Department of Political Sciences

Chair of Energy and Environmental Policies

European Green Deal: the challenge of decarbonization and the possible consequences in political and economic terms

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Introduction

Climate change, which is the subject of an extensive international debate, is due, according to a shared opinion, to the growth of carbon dioxide emissions into the atmosphere. This growth is principally traced back to the emissions of the fossil sources of energy, which, still today, accounts the 80% of the energy generation. In order to contrast the climate change, the necessity of an energy transition is indicated that is substantially identified in the goal of a rapid decarbonization.

The paper aims to analyze the energy transition. What, most of all, can teach us what the future will be is the past, and that is why defining the concept of energy and then analyzing what caused the other energy transitions in history, recognizing their drivers and the surrounding market conditions, is of vital importance. The paper continues with an analysis that combines the political scenario with the technical explanations of energy sources, highlighting their limits but also the enormous impact, both economically and in everyday life, that it has had on human development. For each source that realized the transition, a graph will be shown, containing the main drivers and how they occurred.

The thesis will then analyze the history that linked the climate to energy, with the first literary productions that formed the basis of the international climate meetings (COP), then analyzing the results, in terms of emission reduction, resulting from the protocol of Kyoto and the Paris Agreement.

Human-related global warming is, rightly or wrongly, the theory shared by much of the scientific community. It deserves to be highlighted that there is another slice of scientists, not indifferent in terms of reputation, who do not deny global warming, but who argue that further studies are needed to link anthropogenic activities to this result. The paper will analyze the literary history and the moment in which fossil sources were indicated as responsible for significant climate impacts, first in Global Cooling, then in Global Warming.

The analysis of what in fact led to the birth of environmentalism that contrasts fossil fuels with renewable sources is fundamental to be able to answer Epstein's question, contained in the final part of the second chapter: what value do we give to human life?

In the following, the European Green Deal will be analyzed, presented by Ursula Von Der Leyen on 11 December 2019, which, for the first time in history, establishes a deadline for the energy transition, 2050. In a period in which only doubting the feasibility of the energy transition, at least in the ways in which it is prophesied, is sufficient to be qualified at best as ignorant and at worst as "morally reprehensible", an analysis of the limits underlying the Green Deal (the low climate impact of Europe alone, the technical limits of the New Renewables and the fragile geopolitical balances based on the oil market) is indispensable. For this reason, each limit will be accompanied by a case study, to make understand the interests at stake of the main countries in the global scenario and to find empirical confirmation of what is explained in theory.

China will be the first case study analyzed. A climate deal that sees China marching in the opposite direction can only have counterproductive results. At the same time, it is difficult to believe that China can or wants to move in the direction indicated by the European Union, due to the growing demand for energy in its borders, which can be met (for now) in large part by coal. CO2 has the great limitation of being global, it knows no borders and does not need a passport to move from one country to another. The reduction of emissions by Europe alone is not sufficient to achieve a significant climate impact, a limit that the Green Deal must consider.

The second case study, linked to the limits of New Renewables, will be Italy. The history of Italy, characterized by massive investments and incentives in the photovoltaic sector, is of fundamental importance to understand how the massive policy decisions made in favor of renewable energy in recent decades have not obtained the result of pushing them towards an impact, in terms of energy requirement, significant. This is due to the technical limits that renewables present, which are difficult to overcome in the short term.

The third case study will be Saudi Arabia and Russia, to frame the fragile geopolitical balances between Europe and these two countries and the role that fossil fuels play from a purely economic but also political point of view.

Saudi Arabia is functional in demonstrating how the export of oil is able to form and maintain an entire economy, which, driven by the low-carbon pulsations of Europe, its major importer, but also by the characteristic volatility and uncertainty of the oil price, has decided to make an attempt to detach from it, through the Saudi Vision 2030, which, however, is not achieving the desired results. Russia, on the other hand, serves to present the current natural gas market, seen by many as transitional energy (including from Europe, which recently decided to include it in the investments accepted by the Green Deal to encourage decarbonization) but which it still has some limitations, one of which is the need for large and expensive infrastructures, impossible to limit within its borders and which therefore require agreements with neighboring countries.

Finally, the thesis will analyze zero emission technologies, and the possible impact they can have in a transition to zero CO2 emitted. The first, more than a technology, is an alternative energy source, nuclear energy, capable of having a major impact on the energy needs of countries. France could have been an excellent case study, but Sweden was chosen, a country also defined by numerous environmental movements as one of the most virtuous in terms of low-carbon emissions.

Nuclear energy, demonized by a large part of public opinion, is moving towards important technological advances, which promise to limit the problem of radioactive waste and increase its safety, already very high.

Then, the hydrogen will be analyzed to understand its potential and feasibility. Today the Green Deal is very much linked to hydrogen defined as "green", produced by electrolysis from renewable sources. But the risk is that we are focusing on a source (for hydrogen, as we will see, the term "energy vector" would be more correct) that is not yet mature at the technological level.

Finally, the CCS (Carbon Capture Storage) and CCUS (Carbon Capture Utilization Storage) system will be presented, analyzing their technical nature and the investments necessary to produce a significant impact on the environment.

Europe is preparing to face an enormous challenge, perhaps too great, which will have to be realized by 2050. There are many areas that will require major commitments, and it is necessary to understand if the technology will be available in this time limit.

1ST CHAPTER - THE HISTORY OF ENERGY

What is Energy? The two principles

"If you want to find the secrets of the universe, you need to think in terms of energy, frequency and vibrations."

This quote comes from Nikola Tesla, one of the most important inventors, physicist and electrical engineer of the first years of the 20th century. This sentence makes us understand that energy is the only universal currency; from it, through its transformation, we obtain everything.

Its history, relationship to society, and the role it has played in human evolution are elements of great interest to fully understand what is happening today. But, first of all, how could we define Energy?

Answering this question is of extraordinary difficulty. In fact, Richard Feynman declared in his work *Lectures on Physics* that "it is important to understand that today we have no idea of what energy is." All we can consider is that energy manifests itself in many forms, which in turn are connected to each other through conversions[1]. Understanding these conversions, energy flows and the complexity of energy transformations, represented an important step in human history. There are many principles to consider if we want to understand the concept of energy conversion.

First of all, all forms of energy can be converted into heat, without losing energy in any way. We know this thanks to the first law of thermodynamics, which everyone calls to mind with the phrase sentence: energy is not created, nor destroyed, but transformed[2]. However, if we continue to move on the conversion chains, the potential for useful work decreases. By this concept, we understand the second law of thermodynamics, entropy.

The formulation of the second principle of thermodynamics is due to the German physicist Rudolph Clausius, who in 1865 published an article where the term entropy was used for the first time in history as a measure of the degree of disorder of an isolated system. The second law can therefore be summarized with the words: the

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[1] Richard Feynman, *The Feynman lectures on Physics*, Addison Wesley (1988)

[2] this law owes its birth to the observations of the German doctor J.R. Mayer, but the final formulation is attributed, after countless experiments, to the great English physicist J.P. Joule.

entropy of an isolated system continuously increases[3]. In simpler words, this means that in an isolated system there is less and less energy available to do useful work. this inexorable reality can be explained with an example: a piece of carbon, before it is burned, contains "high quality" energy; this means that its entropy is low. Once it is burned, the energy that he has does not disappear, but it transforms into heat, which is a disordered form of energy. The fact that it is disordered, indicates the high entropy of heat. Once the energy is transformed into heat, it cannot be used again for useful work[4]. This is the reason why, for example, in each engine the heat is produced as a consequence of the gear clutch, and it does not work without fuel, that gives it the energy that the gear loses in the work process. It must be said, finally, that any type of energy can be converted into heat, but the opposite can never happen.

A question can arise spontaneously: if the law of entropy is true, how do we explain renewable energy sources? Should they run out? The answer is simple: no, because our planet is an open system, which is located in an isolated system, that is the universe[5].

The second law of thermodynamics, in fact, predicts the thermal death of the universe. The expansion of the universe, which has never stopped and continues today, will lead to the cooling of the particles that compose it, until it reaches the instant of maximum disorder (absolute cold).

Drivers of an Energy Transition

An energy transition, to be fully realized, needs to respond to certain conditions. So, if we ask ourselves what these *drivers* may be, we must resort to economic and technological parameters.

The first is clearly a *demand for energy services*. As we will see in the transition from wood to coal, the energy demand caused by massive deforestation, which had

[3] Arieh Ben-Naim, *L'entropia svelata. La seconda legge della termodinamica ridotta a puro buon senso,* librerianuniversitaria.it (2009)

[4] Juan Jose Gomez Cadenas, *L'Ambientalista Nucleare*, Springer (2012)

[5] G. Boyle, *Renewable Energy*, Oxford University Press

effectively dried up much of the wood available in developed countries, has (slowly) led to the use of coal as an energy source.

This happened because, linked to this first condition, there is the second: *supply constraints*. That simply happens when a resource cannot be expanded in step with increasing demand.

The third condition are the *cost advantages*, which include not only the actual fuel cost, but the associated labor costs, energy converter costs and other economic impacts.

As we will see in the transition from wood to coal, in the first few decades of American railroads wood were the fuel for locomotives. It was plentiful, accessible from land cleared for agriculture, and easy to burn. The change to coal was a result of wood prices (reflecting growing wood scarcity near urban areas and main lines) and falling coal prices as the coal industry expanded. Coal rates declined from $7 to $10 / ton in the 1830s to $3 / ton in the 1850s, down to $0.75 / ton in some areas in 1862[6]. White says, "It was this fall in the price of coal rather than the drastic rise in the price of wood that contributed to the great conversion of locomotive fuel"[7].

The fourth condition are the *Performance benefits*; they include all advantages, from speed and acceleration to protection and cleanliness, that are not usually measured in terms of resource price. These are a subset of cost advantages, which definitely have an implied value shown by customer actions, although the attributes are not specifically priced in certain instances. They may be the product of a new fuel, but they are mostly connected to advances in energy converters[8].

An excellent example of a transition driven by Performance Benefits, even more than by the other drivers (however present) is agriculture. As we will see, the birth of agriculture is not justified only by economic factors, given that, at least in the transition phase, foraging societies yielded more in terms of net energy returns, but also by factors that cannot be calculated at an economic level.

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[6] A. O'Connor, P. (2010). *Energy Transitions*. [online] Available at: https://www.bu.edu/pardee/files/2010/11/12-PP-Nov2010.pdf.

[7] White, John H. (1979). A History of the American Locomotive: Its Development 1830–1880. New York: Courier Dover Publications.

[8] Energy Converters can be defined as the tool that converts energy into a useful form; a good example would be oil transformed into electricity thanks to a converter.

The final driver is the *Policy Decisions*. Tariffs, incentives, subsidies, codes, legislation, infrastructure growth, and other steps are among the acts taken by governments affecting energy supply. Cultural expectations frequently affect policy choices.

This driver, according to many, is seen as secondary, as it has never represented, in human history, the first to be realized, in the context of energy transitions. Indeed, when an attempt was made to impose a policy decision that in a certain way "forced" the transition, it never took place, as we will see with OPEC supply decisions, in 1973 and 1979, and, from the 1980s onwards, with the policy of incentives and subsidies for new renewables.

Transition	**Year**	**Type of Transition**	**Main Driver**
Charcoal to Coal for smelting iron	1850	Resource	Local wood cost increases (cost advantage)
Rise of Railroads	1830-1930	Converter	Performance (Speed), cost (time)
Wood to Coal for Railroads	1870	Resource	Coal cost decreases (cost advantage)
Waterwheels to steam engines	1870	Converter	Extent of coal distribution expanded
Sailing ships to steam vessels	1810-1880	Converter	Performance Advantage
Competition among lamp oils	1830-1880	Resource	Cost advantage
Wood fireplaces to coal stoves in UK	17th century	Resource, Converter	Rising cost of wood (cost advantage)
Oil lamps to electricity	1930	Converter	Performance
Gaslight to electric	1910	Converter	Performance (safety), Cost
Wood to anthracite for domestic heating	1900	Resource	Urbanization, local wood cost increases (cost advantage)
Anthracite to oil/gas for domestic heating	1950	Resource/Converter	Cost (including associated labor cost)
Decline of oil for electricity and heating	1970-1980	Resource	Cost, Policy
Railroads to automobile for passenger travel	1916	Converter	Performance (flexibility)
Coal to oil for UK naval vessels	1913	Resource, Converter	Performance (speed), labour cost
Internal Combustion Engine becomes automobile standard	1910	Converter	Performance (range, power, weight), cost

Source: A. O'Connor, P. (2010). *Energy Transitions*. [online] Available at: https://www.bu.edu/pardee/files/2010/11/12-PP-Nov2010.pdf.

The graph shows different transitions, flanked by the most important driver that allowed the realization. Another interesting data in the graph is the type of transition that has taken place. In fact, a distinction is made between:

Resource - means a transition from one energy resource to another, such as switching from wood to coal.

Converter - means a transition from one energy converter to another.

In the next paragraphs, following the history of man in relation to energy, we will see how any energy transition is conducted by these factors, to be able, at the conclusion of the thesis, to answer the question: "does an energy transition today respond to these factors? "

History of Energy: Homo Sapiens

Life on Earth is powered by energy. Living organisms have to assume energy to power theirselves. The livings are distinguished by the way they get energy for nutritional activity and metabolism. *Autotrophic organisms* (essentially plants) are capable of nourishing themselves by synthesizing directly organic substances from not organic ones. They obtain energy through a chemical process. Combining solar radiation, water and carbon dioxide absorbed from atmosphere, they synthesize carbohydrates and organic substances (producing oxygen as by product). *Heterotrophic organisms*, not able to synthetize directly organic substances, get it from feeding autotrophic organisms.

Homo sapiens is one of those heterotrophic organisms, but a particular one: in fact, it is the only living organism with a specific ability: to use energy in an extrasomatic way, outside its own body, to allow using much more energy than any other heterotrophic, to do useful work. This is evolution.

The word energy means the ability to do work. But for the work to be done, energy needs to change its forms, since everything is produced by its transformation. The link between energy and human development is very strong. Leslie White has defined "the law of cultural development" in the form of the equation *C = ET:* E is the energy per capita consumed in the year under consideration; T is the efficiency of its use, which we can be defined as technology and C indicates the extent of cultural development.

Leslie White was an anthropologist who consider energy, in the history of civilization as the first indicator for human evolution. Beginning with Homo Sapiens. Knowing the history of the genus Homo and filling in the specifics of its development is an unending search, as new discoveries drive back several old markers and complicate the overall picture with the discovery of organisms that do not easily fit into an established hierarchy[9].

According to the famous discovery of Richard Leakey in Ethiopia in 1967, the first Homo Sapiens bones are dated 190,000 years ago but only 10,000 years ago, Holocene period, the first populations started a sedentary existence based on plant and animal domestication[10], setting up the civilization. This indicates a large period in which hominin's foraging techniques mirrored those of their primate ancestors. All human development can be described as a process that requires a *source* of energy and a converter that transform it in useful work. In the *animal* scenario (pre-Holocene period) the source is food, and the converter is muscles. Differently from animals, Sapiens specializes himself supporting hunting with the construction of spears, rods or new handles. The first society built was a community supplying energy (in the shape of food and materials to handle fire) to serve the activity to enlarge space or territory for hunting and gathering. Already at this phase, man experiences his first problem: the climate changes. As Nicolazzi says, already at this epoch, this is the greatest volatility factor in Sapiens' survival and living settlement. Even though in an opposite way of what we see today: his problem was the global cooling as a risk of extinction. The first specific extracorporeal source of energy Homo develops is the use of large animals as supplying food and the production of tools as the way to increase the useful hunting work you can get through the muscle-converter. For this the first tools that Homo develops are weapons. In primitive society the ways in which Homo manages to obtain the source-food dictate the conditions of his sociality. For this reason, people lived in groups often built on family ties, where mobility must be very wide to ensure continuity of access to the source. Meanwhile, the first techniques of food preservation

[9] Sally Reynolds & Edward Gallagher, *African Genesis: Perspectives on Hominin Evolution*, Cambridge (2012)

[10] Vaclav Smil, *Energy and civilization: a history*, The Mit PRESS (2018)

are also seen. The group then shares the "social culture of the focolare", because, differently from the other animals, they have fire.

Fire represents the first energy source in history. Learning how to handle it, and understanding its benefits, was the first challenge, in the energy topic, that the primitive man had to face. Thanks to its resilience, to bipedalism that leaves hands free, and to the sweating capacity that has allowed man to cover great distances, the human brain has grown[11]. We discover, thanks to the fire, many food benefits and our incredible ability to change the environment around us. Fire is also the starting point of technology, the tool that allows Sapiens to go beyond what our physical conformation allows.

