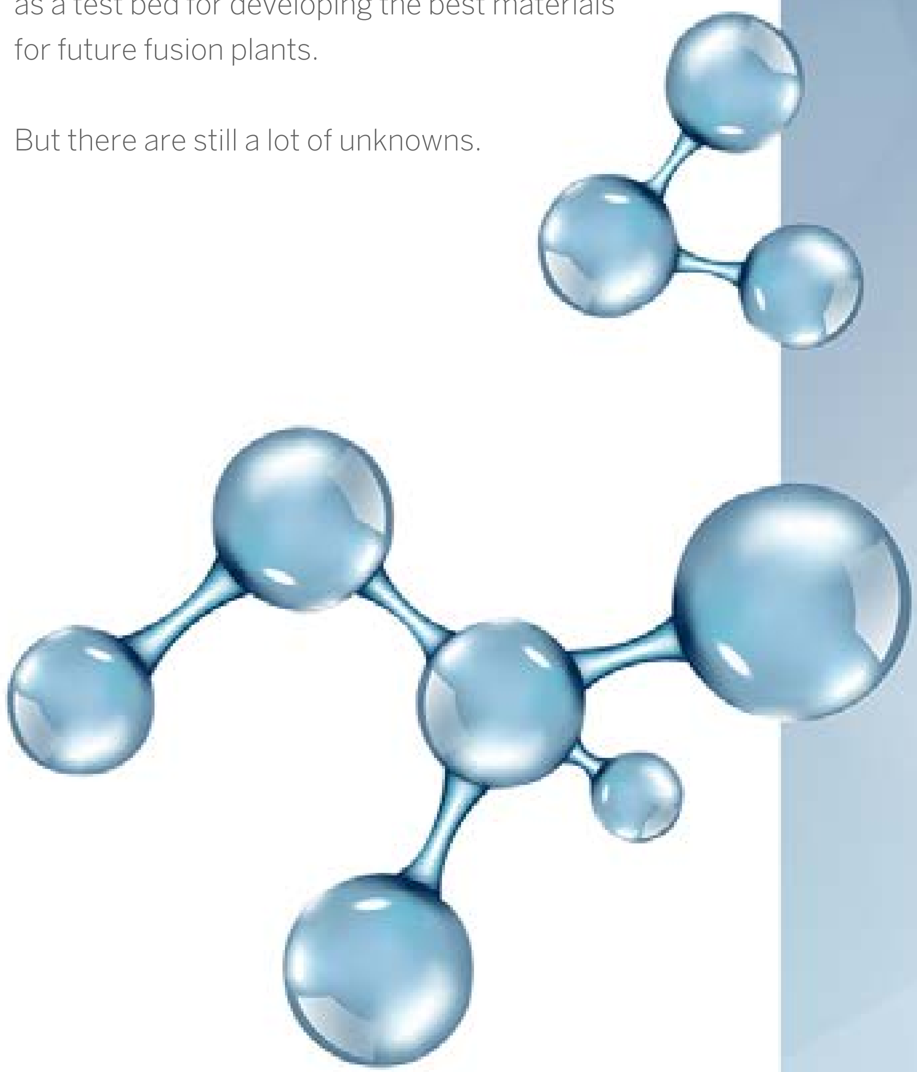
“The key to this is the large particle accelerator IFMIF-DONES to be built in Granada”.

Another challenge lies in the materials themselves. How will the materials react to such a heavy flow of neutrons? And not only in that first wall, but also in the structures and systems next to the reactor, which the neutrons also pass through. We must be sure that neither the first wall, which is critical in the recovery of tritium, nor the structure, nor the various basic diagnostics in plasma control, lose their properties.

Yet another challenge is the development of new special materials that can withstand the conditions of future fusion reactors. The key to this is the large particle accelerator IFMIF-DONES to be built in Granada. This is a project promoted and developed by CIEMAT in partnership with the University of Granada. The accelerator will serve as a test bed for developing the best materials for future fusion plants.

But there are still a lot of unknowns.





