world energy

WE.

OCTOBER 2022 • N. 54

DANCING WITH THE ENERGIES

CONTENTS

TECHNOLOGY, NOT IDEOLOGY

by Mario Sechi

WE NEED CRITICAL SKILLS AND LEADERSHIP BECAUSE SCIENCE WITHOUT CONSCIENCE LEADS AWAY FROM WHAT IS HUMAN. AND, ABOVE ALL, WE NEED A DEBATE ON CLIMATE THAT IS NOT POISONED BY PREJUDICE. THE LITMUS TEST IS COP27 IN SHARM EL-SHEIKH

MAN FIRST SEPARATED SCIENCE from philosophy, then he extracted technology from science to the point of isolating it in a dimension where "he is always right" (and he is not always right). The result is a domination of technology, its indisputable primacy, beyond science. After Albert Einstein's annus mirabilis (1905, when he published four fundamental works for the study of physics, the understanding of the world tout court), the twentieth century accelerated "secularization," first with the end of the sacred and then with the marginalization of humanism. What remained was science, but it too underwent this process of erosion (and deviation) of meaning.

The reduction of the problem of our time to the presence or absence of a given technology (in energy production, cybernetics, protecting the environment, space exploration, defense, medicine) confirms the poor historical sense of the elites. During (and even after) the industrial revolution, the definition of "steam economy" was coined, but the change of scene came with the internal combustion engine, a turning point in our life: for the first time, people could travel great distances in autonomous vehicles, on urban roads and beyond, at great speed and with the mass production of what would later become the car. In this case, the object became a historical subject: the car triggered a process that has reached as far as the present day, launched the production method (Fordism), kick-started the oil industry, "retired" coal (not forever and not too much, it is still with us and the market is excellent), opened the door to a very long cycle of innovation and social transformation. For better or for worse, after the invention of the wheel, it was the internal combustion engine that represented the 'technological leap' that responded to a concrete need of the masses: "movement".

Tomorrow, this space will be occupied by the electric motor (there are no numbers yet, the vehicle fleet is Lilliputian) but it is a story that needs writing. To give a new direction (which?) to history, rare conditions are needed to ensure that discovery or invention play a decisive role: availability at low cost, energy efficiency, penetration capacity and resistance to the shocks of economic cycles. Is the electric car a unicorn in a sea of horses? It does not appear to bear the characteristics of uniqueness; there has not, as yet, been any exponential growth; a quick glance around shows other sectors that promise a much higher rate of change. Think of the biotechnology laboratory and the applications of artificial intelligence, which range from the perspective of an "extended" life (the novel "K" comes to mind, by Don DeLillo, which depicts a future of cryogenics, pursuit of immortality and confirmation of the precariousness of life) to the utopia of the robot that relieves man from fatigue and frees the world from the oppression of capitalist production. Okay, let's go back to liberation from work, to the Frankfurt School, the "One-Dimensional Man" by Herbert Marcuse, but in the reporter's notebook the question always remains: to do what? There is no answer; there is the idea that something will happen and it will always be better. Work in Progress.

We have reached the idea of salvation that comes thanks to the *Deus ex machina*. When you no longer know how to turn the plot of a story around, the Almighty appears on the scene, God is an excellent ploy, as Moisés Naím recalls in *WE*: "Politicians, technocrats and scientists promise to lead us to a technocratic haven, where science and technology offer solutions without anyone making any effort or sacrifice. I have a name for this almost religious belief in new technological solutions: 'technological populism.' It is the call of the siren that sings the solution to climate change, without pain, without sacrifices." Perfect synthesis, strike.

I have never been convinced by this idea that everything is solved with the machine, with the technological totem. It only takes a second to go back, assuming that what we're doing is really moving forward. I recommend (re)watching "Wall-E," the Pixar film (a milestone in animation first released in 2008), in which a robot-compactor left on a planet Earth that is reduced to a landfill, devastated by pollution, meets Eve, another robot that has the job of assessing the sustainability of life on our planet (a blade of grass, we are always indebted to Walt Whitman). Little Wall-E redeems a humanity that is obese, laid flat and gaseous, wearily orbiting in space, thanks to his arrival with Eve on the Axiom spacecraft.

It is not a cartoon, it is not some artistic fantasy, after all, this is what we are, with the difference that we orbit between our homes (a monument of energy inefficiency) and our "green" weekends with brunch (thoughtful and responsible, naturally) where the convivial consumer strikes the pose of a bucolic intellectual, but in reality, it is a producer of carbon dioxide who has moved from the metropolis to the countryside. The ideal for the *Homo Metropolitanus* is to spend the holidays in the city, when there is room to breathe.

Critical ability and leadership are not only a problem of the political class, they are an issue that concerns man and also the scientific community, which is considered indisputable (and is, according to experimental evidence) and demands exemption from the analysis of own responsibilities. Science without conscience leads away from what is human. And thus, the policy that follows, stripping itself in turn of responsibilities.

We are on the highest playing field. When Alan Turing revealed the foundations of the Atlantis of artificial intelligence, he did so in Mind, the Oxford University philosophy journal. Einstein had the idea of the theory of relativity while thinking about time and space (and gravity, the force that moves the cosmos) in everyday life.

The COP27 climate summit in Egypt, in Sharm El-Sheikh, is the ideal place to measure all of the above. Before fighting climate disorder, we must first tidy up the mind of politics. We need technology and not ideology, a mix of sources and a new way of consuming (without predicting unhappy degrowth). A debate on climate poisoned by prejudice has the pretense of making a world dominated by hydrocarbons (and by the powers that produce them) disappear with a snap of fingers. It would like to replace it with renewable energy, only without considering "details" such as supply and security, efficiency and costs; there are even Utopian dates set for an industrial reconversion (N.B. of the West alone), which, in reality, requires several decades to be accomplished (and we don't yet know if it is the secure solution).

What will our adventure be like in the future? In an overheated Earth, it is a world that we know well, the world of Mad Max, where the hunt is on for two elements: water and petrol. Art anticipates the future; reality sometimes surpasses it.

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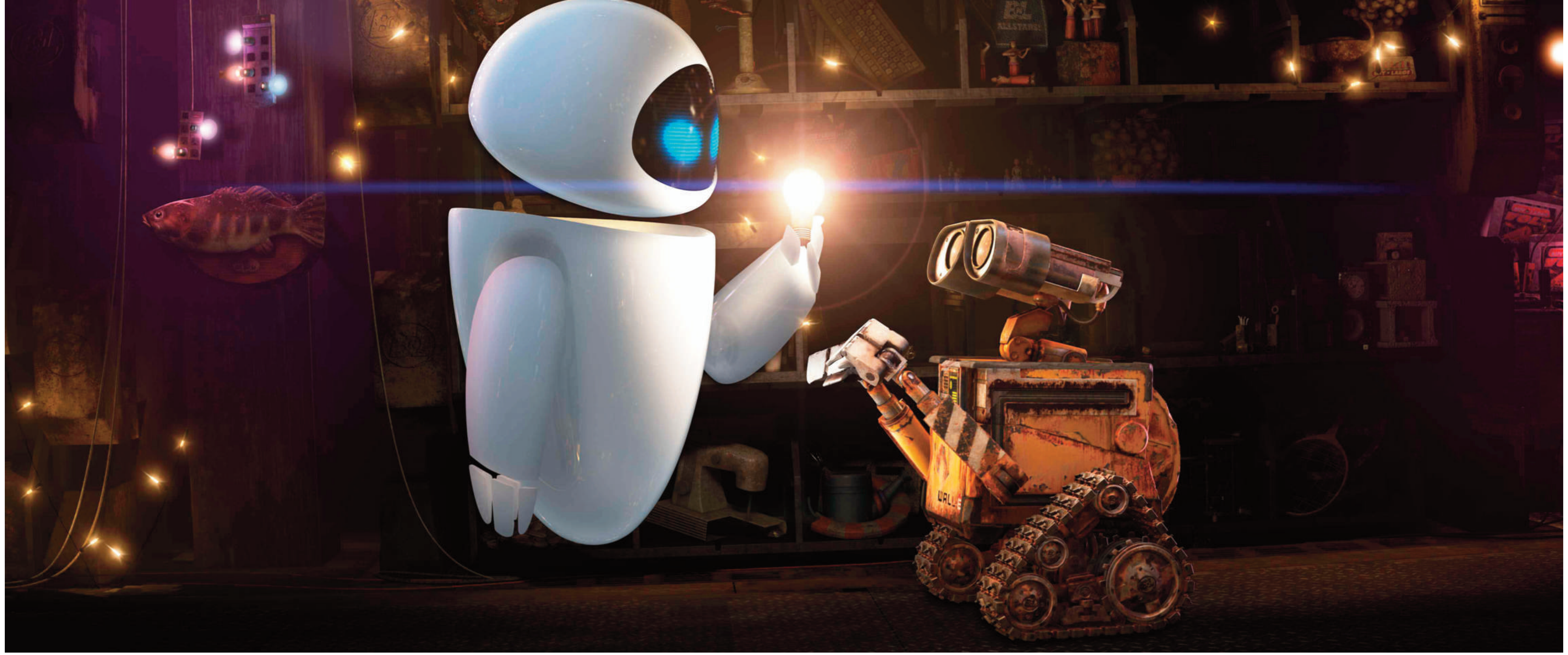


Maurits Cornelis Escher,
Bond of Union, lithograph, 1956.

2008 Pixar animated film, Wall-E. The Oscar-winning feature film tells the story of a robot left the only inhabitant of planet Earth, abandoned by humans due to excessive pollution and accumulation of waste.

BEWARE OF TECHNOLOGICAL POPULISM

by **Moisés Naím**

WHAT HUMANITY FACES IS NOT A CHOICE BETWEEN DRASTIC REDUCTIONS IN GREENHOUSE GAS EMISSIONS OR EMBRACING NEW ENERGY AND CLIMATE TECHNOLOGIES BUT A PRESSING NEED TO DO BOTH

THE PLAY IS IN ITS FINAL ACT, and the hero seems hopelessly mired in his troubles, with no credible way to overcome his difficulties. The rapt audience is in despair, there seems no way out of the morass of this plot. Then suddenly, a complex crane mechanism drops an as-yet unseen actor into the scene. A God—Zeus or Jupiter—descends from the machine and dispenses supernatural justice, smiting the wicked and rewarding the good. The moral order of the universe is restored, and the audience can go home reassured that the world is as it ought to be.

When ancient playwrights got themselves into plot trouble, the old device of bringing God onto the stage through a machine was always at hand. But modern critics have always looked down on *Deus Ex Machina*—Latin for bringing God from the machine—as a lazy plot device hack writers used as a rough and ready cheat. Good playwrights, they think, don't need such artifice to make their stories come out right at the end.

THERE ARE NO EASY SOLUTIONS

There's undoubtedly an air of "god from the machine" thinking in our current debates about new technologies and climate change: politicians, technocrats and scientists promise to take us to a technocratic oasis where science and technology bring solutions that require no effort or sacrifice on anyone's part. This almost religious faith on new technological fixes is what I mean by technological populism: the siren call of a solution to climate change that is painless and requires no sacrifice.

Why is technological populism so alluring? Because collectively, humanity has written itself into an impossible corner. An energy strategy that has brought hundreds of millions if not billions of people out of dire poverty and into a dignified life now cruelly threatens to render dignified life impossible, through the ravages of climate change. We're badly in need of a god from the machine.

And there are plenty of candidates for it: from the mass adoption of solar power and wind to sustainable aviation fuels and green hydrogen to more exotic gods like stratospheric geoengineering, atmospheric carbon capture and nuclear fusion. Like a god descending onto the scene from a machine, each promises to tie up the messy loose ends left by humanity's overreliance on fossil fuels with minimum pain for those already on the stage.

I share modern critics' concerns that this kind of plot device can be lazy. At its worst, technological populism turns us into passive spectators endlessly putting off the hard work of reducing carbon emissions on the vain promise of a miracle cure that may or may not ever come. Suspicion is heightened by the tendency among politicians to hold out as-yet non-existent technologies to exempt themselves from meaningful action now. Like quick-fix dieters out hunting for the next miracle slimming pill, technological populists prey on something-for-nothing thinking. Rather than undergoing the hard, slow slog of adjusting our diet and exercise habits to healthier options, some people will always prefer magical thinking. Waiting for the technological fix to seemingly intractable problems is as seductive as it is dangerous.

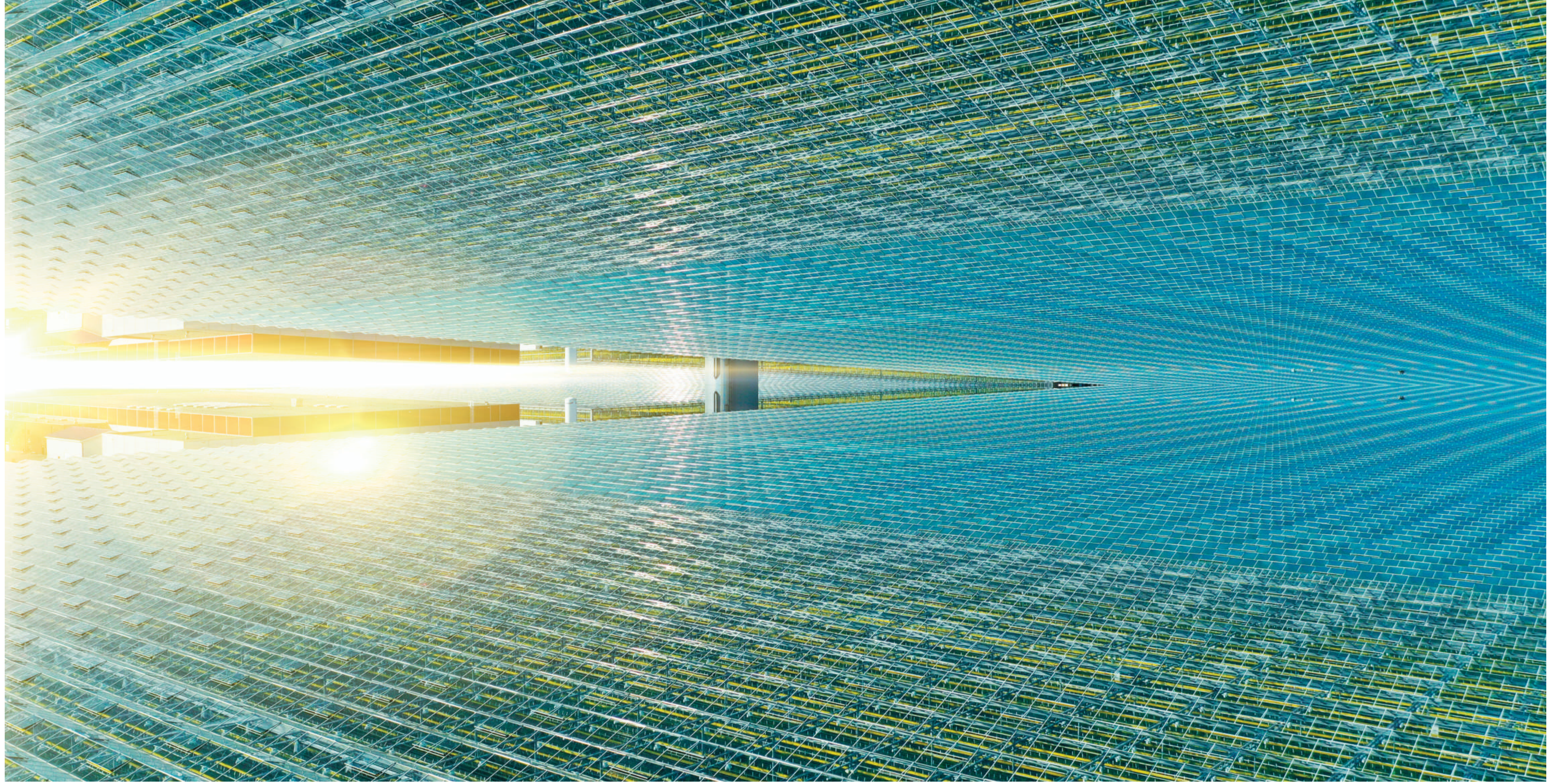
THE POWERFUL SCIENCE MACHINE

And yet, a balance must be struck between our suspicion of technological populism and the self-chastising puritanism of environmental extremists, for example. Unlike the contrived stage machines of the ancient theater, the device being used to bring climate solutions onto the stage is the fearsomely effective machinery of modern science. The new techniques under development are not fakes. They represent some of the most advanced achievements of the world's most sophisticated minds. It is a machine that has produced many gods before across a range of human experience, from medicine to engineering to hygiene to aeronautics.

Humanity's response to climate change, if it is to be successful, will need to adopt both. At our current rate of emissions, the speed of abatement needed to keep average temperatures within reasonable boundaries is increasingly unrealistic. Even the most drastic falls imaginable in the rate of new emissions will not be sufficient to keep the earth habitable for all the people now on it.

At the start of *The Ministry for the Future*, Kim Stanley's all-too-realistic 2020 Cli-Fi novel about a world of runaway climate change, a devastating heatwave in northern India brings

Greenhouse roof made of transparent glass. Greenhouse roofs allow the exploitation of unused spaces as meeting places or to produce food at zero km, creating considerable added value.



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wet-bulb temperatures so high that the electric grid collapses, leading to 20 million deaths. Scientists no longer consider scenarios like that one outlandish: more like just a matter of time. It's easy to see how, faced with such extreme climate outcomes, governments will have no choice but to adopt some of the boldest and riskiest climate solutions. Spraying fine sulphur compounds onto the stratosphere to increase the proportion of the sun's radiation that bounce back out onto space is now a long shot, but if current trends continue the appetite to try this fix will be much higher.

What humanity faces is not a choice between drastic reductions in greenhouse gas emissions *or* embracing new energy and climate technologies but a pressing need to do both. The hard, grinding task of changing deeply ingrained habits cannot be wished away: there are no something-for-nothing solutions.

And yet new technologies will clearly play a leading role as well: human ingenuity got us into the current climate mess, and human ingenuity will have to play a major role in getting us out of it. Both new habits and new technologies will have to come into play. Because even the god that comes out of a machine will do nothing for our hero if he will not join the fight himself.

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TOWARDS COP27

by Karim Elgendy

THE SHIFT OF THE CONFERENCE'S FOCUS TO THE IMPLEMENTATION OF EXISTING CARBON REDUCTION PLEDGES PROVIDES AN OPPORTUNITY FOR ESTABLISHED SUSTAINABLE TECHNOLOGIES, SUCH AS RENEWABLES, WHICH WILL BE ABLE TO PLAY A MORE CENTRAL ROLE IN THE TRANSITION EFFORTS

© DENNIS SCHROEDER/CLIMATE VISUAL

LAST NOVEMBER, the 26th edition of the annual United Nations climate summit, known as the Conference of Parties (COP), drew to a close in Glasgow. COP26 was widely recognized as a success in achieving the priorities of its U.K. presidency, which jointly presided over the summit alongside the United Nations Framework Convention for Climate Change (UNFCCC). These priorities were about raising ambition for climate change mitigation by encouraging countries to increase their ambitions for carbon emissions reductions in their Nationally Determined Contributions (NDCs), their pledges under the Paris Agreement and by championing voluntary coalitions to reduce emissions in several critical sectors such as clean energy transition, phasing out coal, zero emission vehicles and stopping deforestation.

The outcomes of COP26 appear to have successfully moved the needle slightly away from the worst-case climate change scenario, and if implemented they could bring us closer to the safe climate change limit of 1.5 degrees Celsius above preindustrial temperatures, even if such safe limit appears increasingly out of reach. According to post-COP26 assessments if all conditional and unconditional NDCs as well as net zero targets were implemented in full and on time, warming can be kept just below 2 degrees Celsius.

THE SHARM EL-SHEIKH CONFERENCE

With preparations currently underway in Egypt to host the COP27 at the resort town of Sharm El-Sheikh in November, the annual climate summit's attention is expected to shift to climate adaptation, climate finance, and the implementation of pledges made to date. This shift of focus reflects the priorities of the COP27 hosts, the discussions already scheduled by the UNFCCC, and the disappointment felt by some developing countries who saw their priorities not adequately addressed in Glasgow.

This focus on implementation at COP27—which was defined as focusing on implementing existing carbon reduction pledges rather than pushing countries to pledge further carbon cuts—broadens the conversation around mitigation to incorporate

policy levers, finance mechanisms and technologies that support decarbonization. It also brings to the table new stakeholders with technical and financial know-how, including development finance institutions, research institutes and international energy companies.

This shift in focus presents a great opportunity for proven clean technologies such as renewable energy to become more central to the energy transition and global decarbonization efforts.

THE ROLE OF RENEWABLES

Five years ago a study estimated that 139 countries could source all of their energy from renewable energy sources by the middle of the century, if they electrify their energy sectors (including transportation, heating, cooling, industry, agriculture, forestry, and fishing) and source the electricity from wind, water and solar power.

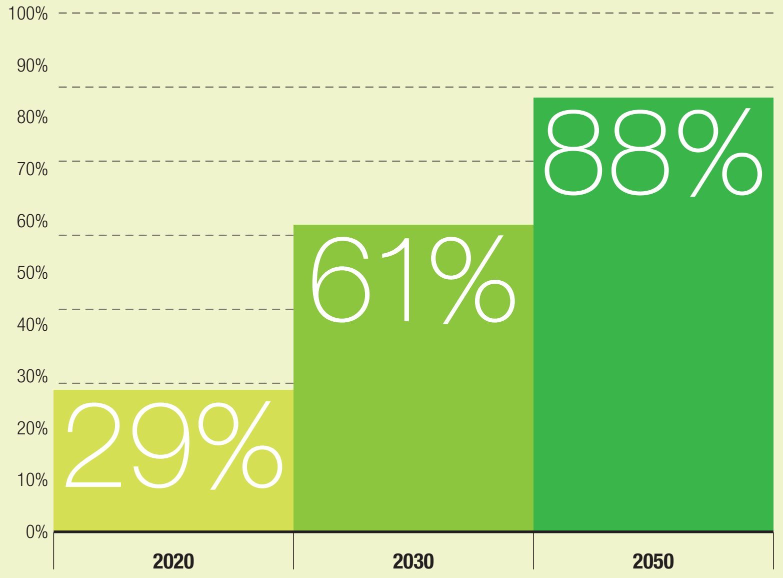
Today 38 percent of global electricity is generated from clean electricity sources, which surpassed coal for the first time ever. 29 percent of all electricity is sourced from renewable energy sources, whose growth came at the expense of coal. Since 2015 wind and solar power have captured 5 percent of the energy production mix from coal and today these two technologies alone represent 10 perecnt of all electricity generation. To put this in perspective, the share of renewables in electricity generation globally must rise to 61 percent by 2030 and to 88 percent by 2050 if the world is to reach carbon neutrality, according to the IEA's net zero emissions roadmap.

But the momentum behind renewables continues to grow. Last year renewable energy capacity additions broke a new record, increasing 6 percent to almost 295 GW, and are expected to increase further by 320 GW this year.

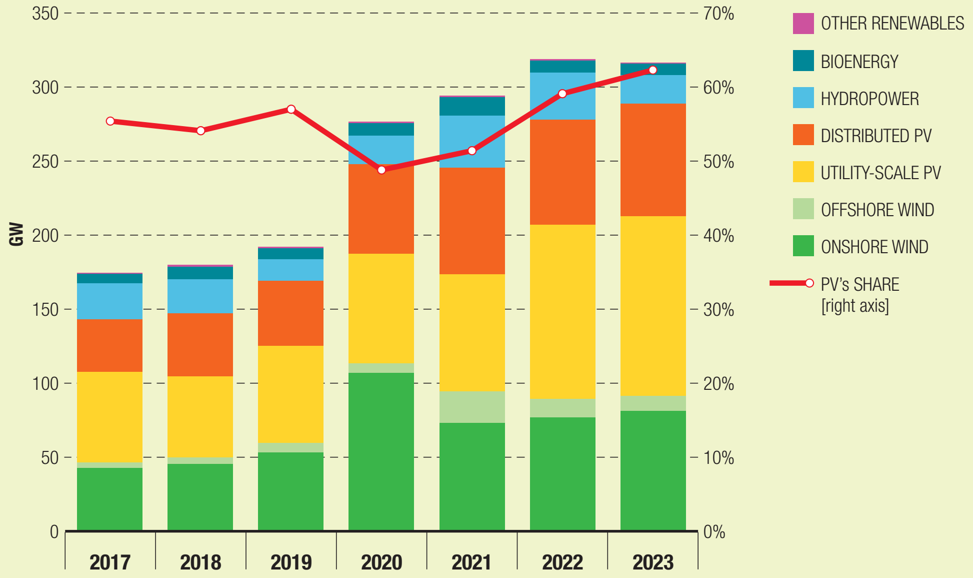
The cost of electricity from renewable energy sources has also dramatically fallen in the last few years. Between 2010 and 2021 the average Levelled Cost of Electricity of newly commissioned utility-scale solar Photovoltaic projects declined by 88 percentage . Similarly, those of onshore wind and Concentrated Solar Power fell by 68 percent, while that of offshore wind dropped by 60 percent. In some locations, the cost of solar and onshore wind power fell so much it became competitive against fossil fuels in new electricity generation installation.

Additionally, the renewable energy industry is approaching a point where it could resolve the challenge of intermittence in solar and wind technologies, which limited the deployment of renewable energy system as a source for base load electricity. The constant drop in the cost of electricity storage in recent years alongside the rise of interconnections between national grid together hold great promise for managing intermittence.

The use of battery storage and grid interconnection technologies alongside renewable energy is perhaps best demonstrated in the project to export electricity from Morocco to the U.K. via sea cables. The project uses 10.5 GW of generation capacity



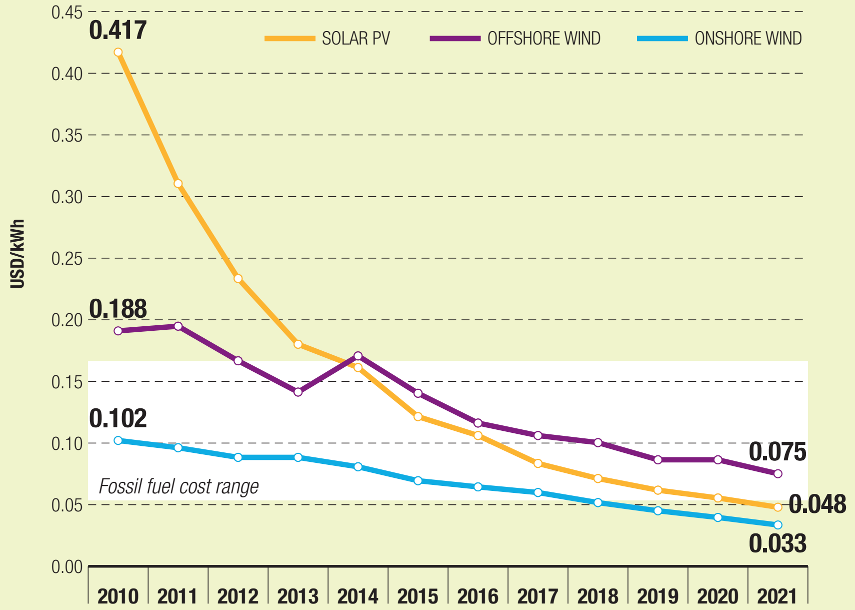
1 SHARE OF RENEWABLES IN ENERGY PRODUCTION
According to projections by the International Energy Agency (IEA), the share of renewables in electricity generation must rise to 61 percent by 2030 and to 88 percent by 2050, globally, if we are to achieve carbon neutrality by 2050.



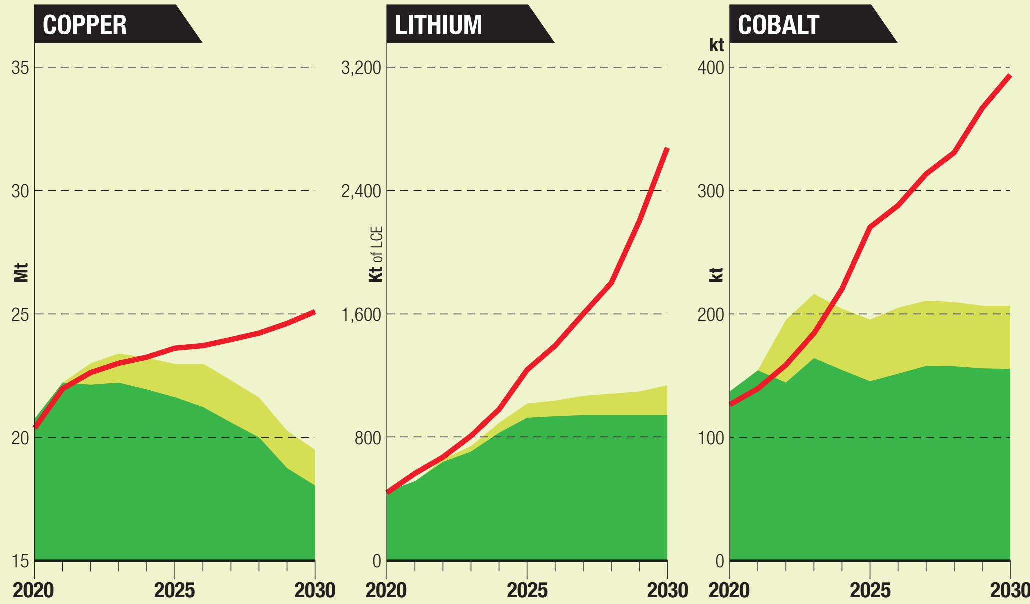
2 ADDITIONAL CAPACITY OF RENEWABLES BY TECHNOLOGY
Renewables are growing at an ever-increasing rate. Last year, renewable energy capacity additions broke a new record, increasing by 6 percent to nearly 295 gigawatts. A further increase to 320 gigawatts is expected this year.

The growth of renewables

Source: IEA



3 LEVELIZED COST OF ELECTRICITY
Between 2010 and 2021 the average levelized cost of electricity for new industrial-scale solar PV projects fell by 88 percent and that of onshore wind projects fell by 68 percent, while the average levelized cost of offshore wind projects shrank by 60 percent.



4 GAP BETWEEN MINERAL SUPPLY AND CLIMATE AMBITION [IN THE SUSTAINABLE DEVELOPMENT SCENARIO, SDS]. According to an estimate by the IEA, in order to achieve the targets of the Paris Agreement, over the next ten years, the share of total mineral demand for green technology will have to increase by more than 40 percent for copper and rare earths, by 60-70 percent for nickel and cobalt and nearly 90 percent for lithium.