We shall never know the earliest dates for the controlled use of fire for warmth and cooking: many subsequent events removed all relevant evidence in the open, and generations of later use were destroyed in occupied caves. There has been a receding of the earliest date for a well-tested use of controlled fire: some authors collocate it in around 250,000 years ago[12], and some others push it further, until 790,000 years ago[13]. Aside from warming and cooking, fire was also used as an engineering tool: as early as 164,000 years ago, modern humans were heat-treating stones to improve their flaking properties. It's also suggested that controlled vegetation burning goes back to 55,000 years ago[14].

The practice of hunting and the hearth around the fire are the first socialization practices of Homo Sapiens, who through these situations builds what appears to be a first society of human beings. The first impact of energy is just that. Fire and food as sources of energy represent the beginning of society.

The supply of energy is clearly only collective, which is certainly not a novelty in the animal world (hunting with the herd). But what distinguishes Homo from other living

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[11] Massimo Nicolazzi, *Elogio del Petrolio: energia e disuguaglianza dal mammut all'auto elettrica*, Feltrinelli Editore (2019)

[12] Johan Goudsblom, *Fire and Civilization*, MW Books (1992)

[13] Naama Goren-Inbar, *Evidence of Hominin Control of Fire at Gesher Benot Ya`aqov, Israel* (2004)

[14] Paul Mellars, *Why did modern human populations disperse from Africa ca. 60,000 years ago? A new model*, PNAS (2006)

beings is his ability to communicate. This is where we see the first common infrastructures (public goods) dedicated to hunting and fishing being built.

Foraging Societies

The most detailed collections of credible data indicate that the average population densities of modern foraging populations, representing a variety of natural environments and skills and techniques for the acquisition of food, varied over different magnitude ranges. Hunting was more lucrative in tropical or temperate grasslands or tropical forests, however, contrary to the popular belief of an abundance of animal species, tropical forests were an inferior habitat to be exploited by hunting. Most of the tropical forest animals are small arboreal folivores and fructivorous organisms that are involved and inaccessible in canopies of high tree and hunting them yields low energy return[15].

In comparison, grasslands and open forest provided excellent opportunities to gather and hunt. We store much less energy per unit area than a dense forest but a higher proportion of it comes in the form of easily collectable and highly nutritious seeds and fruits, or as compact patches of large starchy roots and tubers. High density of energy, as much as 25 MJ / kg, has made nuts special favorites[16].

The role of Hunting in the evolution of human societies is evident. Individual performance in hunting large animals with primitive weapons was unacceptably small, and feasible hunting groups had to maintain minimum cooperative sizes to monitor wounded animals, kill them, bring their meat, and then pool the profits. Food reflected the source of energy that the men and women were seeking; all pre-agricultural societies were omnivorous in this context. They had not the luxury of overlooking any food resource available. While foragers ate a wide variety of plant and animal species, their diets were typically dominated by only a few major foods. A preference between

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[15] Murdock, Bennet. (1967) *Recent Developments in Short Term Memory*

[16] Vaclav Smil, *Energy and civilization: a history*, The Mit PRESS (2018)

gatherers for seeds was unavoidable. Besides being fairly easy to harvest and store, seeds combine high energy content with relatively small shares of protein[17]. Wild grass seeds have as much food energy as grown grain, while nuts have as much or even higher energy density as around 80 per cent.

Yet energy factors alone cannot fully explain foraging behavior. If they were still dominant, then their universal strategy would have been optimal foraging, whereby gatherers and hunters seek to maximize their net energy gain by reducing the time and effort expended in foraging. Optimal foraging describes the preference for killing large, fatty rodents or gathering less nutritious plant parts that don't need to be processed rather than energy-dense nuts, which can be difficult to crack. Many foragers acted in ways that maximized their energy return, but often other existential imperatives operated against such behavior[18].

Agriculture

The Holocene period, the last then thousand years, the proper era of civilization, starts with the first two, historically and scientifically, primary and specific human activities: pastoralism and agriculture. They represent a leap in human evolution and, in particular, the first breakthrough in the impact of energy in civilization. In fact, they represent two indirect types of energy control: from animals, raised and collected in quantities, man obtained both food (chemical energy) and manpower (kinetic energy), while agriculture allows humans to arrange ample amounts of carbohydrates, fibers and vitamins (all chemicals). Thanks to agriculture (7000 BC), man learns to control the most important source of food: the seeds thus produced can be transported and stored easily. The possibility of growing food transforms nomadic hunter peoples into small, permanent groups of farmers, although hunting still remains one of the most important activities of the villages. The question we need to address is: why did these foragers start farming? Overwhelming evidence for the evolutionary nature of agricultural developments helps the possibilities to be narrowed down. The most convincing explanation of agricultural origins lies in the combination of population growth and environmental stress, in understanding that both natural and social forces

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[17] Johan Goudsblom, *Fire and Civilization*, MW Books (1992)

[18] L. Aiello, J.C.K. Wells, *Energetics and the evolution of the genus homo*, Annual Review of Anthropology

drive the transition to permanent crop production. Since the atmosphere was too cold and the rates of Co2 were too low during the late Paleolithic period and because these conditions changed with subsequent warming, some authors concluded that agriculture during Pleistocene was unlikely but inevitable during Holocene[19]. This claim is supported by the fact that cropping originated independently in at least seven places on three continents, between 10,000 and 50,000 years before the present[20]. Cultivation of crops is simply an attempt to ensure sufficient food supply, and so the roots of agriculture may be thoroughly clarified as yet another example of an energy imperative. The transition from foraging to agriculture driven only by energy, would be, certainly, a simplistic interpretation. None reasonable interpretation of the history of agriculture should ignore the many social benefits of farming. Orme (1977) states that food production may have been unimportant as an end in itself, but there is no question that there are vital social cofactors in both the development and the diffusion of agriculture. After all, early farming's net energy returns were often inferior, in the transition phase, to those of earlier or concurrent foraging activities[21]. Nevertheless, the evolution of agriculture goes hand in hand with the desire to increase land *productivity* in order to satisfy the greatest number of people. Despite the differences in agronomic practices between different societies, there is one huge point in common: all traditional agriculture shared the same sources of energy: solar energy exploitation (photosynthetic conversion of sun radiation), and muscle energy heightened by animals and gears. It is therefore clear: in the beginning, traditional farming was fully renewable[22]. The focal point, however, is that this full renewability was not synonymous with *sustainability*, a modern term often understood as unchanged natural environment.

Poor agronomic practices lowered soil fertility or caused excessive erosion or desertification, resulting in reduced yields and even the abandonment of cultivation[23].

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[19] Richerson, Peter & Boyd, Robert & Bettinger, Robert. (2001). *Was Agriculture Impossible during the Pleistocene but Mandatory during the Holocene? A Climate Change Hypothesis*.

[20] Armelagos, G.J. and Harper, K.N. (2005), *Genomics at the origins of agriculture*, part two. Evol. Anthropol. doi:10.1002/evan.20048

[21] Vaclav Smil, *Energy and civilization: a history*, The Mit PRESS (2018)

[22] Ibidem

[23] G. Boyle, *Renewable Energy*, Oxford University Press

Modern agriculture has advanced from extensive to intensive farming in most regions: its primary movers, humans and livestock, have remained unchanged for centuries, but traditional methods and labor organization have been transformed progressively. Consequently, both constancy and change mark the conventional farming evolution. The advancing intensification of farming maintained higher population densities, but it also required higher energy expenditure, not only for direct farming activities but also for such important supporting steps as digging wells or building irrigation canals. These developments, in effect, required more resources to produce a broader variety of better tools and simple machines powered by domestic animals or water and wind. So, technology to increase renewable energy sources became the key for agricultural growth.

Preindustrial Period

Many people in pre-industrial societies have had to spend their lives as peasants, working ways that have remained essentially unchanged for centuries in certain cultures. Yet the inconsistent food surpluses they created with the aid of a few simple tools and the exertion of their muscles and the draft of their animals were enough to sustain urban societies advancing complexity. For centuries, the prime movers and fuels remained unchanged but in many fascinating ways human innovation enhanced their efficiency. Some of those conversions gradually were so effective and so productive that they could energize the initial stages of modern industrialization. Two main roads brought higher outputs and improved efficiencies. The first was the multiplication of small powers, essentially a matter of superior organization, with the application of animate energies in particular. The second was technical innovation that introduced new energy conversions or increased the efficiencies of the processes established. The two methods also melded in reality.

One good example could be the Lady Isabella (Laxely Wheel), the England's largest iron overshot wheel, capable of delivering more than 400 kW, which is, more or less, the power equivalent to 600 strong horses[24].

Since the end of the Middle Ages, Western people have been seeking various ways to address energy issues: firstly, to expand existing supply chains and then seeking to

[24] To more consult, visit https://uh.edu/engines/epi2728.htm

build new ones. The first of these issues is evident in the continuity of medieval innovations (machines used for agriculture and the attempts to increase the productivity of the land,). But the decisive break occurs in a completely different way: the creation of new converter-machines, the steam engine. It plays, in the history of energy and man, a role of fundamental importance. Thanks to it, in fact, man's perception and interpretation of energy changes, firstly because it is the first "machine" that consumes the material from which it draws energy, unlike a windmill or water mill, that leaves the environment intact. Secondly, the new supply chains and the opportunities given by this discovery have required scientific knowledge of a level that is capable of implementing scientific and technical knowledge never seen before. Energy becomes, for the first time, a matter of investors, scholars, scientists and even workers, and it will become, from here on, a fundamental equilibrium for the development of the economy. Aagricultural rural development was not the same everywhere. Disparities of some European regions provoked the mobilization of the peasant workforce, using excess human resources and thus supporting the optimization of conventional converters' use. Throughout this way, in the seventeenth and eighteenth centuries, factories developed in the woods and along rivers started to develop in Europe, in areas that had remained outside of the territorial enhancement until then[25]. The mountainous areas exploited the possibilities provided by wood, running water and the quality of the soils, and by the end of the Middle Ages, they became the scene of rapid industrialization[26]. In reality, the pre-industrial era portrays itself as a vast exploitation of forest reserves, which in the European panorama took on the position that would have been assigned in the following years to coal mines or oil wells: an energy resource viewed as inexhaustible.

Of course, greater consumption is followed by increasing energy output, both by building new mills and by increasing the capacity of existing ones.[27]

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[25] Dudley Baines, *Emigration from Europe 1815-1930*, London Macmillan (1991)

[26] Massimo Nicolazzi, *Elogio del Petrolio: energia e disuguaglianza dal Mammut all'auto elettrica*, Feltrinelli (2019)

[27] For example, water mills were necessary for many activities, like grinding, and the wind mills enhanced this capacity.
The wind mills were more powerful than the water mills (maybe in a range that goes from 10 to 30 CV), but clearly they were dependent from a less regular energy.

The energy effects of protoindustrialization where contradictory. On the one hand, the main approach to the family caused a strong demographic impact due to the fact that having more children meant having more arms ready for work and, therefore, more money. On the other hand, was necessary to combine production with a market to avoid oversupply both in demand than in supply of workforces.

Patrick Verley, in his book "La Révolution industrielle", declares: "the demand could be the first explanation of industrialization; but supply factors are themselves creators; by increasing productivity they cause a lowering of prices, which widens the mass of consumers. It is therefore a threefold mutation: the use of machines; the use of more capitalistic production combinations; finally, the concentration of manpower in these factories."[28].

Furthermore, energy is fundamental in this period for the exchange activities to take place. In fact, trade moves products, and only thanks to means of transport such as sailing ships, which exploit an irregular but inexhaustible source like the wind, the trade of pre-industrialization can take place and expand.

The first energy transition: from timber to coal

The history of the Industrial Revolution starts from England, in the period between the 14th and 15th centuries. The demographic decline happening in those years led to an abandonment of the lands and an expansion of the forests. It is for this reason that in the 16th century deforestation began, again, massively and people were forced to turn to a new type of fuel: fossil coal. Coal was already known for some time, as well as its potential in thermal energy, but the fact that it was dirty and smelled, unlike wood, restrained the people of the time from its use. But then there was a situation favorable to the energy transition: timber was starting to run low[29], and its cost was growing twice as much as the price index[30]. A thermal alternative was needed, and coal was

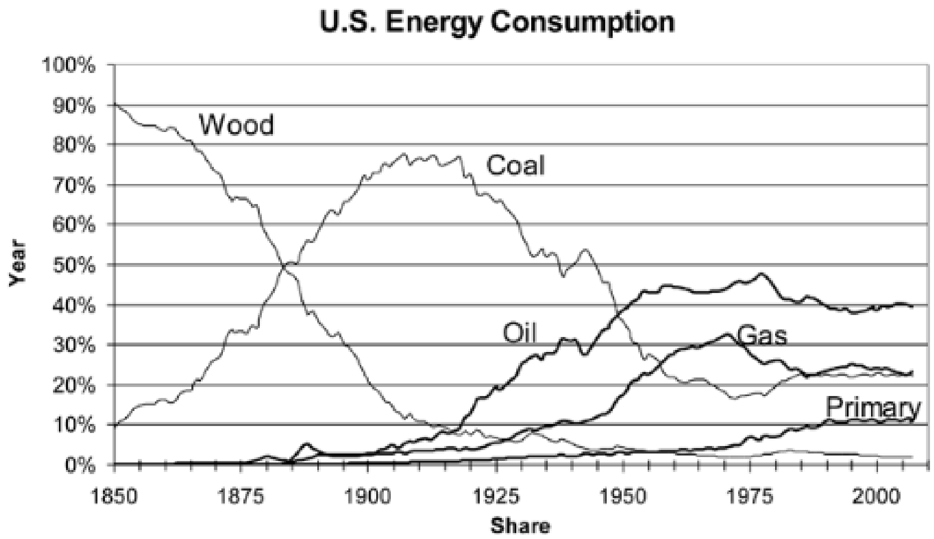
[28] Patrick Verley, La Révolution industrielle, Gallimard (1997)

[29] Nicolazzi declares that, perhaps, the idea that the scarcity of wood led to the first energy transition in history is a little too mechanical. In fact, to cover the energy needs of the eighteenth century, a forest area of 2% of English soil would have been enough, and if this was not available there was still the possibility of importing it, since the timber, in 1750, represented 50% of the tonnage of maritime imports from England.

[30] Wilkinson (1973)

identified as the perfect candidate. It cost less, had a higher energy density, and above all it was much more easily (and economically) transportable.

But we must remember that the first use of coal is still domestic. In fact, wood still plays a role of "industrial" thickness, due to the position it maintains as a building material. In addition, there is another thermal use of wood, which is applied in foundries, to give life to iron. To tell the truth, as Vaclav Smil explains, they use a material called charcoal, which is nothing more than a product of controlled combustion of wood that deprives it of its wet fraction. For coal, this is a big obstacle to overcome if it intends to take its place also in this dimension. It is in this space that technological progress is placed, and it is thanks to the new foundry techniques applied in the following century that the fossil thermal equalizes (or almost) the vegetable one[31]. It is from here that a new energy system based on coal, the steam engine and cotton is born. From this point on, it goes beyond the energy rationing of organic society, and begins, for the European economies, a path towards mass production.



Sources: Etemad and Luciani (1991), Schurr and Netschert (1960), Energy Information Administration (2008)

Vaclav Smil's reconstruction of global energy transitions, presents coal reaching 5% of the global market around 1840, 10% in 1855, 15% in 1865, 20% in 1870, 25% in 1875, the 33% in 1885, 40% in 1895, and 50% in 1900. As we can see, the transition took sixty years. The graph, on the other hand, shows how the growth of coal is

[31] David Landes, *The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor*, W.W. Norton (1998)

accompanied by a gradual and almost directly proportional fall in the use of wood. As we will see in the next paragraph, therefore, coal has responded positively to the drivers necessary to achieve an energy transition.

From the age of muscle to age of consumption: coal

Coal changes the way we relate to energy. As mentioned before, in fact, this is the first time that an energy source independent of photosynthesis is used. Coal is a "product" of the earth, which leaves us free on how and when to use it (and in what quantities, so it is a performance benefit), contrary to the renewable energies that led man to be dependent on something that he could not govern. With the fossil, the link between climate and the availability of energy sources is lost[32].

Coal is a low-cost thermal energy, but initially man's muscles and his work were still important in the production phase. Hydraulic energy, which depends on the mills, is still of fundamental importance, but has a big limit, which is revealed by the onset of the population increase. The power of the mills could not be increased in parallel with the increase in the population (supply constraints), nor could it make up for the insufficiency of water during periods of freezing or drought. This is why we turn to James Watt. In 1779, he was asked to repair a Newcomen machine (the first application of steam to an industrial process). In fact, the Scottish inventor thought up a completely new model of steam engine which reduced the quantity of coal by two third and, mainly, raised (with a valve called “Watt regulator”) productivity and efficiency of the engine. In fact, James Watt is called the very inventor of steam engine. He transformed the steam engine in a source of power economy avoidable. The power he gave to steam engine (intended as power of a machine on a time unit) give the name to the unit measure of power in energy: Watt. The *converter* energy sources, from natural renewable ones (sun and muscle), reinforced by tools and animal in agricultural epoch

[32] Massimo Nicolazzi, *Elogio del Petrolio: energia e disuguaglianza dal Mammut all’auto elettrica*, Feltrinelli (2019)

and by artificial tools in pre-industrial era, boosts up with the steam engine and the use of coal as fuel. The comparison with previous energy sources is unthinkable: coal has in fact allowed to dissociate the converter from its natural and limited source of energy, thus allowing not only an increase in production, but also a reduction in costs (cost benefit).

