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Energy Journal

Decarbonized and interconnected: the future energy markets

A magazine about energy and more by CESI

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Editorial

Unstable Markets Veering Towards an Interconnected Future

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At the end of November, United States President Joe Biden ordered the release of 50 million barrels from the strategic oil reserve, in coordination with other countries, including China, India and Japan. It was the first time that such a large group of countries coordinated an effort of this type to reduce the price of oil. Indeed, this reveals one of the many evolving scenarios in the energy transition landscape: new dynamics are overturning established ones, driving to new market models (related to various types of environmental technology) and raising great interest in regions of the world, which are endowed with a great natural wealth in critical materials and rare earths.

The four pillars of the energy transition – decarbonization, electrification, digitalization, and decentralization – are consolidating around China's strong technological competitiveness, the green revolution advocated by President Biden in the United States, the leadership of the European Union on the path to decarbonization (thanks, amongst other factors, to the European Green Deal) and the emergence of new territories, once considered secondary in terms of energy markets (Africa, Central and South America, Asia, and Australia).

The present issue of Energy Journal, which is dedicated to the changes that energy markets are undergoing, revolves around the electrification of energy consumption as one of the drivers in many areas of the world for the fight against climate change. You will find in-depth focuses, interviews with sector experts, and a large section dedicated to the four mentioned trends, as well as to the future of power networks. Indeed, the modernization of the latter is fundamental for the adoption of innovative solutions.

The starting point is to understand why the transition towards renewables cannot happen instantly, and why we need to plan a gradual but progressive phase-out of fossil fuels. There are many reasons for this. The foremost is our historical dependence on coal and oil, two fuels that have driven energy markets for well over two centuries. In the "Scenario" section, we describe how the transition from fossil fuels will be a complex process that will profoundly modify global energy markets, with economic, political, and social implications that extend far beyond the energy sector.

Reporting on the results of the 26th United Nations Climate Change Conference (COP26), which ended on November 13th in Glasgow, we will also address the data provided by the "Political Risk Outlook 2021". This reveals a shift in geopolitical power balance from those oil-exporting countries, which have not implemented policies to diversify their economies, to areas of the planet with larger solar and wind resources. The report indicates that Algeria, Iraq, and Nigeria will be the first countries to undergo waves of political instability, followed by Angola, Gabon, and Kazakhstan. On the contrary, the geopolitical analysis predicts a great change for those countries that possess the technology to produce wind turbines and photovoltaic panels (as well as electric vehicles, electric networks, and fuel cells). Similarly, countries that have a natural wealth of the raw materials necessary to produce low-carbon technology (such as rare earths) will also fare well.

Our "Top Story" addresses interconnected systems and the energy markets, two areas that are increasingly affected by the digital revolution. We are aware of the dangers posed by climate change and increasingly frequent extreme weather conditions (freezing temperature, unusual heat, drought, fires, and floods). Indeed, the exceptional wave of arctic weather that hit the United States in February 2021, in conjunction with the insufficient resilience of the power system in Texas (due both to infrastructural and market mechanisms) and the impossibility of balancing power flows, forced the grid operators to schedule a series of power shutdowns to avoid a statewide blackout. Europe reacted differently to similar critical occurrences, thanks to a better interconnected continental power system, which allows high cross-frontier energy transfer.

As we explain in the "Future and Technology" section, CESI is at the forefront of power networks modernization – a challenge that can be addressed by increasing interconnection capacity and improving the digitalization of the power system. In fact, in a world in which extraordinary events are becoming increasingly frequent, rigid and isolated systems may easily get caught up in a crisis as demand rises and production declines. Besides developing Master Plans that take into consideration the United Nations' Sustainable Development Objectives, CESI has also designed market simulation tools that point to the key role of batteries and electrolyzers for the integration of renewables on the grid. Moreover we will also look at how HVDC technology, a core competence of CESI, represents the "broadband" of modern electric systems, allowing the transportation of vast quantities of energy over long distances at a low cost and minimal loss.

The "Opinions" section provides invaluable comments by Laura Cozzi (Chief Energy Modeller at IEA and Head of the Demand Outlook Division with responsibility of producing the annual World Energy Outlook), Michael Pollitt (Professor of Business Economics at the Judge Business School, University of Cambridge and Member of Energy Transitions Cambridge Strategic Advisory Board) and Anna Creti (Professor of Economics at the Paris Dauphine University, LeDA-CGEMP – Dauphine Economics Laboratory-Center for Geopolitics of Energy and Raw Materials). In the words of IEA Chief Energy Modeller, "What is essential now is that governments turn their pledges into clear and credible policy actions and strategies." In his interview, Professor Pollitt echoed Ms. Cozzi, by claiming that "We need to agree to absolute caps on GHG emissions out to 2050 at the global level and to allocate these to countries and regions." According to Professor Creti, "The revision of international carbon accountancy is a step forward to set economic instruments to decrease emission from electricity production worldwide."

In an interesting appendix on green jobs, Bruno Cova, Advisory Services & Studies Unit Director of CESI, introduces readers to the skills required to work on the energy market, an area that is increasingly interconnected and interdisciplinary. "Cutting-edge resources and a high-level preparation are key to producing competitive market analyses and developing new models."

Enjoy the reading.

Guido Bortoni, CESI Chairman
Matteo Codazzi, CESI CEO

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“Clean-energy technologies are slowly but surely going to replace the existing energy industry.”

***Fatih Birol**, International Energy Agency Executive Director*

News

Latest from CESI

HVDC tests

Full-Power Test of HVDC Circuit-Breakers at KEMA Labs

The Full-Power Test of HVDC Circuit-Breakers with AC Short-Circuit Generators Operated at low Power Frequency paper by KEMA Labs (the CESI Testing, Inspection and Certification Division) experts has been given by IEEE an award as IEEE PES best prize paper of 2021. The paper introduces and demonstrates an innovative test method for HVDC circuit breakers. A fault current interruption test method utilizing available AC high-power installations is proposed for DC. The method avoids significant investment needed for the development of test circuits for HVDC circuit breakers. The paper links the critical stages of the fault current interruption process, identified from system studies, to performance requirements that need to be verified during a test. Finally, a complete and adequate test circuit that can, in one step, apply all the necessary stresses to an HVDC CB and hence, to its internal components, has been developed, verified, and demonstrated by testing a prototype of an 80 kV, 16 kA HVDC active current injection breaker. Results of complete HVDC CB tests, executed for the first time at an independent test facility, were analyzed. The paper, subsequently, led a foundation work for the testing of three different technologies of HVDC circuit breakers, rated up to 350 kV, which were carried out in 2020.

"Awarded as best IEEE PES article of 2021."

Nigeria

Rehabilitation of SCADA Systems in Nigeria

The Transmission Company of Nigeria (TCN) is having major issues connecting and communicating to all the substations and generating stations on a real-time basis, due to the lack of any Supervisory Control and Data Acquisition (SCADA). Such missing piece has led the country to experience several system blackouts every year. In this respect, the Rehabilitation of SCADA Systems project – entirely funded by World Bank Group (WBG) – aims to implement a full-scale state-of-the-art SCADA, EMS and telecommunication system to monitor and manage in a safe and reliable manner the relevant electrical network. Furthermore, the project has the goal to monitor energy changes in the interconnected zones. In addition, the scope of the projects includes the implementation of Remote Terminal Units (RTUs) and related adaptation works at relevant substations. Due to its expertise in the field, CESI has been assigned Consultancy Services supervision for the project. Specifically, the scope of our role comprehended the construction supervision of the EPC contract, including detailed Engineering Design Review, Site Supervision and Commissioning works. Furthermore, CESI involvement in the project includes procurement support for the selection of the design, supply and installation contractor for SCADA/EMS systems. CESI commitment in the Rehabilitation of SCADA Systems project began in October 2021 and is set to be completed before January 2025.

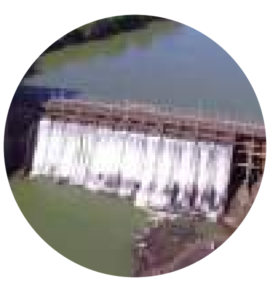
"A project to reliably manage the electricity grid."

United States

High Energy Arc-Fault Testing for International Nuclear Power Plant Safety

High Energy Arc Faults (HEAF) events are defined as energetic or explosive electrical equipment faults, characterized by a rapid release of energy in the form of heat, light, vaporized metal and pressure increase due to high current arcs between energized electrical conductors or between energized electrical components and neutral or ground. HEAF events may also result in projectiles being ejected from the electrical component or cabinet of origin and result in fire. In this respect, the United States Nuclear Regulatory Commission (NRC) has been conducting High Energy Arc Fault testing at the KEMA Labs Chalfont facility since 2015. International HEAF testing was performed at KEMA Labs Chalfont by the NRC Office of Nuclear Regulatory Research (RES) in collaboration with 7 other member countries, including; Canada, France, Finland, Germany, Korea, Japan and Spain. The recent international tests suggest that HEAF scenarios involving certain components may have a zone of influence that is not bounded by the current regulatory guidance, thereby underestimating the risk from HEAF events. Additionally, mitigation techniques have been used as part of the transition to NFPA 805 including "HEAF shields" which theoretically enable an NPP to mitigate damage conditions and reduce the risk of a certain scenario. "HEAF shields" currently in use are based solely on engineering judgment and have no design basis, no qualification tests, no test standards, no acceptance criteria and minimal regulatory footprint. Subsequent evaluation may be needed to asses these HEAF scenarios in order to maintain an acceptable risk profile.

> **"International HEAF testing was performed at KEMA Labs Chalfont."**



Brazil

CESI guarantees structural safety of Brazilian dams

Enel Green Power operates more than 33 small- and medium-sized hydropower plants in Brazil. Several of these power plants were, however, built more than 50 years ago, therefore Enel Green Power started a multi-year program to review and improve the safety conditions of the most aged. In this respect, CESI has been chosen to support the project, thanks to the Group's know-how and expertise in structural and safety analysis of hydroelectric plants. In particular, CESI's involvement has been requested for the Paranapanema Power Plant 31,5 MW/17 m water level, on river Paranapanema in the Sao Paulo state, and Torixoreu Power Plant 2,5 MW/4 m water level, on Sao Domingo River in the Mato Grosso state. In both cases CESI analyzed the current situation of the dams and studied the best solutions to improve the safety condition and optimize the operational cost. CESI's engineers studied the new decamillennial maximum flow and made the executive design of the additional discharging gate necessary to control the increased flow, taking care of the planning of all the construction phases and of the budget estimation. The stability of the bridge has been studies through the construction of 3D models, which main data has been validated by static and dynamic test on the bridge.

> **"The stability of the bridge has been studied through the construction of 3D models."**

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Ulderico Bagalini
RES Integration & Interconnections Product Leader – CESI

Scenario

The Energy Transition Is Reshaping Global Markets

The uptake of renewable energy is key to ensuring a sustainable future, one that is approaching rapidly and profoundly modifying both geopolitical aspects and leadership in the energy sector. And there is more.

The transformation of the energy system is a fundamental element in the fight against climate change, which calls for a 1.5°C reduction in global warming over pre-industrial levels. This is a decrease in CO_2 emissions and the conversion of energy production from fossil fuels to renewables, especially solar and wind energy. The changes underway, because of the energy transition, are undermining traditional equilibria (China's technological hegemony, President Biden's green plans, and the leading international role played by the EU thanks to the Green European Deal), leading to the development of new market models (all concerning key technological innovation for the environment and the development of clean energy), and raising interest in latitudes rich in critical materials and rare earths (areas in Africa, Central and South America, Asia, and Australia). Thus, various aspects must be addressed to fully comprehend the **geopolitical dynamics set in motion by the reorganization of the energy sector** and to identify the quickest route to achieve decarbonization.

This process is unfolding along two interconnected axes. **The first addresses**

the development of renewables and smart digitalized networks, while the second concerns the electrification of energy consumption. Thus, decarbonization, electrification, digitalization, and decentralization are four interdependent trends that can sustain the energy transition through the wide diffusion of electric plants fueled by renewables, which can also be employed in alternative sectors such as transports and heating, thanks to the electrification of final usage. Although indirectly, even so-called "hard to abate" sectors that base their consumption on green hydrogen will be electrified (hydrogen is produced by electrolyzers fueled by green energy). The proficiency of the entire process is driven by digitalization that allows an efficient, regular, and reactive operation of energy systems through decentralized solutions that more easily adapt to the integration of renewables and are more resilient to external phenomena.