PRODUCTION (OPERATING) PRODUCTION (UNDER CONSTRUCTION) PRIMARY DEMAND IN THE SDS

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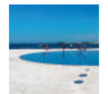
London, U.K. Hydrogen fuel cell bus. Stored in cylinders on the roof of the bus, the hydrogen reacts with oxygen to produce water and energy; the only by-product is water vapor. According to the IEA roadmap to achieve net zero CO_2 emissions, the use of hydrogen worldwide needs to exceed 200 million tons by 2030.



Zadar, Croatia. Monument to the Sun, or The Greeting to the Sun is created with multilayer glass by the Croatian architect Nikola Basic. The installation collects solar energy during the day and illuminates the waterfront at night. Today wind and solar alone account for 10 percent of total electricity generation.

from new solar and wind farms in Morocco (on an area equal that of Washington DC) and utilizes 20GWh of battery storage to convert this intermittent supply into 3.6GW of constant power (20 hours per day) ready for transmission to the U.K. via sea bed cables. The project is expected to provide 8 percent of the U.K.'s electricity needs at a commercially competitive rate. Transmission losses are to be minimized by using Direct Current rather than alternating current between Morocco and the U.K.

But the energy transition is not without its environmental challenges. A global energy system powered by renewable energy technologies differs greatly from a system fueled by fossil fuels in that it requires significantly more minerals. According to one estimate by the IEA, to meet the goals of the Paris Agreement, clean energy technologies' share of total demand for minerals will have to rise over the next two decades to over 40 percent for total demand of copper and rare earth elements, 60-70 percent of total demand for nickel and cobalt, and almost 90 percent of lithium demand. To ensure access to such critical minerals, circular economy principles will need to become integral to the lifecycle of renewable energy systems.

LOW-CARBON HYDROGEN

In addition to renewable energy sources and battery storage, hydrogen is also emerging as a promising clean source of energy. Low carbon hydrogen technologies present an alternative route to decarbonization for hard-to-electrify sectors such as high temperature steel and chemical industries, refineries, shipping, and freight. In these sectors hydrogen acts as a high energy intensity carrier of energy produced either from renewable energy sources via electrolysis (green hydrogen), or from natural gas where released carbon is captures and sequestered (blue hydrogen).

According to the IEA's net zero emissions roadmap, global hydrogen use will need to expand to more than 200 million tons in 2030, with the proportion of low carbon hydrogen rising from 10 percent in 2020 to 70 percent at the end of the decade.

It is worth noting here that the rise in the cost of natural gas following the Russian invasion of Ukraine has left green hydrogen as the most commercially competitive amongst low carbon hydrogen technologies.

The European Union's target to use 20 million tons of low-carbon hydrogen annually by 2030 has further energized this sector. The bloc's plans to import half of this target has also made it a credible export market for countries in its Southern Neighborhood with commercially competitive renewable energy industries. Many of these countries are vying for a share of this market by rapidly developing green hydrogen and green ammonia infrastructure.

AN UNPRECEDENTED OPPORTUNITY

The confluence of these mature and emerging technologies alongside the collective global commitment to decarbonization and the focus on implementation this year all present an unmatched opportunity for the energy industry to double its efforts and to divert its investments further towards clean technologies.

But time is of the essence, and for the energy transition to take place at the pace required to meet the goals off the Paris Agreement, the stakeholders must pull together. To ensure that the energy industry is driving the energy transition, policy makers must send clear unambiguous signals to the market on the desired direction of travel, provide clear market incentives, and support research and development. More importantly national policy makers must advance international collaboration to ensure a just transition, fair access to critical minerals, and increase the resilience of the global energy system.

As with previous climate summits, the world leaders will come together at COP27 to plan how to best avoid the worst impacts of climate change. They will continue to chart a road for a safer future for us and future generations. Whether we follow their roadmap is up to us.

KARIM ELGENDY
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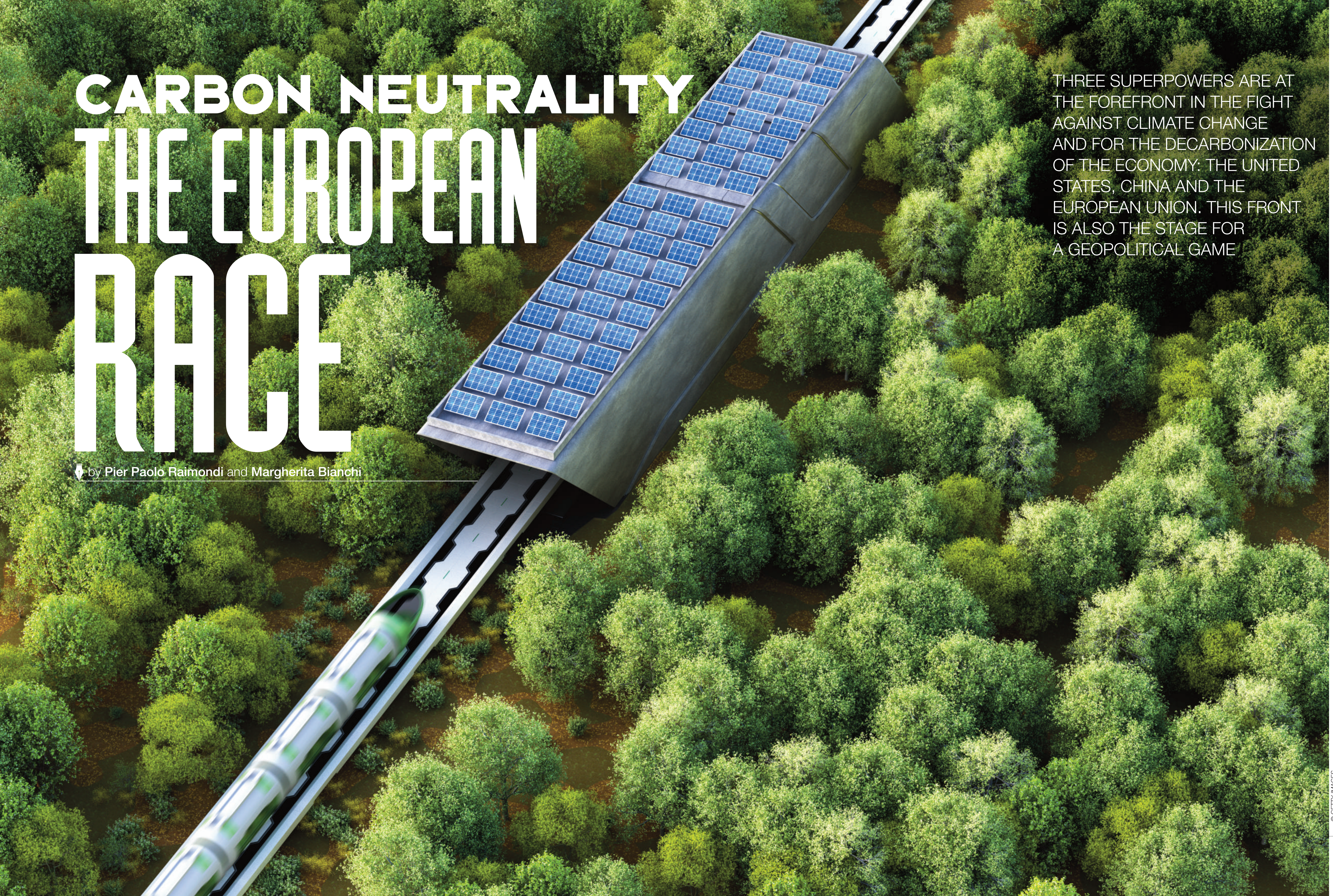

CARBON NEUTRALITY THE EUROPEAN RACE

by Pier Paolo Raimondi and Margherita Bianchi

THREE SUPERPOWERS ARE AT THE FOREFRONT IN THE FIGHT AGAINST CLIMATE CHANGE AND FOR THE DECARBONIZATION OF THE ECONOMY: THE UNITED STATES, CHINA AND THE EUROPEAN UNION. THIS FRONT IS ALSO THE STAGE FOR A GEOPOLITICAL GAME

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COUNTRIES HAVE INCREASINGLY pledged to reach climate neutrality near mid-century. Alongside the EU, China and the U.S. have emerged as key players. The EU presented its cutting-edge European Green Deal strategy, the U.S. has rejoined the Paris Agreement and China has issued an action plan to achieve its carbon emissions peak by 2030. Their commitment and co-operation on climate are essential per se and for the impact they have on global dynamics. The three are collectively responsible for approximately 50 percent of CO_2 emissions and play a pivotal role in innovation and technologies, global value chains and political leadership. Cooperation is mandatory to successfully tackle a global issue like climate change, but the nature of climate policy entails a high level of competition over green technologies and supply chains. Indeed, the energy transition will result in the redrawing of global industrial and technological leadership, altering the current political, energy and economic landscape. Countries may compete for technological supremacy in order to dominate cutting-edge technologies, a trend that could derail global efforts to tackle climate change. Countries must therefore find an equilibrium between cooperation and competition in order to enable appropriate climate action for all. Without this balance the EU may find itself vulnerable if it ill-manages the transformations of the next thirty years; however, it has instruments to guide these changes along with other superpowers and the rest of the world.

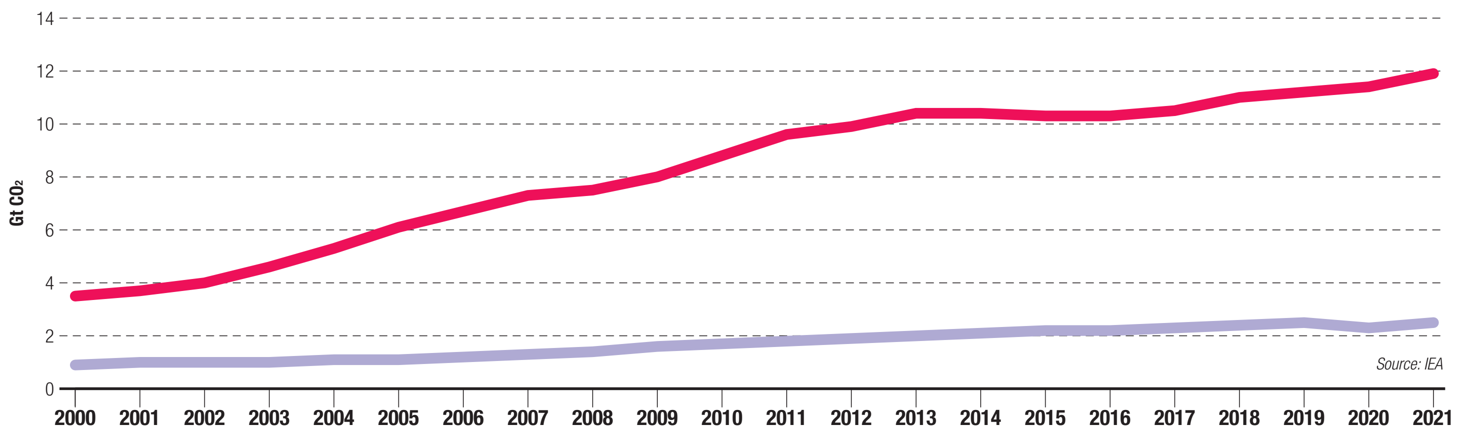
THE TRANSITION: AN OPPORTUNITY FOR EUROPE

For Europe, the transition is the new raison d'être, the opportunity to foster its much-needed integration, the recipe to increase its bloc's energy security and to lead at the global level. EU's energy vulnerability, so evident in current circumstances, goes well beyond that for oil and gas. The EU must manage future transformation wisely to avoid a new phase of vulnerability. For example, ending the sale of internal combustion engines vehicles by 2035 entails socioeconomic and geopolitical challenges for the European automotive industry as it involves a full shift to electric vehicles. Competition over battery production has already started with China accounting for 76 percent of global EV

Who goes up and who goes down

Global economic output in advanced economies returned to pre-pandemic levels in 2021. Almost all regions recorded an increase in CO_2 emissions in 2021, with an annual variation ranging from growth of over 10 percent in India to less than 1 percent in Japan. Emissions in China increased by 5 percent compared to the previous year, while the United States and the European Union both recorded increases of around 7 percent. In any case, China continues to drive the increase in CO_2 emissions, as the only country to have experienced economic growth in both 2020 and 2021. In 2021, China's CO_2 emissions reached 11.9 billion tons, representing 33 percent of total global emissions. Next on the list, the IEA points to India, where the consumption of coal increased 13 percent above the 2020 level.

CO_2 EMISSIONS IN SELECTED EMERGING ECONOMIES, 2000-2021



battery production capacity compared to EU's 7 percent and U.S.' 7 percent.

While there is a rising consensus about climate policy around the world, global affairs have also been characterized by attempts to enhance domestic autonomy. Such trends, visible in each of the three superpowers, were reinforced during the pandemic. However, strong calls for decoupling from China may delay the global transition: over the past decade, the remarkable decline in the cost of renewables has been possible thanks to U.S. and EU technologies paired with China's large investments. At the same time, growing competition among superpowers has also involved their cooperation with third countries, particularly through international infrastructural investments. The EU and the U.S., along with other G7 countries, have announced infrastructural programs, the Global Gateway Strategy and the Build Back Better World (B3W) visions, that contrast with Beijing's Belt and Road Initiative.

GREEN DEAL DIPLOMACY

Notwithstanding this rivalry, the EU is deeply committed to preserve international cooperation with its partners in order to foster the transition around the world. Meanwhile, countries need to consider ways to deliver their commitments as quickly as possible. One way to accelerate this commitment could be the creation of climate clubs through which countries would find formats to quickly implement their targets. As an addition to the current EU-U.S. rapprochement in the energy and climate spheres, some analysts advocate for the formation of climate clubs to increase competition and further incentivize other countries (foremost China) to achieve their environmental targets. Moreover, the EU bloc could use climate clubs to increase bilateral partnerships from different sectors to increase its climate standards.

The EU can and should prioritize its "green deal diplomacy" especially in its neighboring areas (e.g., the Mediterranean Sea and its eastern flank). For example, North Africa holds favorable conditions to produce green hydrogen, which could help decarbonize hard-to-abate sectors, avoiding the risk of being targeted by the European Carbon Border Adjustment Mechanism (CBAM), currently under discussion within EU institutions.

The global energy transition represents an opportunity for the sustainable socio-economic development of many countries and the local dimensions of EU's initiatives in developing countries should be of utmost priority. Furthermore, the EU could use part of its CBAM revenues to increase its financial assistance abroad and reduce the regressive effects of such a measure.

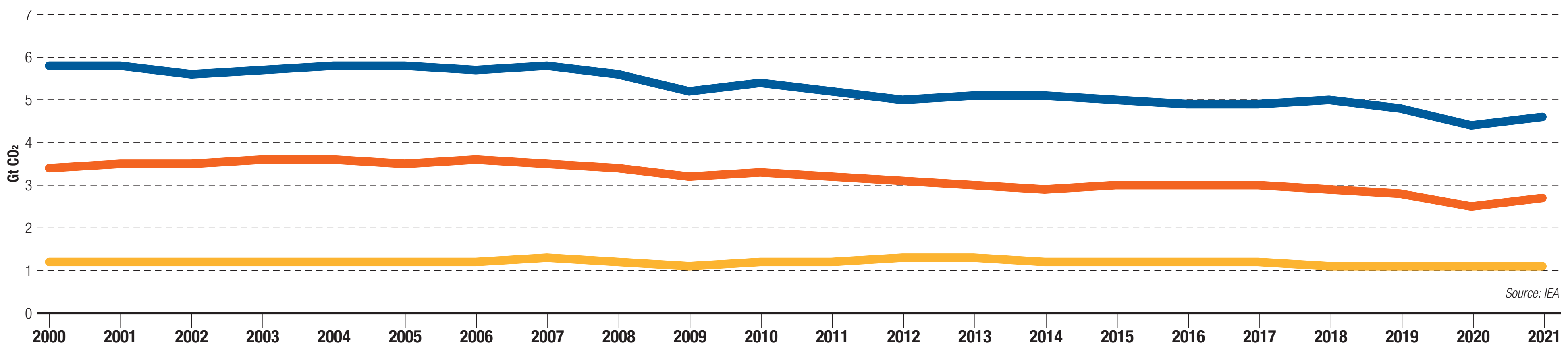
For the EU, financing and supporting clean energy transition abroad also provides viable alternative solutions for countries to compare to other superpowers' projects. This is the case of China, which has increased its international influence under the Belt and Road Initiative umbrella. The EU has launched its Global Gateway and has identified the European Fund for Sustainable Development Plus (EFSD) as the main financial tool for mobilizing investments under Global Gateway.

The EU can benefit from several advantages in promoting its international role. First, it is already the largest donor of development aid in the world. Second, the EU has strong political and energy ties with Southern Mediterranean countries. However, the EU needs to better streamline its funding instruments to be more effective in assisting Southern countries through their energy transition. Moreover, the EU needs to expand its external investments if it seeks to enhance an international role, especially in its neighborhood. In March 2021, the EC formed "Global Europe" with an overall budget of €79.5 billion for the next MFF period (2021-2027), of which only €19.3 billion is committed to the whole neighborhood.

THE REGULATORY POWER OF THE EU

By preserving cooperation, at least with like-minded partners, stepping up its external investment programs and leveraging its regulatory power, the EU could enhance its technological capabilities in different fields, such as green hydrogen. Previously,

CO_2 EMISSIONS IN SELECTED ADVANCED ECONOMIES, 2000-2021



the EU has seen technological leadership in key technologies, such as solar Panels and EVs, move to other countries. In 2020, the EU launched its Hydrogen Strategy and in 2022 hydrogen was identified as a solution to reduce Europe's overdependence on Russian gas in the REPowerEU plan, which expanded targets for domestic production and import volumes. The EU has developed a leading position in the electrolyzer manufacturing industry by developing the largest manufacturing capacity in the world. Furthermore, the EU is aiming at denominating its future hydrogen in euros.

The EU could also accelerate the race towards decarbonization by leveraging its regulatory power and has produced regulations that influence how products are built and this effects business behavior around the world (known as the Brussels Effect). It is clear that EU standards have contributed and might contribute to elevate the bloc as an example for other economies (e.g., on carbon pricing: the European Trading System has provided a model for a Chinese ETS). The Brussels Effect might be particularly evident with the introduction of the CBAM—whose aim is to prevent and avoid carbon leakage and protect domestic industries while encouraging third countries to establish carbon pricing policies.

Nonetheless, the CBAM has received harsh opposition both from the U.S. and China, and the latter has called on developed countries to cease creating such barriers. However, as net zero targets are pursued around the world, similar measures could be inevitable for others. Therefore, the EU needs to convince more countries that stronger abatement efforts in the high emission sectors are unavoidable or accept CBAM or similar instruments. While sharing opposition to the CBAM, there are some differences in Washington and Beijing—in the first case, carbon pricing has been discussed extensively with very modest results, while China's ETS could provide a good starting point although its reach is far limited compared to the EU's.

Today, the development and deployment of clean energy technologies is potentially undermined by a negative economic outlook and the re-emergence of urgent security concerns. Yet, the EU has reaffirmed its commitment to decarbonization. To achieve its climate objectives during this transformative and challenging times, the EU will need to pursue and implement concrete industrial policies in collaboration with like-minded countries, policies aimed at promoting clean energy technologies both in the EU and abroad in line with its international ambitions. For example, the EU could address its strategic vulnerabilities in the field of batteries by working together with the U.S. as illustrated by the announcement by the European Battery Alliance and the U.S. Li-Bridge Alliance to collaborate for accelerating the development of Li-ion and next-generation batteries.

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ELECTROMOBILITY & just transition

by **Herald Ruijters**

A JOINT EFFORT IS REQUIRED TO ENSURE THAT THE MEASURES NECESSARY TO ACHIEVE THE EUROPEAN UNION'S DECARBONIZATION OBJECTIVES ARE IMPLEMENTED SWIFTLY. IMPROVING SYNERGIES BETWEEN THE ENERGY AND TRANSPORT SECTORS HAS NEVER BEEN MORE IMPORTANT

CLIMATE CHANGE and environmental degradation are an existential threat to Europe and the world. To address these challenges, in December 2019 the European Union adopted the European Green Deal intending to transform the EU into a modern, resource-efficient and competitive economy. In practice, this implies three key objectives:

- no net emissions of greenhouse gases by 2050
- economic growth decoupled from resource use
- no person or place left behind

The European Green Deal is also the EU's lifeline out of the COVID-19 pandemic. One third of the €1.8 trillion in investment from the Next Generation EU Recovery Plan and the EU's seven-year budget will finance the European Green Deal.

NINETY PERCENT CUT IN TRANSPORT EMISSIONS BY 2050

Transport is responsible for approximately 27 percent of the EU's greenhouse gas emissions. The European Commission's Sustainable and Smart Mobility Strategy of December 2020, together with the accompanying Action Plan of 82 initiatives, is a roadmap to reduce that figure, cutting transport emissions 90 percent by 2050. The strategy lays the foundations for a green and digital transformation and greater resilience to future crises. Europe's future transport system will be smart, competitive, safe, accessible and affordable.

Today, passenger cars and vans are respectively responsible for around 12 percent and 2.5 percent of total EU CO_2 emissions. Aspirational objectives therefore imply having at least 30 million zero-emission cars in operation on EU roads by 2030, that goal enabled by three million publicly accessible recharging points.

The European Climate Law is setting a legally binding requirement for the EU to reduce net greenhouse gas emissions compared to 1990 levels by at least 55 percent by 2030. With the 'Fit-for-55' package in July 2021, the European Commission adopted proposals to make the EU's climate, energy, transport and taxation policies fit for achieving this ambitious target. For road transport, stronger CO_2 emission performance standards for cars and vans and a regulation on the deployment of alternative fuels infrastructure are part of the solution.

ACCELERATING THE ROLLOUT OF EU INFRASTRUCTURE

Stricter CO_2 emissions standards for cars and vans will accelerate the transition to zero-emission mobility. They will require average emissions from new cars to come down by 55 percent from 2030, and those from vans by 50 percent in 2030. By 2035, the target is 100 percent for cars and vans, compared to 2021 levels. Across the globe, governments are also adopting strong policies to push zero-emission vehicles, including in California, which recently announced that it will end sales of combustion engines from 2035.

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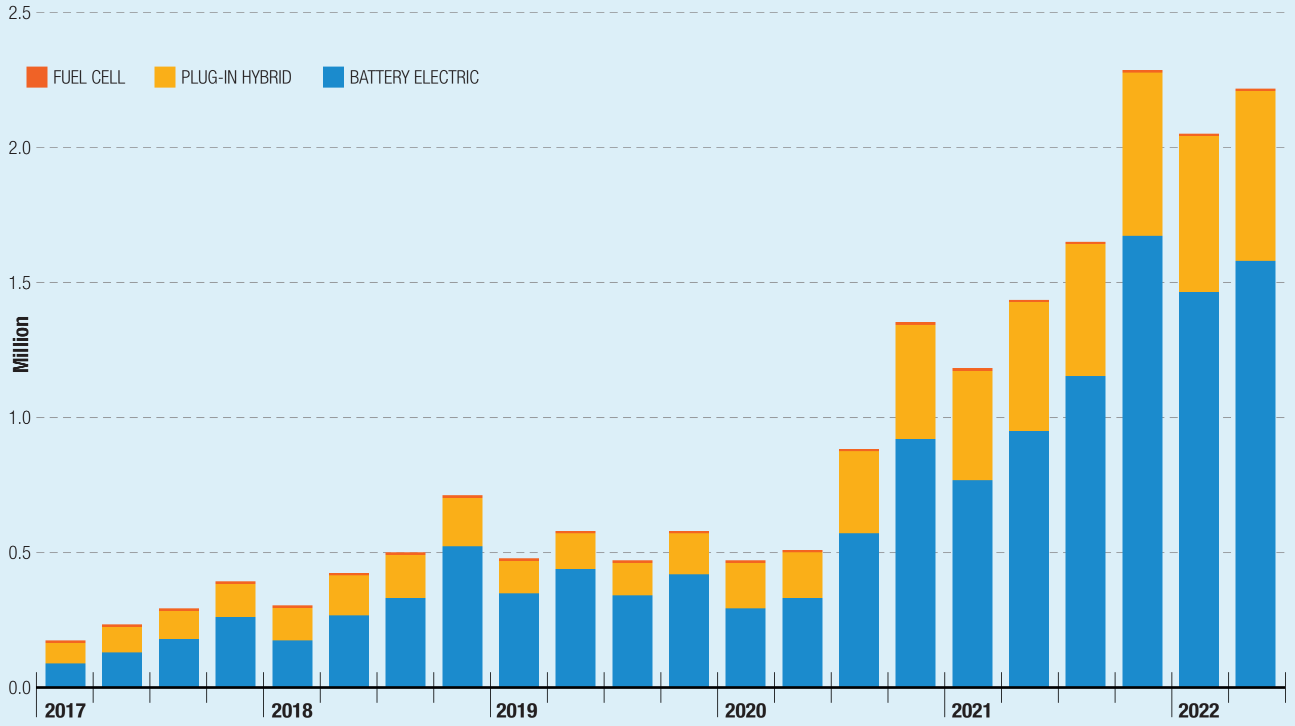
By 2030, at least 30 million electric vehicles, or 50 million if plug-in hybrid vehicles are included, could be registered in the EU. To ensure that all these vehicles have sufficient recharging infrastructure, the Commission proposed a regulation on alternative fuels infrastructure (AFIR) last year. It sets a number of mandatory national targets for the deployment of alternative fuels infrastructure in the EU, for road vehicles, vessels and stationary aircraft.

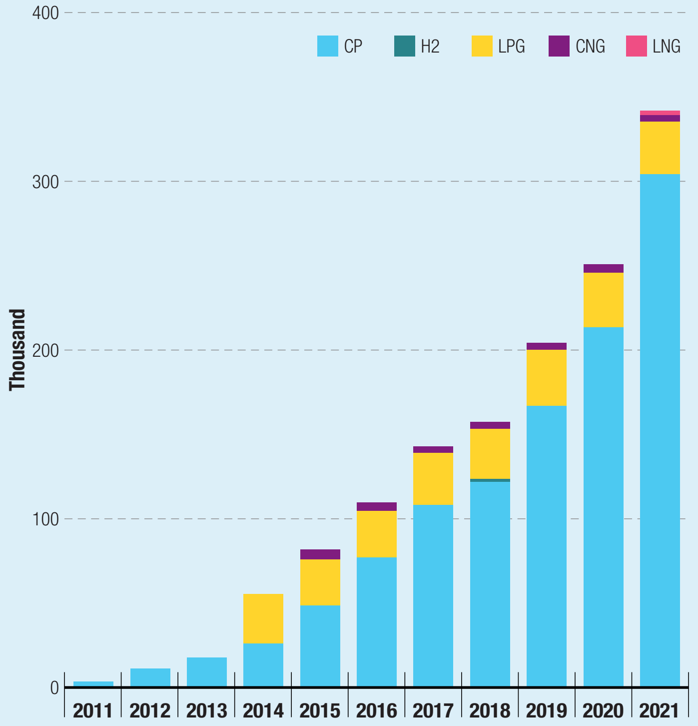
For publicly accessible electric recharging infrastructure for light duty vehicles (cars and vans), the proposal contains mandatory national fleet-based targets (i.e., for every battery



GLOBAL SALES OF PASSENGER ELECTRIC VEHICLES

Globally, sales of battery electric vehicles far outrun those of plug-in hybrids. Registrations of hydrogen fuel cell vehicles are still very low.

Source: BloombergNEF



NUMBER OF CHARGING POINTS IN EUROPE

At the end of 2021, the EU surpassed 300,000 electric charging points (CPs). The number of LPG distributors has remained constant over the last 10 years. The number of hydrogen (H2) compressed natural gas (CNG) and liquid methane (LNG) distributors is still very low.

Source: EAFO

electric light duty vehicle, a total power output of at least 1 KWh should be provided through publicly accessible recharging stations; for every plug-in hybrid light-duty vehicle, a total power output of at least 0.66 KWh should be provided). These are complemented by distance-based targets for light duty and heavy-duty vehicle infrastructure on the Trans-European Transport Network (TEN-T). For hydrogen, publicly accessible hydrogen refuelling stations shall be deployed at least every 150 km along the TEN-T core and the TEN-T comprehensive network, while at least one should be available in every urban node.

For electromobility, the number of recharging points is important, but so is the recharging experience. For this reason, AFIR sets specific data and interoperability requirements to ensure an easy and intuitive recharging experience. These clear the way for common minimum requirements for easy payment, and new technological solutions such as e-roaming and smart recharging. This will help to encourage those who are hesitant about electromobility to make the switch.

MARKET SHIFT TOWARDS ZERO-EMISSION VEHICLES

The Commission's proposals come at a time when the market already is seeing a shift from fuel-burning to zero-emission vehicles. The EU's electric vehicle fleet is doubling every year. In the EU-27, 920,000 electric vehicles were sold during the first half of 2022. The EU and China have led the global passenger electric vehicle and hydrogen fuel cell segment since 2015, accounting for 84 percent of global electric vehicle sales in the first half of 2022.

Sales of battery electric vehicles are now outweighing sales of plug-in hybrids in many European markets, and massive investment in new vehicle models and battery technologies continues. Fuel cell hydrogen vehicle registrations are still at very low levels for the car and van market.

Zero-emission powertrains are also starting to scale-up in the heavy-duty vehicles market segment. For buses, we are seeing real market momentum, with increased procurement of battery-electric, but also fuel-cell hydrogen buses, driven inter alia by the European Commission's revised Clean Vehicles Directive. Moreover, manufacturers are starting to invest heavily in battery-electric heavy-duty vehicles, while the urban and interurban delivery market is starting to use these vehicles.

Economies of scale with electric light duty vehicles will favor further uptake. Long-distance road haul solutions will enter into the market for both battery- and hydrogen fuel-cell trucks from 2022, increasing in the following years. This process is also driven by the existing CO_2 standards for heavy-duty vehicles, for which the Commission is currently working on a revision. Finally, rapid adoption of the proposed standard for Megawatt Charging System (MCS), a connector developed for electric trucks capable of delivering power amounts of up to 3.75 MW, will be critical for market uptake.

CONTINUED GROWTH OF PUBLIC RECHARGING INFRASTRUCTURE

At the end of 2021, the total number of recharging points in the EU had surpassed 300,000. Charging points operators had invested substantially and are likely to continue doing so. We are also seeing the start of investments in dedicated truck recharging infrastructure, sometimes driven by industry partnerships. Uneven distribution remains a challenge, however, which is one reason we want to see the Commission's new Alternative Fuels Infrastructure Regulation adopted rapidly.

When it comes to recharging infrastructure, it is important to consider complementarity between public and private infrastructure. The Commission's proposal for an Energy Performance for Buildings Directive (EPBD) is designed to ensure that private recharging points are available in office and apartment buildings, ensuring a "right to plug" in private residential buildings. The two proposals—AFIR and EPBD—contribute to a clear regulatory framework for both the market and consumers. Importantly, access to private recharging (e.g., at home, at work, at depot) will condition the drivetrain mix and utilization of public infrastructure.