The situation rapidly evolved. Just as the sailing ship was the symbol of the English energy system at the time of the First Industrial Revolution, railways were making room in the European system. Therefore, the English model that applied coal as a source of productive energy for industry and maritime trade was joined by the European (and North American) model that used coal as an energy source for internal transport in the continent, obviously alongside other energies (timber and hydraulic energy). Rail and coal are an indissoluble union: in fact, the first railway lines were born to transport coal production. We can therefore say that coal spread thanks to the railway, which in turn enhanced coal, as it transformed it into a driving force[33].

Coal allows overcoming the limitation given by the soil, the unpredictability of renewable sources and the limits of man's muscles. Indeed, a single machine is capable of transforming energy as much as 10 or 11 energy converters.

This allows an energy production able to face the inexhaustible demand that had developed during the industrialization. The offer then moves from the place of production to the place of use. As we have mentioned, new forms of transport also correspond to the entry into the field of new forms of energy; it is no coincidence, in this sense, that many producers of gas, electricity and oil have also been energy transport companies at the same time. The attempt was to create an energy network, and the prototype of this network, not surprisingly, is the British network. In the nineteenth century the technical system of the sailing ship was joined by the steam engine system. The steamship required a greater investment than the sailing ship, but as early as 1850 this was cheaper as regards operating costs. Britain then exploited its

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[33] The changes that the railway and the coal made possible were very difficult to quantify. It is enough to think that in 1850 a train with fourteen wagons, taken from a 100 hp locomotive, could carry 90 tons of goods, which was equivalent to 18 stagecoaches with their respective coachmen and 144 horses. If we consider that the diligence took two and a half days to complete the Paris-Lille journey, while the train four hours and fifty ... the difference is immediately evident.

coal basins, from the Scottish valleys to those of South Wales. In 1913, Britain exported a third of the coal it produced[34].

As early as 1900, however, coal is no longer an exclusively British monopoly. Germany, in fact, in 1913 produced 190 million tons of coal and exported 45, as well as the United States, approximately[35]. The First World War then gave a considerable blow to Great Britain, which had to go down in export quantities. Obviously, Germany also suffered a blow, and it was the United States that took the opportunity. So, in a short time, coal was extracted in many parts of the world, and it was again believed to be dealing with an inexhaustible source of energy.

	Energy service demanded	**Supply Constraints**	**Cost advantages**	**Performance Benefits**
Coal	Transport and heating	Deforestation made impossible for timber to face the growth of demand	Coal is a low cost thermal energy	Coal is a "product" of the earth, which leaves us free on how and when to use it

Gas

"Man has no limits and when one day he realizes it, he will also be free here in this world."

This quote, from Giordano Bruno, could explain the special relationship between man and energy. Energy was used, in fact, to overcome the limits that Nature imposes on man. Industrialization could be intended as a step forward in defeating natural limits by the passage of energy sources towards the fossil fuels. Thanks to it, man had managed to defeat the distance, to control the energy and to overcome the limits given by his muscles. Coal is preceded, in mass uses as a new power technology, by a secondary form of energy derived from the distillation of coal: gas. The first use of a fossil resources was Kerosene, a liquid mixture of saturated hydrocarbons, derived from carbon or oil used on the first light bulbs instead of whale oil. Supplanted by electrical light bulbs, Kerosene was the original domestic use of coal before the breaking phase of motorization. Another form of indirect coal utilization is *natural gas*. Natural gas, in nature, is found together with oil and coal within the fields. It is

[34] Eric J. Hobswaum, George Rudè, *Rivoluzione Industriale e rivolta nelle campagne*, Res Gestae (2013)

[35] Maurizio Godart, *le fonti dell'energia: storie e prospettive*, De Agostini Libri (2014)

formed by a mixture of gaseous hydrocarbons, the main component of which is methane. Thanks to it, man exceeded the limit of light, available only during the day, and was able to lengthen and manage even the daily cycle. The first use of gas was to act as lighting, and it is in 1802 that in England we see its use in Watt's workshops.[36] The transport of a gaseous material was however conceivable only through watertight pipes. It is for this reason that the first distillation and storage devices were manufactured in 1830[37]. With the lighting gas a technical, spatial and financial reticular structure was organized. At the center there was no longer only the realization of profits, but the intelligent exploitation of a productive capital.

Between 1840 and 1850 gas lighting became popular in many American and European cities, to the point of changing citizens lifestyles. However, these advantages were limited to where natural gas naturally came to the surface, as the technologies for testing, production and transportation were not yet adequate. For a long time, as soon as it reached the surface, natural gas which came from oil wells was burned by a torch or released into the atmosphere. Thus, several billion cubic meters of natural gas went up in smoke. Lightning use of gas was overcome by the invention of electrical light bulb by Thomas Alva Edison (1847-1931). So was stopped one of the greatest resource wastes in history, an improper use of gas and a significant environmental harm. Natural gas will have a revenge at the beginning of our century becoming the second power source replacing carbon.

	Energy Service Demanded	**Supply Contraints**	**Cost Advantages**	**Performance Benefit**
Gas	Light	Light was available only during the day, because there were not a system of illumination	Intelligent exploitation of productive capital	Thanks to it, man exceeded the limit of light

The first usage of Oil

In 1859 Edwin Drake, also known as The Colonel", in Titusville, Pennsylvania, started a series of trepanations which resulted in the first industrial exploitation of oil[38]. Until

[36] https://magazine.eon-energia.com/in-evidenza/illuminazione-casa-storia-della-luce/

[37] Ibidem

[38] Marco Magrini, il Petrolio ha 150 anni e qualche ruga, Il Sole 24 Ore (2009)

then, oil was appreciated, as said, only as a fuel for lighting and heat. In its first years of life, oil presented itself as a concurrent and complementary source to gas, limited to the use of lighting. But it took a few years to understand that oil was perfect for transportation. It is in fact the fossil with higher energy density and is liquid, therefore more easily transportable than gas.

In Europe we discover oil thanks to the First World War. At the end of this, in fact, we see the first uses of aerial bombing and tanks, supplied almost exclusively with American oil. It is easy to understand that without oil, the war would have been lost. The history of oil then radically changes thanks to Henry Ford. His invention, the Ford: Model T car, was the first car that became utilitarian for price.

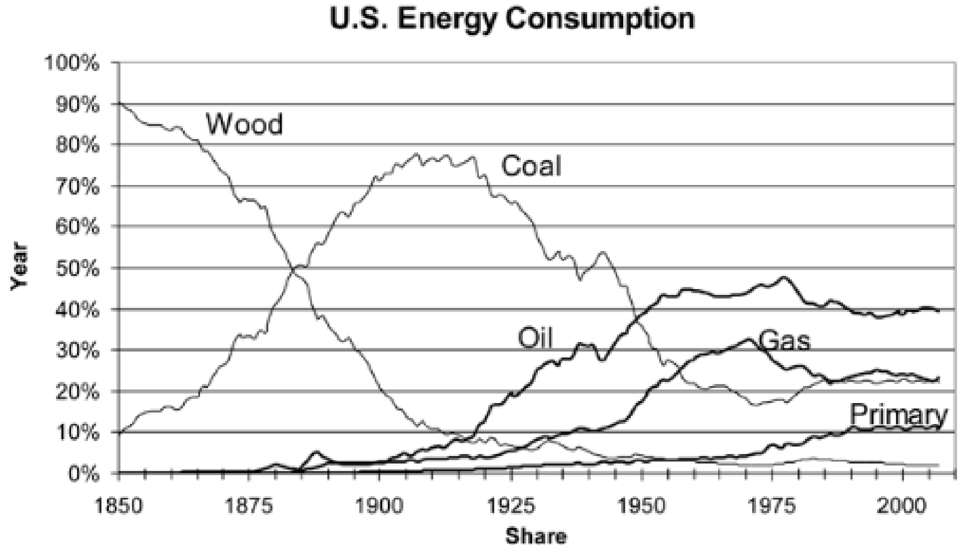
To fill up the Ford Model T, you need gasoline, which represents a light fraction of crude oil. At the time, distillation obtained an 11% gasoline yield from the best crude, which risked being insufficient. But when, in 1913, for the first time the use of oil as fuel exceeds that of lighting, William Burton, director of the Whiting refinery, intervenes[39]. He works on a process called thermal cracking[40], which in simple terms makes more gasoline from crude oil. Already in 1921, the gasoline yield reaches 25% and later, with catalytic cracking, even 50%. In 1919, oil was proclaimed "the new monarch of motion"[41].

	Energy Service Demanded	**Supply Contraints**	**Cost Advantages**	**Performance Benefit**
Oil	Transportation	Coal was not easy to transport, because it was heavy and expensive, and Gas needed a system of pipelines.	Labour costs of oil are cheaper than coal and gas	Speed, Time, higher energy density, production of gasoline, which is a light fraction of crude oil. possibility of extending the benefits of energy even farther than the physical place of proximity from the source.

[39] To consult, visit http://marcocapponi.blogspot.com/2016/08/breve-storia-del-cracking.html

[40] thermal cracking consists in breaking the molecular structure of the combinations of crude oil with more carbon atoms, in order to have "lighter" molecules as a result.

[41] Reild Sayers Mcbeth, *Oil: the new monarch of motion; an unbiased presentation of the whole oil industry*, Markets Publishing Corp. New York (1919)

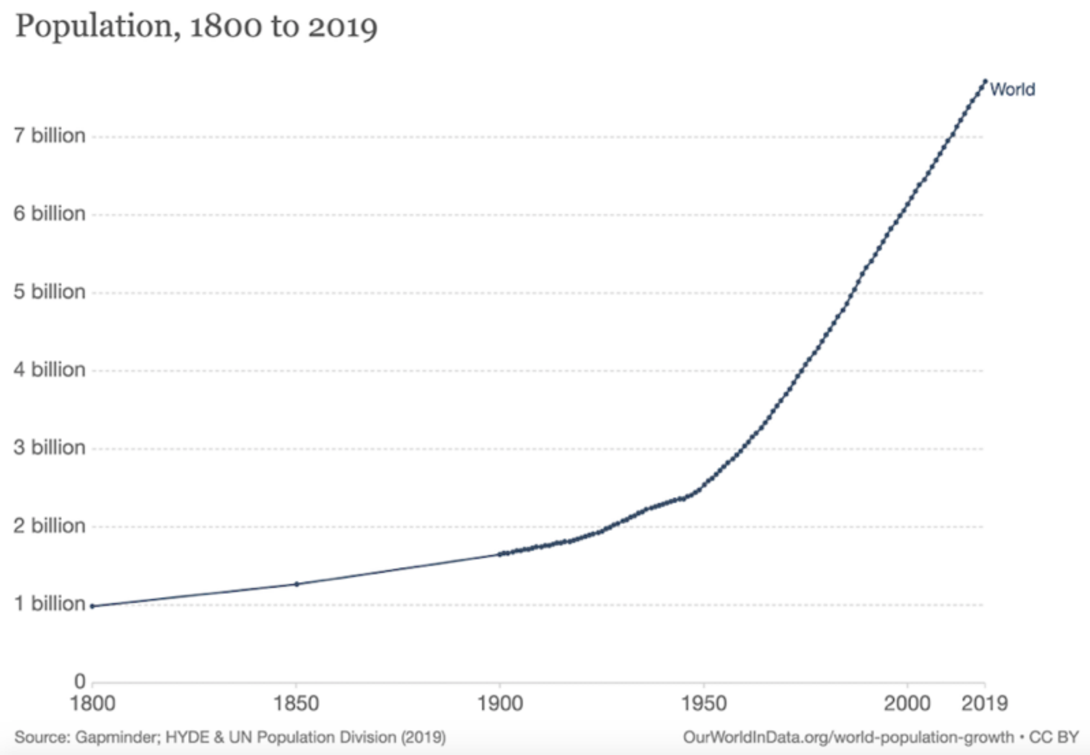


Sources: Etemad and Luciani (1991), Schurr and Netschert (1960), Energy Information Administration (2008)

If we take the graph of energy consumption in the United States again, we can see that the intervals required for oil to replace coal, with 5% of the global supply reached in 1915, are virtually identical to those that served coal to replace wood. The essential difference with coal is that oil never reached 70%, but stopped at 40%, and then (very slowly) began to decrease.

XX Century: Oil on podium

What oil, and all the hydrocarbons, has represented for the economy is of immeasurable importance. First of all, from the demographic point of view: it took 200,000 years to reach the one billion people on earth (in 1804), but in 1927 we were already 2 billion. Finally, in 1960 we reached 3 billion.



The fossil-economy binomial becomes indissoluble, and we therefore enter the era of consumption.

In particular, the automobile led to a real market revolution, which in turn caused a gap between the price of petrol and other petroleum derivatives. The century was marked by the rush to the fields, which became of fundamental importance for the countries, and the geopolitical implications were not long in coming.

The first issues appeared in the United States, having been the country that had benefited most from oil in the previous century. In fact, in 1912 there was the decision of the United States Antitrust against the Standard Oil Company, which led to the dismemberment of the large company into 33 dismembered companies. The question arose from the fact that oil took a short time to enter the political sphere. Edgar Faure, in 1938, wrote: "It is difficult for a body developed as a trust, albeit made up of private interests, to remain limited to a pure commercial activity. It will naturally be led to overflow from its role, thus starting to deal with political issues. "

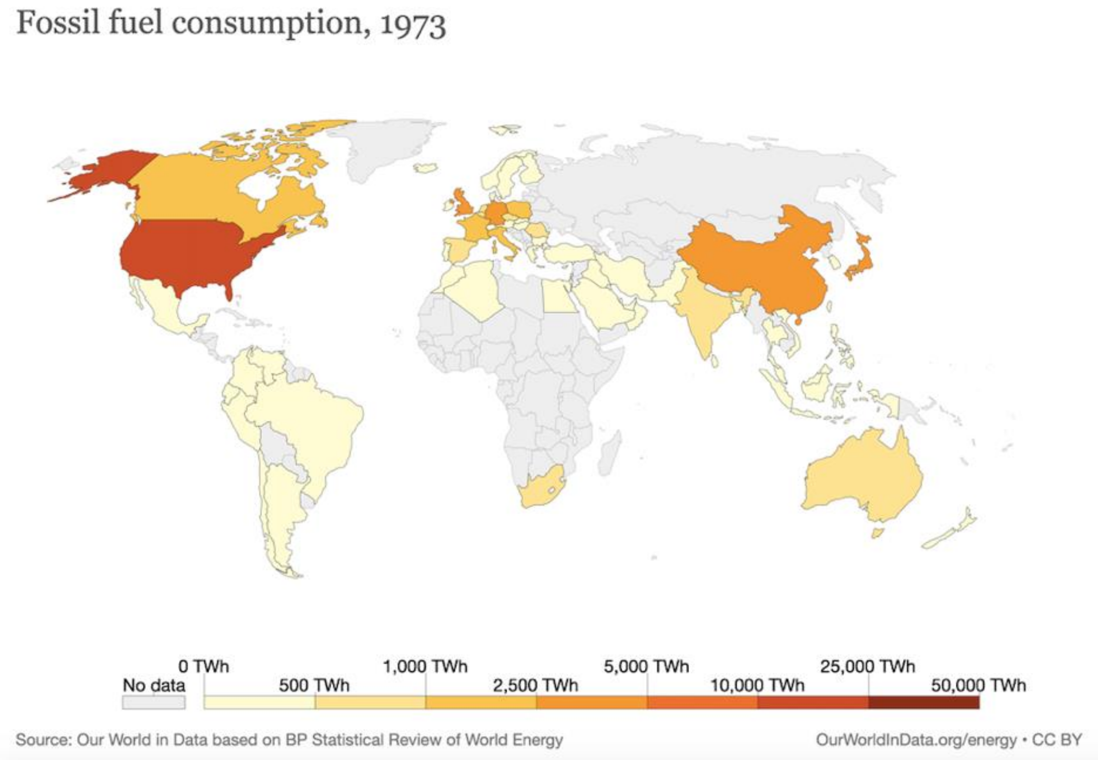
The same question, which posed the role of the state in oil hegemony as a question, also arose in England for the Anglo-Persian company called the Oil Company. The British Admiralty had decided to replace coal with diesel in warships and Winston Churchill, as a result, began to worry about the oil supply. Therefore, the British state had financed this company, to make it independent in the supply of its own fuel. The biggest problem England was trying to avoid was having to resort to the United States to refuel the fleet in the event of a conflict.

Until 1928 there was any world agreement on oil production, and this started a war on the market.

