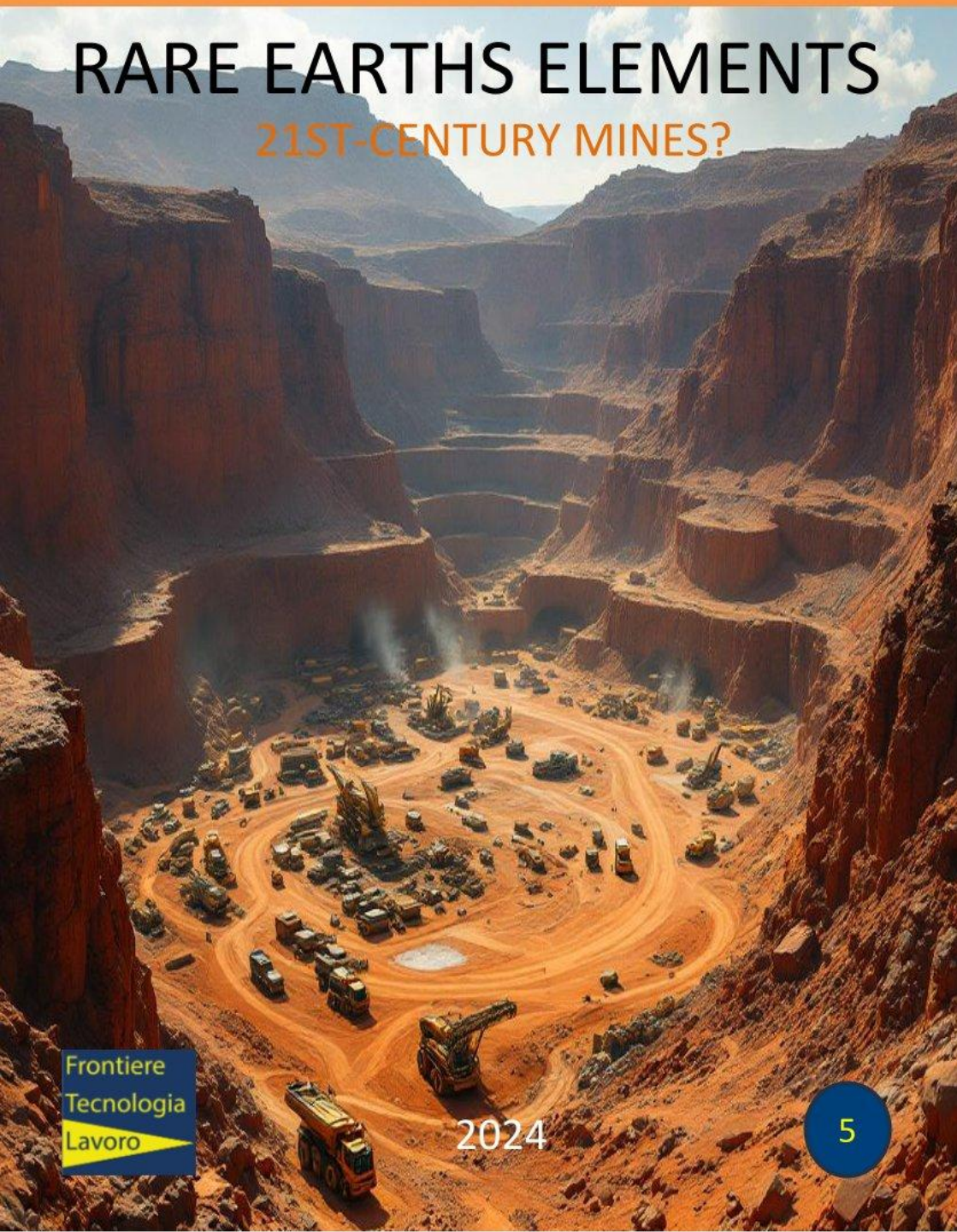
MASSIMO TAMIATTI

RARE EARTHS ELEMENTS

21ST-CENTURY MINES?



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What is it? This is a scientific dissemination website that studies the impact of new technologies on the world of work. Changes today are very fast and exponential. Professions are not static but very dynamic, so the ongoing evolutions can make them obsolete, transform them, or create entirely new ones. What skills will be necessary to face all this? Upskilling and reskilling, but not only.

Why? After 25 years of research, I have realized that to go beyond the boundaries, numbers are not enough. Traditional approaches are obsolete and tied to the old way of doing research. Today, we need to study the weak signals that are right before our eyes but that we see without really noticing. Stopping to consider these signals and imagining multiple possible futures will be the task of Frontiere. Traditional sources respond in real-time but only photograph the present. Today, however, there is a need to make predictions at least five years ahead, without neglecting the past and without forgetting that every topic addressed has a history to consider.

Who is it for? It's easy to make long-term predictions that cannot be verified. I am convinced that the research world needs an immediate confrontation with the world of education and orientation, and with young people who risk studying for professions that may not exist in a few years. They will be here to exchange opinions with the undecided, the disoriented, and those who intend to start over. Young people need to understand that there is a world above and a world below in the job market. A world of those who program algorithms (few and well-paid) and those who work for algorithms (many and poorly paid). We need to understand what to do to escape a job market that risks condemning young people to €1,000 per month salaries for life.

How will it be? Each topic will be addressed with light publications, with a strong emphasis on temporal depth. The publications will be accompanied by short videos (elivri) that get straight to the point. There will be an open chat for young people on the future scenarios of work, the profiles required, and the necessary skills.

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RARE EARTHS ELEMENTS

21ST-CENTURY MINES?