Nonetheless, the transition to renewables cannot be achieved via a simple, rapid shift from fossil fuels to a massive use of green resources. Indeed, the process is complicated by history. Coal and oil have been the backbone of global energy markets for two centuries. In the 19th century, coal bolstered the British Empire, while, in the 20th century, oil drove the supremacy of the United States and then shifted it to the Middle East and the Gulf Countries. This historical importance partially explains

"Nonetheless, the transition to renewables cannot be achieved via a simple, rapid shift from fossil fuels to a massive use of green resources. Indeed, the process is complicated by history."

why, notwithstanding the climate policy that various states are striving to implement, fossil fuels still constitute ca. 80% of the global energy supply. However, IEA research reveals that the trend is changing; in fact, oil dropped from 46.2% of global energy supplies in 1973 to just 31.6% in 2018.

Thus, bringing the use of fossil fuels to an end is necessarily a gradual and complex process that will determine a **profound transformation of global energy systems**, with economic, political, and social implications that will extend far beyond the energy sector.

COP26: New Agreements and the Need for Investments

The importance of the transformation of the energy market and the complexity of the new equilibria that will derive from this change is evident from the results of the 26th **United Nations Climate Change Conference** (Cop26), which ended in Glasgow on November 13. After two weeks of relentless negotiations, nearly two hundred countries undersigned an agreement that, for the first time, explicitly states the need to limit the use of fossil fuels. This achievement was partially tarnished by China and India's requests to modify the text on the "elimination" of the use of coal and substitute it with a more generic reference to a "reduction."

Another controversial issue concerning greenhouse gasses addressed at Cop26 relates to the **international market regulations for emission credits**, which, to date, had only been mentioned in Art. 6 of the 2015 Paris Agreement. Cop26 eliminated the key loopholes that threatened to make this tool inefficient. Moreover, a further series of separate agreements will bolster the transition. Amongst the most important, an agreement was undersigned by over one hundred countries to promote a 30% reduction of methane emissions by 2030, a stop to deforestation by the same date, and the commitment by the two largest global producers of greenhouse gasses – China and the United States – to cooperate on the fight against climate change.

The consequences of these agreements will drive a profound transformation of the economies of participating countries via significant investments in the modernization of energy infrastructure, industrial systems, and mobility. Indeed, this is confirmed by a research paper published this year by **BloombergNEF**. Bloomberg analysts determined that in 2020, for the first time in history, over US$500 billion in investments targeted low-carbon-emission technology (including the production of electric energy, hydrogen, CO_2 capture and storage and electrified vehicles), a figure that trumps investments in the hydrocarbon exploration and production sector. More specifically, the analysis reveals that in 2020, companies, governments, and families invested US$303.5 billion in new renewable energy capacity, a 2% increase over the previous year. Moreover, US$139 billion were spent on electric vehicles and charging infrastructure, with a record 28% increase.

According to the IRENA – the International Renewable Energy Agency – this positive trend has triggered a more rapid development and diffusion of renewables than any other source of energy. And this is mainly due to the progress of technology, which, by reducing costs, has made green energy more competitive than fossil fuels. The rapid expansion of renewables is also determining a shift in geopolitical equilibria, favoring areas with greater solar resources (Africa, Central and South America, Asia, and Australia), and wind resources (Northern Europe, Patagonia, the Horn of Africa, and Central Asia) to the detriment of oil exporting countries that are not implementing a valid policy for the diversification of their economies with a view to relinquishing their exclusive dependence on fossil fuel exports. According to data presented in the "Political Risk Outlook 2021" Report by the Verisk Risk Assessment

Firm, Algeria, Iraq, and Nigeria will be the first countries to suffer a new wave of political instability due to this turmoil on the oil market. These countries are not prepared to face a drastic reduction in the demand for oil. The research also sounds an alarm for Angola, Gabon, and Kazakhstan.

The New Leadership of the Transition

Which country will manage to achieve a **leadership in the green sector** during this transition towards renewable energy sources? And which strategic factors will determine this? The top performer will certainly have to possess the technology necessary to produce wind turbines and photovoltaic panels, as well as that of electric vehicles, electric networks, and fuel cells. It will need plants capable of producing the tools and equipment necessary to generate renewable energy. And, of course, it will need to manage the production of microprocessors, which are essential, for example, to operate and monitor wind turbines and photovoltaic panels. Finally, major reserves of the **raw materials necessary to produce low carbon technology** (such as rare earths) will also be fundamental.

Examining the countries that produce renewable energy, China would appear to the perfect candidate for this green leadership. It ranks first globally in the production of patents related to renewable energy. It is the foremost manufacturer of wind turbines and photovoltaic panels, as well as the leading country both for their installation and the generation of electricity from renewables. Moreover, China is also the global leader in the production of electric vehicles.

However, in addition to the ability to develop and deploy technology, it is also important to understand **which critical materials are strategic** to the production of wind turbines, electric vehicles, electric networks, and fuel cells. Indeed, the demand for these materials is destined to increase exponentially with the implementation of the energy transition. **The IEA has already developed a series of medium-term forecasts.** For example, by 2040, the global demand for copper. a fundamental component for the development of electric networks, will double. In the battery and storage systems sector, there will be no less than a thirtyfold increase in demand for elements such as lithium, nickel, cobalt, manganese, and graphite. Moreover, the demand for rare earths will increase, too, as these elements are essential to produce the magnets used in wind turbines and electric motors. Similarly, the expansion in the use of green hydrogen over the next decade will require ever greater quantities of nickel and zirconium to produce electrolyzers. And there will also be an increase in the use of platinum-group metals that are fundamental for fuel cells.

The situation looms even more complex, if we factor in another important aspect: fundamental resources for green technology are not readily available on the market. They are concentrated in a few countries. In the case of lithium, for example, the top three producers detain over three quarters of global production. These are Australia (over half of the global production), Chile (23%), and China (10%). If we look at cobalt, the Democratic Republic of the Congo detains over half of the global reserves, or nearly 71% of the total production. China controls nearly one third of the global reserve of rare earths (44 million cubic tons) and is the top producer with nearly 60% (57.6% of the global market in 2020 according to the US Geological Survey). This situation engenders a strong rivalry with the United States, the second global producer of rare earths, with a 15.5% share of global production, all of which are extracted and processed at Mountain Pass in California. European production is practically negligible. Indeed, most of these elements are concentrated in poor or developing countries in the African continent.

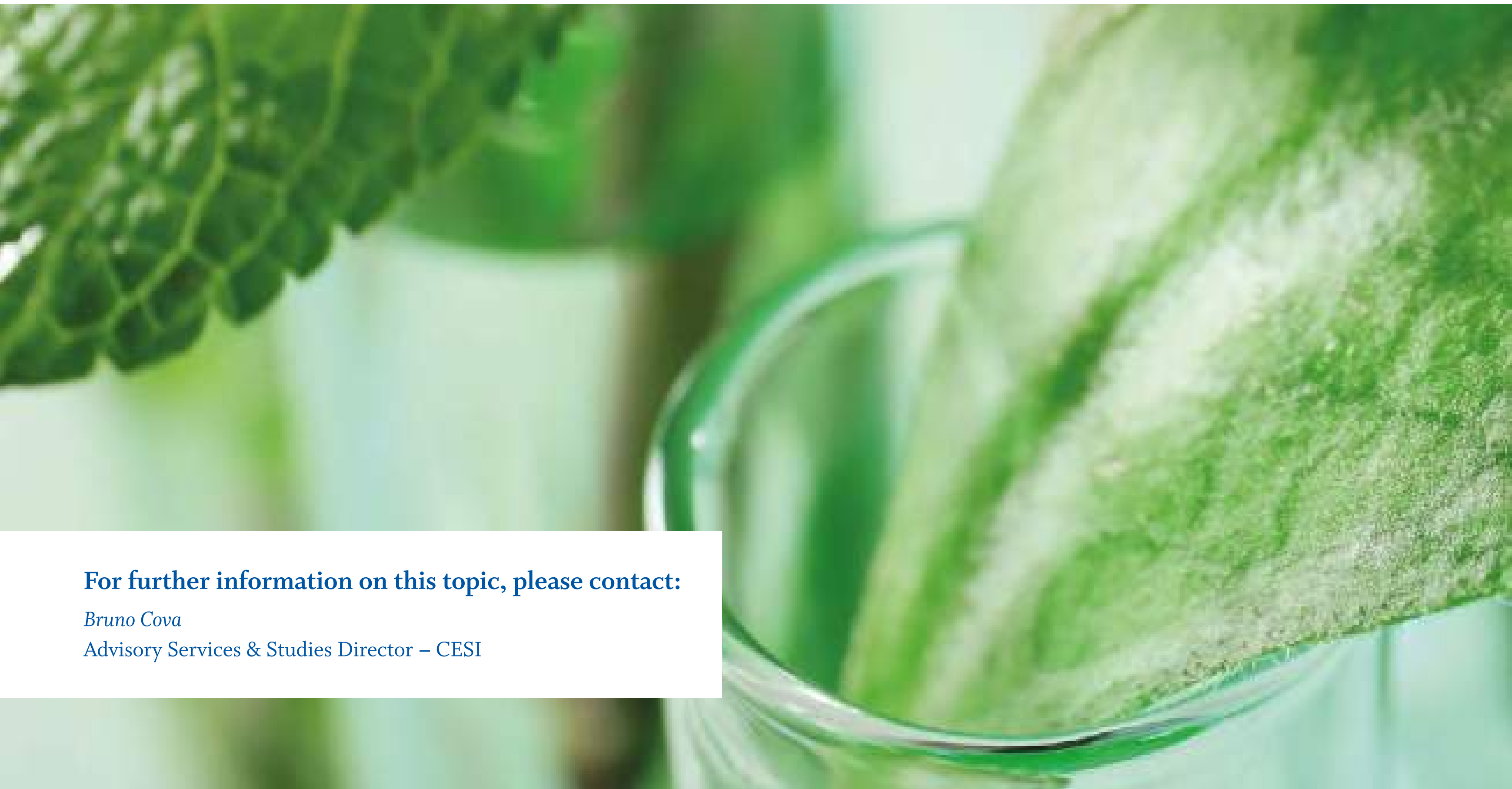
The control of rare earths has generated rapid changes on international markets. In 2010, the Chinese production quota represented close to 100% of the market share. And with that power, China decided to block its exports to Japan. However, this initiative had negative repercussions for China. Besides an admonishment by the World Trade Organization (WTO) for breaching trade regulations, the global increase in prices (caused by the exports block) led other countries to increase their extraction of rare earths. As a result, by 2020, China's quota had fallen to a 57.6% share, both on account of the reopening of Mountain Pass and the activation and extension of mines elsewhere around the world – from Burma to Russia and from Madagascar to Vietnam – by countries that took advantage of the situation.

This means that, during the energy transition, our historical dependence on fossil fuels may be replaced by new needs in terms of the metals and rare earths necessary to produce green and renewable energy with photovoltaic panels and wind turbines or for electric vehicles and fuel cells. Whoever will lead the way in these sectors will detain a fundamental advantage; their technical and regulatory standards will be adopted internationally. And this is the game that the countries currently leading the energy transition know they must compete in and win. The leading country will finance and implement, through its technology and standards, the transition in developing countries too. Indeed, it will introduce a **new form of energetic dominance**, that will be more sustainable and in-line with current market trends.

Industries & Countries

Demand for Rare-Earth Elements and Development of Green Markets: A Complex Relation

Rare-earth elements, the metals used to develop key products for the energy transition, are essential to cutting-edge developments in renewable energy (wind, solar, electric), consumer technology (smartphones and LCDs), industry (microchips, optic fiber) and even in the military (missiles, radar).



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Indeed, more than rare, these elements have become indispensable. The entire future sustainability of humanity seems to depend on Rare-earth elements (REE). They are fundamental to several markets, including renewables, electric vehicles, and green chemistry, as they are essential to develop the advanced technology that enables green sectors. And it's not just about smartphone touchscreens or computer hard drives, REEs are also used to produce permanent magnets, electric sensors, and catalytic converters (essential for wind turbines, photovoltaic panels, and electric vehicle batteries) as well as fiber optic cables and lasers. In fact, Rare-earth elements are essential for the development of no less than 200 products. The International Energy Agency (IEA) and the World Bank have produced two full reports officially recognizing their strategic importance for a green future.

Before proceeding with the analysis of the supply and demand or REEs, we should define these precious elements better. There are 17 Rare-earth elements listed in the periodic table of elements. The first to be discovered was Terbium, in Sweden, in 1782. The full list of REEs includes scandium (Sc), yttrium (Y) and the Lanthanides (chemical elements with an atomic number of 57 to 71) – lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Other raw materials that are similarly important for the development of green technology include ferrous metals and several non-metals such as lithium, cobalt, and nickel.

In order to understand the impact that the energy transition will have on these elements in the coming years, it may help to extrapolate a fact from the "Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition" Report published by the World Bank. The study affirms that to satisfy the growing demand for renewable energy and achieve the objective of limiting global warming to less than 2°C, we will need to extract 500% more lithium, graphite, and cobalt, an interesting point that reveals the massive change of pace set in motion by the development of green technology.