In fact, in 1925 the opening of new fields in Venezuela and Mexico generates an overabundance of oil such that about a third of the world production cannot find buyers. From here begins a price war between the two most important companies in the world: The Standard Oil Company and the Royal Dutch oil company, Shell. The war is devastating, as Shell unleashes a price war aimed at penalizing Standard and forcing it to buy in the Soviet market, while Standard responds by lowering its prices on the British market. The two, to avoid the collapse of the market, are forced to an agreement.

The Achnacarry Agreements of 1928 ended the oil war by setting prices for the next forty years. The agreement was signed by the 3 major oil companies, to which 4 others were added. Thus, the cartel of the "seven sisters" was born. This cartel dominated the oil market until the 1960s, being able to set prices and controlling 3 quarters of the world's refining. Only in the 1960s did the emergence of new companies lead to a race to the bottom that called the cartel's dominance into question. This race to the bottom undermined not only the relations between the companies that were part of it, but also those between the companies and the producing states. After two price decreases, which took place in 1958 and 1960, Standard unilaterally decided to decrease the quota paid to the producing States, which responded in 1960 with the creation of OPEC.

1973: the oil crisis and the adaptation of the dominant networks



In the early 1970s, the idea began to spread that oil overcapacity was dwindling. Due to the growing increase in consumption, some are starting to think that the quantities of oil may not be sufficient. It represented 40% of world energy consumption, and the United States produced only 20%. For this reason, in 1971 the United States decided to remove all legal limits on production from oil wells. Unfortunately, the idea does not give the desired results, because if in 1970 the United States had imported the equivalent of 4.4 million barrels per day, in 1973 it had already become 6,256,000[42]. The US administration started to worry, as they know that "importing means having to depend" on another country. The most active in this regard is James Akins, at the time director of the Fuels and Energy office of the State Department. Among other things, one of Akins' greatest statements at the time was that demand could only yield to supply, discounting an inexorable price increase. The oil reserves were running out and the Arab countries therefore had all the conditions to use it as a political weapon. In this case, it did not matter whether the oil shortage was real, what mattered most was the perception.

[42] Massimo Nicolazzi (2009). *Il prezzo del petrolio*. Milano: Boroli

The 1973-74 crisis is the result of the long period of cheap energy of the previous century. The existence of the seven sisters and their capillary control of the market (92% of reserves and 88% of production) had lowered the reference prices of crude oil and reduced the amount due to exporting countries[43]. Oil had by now supplanted all forms of energy, and even electricity producers are starting to equip themselves with oil-fired power plants. In terms of numbers, oil consumption went from 0.4 billion toe in 1950 to 2.6 billion in 1973[44]. But the undisputed domination of oil hid pitfalls, which would have exploded in the early 1970s, due to the decision of large companies not to invest in the Middle East, to keep prices stable and thus avoid competition.

Furthermore, since the early 1970s, the enormous growth of oil has to cope with a relative rigidity of supply. The United States is starting to have difficulty in procuring, and companies begin to launch real campaigns against the dangers of their decline and the increase in imports. On April 13, 1973, Richard Nixon, in his message on energy, approved the increase in American oil prices to encourage investment and OPEC, which in thirteen years had never raised the prices of crude oil, decided to quadruple it. In 1973, however, the bubble began to burst: oil consumption continues to grow enormously in industrialized countries, reserves do not have sufficient security to meet demand, and as if that were not enough the Middle East, holder of the main world reserves, enters in a period of instability.

In 1972 the price of oil was about $ 3 a barrel, and by the end of 1972 it had quadrupled to nearly $ 12. In the period of the beginning of the Yom Kippur war, several Arab nationals, all allies of the United States, imposed an embargo on the US and the Netherlands for their support to Israel, cutting production of 5 million barrels/day (b/d); 1 million barrels were injected by other countries. This means that production is cut by 4 million b/d, 7% of the total.

Even if the embargo lasted only two months and the reduction in supply was limited overall, with an increase of 400 percent in six months the extreme sensitivity of prices to supply shortages became manifest to the whole world. Once the embargo was lifted the theory would suggest that prices return to their previous level. However, these remained high: from 1974 to 1978 world crude oil prices fluctuated from $ 11.5 to $ 13.5 per barrel.

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[43] Maurizio Godart, *le fonti dell'energia: storie e prospettive*, De Agostini Libri (2014)

[44] Ibidem

The high costs of oil therefore push countries to turn to new energy sources, and for the first time in its history, oil is questioned.

After 1973: can Oil run out?

In 1973 we begin to understand that energy is a condition of growth. Before this date, growth was believed to depend on other factors, because energy was seen as an independent variable. From the Arab embargo we discover that this is not true, since oil can really run out and, even if this is not true, we cannot be sure that tomorrow the price will not rise suddenly and even by a lot. The immediate reaction was one of panic; it is from here that we begin to see the first energy saving programs, such as walking Sundays or lowering the heating. What happened in those years then with Watergate, brought even more uncertainty in the minds of the population and was the first lesson (the second came in 2008) on how much the mass perception could be a stronger price index than many other factors.

In the oil field, demand exceeds supply, in reaction to the reduction of the second. The price, consequently, goes up a lot.

The world economy enters a phase of recession, which will reappear in 1980. In the United States, oil spending in the early 1970s was around 4.5% of gross domestic product; and the total for energy corresponded to 8% of GDP. In 1974 we exceeded 6 and 10%. In 1981, on the other hand, the numbers stood at 8 and 13.7%[45].

Although many economists today argue that this recession was not caused only by oil shocks, considering the perception as a determining factor for the trend of the supply / demand balance, the feeling in those years is that oil (its lack) is capable of bringing the economy to its knees. Prevention becomes the motto, if by prevention we mean a situation in which what can be done is done with oil, never without it. The years of oil storage began, which reached its peak between 1981 and 1985, after the Energy Policy and Conservation Act of 1975 which authorizes the storage of a strategic reserve. Together with the storage it follows the energy saving policy, which for example in Japan is enormously applied. The last practice is diversification. As we said earlier, these are the years in which oil is first questioned. Old coal is reconsidered, gas is

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[45] Morris Albert Adelman (1993). *The economics of petroleum supply : papers 1962-1993*. Cambridge: Mit

discovered, the French and Japanese nuclear programs are set in motion; also, in the early 1980s, the photovoltaic investments began. Finally, and it is one of the most important processes, there is the cut of what is possible in the industrial use of energy.

The United States, which we take as a model at this point of the thesis as the main oil consumers of those years, associated, as we have said, the abundance of oil with independence, but when the paradigm changed after 1973, the market too around oil was totally revolutionized. Nicolazzi explains that the market, in fact, has become global, and the destination of the oil is no longer indicated by the chancelleries, but by the refineries themselves. This concept can be explained through the very characteristics of the crude oil, which differ in weight, which we indicate with the API grade[46], and in "acidity". Each refinery buys crude oils that are optimal for the characteristics of the plant itself and this has radically changed the market system around oil. Today, for example, the United States produces so much oil that it can almost be defined independent, yet now it exports and imports it in large quantities, simply because due to its characteristics it is possible that the United States would be better off importing a part of Saudi oil rather than using it. which is produced at home[47]. Furthermore, it must be considered that each refinery is built not only on the basis of certain inputs, but also on certain outputs, the possibility of exchanging refining products with other countries has also been introduced[48].

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[46] There are two classification types, based on the crude oil characteristics. These two characteristics are the mass fractional density and the sulfur content present.

Oil sulfur is very dangerous because it decreases the crude oil's energy content, so it removes the "useful" hydrocarbon molecules. In addition, sulfur, with its derivatives, corrodes the metal pipes and tanks used in the oil industry. The first classification was introduced by the American Petroleum Institute (API) and is a measuring unit that, under standard conditions, indicates the particular weight of crude oil as regards water. Use the relation ° API = (141.5 / SG)-131.5 where SG is the norm of gravity and is measured at 60 ° F or 15.5 ° C, and SG = crude density at 60 ° F / density water at 60 ° F.

So 40 ° API represents a mixture which has a specific gravity of 0.825. In comparison, a mixture with a fixed gravity of 1.014 would have 8 ° API instead.

[47] Just to give the numbers, the United States imported 9.14 million b/d of crude oil and other hydrocarbons in 2019. Crude oil imports of about 6.80 MMb / d accounted for about 74% of U.S. total gross petroleum imports in 2019, and non-crude oil petroleum accounted for about 26% of U.S. total gross petroleum imports.

The exports are 8.47 MMb / d of crude oil and other hydrocarbons to about 190 countries. Crude oil exports of about 2.98 MMb / d accounted for 35% of total U.S. gross petroleum exports in 2019. The resulting total net petroleum imports (imports minus exports) were about 0.67 MMb / d in 2019. This data was provided by the Us Energy Information and Administration.

[48] "It is independence that breeds interdependence." Massimo Nicolazzi

Oil and Gas: independence or interdependence?

The great problem that the world had to face after the embargo was not only the problem of the alleged scarcity of resources, but also the fact that the ban imposed on the United States and the Netherlands had made clear the power, even political, that the Arab countries had thanks to oil. It should be emphasized that the oil embargos of recent decades (Iran and Iraq among all) have been from consuming countries to producing countries. If we consider the current situation, with Venezuela producing less than 1 million b / d[49] and Libya in a rather uncertain production phase[50], and add it to Iran sidelined on the market, we understand that the dynamics of interdependence in the scenario of oil have evolved, making situations like that of post 1973 at least more difficult to imagine today.

The discourse on gas, however, is different. The first major issue to consider with gas is the infrastructure that needs to be built around it. Trivially, while the price of oil does not depend on transport costs, a pipe connecting the arrival market to the gas field is, today, indispensable. Although there is LNG (Liquefied Natural Gas) that is transported by ships, this method of transporting the commercialized gas occupies only 30% of the gas market. This means that we are far from that Single Market situation that globalization and the Nymex[51] listing have made possible for oil. Then there is the considerable cost of keeping the gas cold and transporting it by ship.

This situation, adding the fact that there is a pipeline supplier, Russia, in a dominant position that alone is worth 40% of imports, could suggest that if a "1973 paradigm", as Nicolazzi defines it, is difficult to imagine for oil, however, it is still possible in the

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[49] Mir, R. and a (2020). *Petrolio, Maduro dichiara l'emergenza. E ora?* [online] Formiche.net. Available at: https://formiche.net/2020/02/venezuela-emergenza-petrolifera/ [Accessed 6 Sep. 2020].

[50] Alessandro Sperandio (2020). *Petrolio e gas, tutte le ultime novità sulla Libia*. [online] Energia Oltre. Available at: https://energiaoltre.it/petrolio-e-gas-tutte-le-ultime-novita-sulla-libia/ [Accessed 6 Sep. 2020].

[51] The New York Mercantile Exchange is a commodity futures exchange owned and operated by CME Group of Chicago.

gas scenario. But the difference is substantial: in Europe, the price formation mechanism for natural gas is transparent. This means that, at least on a regional European basis, a Single Gas Market exists and LNG, which allows access to gas without restriction of destination, guarantees us a certain competitiveness.

What we learn from history

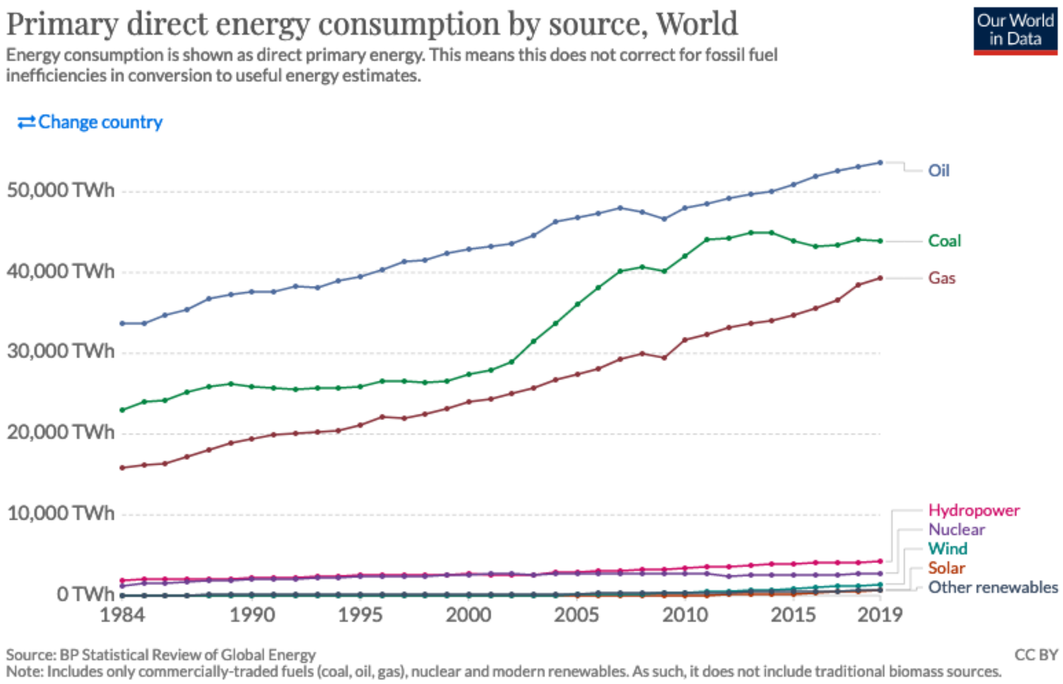
The history of energy tells us how an energy transition occurs and under which conditions it responds.

The most important element to consider is the evolutionary nature of energy transitions. As we have seen by analyzing the history of energy sources, established sources and prime movers can be surprisingly persistent, and new techniques or new sources can only become dominant after a long period of time. The reason for this is explained by the drivers of an energy transition that we mentioned before. It must therefore be assumed that, as long as the established sources or prime movers are present in an economic way, in terms of costs, abundant, in terms of quantity, and reliable, in terms of its use, their successors, even if they have attributes in certain higher realms, will advance very slowly. An example of this can be the Roman water mill, first used in the first century BCE, but which only became popular 500 years later.

The amount of time required is easily explained: before a source can be defined competitive on the market, a long period of research, experimentation and capital formation is needed.

The similar progress, in terms of global energy supply, that we saw with coal, oil and gas is another remarkable element to consider, because these three fuels require different production, distribution and conversion techniques. So, why the pace of these transitions is so similar? The two most important factors that explains these similarities are the prerequisites for enormous infrastructural investment and the inertia of massively embedded energy systems.

Although the pace of coal, oil, and gas transitions is not alone an indicator that can tell us whether the transition to 2050, envisaged by the Green Deal, should follow the same path, there is no element to make us think that this will not happen also for the transition to the new renewable sources. In 2015, the two major renewable energies for the electricity system, sun and wind, were still under 2% of the world's primary energy supply and in 2019 the level was still pretty low.



There is also another element to consider: the current structures of energy production, distribution and transformation are of an enormously higher dimension and are placed in a more complicated market than in the past; This means that there is greater resistance to any drastic transformation[52]. However, to better understand how an energy transition takes place, we must understand that it strictly depends also on the level of technology available at the given moment. Taking the transition to coal as an example. It took a very long time and was delayed by the decline in the quality of energy services that resulted immediately from their use as regards wood[53]. A century after Watt 's invention, the contribution of coal to energy consumption in English manufacturing in the mid-nineteenth century remained minimal relative to that of hydraulic and biological (human / animal) oil. The same was in America, whose wood consumption was still satisfied by more than 90 percent in 1850[54].

So, if we take technology as the driving force behind any transition, we understand that the transition is determined not so much by abundance or scarcity of the current

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[52] This is what should be called "Path Dependency", in the sense that, owing to technological, infrastructural, institutional and behavioral lock-ins, energy systems are subject to strong and long-lived path dependency.

[53] When we think about energetic transition today, we should keep it in mind

[54] Vaclav Smil, *Energy and civilization: a history*, The Mit PRESS (2018)

source of energy, nor by the costs it requires, but by technology. Coal, and consequently oil, have entered the energy market forcefully as they are better suited to respond to the challenges that were imposed by technological advances at the time.

Therefore, if the penetration of coal, and consequently of oil, was connected to the confirmation of new technological paradigms, the same cannot be said – as we will see in the following chapters - for the other sources that have since the middle of the last century developed themselves on the energy scene: natural gas, nuclear power, and mostly, emerging renewables (excluding traditional hydroelectric plants).

2ND CHAPTER: CLIMATE AND ENERGY

The Environmental Issue

Awareness of the environmental issue began in the mid-19th century, precisely in 1866 when Ernst Haeckel coined the term "ecology"[55]. Nature, until then seen as something that man had to learn to govern, becomes something to be protected precisely from human intervention.

The first important study on the correlation between man and climate comes in 1864, by George Perkins Marsh with his work "Man and nature: Or physical geography as modified by human activity". It, starting from Roman times, analyzes the changes produced on the nature by man, focusing above all on the massive deforestation due to the demand for wood. Marsh's considerations prompted the United States government in 1872 to establish the world's first national park, Yellowstone Park, with an extension of 8,960 square kilometers.