MINING ACTIVITIES OF THE 21ST CENTURY

Until recently, they were not given much consideration. Today, however, everyone is on the hunt for Rare Earths. Our rapidly advancing technology needs Rare Earths to translate into ever more efficient devices. Rare Earth metals are transforming the world. They are key elements for magnets, motors, and batteries, widely used in fast-growing sectors such as electric vehicle production and wind turbines. In reality, the term "rare" is misleading, as they are more common than one might think. They are not rarer than other elements such as lead, gold, and silver. The greatest difficulty lies in extraction, as they must be found in significant quantities within the soil; in fact, they are often present even in our home gardens, but in limited quantities. Additionally, since they are dissolved(1) in the soil and bound to other elements in the form of oxides and isotopes, they require many steps and the use of solvents, which unfortunately generate a considerable environmental impact; they pollute both the atmosphere with CO_2 emissions and the soil with radioactive and chemical waste released. These substances are present in many minerals, but they only have commercial value when their quantities justify extraction. Otherwise, extraction is not economically advantageous. The fact that they are so diluted results in very high extraction costs, which in many cases are not justifiable unless balanced by extremely low labor costs or supported by state subsidies. It is for this reason that there is increasing thought given to recycling electrical and electronic equipment to reuse their precious elements(2).

The latest estimates from the United States Geological Survey suggest that there are more than 120 million tons on Earth, a quantity sufficient to meet current global demand for three or four centuries. Therefore, they are not "rare" in terms of average abundance in the Earth's crust, but rather due to the low concentration of their deposits. There are no deposits full of Rare Earths, but as we have already understood, they are very dispersed. Rare Earths, in our opinion, represent one of the industrial themes of the human community of the 21st century. These are elements so important that they impact global geopolitical alignments and consequently our lives and daily existence. Rare Earths, often abbreviated as REE or "Rare Earth Elements," are a set of 17 chemical elements(3) that are mainly part of the lanthanide family(4). All these elements, which are rarely discussed, are actually very present in our daily lives. Until about a hundred years ago, they were practically unknown; today, however, they are becoming the key to the most advanced technologies.

One of the peculiarities that makes these elements precious in today's industry is their ability to exert magnetism resistant to high temperatures. They are necessary components in hundreds of products across a wide range of applications, particularly in "hi-tech" consumer products such as smartphones, tablets, PCs, hard drives, rechargeable batteries, electric vehicles, monitors, flat-screen TVs, and much more. Furthermore, the use of these elements is now fundamental in many sectors, such as aerospace, electronics, medical, petrochemical, and especially energy. Their particular properties, such as excellent magnetic characteristics, allow magnets made with these elements to be more powerful and lighter than conventional ones, as well as maintaining their properties at high temperatures. All this makes them indispensable in the production of most technological products. As renewable energy sources become increasingly important and widespread around the world, their demand is continuously increasing. Even for electric mobility, the need for Rare Earth Elements becomes important to

address, considering that a hybrid vehicle contains approximately one kilogram of these minerals. A 5-megawatt wind turbine can contain up to 800-1000 kilograms of Rare Earths. However, their strategic importance arguably reaches its peak in the military sector. Elements such as holmium and neodymium are fundamental for the construction of the most sophisticated weapons and ballistic systems of armed forces around the world. The curious aspect is that the quantity of Rare Earths in an electronic device, for example, a smartphone, is practically insignificant in terms of weight and volume, yet without that tiny amount, it would not be as high-performing as the models of the last 15 years. Our smartphones are so fast precisely because of Rare Earths. In short, they can be considered the "magic" ingredient of modern industry. China owns about one-third, and there are reserves in Vietnam (18%), Brazil (18%), Russia (15%), as well as in India, Australia, Greenland, and the United States. More than being rare, they are difficult and expensive to extract. Since the 1990s, China has managed to gain control of about 97% of the Rare Earth industry through low-cost production, high export tariffs, and artificial supply restrictions. But Rare Earths only came to international attention after China "unofficially" blocked exports to Japan, the United States, and Europe. Although it was forced to remove the restrictions, China still controls these elements that are so critical to the economic and security interests of the U.S. and its allies. More than a simple trade dispute, the Rare Earth crisis must be seen as part of the broader discourse on global power dynamics. The inability of the United States and Europe to implement policies aimed at future supply and to find a sustainable solution for their production outside of China indicates that resource competition is destined to persist(5). China is undisputedly the world's leading producer, despite its market share having progressively decreased over the past ten years, from 98% in 2010 to "only" 60% in 2021, according to data from the US Geological Survey. Much of this production comes from a single mine, Bayan Obo(6), located on the border with

Mongolia, which is estimated to represent 32% of global production. China's market share rises to as much as 85% in the subsequent phase of the supply chain, the separation of Rare Earths. Finally, China produces 90% of Rare Earth-based magnets, which are the most sought-after products on the market. China practically has a monopoly. In the 20th century, most of these minerals came from sites primarily in India and Brazil(7). In the 1950s, South Africa became the world's leading producer, only to be surpassed by the United States thanks to production in Mountain Pass, California. However, by the 1990s, Chinese production, driven by very low labor costs and state-supported investments in infrastructure and technology, had already begun to reach levels capable of meeting global demand at a much lower price, a price with which the United States could not compete. By the 2000s, China had almost complete control of Rare Earth production. The reasons for this monopoly are several: in addition to having 37% of global reserves, China has built production and refining factories near the mines so that the extracted raw material could quickly reach them. It was certainly a clever move, which, together with the extremely low labor costs, reduced the overall costs of Rare Earth production. Other countries, primarily the United States, were unable to keep up with China, remaining out of the competition. But the Chinese did not stop there. Over the past 15 years, they have sought to expand production abroad, acquiring exclusive extraction rights in Africa in exchange for grand promises and infrastructure construction. Agreements have been signed in the Democratic Republic of the Congo and Kenya, for which China has committed to providing nearly 700 million dollars for the construction of a Data Center and a highway. In general terms, having a monopoly on a resource means, to some extent, making other countries dependent and thus much weaker. The U.S. government is well aware of this and is obviously trying to find a solution to cope with a potential Chinese blockade of these essential minerals. However, the options on the table are not many. Vietnam could be a solution, given its close ties with Washington,