The transition to cleaner transport will come with a cost. Vulnerable households, micro-enterprises and transport users will come under pressure in the short term. This pressure is being accentuated by Russia's illegal aggression against Ukraine and the resulting global macroeconomic outlook and impacts on Europe's energy market. The European Commission is fully aware of this situation and has put in place measures to help alleviate the pressure.

THE EU'S JUST TRANSITION

In the context of electric vehicles, the price of energy deserves special attention. The EU depends on a range of different supply and demand conditions, including the geopolitical situation, national energy mixes, import diversification, network costs, environmental protection costs, as well as levels of excise and taxation. In response to Russia's invasion of Ukraine, the Commission published the REPowerEU plan in May 2022. It puts forward additional actions to save energy, diversify supplies and replace fossil fuels by accelerating the rollout of renewable energy, supplemented now by emergency action to help stabilize the electricity market. This action complements proposals

for a Just Transition Mechanism and new European Social Climate Fund, which target social fairness by mobilizing funding to support investment in the economy and a socially just transition.

We are facing an extraordinary situation. These are difficult times, requiring extraordinary measures. The Commission is working to level out the costs and bring consistency to electricity prices throughout Europe. During her State of the Union speech on September 7, 2002, European Commission President Ursula von der Leyen proposed new measures, including smart electricity savings, a cap on revenue for companies that produce electricity at low cost, and additional liquidity to cope with market volatility.

It will now require a joint effort to ensure the necessary measures at EU and national level are adopted and implemented quickly so that the EU meets its decarbonization target. Improving synergies between the energy and transport sectors has never been more important. The joint optimization of the energy and transport systems will be key. The solutions outlined in the European Green Deal can only succeed if people, communities, and organizations are all deeply involved and take common action.

we

HERALD RUIJTERS

He is Director, responsible for Investment, Innovative & Sustainable Transport in DG Mobility and Transport. As regards investments in transport, his main responsibilities are the funding instruments Connecting Europe Facility and Horizon Europe and the financing instrument InvestEU. He is also responsible for the relationship with the EIB and with national and promotional banks.

INDEPENDENCE Day

by Francesco Gattei

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THE UKRAINIAN CRISIS HAS SWEPT AWAY THE OPTIMISM THAT CAME WITH THE ENERGY TRANSITION NARRATIVE, EXPOSING THE FRAGILITY AND DEPENDENCES OF THE WEST (BOTH OLD AND NEW)

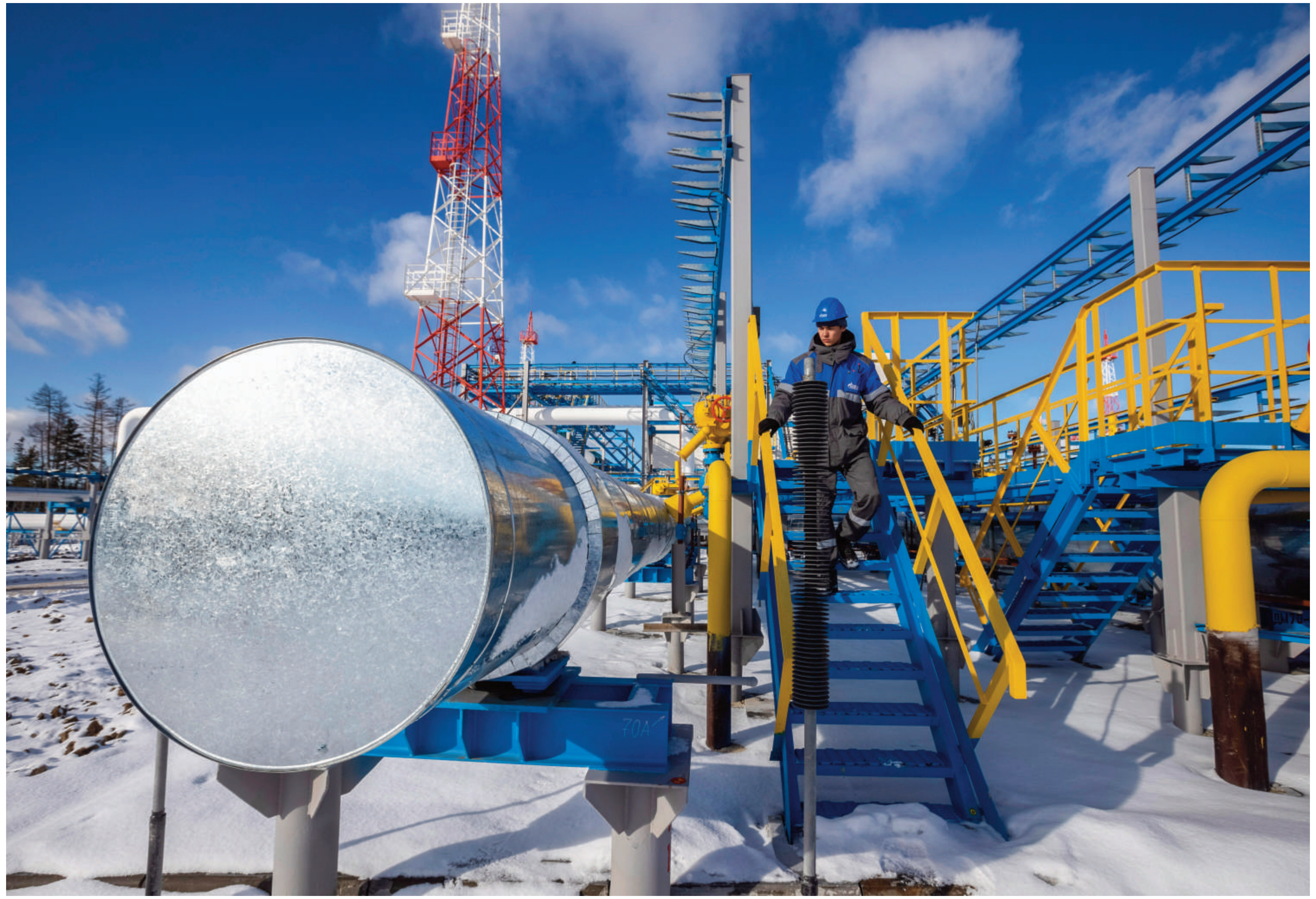
WINSTON CHURCHILL GAVE the first definition of energy security a hundred years ago. He was at the head of the British Royal Navy when he warned that "certainty and security consist in variety, and variety only, of supplies." It was the first energy transition of the modern era, from coal to oil. In the last two decades, intoxicated by the "end of history" and globalization, which made the world increasingly flat, we forgot that lesson. Still, many of us should have remembered the energy shocks, the cold war, and the geopolitical crises of the twentieth century.

Guided by purely financial logic and the invincible optimism of Western cultural supremacy, we believed in the prospect of creating an increasingly interconnected and specialized world. A peaceful world ruled by Western values, with free market eclipsing any geopolitical risk. A world that allowed the West (and especially Europe) to achieve deindustrialization, moving away from mining and the other major energy-related activities that marked our development in centuries past.

Better to import than to produce, heading for the more attractive world of the tertiary sector, and, thanks to the digital revolution, its sublimation into the quaternary sector. Finance and business, the two gods of our metaverse. A light, clean and silent world that allowed us to reap the advantage of receiving goods at ever lower costs. It is amazing to think that we are now struggling with double-digit inflation, when only a couple of years ago there was talk of a permanent period of deflation driven by productivity gains and continued globalization. In short, a win-win situation, even with some occasional doubts about the environmental and labor standards of the "world's factories," but with an optimistic narrative predicting that said standards would grow and improve with the social and economic progress of emerging countries.

IN NINE MONTHS, THE SCENARIO CHANGES

The Net Zero Emissions by 2050 Scenario of the International Energy Agency (IEA), a manifesto for the festival of optimism,



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Sakha Republic, Russia. Gas pre-treatment unit at the Chayandinskoye field owned by Gazprom PJSC. Before the crisis in Ukraine, the large Russian fields supplied 40% of the gas consumed in Europe, 46% of coal and 27% of oil.

Yangzhong, China. Solar panel installations in a city park. China holds 66 percent of the global construction capacity for solar panels, and 88 percent of that for electric car batteries.

was proudly presented in May 2021 as the "most technically feasible, cost-effective and socially acceptable" roadmap to reducing carbon emissions. It is paradoxical that the plan of the IEA, the institution created in 1974 to manage the oil shock, did not even consider energy security, recommending instead that approval of new oil, gas and coal projects be stopped (!), leaving the few and large energy-producing countries in charge. Some elements of risk were surely pointed out, like dependence on OPEC rising from the current 37 percent to 52 percent in 2050, the highest in history, and on China for all the minerals and key production processes for renewables and batteries, and not even a passing mention of dependence on Russian gas. Alas, the IEA pamphlet said with conviction, "the unshakable focus of all governments towards the common goal of decarbonization will prompt all players to co-operate efficiently." No comment on how this could have happened with a slump in oil revenues expected for some key regions.
The IEA plan, which the Saudi oil minister had ironically labeled "LaLa Land," crashed into the reality of geopolitics on February 24, 2022, less than nine months after its launch. We went back to the 1962 missile crisis in a heartbeat, with the fear of an energy shock like in 1973. The IEA's request not to approve new fossil projects or to reduce subsidies was met right away with Europe reopening coal plants, release of strategic oil stocks in OECD countries and multi-billion-dollar plans to protect consumers from rising bills (in the rich, advanced countries). LaLa Land suddenly turned into the updated version of Mad Max.

In the space of a moment, we discovered the dependences and fragility of the world we have created. Europe realized its connection to the great Siberian gas fields, with 40 percent of consumption guaranteed by Russian methane (with peaks of 65 percent in Germany), not to mention 46 percent of the coal and 27 percent of the oil also coming from Russia. As energy goes, Eurasia is a more fitting term than Europe.

THE NEW DEPENDENCES

However heavily dependent we are on fossil fuel imports, we are even more so on rare earth minerals for the global energy transition and electric motors, with 60 percent produced in China, which processes 90 percent, along with 70 percent of the cobalt, 60 percent of the lithium, and 40 percent of the nickel and copper. Europe's dependence on the most critical transition metals fluctuates between 70 and 100 percent. This means that China holds 66 percent of the global construction capacity for solar panels and 88 percent for electric car batteries.
What about steel, essential to build old and new industries? 50 percent of world production belongs to China, from which Europe does import relatively little, but dependence on foreign countries has risen to 25 percent of total consumption in recent years, with Russia and the occupied areas of Ukraine among the main suppliers, especially for semi-finished steel products, respectively 40 percent and 27 percent.
Europe produced 40 percent of the world's computer chips, fundamental for artificial intelligence, energy transition and defense, in the early 1990s; now we are down to 9 percent. Similarly, the United States dropped its production from 37 to 12 percent. The largest producer is now Taiwan, a potential area of conflict, with 60 percent of the world's semiconductors. Basically, we have diversified our electronic supplies in a country that has always been disputed by the Asian power from which we receive most of our industrial and mineral materials.

THE STRATEGIES OF THE U.S. AND EU

It is now clear that our plans will need to be revised. Free trade no longer means security, which people thought it did even right before WWI. We need to bring industrial processes back home and start working on diversification of supplies.
Although the U.S. has reduced its foreign energy dependence for several decades thanks to the practice of fracking (and becoming a net exporter of gas in the process), it is reacting rapidly, promoting chip production expansion plans, possibly mining rare minerals and soon reviving national energy production.
Nonetheless, Europe's narrative is still stuck on February 23. Even though the EU plans to double production of semiconductors to 20 percent, allocating €43 billion, barely thought to be enough for a few incremental points, there is of yet no strategy on the cost of energy, which you need to build industries.

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Europeans have argued for months to exclude nuclear and gas from the green taxonomy, on top of oil and coal, of course, which leaves little to work with as far as the energy security agenda. An agenda that presupposes unshakable trust in China for the entire renewable energy supply chain, and the capacity to develop new technologies, such as hydrogen, which require extensive reorganization of demand, supply and networks.
In the absence of low-cost energy, i.e., fossil fuels, to power industrial activities, any plan is bound to run aground. It will take a lot of patience, and a radical reset of priorities to get this continent back on track. In conclusion, again Churchill: "The history of humanity is a history of war." It is best to keep this in mind when we make long-term plans, including decarbonization, trade, and industrial processes.

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He is Chief Financial Officer at Eni. Previously he was the Americas Upstream Director of Eni, Vice President of Strategic Options & Investor Relations at Eni and, before that, in charge of the E&P portfolio at Eni.

KEY PLAYER in the transition

by Francesca Zarri

THE ROLE OF TECHNOLOGICAL INNOVATION TO CONCRETELY ADDRESS THE ENERGY "TRILEMMA," THAT IS, THE NEED TO KEEP TOGETHER SUSTAINABILITY, SECURITY OF SUPPLY AND AFFORDABILITY FOR ENERGY PRODUCTS AND SERVICES

I WOULD LIKE TO ADOPT two perspectives for considering the role of technological innovation in the energy transition, a transition that Eni understands in the noblest sense of "just transition," that is, sustainable and socially and economically fair. The first is the perspective of Eni, a company engaged in a profound transformation. The second is the international perspective, which involves the energy sector, with implications that, today like never before, are becoming clear in our lives.

Our company is engaged in a profound project dedicated to change that arises from an awareness of our responsibility to pay attention to the various demands on energy issues brought by the communities that host us and by the interlocutors with whom we interact. The word "responsibility" is a recurrent term in this reflection because it is inextricably linked to Eni's role as an entity capable of creating all-around value, not just financial considerations, with an "inclusive transition" approach. Inclusiveness and the ability to innovate processes and technologies have always been our hallmark.

In order to address concretely the energy "trilemma," to keep together sustainability, security of supply and affordability for energy products and services, Eni has chosen the path of technological and digital innovation, a tool of transformation that helps us respond to challenges and be resilient in the current and future landscape, a future characterized by growing geopolitical and regulatory uncertainty and continuous transformation. This choice keeps us firmly and credibly on the "net zero" path that we have set for ourselves and enables us to remain faithful to the strategic framework built by our Mission and by the vision of our top management. The ability to innovate allows us to "reinvent ourselves" without losing solidity and to maintain our identity as an Italian industry, recognized worldwide for its excellence and as a model and engine for change for entire industrial sectors in Italy.

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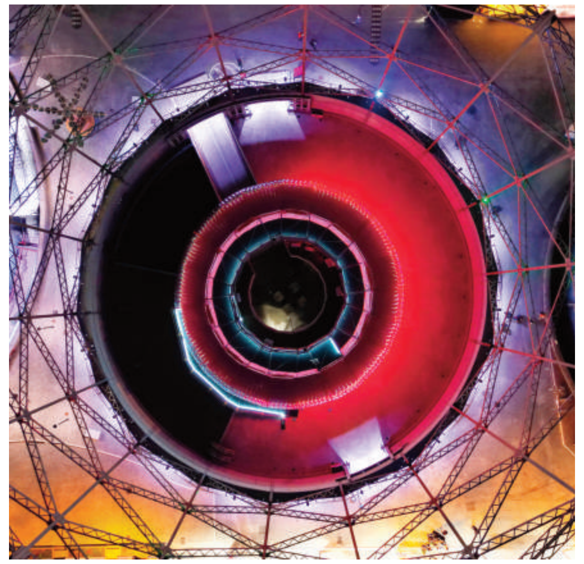
ENI'S APPROACH TO TECHNOLOGY AND ITS REFLECTIONS

Eni has the capacity to conceive and develop technologies internally, especially a strength for those "incremental" technologies that are making our exploration and production activities in the traditional, increasingly gas-oriented environment ever more efficient and sustainable, as envisaged by our strategy. The strength of our innovative drive, however, goes far beyond improving existing processes and products and extends to the domain of disruption and a net change in industrial paradigm and business trajectories. In summary, Eni pursues three degrees of innovation: incremental, which innovates and improves traditional processes; disruptive, which radically modifies existing processes or products, to create new sustainable business models; breakthrough, which has the potential to drastically improve the overall energy paradigm.

ONE EXAMPLE OF A "DISRUPTIVE" APPROACH: BIO-REFINERIES

Our technologies form the basis of the conversion of the Gela and Venice plants into biorefineries and planned work at the Livorno plant. However, our world leadership in the process of profound change in the way we produce fuels, with a view to decarbonization, is not exclusively technological. The technologies become an integral part of a much more articulated and complex supply chain, with which Eni intends to create a resilient and sustainable value chain for bio-feedstock that will increasingly power our plants, helping us to abandon the use of palm oil as early as 2023. To build this supply chain we must: develop new expertise, such as agricultural skills, within our structures; interact with the communities that will work the land; demonstrate skills in project management and industrial scale-up that benefit both our people and our local contacts, with whom we share creative effort and vision.

The example of Kenya—where in July 2022, production of bio-feedstock began from the first agri-hub, just one year after the signing of the MoU between Eni and the government—demonstrates our ability to move quickly from the experimentation of an idea to its application, speed which benefits the sustainability of our products, but also improves the economic and social conditions of thousands of people who collaborate locally with Eni.



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FUSION: A REAL "BREAKTHROUGH"

But we can go further; we can achieve a veritable breakthrough, the discontinuity that has the potential to change the energy paradigm forever. In our strategy, we consider the possible advent of these technologies an added bonus, because we do not want to rely on them as a panacea; at the same time, we work to ensure that they take shape and adopt an industrial approach to enable them to materialize in a shorter timeframe than has been generally accepted up to now.

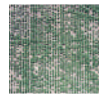
This is the case of magnetic confinement fusion, on which we are working both directly—with Eni researchers, together with national and international excellences such as CNR, ENEA and MIT of Boston—and by "injecting" our experience in highly complex projects and our supply chain vision in Commonwealth Fusion Systems (CFS), the spin-out of MIT, in which we have been investors since 2018 and with which we collaborate with a much more articulated and "innervated" approach to their vision and their activities than usually occurs from a purely financial partner.

Magnetic confinement fusion promises a real revolution in the energy field because, once developed on an industrial level, it

HPC5, the supercomputer at Eni's Ferrera Erbognone Green Data Center. With just one Watt of electricity, it calculates nearly twenty billion operations per second. Digital innovation plays a decisive role in Eni's energy transition strategy.

Aerial view of Tokamak – installation created by Carlo Ratti Associati and the architect Italo Rota together with Eni – at the Maker Faire Rome 2022 at the Gazometro Ostiense. It is a conceptual structure in which the public can learn about magnetic confinement fusion. The tokamak, whose shape inspires the project, is the donut-shaped chamber in which the magnetic confinement fusion reaction takes place.

Castor fruit grown at the SK AGRI farm in Boulankio, Pool province, Congo. Eni is developing agricultural projects in various African countries for the production of agri-feedstock: plants from which to extract the vegetable oils needed to produce biofuels.



Marula Farm, Naivasha County, Kenya. The technologies become an integral part of an articulated and complex supply chain, with which Eni intends to create a resilient and sustainable value chain for bio-feedstock that will increasingly power bio-refineries.

would provide a clean, safe and virtually unlimited source of energy, exploiting a physical process similar to that which keeps the stars alight. However, fusion is very difficult to replicate on Earth: according to the scientific community, it is one of the greatest technological challenges that humanity has ever faced and involves different disciplines and fields of research.
Over the last few years, alongside international programs financed by governments, such as ITER, action has been taken by numerous private entities, which intend to achieve fusion using different methods and timing from those seen in "historical" programs. CFS plans to build and test the first pilot plant (SPARC) by 2025, which will serve as a testing ground for the development of ARC: the first fusion plant on an industrial scale capable of feeding carbon-free electricity into the grid, which is expected to be built at the start of the 2030s.
Eni was the first energy company to believe in fusion, investing in CFS, but above all, framing its work as a "program," which also includes collaboration with ENEA on the experimental DTT reactor that will be built in Frascati and with the CNR and MIT, to study various aspects of preparation of the fusion process. The work on fusion is a precious opportunity for growth for the Eni people involved and for all those with whom we interact. To this work on fusion, we bring our industrial vision, according to which research must never remain an end in itself, but arrive quickly "on the market," because the energy transition requires speed and incisiveness.

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SUPERCOMPUTING, A GREAT "ENABLER"

For Eni, digital innovation plays a decisive role; in fact, with digital technology, we can make connections and data sharing with an ease and extensiveness which were unthinkable until only recently; this facilitates innovation, helping us to develop the right tools for our energy transition. Digital technologies, if applied in a framework of redesign of processes and products, can simplify these processes and improve the efficiency of our operations, helping the careful management of resources and the general improvement of our sustainability profile. We recall that the IEA defines energy efficiency as "the first fuel" for the transition, with an expected contribution of 30 percent of the global primary mix as early as 2030, in its Net Zero scenario. For the IEA, energy efficiency is critical, as it provides some of the fastest and cheapest CO_2 mitigation options, while reducing bills and reinforcing energy security.
Eni can rely on its digital tools for both traditional activities and innovative businesses, relying on a great "enabler," supercomputing, made possible by HPC4 and HPC5, the supercomputers hosted in our Green Data Center in Ferrera Erbognone. But in the supercomputing sector we now want to move the bar higher: we are studying possible applications of quantum computing with various initiatives, which include in particular our investment in Pasqal, a company now known to the general public due to one of its co-founders, Alain Aspect, winning the Nobel Prize for Physics 2022. In the digital field, Eni also collaborates with various associations with a view to co-innovation (CINECA, IFAB, COTEC) and continues to nurture important synergies at national and EU level to catalyze ideas, skills and innovations.
With this in mind, we participate in the National Center for High Performance Computing, Big Data and Quantum Computing, one of the five National Centers envisaged by the National Recovery and Resilience Plan (PNRR).

PEOPLE: ACTORS OF INNOVATION

In Eni's transformation project, driven by research and innovation, the real protagonists are and remain our people. The capacity for dialog between different experiences, work paths, and generations is an enormous wealth, which is strongly promoted by the organization of our company. Innovation passes through the curiosity that arises from skills and the desire to go further; our management therefore has the responsibility of valuing the efforts of everyone, without fearing the drive for change. Innovation is the very essence of our processes, and we continue to pursue it internally; but at the same time, we are increasingly open to the outside and, in order to seize the best external stimuli, we have created a complete and flexible organization.

DIALOG WITH THE OUTSIDE WORLD AND INNOVATION ECOSYSTEMS

Combining our internal research and innovation skills with collaboration with universities and leading institutions is a choice that reinforces our path of innovation. This is why we have begun to include projects of joint research centers in the recent agreements signed with institutions of academic excellence, such as the Politecnico di Milano, the University of Padua, the University of Bologna and Bicocca University.
Dialog with the outside world also takes place through Open Innovation processes for monitoring young talent and innovative start-ups. This is the reason for Joule, our business school for the growth of new start-ups; Eninext, the CVC that invests in high-potential start-ups for game-changer technologies; Eniverse, the CVB that also supports and concretizes outbound innovation; the New Energy One Acquisition Corporation, our SPAC listed in London to raise capital to invest in innovative initiatives in the scale up phase. With the outpost in San Francisco, we then activated an "antenna" for trends and key players of high-tech, fin-tech and deep-tech in one of the most fertile areas for innovation.

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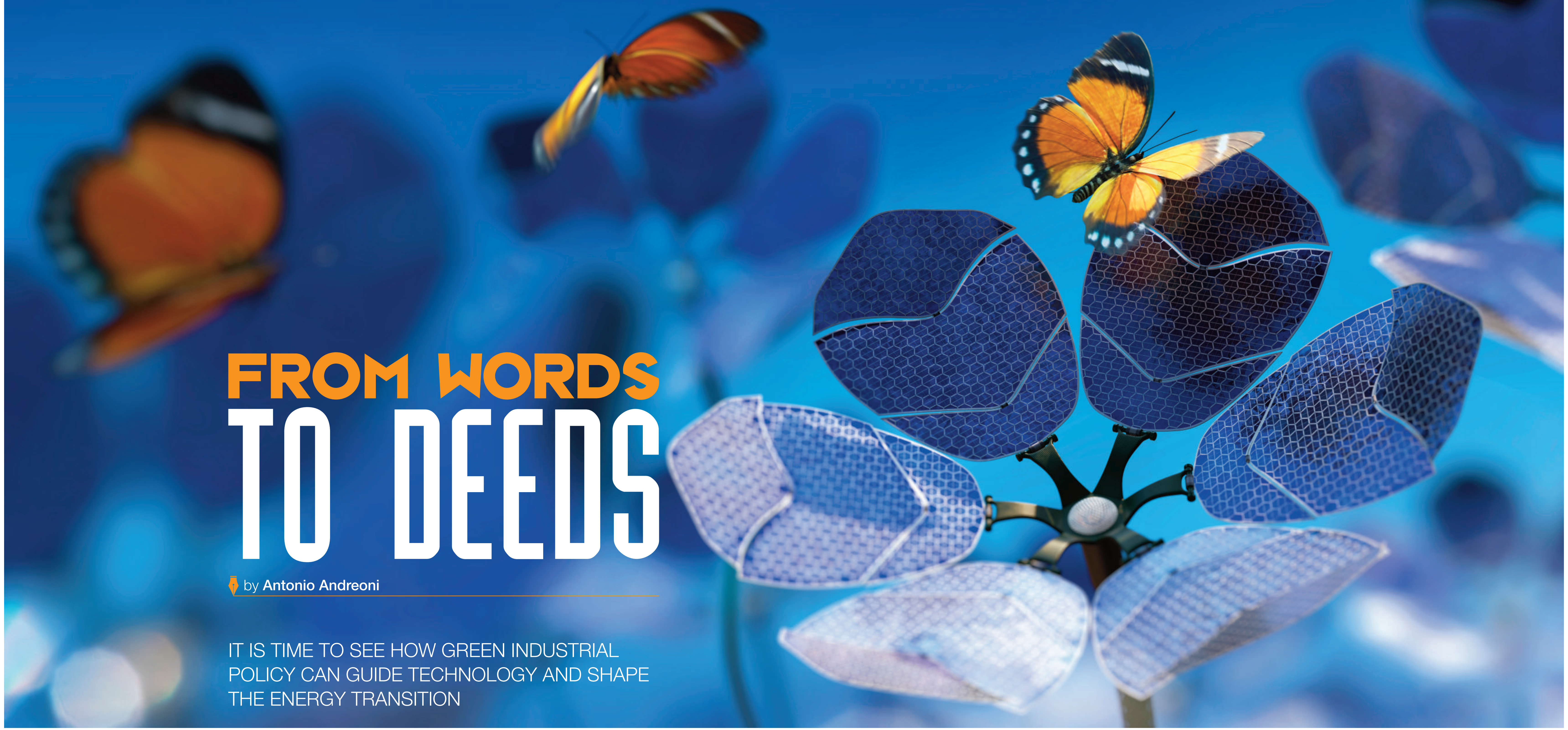
THE INTERNATIONAL PERSPECTIVE

Eni's activities are positioned in an international context in which we reinterpret our role from an energy company to a Tech Company, in a landscape marked by a desire for "discontinuity" with respect to the world of fossil fuels. This discontinuity, invoked by many, does not pay sufficient attention to the context and complexity—if not impossibility—of decarbonizing energy only through the massive use of renewables.
Unfortunately, reality has recently presented us with the bill. Today, in the face of two epochal events such as pandemic and war, alongside the demand for decarbonization, there is the urgent need to respond to the global and European energy crisis in particular.
It should now be clear to everyone that the challenge of the energy transition plays on a delicate balance of "fading out" from the old to the new, supported by extremely complex investment dynamics. In such a complex framework, companies in our sector, as Eni has done, must become technology-driven, to provide an innovation portfolio with tools to tackle decarbonization and the energy emergency in a balanced manner. Our sector has the responsibility of supporting the energy transition in the current emergency because it has the experience, capacity, financial strength and innovative drive to govern this very delicate phase.
The large energy companies, however, operate within an enormous paradox: on the one hand, they are considered by large layers of public opinion and politics as part of the problem; on the other, they are considered key players in defining and pursuing the path of global transition, since they possess the levers of innovation—enabling transformation—and the industrial capacity to make it concrete, maintaining the necessary continuity of energy systems. Resolving this paradox is the prerequisite to ensure that their proposals for solutions to energy and environmental issues are finally valued in a "secular" manner (without ideological preclusions). Continuing to invest in research, innovation and technologies is the best —if not the only—way to successfully tackle the energy trilemma, which will continue to accompany us for a long time to come.

we

FRANCESCA ZARRI
Director of Technology, R&D & Digital at Eni. Having joined the Group in 1997, since April 2020, Zarri has been President of Eniservizi, President and CEO of SPI, Eni representative in Assomineraria. Since 2014, she has been a director on various boards of directors of Eni subsidiaries, both Italian and foreign.



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FROM WORDS TO DEEDS

by Antonio Andreoni

IT IS TIME TO SEE HOW GREEN INDUSTRIAL POLICY CAN GUIDE TECHNOLOGY AND SHAPE THE ENERGY TRANSITION

CLIMATE CHANGE is the defining challenge of our time. The 2022 report of the Intergovernmental Panel on Climate Change (IPCC) indicates that Nationally Determined Contributions (NDC) in effect prior to COP26 are insufficient to limit temperature increases to 1.5 degrees Celsius above preindustrial levels. If climate policies are not strengthened, the median global warming could hit 3.2 degrees Celsius by 2100. The International Energy Agency (IEA)'s Net Zero 2050 Roadmap also stresses the need for a dramatic acceleration and large financial investments in energy transition. While the global community talk about climate change and the risk of reaching tipping points, climate change is increasingly impacting countries, social groups, industries, and places in multiple and asymmetric ways. Inequalities, both within and across countries, are widening as a result of the widespread impact of climate change, with the most vulnerable paying the highest cost.

THE POLICIES OF THE EUROPEAN UNION

In 2019 the European Commission has put forth the EU Green Deal (EGD) as the flagship strategy to drive the EU's climate action. The EGD, alongside the European Climate Law and "Fit for 55" package, commit the EU to a 55 percent net reduction in GHG by 2030 with climate neutrality achieved by 2050. The EGD expects action in multiple interdependent areas, including energy production, transport, agriculture, buildings, finance, innovation and others. Against the risks that the current invasion of Ukraine by Russia poses to the EU's energy system, the EGD has recently been bolstered by the REPower Europe (EC, 2022). Issued in May 2022, REPower Europe seeks to increase energy savings, diversify energy supply sources, speed up the substitution of fossil fuels by renewable energy sources and promote smart investments and reforms, such as improving grid infrastructure and connection across European countries. Member States are also required to review their existing Recovery Plans and their National Energy and Climate Plans.