While in America there was concern about deforestation and the environmental damage caused by the combustion of wood, in Europe there was a move towards industrialization and the use of coal. Due to its widespread use, the Smoke Nuisance Abatement of 1853 and the Public Health of 1875 were adopted in England, which however did not change the situation regarding the massive use of this resource[56].

In the same years, beginning with the pioneering contributions of Thomas Robert Malthus and John Stuart Mill (1806-1873), the economy took an interest in the issue of natural resources. The first movements of opinion on the issue of the environment were founded in America at the beginning of the twentieth century after the speech to the nation of the President Theodore Roosevelt, where he made the preservation of forests and wildlife one of the key points of his program and, above all, by Gifford Pinchot, considered the father of the environmental movement, who would make a drastic change in the organization and public management of the American forest

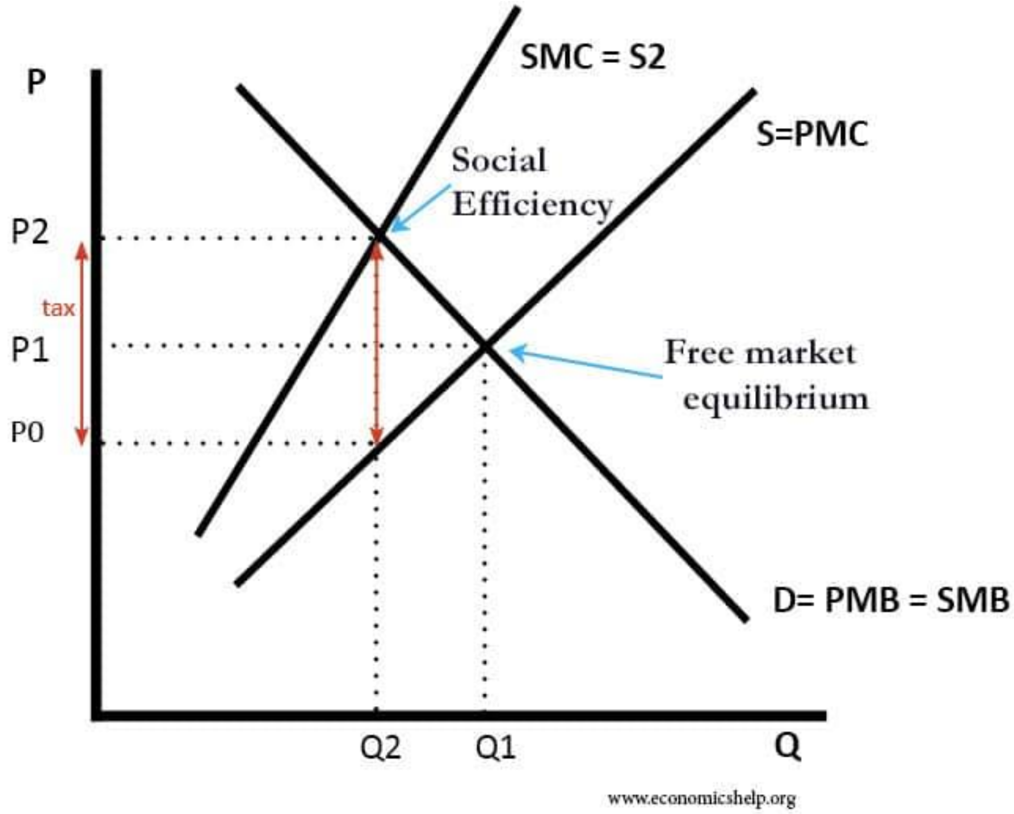
[55] Ernst Haeckel (1834–1919), a German zoologist and Charles Darwin's follower, planned to create a branch of biology called "oecologia," which would deal explicitly with how organisms respond to their "external world." With the increasing environmental consciousness in the latter half of the twentieth century, the word, which translates as "ecology," has since come into popular use well beyond.

[56] Alberto Clô, *Energia e clima. L'altra faccia della medaglia*, Il Mulino (2017)

resources at the helm of the new Forest Service, taking national parks from 60 to 150 to 172 million acres.

For a long time, the environmental problem remained the domain of philosophers, but it was in 1960 that a "counter-current" approach was introduced in relation to the heavy use of oil and coal implemented during those years. Ronald Coase, Nobel laureate, in fact, opens a new perspective to the methods hitherto proposed to address these externalities, substantially the "Pigouvian taxes" to internalize them[57].

A Pigouvian tax is a tax on a benefit that generates negative externalities. This is aimed at making the price of the product equal to the social marginal cost and at producing a more economically productive distribution of capital/resources.



- In a free market, the equilibrium will be at Q1 – where D=S. At this output, there is social inefficiency.
- At Q1, the social marginal cost (SMC) is greater than the social marginal benefit (SMB) – there is overconsumption.
- If the government place a tax equal to the external marginal cost, then consumers will be paying the full social marginal cost. (SMC)

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[57] Arthur Pigou, *The Economics of Welfare, Macmillan and Co.,* (1920)

- This will reduce the demand from Q1 to Q2 and this will be socially efficient because at Q2 (SMC=SMB)[58]

This is named after Arthur Pigou, the philosopher who established the idea of externalities in the 1920s.

Coase proposed the development of a free-trade system between the parties, on the basis of a comparison between the respective costs / benefits caused by the operation. This would achieve an optimal balance in resource allocation and social welfare irrespective of the legal obligations defined by law. The State should grant "property rights" to establish and operate a market, particularly for the use of any resource commonly owned, so as to attach a value to it and the its waste. Goods, such as the atmosphere or the oceans, are unrivaled in use and almost difficult to render excludable[59]. Hence, it's difficult to price and re-enter the private property domain, even because their offer's marginal cost is zero. They are common goods with the right to use each and every one without paying anything.

Since no one possesses them, no one cares about them, even though their destruction is to everyone's disadvantage[60]. In this context, they can be included in the public goods category, constituting a classic case of externality. Such assets are inadequately given without the interference of a governmental authority because each actor is opportunistically allowed to take advantage of the actions of others without bearing the responsibility.

From this point starts the re-emergence of the conviction that natural resources put a limit on growth that can be said to be sustainable: capable of satisfying our needs, according to the canonical definition, without preventing future generations from satisfying their own by being able to provide our own opportunities[61]. Therefore, growth, it concludes, will have to be reduced before it prevents or even reverses by converting to the ideology of "good degrowth" à la Latouche or of "frugal abundance"

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[58] Tejvan Pettinger (2018). *Pigovian Tax | Economics Help*. [online] Economicshelp.org. Available at: https://www.economicshelp.org/blog/glossary/pigovian-tax/.

[59] Ostrom, E., *Governing the Commons: The Evolution of Institutions for Collective Action* (Canto Classics). Cambridge: Cambridge University Press. (2015)

[60] Subhes Bhattacharyya, *Energy Economics, Concepts, Issues, Markets and Governance*, Springer (2011)

[61] Consult https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

in which, in return for the renunciation of the superfluous that makes life superfluous, new models of life and values should be rediscovered, such as the re-evaluation of friendship and conviviality, the preparation of life.

It is clear how positions of this kind reflect the inability to maintain the living conditions that were present at the time, even if it is rather difficult to argue that in the West this position had an empirical consistency or that, in any case, did not require lengthy processes. The extremization of this position was already present in the first environmental movements, such as Deep Ecology in the seventies, which at the motto of Earth First! recognized rights to animals, climate and rock formations, even higher than those of man, that was condemned whenever it interfered with the processes of nature, whatever they were. The fact that such an extreme position was created, flanked by other more moderate but still radical movements, meant that the environmental question was becoming important not only from a social point of view, but above all from a political and industrial point of view.

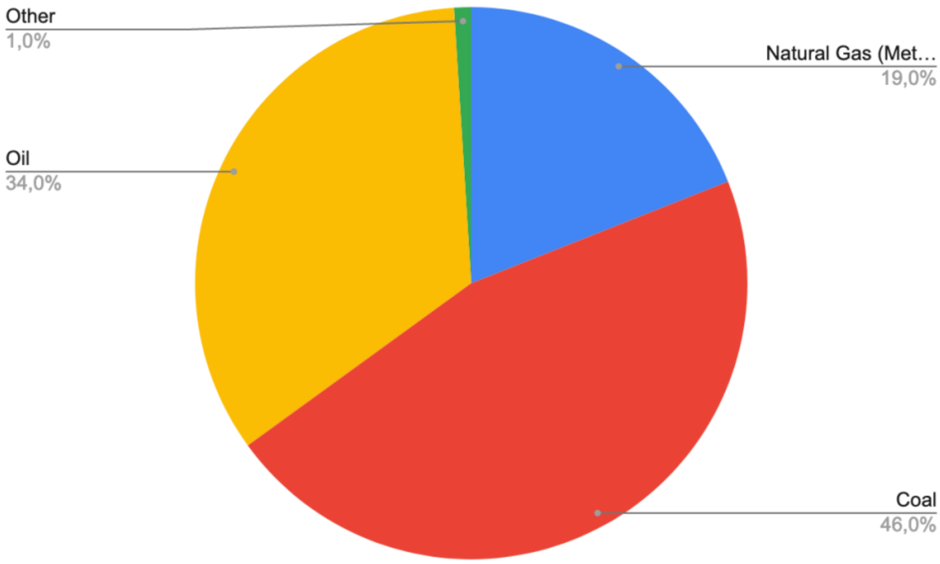
Global Warming

The various environmentalist souls that had formed over the years managed to converge on one point: the condemnation of fossil fuels, because they were held to be the main culprits of global warming caused by carbon dioxide emissions.

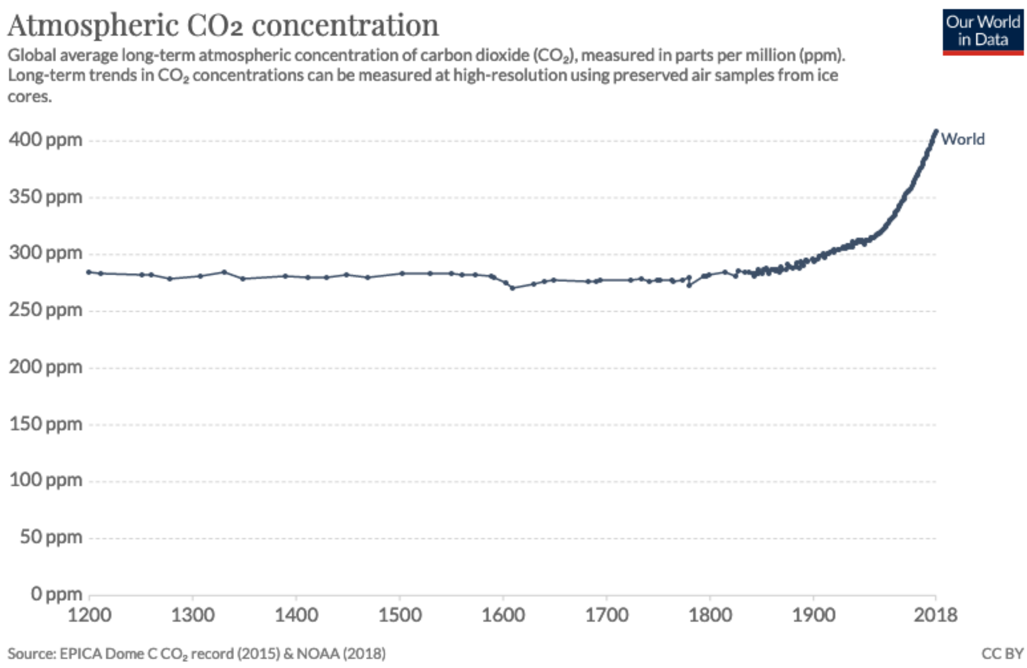
The greenhouse effect is responsible for global warming. Thanks to it, Earth's atmosphere is life-hospitable, and the average temperature is about 15 ° C. If no greenhouse effect occurred, our planet's surface temperature would be -15 ° C, much lower than the freezing point of water, and the living conditions would be prohibitive for most living organisms.

The greenhouse effect is caused by the fact that the solar radiation that falls on earth is partly radiated back into space in the form of infrared rays (the component of radiation associated with heat and thermal emission) which, absorbed by greenhouse gas molecules- carbon dioxide (CO_2, water vapor (H_2O) methane (CH_4) and others- present in the atmosphere, are stored on the surface of the planet, raising the earth's temperature. The greater the growth of greenhouse gas emissions (flux), the greater the concentration of greenhouse gas emissions in the atmosphere (stock), the greater the amount of heat stored on earth and thus the higher the temperature thereof[62].

About half of the carbon dioxide emissions in the energy sector come from the use of coal, followed by oil for a third and natural gas for a fifth.



IEA [2016a].



[62] Alberto Clô, *Energia e clima. L'altra faccia della medaglia*, Il Mulino (2017)

The whole scientific world agrees that the amount of Co2 present in the atmosphere has increased (from 277 ppm in the pre-industrial era to more than 400 today) and that the extraction and refining of oil, carbon and gas are partly responsible. For many this increase of greenhouse gases is causing an inedited climate change and a progressive raising of average temperatures of the Earth, with catastrophic effects on the long period. Even if there are scientists that dispute the catastrophic point of view on climate changes and that are skeptics on the overestimation of CO_2 effects, the position, more commonly accepted also by States, is the role of the Anthropogenic emissions in the global warming. It argues that warming trend will lead to an increase, of CO_2 molecules in the atmosphere of up to 600 ppm, which will cause an increase in temperature of up to 6 ° C. This increase could cause serious and irreversible ecological alterations (such as, for example, rise in sea levels).

Beyond the position that can be taken on the issue of global warming, we must also know that climate science has not contributed much to dispel doubts, as stated by the climatologist Kevin Treberth of MIT, in the article "More knowledge, less certainty".

Nevertheless, given the numerous concerns, it is incontrovertible that a widespread feeling about the need not to wait to intervene in the eventual precipitation of events has matured worldwide, in government officials, international organizations, public opinion-overcoming the disinterest that has arisen so far[63]. Perhaps it may be too late, but we try to obey the 'principle of precaution' introduced in the Treaty of Amsterdam of 1997, which requires law enforcement action when there is even a possibility of 'severe or permanent' environmental harm, often in the absence of utter scientific certainty about the specific hazards. Article 174, adopting art. 130 of the Maastricht Treaty, states: "Environmental Community policy [...] is based on the principles of precaution and preventive action on the principle of correction [...] of the damage caused to the environment, as well as on the "polluter pays" principle.

There are two lines of action indicated by the scientific community and accepted by the States: the first is *mitigation*, aimed at intervening on the causes from which climate change originates, thus reducing greenhouse gas emissions through the replacement of fossil sources and the reduction of consumption. The second line is *adaptation*, aimed at preventing or containing the damage that could derive from climate emergencies through the construction of more resilient infrastructures.

[63] Allan Adam Carter Staff, *Environmental Risks and Media*, Psychology Press (2000)

On the other hand, the adaptation strategy certainly appears less conclusive and angsty, but more effective in the relationship between actions and effects, relatively less expensive with benefits to the advantage of those who have directly borne the costs.

These are two strategies that respond to different needs to be understood as complementary rather than antithetical, with the effect, however, of raising the overall cost of the fight against climate change.[64]

On the 1972 a book "The Limits to Growth" calculated for the first time the limits of human growth on planet Earth. The report, commissioned to MIT by the Club of Rome, opens the long phase of ecological concerns for the fate of Earth, the physical limitation of resources, the controversy over human excesses and the criticism of the economic model of consumption and development. In the Eighties and Nineties this worried vision, on the limits of development, translates into the concern about global warming. The climate change became an official international issue of United Nations and governments.