but the most interesting market from a political standpoint is represented by Australia, which has estimated reserves of 3.2 million tons, or about 3% of the global total. This example provides an excellent illustration of how geological aspects, the wealth contained in rocks, and their extraction intertwine with the economies of countries, their alliances or conflicts, and consequently our lives. Control and production of georesources is probably the determining factor in international geopolitics and is capable of defining power dynamics. This is how it works for oil, lithium, and natural gas. Whoever manages to control these resources in a certain sense controls the world. Today, China is effectively the master of our future and the future of the planet. How can the supply chain of critical raw materials be regulated? Given the dependence on China, is there a possibility for our country to return to mining? The current situation in Italy is entirely similar to that of Europe. In March 2024, the Commission adopted a new European Regulation on the secure and sustainable supply of critical raw materials. The Regulation came into force on May 25 and became operational(8). This European Union regulation, known as the "Critical Raw Materials Regulation," aims to ensure a secure and sustainable supply of these materials, which are essential for the green and digital transition. The final goal will be to limit as much as possible what appears to be a new energy dependence. We have experienced what dependence on a single supplier means. We experienced it with Russian gas, but for critical raw materials, it is even worse. At this moment, we are almost entirely dependent on China. This involves a whole series of elements that are indispensable for implementing the Fourth Industrial Revolution and simultaneously achieving climate maturity goals. All this high technology, which is needed for clean energy, electric vehicles, and decarbonizing the automotive sector, is totally dependent on mineral resources, which are largely in Chinese hands(9). China not only has dominance over internal mineral production but also directly or indirectly controls much of the world's production. It controls African cobalt mines,

much of South American lithium mines, and all of Southeast Asia... For example, cobalt, which is produced in the Democratic Republic of the Congo and Burundi, is purchased by the Chinese, transformed, and refined in China, and then resold as raw material. More than 300 new mines may be needed in the next decade to meet the demand for electric vehicles and energy storage batteries. 384: this is the number of new mines needed, according to a study conducted by "Benchmark Mineral Intelligence"(10), to meet the demand for electrification by 2035; 336 if recycling of materials is taken into account. The estimate, which concerns the extraction of graphite, lithium, nickel, and cobalt, takes into account the average sizes of mines in each sector(11). Fortunately, things are also changing in Europe, and self-sufficiency appears less and less like a pipe dream. It all started 10 years ago, in 2013, when the European Union launched the Eurare project, with which it began studying solutions to create a "local" supply chain for the automotive industry, electronics, and chemistry(12). Today, the European Commission's strategy aims to cover 10% of the community's needs with extraction on European territory, 15% through recycling, and at the same time increase the processing of critical raw materials to 40%. The strategy to strengthen the EU's autonomy in the transition towards sustainable technologies, such as electric vehicles, and thus increase energy independence, involves a new plan for the extraction, recycling, and processing of Rare Earths and critical raw materials. This is provided for in the draft of the "Critical Raw Material Act"(13), the new Community Regulation aimed at breaking Europe's dependence on foreign suppliers. According to the text of the Regulation, the European Commission intends to introduce strategic objectives to increase Europe's strategic self-sufficiency in the Rare Earth and critical raw material sectors(14). In Europe, over the years, valuable deposits have been found in Norway and Finland. Added to these is the recent discovery of the mega-deposit in Kiruna, Sweden, which will allow the supply of essential elements such as scandium,

lanthanum, and neodymium. Thus, it is precisely from the deep north of Swedish Lapland that Europe's challenge to the rest of the world for the great race for raw materials begins(15). The deposit is located in a mining region 150 kilometers north of the Arctic Circle. The new discovery could meet Europe's demand for magnets used in electric motors. Currently, almost all sintered Rare Earth permanent magnets(16) needed for electric vehicle motors are produced by China. Europe is aware of the need for new mines and to strengthen its position in this sector. At the moment, it depends on a small number of third countries, particularly China, which supplies 66% of all critical raw materials and 98% of Rare Earths. Italy also aims to increasingly avoid dependence on China for energy, mobility, and telecommunications. This dependence could bring our economy to its knees, considering that according to the European Community, one-third of Italy's GDP is produced by companies that use the 34 "critical raw materials"; the leading position is held by copper, at 1,300 tons out of the 2,782 tons of strategic metals used annually by our country. Therefore, it is urgent to invest in the recycling economy. If China were to stop supplying Rare Earths to Europe by 2030, 241 gigawatts of wind power (47% of the total) and 3.8 million electric vehicles, or 66% of the battery-powered vehicle fleet, would be at risk. Italy's demand for rare metals is expected to grow up to 11 times by 2040. To address the shortage of critical raw materials, there is a consideration to tap into the market for recyclable products containing them, which is expected to grow 13-fold by 2040, hoping that it can meet Italy's annual demand. Iren is developing two large plants (one in Arezzo)(17) that will recover gold from rare materials. But this policy will also apply to palladium, silver, and copper(18). Our country had a "know-how" both in scientific and technological terms related to the mining world, which was absolutely unique in the world. Unfortunately, due to the choices made by our country, Italian metalliferous mineral mines were abandoned. The choices were justified by the alleged depletion of resources, but they were made mainly

for economic policy, as it was more convenient to import at low cost rather than invest in the renewal of mines, which were by then obsolete from an environmental and technological standpoint. In this global situation, there is nothing to do but rediscover our "dusty" volumes. Knowledge of our mining heritage was strong, widespread, and distributed from the Alps to the Islands, with deposits of all types of minerals that have been extracted over the centuries. Now, due to recent global developments, the situation has changed and is becoming very heated. In particular, over the past year, the exponential growth in the prices of raw materials, starting with those we use in construction sites, Italy has understood the dramatic importance of this sector; for example, the cost of iron and all rare metals has practically doubled. After a period of stagnation, the sector has regained momentum. Over the past five years, a constant effort of research has finally resumed. It is mainly foreign multinational companies, which have a better pulse on the market and are more competitive, that are interested in and directing their research activities towards the large Italian mines that were stopped by Italian policy in the 1960s-'70s and are now being restudied, resampled, and drilled. The deposits are retraced to evaluate their productivity and reopening and to verify how profitable the investment might be. Therefore, it is a period of great ferment for our country, but this clashes with a territory that has no equal in the world in terms of landscape, dotted with parks and natural beauties that must be protected. Great attention must be paid to safeguarding our natural and environmental heritage, something that was often not done in the past. There have been, unfortunately in our country, serious environmental problems created by industrial development. Just think of Seveso or the major river pollution in northern Italy. However, this does not detract from the fact that there is more than ever a need to exploit our mineral resources, and it is up to technicians and the Public Administration (PA) to find the best sites with the least environmental impact where mining activities can be resumed(19).