Q

You are a researcher at CIEMAT's fusion lab. **What are you looking into there?**

A

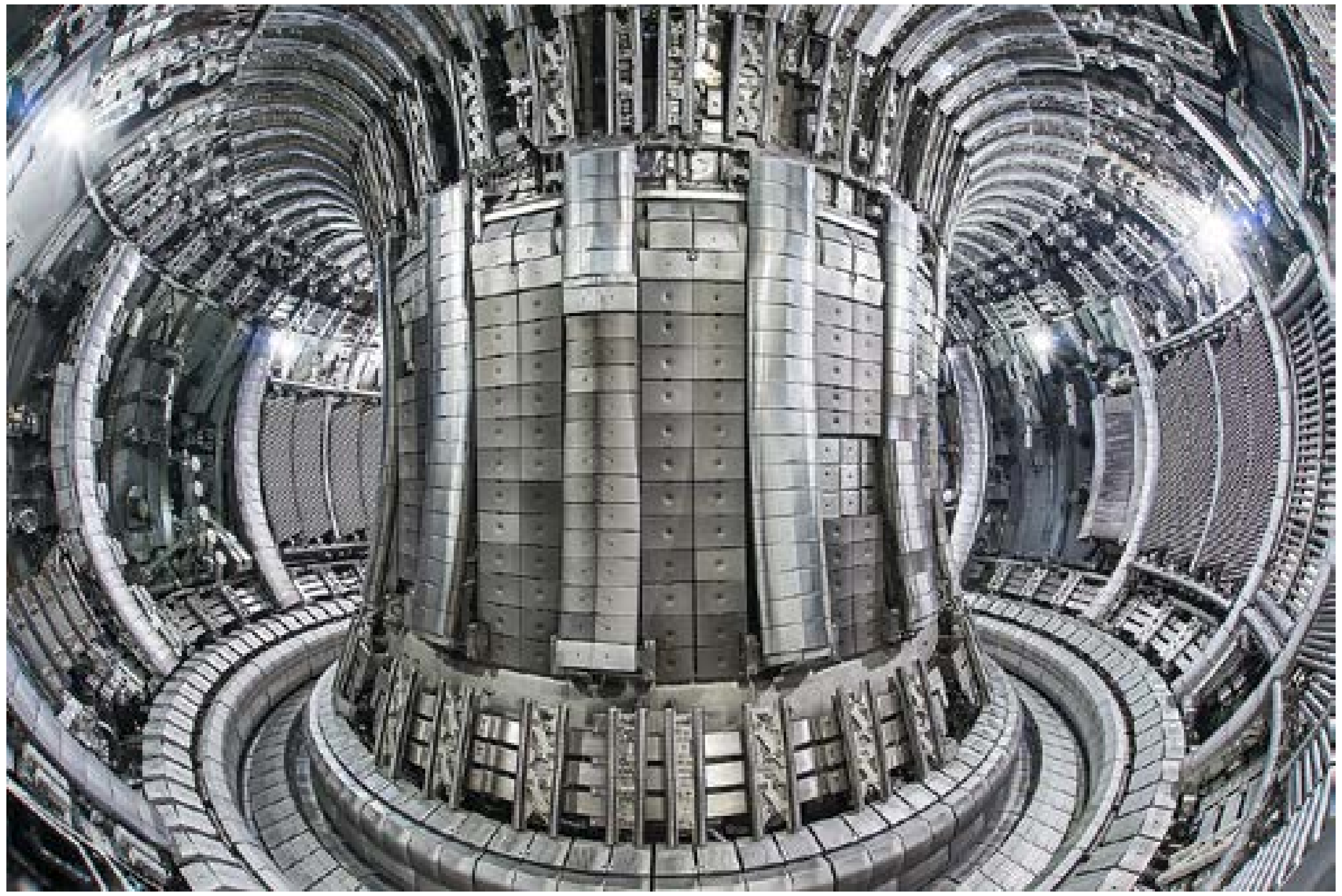
The flagship of our lab is the TJ-II fusion device at CIEMAT's Moncloa headquarters. It has been producing plasmas since the 1990s. The device is part of the European project for developing fusion as an energy source. We work with other international institutions to try to answer questions about magnetic confinement. For instance, how do different magnetic setups affect plasma confinement?

"The flagship of our lab is the TJ-II fusion device at CIEMAT's Moncloa headquarters. It has been producing plasmas since the 1990s".

Building machines to investigate plasma under fusion conditions and their operation is expensive. Investment in this branch of science is therefore centralized at the labs that house these devices. In Spain, for example, the leading center is CIEMAT, because it houses the TJ-II. In addition, each device has unique features and specializes in certain lines of research. The intention is that all the knowledge will converge toward the development of ultramodern devices.