The COP (Conference of Parties) of ONU

It was in 1995 that took place, in Berlin, the first Conference of Parties (Member States), the United Nations Convention on Climate Change (UNFCCC), and the first international environmental treaty dealing with global warming, known as the *Rio Agreement*, because it owes its existence to the landmark 1992 Rio de Janeiro Earth Summit. In the 1988, had been formed the Intergovernmental Panel on Climate Change (IPCC), a scientific forum formed by two UN agencies (World Meteorological Organization and United Nations Environment Program). The purpose of IPCC was studying global warming and advise UN on possible contrast measures. Over time, the IPCC's role as consultative will become more and more imperative and binding. The history of climate annual COPs starts from here. The 26 COP should have taken on 2020 in Glasgow but has been postponed, due to the Covid pandemic. Since 1995 COP is dealing with the reduction of carbon dioxide emissions, intended as driver of warming, as a world commitment. Since the beginning COPs had to deal with an

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[64] Climate Change Impacts and Adaptation Strategies in Italy: An Economic Assessment
Alessandra Sgobbi, Carlo Carraro, FEEM Fondazione Eni Enrico Mattei Research Paper, CMCC Research Paper No. 14

evident division between the industrialized countries (major emitters) and the developing countries. For many of the last, emission reductions would mean give up the economic standards of consumption and incomes of developed countries. This thorny question will mark all subsequent COPs meetings until now. Moreover, the cleavage on emissions is not only between rich industrialized and poor countries, but between a pool of big populated emitter countries, included China, India and Brazil, and the remaining countries. Due to this division, it's very difficult for COPs to overcome the unanimity on the face of reduction wishes, solemnly reaffirmed in the last COPs, which by now includes the totality of UN countries, and concrete, effective and "binding" commitments of the emitters States. Since emission reduction identifies with degrowth and the abdication at the energy consumption targets, already reached by developed countries, a truly stringent international agreement seems impossible. In fact, the limit and the cross of all COPs by now has been the "not binding" goals for countries to reduce their single greenhouse gas emissions. Some COPs were more relevant than others. The COP 3, held in Japan in 1997, issued the *Kyoto Protocol*, a "magna carta" of climatic environmentalism. The protocol will come into effect only on February 2005 (thanks to the ratification of the protocol by Russia). The delay on the signature of the Protocol was due to the necessity to obtain the withdrawal of, at least, a sufficient number of representative countries. Kyoto Protocol was drafted on the basis of the *principle of precaution*. The term means a policy of precautionary conduct with regard to political and economic decisions on controversial issues. Quite logical but limiting in many cases and discouraging of demanding and innovative decisions and government choices. The Kyoto Protocol on Climate Change was the first international framework that set goals, for the developed countries that have signed it, to cut emissions of gases blamed for the greenhouse effect and global warming. The Protocol ended a long discussion on the United Nations Framework Convention on Climate Change (UNFCCC), started at the Earth Summit in Rio de Janeiro in 1992. Kyoto, in 1997 intended the "protocol" at the Rio treaty, as enforcement of the agreement, which sets out times and procedures for meeting the climate Rio targets. The Protocol, of a voluntary nature, was finally signed at the Kyoto Conference of the Parties (COP3) on 11 December 1997, but ss we said, entered into force only on 16 February 2005 thanks to ratification by Russia and by other countries. In fact, in order to give credibility to the treaty, was appropriate for it to be ratified by no less than 55 nations, that should represent, all together, the 55% of global emissions[65]. Every signatory state agreed to restrict its emissions in separate percentages, but as a whole had to reduce them by 5 percent compared with the 1990 base year. This system tried to prevent industrial production by promoting non-capped carbon delocalization to nations. Nevertheless, unfortunately, these mitigation attempts put in place have not been able to reverse the inexorable trend dynamic with global emissions increasing by about 55 per cent from 1990 to 2015. A very important factor to remember is the inability to adhere to the protocol of the countries that are most responsible for pollution: United States, but above all China and India, which are mainly responsible for coal pollution. Europe, faced with the gradual decline of its position as an international emitter, tried to claim moral leadership on climate change. But, the objective limited relative weight of European emissions on the total worldwide amount will, paradoxically, weaken its contractual weight. The European amount of emissions, on the other side, could appear more symbolic than real. If, on the one hand, it is true that Europe has managed to reduce emissions well in advance to 20 percent by 2020, it is also true that this has helped to eliminate less than 1% of global emissions on a global scale. There is also another aspect to consider: Europe, in turn, though growing its carbon output at a high price, has exported it even further by relocating its manufacturing activities and then re-importing carbon integrated into manufactured and consumed commodities. The Kyoto Protocol, signed by 84 counties, 39 of which engaged themselves to reduce their greenhouse emissions by 2008-12, commits the signatory countries to three main goals: a quantitative reduction of their emissions compared to 1990 emission (baseline), to implement a national system for monitoring national emissions, to a national inventory, update annually, for definition of the measures for reduction. Needless to say, the first of the three commitments turned out to be very difficult to fulfill, until now. Deserve a mention the COP 13, held in Bali (Indonesia) in 2007, which tried to bring to life an "action plan" aimed at implementing the global agreement. Its purpose was to have an increase in the CO2 reduction obligations of rich countries and the inclusion of emerging economies (China, India and Brazil) on mandatory assignments. In fact, until 2007, these big emitters did not have constraints as considered developing economies. Unfortunately,

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[65] ENAC. (2018). *Il Protocollo di Kyoto*. [online] Available at: https://www.enac.gov.it/ambiente/impatto-ambientale/le-emissioni-gassose/il-protocollo-di-kyoto [Accessed 14 Aug. 2020].

the blocking commitment and stabilization of the exponential growth of the emissions by these counties where never implemented. A new treaty was due to be adopted at COP 15 in Copenhagen, Denmark, December 2009. The attention for this COP was very high, due to an impressive media campaign on the effects of global warming. Unfortunately, the results were tragic: just a simple diplomatic compromise on the search to contain below 2 degrees centigrade of the global average temperature rise over time. Throughout the following year, the subsequent COPs did not perform differently, producing not great results. And ever with repetitive goals. The COP 17 of 2011 sought to establish a new *global agreement* on pollution reduction replacing the Kyoto Protocol, visibly old and consigned to the history books. At the COP 18 (Doha, 2012) governments reached only an agreement on the last three years of negotiations. They were forced to a maintenance of Kyoto Protocol as the persistent legal platform of UNFCCC, although clearly dated. Doha, this is its importance, issued a platform for an Enhanced Action Plan /ADP), a new Protocol, to be adopted on 2015, at the Paris COP. The most important fact, however, was the institution of the *Green Climate Fund* which aims to support developing countries economically in adapting to climate change through national projects and plans in the medium term. The fund was to guarantee $100 billion (about €91 billion) a year until 2020. Today the European Union is the fund 's largest lender with EUR 14.5 billion already paid out in 2014[66].

The Paris Agreement

The COP 21, held in Paris (November- December 2015) led to a new global agreement, explicitly aimed at containing the increase in the earth's average temperature to 2° C (making every possible attempt to stay within 1.5° C)[67].The Paris conference and the agreement that followed is a historic step, which brings to a conclusion the path started in Rio De Janeiro in 1992 and in Berlin in 1995 with COP 1. From a political point of view, Paris represented a great step forward in the international sharing of the climate problem (190 countries attended the conference)

[66] Perrone, T. (2017). *La storia delle conferenze sul clima, anche note come Cop*. [online] LifeGate. Available at: https://www.lifegate.it/la-storia-delle-conferenze-sul-clima#nascita-cop [Accessed 19 Jun. 2020].

[67] Ferrari, M. (2016). *Chi ha firmato l'accordo sul clima di Parigi? - Focus.it*. [online] www.focus.it. Available at: https://www.focus.it/ambiente/ecologia/chi-ha-firmato-laccordo-sul-clima-di-parigi.

and on focusing on industrial aspects, first of all energy, of the climate issue. Paris tried to implement the traditional commitment to reducing greenhouse gas emissions, in a reinforced legal framework. The Parties committed themselves to ratify, on National Parliament, by 2015 and 2016, the Paris Agreement. It will be mandatory if signed, at least, by 55 countries representing 55% of global emissions: the same commitment of Kyoto Protocol. Unfortunately, like any other previous COPs, also Paris will end in an agreement more political than practical. Nobel laureate Jean Tirole spoke clearly of "a compromise far below ambition with no progress compared to six years ago"[68]. Even more radical is the climatologist James Hansen, who even spoke of a "fraud"[69].

Anyway, other than the cornerstone of the entire agreement- restricting the rise in temperature below 2º C relative to pre-industrial temperature rates, with a promise to contain the increase in temperature by 1.5º C- the other main objectives were:

- reaching the peak of greenhouse gas emissions as soon as possible, starting with continuous reductions until a balance between emissions and cuts for the second half of the century is found.
- Ccountries have to communicate their commitments at national level, having to regularly (every five years) provide for improvement reviews.
- Funds destined for the most countries.
- Financial resources to help developing countries: the goal of the road map is to create a fund worth $100 billion a year until 2020, with the commitment to increase the adaptation and international cooperation funds in turn.
- The question of openness and versatility to ensure that everybody can participate in accordance with their abilities[70].

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[68] Patti, F. (2017). *Intervista al Nobel | Jean Tirole: «Trump ha ucciso l'accordo sul clima? È la prova che non funzionava»*. [online] Linkiesta.it. Available at: https://www.linkiesta.it/2017/06/jean-tirole-trump-ha-ucciso-laccordo-sul-clima-e-la-prova-che-non-funz/.

[69] Climatemonitor. (2015). *COP21 Parigi – Giorno 13: ecco l'accordo.* [online] Available at: http://www.climatemonitor.it/?p=39827.

[70] ANSA.it. (2017). *I punti principali dell'accordo di Parigi sul clima - Cronaca*. [online] Available at: https://www.ansa.it/sito/notizie/cronaca/2017/05/29/i-punti-principali-dellaccordo-di-parigi-sul-clima_5f3ce04d-b00a-46ce-9b63-a4d0a8f86917.html.

According to Alberto Clò, the weaknesses of the agreement are essentially three:

-uncertainty of the timing. The States must implement the agreement at an operational level. Not a very mandatory level. The uncertainty on time is of some importance, considering that CO2 emissions, in the 15 years preceding the Paris agreement, increased by the level of previous fifty years. The risk of ineffectiveness of mitigation, from the COP point of view, is enormous.

- the agreement it is not clear how emissions should be reduced. The focus is on carbon emissions (naturally related to energy) but, contradictorily, the word "energy", represented as the first responsible of emissions, is never used throughout the document.

- the commitments to keep the temperature increase below 2° C is binding, but the emission cuts necessary to achieve the result is not coherent.

The bottom-Up approach of Paris Agreement rests on the recognition, in reducing emission efforts, of the sovereignty of states. They are likely to act in their interest unless incentives intervene to push them towards the common good of reducing emissions.

This pursuit of the common good of reducing emissions can, at times, correspond to market issues. In this sense, the case of the United States, from the entry (October 2016) with Obama's presidency into the agreement to the request for exit (November 2019) under the Trump presidency. In fact, in the decade preceding the Paris agreement, the United States were already experiencing a reduction in carbon emissions due to the progressive replacement of coal with shale gas, a methane gas extracted from unconventional deposits. In 2016, in fact, methane overtook coal. The "shale revolution"[71] led to a collapse in the prices of methane gas. By 2040

[71] The "Shale Revolution" refers to the combination of hydraulic fracking and horizontal drilling that allowed the United States to increase its oil and natural gas output, particularly from tight oil reservoirs, which now account for 36 percent of the total U.S. crude oil production. The increased production capacity has decreased America's reliance on overseas oil imports and helps to provide a major economic boost as the nation recovers from the 2008 recession. Oil and gas accounted for and is rising 1.6 per cent of the US GDP in 2011. The shale formation growth has been associated with an increase in employment, with the oil and gas industry adding 169,000 jobs between 2010 and 2012.

shale gas is forecasted to cover 50% of the electric energy production in the United States. They will also become the first exporter of methane and oil by the 2019. In this sense was not easy for Barack Obama, who was a strong supporter of the Paris Agreement, to move USA on the consenting side with the treaty. The United States, in 2019, notified their exit from the Paris Agreement, primarily, for an economic fear: according to research by the conservative Think Tank Heritage Foundation, the Paris agreement was said to cost, to American manufacturing sector, hundreds of thousands of lost jobs, resulting in a huge loss for the country GDP by 2035 (-2.5 trillion dollars)[72]. There was, however, also a geopolitical motivation: Trump, in his electoral campaign, argued that climate change was a Chinese gimmick to destroy American production. Although this hypothesis is unfounded, it must be said that China, for a long period of time, was not considered a developed country and was able to invest and emit almost completely freely, especially as regards coal. In fact, in 2019, Beijing's net coal-fired electricity capacity grew by 42 GW[73], caused by the investments in this sector.

The situation is different for European Union. Thanks to higher efficiency levels and a strong support to renewables, UE managed to achieve a greater emission reduction than USA (and any other competitor). But at the cost of an increase in energy prices which are two times higher in electricity and four times in methane compared to the USA[74]. Five years later Paris Agreement

carbon emissions have remained almost stable, at the 2015 level. So, not even COP 21 seems to be heading towards a success. This is a reason why European Union, to search remedy to the problem of difficult implementation of the Climate Agreement, has created the *Green New Deal*, which we will discuss in the next chapter.

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72 Graziosi, S. (2019). *Ecco perché Trump è uscito dall'accordo sul clima*. [online] Panorama. Available at: https://www.panorama.it/news/perche-trump-uscito-accordo-clima-parigi.

73 QualEnergia.it. (2019). *In Cina era carbone, è carbone e sarà carbone*. [online] Available at: https://www.qualenergia.it/articoli/in-cina-era-carbone-e-carbone-sara-carbone/.

74 ec.europa.eu. (n.d.). *Statistiche sul prezzo dell'energia elettrica - Statistics Explained*. [online] Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics/it.

Is energy transition possible?

The Green new Deal is identified with a way to realize, in a concentrated year numbers, a decarbonization of European economy, the replacement of coal, oil, gas and with renewables sources and a transition from fossil fuels to a different type of energy. Hard version of Green New Deal argues that decarbonization must achieve 90% of the transition goal by 2030 and be completed by 2050. The challenge to this wish appears to be technology. As we have seen in the previous chapter on impact of energy on civilization history, transition on energy sources takes a very long time. This happens because, even if technology is a driver of a transition, there is no immediate link between technological progress and energy policies. It's very important to understand that, in order to evaluate the "sustainability" of an energy transition to a no-carbon system. The proof is the experience of the experience of 90's in the Western world. In order to face conflicts and tensions on oil front, that shook the economy world between since the 70's (first oil shock 1973) until the end of the 90's (continuous fluctuations of oil and gas prices and supply, financial and industrial crises, social reluctance to austerity policies, the URSS collapse, the explosion of Middle eastern conflicts, terrorism) forced a massive deployment of existing renewable energy sources into western electricity system, in order to alleviate dependence on oil importation. This political orientation was in line with the suggestions of environmental policy of the two decades from the Club of Rome Report (1971) and Rio Conference (1992). Massive incentive policies were set up to support displacement of wind and solar plants in national electricity system. Perhaps even then Western governments had evidence of a thorny reality: current renewables sources were not ready, for technological reasons, to replace oil extensively. This problem will come back at the end of this quarter of the new century, when the replacement of oil is demanded for environmental reasons and no longer for economic and geopolitical ones. The fact remains that, in order to deploy renewables, in the 70's and 90's, investors gave credit to short term technologies. To cope with an enthusiastic expectation on existing renewables technologies, first of all wind and photovoltaic, States decided to support heavily the renewables deployment. Despite notable financial support for this policy, the share of fossil fuels in western energy portfolios was only slightly scratched. To force renewables to be compatibles with energy markets, strict internal regulation of energy activities by States was necessary. The freedom of choice of companies was therefore decreasing, and this was not at all smoothed out by the choice of the States to internalize negative externalities in energy policies. At first, political externalities related to oil were internalized, as dependence on imports had consequences on national security and sovereignty, later also environmental externalities, with oil seen as harming the environment. These problems still drag on. With both internalizations, the States have directed investors towards the new renewables, first of all for the zero content of CO2 emissions, but above all for the possibility that these energies had to reduce compatibility with mere market logic and therefore to make greater leverage on public policies. From the political point of view, this initially translated into a Command And Control approach, with also important results such as the limitation of acid rain or the reversal of the trend regarding the ozone hole, then the approach moved towards an imposition on energy systems, mostly electric ones, to convert to renewable energies with rather evident contradictions: the most important was undoubtedly the claim that this could "get stuck" in the logic of the market. The interventionist spiral that followed this approach was evidently unsuccessful and frantic.

Regulatory father Alfred Kahn argued that the option would not be between perfect market competition and perfect state control, but rather between an imperfect version of the two. Thus, Paul Joskow added, the liberalization of certain sectors like electricity will take the "worst of both worlds." “A view” wrote John Mott, former president of the American Federal Energy Regulatory Commission “that we are continually facing in regulated energy markets where tariffs produce a volatile combination of incomplete competition and flawed control that reinforce one another. We can rationally disagree about the degree of harm it has done, but not about whether it is actual and increasing…”.

As we saw in the first chapter, oil, in its statement on coal and old renewables, led to three important changes: the first was the overcoming of the localization rigidities, simply due to the fact that the greatest development took place where that energy source was close and easily accessible. It must be said that this is very true for wood and water courses, while coal broke up, but only partially, this trend. At a substantial level, however, the fact that countries with large quantities of coal mines could guarantee themselves greater development remained true, leaving behind those who did not, such as Italy.

Oil drastically breaks these stiffnesses, thanks to its great abundance but above all for the ease of carrying it. With its advent, the development and power of nations detach themselves from the close ownership of the energy they feed on.