The abandonment of mines has led to the progressive loss of scientific, technological, and management skills in the field, which must be partially or totally reconstructed through specific training processes involving universities, research institutions, associations, professional orders, category and environmental associations, and Italian professionals operating abroad. About 3,000 mining sites have been recorded in Italy from 1870 to the present. Of these, about a thousand are metalliferous, that is, those from which the essential elements for the national industry are extracted. There are currently 76 active mines, all of which are for industrial use. The only minerals extracted that fall into the list of critical raw materials are "fluorite," extracted near Rome and, since a few days ago, in Silius, Sardinia, which has just obtained the mining concession. This deposit is characterized by vein-type mineralization(20), the association of which is given by Fluorite-Barite-Quartz-Calcite with sulfides of Pb, Zn, Ag, and Cu, and then some other feldspar mines(21). These choices made in the past are evidently due to the economic policy of our country, which decided to dispose of these activities in the face of costs that were too high compared to abroad. Moreover, with these choices, many conflicts with environmentalists, who were very active in those years, were resolved.

Only now the situation has changed, and it is necessary to resume mining activities, but they must be carried out with a focus on environmental sustainability, in accordance with the rules that are well defined both at the national and European levels. After all, we have the example of Carinthia in Austria, in a territory with a strong tourism vocation, where activities for the largest underground lithium mine in Europe have begun. Now, if the Austrians, who are generally very environmentally conscious, can do it, it is not clear why we could not. Italy has one of the most advanced environmental legislations in the world, which can allow us to start talking about mining activities again without the risk of falling back into past mistakes. Mining activities can and must be conducted in an ethically and

environmentally responsible manner, minimizing their impact and adverse health effects, according to the criteria advocated by the EC and already applied in Scandinavian countries (Green Responsible Mining)(22). It is necessary to focus on aspects such as the reduction and reuse of waste and process water, the use of renewable energy sources, and alternative substances for mineral treatment, and the issuance of permits and concessions to companies with ESG certification(23). Activities can and must be controlled and monitored throughout their lifecycle, from research to closure. It is then necessary to carry out the recovery and rehabilitation of the affected sites, using modern control devices and satellite technologies to support state and regional supervisory bodies according to criteria of sustainability and safeguarding. Naturally, without forgetting to guarantee regulatory certainty and appropriate timelines for national and international investors(24). The lesser impact obviously starts from the design, that is, going underground only if it proves to be an economically sustainable activity. In our country, there are already deposits in Piedmont, Liguria, Lombardy, Tuscany, Lazio, Sardinia, in addition to about three thousand abandoned sites. Unfortunately, data and an updated map are lacking. We must point out that currently, there are some areas where research has already resumed(25). But what is the serious problem? With the abandonment of mines, all mining research was abandoned, and specific degree programs, such as those in mining engineering, were also abandoned. Currently, only one course is active at the Polytechnic University of Turin. The training problem is essential. It is necessary to rebuild an entire class of operators, researchers, and employees within the PA. Unfortunately, at this moment, there are no experts in the PA capable of evaluating mining extraction projects. It is urgent to invest in training to prepare people and put them in a position to compete at an international level and collaborate on projects in other parts of the world. But what should mining work become? It must be admitted that mining projects can be done very well

even in Italy. The problem is being able to communicate them, beyond the actual lack of skills on which we need to work. The sector must address a systematic shortage of high-profile figures, such as geologists and engineers, but the real problem is the shortage of more operational profiles, basically workers and miners. It is very difficult to find companies that can work well underground. Often, Italian deposits for extraction use Polish, North African, or Ukrainian labor because mining skills can no longer be found in Italy(26). Therefore, the resumption of university training is absolutely essential. That said, the research projects currently underway have shown what we expected; that is, even old mines declared exhausted and abandoned can still be important. We have examples such as Gorno in Lombardy (Zinc, Lead, Silver) and Punta Corna in Piedmont (Cobalt). In the latter case, we are faced with an old mine used until 1750 for cobalt extraction for coloring purposes, which is currently proving to be one of the most important deposits in Europe, with multiple mineralized veins. Similarly, in Sardinia, particularly in Silius, we have certainty of interesting quantities of various minerals and even Rare Earths.

Mining activities closed or abandoned previously with Legislative Decree 117/08 have left large quantities of extractive waste stored in storage structures (landfills and settling basins) of considerable size. In the Sardinian mining district, the most important in Italy, there are about 70 million cubic meters, with a consequent high environmental impact. These deposits could represent an important source of secondary raw materials. In general, they have good mining potential, with even high grades, as in the case of the red muds of Monteponi (Iglesias), which have an average content of 7-8% zinc. In several cases, storage deposits also contain interesting quantities of critical raw materials, but much still needs to be done in terms of characterization and total reuse of materials. Regulatory constraints must be overcome. Unfortunately, Rare Earth research ended at the end of the last century, and this is now a big problem. At that time, Rare Earths were of little