In its 287-page special report on the “Role of Critical Minerals in Clean Energy Transitions,” the IEA illustrates how an energy system driven by green technology is inherently different from a traditional one fueled by hydrocarbons. In fact, the report begins by explaining that the development of solar photovoltaic plants, wind turbine farms, and electric vehicles require a far greater supply of minerals than was necessary for internal combustion engines. We will now examine the REE supply required by several different market sectors.

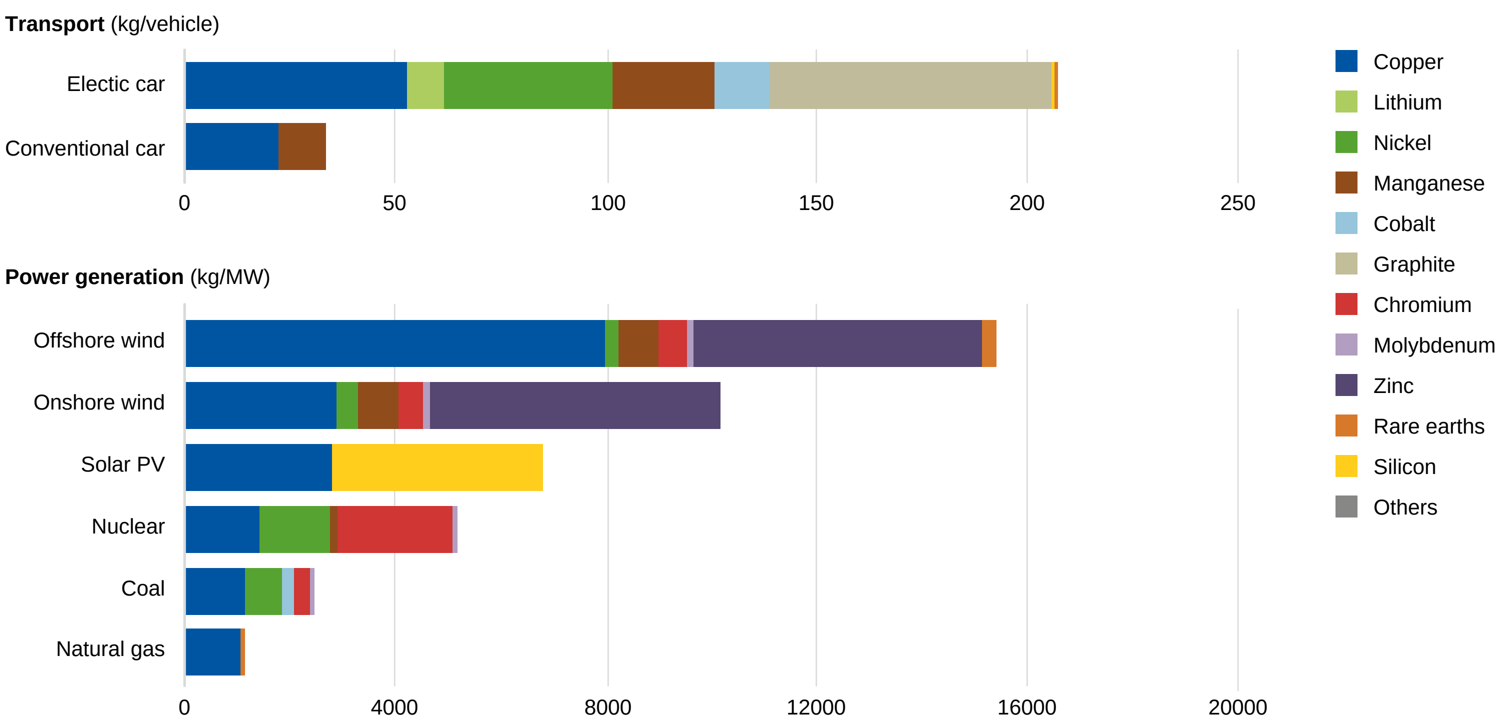
Increase in Demand and Development of Markets. A Boom in Electric Vehicles

While it is important to emphasize that any supply and demand forecast will vary based on the specific mineral under scrutiny, the IEA study underlines that, overall, key minerals requirements in the energy sector could increase sixfold by 2040. And while different types of green technology will drive the development of different market sectors, it is also true that market growth will bolster the demand for one or more fundamental minerals. So, the availability of these elements will be essential to satisfy the demand and development of the market.

For example, the research states that the electric vehicle (EV) market will represent 15% of global vehicle sales by 2030. This forecast is related to another important piece of information. Namely, that six times more mineral elements are necessary to produce an EV as compared to a traditional vehicle. In fact, besides copper for the electric cabling, an EV also requires cobalt, nickel, graphite, and lithium to guarantee performance, longevity, and the energetic density of its battery. Moreover, REEs are also essential to produce magnets for EV motors. More specifically, lithium (which is the main component of lithium-ion batteries for EVs) is rarely found in easily extractable deposits. Currently, 58% of global lithium reserves are produced in Australia, 20% in Chile, 11% in China and 6% in Argentina. Cobalt is also rare and practically only produced through the extraction of copper in the Republic of Congo. Other REEs (dysprosium, lanthanum, neodymium, and terbium), necessary to produce alloys, are used to prolong the magnetization of electric motors. These REEs are concentrated in China (70%), Australia (12%), and the United States (8%).

The rapid deployment of these technologies as part of energy transitions implies a significant increase in demand for minerals

Minerals used in selected clean energy technologies

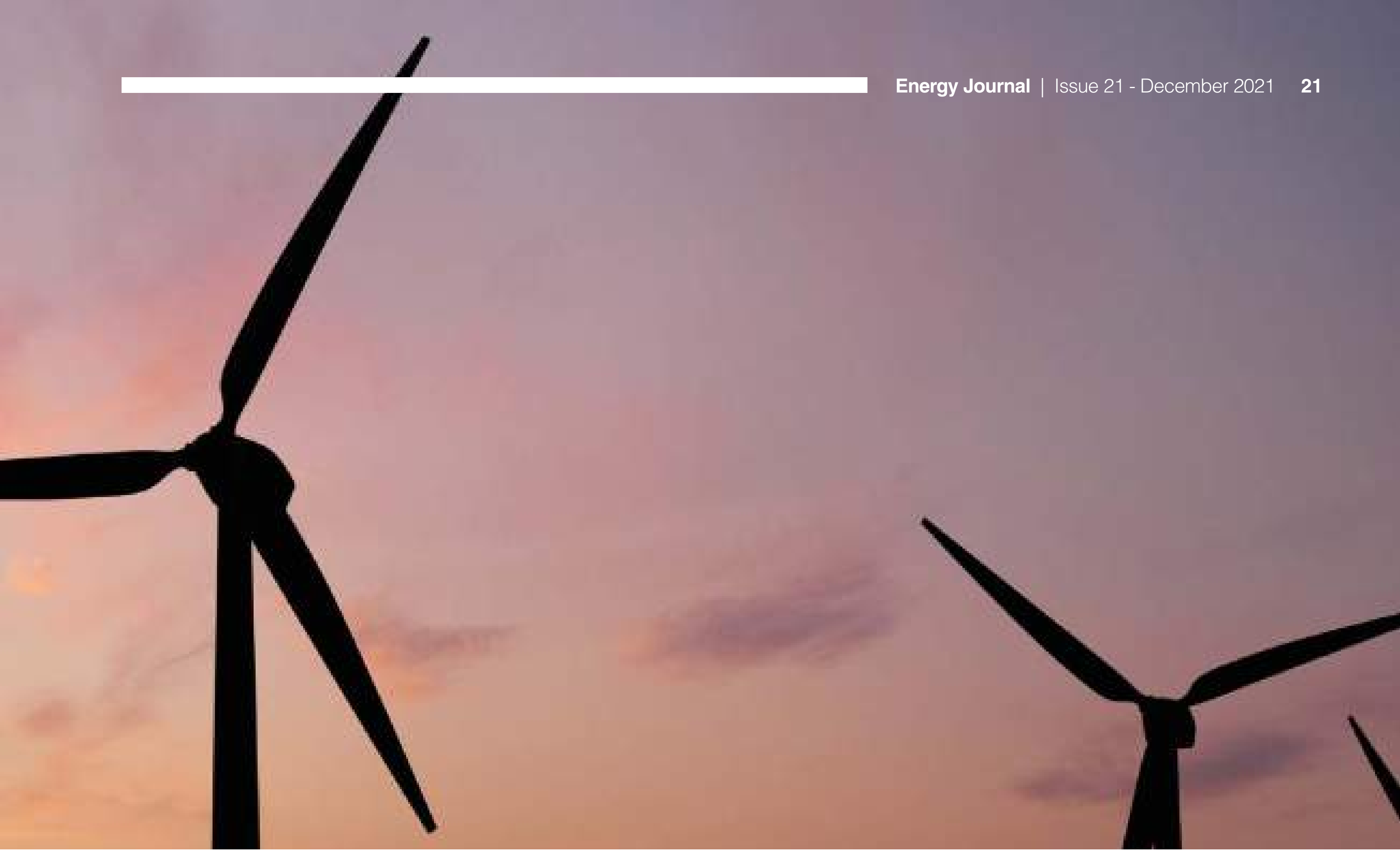


Notes: kg = kilogramme; MW = megawatt. The values for vehicles are for the entire vehicle including batteries, motors, and glider. The intensities for an electric car are based on a 75 kWh NMC (nickel manganese cobalt) 622 cothode and graphite-based anode. The values for offshore wind and onshore wind are based on the direct-drive permanent magnet synchronous generator system (including array cables) and the doubly-fed induction generator system respectively. The values for coal and natural gas are based on ultra-supercritical plants and combined-cycle gas turbines. Actual consumption can vary by project depending on technology choice, project size and installation environment.

The Demand for REEs, Magnets, and the Wind Energy Market

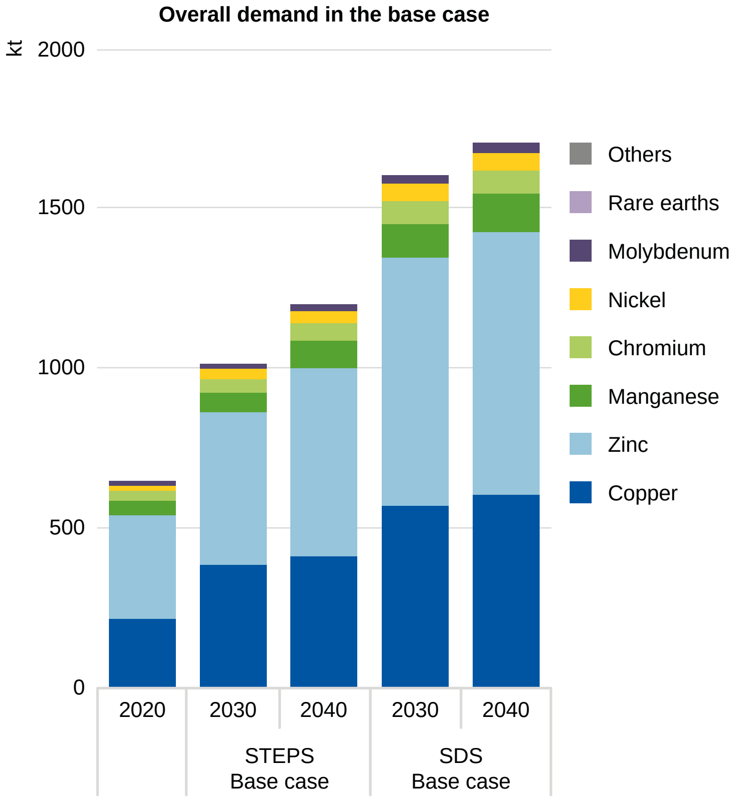
At present, REE mining mainly concerns neodymium and praseodymium, which are the most used in industry and the most expensive. They are used not only to produce the magnets for electric vehicle motors, but for wind turbines, too. As a matter of fact, wind turbines require forty times more neodymium and praseodymium than that necessary for am EV motor magnet, for every Megawatt (MW) of installed capacity. Considering that a wind turbine has a capacity of ca. 3 MW, we can calculate that, on average, the quantity of neodymium and praseodymium necessary for a turbine is 120 times greater than that necessary for an EV motor. Moreover, in 2020, permanent magnets accounted for 35% of REE sales and 91% of their overall value. According to market projections, the demand for magnets will increase by 500%. By 2030, their sales value will increase from US$2.98 to US$15.65 billion, for a total of 270,000 tons (compared to the current 130,000 tons), and will account for 40% of REE demand.