These measures result from an increasing recognition that markets alone have failed to internalize environmental costs and steer economies towards a much-needed energy and industrial transition, at the scale and speed required. Markets and market-fixing policies such as carbon pricing alone have also proven incapable to provide a solution to the most pressing political economy challenge countries and regions face, restructuring their industrial sectors towards new models of sustainable prosperity. For the supply side, feasible pathways must be opened for firms and workers towards new production, technological and organizational models. These pathways need to favor and direct new "green entrants" while at the same time manage the exit of "brown firms" from specific industries or technology paradigms. In most cases, turning the existing brown firms into green firms will call for "deep" industrial restructuring. From this perspective, energy transition is a quintessential "wicked" problem whose solutions call for coordinated and targeted interventions that include the management of complex trade-offs, both static and dynamic, and the advancement of a new sustainable and inclusive social contract. Green industrial policy can provide a framework and practical tools to address some of the fundamental challenges of energy transition in Europe and beyond. Specifically, green industrial policy can help in targeting, accelerating and coordinating the restructuring of highly heterogeneous and place-based industries, including the energy system. Each industry and the firms within them are part of complex industrial ecosystems involving interdependent production, consumption and technological activities spanning along and across regional and global value chains. While decisions about these activities and their impact on climate change are interdependent, achieving coordinated decisions across actors is almost impossible, given dispersed and unaligned interests, power, and ownership.

THE KEY ROLE OF THE STATE

Historically, in all of today's advanced economies, the state has played a key role in addressing these structural transformation challenges through various industrial policies. The state at different levels of governance can play a key inter-temporal and spatial coordinating function beyond fixing markets. The state can reshape industries, align incentives among institutions and organisations, build coalitions of interests and provide direction to technological and organizational innovation. This does not necessarily mean preselecting technological pathways at the exclusion of others or limiting private sector initiative. On the contrary, the state can steer the search for both sector-specific and cross-sectoral solutions; de-risk experimentation and innovation efforts; crowd-in private investments by committing resources in infrastructural investments or creating demand via procurement; promote competition among alternative solutions

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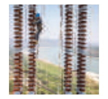

Chongqing, China. Cabling operation for the Chongqing section of the Baihetan-Zhejiang 800 kv ultra-high voltage direct current (UHVDC) transmission line across the Yangtze River. This line is expected to transfer more than 30 billion kWh of clean electricity annually from western to eastern China, reducing coal consumption by approximately 10.57 million tons and carbon dioxide emissions by approximately 19.19 million tons.

South Beach development in Singapore, designed by British architect Norman Foster. A wide pedestrian avenue—a green spine—weaves through the site and is protected by a large canopy, which shelters the public spaces beneath from the extremes of the tropical climate, allowing significant energy savings.

and enable the absorption and diffusion of the most appropriate innovative technologies.

Since 2009, the dramatic decline in the cost of electricity from renewables—solar photovoltaics and wind, on-shore in particular—has offered a viable pathway for accelerating energy transition. The steep learning curves associated with these technologies and their increasing installed capacity are responsible for a dramatic shift in prices and the opening of new windows for green opportunities. Complementary investments and advancements in digitally-enabled energy infrastructures—the so called “green-digital twin”—are also playing an important role. Furthermore, green hydrogen is increasingly seen as a feasible option to replace fossil fuels, especially in high-energy intensive difficult-to-abate industries such as steel, metal foundries, cement, and chemicals and liquid fuels for heavy transport. Given the expectation that in the coming decade green hydrogen will be competitive with fossil fuels for heavy industries, based on reasonable expectations related to carbon taxes, future industry competitiveness depends on decisions that must be taken now.

Green technology innovation and diffusion should not be seen from a supply-side perspective only. These technologies are major sources of new intermediate and final demand for green products and services and that will lead to investments and job creation. Globally, the energy sector employed over 65 million people in 2019, with over 50 percent occupied in clean energy activities such as manufacturing of solar and wind technologies (7.8 million) and electric vehicle manufacturing (13.6 million) (IEA, 2022). New clean energy projects, especially in China, are a major driver in this surge in green jobs. Re-skilling workers and creating energy employment through green industrial policy investments is central to accelerating a green energy transition.

These multiple goals can be achieved with different industrial policy instruments and packages including public finance and public procurement, setting green standards, and providing technology services along the entire innovation/production chain, from basic research to full deployment and diffusion of new technologies. The emphasis is often on the quantum of finance; however, the main problem is the direction that financial investments take and the extent to which finance gaps are addressed in a targeted manner. Indeed, public financing is not simply important in terms of delivering a portfolio of viable innovative solutions and crowding in private investors. It is also critical in addressing problems associated with effective scaling up, deployment and diffusion of new technologies. Public procurement can also play a central role in energy transition and can be used to perform different functions. For example, it can create or increase the demand for products, both goods and services, as well as emerging technologies. Public procurement can also be designed around problems and solutions—i.e. functional procurement—something that is already contemplated, but little used, in the EU. The state can also set the standards and regulatory requirements (e.g. emissions, performance targets, energy intensity) under which new goods and technologies are both produced and deployed. Standards setting is of central importance: it can be used to shape the emerging markets and industry, but also to provide coordination across innovation and technology investments, shifting competition away from areas where industry coordination delivers better payoffs. Technology services and access to infra-technologies via institutions like the Fraunhofers in Germany and manufacturing extension schemes greatly matter in the scaling-up of a decentralized and more resilient energy system and the adoption of sustainable manufacturing processes and technologies among small and medium enterprises.

FOCUS ON CONDITIONALITIES BETWEEN PUBLIC AND PRIVATE

In the design of these green industrial policy instruments, an “entrepreneurial-regulatory” state can rely on various types of conditionalities reflecting risks and rewards associated with the green energy transition. These conditionalities can operate beforehand by setting different types of requirements on the types of firms who can access incentives or by selecting the types of activities supported. They can also operate after implementation by setting specific requirements on firms’ future performances or corporate governance decisions (e.g. limiting stock buybacks or dividends distribution). Attaching conditionalities to policies such as financing and procurement, but also company bailouts, investment attraction schemes and business restructuring is no longer taboo; international experiences from Austria and France during the COVID pandemic are testament of such public-private conditionalities. Conditionalities are a way to steer financial resources strategically and make sure that they are retained and reinvested within productive business organizations towards socially, economically and environmentally desirable outcomes.

Such a strategic approach to green industrial policy goes far beyond the hands-off innovation policies which have been dominant over the last two decades in Europe, until the COVID-19 pandemic and the acceleration in the climate and energy crisis. One of the main lessons learned during the pandemic is that the type of targeted and coordinated interventions that extreme events like a pandemic or climate change require cannot be implemented by a government with limited capacity. Rebuilding the state capacity to think, design and implement industrial policy instruments is in itself a much needed industrial policy. This is particularly the case for those peripheral regions or countries in Europe who need to learn or re-learn how to use industrial policies to address the most pressing and overlapping crises of our century. Shifting away from an unsustainable economic model centered on fossil fuels is the key to overcoming climate change and mitigating its dramatic impact on societies and countries. It is time to walk the talk.

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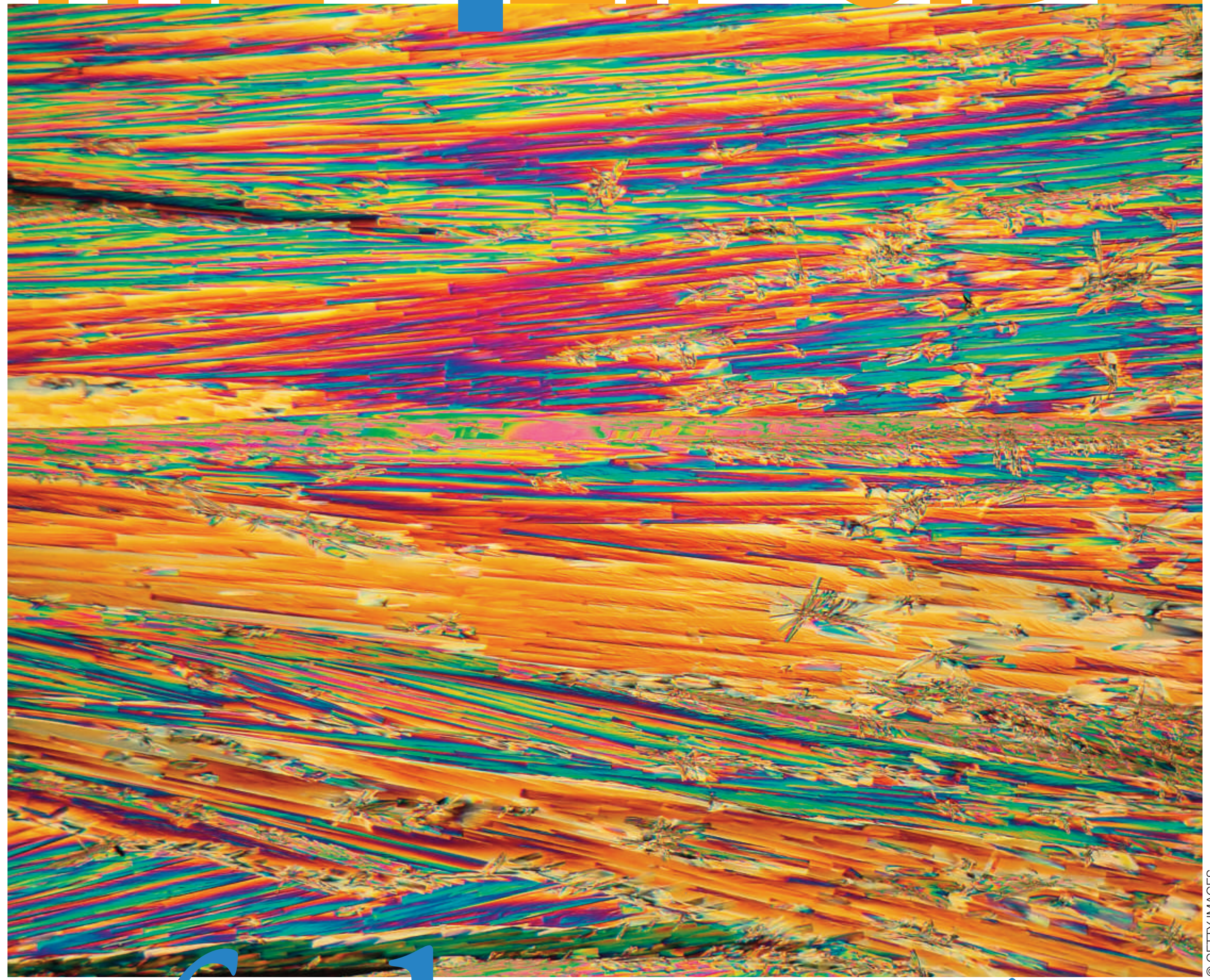
THE FLIP SIDE of the coin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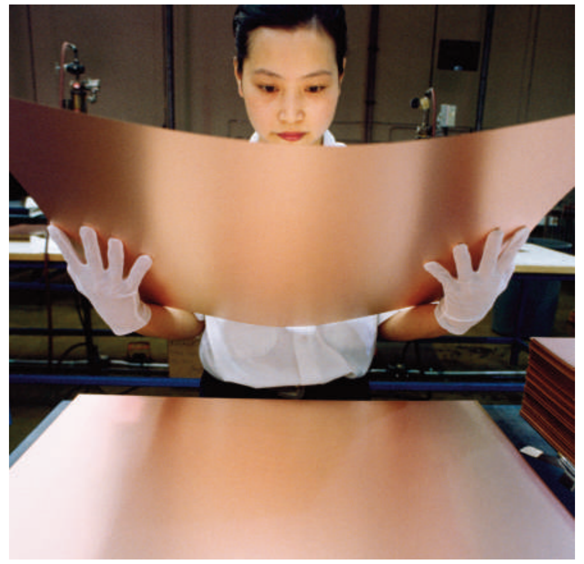
by Tae-Yoon Kim

RISING DEPLOYMENT OF CLEAN ENERGY TECHNOLOGIES IS SET TO SUPERCHARGE DEMAND FOR CRITICAL MINERALS, WITH RISKS IN TERMS OF AVAILABILITY AND RELIABILITY OF SUPPLIES

AN ENERGY SYSTEM powered by clean energy technologies differs profoundly from one fueled by traditional hydrocarbon resources. Building solar PV plants and wind farms and electric vehicles (EVs) generally requires more minerals than their fossil fuel based counterparts. A typical electric car requires six times the mineral inputs of a conventional car, and an onshore wind plant requires nine times more mineral resources than a gas-fired power plant. Since 2010, the average amount of minerals needed for a new unit of power generation capacity has increased by 50 percent as the share of renewables has risen.

The types of mineral resources used vary by technology. Lithium, nickel, cobalt, manganese and graphite are crucial to battery performance, longevity and energy density. Rare earth elements are essential for permanent magnets that are vital for wind turbines and EV motors. Electricity networks need a huge amount of copper and aluminum, with copper being a cornerstone for all electricity-related technologies.

The shift to a clean energy system is set to drive a huge increase in the requirement for these minerals. In the IEA's Stated Policies Scenario, overall requirements for critical minerals for clean energy technologies nearly triple between today and 2050. In the IEA's Net Zero by 2050 Scenario, a scenario that achieves net zero emissions globally by 2050, record levels of clean energy deployment require around five times more mineral inputs in 2050 than today.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The prospect of a rapid increase in demand for critical minerals—well above anything seen previously in most cases—raises questions about the availability and reliability of supply. Current supply and investment plans are geared towards a world of gradual and insufficient action on climate change, raising the risks of supply lagging behind projected demand in climate-driven scenarios. The challenges are compounded by long lead times for the development of new projects, declining resource quality, growing scrutiny of environmental and social performance and a lack of geographical diversity in extraction and processing operations. For example, the world's top-three producing nations control well over three-quarters of global output for lithium, cobalt and rare earth elements. The level of concentration is even higher for processing operations, with China having a strong presence across the board.

In the past, strains on the supply-demand balance for different minerals have prompted additional investment and measures to moderate or substitute demand. But these responses have come with time lags and have been accompanied by considerable price volatility. Similar episodes in the future could delay clean energy transitions and push up their cost. Given the urgency of reducing emissions, this is a possibility that the world can ill afford.

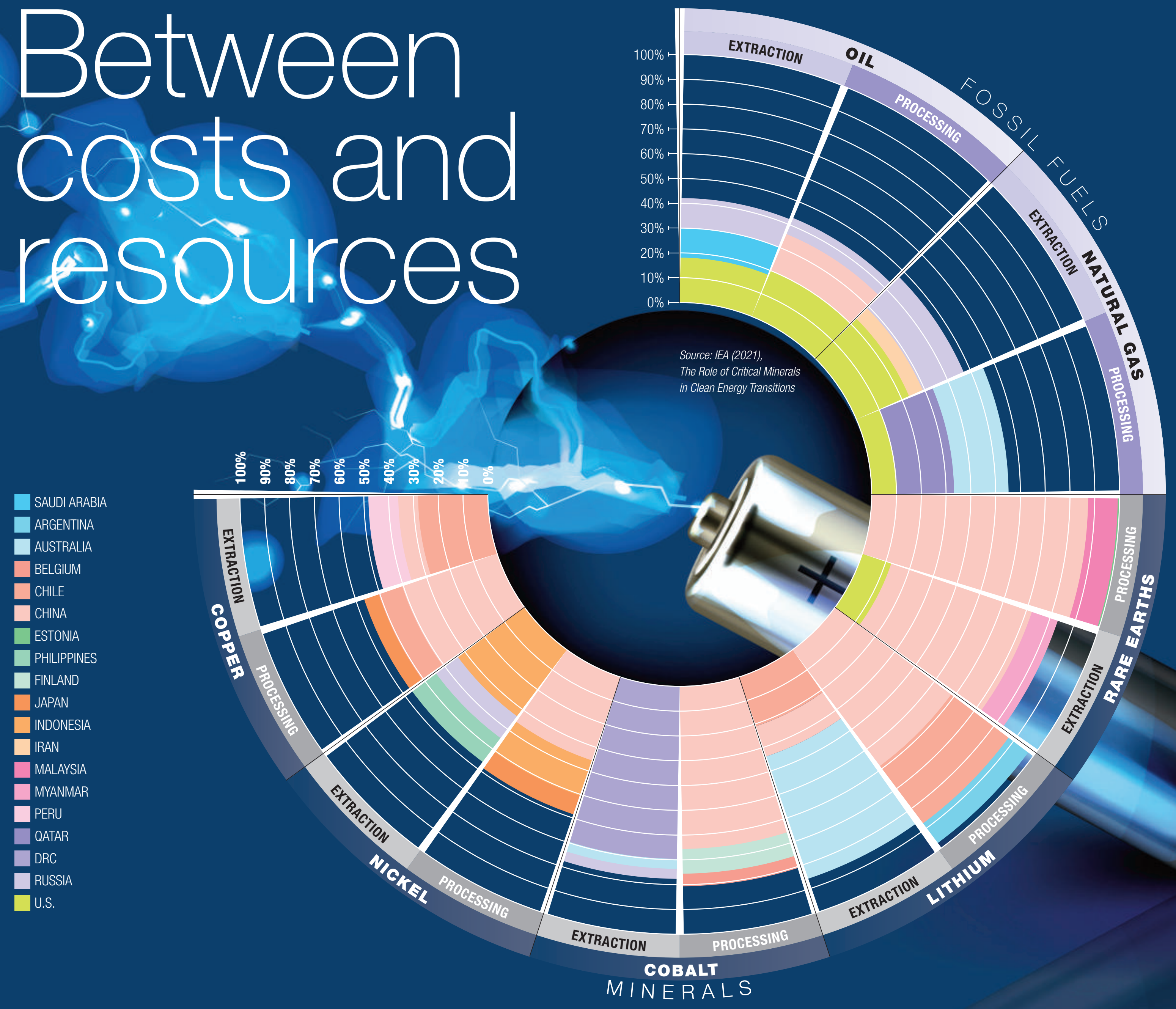
THE SOARING COSTS OF GREEN TECH

Prices of many minerals and metals that are essential for clean energy technologies have recently soared due to a combination of rising demand, disrupted supply chains, heightening geopolitical tensions and concerns around tightening supply. The prices of lithium and cobalt more than doubled in 2021, and those for copper, nickel and aluminium all rose by around 25 percent to 40 percent. These elevated prices continued into the first few months of 2022 although they somewhat moderated in recent months. The increase in lithium prices has been particularly astonishing, with prices going up two-and-half-times between January and April. For most minerals and metals, price increases since the start of 2021 have outpaced or been comparable to the largest annual increases seen in the 2010s.

Market tensions are exacerbated by questions over Russian supply. Russia is the world's leading producer of palladium (43 percent), used for catalytic converters in cars. It is the largest producer of battery-grade Class 1 nickel, with 20 percent of market share. Russia is the world's second largest producer of aluminium (6 percent), and the second and fourth largest producer of cobalt and graphite respectively.

The surge in prices for critical minerals is taking a toll on the cost of clean energy technologies, reversing a decades-long trend in cost declines. In 2021 prices for wind turbines and solar PV modules rose by 9 percent and 16 percent respectively. Prices for lithium-ion batteries are likely to see a major uptick in 2022 as the impact of rising raw material prices are reflected in final prices. Taking one example, the share of cathode materials in the cost of lithium-ion battery packs was less than 5 percent in the middle of the last decade, when there were only three battery gigafactories in operation or under construction globally. The share has risen to over 20 percent today, when some 300 gigafactories are at different stages of planning and construction as of April 2022. The higher prices for cathode materials in early 2022 caused upward cost pressure on lithium-ion battery packs estimated at 20 percent compared with 2020 levels and 15 percent compared with 2021 levels. In China the

Between costs and resources



MINERALS AND FOSSIL FUELS: PRODUCTION QUOTAS

The extraction and processing of critical minerals are concentrated in just a few countries. The world's top three producing nations control well over three-quarters of the world's production of lithium, cobalt and rare earths and an even greater share of the processing, with the absolute dominance of China.

relentless rise in lithium prices is already translating into higher prices for EVs, with Tesla and BYD announcing price hikes of 2-5 percent in March 2022.

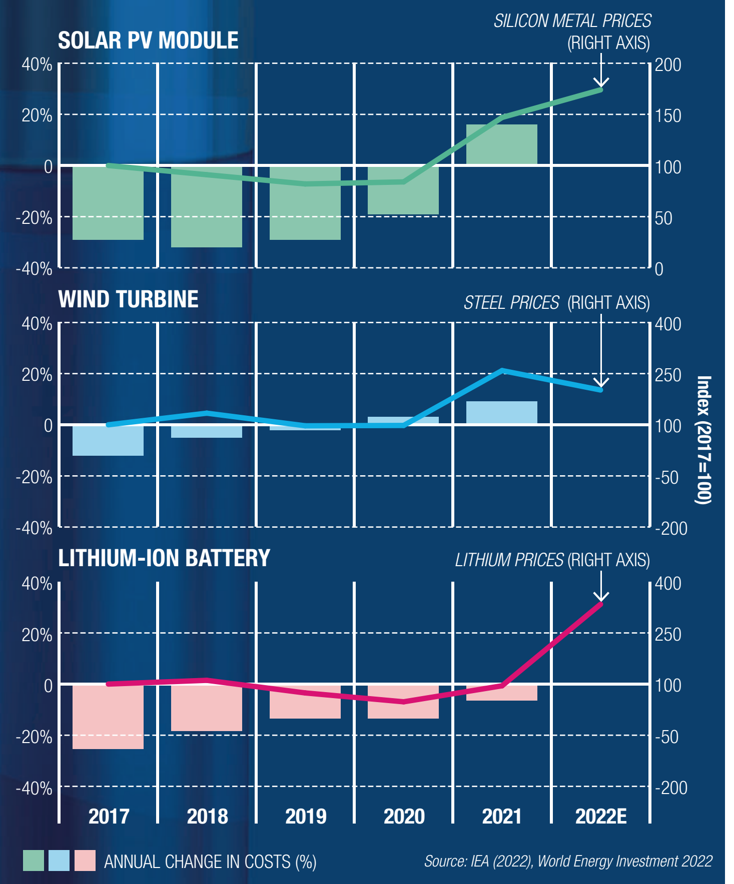
This does not mean that further reductions in the cost of clean energy technologies are unattainable, but these efforts are increasingly facing an uphill near-term battle as raw material costs rise. High material prices require a redoubling of efforts to reduce costs by other means (e.g. technological innovation, efficiency improvements and economies of scale) to keep the overall costs on a continued downward trajectory. Otherwise, pronounced disruptions in supply chains and rising costs could increase the cost of clean energy technologies, potentially slowing their rollout and clean energy transitions more generally.

NEW AND MORE DIVERSIFIED SUPPLY SOURCES

As countries accelerate their efforts to reduce emissions, they also need to make sure that energy systems remain resilient and secure. The rising importance of critical minerals in a decarbonizing energy system requires energy policy makers and industry stakeholders to expand their horizons and consider potential new vulnerabilities. Concerns about price volatility and security of supply do not disappear in an electrified, renewables-rich energy system. The risks to mineral supplies are real, but they can be mitigated through comprehensive policies and actions by government and industry. The IEA's special report on the Role of Critical Minerals in Clean Energy Transitions presented key areas of action to ensure reliable and sustainable mineral supplies. Scaling up investment in new mining and processing facilities is vital. To attract capital to new projects, policy makers must provide clear signals about their climate ambitions and how their targets will be turned into action, while taking steps to strengthen geological surveys and streamline permitting procedures.

TECHNOLOGY COST TRENDS AND KEY MATERIAL PRICES

Rising costs of raw materials make it increasingly difficult, in the short term, to keep the trajectory of the overall cost of clean energy technologies steadily downward. The graphs show the correlation between the prices of silicon metal, steel and lithium and, respectively, a photovoltaic solar module, a wind turbine and a lithium ion battery.



Technology innovation on both the demand and production sides can bring substantial security benefits by promoting more efficient use of materials, enabling material substitution and unlocking sizeable new supplies. For example, 40-50 percent reductions in the use of silver and silicon in solar cells over the past decade have enabled a spectacular rise in solar PV deployment. Emerging production technologies, such as direct lithium extraction or enhanced metal recovery from waste streams or low-grade ores, can also offer the potential for a step change in future supply volumes.

Reuse and recycling can also relieve pressure on primary supplies while reducing adverse environmental and social impacts associated with mineral extraction and processing. For example, spent EV batteries could be repurposed for grid storage applications. Better collection systems and investment in new recycling plants and supporting infrastructure are needed to extract critical minerals from spent batteries and other clean energy technologies that reach the end of their life in the coming decades.

A BROAD STRATEGY

These measures should form part of a broad strategy that also encompasses supply chain resilience, transparency and sustainability standards. Efforts to incentivize higher environmental and social performance can increase sustainably and responsibly produced volumes and lower the cost of sourcing them. If industry players with strong environmental and social standards are rewarded in the marketplace, this can also bring new suppliers to a more diversified market.

There is no shortage of resources worldwide, and there are sizeable opportunities for those who can produce minerals in a sustainable and responsible manner. Because no single country will be able to solve these issues alone, strengthened international cooperation between producers and consumers is essential. This is what energy security looks like in the 21st century as the transition to a clean energy system brings new energy trade patterns, countries and geopolitical considerations into play. We must pay close attention to all potential vulnerabilities. The response from policy makers and companies will determine whether critical minerals remain a vital enabler for clean energy transitions or become a bottleneck in the process.

we

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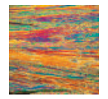
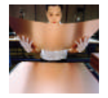


Neodymio crystals observed under the microscope. Neodymium is a rare-earth metal that is used in the construction of lasers used in nuclear fusion experiments to obtain the inertial confinement of hydrogen.



Woman inspecting a copper sheet. Copper is fundamental in all technologies related to electricity. The transition to a clean energy system will inevitably lead to a huge increase in the need for this mineral.

ELECTRIC VEHICLES & NEW DEPENDENCIES

by Gregor Sebastian

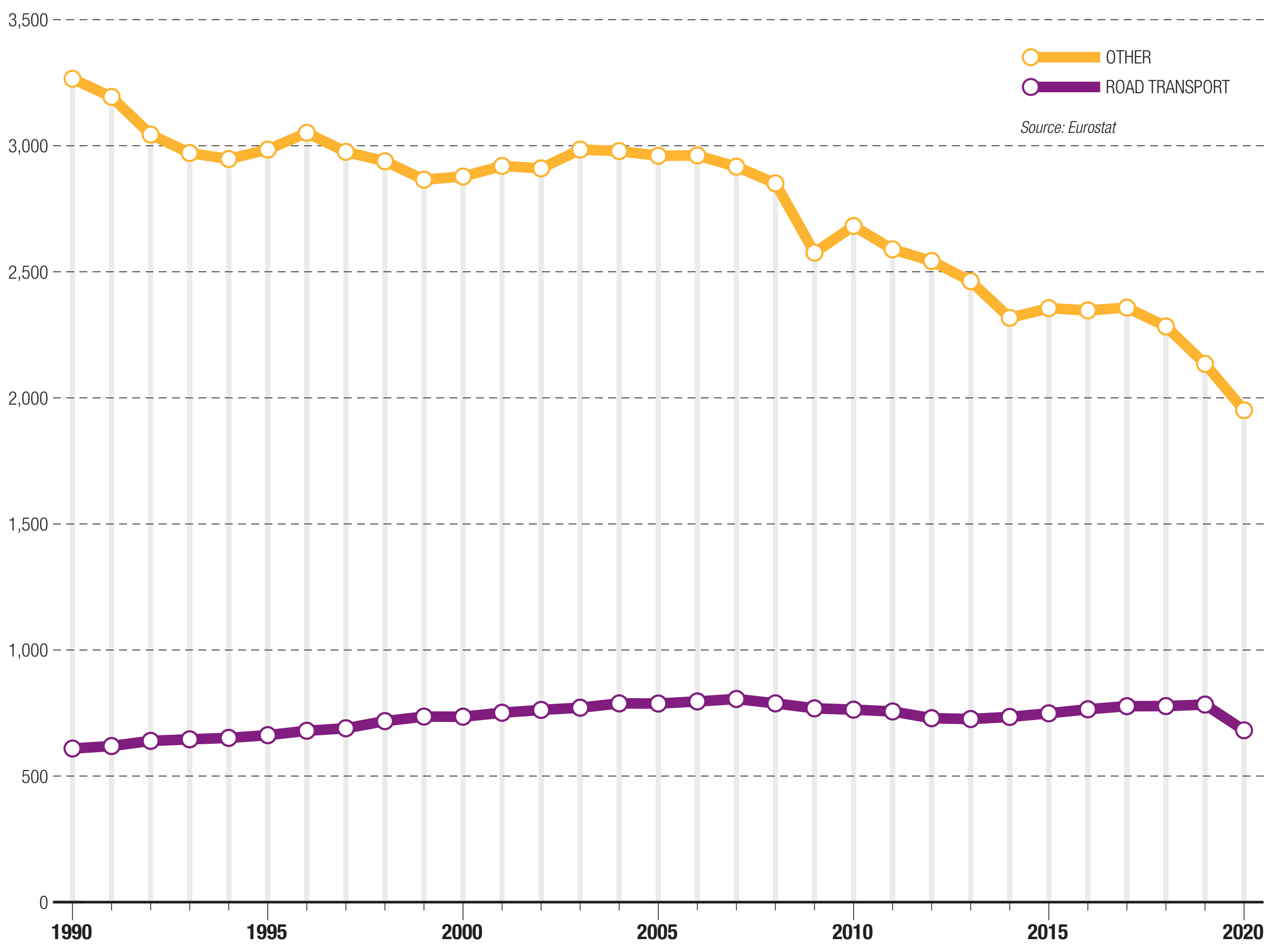
THE EV TRANSITION WILL PLAY A KEY ROLE IN THE DECARBONIZATION OF THE TRANSPORT SECTOR, BUT IT BRINGS WITH IT ECONOMIC AND GEOPOLITICAL RISKS. THE PRODUCTION OF BATTERIES REQUIRES LARGE QUANTITIES OF RAW MINERALS, WHICH ARE CONCENTRATED IN A FEW COUNTRIES

ELECTRIC VEHICLES (EVs) are likely to play a key role in decarbonization efforts. But their rise also has economic and national security implications because the production of EVs requires copious amounts of raw minerals that are not evenly distributed between countries. Their mining, processing and use for battery production could create new dependencies, especially on China, and heighten the risk of geopolitical conflict at the same time as reducing reliance on fossil fuels.

The EU and China have become the biggest EV adopters worldwide, as over 80 percent of all EVs drive on their roads. They are therefore good examples to illustrate the role of EVs in decarbonization and the emergence of new dependencies. The EU is the biggest region that has announced targets to phase out internal combustion engine (ICE) vehicles that run on petrol and diesel, to become carbon neutral by 2050. China, on the other hand, has emerged as the most important actor for global battery and EV supply chains. In both markets EVs now account for roughly 20 percent of new cars sold.