interest; they were a niche product, while today they represent the basis of the entire ecological transition. We know for certain that there are deposits, but they need to be evaluated; we need to see if they are economically valid or not. For example, in Liguria, there is titanium, estimated at several million tons, with an economic value of several billion euros. Unfortunately, it is in a Park, exactly in the Beigua Park, and it is quite difficult to think of building a 1-kilometer-diameter open-pit mine 300-500 meters deep inside it. In a delicate environmental situation like the Ligurian one, it seems quite complicated, and if it is to be done, it will certainly be necessary to think of different solutions. It is necessary to demonstrate that mining activity can be compatible even with the most delicate territories. Clearly, this requires an evolved mining industry with advanced skills that knows how to do things the right way. It is necessary to launch a constructive provocation even to those who must evaluate the authorization practices, as they must understand the philosophy of the project, the margins for improvement, and also the possibility of control. If we go in this direction, perhaps a "mining spring" will restart that will no longer see the mining disasters that occurred in the past. We have had well-managed mines in the past, but also mines that have caused serious pollution problems. The issue of mining landfills and the legacy they have left in terms of ecological impact on water and land remains open. This is a factor that we will face for decades, and much will depend on the quality of the projects and the cleanup operations with which we will try to reoccupy the territory. The good news is that most of the landfills and extractive waste, that is, the waste material that was accumulated outside the tunnels, contains a series of metals that were not sought at the time but are very useful today, such as Rare Earths, tin, titanium, etc. The problem we have is essentially regulatory. In fact, these piles are currently considered "waste," and according to environmental regulations, they cannot be recovered. Work is being done at the ministerial level to propose legislation that provides for the use of those deposits;

something that, among other things, would help eliminate a serious environmental problem. Another fairly serious problem is that the regulations are often at the regional level, so an agreement with all the regions is needed, which is absolutely not simple. However, the new European law, which provides for the characterization and potential assessment of various mining sites, could help us. Therefore, the entry into force of the European Regulation will mark a new phase. We will only need to find the best way to extract what we need. This is a typical case of a circular economy applied to extractive sites and certainly a virtuous practice that, unfortunately, until now has been prevented by current regulations(27). Rare Earths and gold, what can be recovered from an old cell phone? As mentioned, Rare Earths were (and still are today) fundamental for designing and producing smartphones. Old cell phones could become a resource from which to extract those Rare Earths and precious materials that Italy needs, thus avoiding total dependence on imports. Just consider that a single device can contain more than 60 different metals, including gold. But to extract large quantities, tons of old cell phones are needed. According to a study by E-WASTE LAB of Remedia(28), in collaboration with the Polytechnic University of Milan, the average composition of a single cell phone is: 9 grams of copper, 11 grams of iron, 250 milligrams of silver, 24 milligrams of gold, 9 milligrams of palladium, 65 grams of plastic, and 1 gram of Rare Earths. Furthermore, the cell phone's lithium battery contains 3.5 grams of cobalt and 1 gram of Rare Earths. Therefore, if you have tons of old cell phones at your disposal, it is possible to recover 2.7 kilograms of precious and recyclable materials for every ton of smartphones. Recovering these precious materials and rare metals from end-of-life cell phones is the goal; a more than possible task if you consider that in 2020, the collection of WEEE (Waste Electrical and Electronic Equipment) in Italy exceeded 78,000 tons(29). Moreover, in the circular economy(30), Italy has been defined as a "superpower," as recently stated by Ermete Realacci(31), president of

Symbola; in fact, it has the highest recycling percentage of total waste (83.4%) above the EU average (55.8%). As if to say that the shift towards such a course can no longer be just an option but will be a necessary step capable of requalifying businesses and investments. The potential is not lacking even on the front of critical raw materials. This is well explained by Luca dal Fabbro(32), president of IREN: "our group aims to be the Italian leader because we also see a business opportunity." In fact, the multi-utility has already planned an investment of 10 million euros for two plants in Tuscany that will be used to recover precious materials and critical raw materials(33). Without critical materials, there will be no energy transition. Yet we Italians, great recyclers of paper, glass, plastic, with record rates in the EU, are far behind on WEEE: we collect only 3%. In Europe, we are at the bottom of the list: Bulgaria is at the top with a surprising 92%. Worse than Italy are Portugal, Cyprus, Malta, and Romania. From our homes, at least 720,000 tons of WEEE are discarded annually: we receive 360,000 tons. The rest disappears into thin air, reports Giorgio Arienti, general manager of Erion WEEE(34). Not exactly into thin air; some of it ends up in illegal landfills, and a significant portion leaves Italy's main ports illegally, reaching developing countries where disposal is conducted in a manner that is not very respectful of the health of those involved or the environment. As for small WEEE, which in the Ambrosetti Report are indicated as the most interesting equipment because they are richer in critical raw materials (cell phones, tablets, USB drives, etc.), the situation is different. We find them in trash bins along with common garbage. These chemical elements possess extraordinary magnetic and conductive properties that are fundamental for the electronics and technology industry as well as the aerospace and military industry. For example, Rare Earths can be found inside smartphones, touchscreens, computer hard drives, fiber optics, lasers, and many medical devices, not only in batteries for electric cars. A distraction that comes at a high cost: according to the Ambrosetti study, if Italy were to reach the target of 65% of

WEEE produced each year, we could recover 17,000 tons of critical raw materials, corresponding to 25% of those we imported from China in 2021. The study calculates, considering also the environmental benefits, a social benefit quantifiable at 487 million euros. We have an urban mine in our homes that we struggle to valorize for various reasons. The lack of citizen awareness, the obstacles they encounter in adopting virtuous behaviors, the lack of counteraction to parallel flows, up to an inadequate plant network, mean that thousands of tons of critical and strategic raw materials are not valorized in Italy, diverting their economic, employment, and environmental benefits elsewhere. Sometimes it is not even the citizen's fault: few know, for example, that stores are obligated to take back small WEEE, even without a purchase by the customer (but this only applies to stores with floor areas larger than 400 square meters). And then there is the issue of complicated and very lengthy authorization processes for WEEE disposal plants. According to the Ambrosetti study, an average of 4.3 years is needed. What entrepreneur would want to face a situation like this, especially in the absence of certainty about the quantities collected? Even the PNRR does not help: the funded projects are marginal. Rare Earths, in addition to being indispensable for many sectors of the global industry, are fundamental for the ecological transition. Thanks to them, permanent magnets, electric sensors, and catalytic converters can be built, which are indispensable for the production of green technologies such as wind turbines and photovoltaic panels. Paradoxically, however, extraction has a considerable environmental impact. Therefore, a sustainable extraction policy must be adopted. For this reason, ENEA researchers have developed hydro-metallurgical technologies that will produce low energy consumption and reduced emissions in the extraction process. Therefore, it is possible to hypothesize that in the future, Italy could make itself at least partially self-sufficient in this field. At this moment, there are many issues on the table; there are many technical problems to resolve, and time is short. These obstacles must be overcome as