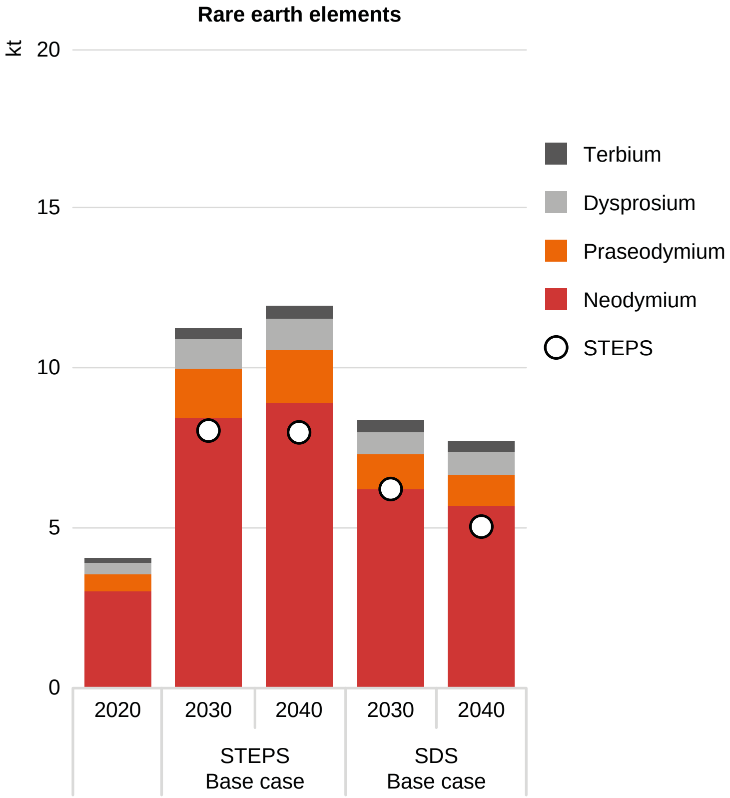
The photovoltaic market also requires uncommon elements, which could hinder the diffusion of solar energy if they were not available in sufficient quantities. A silicon crystal panel is composed of silicon, a very common material, along with aluminum, plastic, and glass. However, they also require silver wiring (necessary to capture the positive electric charge produced in the silicon by light), silver plating on the back of the cell to capture the negative charge, and two rare elements: indium and bismuth. The limited production of these three metals could hinder the request for photovoltaic energy. Considering that 3 TW of energy are forecast to be produced from photovoltaic by 2030, this would require 45,000 tons of silver (only 29,000 tons were produced in 2019), 39,000 tons of bismuth (current production: 21,000 tons) and 12,000 of indium (2100 tons). Furthermore, all three of these elements are in strong demand for other products, too (such as PC and smartphone touchscreens).



Wind: Demand for rare earths quadruples in the SDS by 2040, although the scale og the growth may vary depending on the choice of turbine technologies

Mineral demand for wind by scenario



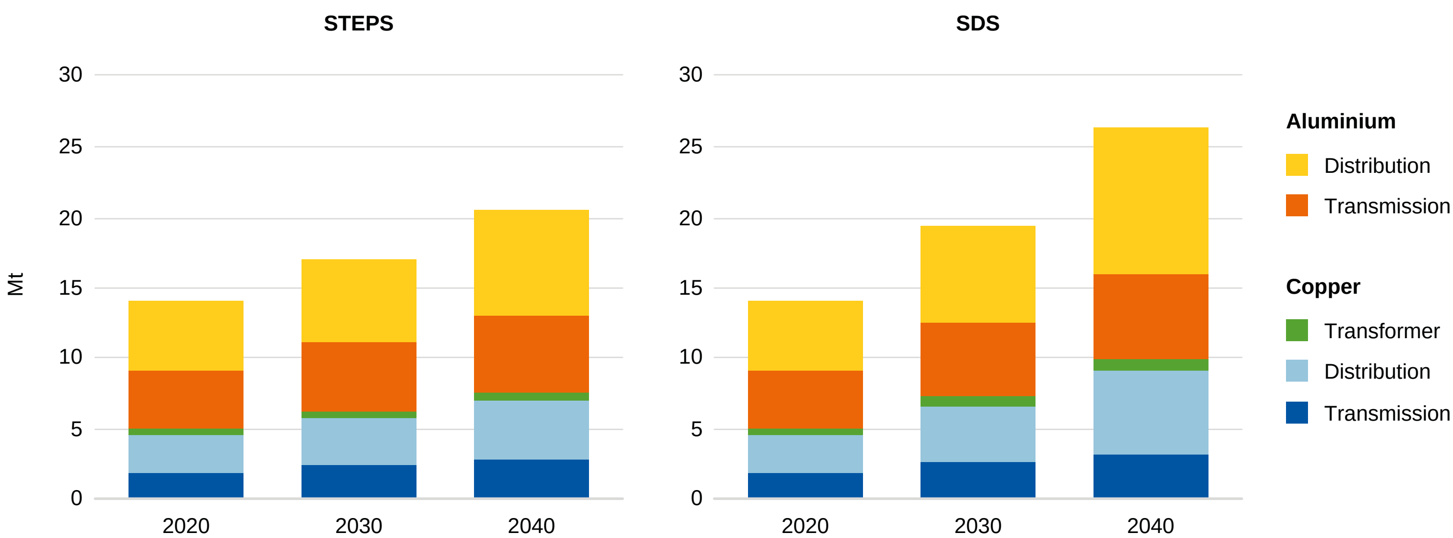


The Red Gold of Electrification

We must also analyze the implications to the development of power grids, which the IEA forecasts should double in size by 2040, producing a sharp spike in the demand for copper. Thus, the price of this red gold will determine access to electricity for over 786 million people that currently have no power. According to the IEA, there are 600 million in Africa, alone. So, copper is clearly another key element for green technology. It is fundamental for the development not only of power grids, but also that of photovoltaic cells and wind turbines, which may require up to 5000 tons of copper per installed GW. Moreover, copper is also essential to the electrification of transport. According to Bloomberg New Energy Finance (BNEF), by 2040, circa 30% of vehicles worldwide will be electric. This means there will be 500 million electric vehicles out of a total 1.6 billion circulating vehicles. Calculating that every EV requires ca. 85 kgs of copper, the global fleet of EVs would require 42.5 million tons, more than double the current production. BloombergNef also predicts that by 2040 we will need 12 million domestic charging stations, in addition to rapid charging stations. While the former requires 7 kgs of copper each, the latter (DC Fast Charge) needs 25 kgs each. Moreover, copper is also necessary for 5G infrastructure, along with lithium and silver. Each 5G base station requires an average of 12 kgs. So, China Mobile, which will erect 50,000 stations, will need 600 tons of copper. Indeed, 72,000 tons of copper will be needed to develop the 6 million stations necessary to cover the entire Chinese 5G network. Notwithstanding the significant demand for copper, the production outlook is not positive. The Commodities Research Unit (CRU) forecasts that, without any new prospecting and investments, the global production of copper will decrease from the current 20 million tons to ca. 12 million by 2034. This is mainly caused by depletion of several mines, some of which have already drastically reduced production due to dwindling reserves. In Chile, for example, where ca. 30% of global copper reserves are produced, the Chuquicamata mine is currently experiencing a 40% decrease in production, while the Escondida mine in the Atacama Desert (famous as the world's largest copper mine) registered a significant drop in production in 2019 and does not plan to return to full productivity until 2022.

Growing need for grid expansion underpins a doubling of annual demand for copper and aluminium by 2040 in the SDS

Demand for copper and aluminium for electricity grids by scenario



Note: Includes demand for grid expansion and replacement.

A Complex Issue: Chinese Monopoly and Environmental Impact

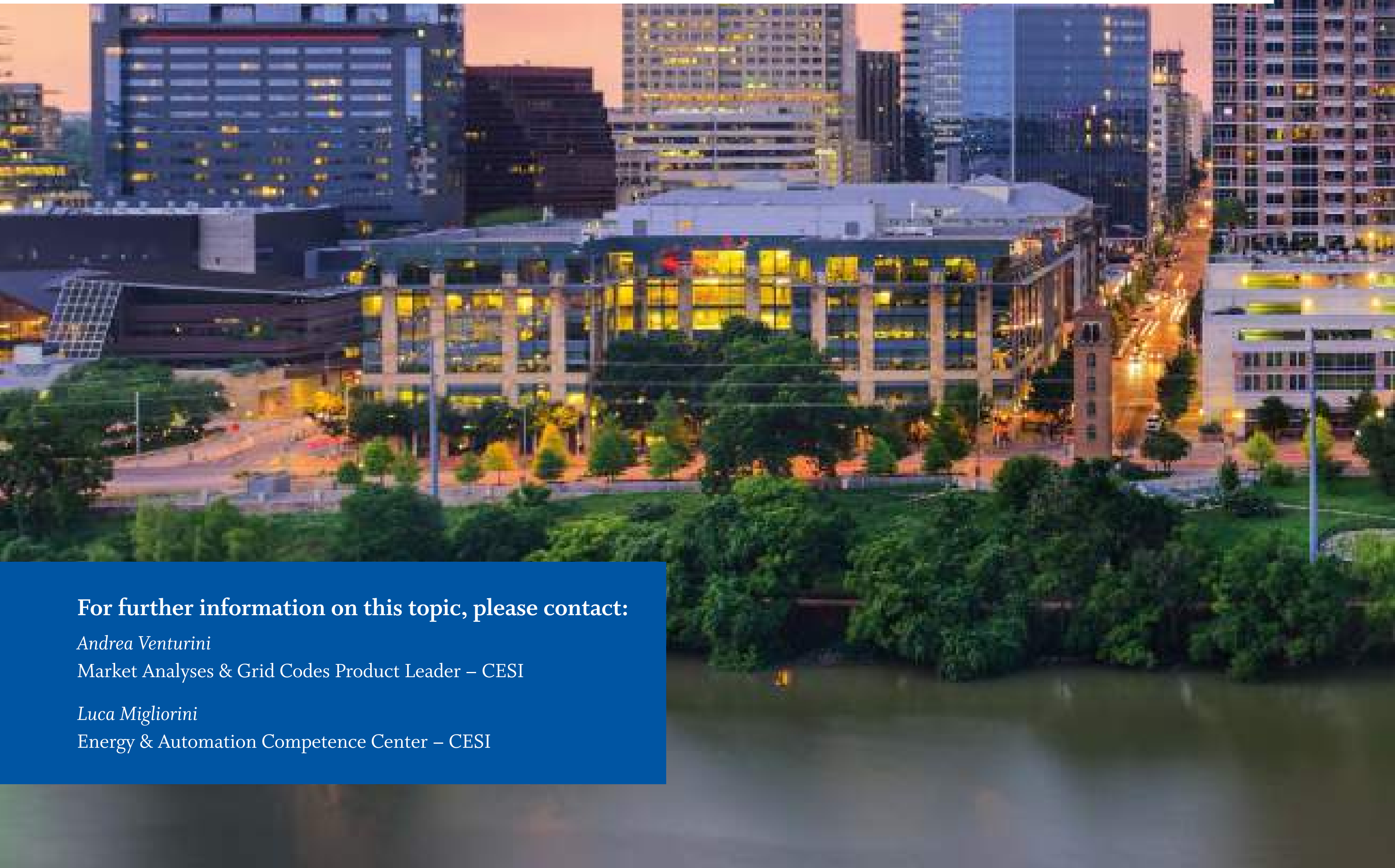
The overall picture that emerges from this analysis clearly reveals how the evolution of technology, the energy transition, and the development of green markets drive a keen interest in REEs. Nonetheless, there also are critical issues. First, the Chinese monopoly on REEs, which developed exponentially until the 2010 crisis, forced the major advanced economies to seek alternatives to the import of Rare-earth elements from China.

Second, there also are problems concerning REE mining and productive processes that precede market issues. REEs have a high environmental impact. According to the China Water Risk Report, on average, every mined ton of REEs produces 60,000 cubic meters of gaseous waste, 200 cubic meters of acid, and 1.4 tons of radioactive material. So, to reduce the social and environmental impact of these processes, the European Union and other countries have been seeking more sustainable solutions, such as diversification of sources and a reduction of their use, as well as substitution and recycling (currently limited to 1%). Unfortunately, after a decade of research, the scientific community has concluded that there are no valid alternatives to REEs; the use of other elements would cause a drastic reduction in the efficiency of technology. Thus, the relation between the demand for Rare-earth elements and the development of green markets remains a terribly complex issue.

Top Stories

A Texan Lesson and the Digital Market Revolution

Interconnected systems and increasingly digitalized energy markets. Stability and security from climactic events require market regulation and investments in infrastructure to allow a simple, flexible, and rapid management of the demand for energy.