At our lab, besides the research using TJ-II, several successful working groups have appeared. Some of our researchers--all women, incidentally--are working with JET in the UK, for instance. It's the only device capable of simulating reactor conditions. They have conducted recent experiments and their results will have profound impact on the development of ITER and future machines.

We are a multidisciplinary group. Therefore, we have a strong capability to address technological developments related to fusion energy. For example, CIEMAT is coordinating the design of several diagnostic and control systems for ITER that will be key to its start-up and scientific output. Another key group at our lab is developing the IFMIF-DONES infrastructure, which addresses the challenge of fusion reactor materials.



"We are a multidisciplinary group, therefore, we have a strong capability to address technological developments related to fusion energy".

In my own group, we are looking at an alternative method to feed the plasma using solid hydrogen pellets of one millimeter in diameter at cryogenic temperature (4 degrees Kelvin), which we inject at high speed to easily reach the center of the plasma, where the best conditions for fusion reactions occur. Using TJ-II we have seen that this way of introducing the fuel into the plasma extends the operational range of the device, with better plasma quality and enhanced confinement. We have achieved records in these parameters. It's a partnership between three labs in Spain, Germany and Japan. The results have an impact on the development of these systems for future reactors.

Q

What role will nuclear fusion play in future in the international energy mix?

A

There are still hurdles to overcome, which is why most of the investment in fusion energy research is government-funded. If there were absolute certainty that fusion power plants are a viable business, in fact, their development and construction would already be in the hands of the leading power utilities.

But I believe human beings are used to overcome challenges that may have seemed impossible for generations. So I do believe fusion power plants will be a reality in the not too distant future.

"The future of the energy mix should be geared toward renewables plus nuclear. This is essential to make progress in the decarbonization of the planet".

What role will fusion play? Fusion will play a role, but it will not solve the whole energy problem. Humankind is a voracious consumer of energy, and I am sure we will have to make use of all sources available to us.

We should be far more careful with the environment and try to scale down our dependence on fossil fuels. The future of the energy mix should be geared toward renewables plus nuclear. This is essential to make progress in the decarbonization of the planet.

What will the future look like? Given the geopolitical changes we're seeing lately, it's hard to imagine. These changes have a huge influence on countries' energy policymaking. At one time it may be a priority to close down nuclear power plants in Germany. Yet, at another time, in the face of the impossibility of importing gas to produce energy, nuclear power could be a lifeline.

Some sociological studies suggest that fusion power will replace fission power as resources run out. But this, as I said earlier, is part of the long term view, and is hard to foresee.

Turning Plastic into Fuel

INTERVIEW WITH:

Marta Muñoz Hernández

Interview with Marta Muñoz Hernández, Professor and Researcher, Materials Science and Engineering Faculty, Rey Juan Carlos University.

Q

What is Materials Science?

"Materials Science is the scientific branch that studies the structure of matter, both at microscopic and macroscopic levels".

A

Materials Science is the scientific branch that studies the structure of matter, both at microscopic and macroscopic levels. This atomic structure is closely related to the properties exhibited by the materials.

This science is also linked to materials engineering, which involves properties, structure and different processing techniques, i.e., the different manufacturing technologies that allow the design of new products with different applications.

Materials are used in many areas of society - in transportation, medicine, energy, mechanics, ecology, nanotechnology, to name but a few. Materials science permeates our daily lives: where we live, where we work, our modes of transport, the clothes we wear, etc. Everything is made of materials and it is important to study their structures, properties and uses.

Q

What types of materials exist?

"There are many classifications of materials, one of the most common ones divides them into four main groups: metallics, ceramics, plastics and composite materials".

A

Although there are many classifications of materials, one of the most common ones divides them into four main groups:

One of these groups is metallic materials. With a specific atomic structure and characteristic properties such as high conductivity (both electrical and heat), high hardness and strength, and low corrosion resistance. These typical properties of metals are a direct consequence of their microscopic structure, i.e. how the atoms are arranged in space.

Another group is ceramic materials. These have a different structure and, therefore, a different atomic and molecular organization. As a result, they have different properties: they are hard and rigid but fragile materials, as they do not deform and are highly resistant to corrosion.

We also have the group of polymeric materials or plastics. Then there is the polymeric or plastic materials group. We often use both terms interchangeably, although there are some differences between them as we will see below. Polymers are long chains of mostly carbon and hydrogen bonded together.

"Composite materials have superior performance, but are nevertheless more difficult to recycle".