soon as possible, as they prevent the realization of true circularity. However, positive facts also emerge regarding extractive activities from quarries and not only mines. There is increasingly the possibility of working well on the theme of circularity because many companies are equipping themselves with systems to optimize the deposit, aiming for an increasingly high yield. For example, in stone or marble quarries, a more intelligent cutting procedure is adopted to avoid obtaining fractured blocks, or it is decided to leave on-site the material that is less suitable for use so that it can then become a mining landfill. There is a growing trend towards greater specialization of consolidation and resin systems, which allow more useful material to be obtained, material that would once have been discarded due to damage during cutting. Therefore, work is needed in both directions, that is, both recovering the good from mining landfills, which are true deposits, and working well on the new to avoid producing others. To avoid conflicts with communities in the territories, communication should also be changed somewhat because, unfortunately, fears from the past remain, and it is necessary to reassure the population about the environmental impact. Sharing project approaches and industrial practices with communities becomes very important. The citizen's perplexity is well explained by the recurring statement: "That stuff you extract ends up in my house too!" The rift between civil society and mining activities remains large, also because perhaps they have stopped talking to each other. Therefore, today, when we talk about the "mining sector," everything is still mentally associated with those disasters linked to accidents in African mines, collapses in Chinese mines, or open-pit landfills in the collective imagination. Miscommunication can amplify environmental terror in the population. Precisely in Africa and particularly in the Central African Republic, until a few years ago, the mines belonged to rich Muslim merchants. In recent years, ownership has passed to Chinese companies that have obtained licenses for large areas of the territory. Recently, the Russians have also arrived, present with the infamous

Wagner Group, the so-called "Brigade of Darkness." Machinery, excavators, and mechanical sieves are used to extract large quantities of gold and diamonds in a short time. Unfortunately, mercury is also used, which causes serious damage to the soil, animals, and people who work there. Another problem is the opacity in mining exploitation contracts and the treatment of often underage labor; moreover, the economic benefits of deposit exploitation for the states that host them are marginal. For example, in 2019, the Central African Republic received compensation for 140 kilograms of gold extracted in the year, while according to other estimates, at least 5,400 kilograms were actually extracted. All these companies have begun to exploit the territory in a wild manner, considering it their own and using the local labor force indiscriminately, often underage and without any protection, with serious violations of human rights. There have been deaths due to drownings because the companies did not fix the bottom or because they diverted the course of rivers at their discretion. The Chinese and Russian companies are escorted by military personnel who do not hesitate to threaten or even kill people when they start asking too many indiscreet questions(35). In African countries and much of the world, there is a serious problem of corruption in the state apparatus, and only a very few states, for example, Botswana, have managed to organize a healthy and profitable management of raw materials, bringing well-being to the population. Naturally, it is not only the Chinese who act in this way, but also Western companies, especially British and American ones, which show their worst side in Peruvian and Bolivian lithium mines. Fortunately, these are extreme situations that could never occur in our country. Clearly, this different approach has a cost and will entail costs that are not comparable to those of the previously mentioned countries. They will therefore need forms of subsidy to make European products more competitive. If we want to move towards sustainability, we must address the issue of costs. However, we must consider that for many years, we have based our well-being, our

smartphones, and our clean energy on the skin of the "last" of the world; this is no longer admissible.

What is the availability of labor in Europe today?

Today in Europe, there are about 200,000 people working in the coal mining industry. Some of the skills in coal extraction could really be very useful for these new extractive industries(36). But is there a possibility of training new people? The future is indicating this direction. Administrations and municipalities must begin to believe in this new type of project, even if today there are few miners, and it is already difficult to find qualified workers in many sectors, let alone in this specific sector. But at least among young people, curiosity in this sector is growing. For example, one of the mentioned mines, Gorno, employed very young professionals for its research phase, geologists, and engineers fresh out of university, allowing them to take their first steps in the underground world of mines. The geologist is a professional figure that has grown significantly, occupying professional niches left open by the growing shortage of mining engineers. The Polytechnic University of Turin is trying to push the figure of young mining engineers, as are the French, Germans, and British, who, however, have never abandoned the training of such important figures in this sector. We could say that the interested profiles concern, on the one hand, extractive mining activities(37), and on the other, the management and recycling of waste. These latter profiles are indispensable for promoting the transition towards a circular economy. The more "traditional" profiles that operate in extractive activities in these years in Italy have been employed mainly in the extraction of stone or marble(38). Today, these same figures will have to work on other types of minerals; starting with the figure of the "quarryman"(39) and the "miner"(40). The difference between a quarryman and a miner is very subtle. The quarryman generally deals with excavation and site preparation, while

the miner extracts precious resources or minerals from the earth. Figures of this type in African countries still dig or extract in an artisanal manner, for example, in the Congo for the extraction of Coltan(41), one of the Rare Earths indispensable for the functioning of smartphones. After cutting down the forest, the miners begin to dig with shovels and pickaxes a large pit from which narrow, collapsing, and unlit tunnels branch out. The miners are almost all men, but the disturbing thing is that for the narrowest tunnels, children are used. Every day, many miners die from fatigue, hardship, and disease. There is no exact number, but the United Nations speaks of about a thousand Congolese miners dying every day. The pay, obviously, is almost non-existent. These people are paid less than 2 dollars a day, when they are paid, and they find themselves working out of desperation(42). Landslides, explosions, toxic air, and extreme temperatures are some of the dangers that occur in underground mines. These dangers exist even in the Western world, but obviously, the working conditions are vastly different.