ROAD TRANSPORTATION HAS PROVEN DIFFICULT TO DECARBONIZE

The transport sector is the second largest contributor to greenhouse gas emissions globally and has been notoriously difficult



CO_2 EMISSIONS IN THE EU-27 BY YEAR

The road transport sector is difficult to decarbonize due to the growing demand for transport and travel. In 2020, 26 percent of total emissions in the EU were generated by haulage alone, with minimal variation from 1990.

to decarbonize as demand for transport and travel grow. In 2020, 26 percent of total emissions in the EU hailed from road transport; since 1990 emissions in the sector have barely budged. That is meant to change. Under the Green Deal, the EU seeks to reduce emissions from transport by 90 percent by 2050.

For the EU, the widespread adoption of EVs is seen as an integral step to decarbonize the transport sector. By 2035, the EU wants all new cars to be zero-emission. To reach that, EVs are an attractive option because they have no tailpipe emissions. As long as the electricity used to charge batteries is renewable, running EVs does not produce carbon emissions. This means, however, that EV adoption alone is no panacea. In lock step with greater EV use, countries need to increase the renewables in their electricity mix.

While better public transport is also key for Europe's energy transition, there are currently no attractive alternatives to battery powered EVs for passenger vehicles. Fuel cell vehicles, running on hydrogen, could find applications in heavy commercial vehicles and some carmakers are also eager to pursue synthetic fuels. However, for passenger vehicles, neither option currently produces the same efficiencies as EVs.

THE GLOBAL CHALLENGE FOR EV DOMINANCE

Governments' interest in EVs is about more than decarbonization. One reason why both Europe and China have been more eager to adopt EVs than other parts of the world is their reliance on oil imports. The Russian invasion of Ukraine in early 2022 has highlighted that dependence on strategic rivals for critical resources is a major vulnerability.

Even more importantly, EVs present an opportunity for economic catch-up. Beijing regards EVs as a unique chance to leapfrog international incumbent carmakers. This is because even though China eclipsed the U.S. as the biggest car market back in 2009, the continued weakness of domestic brands has been a thorn in the side of policymakers. In contrast, European carmakers, status quo technology leaders, were less inclined to electrify which has given Chinese competitors an opportunity to challenge them.

China's rise in EVs is no coincidence. It has been achieved through long-term policy support, local experimentation and massive state financing. Building on a ten-city pilot project in 2010, local and central governments financed purchasing subsidies, charging infrastructure rollout and research subsidies to the tune of USD 100.9 billion (between 2010 and 2020), according to U.S. think tank CSIS. Policymakers also forced carmakers to produce EVs through production quotas.

Beijing's bet on EVs proved a major success. While not without waste—there are an estimated 300 EV makers in China many of which are not commercially viable—China has managed to

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become the globally leading EV market. Together with U.S.-based Tesla, Chinese brands now dominate this emerging market segment. And Chinese EV makers have also set their eyes on international markets, most importantly Europe.

THE BATTERY SUPPLY CHAIN IS CENTERED ON CHINA

But even more importantly for Europe, China has managed to become the center of the global battery supply chain. Just like for solar panels, China's strength in EVs extends into upstream sectors including battery manufacturing, raw material processing and even mining activities in third countries. This has consequences for European manufacturers who, in order to produce their vehicles, now need Chinese firms as key suppliers.

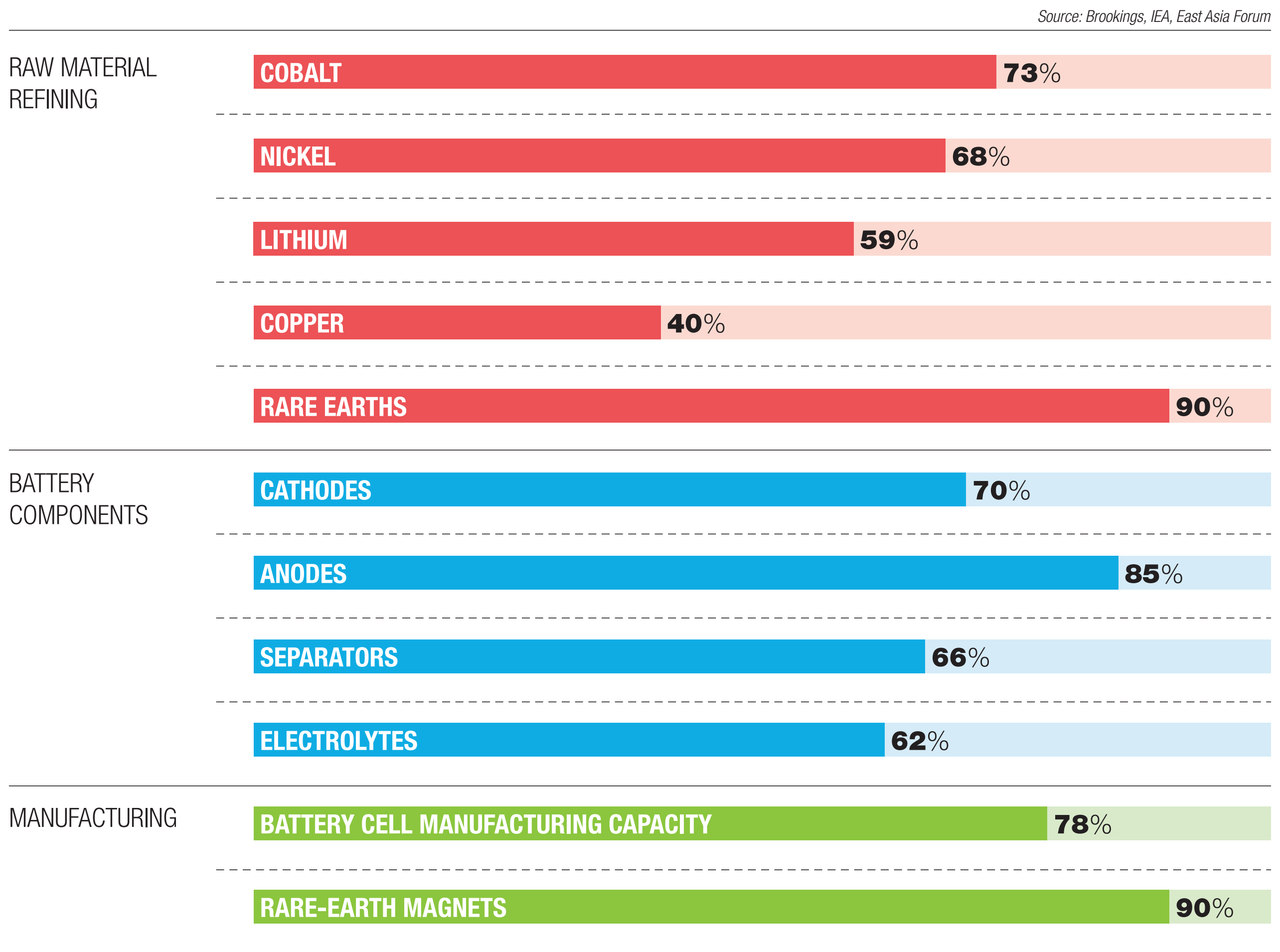
Batteries are the most valuable part of EVs, accounting for up to 50 percent of a vehicle's value. Whereas five to ten years ago the biggest battery producers came from Japan and South Korea, now, six out of ten of the world's biggest battery producers are Chinese. The largest, CATL, accounts for one-third of global battery capacity and is a major supplier to European carmakers. The firm is about to finish building its first overseas plant in Germany and is planning a second one in Hungary. Other Chinese battery makers are in close pursuit. Once again, Beijing buttressed domestic producers through cheap financing and even excluded foreign battery makers from its burgeoning and lucrative EV market.

This is not to say that the EU has been negligent. Europe has its own battery production ambitions and has launched the European Battery Alliance in 2017. The EU has declared batteries an Important Project of Common European Interest, which facilitates the handout of subsidies. However, European battery producers still need Chinese firms for raw materials.

Incentivized by government plans and loans from state-owned banks, Chinese companies have invested in mineral-rich countries, taken stakes in overseas mining projects and built processing and refining plants in China. This includes investment by Chinese miners in Congolese cobalt, Chilean Lithium and Indonesian nickel.

This does not imply that China owns all, or even the majority of the minerals going into EV batteries. Indeed, most minerals—such as lithium, iron, or graphite—are not actually scarce. However, the processing and refining of these minerals is cumbersome and often damaging to the local ecosystems. Many formerly processing countries, including the U.S., have been eager to offshore this supply chain process, while China has been willing to host it.

Now, the majority of battery-grade materials and battery components are produced in China. Indeed, China dominates large chunks of the EV supply chain. At times, European carmakers buy raw materials directly, yet they still need to have them shipped to China for processing.



CHINA'S SHARE OF GLOBAL PRODUCTION OR REFINING

Currently, most of the materials and components for batteries are manufactured in China, which in fact dominates large portions of the electric vehicle supply chain.

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Encouraged by government plans and state-owned bank loans, Chinese companies have invested in mineral-rich countries, acquired stakes in overseas mining projects, and built processing and refining plants in China. In the photos, cobalt extraction in Congo, lithium deposit in Chile (Moon Valley, San Pedro de Atacama) and nickel processing in Indonesia.

EUROPE AND CHINA: PARTNERS OR COMPETITORS?

China is and would like to remain an important partner for Europe's green energy transition. For consumers, Chinese producers have been helpful in driving down the cost of batteries through their massive production capacity, cheaper energy costs and economies of scale. China's vehicle exports generate competition and offer consumers greater choice. Indeed, China would be more than happy to scale up its EV exports.

However, the focus in Europe has shifted in recent years. While green technology used to be seen as a main area for collaboration between China and Europe, especially after the U.S. left the Paris agreement, recently clean energy has become an area of competition, if not rivalry. Europe is eager to avoid replacing its reliance on Russian gas with reliance on Chinese solar panels or EV batteries. This has been amplified by China's more assertive stance on the global stage as well as its use of economic coercion against other countries, including EU member states.

Europe's changing view on China means that the focus in the EU is now on reducing new dependencies. To that end, the EU is exploring several mechanisms, including the following:

- Diversifying Europe's supplier base: The EU is trying to finalize trade agreements with major raw material producers, such as Chile and Canada. This is an important first step to diversifying EV battery supply chains, but a major gap remains the lack of on- or friend-shored refining capacity.
- Promoting technological innovation: Europe is also encouraging technological innovation other than increased efficiency and reduced dependency. For example, several automotive suppliers are developing electric engines without permanent rare earth magnets or batteries without cobalt.
- Stepping up battery recycling: Batteries can be re-used which can reduce carbon emissions related to mining processes and increase Europe's raw material self-sufficiency. A new 'cradle to grave' battery regulation could mean that from 2030 onwards new batteries would have to contain certain amounts of recycled material. It will be crucial to ensure that, despite cost pressures, batteries will not be shipped to China for recycling.
- Advancing a modern mobility system: Sustainable modes of transport could help reduce the demand for battery-powered vehicles, and thus reduce the need for related materials. The EU supports alternative modes of transport including long-distance rail, passenger transport-on-demand and stronger for public transport networks and cycling.

The EU's measures are certainly a step in the right direction, but China's sheer dominance in the EV supply chain—years in the making—will likely persist in the short-term. European producers are unlikely to be able to compete with China on price, which is why it is critical that Europe creates incentives for on- or friend-shoring mining and processing investments that are based on high due diligence and low carbon intensity. Stockpiling critical minerals should also be considered.

In sum, to ensure smooth EV adoption, it is crucial that Europe does not slow down efforts to improve resilience. Europe is, however, not without leverage as China depends on many European technologies not least on specialized machinery, and, for now, it is not in China's interest to abuse its dominant position in the EV supply chain, as that would hasten efforts to diversify away from the country.

GREGOR SEBASTIAN
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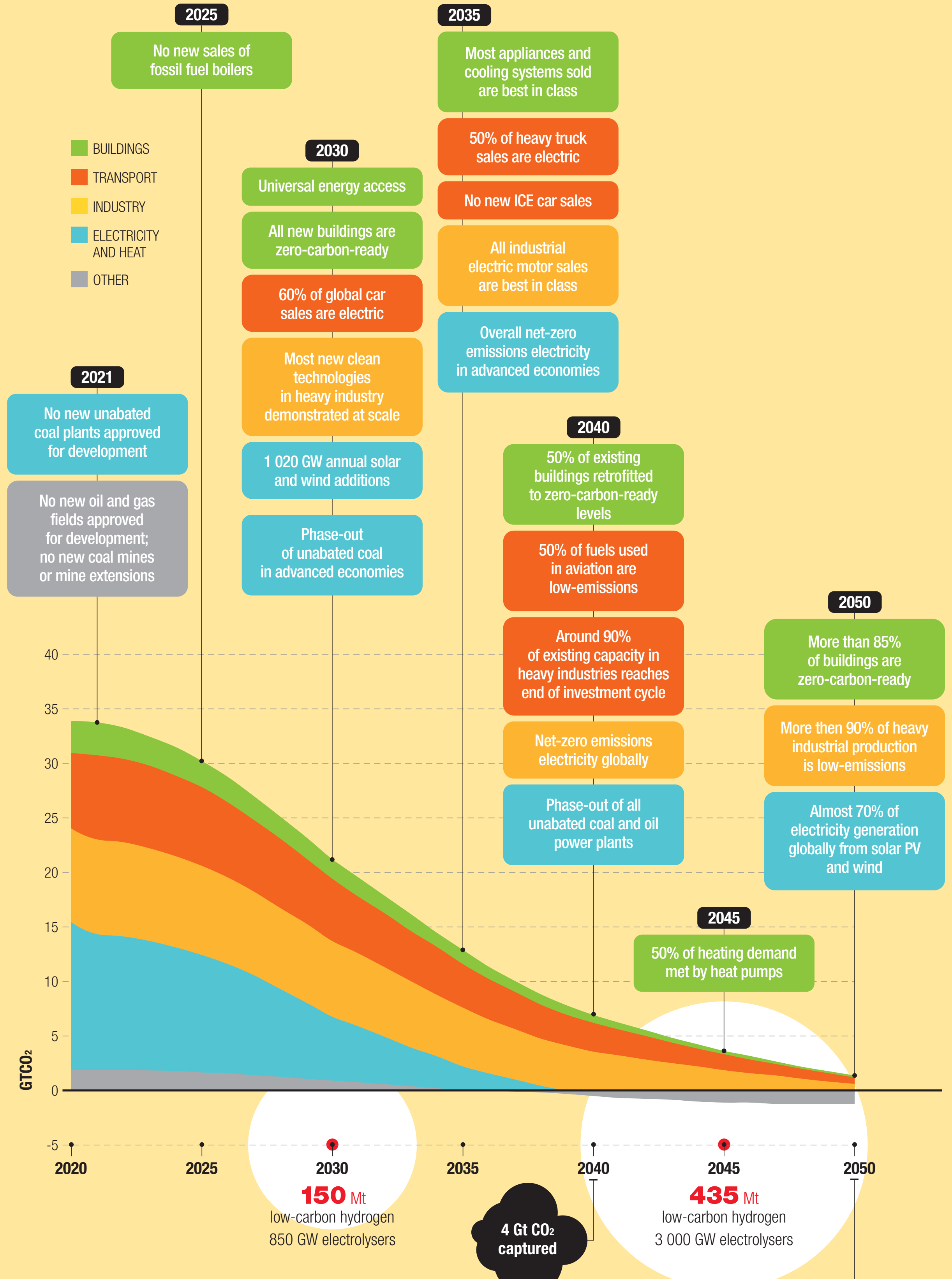
AN UNPRECEDENTED CHALLENGE

by **David Chiaramonti**

THE PERSPECTIVE FOR SUSTAINABLE FUELS IN THE AVIATION AND MARITIME HARD-TO-ABATE SECTORS IS SIGNIFICANT, IF THE DECARBONIZATION PATHWAY IS A SERIOUS GLOBAL COMMITMENT

WAVES OF INNOVATION move forward very rapidly in modern times, faster than ever: from research to pilot, demo, first market introduction and commercial deployment, the market penetration of new solutions takes place in shorter periods, with a more aggressive or disruptive impact on consolidated businesses (fig. 1). This requires not only quick design and implementation of related policies (with short-to-medium and medium-to-long term view), but also the adaptation of the industrial, infrastructural and financial environments to these changed conditions. It is an unprecedented challenge. One of the main drivers of this change, with reference to the energy and transport sectors, is the impact of climate change on our societies, an impact more and more ev-



2 THE ROADMAP FOR NET ZERO

In the NZE scenario, the IEA is aiming for 50 percent low-emission fuels in aviation by 2040, and estimates growth in hydrogen-based fuels starting in 2035. According to the agency forecasts, by 2050, the aviation industry will be responsible for almost half of liquid biofuels used.

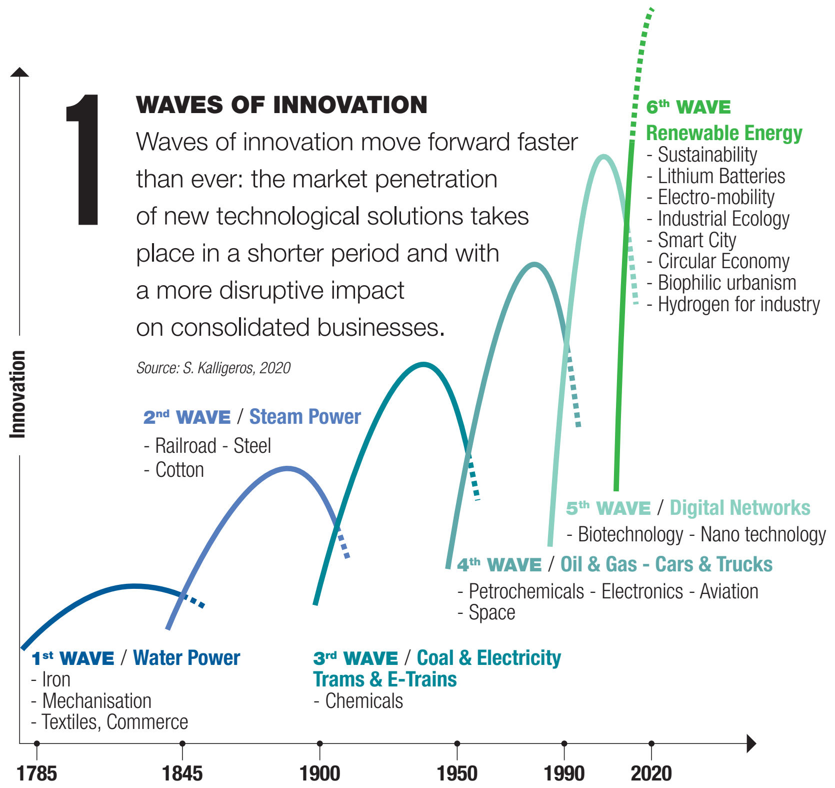
7,6 Gt CO_2 captured

Source: IEA Net Zero, 2021

1 WAVES OF INNOVATION

Waves of innovation move forward faster than ever: the market penetration of new technological solutions takes place in a shorter period and with a more disruptive impact on consolidated businesses.

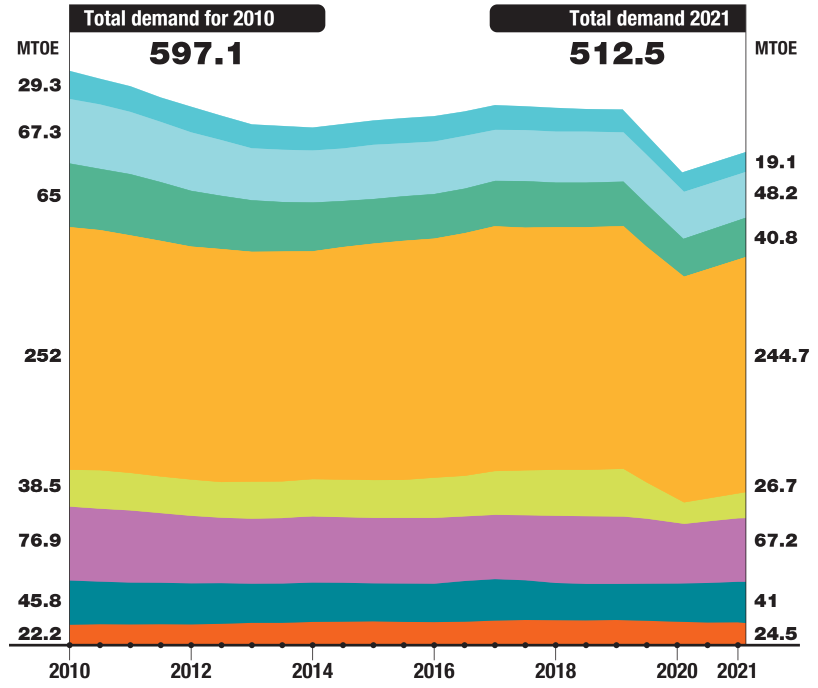
Source: S. Kalligeros, 2020



3 HISTORICAL DEMAND FOR OIL PRODUCTS IN THE EU-27

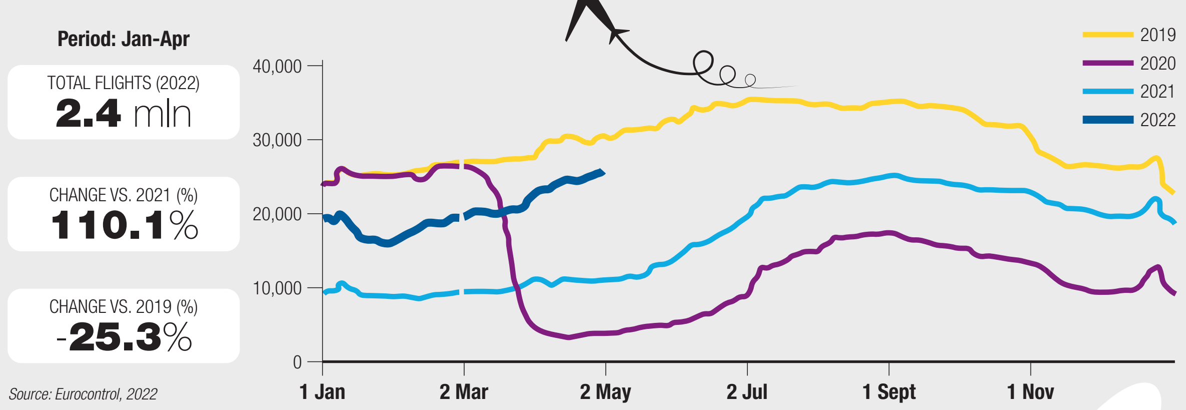
The fuel demand of the aviation and maritime sectors significantly affects the overall demand of the European Union with 27 member states (EU-27). Having collapsed in 2019 due to the pandemic, aviation demand is now recovering slightly, with almost 28 MTOE in 2021.

Source: Wood McKenzie



4 EVOLUTION OF DAILY FLIGHTS IN THE EUROCONTROL AREA (7D MOV. AVG.)

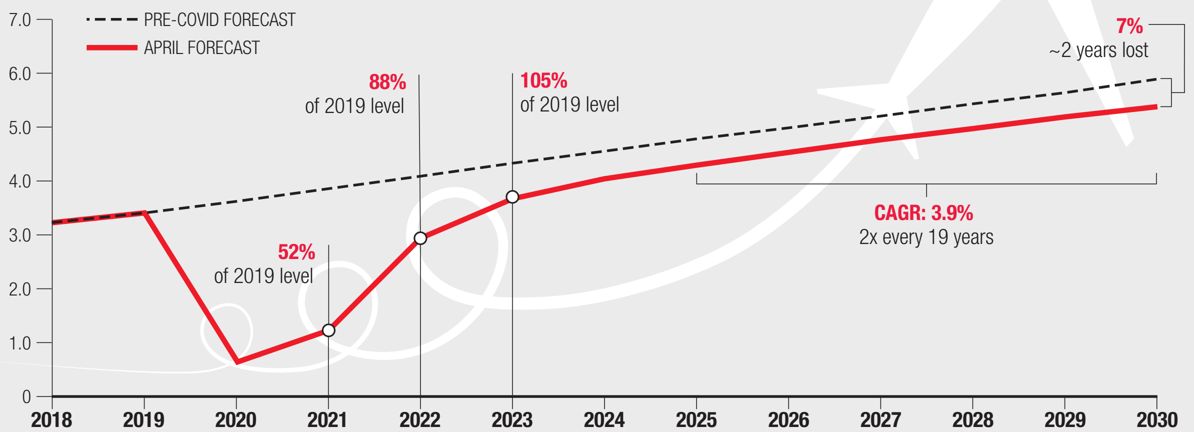
In the first quarter of 2022, the number of flights in the Eurocontrol area reached 2.4 million, up 110.1 percent compared to the same period in 2021, but still down compared to the pre-COVID-19 levels (-25.3 percent on 2019).



Source: Eurocontrol, 2022

5 GLOBAL PASSENGER FLIGHTS POST PANDEMIC (BILLION)

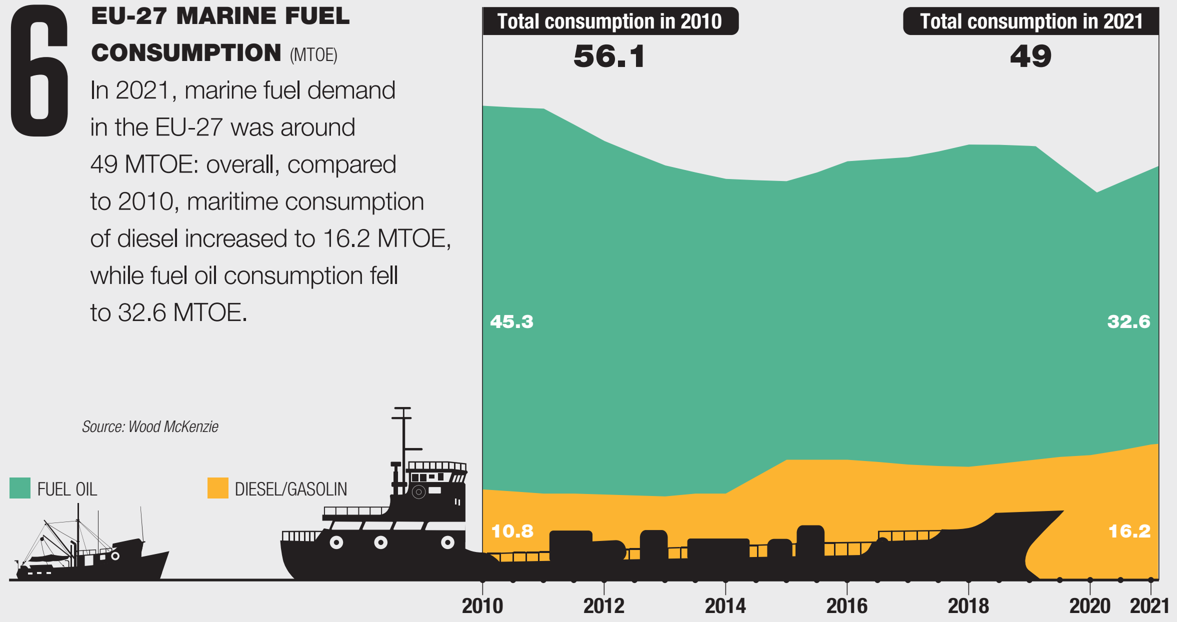
According to IATA's latest estimates, global passenger air traffic will continue to record steady growth in the coming years, which will however remain lower (-7% by 2030) than that predicted by the association before the outbreak of the COVID-19 pandemic. *Source: IATA, 2021*



6 EU-27 MARINE FUEL CONSUMPTION (MTOE)

In 2021, marine fuel demand in the EU-27 was around 49 MTOE: overall, compared to 2010, maritime consumption of diesel increased to 16.2 MTOE, while fuel oil consumption fell to 32.6 MTOE.

Source: Wood McKenzie



ident in everyone's life. Another more recent driver is the energy crisis, and the consequences of Russia's invasion of Ukraine on the market, prices and availability of commodities.

Aviation and maritime are well known as two hard-to-abate sectors, given the difficulties in the electrical transitions. The main opportunity for decarbonization is seen in the introduction of cleaner and sustainable fuels, which are in addition to already established efforts on improving performances and reducing emissions in gas turbines, designing more efficient planes, optimizing flight routes to reduce consumptions and greenhouse gas emissions, etc. For this reason, programs are in place at all levels (i.e. international, European and country levels) to introduce cleaner fuels like sustainable aviation fuels (SAF) in the end-use dimension.

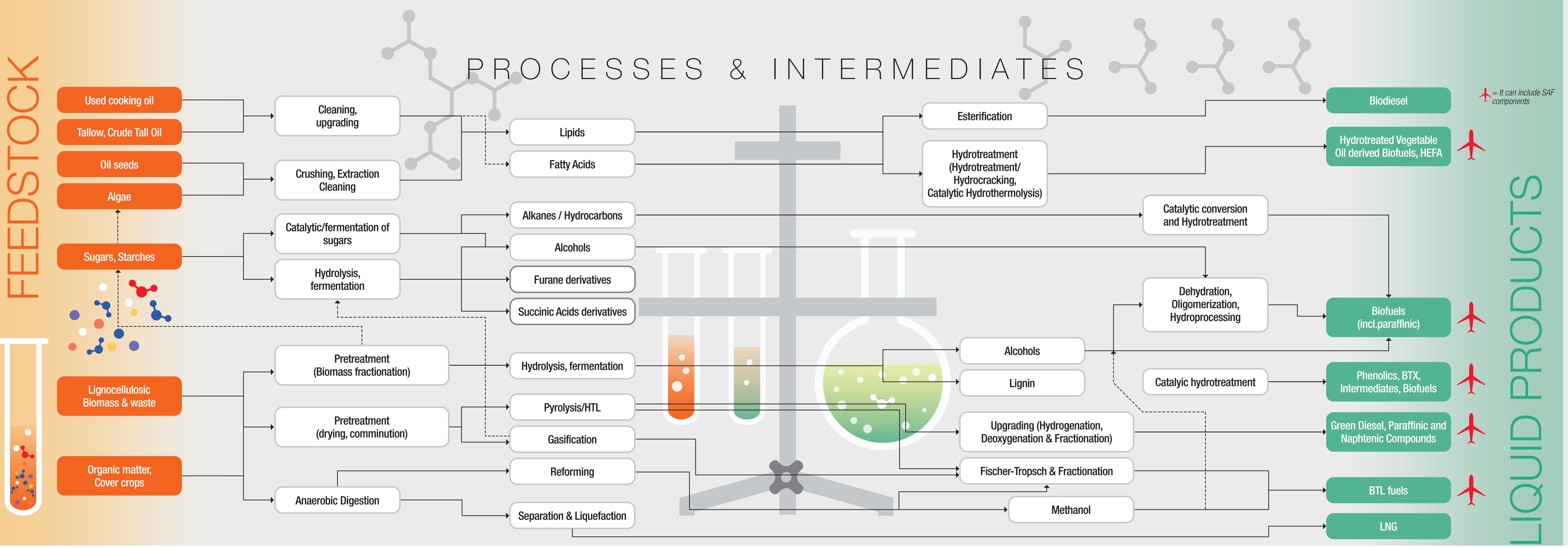
AVIATION AND MARITIME GREENING

The International Energy Agency (IEA) has addressed the net zero transition in its dedicated report (issued before the recent energy crisis) that suggests a roadmap to meet climate goals (fig. 2). On aviation and maritime, IEA aims at 50 percent use of low-emissions fuels in aviation by 2040 and estimates a growth of hydrogen-based aviation fuels from 2035 on. IEA expects that almost half of liquid biofuel use in 2050 is for aviation, where bio- kerosene accounts for around 45 percent of total fuel use in aircraft. The Net Zero Energy (NZE) report assumes that air travel, measured in revenue-passenger km, increases by only ~3 percent per year to 2050 relative to 2020, compared to ~6 percent over the 2010-19 period. Global CO_2 emissions would increase from 640 Mt in 2020 to 950 Mt in 2025, and then impressively reduce to 210 Mt in 2050, thanks to the massive use of low-carbon and renewable sustainable fuels. As a reference, CO_2 emissions in 2019 reached almost 1000 Mt.