Their structure consists of the joining of many monomers, as if they were the beads of a long necklace, and each of the beads is a monomer unit. When one monomer is joined to another, a dimer is formed; if another monomer is added, a trimer is formed, and so the number of monomeric units increases until a polymer is formed, which is a chain of thousands or even millions of monomers. Polymers are light, soft, easily deformed and not very resistant. They do however resist corrosive environments very well.

Finally, composite materials are manufactured by combining any of the materials of the previous groups. One of the best known composite materials are those in which the matrix - the main component - is polymeric. Thus, for example, we have the polymer matrix composites reinforced with glass fiber or carbon fiber, widely used in the aeronautics field, where, thanks to their exceptional properties, they have managed to displace metals. Composite materials have superior performance, but are nevertheless more difficult to recycle, since each component must be separated to ensure proper treatment.

Q

How can materials science contribute to the fight against climate change?

A

Materials science and engineering is studying new materials with interesting properties in many different fields.

For example, in construction, the design and manufacture of new materials can contribute to curbing climate change, with the use of ecological bricks that incorporate part of recycled plastic, photovoltaic tiles that save energy, and self-repairing and self-cleaning materials that also reduce water consumption.

"LEDs are replacing traditional tungsten bulbs or sodium lamps".

Thanks to the development and design of materials, much more efficient lighting systems have been achieved that allow considerable energy savings. LEDs are replacing traditional tungsten bulbs or sodium lamps.

Work is also being done on new materials to make batteries of greater capacity that are more efficient, to manufacture electric cars, and new materials to use hydrogen as a form of energy, and so on.

The manufacturing processes of these materials are also being studied to minimize waste generation.

Q

Why is plastic so harmful and are all plastics equally “bad”?

A

Environmentally speaking, plastics (which are polymers to which an additive has been added to improve some of their properties) offer a very attractive property, which is their durability, but in the long run it becomes their worst enemy. These materials are so durable that once the product's useful life cycle is over, they are not easily assimilated by nature. In other words, they take so long to degrade that they end up becoming persistent waste.

"Plastic waste is the new gold".

The use of microplastics in the cosmetics industry is one such example, as is the very process of plastic degradation, which, although slow, can generate microplastics that end up in the waters of oceans and rivers, becoming part of the trophic chain and the human food system. However, the main problem with plastics is that, once their useful life cycle is over, they persist in nature without degrading, and can take between 400 and 1000 years to disintegrate.

The Chinese government used to buy all plastic waste from many industrialized countries, up until 2018, when this practice was banned. Why? Because this waste has a very high value, both material and energy. Polymers come from petroleum, and this petroleum value remains in any processed plastic product. For example, if we have a plastic bottle, we can reverse the process and turn it back into petroleum or any other fuel fraction. The result is that, as of 2018, we have an increased accumulation of plastic waste in most countries and this requires an urgent solution.

Plastic waste is the new gold. We can transform it into fuels or new value-added products. In this sense, it is a very useful raw material requiring us to extract both its material and energetic value.

Q

You are working with MIT on the "Plastic waste to alternative fuels" project, **what does this project consist of?**

"The idea we proposed was somewhat disruptive and risky because it attempted to unify two very different areas of science".

A

The idea we proposed was somewhat disruptive and risky because it attempted to unify two very different areas of science: plastic recycling and electromagnetism. On the one hand, we proposed to use magnetic nanoparticles that would generate heat under the action of alternating high-frequency electromagnetic fields, and, on the other hand, to use this heat in the cracking or decomposition processes of plastics.

The idea was to use this large amount of energy released by these magnetic nanoparticles under radiofrequency fields to break the bonds of plastics and transform them into different fuel fractions. This idea caught the attention of Alan Hatton, Director of the Chemical Engineering department at MIT, and we were awarded a collaboration grant in January 2019, starting a student and faculty exchange program between MIT and Rey Juan Carlos University.

The proposed technology also proved appealing to companies such as Cepsa, and two postdoctoral researchers with Marie Curie grants from the European Union have also participated in the project.

We have now been awarded a research project as part of the Ecological and Digital Transition 2021 call for proposals, coordinated with the Institute of Applied Magnetism, with which we intend to move from the laboratory scale to the semi-industrial scale. This project will provide the funding to develop this innovative technology and allow its scaling, since it has been proven that it is a technology that works, is efficient on a small scale, and can be a good alternative in these times of ecological transition.