The second improvement linked to the becoming of the sources is the increase in the dimensional scale of their output, also known as power density: energy generated per unit of space, or the capacity to concentrate large quantities of energy in confined spaces supporting large scales of output, which in effect would stimulate advances in electricity, chemistry and transport, leading to the affirmation of the growth model based on consumption[75].

An increase in energy density that went hand in hand, supporting each other, with the processes of urbanization or, in either case, with the population densification in increasingly restricted spaces. During the transition from forest to hydraulic or wind energy, land usage per unit of energy was decreased by 10 times, but by another 100 times with the advent of fossils, and even more with nuclear power[76].The third change was the reduction in real energy prices.

At this point, three questions come automatically: which energy systems are consistent with development models capable of revolutionizing societies? If such systems other than the current one existed today, would they be able to give a positive boost to economies? Third, compared to the three changes we have seen from oil, will renewables be able to achieve the same results?

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[75] Alberto Clô, *Energia e clima. L'altra faccia della medaglia*, Il Mulino (2017)

[76] Bravo, P. and Debecker, D. (2016). *Combining CO 2 capture and catalytic conversion to methane*. [online] Available at: https://dial.uclouvain.be/pr/boreal/object/boreal%3A216172/datastream/PDF_01/view [Accessed 24 Aug. 2020].

Answering to the Epstein's Question

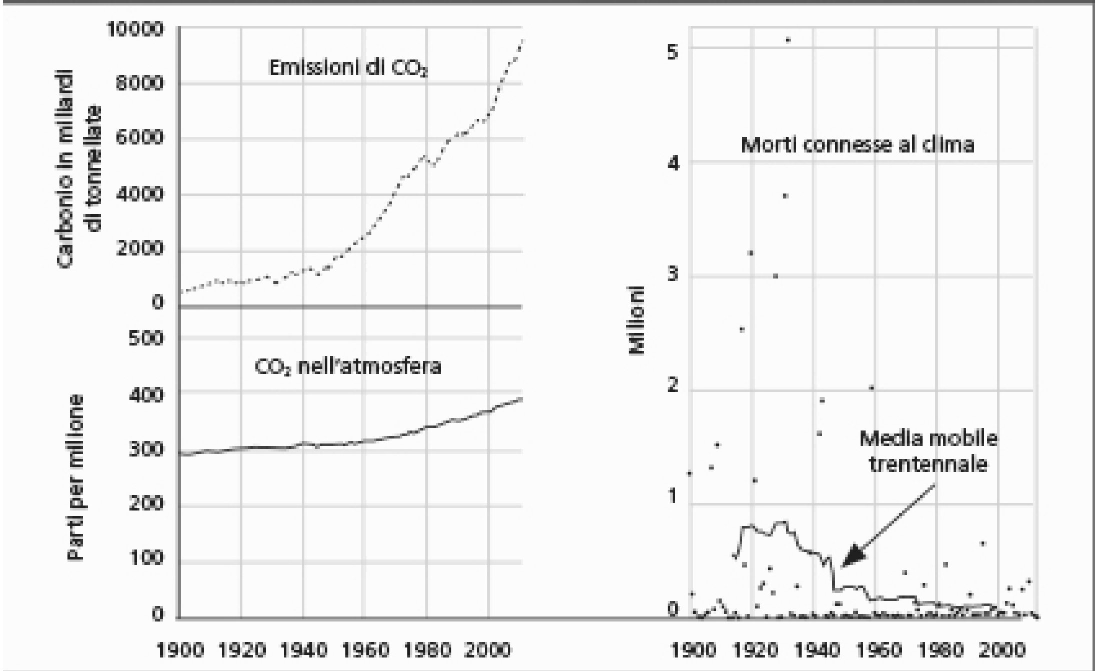
Alex Epstein, energy analyst, asks us a question that, if read without ideology but with curiosity, appears really interesting: what value do we give to human life? And what value, instead, do we give to nature uncontaminated by human intervention? Although the two do not seem to contradict in principle, we must understand that nature uncontaminated by human intervention often affects human life itself. Just think of our birth process, which, in extreme cases like a premature birth, would not have the success rate it has today[77] without the energy-fed machines we produce. Bill Mckibben, US environmentalist defined in 2010 by the Boston Globe as "the most influential environmentalist on the planet", wrote in his book "*The end of nature*" that priority must be given to minimizing the impact on the environment. This noble intention, in fact, was translated into a limitation of our desires and our ambitions, necessary to limit the human impact. Only in a world with fewer human beings, less ambitious and less eager, can nature resume its independent action[78].

It is immediately clear that this position does not give priority to human life, but rather to uncontaminated nature.

[77] Alex Epstein tells in his book *In Defense of Fossil Fuels* a story about a woman in Gambia, happened in 2006, who was unable to deliver her baby due to a lack of energy in the hospital, which was unable to equip itself with an incubator. The story can be found on page 78.

[78] "*even if not in our time, and not in the time of our children, or the children of their children, if we now, today, limit our number and our desires and our ambitions, perhaps one day nature could resume his independent work*." Bill Mckibben, La Fine della Natura, Tascabili Bompiani (1989)

Figura 1.9. Più combustibili fossili, meno morti causate da eventi climatici



Fonti: Boden, Marland, Andres (2013); Etheridge et al. (1998); Keeling et al. (2001); MacFarling Meure et al. (2006); Merged Ice-Core Record Data, Scripps Institution of Oceanography; EM-DAT International Disaster Database

Looking at the graph, however, built thanks to the data reported in the sources and taken from the book by Alex Epstein, *In defense of fossil fuels*, we can see that in recent years, an increase in CO2 emissions has also corresponded to a significant decrease in deaths caused from climatic events. To be precise, in the decade between 2004 and 2013, global climate-related deaths plummeted to an 88.6% lower level than in the peak decade, 1930 to 1939. How is it possible? Alex Epstein explains: "Once again, experts who predicted climate catastrophes have not seen the full picture. There have been far-reaching benefits brought about by exploitation of hydrocarbons. These benefits have made our societies more resistant to extreme temperatures, to floods, storms and so on.”

3RD CHAPTER – European Green Deal

11 December 2019 – Historical Data: European Green Deal

On December 1st, 2019 Ursula Van Der Leyen is elected President of the European Commission. Von Der Leyen immediately presented the outlines of the European Green Deal, committing herself to present it within the first 100 days of her mandate. The Green Deal describes how to make Europe the first climate-neutral continent by 2050, while stimulating the economy, improving people's health and quality of life, taking care of nature and leaving no one behind.

This means eliminating the net emission of Co2 by the 2050.

The European Green Deal will be, in specific terms, a "strategy" that envisages interventions in all economic sectors, from energy production to transport, passing through heating/cooling system, manufacturing processes in heavy industries and so on. This will require new laws and investments to be enforced over the next thirty years. The Commission has currently scheduled the first two years, the most significant ones, to build a framework able to sustain such an ambitious project.

The Green Deal will be worked on by both the Commission, the Union's governing body, the Parliament and the Council, which hold the legislative power. It is handled for the Commission by Frans Timmermans, Commission Vice-President and one of the most respected politicians in Brussels, who has received an official delegation from von der Leyen[79].

The key goal is to limit the rise in global warming which, according to projections by the UN Intergovernmental Panel on Climate Change (IPCC)[80], must stay below 1.5 ° C relative to pre-industrial, so as not to cause major harm to the earth and therefore to

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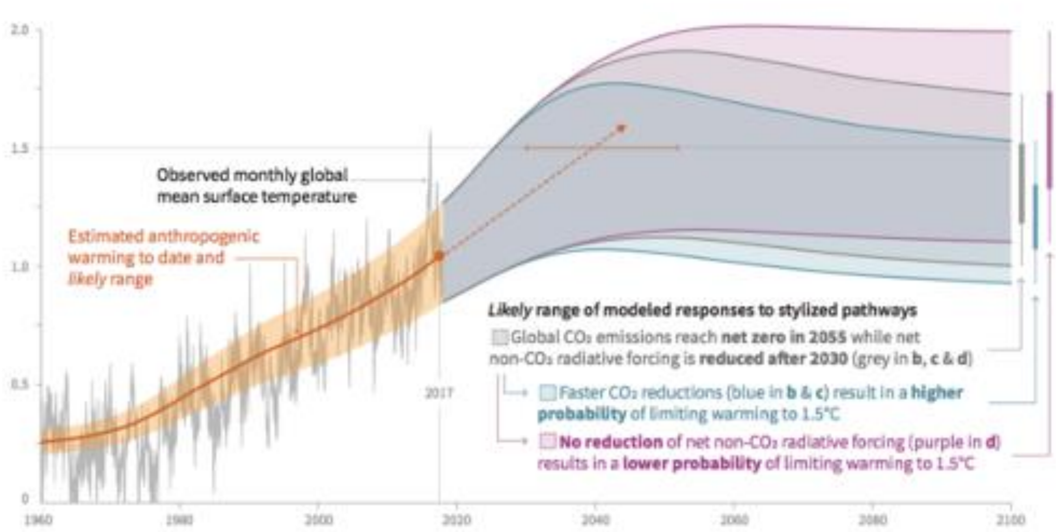
[79] Misculin, L. (2020). *Il Green Deal europeo, spiegato bene.* [online] Il Post. Available at: https://www.ilpost.it/2020/02/02/green-deal-europeo/.

[80] Created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), the objective of the IPCC is to provide governments at all levels with scientific information that they can use to develop climate policies.

the human species[81]. The European Union has undertaken to eradicate its net pollutant emissions by 2050 and to meet intermediate targets for 2030 and 2040 in order to comply with this cap set by the 2015 Paris Agreement.



Source: IPCC Report October 2018 available at: https://www.sisclima.it/wp-content/uploads/2019/07/SR15_SPM_ita.pdf.

The first and most important will be to clean up electricity production, which currently accounts for 75% of greenhouse gas emissions in the European Union (the most common: Co2). It means, above all, the extension of renewable energies and, at the same time, the progressive elimination of fossil fuels.

Another significant aim would be to make a whole set of human activities more sustainable: it means implementing new regulations for constructing or renovating houses and industries throughout Europe. That is to make manufacturing processes less polluting, to boost public and rail transport, to encourage biodiversity, to significantly protect forests and animal species from extinction and to make the circular economy much more popular.

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[81] IPCC (2018). *Sommario per i Decisori Politici*. [online] Available at: https://www.sisclima.it/wp-content/uploads/2019/07/SR15_SPM_ita.pdf.

Green Deal in practice

The Commission will present a 'strategic plan' first for each of the Green Deal's goals and then a 'concrete step' to try to accomplish it. The interventions will be of a different legislative character: the most relevant will be directives and regulations, that are European laws which are binding on national states. At the time, we just know the title and a brief description: we know that by the end of 2021 the Commission aims to set new standards for automobile emissions and that a "concrete action" on the circular economy will take place.

The measures most debated, primarily because they are the most relevant that will be addressed in the coming months, are two: the so-called Climate Law[82], the legal framework for all the steps that will follow in the coming years, and the Funds for a Just Transition, the piggy bank that will be used to finance the most backward and vulnerable sustainability initiatives.

As for the climate policy, there are strong hopes. In an interview for Il Post in Italy, Mauro Albrizio, who has been leading the Legambiente office at the European institutions for twenty years, declares: "It will be the first time that Europe has implemented a formal climate law. Until now, it has only been entrusted with various regulations and directives."

The law was introduced on 4 March 2020. In depth, the law proposes a legally binding commitment to reach zero net greenhouse gas emissions by mid-century. However, this will not result in national constraints: EU institutions and Member States are needed to take the steps necessary to jointly achieve the objective.

On the other hand, the Commission proposed the Just Transition Fund in mid-January, and it is the bulk of the Just Transition System. The Fund will mobilize about 100 billion euros between 2021 and 2027, which the Commission plans to raise until 143 by 2030. The money will come from the current European Structural Funds, with some

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[82] With the European Climate Law the Commission proposes a legally binding target of net zero greenhouse gas emissions by 2050. The EU Institutions and the Member States are bound to take the necessary measures at EU and national level to meet the target, taking into account the importance of promoting fairness and solidarity among Member States. (CABUZEL, T. (2020). *European Climate Law*. [online] Climate Action - European Commission. Available at: https://ec.europa.eu/clima/policies/eu-climate-action/law_en.

very contentious changes, from the co-financing schemes of the states, loans with interest in favor of the European Investment Bank, and from a portion of the InvestEU fund, which is the new name of the European Commission's initiative to encourage private investment (in the previous legislature named Piano Juncker, named after the former president Jean Claude Juncker).

The Commission has published some tables hypothesizing how much will be entitled from 2021 to 2027 for the individual States. Eastern countries would naturally obtain the largest share of funds in relation to the population, according to estimates released by Il Sole 24 Ore but there are some remarkable results. Germany, the only Western country which still relies heavily on coal for electricity, will receive EUR 2 billion in direct funds. Instead, Italy will earn 364 million, an amount close to that which goes to countries such as France and Spain.

According to the rules of the Fund, the national government will have to contribute between 1.5 and 3 billions to co-finance those projects for every euro that the European Union pays to each member, and let the Commission know how it wants to invest this money through territorial plans that the country, the national government and local companies and associations will plan.

The harsh reality

In principle, it is difficult to be against the aims established by the European Green Deal. But history, especially that concerning environmental issues, requires us to understand how it can be translated into virtuous initiatives that can obtain real results, instead of bombastic announcements destined to result in failures, as has been the case up to now for all environmental initiatives involving the collectivity of States.

To read the press, immediately after the Deal was announced, it seems that Europe, with this initiative, could really be the world's first continent to reach complete carbon neutrality in 2050: a pioneering initiative, compared to Ursula von der Leyen, no less than at the moon landing[83].

[83] Mauro, A. (2019). *Il Green new deal come l'uomo sulla luna*. [online] L'HuffPost. Available at: https://www.huffingtonpost.it/entry/il-green-new-deal-come-luomo-sulla-luna_it_5df09baae4b06a50a2e6e17c.

But, after all the enthusiasm, the Commission itself acknowledges the difficulties inherent in the project already on the first page of its website, about the Green Deal. In reality, it is said that "becoming the first climate-neutral continent is at the same time the biggest challenge and opportunity of our time." Only for the intermediate targets set by the Green Deal for a 55 percent reduction in CO_2 emissions by 2030, the 500 billion euros per year expected in June 2019 (5000 billion by 2030 in total) will no longer be enough - the Commission writes -, but 'additional investments' will be required, not quantified at the moment. That is why the Commission is prepared to "mobilize 25 percent of the EU budget," or less than 40 billion per year[84].

It is immediately clear how the plan must face the harsh reality, in order not to have the same outcome as the Kyoto Protocol, as William Nordhaus wisely explained in his requiem, where he exposes the enormous costs it entailed and the almost zero outcomes on global emissions[85].

The first issue the Green Deal faces is the fact that Europe contributes to less than 4 billion tons to global emissions. This constitute just a 9/10% of global emissions in terms of percentage.

In addition, a report from the British Office of National Statistics highlights some gaps in the calculation system regarding the carbon dioxide emission reductions that Europe has achieved in recent years[86]. It is beyond doubt that emissions have dropped within the European Union. If we compare 1990 with 2018, the decline is 21 percent: from 4.4 to 3.4 billion tons, with a sharp acceleration in the last decade (after the Great Recession explosion) that has concentrated 80 percent of the overall decrease.

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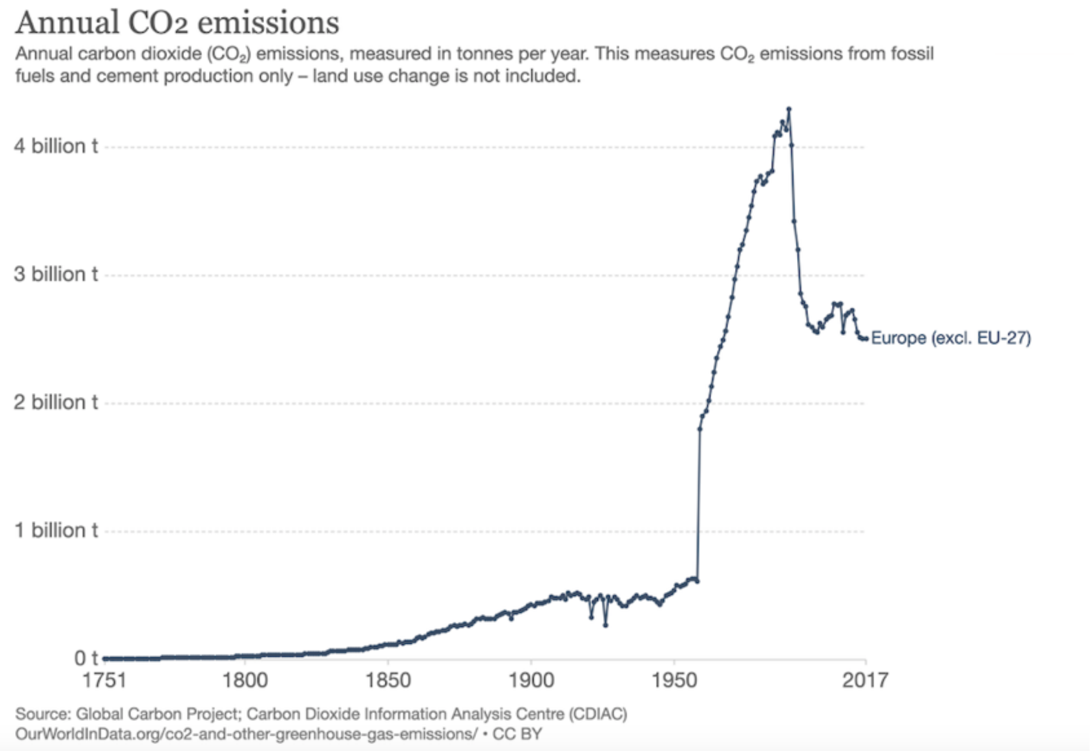
[84] Zollino, G. (2020). *Quale destino per il Green Deal europeo?* [online] Energia. Available at: https://www.rivistaenergia.it/2020/01/quale-destino-per-il-green-deal-europeo/.