Actually, the dimension of aviation and maritime is by vast majority global, and thus governed by the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). These organizations are developing dedicated decarbonization programs, such as ICAO's Carbon Offsetting and Reduction Scheme for International Aviation. In Europe, the RefuelEU aviation and maritime initiatives have been elaborated in the Fit-for-55 package.

Fuel demand in EU-27 for these key sectors is significant on the overall EU demand. Until 2019 the demand of the aviation area stayed at or beyond 39 million tons of oil equivalent (MTOE)/y (EU-27). Then, it collapsed due to the impact of pandemic, now slightly recovering at almost 28 MTOE in 2021 (fig. 3). This is constantly with recording of daily flights and estimates of global passengers by Eurocontrol (fig. 4) and International Air Transport Association (IATA) (fig 5).

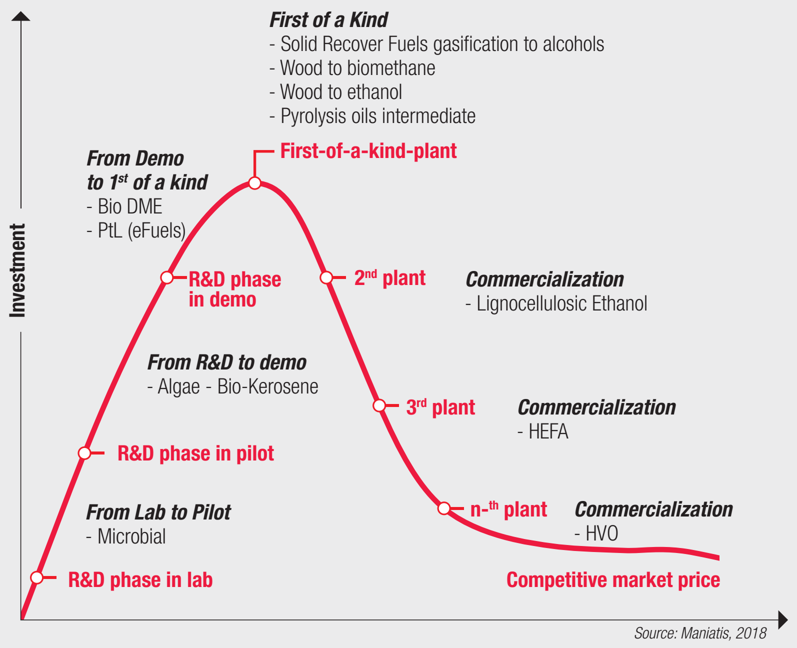
At Italian level, the demand for aviation fuel, normally in the 4.5-4.7 MTOE/y range, dropped to 1.6 MTOE in 2020 (-66 percent compared to 2019): this is today recovering to pre-covid levels.



7

PROCESS ROUTES TO LIQUID BIOFUELS

The main route to decarbonizing the aviation and maritime sectors is the replacement of traditional fossil fuels with sustainable fuels. The diagram summarizes the main possible routes to producing biofuels for aviation. The little red plane indicates the routes that generate possible SAF components.



8

MOUNTAIN OF DEATH OF LIQUID BIOFUELS

The graph illustrates the state of industrial technologies and processes in terms of market competitiveness and full commercialization. The dynamics of the changes in the graph largely depend on existing energy policies, which influence investment decisions on industrial development and deployment.

As regards Maritime, approximately 49 MTOE fuel demand in the EU-27 was observed in 2021: overall, compared to 2010, the consumption of marine diesel/gasoil increased to 16.2 MTOE while fuel oil consumption diminished to 32.6 MTOE (fig.6). Switching to cleaner fuels, such as Liquified Natural Gas (LNG), or the adoption of scrubbers, is expected to fulfill the IMO emission limits. The use of mildly upgraded biocrude oils from lignocellulosic biomass (as those form fast pyrolysis or hydrothermal liquefaction) also could be very interesting for this sector in the coming decades.

SUSTAINABLE FUELS IN AVIATION AND MARITIME FUELS

Substituting conventional fossil fuels with sustainable ones in these two sectors is seen as the main road towards decarbonization (in particular, by 2030-2040), given not only the constraints posed by the current end-use technologies used in plane and ships (internal combustion engines and gas turbines), but also the infrastructural issue when dealing with the introduction of green electricity and hydrogen. There are many different possible routes to produce sustainable aviation fuels, the main summarized in the scheme number 7.

The Fuel Readiness Level—a parameter rather analogous to the most used Technology Readiness Level (TRL)—is notably different among the various pathways. Today, by far the most diffused renewable product used in aviation is Hydroprocessed Esters and Fatty Acid (HEFA). HEFA is derived from Hydrotreated Vegetable Oil (HVO), with an EU installed capacity beyond 1.8 Mt/y for HVO/HEFA. (This does not include co-processing of lipids in existing refineries.) No other routes even approach such volumes (much larger at global scale: total hydrotreating capacity already reached 6.5 Mt in 2018). At least until 2030-2035 HEFA can be reasonably expected to remain the largely dominant SAF product, which therefore (as with all lipid-based biofuel routes) implies the urgent need to supply sustainable lipids in huge amounts. Also co-processing of lipids in existing refineries is being pursued by several fuel producers, even if limited by 5 percent v/v when blended in fossil jet fuel. The critical element for the HEFA (and a few others, such as Alcohol To Jet (ATJ) routes is thus the provision of suitable feedstock to the process, rather than the process itself. For this reason, low TRL level research is being conducted on alternative routes to supply sustainable lipids, as microbial oil from algae or yeast. The ATJ route is also being developed by companies active in the sector of advanced ethanol, even if large diffusion at full industrial scale is still limited. Other pathways, based on thermochemical processing such as gasification, pyrolysis or hydrothermal liquefaction, are still under development and mostly at pilot/demo level (in few cases also at First Of A Kind [FOAK] level), even if the yield of SAF components from these routes is often rather modest.

In the Maritime sector, the main alternative fuel today under consideration is LNG, but also alcohol-based (thus bio-based) products such as methanol are possible and under industrial investigation. Indeed, the energy crisis and resulting spiking costs of natural gas represent a very delicate matter today and that will influence future investments in the sector.

Indeed, the physical and chemical characteristics of SAF and maritime fuels greatly differ. While large-scale internal combustion engines can be fed with very crude and heavy fuels, aviation requires the most sophisticated and stable types of fuels, also considering the many functions such as thermal regulation the fuel has on board a plane.

As a consequence, while SAFs are the most challenging products, the maritime sector could be a possible and very interesting target for less refined fuels, such as mildly upgraded pyrolysis or hydrothermal liquefaction fuels from lignocellulosic biomasses or wastes. Nevertheless, beyond the technical feasibility, the cost issue still represents a major barrier hampering industrial deployment. This is also (but not only) associated with the cost of the renewable hydrogen needed for the upgrading step of these biocrudes.

The same element, the cost-competitive availability of green hydrogen, impacts on the so-called power-to-liquid fuels (PtL), which can also be directed to aviation. These fuels are named Renewable Fuel of Non-Biological Origin (RFNBO) or Synthetic Fuels in the EU REDII and ReFuelEU Aviation respectively, or eFuel in a more general public wording. Also, the origin of both the CO_2 and the electricity used in PtL production, as well as the direct connection or virtual accounting methods, will heavily impact the economics. The success of these routes will thus also depend on the policy in place. All transports are heavily determined by policies and are thus considered policy-driven sectors. Finally, the Recycled Carbon Fuels have also been introduced in the REDII. These are essentially those fuels which are produced from non-organic fraction of wastes, through thermochemical conversion. These routes can also target SAF, which is already occurring in some demo/FOAK industrial projects.

COST REDUCTION

It is well known and studied how costs can be reduced by learning factors and scale effects. The exemplary case of industrial (bio)ethanol production in Brazil perfectly demonstrates the possibility of reducing production costs through a series of interventions, from developing the supply chain and the logistics, to innovation in process design, integration, and the adoption of stable and well-designed policy and regulatory measures.

However, as also demonstrated by the Brazilian ethanol case, reducing costs in industrial scale-up requires time, which also depends on the learning factor of the specific case. Two among the most interesting routes in the bio- or waste-derived fuels are the

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waste-to-ethanol and the fast pyrolysis routes: R&D on these pathways started in the 1980s, while the first industrial demo didn't occur until the mid-2010s. When a Demo or FOAK unit has been built and successfully operated, full scale industrial deployment of these technologies has to follow, which requires significant time and investments. Therefore, the path to full commercialization and market deployment (so that significant volumes are produced) will realistically run over a significant amount of time.

The Mountain of Death graph (fig 8) is a way to represent the status of industrial technologies and processes towards market competitiveness and full commercialization. With reference to pre-pandemic and pre-energy crisis conditions, the different routes and pathways can be placed on the graph: the dynamics of change largely depends on the energy policies in place, which affect the investment decisions on industrial development and deployment. Stable policies are thus essential to attract long term investment, and this is typical of the fuel sector.

A SERIOUS GLOBAL COMMITMENT

The potential for sustainable fuels in the aviation and maritime hard-to-abate sectors is significant, if the decarbonization pathway is a serious global commitment. The shift to cleaner fuels is the main approach that meets the deadlines set by Governments and is compatible with existing infrastructures and end-use technologies. It is also worth noting that an increased penetration of domestic renewable fuels will support greater independence and security, a major element of concern in current times.

The two sectors present very different requirements in terms of physical and chemical characteristics of the fuels, as well as costs and economics: thus, future commercial processes and technologies will likely develop along similar integrated, but different, routes, in a biorefinery approach. To match the climate goals with actual industrial development and deployment, a stable policy and regulatory environment is necessary, as large investments with long-term returns are required in transports.

we

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THE GREEN [HYDROGEN] WAVE

by **Emanuele Bianco**

IT HAS GREAT POTENTIAL IN TERMS OF REDUCING CO_2 EMISSIONS, ESPECIALLY IN THE HARD TO ABATE SECTORS, BUT TIMELY INDUSTRIAL POLICIES ARE NEEDED FOR HYDROGEN TO TAKE HOLD, ESPECIALLY ON THE DEMAND SIDE

GREEN HYDROGEN has appeared frequently in conversations about the energy transition since 2019. Looking back, this is hardly surprising. The globe is facing a climate crisis, and in response to the sobering warning of the 2018 Intergovernmental Panel on Climate Change (IPCC) "Special Report on Global Warming of 1.5° C," an increasing number of nations have made commitments to achieve net-zero carbon dioxide (CO_2) emissions. However, achieving the deep decarbonization of economies will need coordinated and extensive efforts across all economic sectors. It is imperative that we make fundamental and transformative changes to the way we produce and consume energy and to the underlying socioeconomic systems. A signif-

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icant switch from fossil fuels to renewable energy sources, such as solar and wind, as well as increased energy efficiency and the broad electrification of energy users, including transportation and building heating and cooling, are necessary for the energy transition. However, not all sectors can move from using fossil fuels to electricity.

Steel, cement, chemicals, long-distance transportation, marine shipping, and aviation are among the sectors that are difficult to electrify (and hence hard to abate); green hydrogen can provide the missing link between growing and sustainable renewable electricity generation and the hard-to-electrify sectors. As a result, net zero scenarios, such as IRENA's World Energy Transitions Outlook 1.5° C Scenario, give green hydrogen a prominent role, albeit with significantly different amounts of penetration. Understanding the link between green hydrogen and hard-to-abate sectors has been the spark that initiated the growth in interest for green hydrogen. This understanding has also shifted the interest in the usage of hydrogen from distributed applications (cars, boilers, fuel cells) to more centralized ones, like large industries.

THE OBSTACLES TO FULL DEVELOPMENT

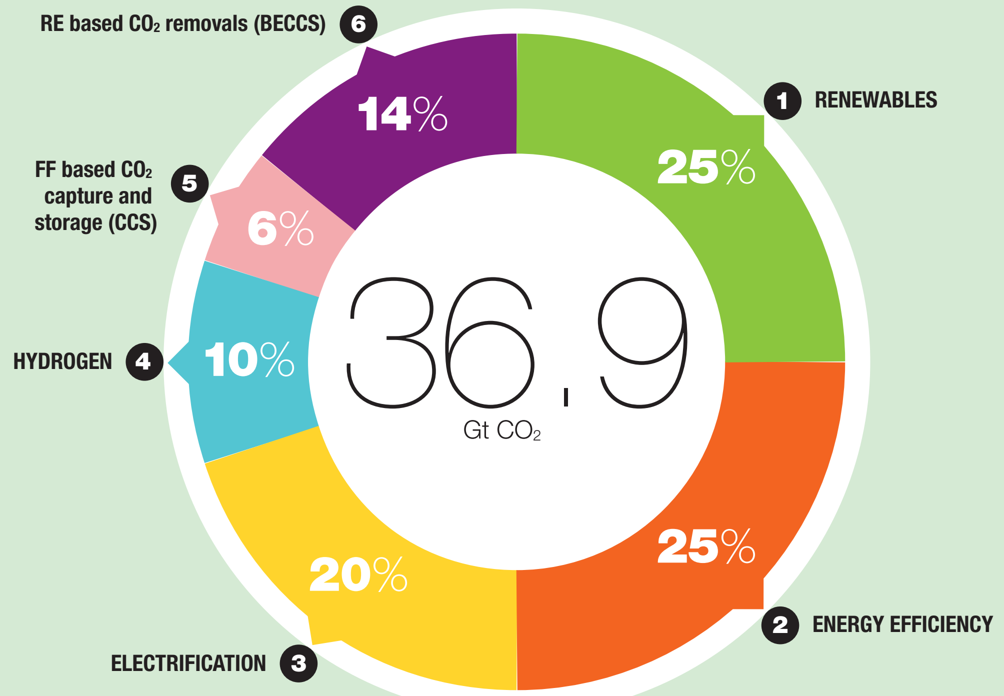
Green hydrogen will still need to overcome many obstacles to realize its full potential. Investment is hampered by the lack of clarity surrounding the demand for green hydrogen, and governments may be reluctant to fund a technology without explicit knowledge of the cost-benefit and business strategy. Investors may think these initiatives are too risky because there is no clear public policy or demand for green hydrogen.

The steel and basic chemical industries consumed 87 Mt of grey hydrogen in 2020: green hydrogen can assist in slashing their emissions substantially. However, these industries are still slow to take up the decarbonization of their processes. Higher-priced green products would compete against established lower-priced grey options, particularly in capital-intensive sectors with low-profit margins, in a situation where consumers have little incentive to buy green products, and the public procurement of goods focuses mostly on cost compression.

An integrated policy approach is needed to overcome the initial resistance and reach a minimum threshold for market penetration: a new wave of policies is expected to support green hydrogen. As set out in IRENA's "Green Hydrogen for Industry: A guide to policy making," green hydrogen policy making will substantially differ from the other sets of policies for the energy transition. Some of these differences are already visible. For example, hydrogen strategies are becoming a recurring feature of countries that intend to make their first steps in the hydrogen sector, as opposed to the solar and wind sectors, for which strategic documents were not so common. Around 60 countries are drafting or had published hydrogen strategic documents by September 2022 (from one country in 2018).

The Irena 1.5°C scenario

The path set by IRENA for limiting the rise in the Earth's temperature to 1.5 degrees Celsius identifies electrification and efficiency as key factors in the energy transition, made possible by renewable energies, hydrogen and sustainable biomass. This path—which requires a massive change in the way companies produce and consume energy—would result in a reduction of nearly 37 gigatons (Gt) in annual CO_2 emissions by 2050. In particular, as regards hydrogen, production is expected to reach 74 Exajoules (EJ) per year, with an investment of USD 176 billion a year.



SIX TECHNOLOGIES TO REDUCE EMISSIONS

To reduce CO_2 emissions by almost 37 Gt per year by 2050, IRENA recommends: significant growth in the generation and direct use of renewable electricity; a substantial improvement in energy efficiency; the electrification of all end uses; an increase in the use of green hydrogen and its derivatives; sustainable bioenergy with carbon capture and storage (BECCS); the adoption of 'last-mile' carbon capture and storage (CCS) initiatives.

KPI

	2020	2030	
KPI	0.8 Mt H_2	H_2 154 Mt	*Production of clean hydrogen and derivatives*

TECHNOLOGY OUTLOOK

KEY INDICATORS	HISTORICAL 2020	WHERE WE NEED TO BE (1.5°C SCENARIO) 2030	2050
CLEAN HYDROGEN PRODUCTION	>0 EJ/year	>19 EJ/year	>74 EJ/year
Clean hydrogen share in total final energy consumption (TFEC)	<0.1%	3%	12%
Clean hydrogen share **in transport** total final energy consumption (TFEC) (%)	<0.1%	0.7%	12%
Ammonia, methanol, **synthetic fuels share in transport** total final energy consumption (TFEC) (%)	<0.1%	0.4%	8%
Clean hydrogen consumption – **Industry** (EJ)	>0 EJ	16 EJ	38 EJ
Clean hydrogen consumption – **Buildings** (EJ)	0 EJ	2 EJ	3.2 EJ

EXAMPLES OF POLICIES TO ACHIEVE KPIs

EXAMPLES OF POLICIES NEEDED TO PROMOTE THE USE OF HYDROGEN AND ITS DERIVATIVES:

- National green hydrogen strategies that define the level of ambition for hydrogen across end-use sectors and the support required for attracting private investments
- Establishment of sectoral priorities for the use of green hydrogen
- Certification systems – guarantee of origin (GO) – to track the origin and to account for the lifecycle emissions of hydrogen
- Industrial policies to mantain competitiveness and create export opportunities
- Mechanisms to enable the shift from grey to green and clean hydrogen (e.g. incentivising demand for low-carbon commodities like green steel, green ammonia)
- Promotion of hydrogen-based steel and chemical production in industry including through pilot projects.

INVESTMENTS

	HISTORICAL 2020	WHERE WE NEED TO BE (1.5°C SCENARIO) 2021-2030	2031-2050
Hydrogen and its derivatives (incl. electrolysers, feedstocks and infrastructure)	0 USD BILLION / YEAR	133 USD BILLION / YEAR	176 USD BILLION / YEAR

CO_2 EMISSIONS ABATEMENT

Hydrogen and its derivatives

AVOIDED CO_2 EMISSIONS IN THE 1.5°C SCENARIO COMPARED TO THE PES IN 2050	**CONTRIBUTION TO TOTAL ENERGY SECTOR AVOIDED CO_2 EMISSIONS IN THE 1.5°C** SCENARIO COMPARED TO THE PES IN 2050
3,7 gt CO_2 / year	10%

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Wesseling, Germany. Fans next to the hydrogen electrolysis plant at the green hydrogen refinery in Wesseling, operated by Royal Dutch Shell. Europe has high hopes for hydrogen in achieving climate neutrality by 2050.

Hesse, Frankfurt am Main. The new Coradia iLint hydrogen train produced by Alstom. From the end of 2022, 27 of these hydrogen powered trains will be in service between Frankfurt and the Taunus region. Hydrogen will play an important role in the decarbonization of the hard-to-abate sectors.

Hydrogen strategies result from a long process and mark the beginning of a new wave of policies. There is no agreed format or standard for drafting a hydrogen strategy. As a result, amongst countries' hydrogen strategies, it is possible to find very detailed documents with comprehensive descriptions of the national hydrogen sectors and many measures the government will undertake, as well as vision documents with high-level commitments for the future.

Answering questions like "why are we investing in hydrogen" and "why in these industries" as well as "when" is a frequent goal of strategies: to this end, scenario modelling typically informs the strategies, frequently with participation from academics and industry. A strategy usually defines medium and long targets (that can take many forms), sets the level of ambition that will guide the work in subsequent stages, and presents a series of measures to support the green hydrogen sector's local growth. The strategy covers specific direct policies and includes integrating and enabling policies that are needed to ensure deployment across the system.

The most common measures so far introduced in strategies are financial mechanisms. These include grants and loans, tax rebates, carbon contracts for difference, and bilateral auctions (such as the H2Global project in Germany). Furthermore, an interesting aspect of the measures presented in hydrogen strategies and, in a few cases, already undertaken by countries is the (re-)emergence of industrial policy making. Industrial policy can be defined as the variety of policy interventions to guide and control an economy's structural transformation process.

THE RENAISSANCE OF INDUSTRIAL POLICIES

While a common practice post-WWII, industrial policy started to lose favor toward the end of the 20th century because it was perceived as an ineffective way for the government to exert control over the private sector. However, a "renaissance" in industrial policymaking happened in many parts of the world due to the need for economic recovery after the 2008 financial crisis. Various societal goals, including the need to move toward low-carbon economies to speed up energy transitions, have been attained through industrial policy, or green industrial policy, in recent years. Industrial policy making has been particularly effective in supporting "infant" industries, meaning those sectors that still cannot compete with the incumbent. Green hydrogen fits this description and is, therefore, a good candidate for dedicated industrial policy, especially now with greater awareness of its importance in implementing structural change.

Examples of the (re-)adoption of industrial policy making for the energy transition include the recent U.S. Defense Production Act Presidential Determination in the U.S., which supports energy transition related industries (including electrolyzer manufacturers) with dedicated funds to create a local value chain.

Further evidence is the emergence of industrial decarbonization strategies. Industrial decarbonization strategies have been adopted in the U.K. and the U.S. recently, and Germany plans to introduce sectorial strategies soon. Industrial decarbonization strategies are used to present the size of the decarbonization challenges while proposing ways to address them, reflecting the specificities of the country's industrial sectors and creating comparative advantage. Importantly, these efforts ought to work toward a step change in technology that lessens the possibility of future stranded assets related to fossil fuels and emissions becoming locked in. A planned transition will facilitate the implementation of the deep decarbonization processes and bring investors' and companies' actions into line with those of the general public.

A step-change approach can also include a ban or mandated phase-out of fossil fuel-based technologies in hard-to-abate sectors since blacklisting certain technologies within a climate-consistent timeframe can open space for decarbonized solutions. Alternatively, binding quotas could generate stable demand for green hydrogen, thus reducing offtake risk.

Last, industrial policy can guarantee a steady and significant demand for green hydrogen. Sustainable public procurement, which would act as an initial and consistent driver of demand for environmentally friendly products and materials, and green material quotas are two policy tools that can help achieve this goal. Together, these tools can lay the groundwork for developing the green materials market, which does not yet exist. All the measures presented so far are not far-fetched ideas: all of them are present in several published hydrogen strategies. However, the actual adoption of such measures is still lagging. Developed countries, and G7 members, in particular, have adopted financial instruments, but most of the focus has been on the supply side—meaning to support the first electrolyzers.

TIMELY INTERVENTIONS ARE URGENTLY NEEDED

Policymakers must translate their commitments into reality to move green hydrogen from niche to mainstream. In such an endeavor, it will be essential to align the efforts on the supply side with the ones on the demand side, prioritizing actions toward large consumers of hydrogen that can create the anchor demand for future upscale. It will be important not to dilute efforts attempting to use green hydrogen in sectors where direct electrification can achieve decarbonization more cheaply and efficiently. Finally, policymakers will have to (re-)adopt an industrial policy frame of mind to shelter and back an infant industry that will substantially assist the fight against climate change. But industrial assets have a long lifespan, and industries are inextricably intertwined with society, providing employment and wealth. As the 2050 climate target date nears, any further delay will complicate industrial transitions. These factors necessitate suitable prompt action from policymakers, who are encouraged to act immediately to guarantee the industrial energy transitions.

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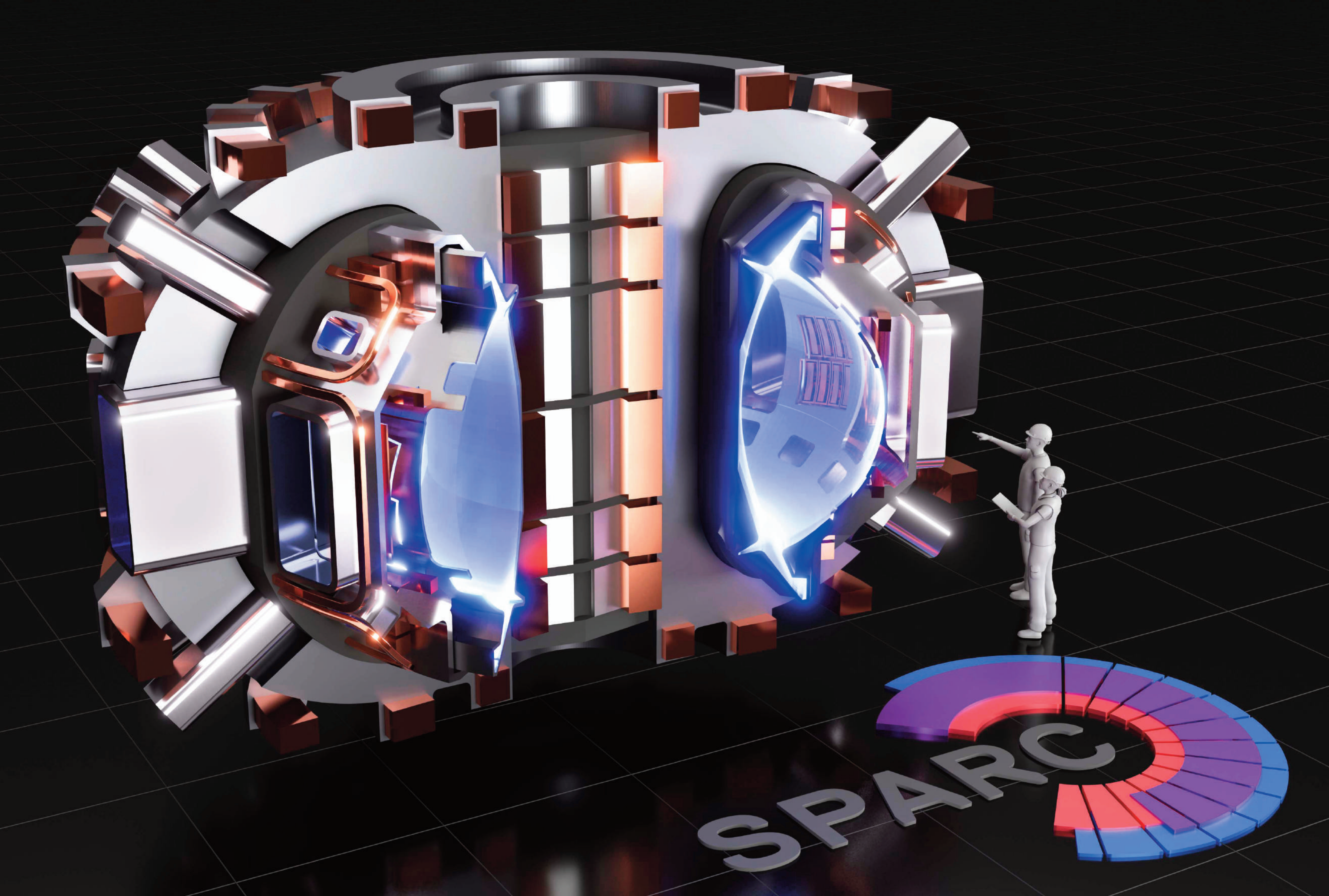


THE ENERGY OF THE STARS

by Bob Mumgaard

NUCLEAR FUSION—THE PHYSICAL REACTION THAT POWERS THE SUN—IS A POTENTIAL GAME CHANGER IN THE ENERGY LANDSCAPE. IT DOES NOT EMIT GREENHOUSE GASES, NOR HIGHLY POLLUTING OR RADIOACTIVE SUBSTANCES, AND IS VIRTUALLY INEXHAUSTIBLE

IN SEPTEMBER OF 2021, our team watched the screen in anticipation as we ramped up our fusion magnet technology towards its goal of 20 Tesla. We knew that if this groundbreaking magnet was successful, we were a major step closer to bringing magnetic confinement fusion to market. This would be the realization of decades of work with the widespread belief that harnessing fusion energy would mean clean, safe and essentially limitless energy for the world and play a major role in the energy transition. Our high temperature superconductors (HTS) magnet technology reached its goal marking a turning point for commercial fusion energy. Eni was an important part of the team watching the results come in that day, making a signifi-

Rendering of SPARC, a compact high-field tokamak currently being designed by a team of scientists from MIT and CFS. The mission is to create and confine a plasma that produces net fusion energy.

A team of engineers and scientists from Commonwealth Fusion Systems and the MIT Plasma Science and Fusion Center working on the high-temperature superconducting (HTS) magnet.

The high-temperature superconducting magnet is characterized by its wide range and large diameter and has been shown to achieve a record magnetic field of 20 tesla. It is the most powerful fusion magnet in the world.

cant step forward on our path towards developing commercially relevant fusion energy.

THE HISTORY OF FUSION

Fusion was first discovered in the 1920s as scientists worked to determine how the stars were powered. Ultimately, they learned that stars power themselves through fusion, when hydrogen fuses together to form helium and releasing enormous amounts of energy in the process. It is the opposite process of fission, commonly known as "nuclear power," which is the process of using neutrons to split heavier and unstable elements such as uranium or plutonium to generate energy. Everything in our universe was made from the stars. They are the largest source of energy in the universe. In the decades that followed this discovery, scientists continued to develop and improve machines that create the conditions to replicate the fusion process here on earth.