Q

Is the overall objective of this research to replace fossil fuels?

"The objective is to transform plastic waste into fuels, reducing the current dependence on oil".

A

The objective of this project is to gradually replace fossil fuels; the use of fossil fuels cannot be eradicated overnight. The objective is to transform plastic waste into fuels, minimizing and eliminating the accumulation of this type of waste and reducing the current dependence on oil. At the same time, however, plastics can also be transformed into new products that can be used as raw materials for other processes. To understand this, we need to delve a little deeper into the concept of plastic waste recycling.

There are two types of plastics recycling. On the one hand, physical recycling, in which those polymers that are recyclable, the thermoplastics, are melted and given a new shape and a new life cycle. For example, by melting a plastic bottle we can turn it into a canvas and this in turn, at the end of its useful life cycle, can be transformed into a hose, and so on. In this type of link, only operations of a physical nature are performed.

On the other hand, chemical recycling, which is the technology we are working on, is based on breaking and forming new bonds through chemical reactions, thus altering the nature of matter. By shortening the long polymer chains, we can return to the initial raw material or to new building blocks to manufacture new products.

If chemical recycling breaks the polymeric chains into very short chains, we have very light petroleum fractions, obtaining methane, ethane, propane or butane, gaseous fractions, made up of few carbon atoms. If we cut the polymers into slightly heavier fractions, we obtain gasoline, with around 8 carbon atoms, which is where the term octane comes from. If it is fractionated into somewhat larger chains, we obtain diesel or kerosene.

So, basically, this chemical recycling consists of cutting the long polymer chains into shorter chains to obtain different fractions of the oil or new raw materials. To do this, we need catalysts to govern the mechanism by which the molecules are broken down, under certain conditions of pressure and temperature, and with a very high energy input. It is in this energy input that the innovation of the project lies. Instead of resorting to traditional heating methods based on resistive heating with electrical energy, we propose to use a new heating system based on magnetic induction to perform this chemical recycling of plastics using radiofrequency fields and magnetic nanoparticles.

These two types of recycling, both physical and chemical, complement one another. First, physical recycling must be used to maximize the material life of the plastic, and once this material pathway has been exhausted, chemical recycling must be used to exhaust its material value and extract and recover its energy content.

P

Do you think we will ever completely replace fossil fuels with alternative fuels?

R

I would like to think so, although joint action is required on a global scale by all countries, both industrialized and those in the process of becoming industrialized. We need to unify policies globally and help these less industrialized countries to be able to manage their waste properly.

Waste policies in Europe differ greatly from those in Asian countries, for example. In Europe plastic waste is collected, sorted, treated and managed correctly, while many other countries in the world do not even have waste collection policies, let alone waste treatment technologies.

"We need to unify policies globally and help these less industrialized countries to be able to manage their waste properly".

A more global approach to the problem is needed, international regulations are needed together with equal collaboration from all countries.

Q

What are the keys to ending climate change?

"Awareness must also be raised among the population regarding the key role played by the citizens themselves in the fight against climate change".

A

Policies are fundamental, but investment in both basic and applied research is also key. This needs to take place via collaborations between universities and companies, between the public and private sectors and between different countries. Funding is needed to research and find solutions to this problem.

We must also focus on scientific outreach, communicating and informing society about what is being researched in universities and research centers. Awareness must also be raised among the population regarding the key role played by the citizens themselves in the fight against climate change. Each of us, from our homes and workplaces, can make a decisive contribution.

For recycling to be carried out correctly, we, the citizens, are the ones who must initiate the whole process in our homes, classifying and cataloging the different waste streams and depositing them in the different containers provided. This in turn allows us to start the most appropriate treatment.

Moreover, there are many small actions that can be done to be more environmentally friendly, from reusing packaging, aluminum foil, recycling used oil, transforming it into natural soaps made by ourselves, etc. There are many measures that we can implement as citizens and society needs to be made aware of the important role it plays.

Bringing back the concept of repairing in our society is also vital. Nowadays we do not repair damaged products. It is easier to throw it away and buy a new one, even if it lasts less and less, since products have shorter and shorter life cycles. We are thus engaging in an unstoppable wheel of consumerism, buying and discarding products. We must abandon this linear “use and discard” philosophy and move towards circularity, i.e. “use and recycle”. Even if we do not close the circle, we should at least try to achieve a spiral that resembles it.

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