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Texas' electric system is ineffectually interconnected with the rest of the United States. This state of infrastructural and productive isolation dates to before World War II when President Roosevelt used the Federal Power Act to create a Federal Power Commission (currently known as the Federal Energy Regulatory Commission) and regulate the sale of electric energy amongst states. In fact, if we examine the layout of the power grid connecting the 48 continental American states, we will notice two macro-areas (the Eastern Interconnection and the Western Interconnection). Instead, Texas has asymmetrical interconnections and a limited power transfer capacity compared to its needs.

The insufficient resilience of the power system in Texas, which is related both to infrastructural aspects (electric network and generation) and to market mechanisms, was laid bare by the exceptional front of bad weather that hit the United States last year. In February 2021, the state was caught unprepared: **4.7 million American families experienced scheduled blackouts** (3.8 million in Texas alone) and there were repercussions on the entire energy sector. Texas lost 40% of its overall power potential due to a series of negative factors, including the unexpected (by any forecast scenario) increase in the demand of power for heating, the lack of methane supplies to thermoelectric plants (due to infrastructural damage caused by the extreme weather), the shutdown of a 1300 MW reactor at the South Texas Nuclear Power Station, and the fact that half of the state's wind turbines were frozen.

Unable to balance its energy flows, in order to avoid a statewide blackout, the Electric Reliability Council of Texas (ERCOT), which manages the Texas grid (and has over 25 million clients), was forced to schedule a series of power shutdowns. Indeed, this was like the situation experienced by California during the summer, when the power had to be shut down as the temperatures rose. However, **the blame levelled at renewable energy sources**, due to their intermittent and unprogrammable nature, is not confirmed by the data published by the U.S. Energy Information Administration (EIA). Indeed, the EIA reveals that over half of the Texan energy mix is based on natural gas (followed by wind, coal, and nuclear).

The importance of fossil fuels in the Texan energy production system is a consequence of the state's vast reserves. In fact, the western part of the state has the largest hydrocarbon reserves in the United States. Nonetheless, Texas has recently begun diversifying its energy mix, especially by installing wind turbines, since 2000.

Interconnection Saved Europe

The key issue in Texas, setting aside supply problems, was the infrastructural situation. The energy supply issue in Texas could have been compensated, or at least reduced, if the network had not been so ineffectually interconnected and could have benefitted from energy produced by neighboring states. In fact, greater interconnection is fundamental for strengthening system flexibility and all the more for a power system that needs to constantly balance supply and demand. We also are aware of how climate change is leading to frequently more common extreme weather conditions (heat, cold, drought, fires, and flooding). **Each of these events can drive critical infrastructure over the breaking point**, as occurred in Texas. In a world in which the development of digital technology promotes increasingly interconnected networks, rigid and isolated systems can easily fail when supply decreases and

demand increases simultaneously. Moreover, the critical event in Texas also involves the complex regulation of the electricity market. Texas suffered the absence of a capacity market that could guarantee backup power and stabilize price dynamics.

> "Greater interconnection is fundamental for strengthening system flexibility and all the more for a power system that needs to constantly balance supply and demand."

Events would have unfolded differently in Europe, both with regard to power availability and price. Over the last decade, Europe has undergone repeated cold fronts, such as in February 2012, when temperatures plummeted, and the energy demand peaked at 557 GW. Notwithstanding two consecutive weeks of intense bad weather, the European energy sector survived unscathed, thanks to the efficient coordination of electricity and gas TSOs and the strong interconnections in place between member states. While system managers employed all the available control reserves to provide electric energy to clients, maximizing imports, government authorities fielded additional measures, including a request to moderate demand via the media. However, the key factor to stabilize energy demand in a critical situation turned out to be the capacity for sufficiently high cross-frontier energy transfers.

Modernizing Networks: At the Core of New Business Models

Along with the need to reinforce interconnections and adopt appropriate market mechanisms (from capacity markets to the right to suspend contracts and an independent regulation to promote market investments, stability, and efficiency), the Texan energy crisis reveals the need to **adapt plants and infrastructure to third-millennium technology**. Building a system that can weather climate change and the energy transition – keeping in mind that the growth of the electric energy market will profoundly affect the decarbonization process – will require the implementation of new measures to adapt and protect infrastructure from exceptional events, such as the "glacial" temperatures in the Texan case.

In order to make the needed investments, network managers need the regulatory authorities to promote **business models that adequately incentivize infrastructural security and technological modernization operations**. The Texan lesson should discourage competition based exclusively on price containment (in Texas, energy prices are 10% lower than the national average, and half that of California) in favor of focusing adequately on service reliability.

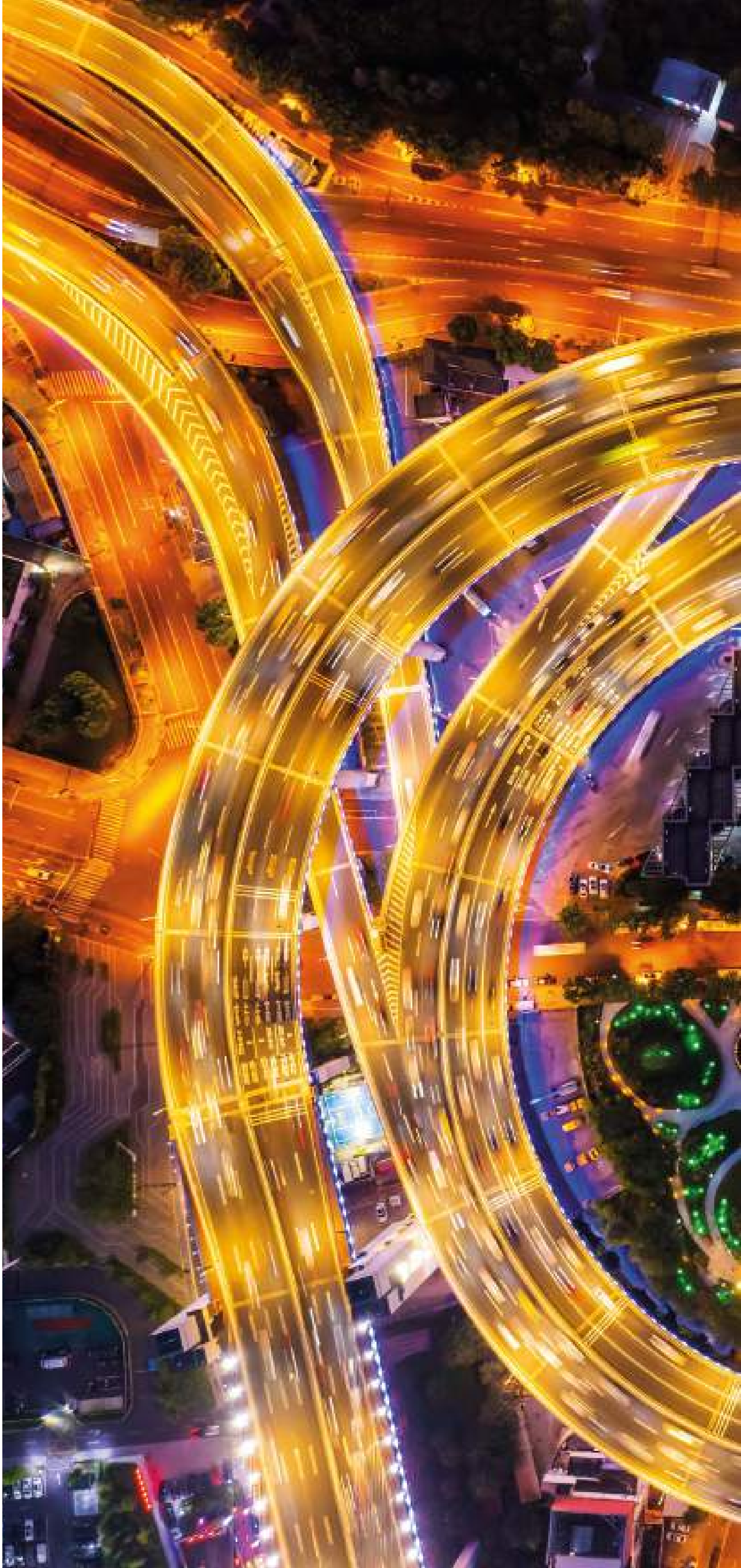
On the other hand, the future of the energy sector is increasingly characterized by digitalization: 5G technology, smart sensors, big data and blockchain. The need for greater efficiency and a better response to client needs is driving the adoption of new, increasingly sophisticated network technology that allows for a rapid, continuous, safe, and reliable exchange between consumer and utility devices.

Digital Investments in Europe and Asia

In March 2021, the European Commission welcomed the agreement reached by the European Parliament and the Council on the second edition of the **Connecting Europe Facility**, a €33 billion program supporting investments in European transport, energy, and digital infrastructure, as envisaged by the European Green Deal and the Digital Decade objectives.

In mid-November, the EU Council also ratified the Single Basic Act that will promote **9 new European partnerships** amongst the European Union, member states, and industry to provide innovative solutions for global health, technology, and climate challenges.

One of the partnerships concerns **smart services and networks**, whose development is considered crucial to the technological challenges that await us, in line with the new Industrial Strategy for Europe on IT



security and the 5G Cybersecurity Toolbox. Regulation objectives include support for the green and digital transitions, and support for technology that will contribute to the economic recovery. The agreement will allow Europe to develop the technological capacity for 6G systems as a foundation for future digital services in view of 2030.

Shifting to **investments underway in Asia**, one of the best reference points is *"Asia's Energy Revolution: China's Role and New Opportunities as Markets Transform and Digitalise"* by **Joseph Jacobelli**, an energy finance expert, and the founder of Asia Clean Tech Energy Investments.

According to Jacobelli, "Asia – the continent with the largest consumption of energy on the planet – already has several markets that are well-positioned to welcome smart energy through, both local and foreign, digital technology and solutions. Over the next ten years, investments in this area will exceed US$200 billion a year." As the Asian continent is home to many emerging economies, energy market investments in digital infrastructure will mostly interest **greenfield projects** rather than imports to substitute and modernize existing digital infrastructure.

In China, a global leader in terms of digital transformation, public companies in the electricity sector, such as the State Grid Corp. of China (SGCC), and private companies, such as Huawei Technologies, have driven progress in digitalization in many different areas through investments in energetic efficiency, electric vehicle charging, UHV transmission lines and smart metering.

In terms of smart grids, capital expenditure by SGCC on smart energy reached ca. 35 billion yuan (US$5.42 billion) over 2011-2020. In March 2021, SGCC announced that it will accelerate through 2035, "the smart transformation of electric network infrastructure." The program includes the development of smart micro-networks, smarter and more reactive power supply systems, smart generation, archive connectivity, VRE dispatching optimization and the large-scale application of new energy storage technology. Huawei and other companies have also invested, alongside SGCC, in digital solutions for energy, including AI, big data, blockchain, cloud and IoT.

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Future & Technology

Energy Markets: Innovation for Sustainable Development

A look at how CESI is addressing the challenges posed by energy markets in connection with the energy transition: from the modernization of electric networks to large-scale interconnection and system digitalization.

Without a strong catalyst for investments in clean energy, global markets will continue to be volatile, the transition towards net-zero carbon dioxide emissions will remain unstable, and prices will continue to increase. According to the International Energy Agency, as economies shift from fossil fuels (and less sustainable industry) to investments in green energy, global energy markets will continue to suffer significant risks. In the 2021 **World Energy Outlook**, IEA experts affirm that investments in green energy and infrastructure must increase threefold over the next decade to reach carbon neutrality objectives by 2050.

A geopolitical vantage point helps us to understand this situation from the market side. The growing use of renewable energy is going to cause a shift in equilibria from areas with great oil reserves to areas with greater solar (Africa, certain areas in Central and Southern America and Asia, and Australia) and wind resources (Northern Europe, Patagonia, the Horn of Africa, Central Asia). In this context, network infrastructure is paramount, starting with the interconnections (addressed below) that are necessary to connect consumption centers with the areas producing renewables. Thus, IEA analyses indicate that investments in green energy and infrastructure will have to triple over the next decade: ca. 70% of additional expenses will have to be made in emerging and developing economies, where funding is scarce, and capital is up to seven times more expensive than in advanced economies.

Market analysts are also carefully looking at a further level. Besides the availability of renewable resources – which as mentioned will lead to a change in energy geopolitics – the most important challenge concerns the production of decarbonization technology and especially that of raw materials. The EU "**Critical Raw Materials Resilience**: Charting a Path towards greater Security and Sustainability" Report emphasizes that the supply of *light and heavy rare elements* – necessary to produce wind turbines, motors, and fuel cells – are at risk. China currently satisfies 98-99% of our requirements.