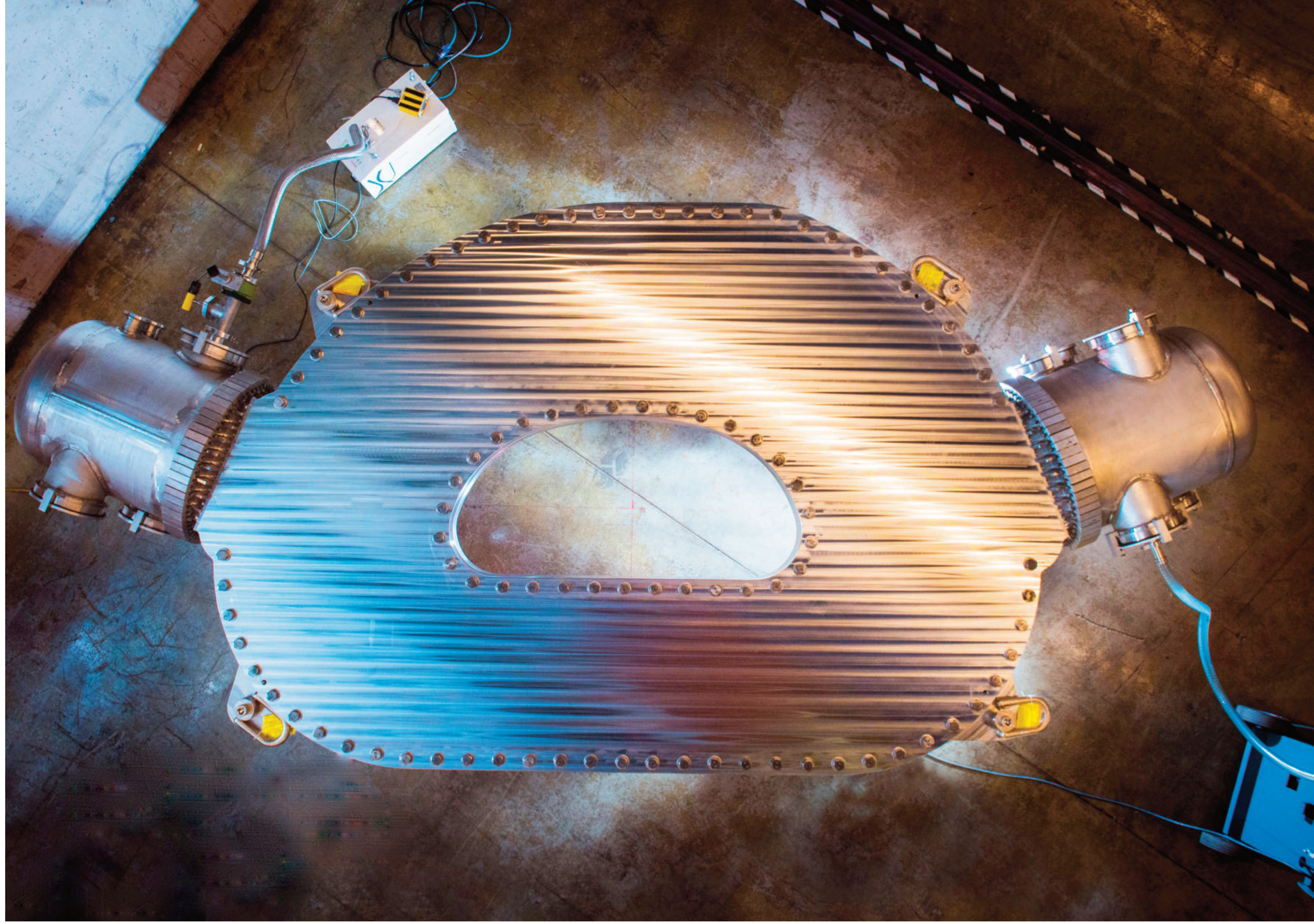
For many decades, fusion has been studied all over the world primarily in academic or research settings. The largest fusion research project is a collaborative endeavor called ITER funded by the major world governments. Its scientific mission is to achieve net energy and ultimately a burning (self-heating) plasma using magnets to confine the fusion process. ITER is a multi-nation statement of conviction that the world should pursue the study of fusion as a global energy source. In parallel, more than 35 private companies have emerged with different approaches to developing commercial fusion energy.

Commercial fusion energy would be a fundamentally new type of energy generation technology. It would use isotopes of hydrogen (deuterium and tritium) in very small amounts as its fuel and would be inherently safe with no risk of proliferation, meltdown, or long lived, high level waste. Fusion would be a baseload power in the form of high quality heat that is 200 million times more energy dense than hydrocarbons. It is also dispatchable, meaning we can turn it on and off on demand. It has the ability to scale quickly and could be built in any geography. In addition, this heat could be useful for industrial processes.

HIGH-TEMPERATURE SUPERCONDUCTORS

For decades The Massachusetts Institute of Technology has been a leading institution studying fusion. More specifically, MIT's Plasma Science and Fusion Center has been studying how to use strong magnets to confine plasma for practical fusion energy. The other co-founders of Commonwealth Fusion Systems (CFS) and I were all at MIT when a new material called high temperature superconductors became commercially available. We believed that we could use HTS to build magnets that could reach much higher magnetic fields than previous technologies. We would then use these magnets in a device called a tokamak, the highest performing and most studied type of fusion device that uses a magnetic field to confine a plasma in which fusion occurs. In the past, with old magnet technologies, tokamaks had to be enormous in size to achieve net energy and ultimately be used for a power plant. This size meant high costs and slow construction timelines that did not make sense for bringing fusion energy to market. We believed that if we could build tokamaks with HTS magnets, we could build them smaller, faster and at lower cost. This would mean that fusion could achieve net energy and also be commercially viable for the first time in history.

Early on, Eni believed in CFS and our plan to deliver commercial fusion energy as well as a commitment to think about the future of energy and what it required from a climate perspective. Eni made a strong commitment to CFS through an early and significant financial investment, but also through invaluable industrial resources and know-how. Eni created the new Laboratory for Innovation in Fusion Technologies (LIFT) program through MITs Plasma Science and Fusion to invest in new fusion research projects that support commercialization efforts. Eni has also participated in ENEA's Divertor Tokamak Test facility (DTT) project and has helped create a joint research center on fusion which is at the center of a scientific



network with the main Italian universities.

Eni can also support CFS with the computing power of its High Performance Computing 5 (HPC5), one of the most powerful and efficient industrial supercomputers in the world to speed up plasma behavior and control simulations and engineering design.

TOWARDS NET ENERGY PRODUCTION

After the successful demonstration of our fusion magnet technology, CFS is now an important step closer to achieving commercially relevant net energy with our device, called SPARC, a tokamak that uses HTS magnets. It will be the world's first commercially relevant net energy fusion device and is now under construction at our new commercial fusion campus in Devens, Massachusetts. SPARC is on track to be operational and achieve its goals in 2025. It will pave the way for our first commercial fusion power plant, called ARC, which is set to be generating electricity in the early 2030s.

We

BOB MUMGAARD

As the CEO of Commonwealth Fusion Systems (CFS) Bob leads the strategic vision for the company. He also serves as a key member of the technical team, leading the SPARC design process and determining how it interfaces with the business strategy.

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A NEW ALLIANCE

by Brahim Maarad

TO SECURE THE SUPPLY OF CRITICAL RAW MATERIALS, THE EUROPEAN UNION IS ENTERING INTO NEW PARTNERSHIPS AND WORKING ON A EUROPEAN REGULATION MODELED AFTER THE ONE ON BATTERIES LAUNCHED FIVE YEARS AGO AND CONSIDERED A SUCCESS

PRESIDENT OF THE EUROPEAN COMMISSION Ursula von der Leyen stated the following in the latest State of the Union address to the European Parliament in plenary session: "Soon, lithium and rare earth metals will be more important to our economy than oil and gas. The demand for rare earth metals alone will quintuple by 2030." This indicates the EU's new emphasis on strategic independence, including from supply chains, and success will require breaking free of China's encumbrance. According to von der Leyen, "At present, only one country has most of the market. We must avoid dependence, as was the case with oil and gas. With our new trade policy we will seek out new partnerships that will empower our interests as well as our values." Von der Leyen had previously announced her intention to submit for ratification agreements with Chile, Mexico and New Zealand, and to continue negotiations with Australia and India. "It is just a first step, and processing is as critical as supply. 90 percent of the world's rare earth metals and 60 percent of lithium are now processed in China," she added. The EU will "identify strategic projects along the entire supply chain, from mining to refining, processing, and recycling, building strategic reserves where supply is at risk."

The European Commission will propose a regulation on critical raw materials modeled after the Battery Alliance, which is considered a success. As pointed out by von der Leyen, "We know

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this approach can work. The Battery Alliance was launched five years ago and soon two thirds of the batteries we need will be produced in Europe."

The same model was applied to the European semiconductor regulation announced last year. "Work on the first major semiconductor plant will begin in the coming months. Now we must replicate this success," von der Leyen stated. The European Commission is working on the creation of a European Sovereignty Fund to have more say on the financial side of this critical industry.

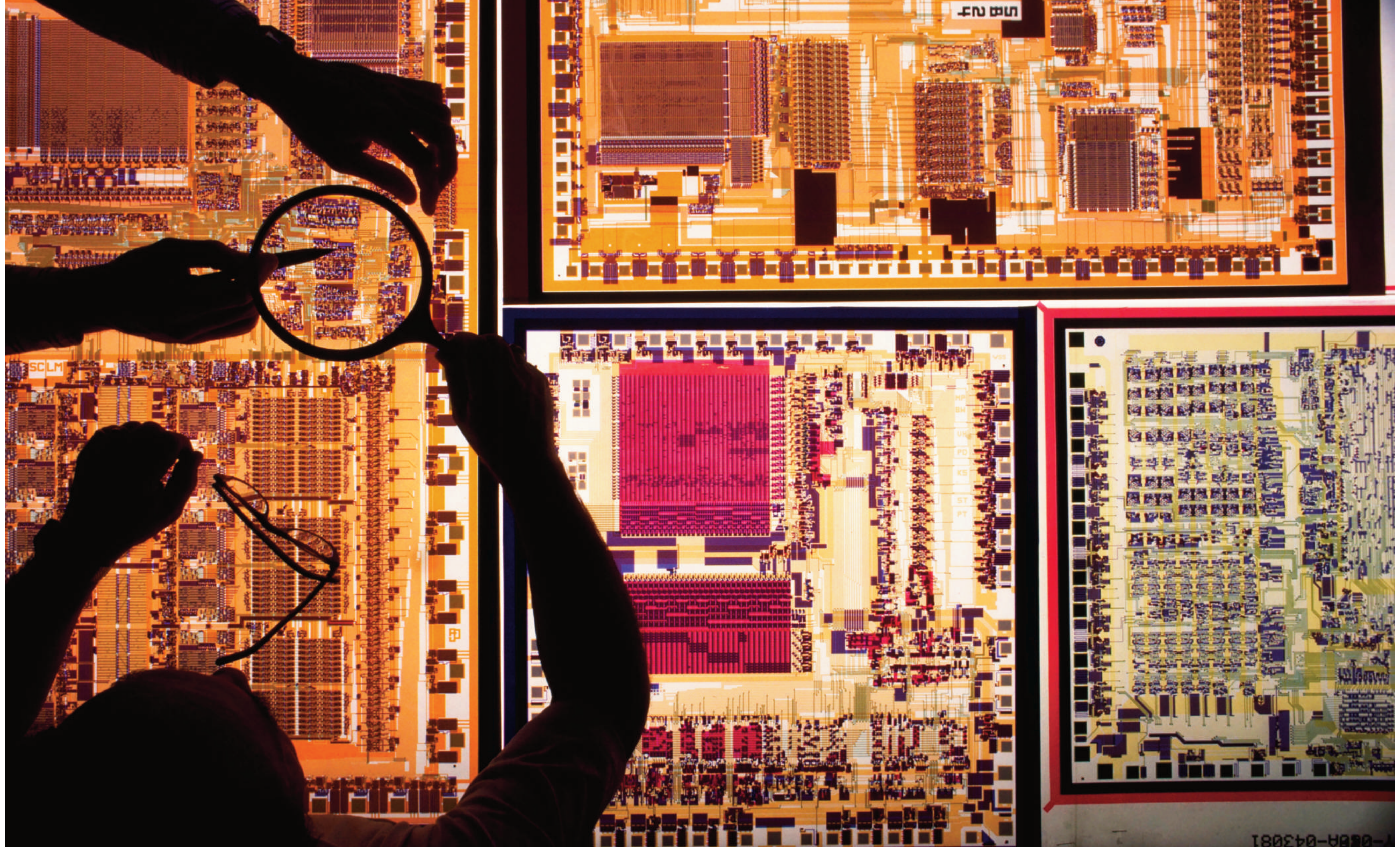
A TOOL FOR EMERGENCIES

In addition, the European Commission is dealing with the supply chain crisis by introducing a new instrument similar to the Defense Production Act of the United States. Having learned a lesson from the Covid crisis, the EU does not want to face other emergencies unprepared. As stated by the European Commissioner for Internal Market, Thierry Breton, "We need to be better prepared to anticipate and respond to the next crisis. Rather than relying on ad hoc improvised actions, the single market emergency tool will provide a structural safeguard for the free movement of goods, people and services during difficult times. It will ensure better coordination with Member States, to help prevent and limit the impact of a potential crisis on our industry and economy and provide Europe with tools that our global partners have and which we lack." The European Council and Parliament are slated to approve the new piece of legislation, thanks to which the EU Commission will be able to request that economic operators provide targeted information, a responsibility that may become binding.

Operators may also be required to prioritize orders for products relevant to a crisis or provide serious reasons for not being able to do so. With faster testing and accreditation procedures, including conformity assessments, certain products will be placed on the market more quickly to ensure availability during emergencies.

EU CHIPS ACT

Europe's Chips Act on the regulation of semiconductors is another step on the path to strategic independence. In 2020, one trillion chips were produced worldwide, but EU production accounted for only 10 percent of the market, albeit the EU is one of the main buyers. The recent global shortage of semiconductors caused factories to shut down in several industries, from automotive to medical devices. This has made more evident the world's semiconductor dependence on a very limited number of players in a complex geopolitical context. A European Commission survey shows that the demand for semiconductors will double by 2030, which will be difficult to satisfy, considering the latest supply chain crises. Thus, the EU wants to double its market share by 2030, by mobilizing more than 43 billion euros in public and private investment, and taking measures, together with Member States and international partners, to prepare for, anticipate and deal with future supply chain disruptions. One of the new projects related to this strategy is a production plant for silicon carbide (SiC) microchips by STMicroelectronics in the Italian city of Catania, a €730 million investment of which €292.5 million will come from European NRRP funds. Silicon carbide is a compound material used to manufacture semiconductors for high-performance devices, such as electric vehicles, fast EV chargers, renewables and other industrial applications. By 2026, the plant will be Europe's first industrial-scale integrated production line of epitaxial silicon carbide wafers, one that also includes the manufacture of SiC powder.



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THE BATTERY ALLIANCE MODEL

In 2017, the EU Commission launched the Battery Alliance to create a complete, globally competitive and sustainable European battery value chain. This was part of a broader goal to ensure strategic independence in an area critical to the ongoing green and digital transition. The Alliance provided a framework for the European Commission, Member States, European Investment Bank and industry and innovation players to work on a shared agenda. According to the Commission's latest report, 111 major battery projects are under development in Member States, with a total investment of €127 billion over the entire value chain and a goal to reach an added value of around €625 billion by 2030. According to European Commission Vice President Maroš Šefčovič, "In 2017, the EU's battery industry was certainly not on the map. Now, Europe is a major global player, with 20 emerging gigafactories in our Member States. By 2030, we plan to produce enough batteries to power 11 million electric cars every year." As for Commissioner Breton, "Five years ago, Europe was in danger of lagging behind its global battery market competitors irreversibly. At the present time, we are on our way to meeting up to 90 percent of our needs by 2030. It is a remarkable turnaround and an example of what the EU can achieve with strong political commitment and joint efforts. However, a lot of progress is still to be made as far as sustainable and responsible production, raw materials supply, and providing the European workforce with the right skills." As a matter of fact, as many as 800,000 qualified workers will be needed and/or retrained by 2025. For this reason, the Commission announced the creation of a European Battery Academy. However, the 30 million electric cars planned for 2030 are not just made of batteries. Breton warned that China "controls the entire value chain of the permanent magnets needed to run electric engines. The prices of rare earth metals used for permanent magnets have risen by 50 to 90 percent in the last year alone. Unless we have greater access to raw materials, our zero emissions mobility goals are in danger, due to a possible shortage or higher costs." Similar conditions and percentages apply to silicon, essential for photovoltaics and semiconductors, as demand is set to increase fivefold by 2030. "It is time to enshrine in legislation which raw materials are critical or strategic for Europe. This list will be our compass and it will provide a stable, agile, and predictable legal framework to identify projects, for example, as well as facilitate investment, manage international partnerships, and set our innovation agenda. This includes mining in Europe, which is still a taboo. Many consider it to be dirty. We prefer to import from third countries, turning a blind eye to their own environmental and social impact, not to mention the carbon footprint. However, mining in Europe can benefit from very low environmental impact thanks to new technologies," the EU Commissioner said.

BRAHIM MAARAD
AGI reporter. Brussels correspondent.

TECHNOLOGY KEY TO TAKING THE LEAD

by **Lifan Li**

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TO GET AHEAD IN THE GLOBAL RACE OF ENERGY TRANSITION, CHINA IS INCREASINGLY INVESTING IN THE DEVELOPMENT OF NEW TECHNOLOGIES

SINCE THE BEGINNING of 2022, the conflict between Russia and Ukraine has caused huge fluctuations in world energy prices, the development of new energy has been affected, and the international energy transformation has slowed down. The proportion of coal power generation in China, Europe and the U.S. increased from 70.4 percent, 19 percent, and 12.25 percent in 2020 to 70.6 percent, 22 percent, and 15.43 percent in 2021. The boost in export demand and lower-than-expected clean energy power generation are the main reasons for the increase in China's demand for coal.

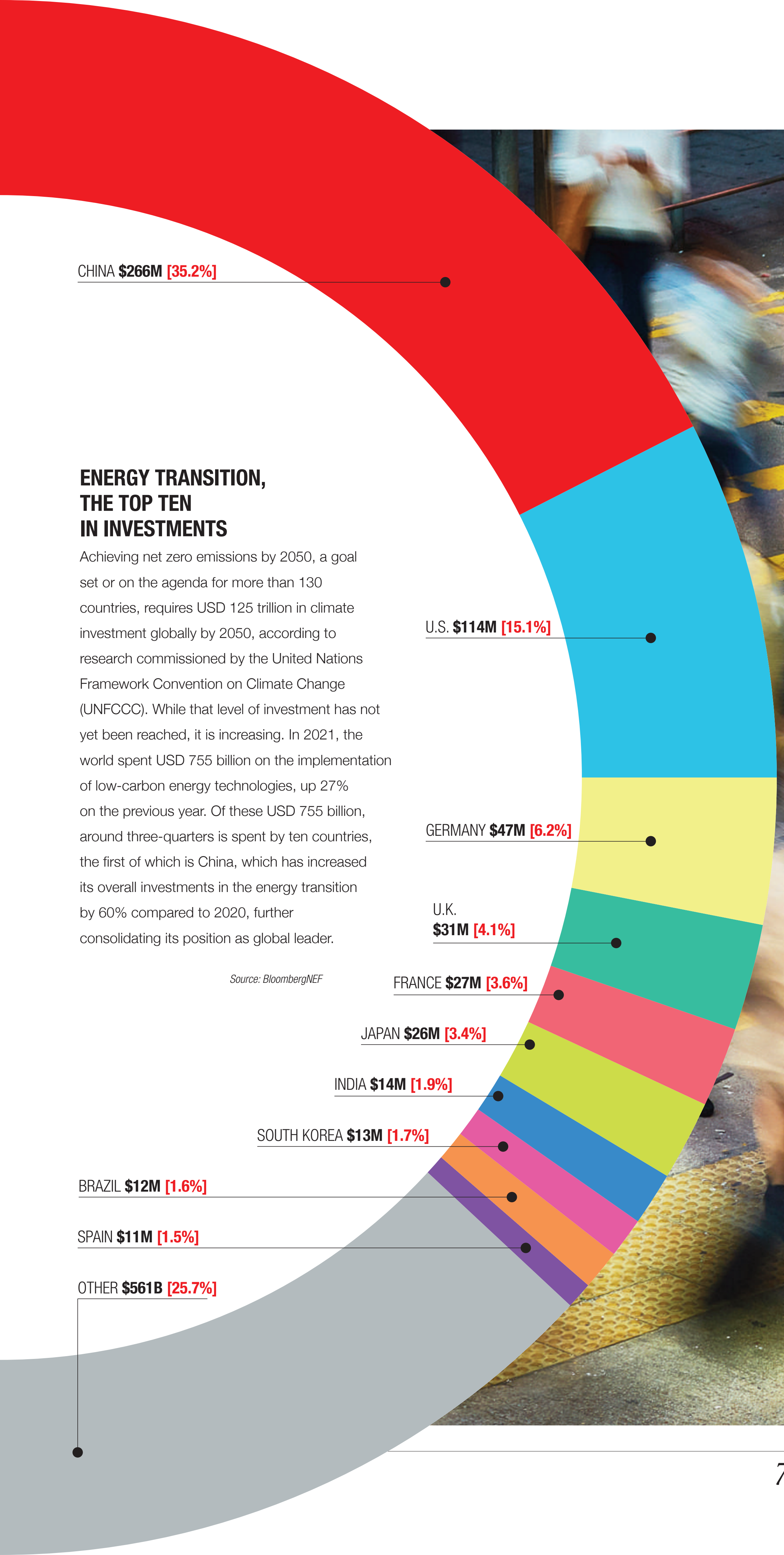
FOLLOWING THE TREND OF GREEN DEVELOPMENT

In 2022, there will be diversification in energy demand and substitution for coal in China and Europe. The demand for coal power has declined in China, a benefit attributable to improved

ENERGY TRANSITION, THE TOP TEN IN INVESTMENTS

Achieving net zero emissions by 2050, a goal set or on the agenda for more than 130 countries, requires USD 125 trillion in climate investment globally by 2050, according to research commissioned by the United Nations Framework Convention on Climate Change (UNFCCC). While that level of investment has not yet been reached, it is increasing. In 2021, the world spent USD 755 billion on the implementation of low-carbon energy technologies, up 27% on the previous year. Of these USD 755 billion, around three-quarters is spent by ten countries, the first of which is China, which has increased its overall investments in the energy transition by 60% compared to 2020, further consolidating its position as global leader.

Source: BloombergNEF



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climate and increased capacity from new installed energy. China's hydropower, wind power, and solar power generation achieved year-on-year growth of 17.5 percent, 12.9 percent and 4.5 percent respectively from January to May in 2022, while thermal power fell by 3.5 percent. In order to complete China's international carbon emission reduction task, China needs to increase investment in new technologies and continue to grow the utilization of new energy.

China believes achieving carbon peaking and carbon neutrality is the only way to follow the trend of green development and promote high-quality and sustainable economic and social development. Through active exploration, initiative actions, accelerating technological progress and development transformation, high-quality carbon peaks and carbon neutrality can be achieved on schedule. As the world's largest developing country and a major carbon emitter, China needs to implement several major strategies including energy conservation and efficiency improvement, energy security, non-fossil energy substitution, resource recycling, re-electrification, carbon sequestration, digitization, and international cooperation. Optimizing and upgrading industry, building a clean, low-carbon, safe and efficient energy system, building a new power system based on new energy, promoting electrification and deepening decarbonization technology research, improving the electrification of the transportation sector, making breakthroughs in key technologies for green buildings, formulating a carbon removal action plan and improving the carbon trading system are all major tasks for realizing carbon peaking and carbon neutrality.

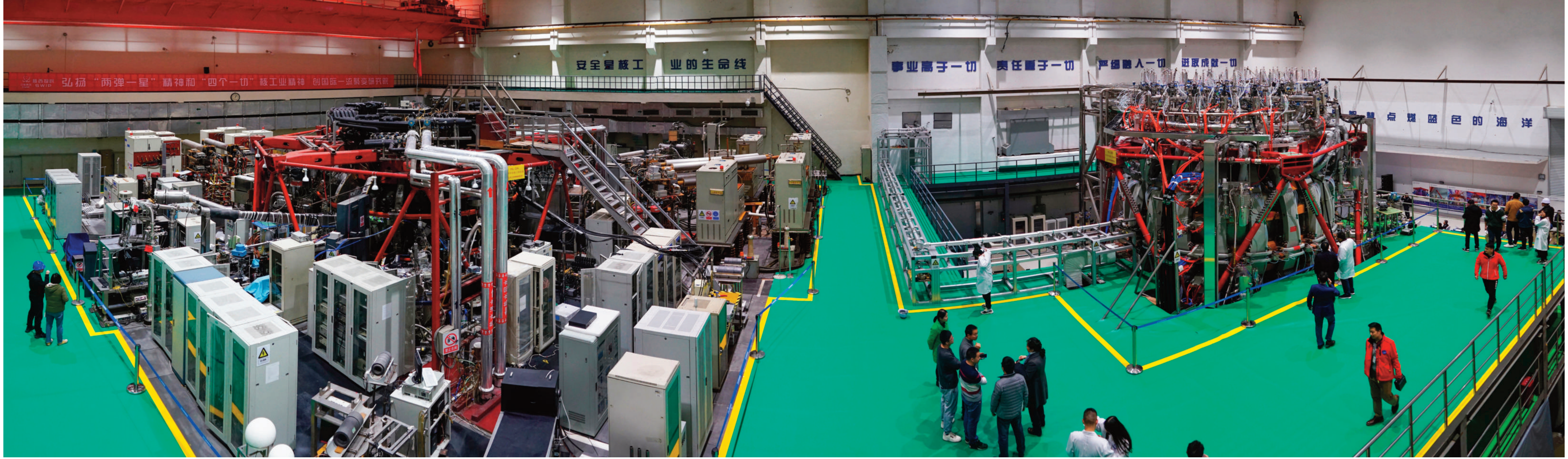
EXISTING AND DEVELOPING NEW TECHNOLOGIES

Development of new technologies boosts China's success in the world context of energy transition. One early task is to optimize and upgrade the combustion of boilers in power plants, an important new path for the green transformation of traditional energy. For a period of time, coal-fired thermal power will still play the role of ballast and stabilizer. How, therefore, can the coal-fired power industry achieve a green transformation? Using technical innovation to optimize boiler combustion in coal-fired power plants is an effective measure to reduce coal consumption for power generation. However, realizing boiler combustion optimization requires monitoring data drawn from the furnace temperature field, and since boiler combustion is a complex heat exchange process, the combustion conditions are very unstable. In 2020, Chinese company ABB released the Uvisor Pyro flame detection instrument which, in addition to the conventional flame detection function, can also perform temperature measurement and has been successfully applied in nearly 20 units in domestic power plants in China. In order to effectively support the in-depth peak combustion optimization of coal-fired units, it improves the safety, stability and efficiency of boiler combustion, promotes the low-carbon transformation of the power generation industry and supports the realization of energy conservation and emission reduction goals. Chinese companies have developed AbilityTM Optimax Energy Management system, which is used from virtual power plants to micro grids, from heating, cooling, water supply management, efficient dispatch control and optimization to carbon emission management.

Second, it conquers the key technologies of green hydrogen, accelerates the advancement of the new energy revolution and adopts an international cooperation model to provide green hydrogen for developed country markets. In the field of new energy, hydrogen energy, as a clean and flexible energy carrier, has the advantages of zero pollution, high efficiency, abundant sources, and a wide range of uses which will bring more revolutionary breakthroughs to the energy transformation. It can provide integrated electrical, control, instrumentation and digital solutions to help maximize the value of the entire hydrogen energy value chain and improve efficiency and productivity. For example, the high-power low-harmonic rectifiers can be developed at the same time the electrolysis of water to produce hydrogen has been developing, and the development and integration of technologies have accelerated the wide application of hydrogen energy. This also includes international cooperation. In Italy, the Chinese company ABB is working with Swiss utility Axpo to develop a modular green hydrogen power plant to produce affordable green hydrogen by creating an optimal operating model. ABB is also working with Canadian sustainable energy conversion company Hydrogen Optimized to jointly explore the development of grid-connected large-scale green hydrogen production systems to provide a clean, sustainable and economical energy carrier.

FOCUS ON ENERGY STORAGE AND FUSION

Third, strengthen energy storage technology: energy storage technology plays an irreplaceable role in the efficient utilization of renewable energy, clean kerosene and gas. With the vigorous development of smart grid, renewable energy power generation, distributed power generation and microgrid, a large number of distributed power sources are connected to the distribution grid. However, the problems of randomness and high load brought by distributed systems need to be solved by distributed energy storage technology. Energy storage is a key technology for developing renewable energy power generation business. In China, energy storage is one of the goals of the transformation of the petroleum industry. It can be integrated with oil and gas and has a wide range of application scenarios. For example, combined with the geothermal resources in the oil field, the energy storage technology can be matched with geothermal power generation to realize the peak and frequency regulation of the geothermal power station; the oil and mining areas actively carry out the effective utilization of wind and solar resources, and cooperate with the energy storage device to realize local consumption; the



energy storage technology can also effectively replace the traditional petroleum engineering energy and realize energy saving and emission reduction. With the development of technology, especially the continuous iteration of string technology, the diversified energy supply becomes visible, manageable and controllable. The new energy storage will move from battery integration to intelligent string architecture, so as to build efficient and safe energy storage system.

Fourth, nuclear fusion can be used to develop a new generation of sustainable and safe energy systems. Nuclear energy has the advantages of high energy density, stability and reliability, is clean and pollution-free, and is the best alternative to fossil energy. As we know, the energy of the sun comes from the continuous nuclear fusion reaction in its core area. Magnetically Confined Fusion (MCF) is used to achieve a continuous and controllable nuclear fusion reaction like the sun to develop nuclear fusion energy, which is also vividly nicknamed Artificial Sun. Compared with nuclear fission energy, nuclear fusion energy has more advantages: (1) Nuclear fusion has a higher energy density than nuclear fission. (2) Nuclear fusion is cleaner and safer than nuclear fission. (3) Nuclear fusion fuel is sufficient and sustainable. In China's fusion energy development roadmap, the China Fusion Engineering Test Reactor (CFETR) is a key step in the practical research of fusion. The Institute of Plasma Physics, Chinese Academy of Sciences (CAS) has successfully built and operated HT-6B and HT-6M conventional tokamak device, HT-7 superconducting tokamak devices, EAST full superconducting tokamak device, and CAS participated in the ITER program as the main unit, accumulating rich experience for the development of fusion energy. In the future, this R&D will provide proof of scientific quality for our new energy development and market entrance.