There is a multitude of profiles that revolve around these activities, both underground and open-pit(43). Especially mining engineers, who have almost disappeared in our country, but also geologists, who fortunately are not lacking. Finally, there are requests related to the environment, safety, and regulations(44). There are naturally those who operate machinery, manage, and control heavy equipment such as excavators, bulldozers, cranes, and mining trucks. In particular, the mythical Fortuna Dumpers(45), indispensable in quarries. The use of autonomous, battery-powered Dumpers monitored via mobile network represents an ecological revolution in the logistics sector. Modern technologies allow us to take a leap forward towards the goal of net-zero emissions, focusing on renewable energies and climate-conscious logistics(46). They are responsible for the safe and efficient operation of machinery for excavation, loading, and transport of mineral material. Another important figure is the mining chemist, who must perform chemical and physical analyses of minerals to determine their

composition and purity. They collaborate with geologists and mining engineers to assess the quality of resources, monitor production, and develop processing methods. We must not forget, above all, blasters and demolition experts, obviously central to all extraction activities. The world of the circular economy also generates many profiles in this case, even very different ones, including some figures related to the environment, health, and safety(47). This is also linked to the type of communication to be managed towards local communities, precisely because of the inevitable impact, given that we are dealing with "dangerous" minerals(48). Fundamental, moreover, is that there are figures dedicated to logistics. Logistics experts manage the transport of Rare Earth waste from the point of origin to treatment and disposal sites. They are responsible for route planning, selecting appropriate means of transport, and managing operations in compliance with current regulations. In these activities as well, the role of chemists is indispensable. Chemists play a key role in analyzing Rare Earth waste to identify chemical components and possible toxic substances present. They use laboratory techniques to evaluate the chemical composition of waste and determine the most appropriate methods for its management. Then, profiles related to waste disposal(49) and recycling(50) are certainly needed. Finally, one of the most important profiles is the plant treatment and disposal operator. Plant operators work directly in the execution of Rare Earth waste treatment and disposal operations, manage and supervise daily activities in plants, following safety procedures, and ensure that the process takes place efficiently and effectively. However, it is necessary to redraft the national mining map to once and for all define the potential of the territory. Furthermore, it is necessary to develop sustainability criteria because our territory is much more complicated than other European territories. It is therefore necessary to take stock to define the areas on which Italian or even foreign investors can then request permits to carry out mining activities. Moreover, part of the PNRR is dedicated to

training courses for PAs and professional orders to prepare and coordinate efficient collaboration between these two worlds, following mining activities from the exploration phase to the closure and post-closure phase for site restoration. It is fundamental and urgent at this moment to arrive at a full revision of the mining map (the current one is stuck at 1973) to be entrusted to expert researchers throughout Italy. Many things have changed compared to the past, but above all, the minerals that are useful today for the transitions we are experiencing have changed.

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(3) Scandium, yttrium, and the entire family of lanthanides (in the periodic table from lanthanum to lutetium, the rarest of all).

(4) Rare Earths are 17 chemical elements considered metals, more precisely: lanthanum, cerium, dysprosium, erbium, europium, gadolinium, holmium, lutetium, neodymium, praseodymium, promethium, samarium, scandium, terbium, thulium, ytterbium, yttrium.

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(20) Subvolcanic or hypoabissal rocks are a type of igneous rock that crystallizes entirely or mostly at shallow depths, in bodies of various shapes but almost always of small size.

(21) Feldspar imparts hardness and strength to materials, making them more impact-resistant. For this reason, it is a fundamental component in the production of tiles and ceramic slabs and glass products that, as such, need to be as resistant as possible over time.

(22) Mining activity is a critical sector of the global economy, providing the raw materials that drive our modern society. However, traditional practices can have a devastating impact on the environment, depleting water sources, destroying habitats, and contributing to climate change. To address these concerns, a new approach is gaining ground: green mining.

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(23) A company that chooses to follow ESG principles commits to minimizing its environmental impact, respecting and promoting social rights, and operating according to criteria of transparency, accountability, and good governance. ESG certification is a tool that allows companies to concretely demonstrate this commitment to their stakeholders, investors, customers, employees, and local communities. It serves as a quality seal that attests to the company's adherence to ESG principles, based on specific metrics and internationally recognized standards.

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(30) The sector has recorded almost 13.5 billion euros in turnover with more than 97,000 direct employees. Significant numbers for a sector now called upon to make a great effort to achieve community goals.

(31) Ermete Realacci is an environmentalist; he promoted and chairs Symbola, the Foundation for Italian Qualities. He is among the founders of the Kyoto Club. He was an Italian parliamentarian, formerly President of the Environment, Territory, and Public Works Commission of the Chamber of Deputies. He has led initiatives for energy saving and renewable sources, for the defense of territories and community cohesion, but also against illegal building, fighting eco-mafias, and promoting high-quality agri-food productions and zero-kilometer, fair trade, and socially responsible business.

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(33) Erion WEEE is the most important Producer Responsibility Organization operating in Italy in the WEEE (Waste Electrical and Electronic Equipment) sector.

(34) There are 34 critical raw materials: antimony, arsenic, bauxite, barite, beryllium, bismuth, boron, cobalt, carbon coke, copper, feldspar, fluorite, gallium, germanium, hafnium, helium, heavy rare earth elements, light rare earth elements, lithium, magnesium, manganese, graphite, nickel, niobium, phosphate rock, phosphorus, platinum group metals, scandium, metallic silicon, strontium, tantalum, metallic titanium, tungsten, and vanadium. Strategic raw materials are the portion of critical raw materials (17 strategic raw materials out of 34 critical raw materials) for which a fundamental and strategic role is recognized in

the realization of green and digital transitions and in defense and aerospace applications: bauxite/alumina/aluminum, bismuth, boron, cobalt, copper, gallium, germanium, lithium, metallic magnesium, manganese, graphite, nickel, platinum group metals, rare earth elements for permanent magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce), metallic silicon, metallic titanium, tungsten.