Clearly, this is a phenomenon that concerns the entire supply system: from the countries endowed with raw materials to those processing them, and from the countries producing components to those assembling final products. In terms of technology for renewables and electric mobility, the “Critical Raw Materials for Strategic Technologies and Sectors in the EU” Report indicates that Europe is on equal – or better – footing with the United States. In comparison to China, however, the EU is losing on all fronts. China has 39-51% of global materials and develops several key technologies. And what about the rest of Asia? It fares better than Europe, too, in terms of component production and assembly, with respectively 20% and 18% of the total. Africa detains a significant quota of the raw materials required for decarbonization solutions, nearly 24% of the total, placing second, after China.

Facing the Challenges Posed by Modernization

Creating **European supply chains** to address the energy transition, along with the adoption of **new measures** to decrease energetic and technological dependence on other countries, seems to be the quickest route to achieving efficient decarbonization. A **CESI analysis** on the electricity system during the first lockdown in Europe revealed the need to implement flexibility measures to guarantee secure operations when markets are subject to a massive use of non-programmable renewable resources. The objective is to innovate smart networks so that they can rapidly counter sudden external changes (due not only to climactic conditions, but also to other unknown and unforeseeable factors). In this context, **CESI has renewed its commitment to technological and digital innovation**, working alongside clients to identify the best solutions for sustainable decarbonization.

In this respect, CESI is focusing on the development of **Master Plans** that address the United Nations’ Sustainable Development Goals, including the Affordable and Clean Energy Objective. A recent example of this is CESI’s work to update the Master Plan for the transmission system of the Oman Electricity Transmission Company (OETC) to 2040. The objective was to define the best technical-economic options for long-term development of the transmission system,

in view of the Oman Power and Water Procurement Company (OPWP) Generation Plan, and to promote the integration of renewable energy sources.

As mentioned above, such **CESI proposals seek to integrate the United Nations' SDGs**. The studies carried out by CESI determine the potential of renewable resources and their location, describing sites in terms of energy demand, network conditions and connection mode, and verifying a correct integration to ensure a reduction in greenhouse gasses over the long-term. Our projects include a series of evaluations conducted to determine an optimal plan for **investments in transmission and distribution networks**, so to guarantee a satisfactory supply for the energy demand and the most efficient solutions in terms of cost/benefit analyses.

CESI also worked on two important consulting projects in the Baltic Republics as part of the program to synchronize the Baltic electric power system with the ENTSO-E synchronous area. The Group developed

the system requirements for synchronous compensation (SC) systems, in **Lithuania** and **Latvia**, that would be connected to the national grid to increase system inertia and improve network stability by providing reactive power, contributing to short circuits, and improving the dynamic recovery of power. Moreover, **in Latvia**, CESI also collaborated on the analysis of technical requisites and the development of a solution for network frequency-power control (respecting European Network Codes).

Market Simulation Tools

As we face a future characterized by an increasing quota of electrification from renewable resources in our power systems, we need to understand how to incorporate the effects of climate change in our predictive models and guarantee an accurate modelling of reliable scenarios in our calculation systems. In this context, simulation tools are fundamental to assist clients in identifying the best solutions for a given scenario,

in terms of energy markets, ancillary services, and capacity. In this context, the CESI Group has developed two different market simulation tools – PromedGrid and MODIS – that also address the key role of batteries and electrolyzers for the integration of renewable energy on the grid.

Employed by the Italian TSO (Terna) to evaluate the market benefits deriving from network upgrades (both in Italy and Europe), **PromedGrid** is a market modelling software package that assists in planning network investments. The software bases optimization on a deterministic model that examines both the technical and economic characteristics of electric energy production systems. **MODIS** is a simulation tool that aims to minimize the overall cost of redispatch caused by operative restraints by providing a quantitative evaluation of the impact of new transmission infrastructure, storage units and virtual units on market dispatch services. By simulating a zonal market and reproducing all the necessary balancing actions, MODIS guarantees adequate secondary and tertiary reserve margins with an hourly time discretization.

Interconnections: Africa and Beyond

Designing generation facilities for the future requires not only adequate preparation against the unforeseen risks posed by climate change, but also the integration of the United Nations' SDGs. Amongst the innovative solutions along the entire electricity chain of value, from generation to final users, the central role of network infrastructure is firmly bound to the issue of the interconnections necessary to **connect the energy demand of consumption centers to the areas producing the greatest quantity of renewable resources**.

In the field of generation, the presence of renewables – volatile non-programmable power sources such as wind and photovoltaic energy – calls for a greater focus on the issue of networks. Currently, interconnection lines are increasingly used for **cross-border exchanges of energy driven by market mechanisms**. The massive use of energy resources requires the development of interconnection/transfer systems even over thousands of kilometers

and the governance of a network with hundreds of nodes. This entails the development of long-distance, high-voltage connections. China, for example, already has operative high-voltage 6-7 GW DC lines (HVDC). CESI contributes to the development of these “broadband” systems for modern electricity markets that allow the transfer of vast quantities of electricity over long distances at a low cost and with minimal loss.

In this regard, CESI activities are particularly significant in terms of the **PROMOTioN (Progress on Meshed HVDC Offshore Transmission Networks) Plan** introduced by the EU in 2020 to drive the growth of new generation networks. In terms of interconnectivity, which allows massive energy flows between different areas, the last Ten-year Network Development Plan 2020 developed by ENTSO-e calls for a 35GW increase in cross-border capacity by 2025 and a further 93 GW expansion by 2040. Italy is enjoying a massive investment drive for new network infrastructure. In terms of transmission networks alone, the last national ten-year plan envisaged an investment of over €18 billion, nearly threefold the investment planned only five years ago.

In terms of HVDC technology, the **EuroAfrica Interconnector**, a submarine cable for the transmission of electric energy between Cairo and Nicosia, will unite Europe and Africa, based on an agreement signed in 2019 by Egypt and Cyprus. CESI is a consultant on this prominent geostrategic project that will allow the transfer of 2000 MW of energy from Attica to Cyprus, via Crete, and from Cyprus to Egypt. This will also provide Egypt with a pivotal role for interconnections with countries in the Gulf area and Sub-Saharan Africa, extending opportunities for the exchange of electricity over even longer distances. In fact, the EuroAfrica Interconnection will guarantee a secure supply of energy to countries on

the Mediterranean basin and, in the future, to the Arab States of the Persian Gulf thanks to the complementary nature of the primary resources used to produce electricity: Cypriot and Egyptian gas reserves and renewable resources throughout the region. Thus, this project represents a tangible and significant contribution to decarbonization objectives.

In Africa, **CESI is also part of the Grid4Africa Project** by the **RES4Africa Foundation** to increase continental interconnection. In fact, a further frontier for interconnection is represented by Sub-Saharan Africa, a region with an access to electricity only reaching, on average, 48% of the population (IEA data), about half of the global average (90%). According to IEA forecasts (positing that about 60 million people a year will need to connect to the grid to reach 100% coverage), the strategy based on interconnection and generation from renewables is the most sustainable solution. Decentralizing production on local networks is another aspect that should be taken into consideration for a greater pervasiveness of electric energy supply, rather than distribution via a limited number of maxi-projects.

Flexibility, Cybersecurity and Sustainable Mobility

During the pandemic, the collaboration amongst European TSOs allowed the system to be managed without any supply interruptions. However, the market was fragmented not by network congestion, but by the lack of flexibility. Indeed, flexibility is **the other fundamental component for a modern power supply system**.

It compensates for V-RES volatility and extreme external conditions, from events related to climate change to those arising from an unexpected pandemic. In a study published in September 2020, CESI highlighted how the situation of the electric system during the lockdown – in terms of penetration of renewables with respect to the load – coincided with the annual data forecast for 2026: 44% as compared to the 35-37% registered in 2019. The analysis pointed to the need to **implement flexibility measures – even through the development of infrastructural interconnection projects** – to guarantee secure conditions when markets are subject to an elevated use of non-programmable renewable resources.

On the subject of adapting energy systems to risk, IT security is fundamental. While increasingly pervasive digitalization may be key to developing a resilient system, it is also necessary to consider **several challenges posed by IT security**, challenges that will probably increase in the coming years. Across Europe, the EU Energy Expert Cyber Security Platform (EECSP), responsible for recommending measures for energy market IT security to the European Commission, has identified the main cybersecurity challenges for the energy market: mitigation of risk for existing infrastructure (i.e., electric networks and nuclear plants), integrity of components used in energy systems, outsourcing of infrastructure and services, and greater interdependence of the various market players.

To ensure protection from cyberattacks, smart grid companies in the United States continue to invest in cybersecurity technology, a market currently valued at US$1.8 billion. In parallel, the Industrial Control System Cyber Emergency Response Team (ICS-CERT), the unit that is responsible for minimizing IT risk, has pointed to the **energy sector as the most frequent target of cyberattacks**, with 33% of reported incidents by associates, followed by the manufacturing industry (26%). As this is particularly critical infrastructure, experts from the US-based company **EnerNex (the American subsidiary of CESI Group) are increasingly involved as consultants and experts to protect and guarantee the full operativity of electric networks**. The objective is to develop an IT security framework addressing all necessary aspects: from requisites for smart meters to the identification of vulnerabilities, risks, and threats to networks.

This journey through **CESI projects and activities on the different energy**

markets, with a particular focus on strategies to accelerate the energy transition, comes to an end with a look at the mobility market. Looking towards a more sustainable future, many investments are focusing on the electrification of short-range mobility. Indeed, available batteries allow vehicles to cover typical mileages and, according to some data, reveal a greater efficiency than hydrogen-driven vehicle fuel cells. **At KEMA Labs (the CESI Testing, Inspection and Certification Division), sector experts and engineers conduct cutting-edge tests to verify the reliability of electric vehicles, charging systems, and their interaction with electric networks**. Moreover, the new KEMA Labs Services & Smart Technologies Unit, based on the collaboration between our offices in Milan (Italy) and Arnhem (Holland), provides a series of tests that satisfy the new requisites for electric vehicle power systems. Even hydrogen – and especially **green hydrogen** – will play an important role in an increasingly more sustainable mobility, especially for heavy transports and trains. That's because cross-sector coupling entails the application of green hydrogen in hard-to-abate sectors such as the chemical, steel, cement, and oil refinery industries, that are by nature difficult to electrify.

Opinions

Energy Transitions Revolutionize Trade Patterns

In this issue of Energy Journal, which is focused on the latest development in the energy markets, we have asked for the opinion of three experts in the sector. Therefore, in the following pages, you will find our interviews with Laura Cozzi (Chief Energy Modeller at IEA and Head of the Demand Outlook Division with responsibility of producing the annual World Energy Outlook), Anna Creti (Professor of Economics at the Paris Dauphine University, LeDA-CGEMP – Dauphine Economics Laboratory-Center for Geopolitics of Energy and Raw Materials) and Michael Pollitt (Professor of Business Economics at the Judge Business School, University of Cambridge).

Ambitions count for little if they are not implemented successfully

Laura Cozzi

Chief Energy Modeller IEA

Laura Cozzi was appointed as IEA's Chief Energy Modeller in 2018. As Chief Energy Modeller, Ms. Cozzi oversees the Agency's work on outlooks and forecasts and is in charge of overall consistency of modelling work and resulting messages. Ms. Cozzi is, also, Head of the Demand Outlook Division with responsibility of producing the annual World Energy Outlook, the IEA flagship publication. The Division produces medium- to long-term energy demand, efficiency, power generation, renewables and environmental analysis for the World Energy Outlook and other publications. Ms Cozzi joined the IEA in 1999, and has been leading several editions of the Outlook, and has been co-author of multiple editions of the report. Prior to joining the IEA, Ms. Cozzi worked for the Italian energy company ENI S.p.A. She holds a Masters' Degree in Environmental Engineering (from Polytechnic Milan) and a Masters' Degree in Energy and Environmental Economics (from Eni Corporate University).

1 *What's the outlook for global energy demand?*

The evolution of global energy demand and trends by fuel are strictly related to the scenario considered. Under stated policies, energy demand continues to grow, with the next decade looking much like the past decade for many fuels: global oil demand rebounds strongly and grows steadily to 2030 before reaching its peak in the mid-2030s (103 mb/d in 2030), natural gas continues a strong growth to 2030 (15% higher in 2030 than in 2020) and output from solar PV and wind triple over the next decade, meeting three-quarters of global electricity demand growth. According to scenario that takes into account all of the climate commitments (pre-COP26) made by governments around the world the outlook of global demand by fuel is quite different. Total global demand will increase but lower than stated policies scenario thanks to efficiency improvement. More specifically, oil peaks by 2025 and flattens and most of this change is driven by high penetration of electric vehicles. Natural gas demand grows 2025,

but flattens thereafter. Most of this change in trends stems from the power sector: in countries with net-zero targets, natural gas loses market shares with the growing role of solar PV and wind. The buildings sector sees also gas demand in 2030 lower than in 2020 with the introduction of strict performance standards for existing and new buildings. Moreover in 2030, solar PV and wind capacity additions near 470 GW, nearly double today. This means that the growth of solar PV and wind keeps up with all growth in electricity demand over the next decade, and raises their share of generation from under 10% in 2020 to nearly 30% in 2030.