Fifth, Artificial Intelligence technology will be applied in a wider range of energy services in the future. China has realized defect and fault diagnosis of power equipment through AI. State Grid of China starts with data media such as vision (image, video), hearing (voice) and perceptual understanding (text), and artificial intelligence applications will penetrate into the field of energy services in many ways. In the fields of electricity sales services, operation and maintenance services, distributed energy services, energy conservation and emission reduction services, demand response services and customer services, AI will assist in the realization of intelligent and safe production, efficient transmission, precise sales and differentiation, and high Satisfaction customer service. On the basis of cultivating and attracting innovative talents and giving full play to the flexible innovation mechanism, AI will make full use of the advantages of the application scenarios of energy service enterprises. And it will build an open and interconnected urban information system on the basis of fully guaranteeing the security of customer information and data, so as to realize the intelligent development of the energy field.

Chengdu, China. The experimental nuclear fusion reactor Tokamak HL-2M, nicknamed the Chinese "artificial sun." Scientists around the world are trying to get net energy from nuclear fusion. When it will be available and usable at the industrial level, such technology will generate huge amounts of energy with zero emissions.

WE NEED TO SPEED UP THE CREATION OF STANDARDS

In summary, the development and utilization scale of China's clean and green energy industry ranks first in the world, and China is the world's largest clean energy market and equipment manufacturer. Taking the photovoltaic industry as an example, the photovoltaic cells and modules produced in China account for more than 70 percent of the global market, and the products are exported to nearly 200 countries or regions. China's newly installed photovoltaic capacity exceeds 40GW each year, and the cumulative installed capacity exceeds 200GW, ranking first in the world. Although China is a major country in the production and application of photovoltaics in the world, the creation of standards is relatively lagging behind. In the context of intensifying strategic competition between China and the United States, China urgently needs to create high-quality photovoltaic standards to consolidate its dominant position in the global photovoltaic industry. In the field of new energy, China will use original and localized innovation, integrated innovation and the introduction of independent technological innovation technologies formed through digestion, absorption and re-innovation, and increase the research, cultivation and creation of international standards, so as to occupy a leading position in the global new energy industry chain. With more expectation, in the promotion of the Belt and Road Initiative (BRI), China needs to pay more attention to improving the adaptability and popularity of Chinese standards of the green energy field in the countries along the BRI.

we

LIFAN LI
He is associate research professor at the Shanghai Academy of Social Sciences and Secretary General of Center for Shanghai Cooperation Organization Studies.

THE TRANSITION OF NOCs

by Ben Cahill

SOME HOLD BACK, OTHERS ARE AT THE CUTTING EDGE. NATIONAL OIL COMPANIES ARE NOT UNIQUELY MOVING ALONG THE PATH TOWARDS DECARBONIZATION, BUT THEY WILL CERTAINLY NOT BE MERE SPECTATORS OF THE EVOLUTION OF THE INDUSTRY

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DISCUSSIONS about the energy transition often center on super majors like Shell and ExxonMobil, while the national oil companies (NOCs) are usually portrayed as laggards. But this is only one side of the coin. Some NOCs are making major investments in areas such as hydrogen and ammonia, carbon capture and storage and renewables. The question is which of them have the investment capital and managerial acumen to decarbonize their activities and build a more resilient business.

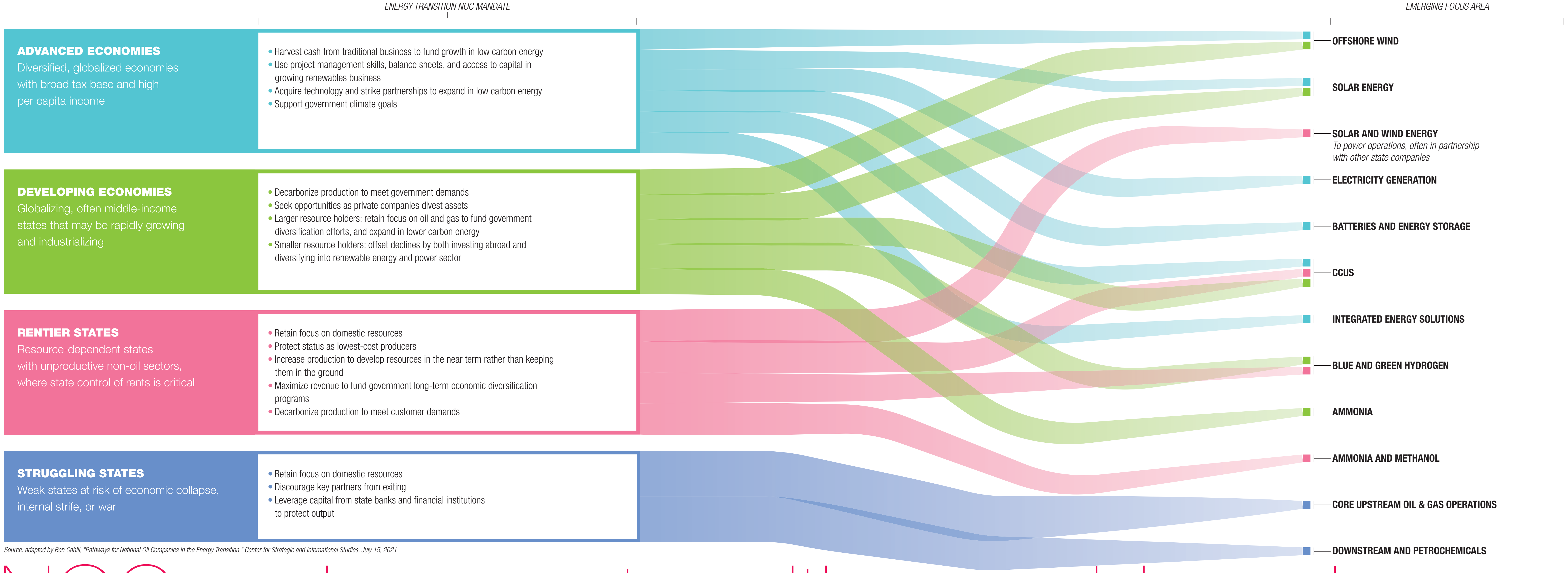
NOC and energy transition: evolving roles

A MIXED SCENARIO

NOCs are a mixed bunch: Some are among the most technologically advanced and best managed in the industry, such as Saudi Aramco; others have unique strengths in key areas, such as Petrobras in deep-sea oil and gas and PETRONAS in liquefied natural gas (LNG). Whereas the NOCs in emerging oil and gas producing states often have limited engineering and project management capacity, and therefore depend on foreign partners. NOCs are approaching the energy transition from very different angles, and it is dangerous to make sweeping claims about their climate strategies. However, there are some observable differences in their approach.

Traditionalist NOCs are hanging on. In some cases, host governments are convinced that the rest of the world is underinvesting in oil and gas supplies and overestimating the pace of the energy transition, while there are governments that believe their NOCs should avoid investing in new areas that could erode yields and put tight budgets under pressure. And many state-owned companies simply fail to map out realistic strategies, due to poor governance, political distractions or inertia. But no NOC is immune to the energy transition. Even fully state-owned corporations face environmental, social and governance (ESG) pressures when issuing bonds, seeking insurance or working in joint ventures with partners that are facing new investor demands.

Most NOCs are already diversifying into various areas, following different pathways (see table), each according to their resource base, their national government's climate targets and the emission intensity of their oil and gas-producing activities. Companies with a more limited resource base face greater pressure to switch to low-carbon energy. In countries with more ambitious climate goals and net-zero commitments, NOCs are aligning their business plans with state targets. And NOCs with emission-intensive resources such as heavy crude oil need to act faster to decarbonize operations. A look at investor presentations and NOC sustainability reports reveals certain common trends.



Source: adapted by Ben Cahill, "Pathways for National Oil Companies in the Energy Transition," Center for Strategic and International Studies, July 15, 2021

HYDROGEN AND AMMONIA TARGETS

Almost all large NOCs appear to have ambitious hydrogen and ammonia targets in an effort to make low-carbon fuels available for transport and heavy industry. Saudi Aramco and the Abu Dhabi National Oil Company (ADNOC), for example, are optimistic about the prospects for hydrogen and ammonia. Saudi Aramco has set itself the target of producing 2.9 million tons of "clean" hydrogen per year by 2030, and to reach 4 million tons per year by 2035. The exact distinction between blue and green hydrogen is unclear (blue hydrogen is produced from natural gas and involves the capture and sequestration of CO_2, while green hydrogen is produced by electrolysis from renewable energy). Saudi Minister of Energy, Abdulaziz bin Salman, claims that a "large part" of the unconventional gas coming from the Jafurah field development project will be used for blue hydrogen. Saudi Aramco also plans to produce 11 million tons of blue ammonia per year by 2030 and has signed preliminary agreements with buyers in Japan and South Korea. There are also other state-owned companies in Saudi Arabia that are working to adopt the strategy to develop green hydrogen. Like Saudi Aramco, ADNOC also has major projects for hydrogen and ammonia: together with its partners, the company plans to build a blue ammonia plant producing one million tons per year, in Ruwais. Abu Dhabi hopes that blue hydrogen will supplant the national industry demand for natural gas, in support of the decarbonization of the steel and chemical industries and other sectors. And

ADNOC, just like Saudi Aramco, intends to acquire the first-mover advantage in hydrogen and ammonia by securing deals with buyers from Asia and Europe. Both companies leverage benefits such as strong customer ties, good port facilities and promising geology for Carbon dioxide Capture, Utilization and Storage (CCUS).

Other NOCs with hydrogen ambitions are the Chinese Sinopec and China National Petroleum Corp. (CNPC), the Malaysian PETRONAS and the Colombian Ecopetrol. Some of these companies have set the objective of developing hydrogen for use in transport, to supplement or replace the current gray hydrogen production for the refining and petrochemical industries; other NOCs, in contrast, are in the initial phase of such developments, in particular as regards green hydrogen, and are still working on feasibility studies and evaluating potential economies of scale. The common thread that binds them is the connection to climate goals and net zero strategies (by the companies themselves and the states that host them).

INVESTMENTS IN CCUS

To reduce the intensity of their emissions, many NOCs are resorting to carbon capture and storage. Of course, carbon capture, use and storage (CCUS) is an established technology; for many years now, the main investments in the CCUS have come from oil and gas companies, which therefore have an initial advantage over the energy and industry sectors. The growing focus on

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Dhahran, Saudi Arabia. King Abdulaziz Center for World Culture in Saudi Arabia, also known as Ithra, owned by the Saudi Aramco Oil Company. The center stands in the place where the first oil field in the country was discovered.

Offshore wind power. Several NOCs are investing in renewable sources. China National Offshore Oil Corp., for example, plans to spend up to USD 3.4 billion on offshore wind and solar projects by 2025, with more than 85 percent allocated to wind power.

Hellisheidi, Iceland. Structures for the storage of carbon dioxide in the subsoil. To reduce the intensity of their emissions, many NOCs are resorting to carbon capture and storage (CCS). For many years now, the main investments in CCS and CCUS have come from oil & gas companies.

the decarbonization of oil and gas activities, and in particular the new greenfield projects, has greatly extended the list of announcements of CCUS initiatives. The sector faces several challenges: first, oil and gas companies, including ADNOC and Saudi Aramco, traditionally use carbon capture for the purpose of injecting CO_2 for Enhanced Oil Recovery (EOC), thus fueling the perception that investments in CCUS will prolong and even increase CO_2 emissions in the industry for many more years to come. Second, these projects are expensive, especially without a carbon tax and emission trading schemes that incentivize CCUS. And third, oil andand gas companies have a mixed track record for carbon capture and storage projects.
However, NOCs remain oriented towards significantly increasing investments in CCUS. For example, Qatar Energy pledged to achieve a CO_2 capture volume of 11 million tons per year by 2035, in an effort to reduce the emission intensity of its LNG production in the context of the North Field East expansion. The company claims it can reduce the carbon intensity of its new LNG production by reducing flaring, powering operations with clean energy and implementing CCUS. Other LNG exporters could follow Qatar Energy's lead, as both new and existing LNG projects are often subject to comparisons in terms of carbon emissions. More generally, there are NOCs who have signed cooperation agreements with companies such as ExxonMobil and Repsol to explore carbon capture and storage opportunities.

RENEWABLES AND BATTERIES

In addition, some NOCs are investing in renewable energy projects, from offshore wind to solar and battery technology. The China National Offshore Oil Corp. (CNOOC), China's leading offshore oil producer, is taking over as national leader in offshore wind and solar power, and has stakes in two projects in the provinces of Jiangsu and Guangdong. The company plans to spend up to USD 3.4 billion on offshore wind and solar projects by 2025, with more than 85 percent invested in wind power, and plans to increase spending on renewables from 10 to 15 percent of its annual expenditure between 2026 and 2030. PETRONAS plans to increase its renewable energy capacity from the current 851 MW to 3,000 MW by 2024. Ecopetrol has ambitious plans for expansion in the field of renewable energy. The Colombian NOC has set itself the goal of achieving net zero (Scope 1 and 2) and reducing emissions by 50 percent by 2050. Its 2040 Strategy announces that the company intends to develop 400 to 450 MW of renewable energy by 2024, mainly from solar projects. The intention to reduce Scope 2 emissions to fulfill net zero pledges is a strong incentive for NOCs to invest in renewable energy or purchase clean energy to power their operations.
NOCs aiming to decarbonize their production and provide more diversified energy focus mainly on hydrogen, CCUS and renewable energy, but this list is not exhaustive. Indonesian Pertamina aims to double its production of geothermal energy (currently 700 MW) by 2028. Petrobras is examining the potential of biofuels (last year it spent more on the research and development of advanced biofuels than on renewables). Over time, other NOCs may increase their spending on methanation to meet the customer demand for CO_2-free methane gas.
The different NOCs will follow different pathways for the energy transition; not all will have the capital or the capacity to develop the technologies needed to reduce emissions and expand into new areas, but they represent roughly half of world oil and gas production: it would be wrong to assume that they will follow the evolution of the oil and gas sector as mere spectators or spoilers.

We

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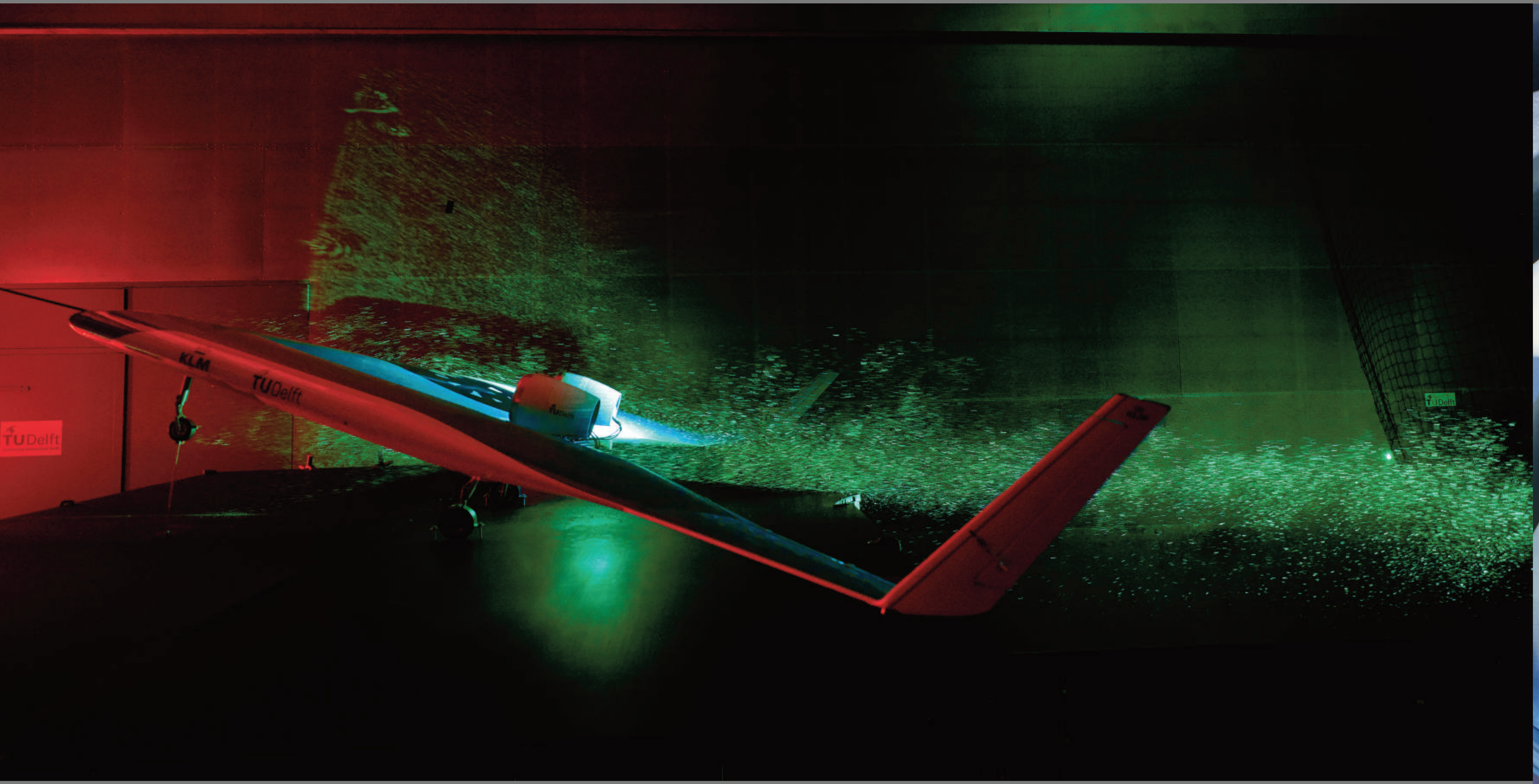
“HOW GREEN IS IT, HOW LONG WILL IT TAKE?” THESE ARE THE QUESTIONS THAT DAVIDE MONTELEONE SOUGHT TO ANSWER THROUGH HIS WORK ON THE SERIES OF PHOTOGRAPHS PUBLISHED IN THIS MAGAZINE. LAST YEAR, THE AUTHOR TRAVELLED THE LENGTH AND BREADTH OF EUROPE TO VISIT SOME OF THE MAIN INSTITUTIONS IN THE FIELD OF AVIATION. THE OBJECTIVE WAS TO INVESTIGATE THE CURRENT SITUATION IN THE TRANSPORT INDUSTRY TO FIND

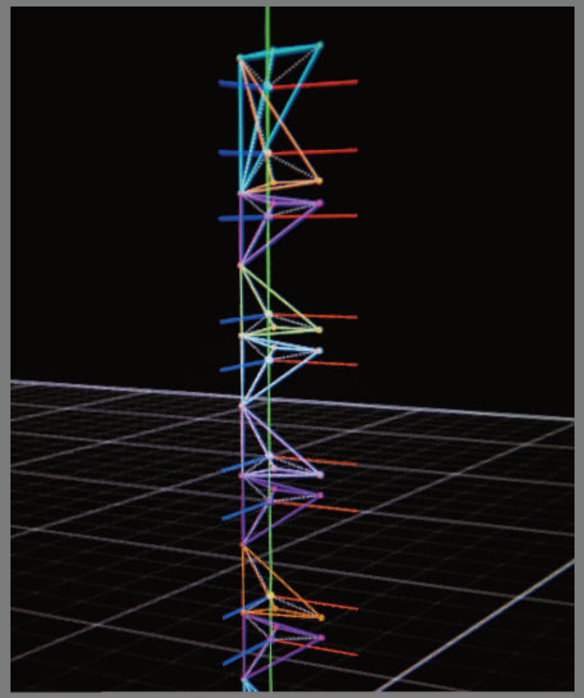
JOURNEY INTO THE FUTURE

OUT ABOUT THE INNOVATIONS IN THE PIPELINE AND HOW MANY WILL BE POSSIBLE IN THE IMMEDIATE FUTURE. WHAT EMERGED IS AN IMPRESSIVE VARIETY OF VISIONARY PROJECTS, WHICH ARE, HOWEVER, STILL QUITE FAR FROM ACTUALLY BEING ACTUALLY PUT INTO PRACTICE, ESPECIALLY AS REGARDS MASS TRANSPORT.

Davide Monteleone is a photographer, artist, and National Geographic Explorer whose work spans image-making, journalism, and writing. A regular contributor to leading international magazines, his work has been presented in the form of exhibitions and installations in galleries and museums all over the world.
Holding a Master in Art and Politics from the Goldsmiths University in London, Monteleone is also active as a curator and educator for numerous public and private institutions.

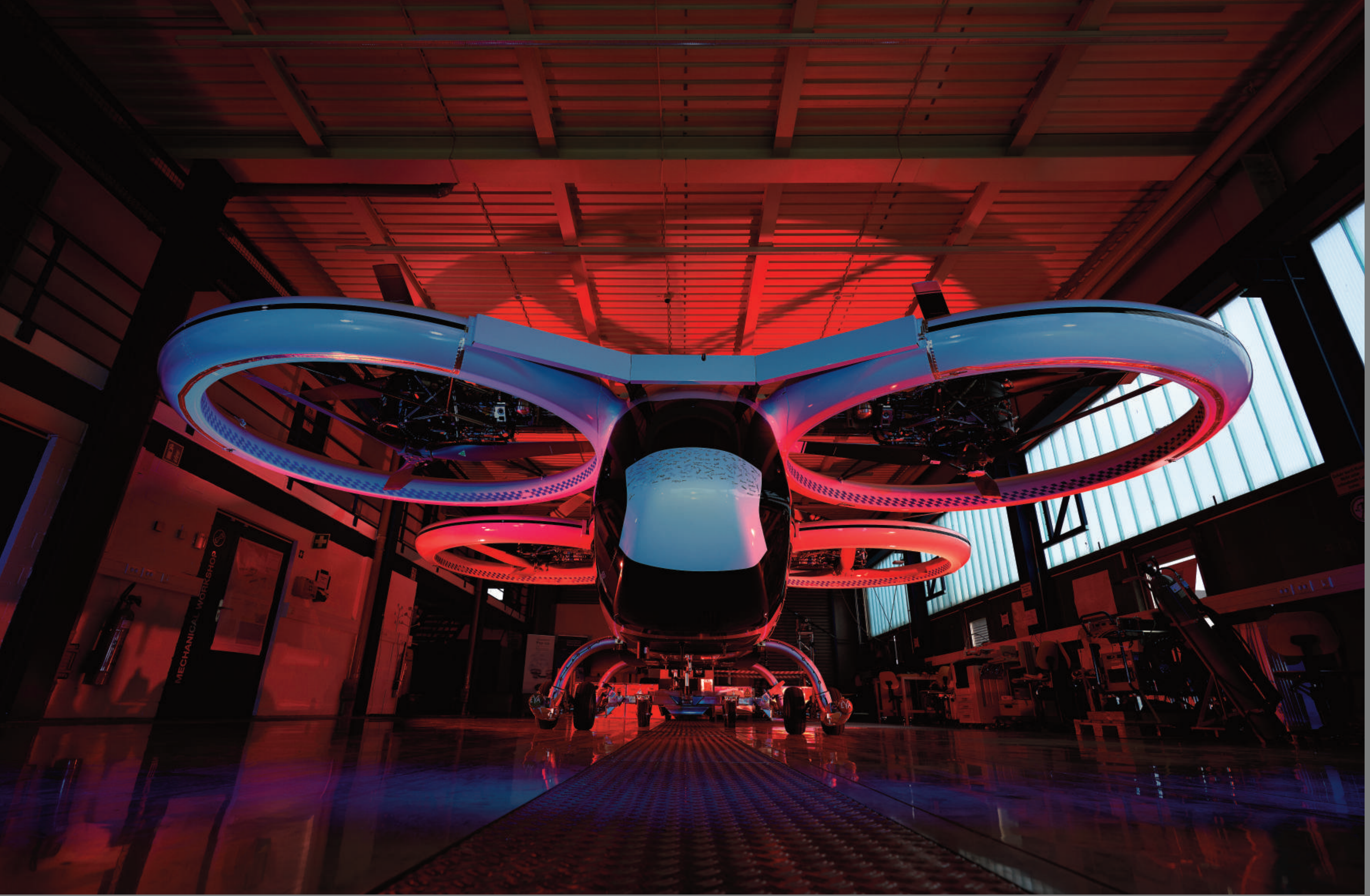
FormulaE Championship 2021, Rome E- Prix, Rome, Italy, April 2021. FormulaE Official Car photo shooting in front of the “Palazzo della Civiltà Italiana”. FormulaE racing cars are powered by pure electricity. With a 250kW of maximum power, the new Gen2 models can accelerate from 0-100km/h in 2.8-seconds and go on to a top speed of 280km/h. The design aims to increase downforce and to maintain aerodynamic grip and lightness by using components made of carbon fiber, kevlar, and aluminium. Due to the energy storage capacity of batteries, drivers are able to cover the full race distance without making a midrace car swap.

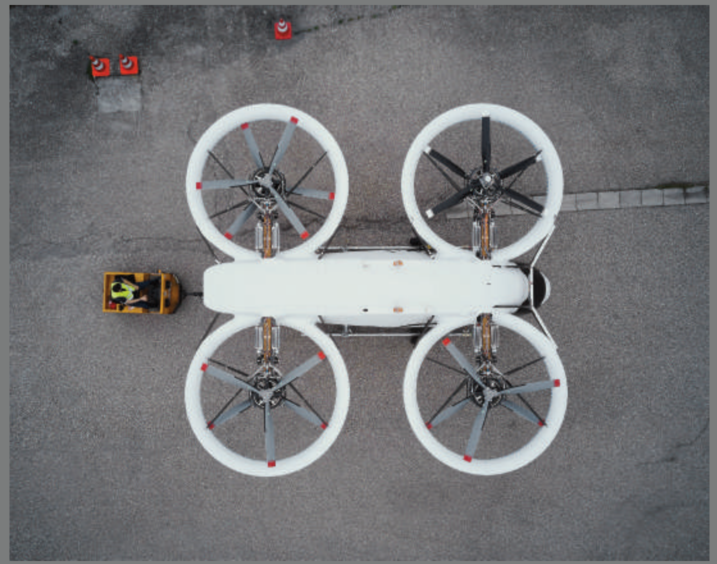




TU Delft, Open Jet Facility Wind Tunnel, Delft, Netherlands, April 2021. Flying-V is an energy-efficient aircraft design in which passengers, cargo and fuel are all located in the wing. Test and simulations have proven that the aircraft will use 20% less fuel than today's most advanced aircrafts thanks to its peculiar v-shape, which improves aerodynamics and reduces weight. The scale model has been developed to be extremely light, weighing over 25 kilograms and measuring 2,76m in length. Its current wingspan reaches 3,06m but the proposed measures of the future aircraft will be 65m in wingspan and 55m in length. It will be able to carry 314 passengers.

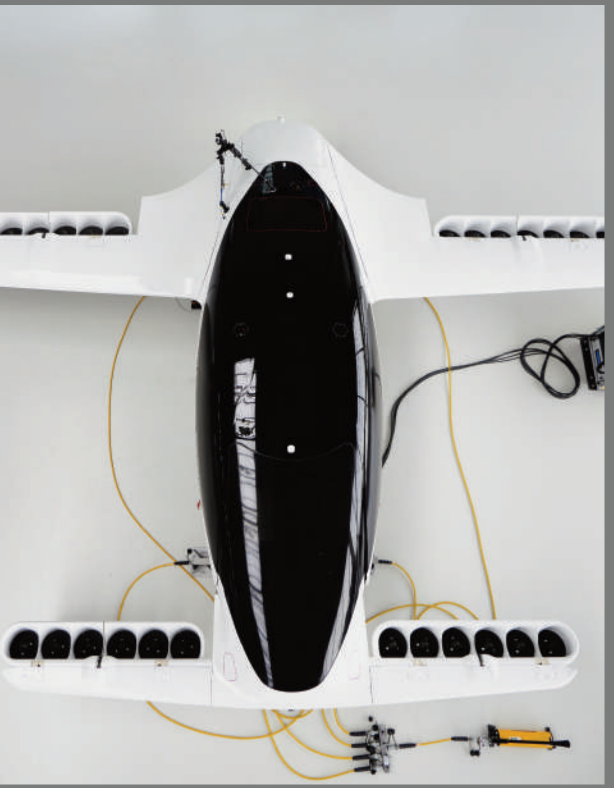
Rolls-Royce, Assembly Line Facility, Derby, UK. May 2021. UltraFan is a brand-new engine concept developed and built by Rolls Royce with a new core architecture combined with ALECSys lean burn combustion system, to deliver maximum fuel burn efficiency and low emissions. The engine has carbon titanium fan blades, a composite casing that reduces weight up to 1,500lb per aircraft, and a power gearbox introduced between the fan and intermediate pressure compressor to ensure that the whole system continues to run at its optimum speed.





Airbus division in Manching, Germany. April 2021. Airbus CityAirbus is an all-electric, fourseat, multicopter vehicle demonstrator that focuses on advancing remotely piloted electric vertical take-off and landing (eVTOL) flight. The CityAirbus full-scale demonstrator conducted its first take-off in May 2019. Its capacity and structure are ideal for aerial urban ridesharing. CityAirbus features four ducted high-lift propulsion units. Its eight propellers are driven by electric motors at around 950 rpm to ensure a low acoustic footprint. Its cruise speed will be approximately 120 Km/h, with up to 15 minutes of autonomy.

Gloucester Airport, Gloucester, UK. May 2021. The Spirit of Innovation is a high performance electric aircraft developed and built by Rolls Royce under the ACCEL (Accelerating the Electrification of Flight) program. With a target speed of 300+ MPH, the Spirit of Innovation has been specifically designed for air racing and it is set to be as the world's fastest zero-emissions airplane. Its 6,000 battery cells are packaged for maximum lightness and thermal protection. An advanced cooling system can withstand the extreme temperatures and high-current demands during flight. The Spirit of Innovation can provide enough energy to fly up to 200 miles on a single charge.



Lilium GmbH, Munich, Germany. April 2021. The new Lilium 7-seater, launched in March 2021, is the first electric vertical take-off and landing jet and it has been developed and designed to enable a sustainable and accessible mode of highspeed travel in regional mobility. The technology at the core of the Lilium Jet is Ducted Electric Vectored Thrust (DEVT), with electric engines integrated into the wing flaps. This provides advantages in payload, aerodynamic efficiency and a lower noise profile. Lilium's jet's timeline is to start production in 2023 with 25 copies.

Quarterly
Anno XII - N. 54 October 2022
Authorization from the Court of Rome
no. 19/2008 dated 21/01/2008

Publisher: Eni spa
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Translated by: Studio Moretto Group Srl [www.smglanguages.com]

Augmented reality: Viewtoo • www.viewtoo.it

Printer: Tipografia Facciotti Srl
Vicolo Pian due Torri, 74 - 00146 Roma
www.tipografiafacciotti.com

Sent to press on October 28, 2022

Paper: Arcoset 100 grammi

eni AGI


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