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(37) Extractive activity consists of the extraction of minerals from the soil. This activity falls within the primary sector of the economy, as it is an activity of exploiting resources present in the environment.

(38) By stone, we mean the natural aggregation of minerals; in particular, it is "a non-polishable building stone" (a characteristic that clearly differentiates it from marble). In general, stone has a background color on which a sort of design stands out due to minerals of different colors. Marble is a metamorphic rock of calcium carbonate that, under the effect of temperature and pressure changes, has undergone a transformation process, taking on a granular and crystalline structure.

(39) The quarryman is a worker responsible for the operations of detaching, breaking, and extracting marble, sand, stones, gravel, pozzolana, materials for cement and bricks, sulfur, and other minerals, both in tunnels and open-pit. The quarryman's work is paid an average of 1,600 euros per month, but with overtime, it is not difficult to reach 2,000.

(40) The miner works as a laborer in mines, providing for both the detachment and breaking of minerals and auxiliary operations, such as the preparation of mine holes by driller, the loading and blasting of mines (loader and blaster), the installation of tunnel reinforcements (reinforcer), and maneuvers in the extraction shaft stations (cager). The term derives from the ancient expression: "who makes mines, who works in mines".

(41) Coltan contains a part of uranium; therefore, it is radioactive, causes tumors and sexual impotence, and is extracted by miners with bare hands.

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(43) In common parlance, the term quarry is reserved for open-pit excavations, while the term mine is attributed to underground excavations.

(44) These are the figures of mining safety experts and environmental and sustainability managers.

(45) Within a construction site, it is essential that work is well organized, especially if there are large quantities of material that could act as potential obstacles or slow down procedures. The function of the dumper is to move this material safely. It is an articulated motorized vehicle in two parts: the container, mainly actuated by a hydraulic system, whose capacity is fundamental for the choice of a dumper, and the cabin inside which the driver who maneuvers the dumper is positioned. These vehicles, generally diesel, in the past had a manual unloading system and could lift between 900 and 1800 kg. However, technological evolution has allowed a significant increase in maximum capacity, which can exceed 10,000 kg, thanks to the introduction of mechanical or hydraulic systems.

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(47) Environmental engineers and health and safety managers. But also experts in environmental impact assessment.

(48) Environmental communication experts play an important role in raising awareness and informing the public about the issues associated with Rare Earth waste management. They communicate clearly and effectively the environmental challenges, measures taken, and the importance of sustainable practices.

(49) Waste disposal experts are responsible for the proper management of Rare Earth waste. They develop and implement safe disposal procedures in compliance with environmental regulations. These professionals must be aware of the various disposal technologies available and evaluate their applicability.

(50) Recycling experts work to develop and improve Rare Earth recovery processes from waste. This may include the use of chemical or physical separation techniques to extract Rare Earths from waste materials and reintroduce them into the production cycle.

Massimo Tamiatti

I have always been involved in the study and dissemination of topics related to new technologies, new jobs, and new skills. I do this in a completely new and different way compared to traditional research approaches because, in addition to consulting traditional sources, I consult sources from major strategic consulting firms, which do not have a static but dynamic vision of reality, as they focus on the future. I systematically use the web to search for the most up-to-date content, perhaps through webinars with privileged witnesses on the subject of the investigation or through some important influencer specialized in the topic being addressed. Obviously, today, I use Generative Artificial Intelligence tools. I do not neglect the present; I try to interpret the signals that we have before our eyes, which we are often used to looking at and not seeing, and which suggest what could happen. I do not neglect the past, that is, history, but in reality, many disciplines are mixed: economics, statistics, sociology, psychology, anthropology, and above all, I use imagination anchored to the facts that happen every day in the world. I consider numbers very important, but they are not everything; at the center, there must always be a particular attention to the privileged witnesses of the things that happen and their personal stories. Frontiere does not have the gift of foresight, but our team can make hypotheses, and among these hypotheses, I have realized that it is very likely to encounter the future. Spreading the culture of anticipation helps people understand what is happening in the world, especially in the world of work, helps them prepare, elaborating strategies, and organizing themselves to make very important conscious and correct choices for the effect they will have on their lives.

Institutional Profile

I was Chief Research Officer of the Agenzia Piemonte Lavoro, where I coordinated groups of researchers in the field of labor and vocational training policies until June 30, 2023. Since July 1, I have become part of the staff of the "Laboratorio Riccardo Revelli" as an honorary member. I am an expert in public employment services. Currently, I am a member of the group that coordinated the organization of the "Settimana del lavoro 2024" and related events on behalf of the Istituto per la memoria e cultura del lavoro, dell'impresa e dei diritti sociali (ISMEL), of which I am a member of the scientific committee. I am a member of the scientific committee of Polis policy, Accademia di alta formazione. I am the founder and director of the online scientific dissemination site **http://www.frontieretecnologialavoro.com** since 2022 and a member of the Associazione dei Futuristi italiani di Roberto Poli. I am an expert in the use of forecasting techniques applied to local labor markets, in collaboration with the start-up Skopìa, specialized in future studies and anticipation, aimed at helping organizations develop anticipatory strategies to support complex decisions in areas of strong uncertainty. I have a degree in letters and philosophy, with a thesis in contemporary history and one in political science, both obtained from the University of Turin, and I am the author of numerous publications related to the labor market, and in particular to the new scenarios of the labor market, new professions, and new skills.

The following collaborated with me on this project: Gabriele Lamberti, Benjamin Dafku, Ivan and Federico Giacobino.