2 *Will power prices become more volatile?*

Price volatility is an ever-present feature of commodity markets, but well-managed transition soffer ways to dampen the impacts on household energy bills. The impact of higher commodity prices is dampened by more rapid efficiency gains, by reduced direct use of oil and gas, and by electricity having a higher share in total household energy expenditure (electricity is less affected by the price shock than oil and gas because of the rising role of renewables). According to Net Zero scenario, If we shock these systems in 2030, with a spike in oil and gas prices, this would be 30% less costly to households in case of rapid transitions compared with a more gradual approach. These benefits though don't come for free. They require a significant amount of additional investment in the meantime, in new low-emissions equipment, electric cars, efficiency retrofits and so on. These solutions are typically very cost-effective, but many households, especially poorer ones, will require help from governments to manage the upfront costs.

3 *What is your opinion on the cop26 agreement? Are the world energy markets ready to embrace it?*

COP 26 has provided a significant momentum for the necessary transformation of energy sector: commitments and collaborations are the main achievements of the Climate Change Conference and they are essential steps in the right direction to clean energy transition. More specifically, up to now countries that account 90% of global economy have put commitments to reduce emission to net zero and more than 100 countries promising to cut emissions of methane (another potent greenhouse gas) by 30% by 2030. Moreover, the international collaboration had an important role in COP 26, such as the declaration joined by US and China (the two largest emitters) and the energy transitions partnership signed by a number of major countries in order to support South Africa. According to our updated analysis of these new targets, the rise in global temperatures will be to 1.8°C by the end of the century if the pledges are met in full and on time. COP 26 achieved a lot but not everything: ambitions count for little if they are not implemented successfully. What is essential now is that governments turn their pledges into clear and credible policy actions and strategies.

4 *To what extent will the new shape that energy markets are taking will lead to a change in geopolitical balance?*

Clean energy transitions are set to bring about a major change in the energy trade patterns that have long been dominated by fossil fuel. The rising importance of critical minerals and low-carbon hydrogen means that their combined share in global energy-related trade rises further to 80% by 2050 in a net zero emissions scenario. The supply chain for many clean energy technologies and their raw materials is more geographically concentrated than that of oil or natural gas. For lithium, cobalt and rare earth elements, the top three producing nations control well over three-quarters of global output. In some cases, a single country is responsible for around half of worldwide production. South Africa and the Democratic Republic of the Congo are responsible for some 70% of global production of platinum and cobalt respectively, and China accounted for 60% of global Rare Earth Elements production in 2019. The level of concentration is even higher for processing and refining operations. China has gained a strong presence across the board. This is inevitably a source of concern because it means that supply chains for solar panels, wind turbines and batteries using imported materials could quickly be affected by regulatory changes, trade restrictions or even political instability in a small number of countries. Early attention from policy makers is required to develop a comprehensive approach to mineral security that encompasses measures to scale up investment and promote technology innovation together with a strong focus on recycling, supply chain resilience and sustainability.

Sustainable technologies to help the energy market

Anna Creti

Professor of Economics at Paris Dauphine University

Anna Creti is currently Professor of Economics at the Paris Dauphine University, LeDA-CGEMP (Dauphine Economics Laboratory-Center for Geopolitics of Energy and Raw Materials); Scientific Director of the Chair of Natural Gas Economics (University Paris-Dauphine, École des Mines, IFPEN, Toulouse School of Economics); Director of the Chair of Climate Economics (Paris-Dauphine University); Senior Researcher, Department of Economics, École Polytechnique; Associate Researcher at UC3E, Berkeley and Santa Barbara, California. Previously, Mrs. Creti held the role of Full Professor at the Université Paris Ouest Nanterre la Défense; Deputy Director, EconomiX, at the Université Paris Ouest Nanterre la Défense. She also worked as Assistant Professor and Research Director, Centre for Environmental and Energy Economics and Policy, at the Bocconi University, in Milan, Italy. Mrs. Creti has also written several papers and articles published on important international reviews and is a co-editor of Energy Economics.

1 *What's the outlook for global energy demand?*

There is a clear trend of increasing global energy demand. The two major agencies releasing energy scenarios, i.e. the OECD-International Energy Agency and the US Energy Information Administration (EIA) both illustrate it in their latest reports.

EIA projects that, absent significant changes in policy or technology, world energy consumption will grow by nearly 50% between 2020 and 2050. The International Energy Outlook 2021 (IEO2021) shows that strong economic growth, particularly in Asia, will drive global increases in energy consumption despite pandemic-related declines and long-term improvements in energy efficiency. If current policy and technology trends continue, global energy consumption and energy-related carbon dioxide emissions will increase through 2050 as a result of population and economic growth.

According to the IEO2021 Reference case, which projects future energy trends based on current laws and regulations, renewable energy consumption has the strongest growth among energy sources through 2050. In this scenario, liquid fuels remain the largest source of energy consumption, driven largely by the industrial and transportation sectors. Renewables will be the primary source for new electricity generation, but natural gas, coal, and increasingly batteries will be used to help meet load and support grid reliability. EIA also projects electricity generation to almost double in developing non-OECD countries by 2050.
Falling technology costs and favorable laws and regulations mean that much of the new electricity generation will come from renewable energy sources, although natural gas, coal, and batteries will remain critical parts of the electric grid, backing up solar and wind resources.

What could happen if we plug in this future world the constraint of net zero emissions? A possible, still difficult, answer is proposed by the IEA, in its Net-Zero 2021 report. The path to net zero emissions is narrow, and immediate and massive deployment of all available clean and efficient energy technologies is needed. In the net-zero emissions pathway, the world economy in 2030 is some 40% larger than today but uses 7% less energy. A major worldwide push to increase energy efficiency is an essential part of these efforts, resulting in an annual rate of energy intensity improvements averaging 4% to 2030 – about three-times the average rate achieved over the last two decades. Electrification of transport and other usages is also an important driver

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of change that puts pressure on electricity demand.

Beyond the different figures and numbers associated to the 2050 scenarios, it seems to me of utmost importance to understand the conditions that make these roadmaps real. This is the role of policymakers, at the national and international level. The scenarios projected today always assume perfect coordination: either we have the business-as-usual scenario, or the sustainable one. Nevertheless, the path to 2050 is not unique, and will crucially depend on which policies will be put in place, how citizens and firms will be convinced about the changes required by the low-carbon transition and which technological advances will become available (and when).

2 *Will power prices become more volatile?*

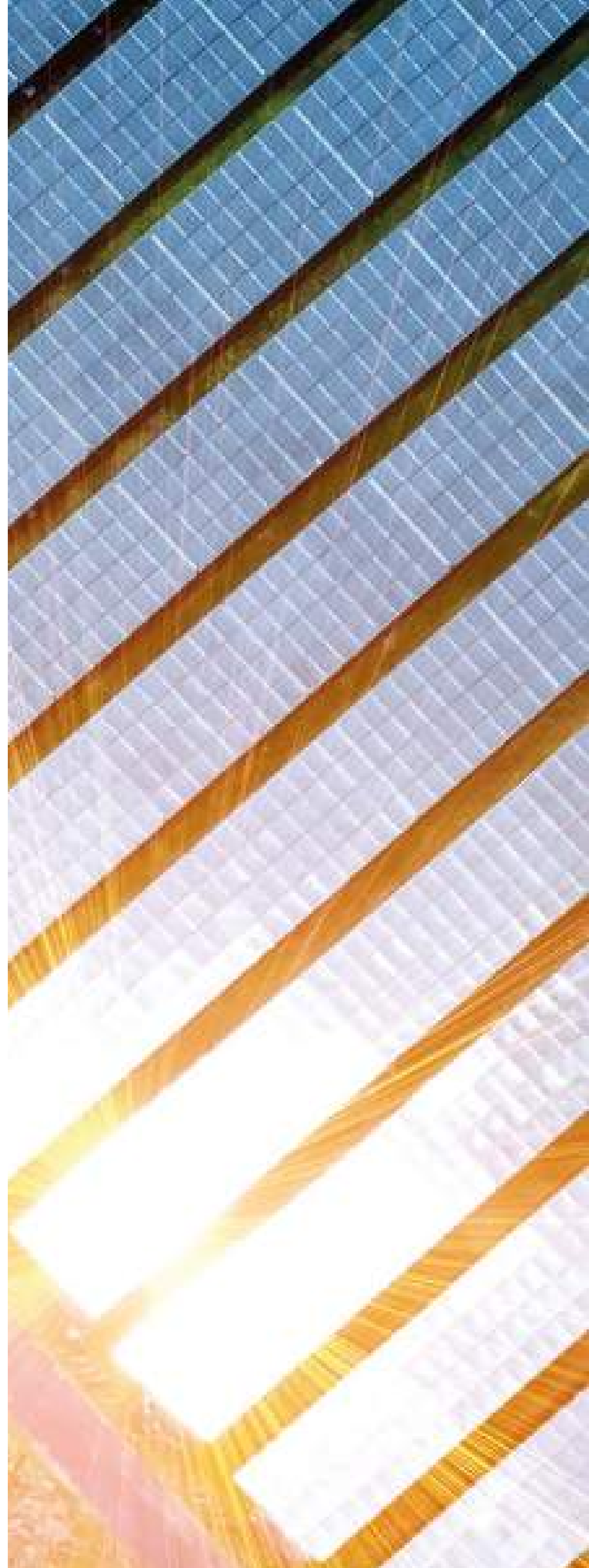
The analysis of day-ahead electricity markets in several countries has shown that once renewables account for more that 20% of the generation mix, there is an increase in price volatility and that this latter increases in a non linear way when renewables take larger market shares. The further need to decarbonize energy production will increase electricity demand, as said before, and will require more and more renewables. At the same time, solutions to reduce volatility will progressively be deployed: large-scale batteries and power-to-gas. Also, smart grids help to absorb part of the volatility. However, there is no consensus at the moment about their availability at profitable conditions. This is an area where further efforts in terms of R&D on one side, and targeted subsidies on the other, are expected.

3 *How will long-run investments be affected by increased participation of electric storage and price-responsive demand?*

In the context of electrification of usages and, as a consequence, increase in electricity demand previously discussed, long-run investment incentives are key factors. Given that the introduction of renewables in the electricity mix is not going to stop, electricity storage is a useful tool to contain price volatility and then to make the price signal for investment more stable. Price-responsive demand is a more ambitious evolution, in my view. Of course, eliminating all forms of tariffs is a leverage of efficiency and will contribute to contain demand. Nevertheless, being confronted to real-time prices will affect consumers' vulnerability, especially the poorest. Therefore, the good balance has to be found between efficiency, which is the most important driver of long-term investment, and equity which is the new challenge to accelerate the transition. Of course, to foster investment in low carbon assets, other instruments such as capacity markets will continue to play a role.

4 *What is your opinion on the cop26 agreement? Are the world electricity markets ready to embrace it?*

Although progress has been made since the Paris Climate Agreement was signed, countries' commitments are still far from limiting warming to well below 2°C/targeting 1.5°C, and their implementation is even



more so. But COP 26 made both concrete and symbolic progress in focusing the multilateral process on the 1.5°C target specifically and keeping it 'alive' by calling on countries to come up with stronger plans next year, increasing pressure on fossil fuel transitions, strengthening multilateral rules under the Climate Convention (UNFCCC) and providing a platform for promising pilot initiatives for international cooperation. The 'catalyst' effect also worked, with the announcement of several coalitions and partnerships, as for instance on methane, deforestation, non-electric vehicles and transition in South Africa. However, COP 26 fell short of international solidarity, failing to compensate for the failure of developed countries to meet the long-standing and symbolic \$100 billion target for developing countries, in a context of exacerbated inequalities under the Covid-19.

In this landscape, two decisions are relevant for electricity markets. The Glasgow Climate Pact is the first COP decision to explicitly call for the phasing out of "inefficient" fossil fuel subsidies. Moreover, the rules overseeing international carbon markets under Articles 6.2, 6.4 and 6.8 are adopted, avoiding the pitfall of double counting. Even if characterizing what is an efficient subsidy does not seem easy, there is a signal that coal and gas electricity generation units becomes more "costly" than before. Instead of stressing the importance of subsidizing renewables, whose profitability progresses, now there is a discouraging effect on fossil fuels. This decision is crucial not necessarily for Europe, where the EU ETS and the different European Directives have already paved the way for decarbonizing electricity, but for many global economies where a carbon regulation does not exist or is weak. Also in this direction, the revision of international carbon accountancy is a step forward to set economic instruments to decrease emission from electricity production worldwide.

Mitigating the cost of energy interdependence

Michael Pollitt

Professor of Business Economics

Michael Pollitt is Professor of Business Economics at the Judge Business School, University of Cambridge. He is an Assistant Director of the university's Energy Policy Research Group (EPRG) and a Fellow and Director of Studies in Economics and Management at Sidney Sussex College, Cambridge. Mr. Pollitt is a former external economic advisor to the UK Office of Gas and Electricity Markets (Ofgem). He is academic co-director for energy at the Centre on Regulation in Europe (CERRE) and Vice President for Publications at the International Association for Energy Economics (IAEE). Mr. Pollitt has a D.Phil. from the University of Oxford.

1 *Will power prices become more volatile as we move to net zero in Europe?*

We should distinguish between retail and wholesale prices. One lesson from gasoline is that high taxes in Europe dampen volatility relative to the US, even though both are exposed to the same underlying volatility in wholesale gasoline prices. The same could happen in power. Higher network costs and fixed costs associated with the energy transition could dampen arising from volatility in retail prices arising for residual use of fossil fuels and wind volatility.

However, wholesale power prices will still be subject to underlying volatility due to fluctuating fossil, carbon and weather-related RES output. Indeed, more dependence on European resources in the power sector, rather than imported fossil fuels could amplify the impacts of shocks rather than dampen them. This is the usual case when effective markets become national rather than global.

2 *What is your opinion on the cop26 agreement? Are the world energy markets ready to embrace it?*

On climate, it is good to talk as this advances understanding and builds support for concerted action. There has been some progress at COP-26. India and Saudi Arabia committed to net zero. The world agreed to move to phase down coal and arrest deforestation. There was progress on common rules for carbon trading. There was also agreement to come back in a year's time to follow up.

However, what needs to happen on concrete policy commitments has not happened. We need to agree to absolute caps on GHG emissions out to 2050 at the global level and to allocate these to countries and regions. This is the only way that we can begin to move towards climate policies which add up at the global level. Without an overarching framework agreement on quantities of emissions we will not limit global temperature rises as intended.

3 *To what extent will the new shape that energy markets are taking will lead to a change in geopolitical balance?*

The world is in a state of energy interdependence with fossil fuels. Any large-scale change to current energy flows between regions is potentially destabilising. For instance, a large and sustained drop in fossil fuel prices could destabilise the Middle East and/or Russia. In addition, energy nationalism remains an expensive preference for both importers and exporters of energy. Thus even as unabated use of fossil fuels declines there remain good prospects for global trading in biofuels, hydrogen and synthetic fuel. If current producers of fossil fuels can transition towards these without significant loss of tax revenue and with good domestic diversification policies then the potential negative international consequences of reduced trade in unabated fossil fuels can be mitigated.

New Skills

Hydrogen Generation: New Skills for Future Markets

Bruno Cova, Director of the Advisory Services & Studies Unit of the CESI Consulting Division, illustrates the increasingly interconnected and interdisciplinary skills that are necessary to work on the energy market. "Cutting-edge resources and a high-level preparation are key to producing competitive market analyses and developing new models."

What is the impact of weather on electricity and gas? And what is that of hydrogen on European markets? How will energy choices change in the "new normal"? What will drive us in 2022? And what effect will the evolution of dispatching services have on new players?

Bruno Cova, Director of the *Advisory Services & Studies* Unit of the CESI Consulting Division, and his team analyze and share questions and wide-ranging forecasts concerning energy each day. Notwithstanding a vast experience developing projects and studies on feasibility and renewable generation (especially in Europe, the Mediterranean basin, the Gulf Countries, and certain areas of Latin America), Mr. Cova and his colleagues understand that the ongoing decarbonization of energy systems and the new reference markets will require a greater commitment and **integrated skills for all the human resources involved** (young and not so young, by age and experience).

Keeping aligned with ongoing trends and producing efficient impact analyses, market simulations, and feasibility studies requires a constant, 360-degree assimilation of professional skills; from the **specific skills** related to energy engineering (and related fields) to **transversal skills** concerning finance, economics and geopolitics (but also chemistry of raw materials, green technology, and big data) and **soft skills**. In fact, according to the **World Economic Forum**'s *Future of Jobs 2020* Report, soft skills will be essential for tomorrow's professionals and to satisfy market requirements for the fourth industrial revolution.

"The coronavirus emergency," explains Bruno Cova, "has highlighted a fundamental aspect. In the coming years, the labor market will be influenced by a dynamic and changing geography. Tomorrow's jobs will have to adapt to the needs of enterprises. So, we must prepare for a business scenario populated by **increasingly qualified professionals with solid technical-scientific and individual skills**."

Critical Thinking and Transversal Preparation

The forecast scenario is particularly complex. It is characterized by digitalization, innovation, and sustainability; one in which

transversal skills will be paramount. According to the WEF study, the key word will be **integration** – the integration of individual skills with those necessary on the market. In this special ranking of skills, the most important concern critical thinking and the potential for analysis, problem-solving, and learning strategies, while the universal trump cards remain, as always, resilience, tolerance to stress, and flexibility.

"We have understood that the evolution of the energy sector," continues the Director of the CESI Advisory Services & Studies Unit, "will require large investments. Electricity producers must base their financial strategies on price scenarios and rely on efficient market mechanisms to efficiently sustain their electric plants, while also considering the cost of raw materials and energy exchange with other regions. Having worked with most major operators, both on the Italian and the international electricity markets, **CESI has developed the skills necessary to support stakeholders in the energy sector**. If, on the one hand, TSOs are working to understand how the need to reinforce energy systems will influence the cost of electricity; on the other, the countries that are reorganizing their systems need independent consultants to define an optimal market structure."

Pandemic Impact and the Integration of Renewables

A good example of this is provided by the analysis prepared by CESI for the Sultanate of Oman, a country that is aiming to diversify its economy and has a growing interest in renewable energy. "Last April, we completed a new study to update the

For further information on this topic, please contact:

Bruno Cova

Advisory Services & Studies Director – CESI

Master Plan for the Transmission System of the Oman Electricity Transmission Company (OETC) to 2040. The objective was to define the best technical-economic options for the long-term development of the transmission system, taking into consideration the Oman Power and Water Procurement Company (OPWP) generation plan and promoting the integration of its RES generation capacity. In this case, as the CESI plan adhered to the United Nations' Sustainable Development Goals, the human resources working on the project required significant competences in the field of sustainability, technical-economic analysis, the integration of RES capacity, and energy market simulations."

In September 2020, a similarly talented CESI team worked on the ***Impact of the Current Pandemic on the Power Sector***, a scenario analysis that revealed how the "lockdown effect" enabled the power system to take a true leap into the future, providing us with fundamental indications on how to develop the sector over the next decade.

"In order to tackle this type of analysis," Cova points out, "an engineer must understand how to manage the many different types of knowledge that concern the **electricity market**, its **ancillary services** (necessary for the security of the overall electric or gas systems and related to the management of transmission and distribution networks) and the **capacity market**. It is more important than ever before to keep updated on new energy market models and simulations. This means understanding how to analyze the measurements that guarantee the supply of electricity, addressing peak loads in all network areas. Indeed, this is the approach that allows CESI to satisfy the demands of its clients and provide cutting-edge resources and high-quality competences around the world."

Green Hydrogen Competence

Hydrogen is another issue that new staff must understand how to tackle efficiently. Green hydrogen has clearly been identified as one of the main fuels that will drive decarbonization in the future energy scenario. In order to provide a better understanding of the rate at which use of this fuel must increase, as well as to trace the most effective scenarios and methods for its use, in September 2021, CESI published a further study – ***Italian Hydrogen Strategy: What Impact on the Power System?*** – to explain its impact on the Italian energy system on the basis of several different production models. "Our analysis," explains the Director of the Advisory Services & Studies Unit, "was based on the targets established in the preliminary guidelines for the National Hydrogen Strategy that defined production and use objectives through 2030 for this new, fundamental fuel. The hydrogen sector is blossoming, and we must be prepared to recognize and evaluate all the new opportunities that may arise. We are aware that the energy transition is influencing our feasibility studies – that are used to evaluate the economic profitability of new assets – in several ways, as well as the very projects implemented to integrate renewables into the energy system. Thus, to remain competitive in cross-sectorial analyses, we must carefully monitor geopolitical equilibria, market regulations, and cost scenarios. This is the only way to become an expert in the analysis of investment impact in terms of production, price, occupation, and environment."

In this context, future energy engineers will have to be trained with a greater focus than in other sectors of industrial engineering with interdisciplinary courses and activities addressing **change-driven dynamics**. In many cases, new Energy Engineering programs, both in Italy and abroad, are already providing a methodological education on the use of energy resources, transformation processes, power generation (both from fossil fuels and renewables), the distribution of electric and thermal energy in industrial processes and civil infrastructure, techniques for the mitigation of the impact of energy systems on the environment, rational use of energy, and on sustainable technology and systems. Nonetheless, our hope is that tomorrow's engineers **will not overlook basic scientific knowledge** such as mathematics, physics, and chemistry, and cultivate a cultural foundation embracing all sectors of industrial engineering, especially electrical engineering, electrochemistry, and applied thermodynamics.

News & Events

Upcoming Energy Events

Powergen International - Destination 2050

January 26-28, 2022

Where: Dallas, USA

https://www.powergen.com/

This international conference presents a technical focus on issues such as decarbonization, digitalization, plant performance optimization, hydrogen, the future of electricity, innovation in energy storage and energy leadership to 2050. The event aims to help participants comprehend the current state of the energy industry, its present challenges, and how to face emerging trends.

EVision 2022

February 8-9, 2022

On-line event

https://evision.eurelectric.org/

This on-line event addresses recent trends in electric mobility with sector experts, mobility policy managers, and company leaders. It provides a unique opportunity to understand the challenges and opportunities that are emerging with the acceleration of electric mobility in Europe, beyond traditional sector boundaries and through continuously evolving supply chains.

E-World Energy & Water 2022

February 8-10, 2022

Essen, Germany

https://www.e-world-essen.com/en/

How will the energy industry achieve a zero climactic impact in the future? The event seeks to answer this question by analyzing several different possible solutions for a sustainable future. The program of conferences and forums includes dedicated appointments on the digitalization of energy sales, e-mobility, aspects concerning the implementation of research infrastructure, and business models for energy efficiency.

Energy storage summit

February 23-24, 2022

London, UK

https://storagesummit.solarenergyevents.com/

The seventh edition of the Summit aims to provide and accelerate investments in and the implementation of global energy storage through information panels, round tables, and workshops. Activities will address energy policy, supply restraints, funding, supply systems, market dynamics and technological developments.

Middle East Energy

March 7-9, 2022

Dubai, United Arab Emirates

https://www.middleeast-energy.com/en/home.html

The foremost energy event in the MENA Region (Middle East and North Africa) brings the global energy community together to present innovative solutions and products in five key sectors for the energy scenario: critical & backup power, renewables, transmission and distribution, energy consumption and management, and intelligent solutions. In the context of the event, the Global Energy & Utilities Forum will hold a series of technical sessions, workshops, and roundtables on the future of energy.

Green Revolution and Ecological Transition

March 24 – 26, 2022

Naples

http://www.energymed.it/

Currently in its 13th edition, EnergyMed returns in 2022 as a true live event at the Naples “Mostra d’Oltremare” to address issues concerning renewables and energy efficiency with a focus on news related to the PNRR Recovery Plan. The event will also address the energy transition through the development of renewable energy and sustainable mobility.

Shaping a Better Energy Future

CESI is a world-leading technical consulting and engineering company in the field of technology and innovation for the electric power sector. In particular, through its Division KEMA Labs, CESI is the world leader for the independent Testing, Inspections and Certification activities in the electricity industry. With a legacy of more than 60 years of experience, CESI operates in 40 countries around the world and supports its global clients in meeting the energy transition challenges. CESI also provides civil and environmental engineering services.

The company's key global clients include major utilities, Transmission System Operators (TSOs), Distribution System Operators (DSOs), power generation companies (GenCos), system integrators, financial investors and global electromechanical and electronic manufacturers, as well as governments and regulatory authorities. In addition, CESI works in close cooperation with international financial institutions such as, among others, the World Bank Group, the European Bank for Reconstruction and Development, the European Investment Bank, the Inter-American Development Bank, the Asian Development Bank.

CESI is a fully independent joint-stock company headquartered in Milan and with facilities in Arnhem, Berlin, Prague, Mannheim, Dubai, Rio de Janeiro, Santiago de Chile, Knoxville (USA) and Chalfont (USA).

www.cesi.it

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