[85] William D. Nordhaus & Joseph G. Boyer, 1998. "Requiem for Kyoto: An Economic Analysis of the Kyoto Protocol," Cowles Foundation Discussion Papers 1201, Cowles Foundation for Research in Economics, Yale University.

[86] Syed, A. (2019). *The decoupling of economic growth from carbon emissions: UK evidence - Office for National Statistics*. [online] Ons.gov.uk. Available at: https://www.ons.gov.uk/economy/nationalaccounts/uksectoraccounts/compendium/economicreview/october2019/thedecouplingofeconomicgrowthfromcarbonemissionsukevidence.



The question to ask, looking at future dynamics as well, is which are the reasons, virtuous or not, that can be attributed to this decline.

Even if complete analyzes are not available, they could be identified in the climate policies defined at European level; in the penetration of electric renewables; in the change in the production mix from high-carbon (industry) sectors to low-carbon sectors; in the improvement of efficiency in the use sectors. Not least: in the low economic growth, reduction of the manufacturing base and economic activities in several countries. Particularly Italy, which has seen its retreat around a quarter since 2007, with employment in manufacturing reduced by 650,000 units[87].

These factors which contributed to emission reduction are contrasted by one that is generally ignored: the emissions integrated in imported products. While it is true that the Union has been able to meet the 20 per cent reduction goal set in advance for 2020, it is equally true that if imported emissions were taken into account the reduction would be lower.

In essence, although Europe has reduced its carbon production at a high price, it has exported it even more by relocating its manufacturing activities to countries with lower

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[87] Clò, A. (2019). *Europa ed emissioni: serve chiarezza per non illudersi*. [online] Energia. Available at: https://www.rivistaenergia.it/2019/10/europa-ed-emissioni-serve-chiarezza-per-non-illudersi/.

emission limits but also with higher carbon intensity per unit of output. To then re-import it integrated into the products manufactured and consumed.

This is the so-called *carbon leakage* phenomenon described by the European Commission as: "Transfer of CO_2 emissions that can occur if, due to climate policy cost reasons, companies plan to move production to countries where emission limits are less strict, which could lead to an increase in their total emissions."

A striking example is that of the United Kingdom, which decreased internal carbon production by 15% between 1990 and 2005, boasting that it had complied with the Kyoto limits, while if carbon had been counted at the level of consumption it would have increased it by 19%, causing an increase in global emissions[88].

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[88] Dieter Helm (2012). *The carbon crunch : how we're getting climate change wrong -- and how to fix it*. New Haven: Yale University Press.

First limit: CO_2 is global

As we have shown, the fund intended to offset the negative effects that the Green Deal could cause, the Just Transition Fund, is very modest, economically speaking. But another factor that has already provoked opposing reactions is Article 5 of the regulation which prohibits the use of the fund for any form of support for projects relating to fossil fuels as well as for construction and decommissioning of nuclear power plants[89].

At this point the question "how to make this Deal?" rises. Tools, times, and above all technologies devoted to the goal leap into the foreground, "because it is on how that the economic sustainability and therefore the feasibility of the project will depend," declares Giuseppe Zollino, Professor of Technique and Energy Economics, Department of Industrial Engineering at the University of Padua.

The concern that the result for the Green Deal may be bankruptcy as well as other pollution deals is exacerbated by the fact that, in the view of many analysts, the Green Deal, as it presents itself, does not seem all that new.

Indeed, in 2000, the European Climate Change Program stated that "the European Union has been involved in the fight against climate change on an international level for some time" and that "it feels the responsibility to be an example with clear policies and steps."

Nearly two decades later, EU CO_2 emissions have fallen from 3.7 billion tons in 2000 to 3.4 billion in 2018 (again ignoring the carbon leakage phenomenon): 0.3 billion fewer. However, there were 19.5 billion tons in the rest of the world in 2000 and today they are more than 30: a rise that is almost 18 times greater than the decline achieved in the EU.

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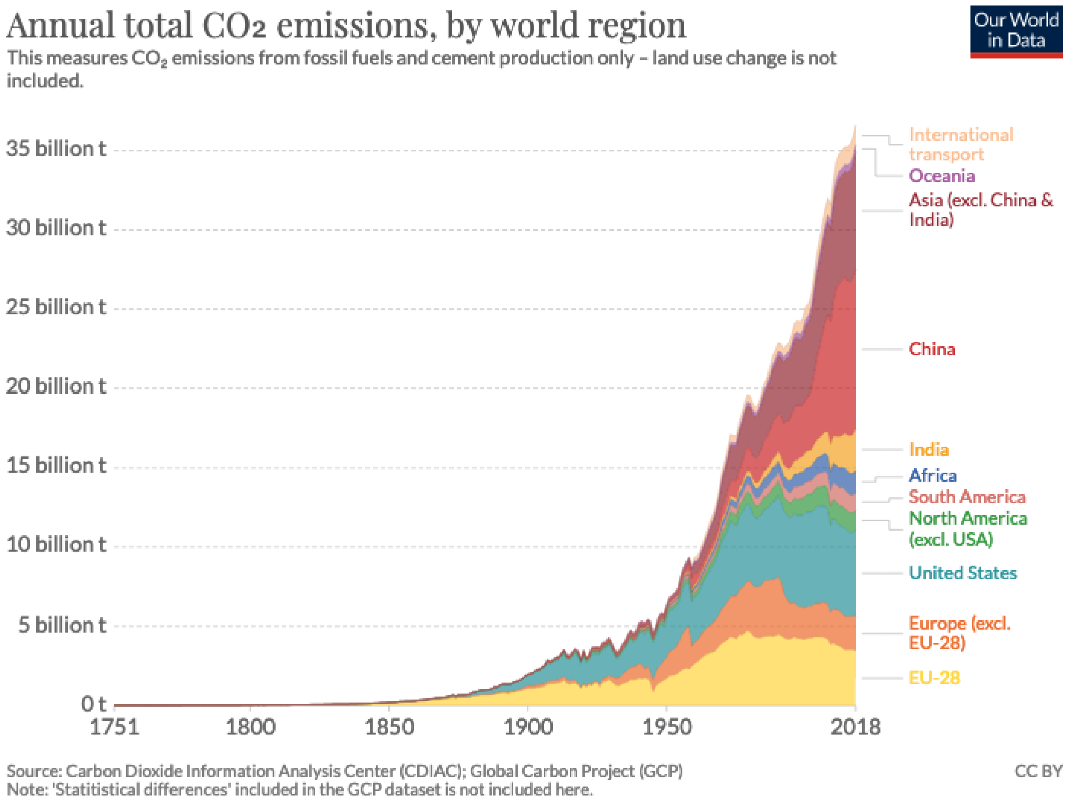
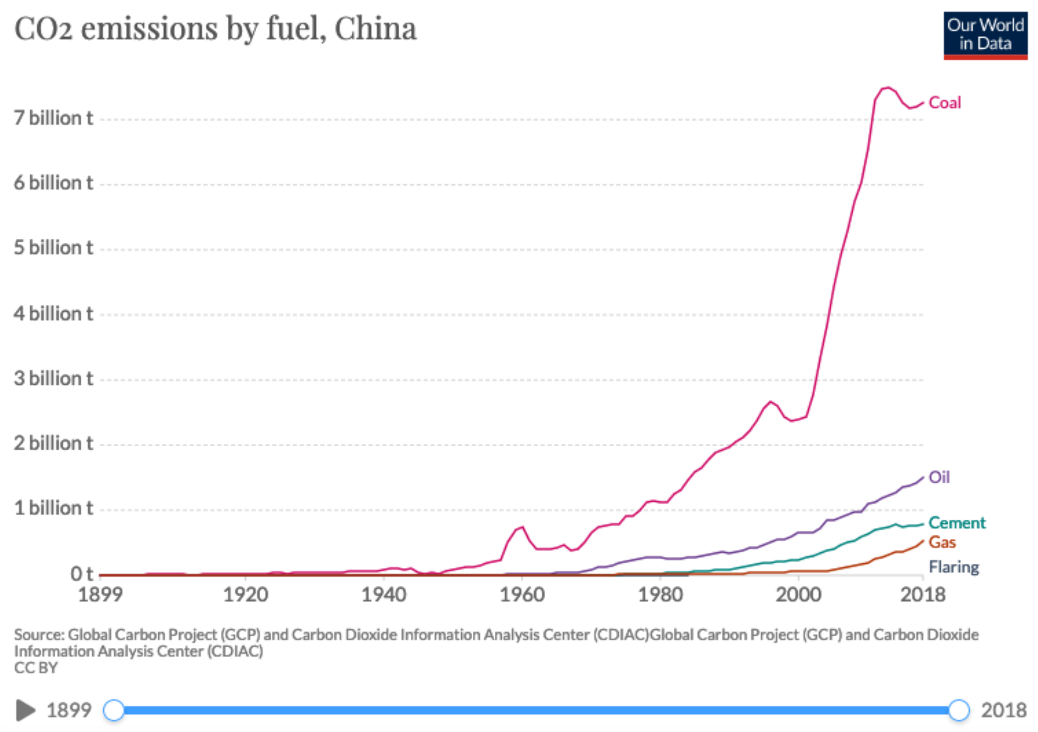
[89] Art. 5 “Exclusion from the scope of the support” - Just Transition Fund Regulation (n.d.). *EUR-Lex - 52020PC0022 - EN - EUR-Lex.* [online] eur-lex.europa.eu. Available at: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52020PC0022



It becomes difficult at this point to believe that a kind of "imitation effect" can be obtained which would also be necessary to have real effects on the environment.

Case Study: China



The CO2 emitted is global. This means, for example, that the concentration on certain days of polluting particulates in the American skies originates from the massive use of coal in China. As we can understand by combining the information from the two previous graphs, China contributes for, more or less, 30% to global emissions, and of these emissions the largest share comes from coal.

Abandoning the economic model of the Chinese giant, centered on a huge production of coal, is difficult to imagine. Above all, considering that, before the Covid-19 pandemic, China intended to increase its energy capacity by 148 GW, according to the data provided by the latest report from the non-profit organization Global Energy Monitor[90], which in turn used the data made available by the Global Coal Plant Tracker project[91]. The value of the energy capacity of Chinese coal would thus be almost identical to that of the entire coal capacity registered today in the European Union.

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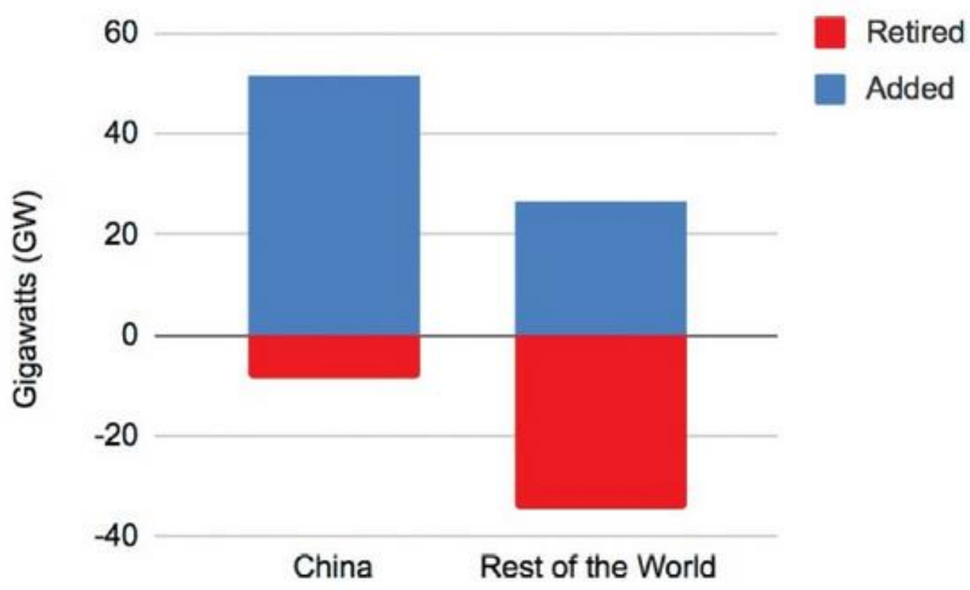
[90] Global Energy Monitor (n.d.). *End Coal | Out of Step: China Is Driving the Continued Growth of the Global Coal Fleet*. [online] End Coal. Available at: https://endcoal.org/global-coal-plant-tracker/reports/out-of-step/

[91] End Coal. (2017). *End Coal | Global Coal Plant Tracker*. [online] Available at: https://endcoal.org/global-coal-plant-tracker/.

In the period between January 2018 and June 2019, therefore, the production capacity of the coal-fired power plant in the world - excluding China - fell for the first time since the 1980s, recording -8.1 gigawatts (GW). At the same time, however, the total Chinese capacity in the sector increased dramatically: +42.9 GW. This means that despite the strategic choices in favor of decarbonization carried out on the planet, the overall global capacity of coal plants has increased by almost 35 GW in the space of 18 months.

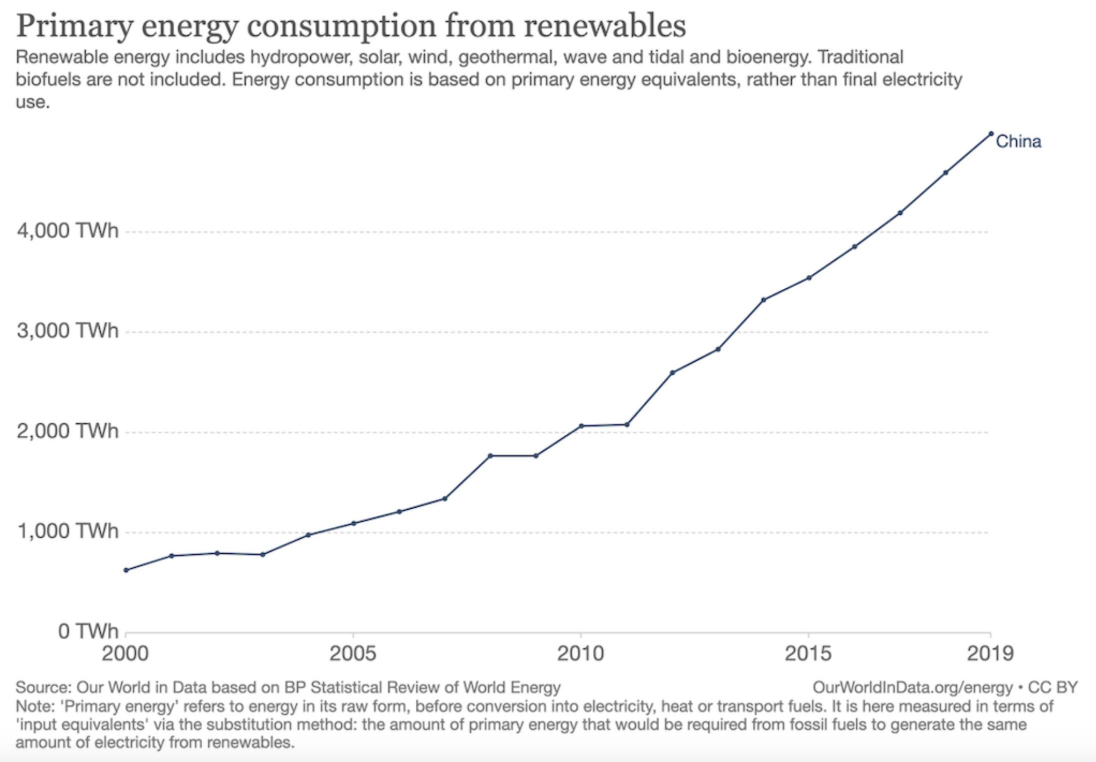


Source: GEM, Global Coal Plant Tracker, July 2019.

Behind the Chinese expansion in coal, according to many researchers, there is above all the "short, but massive wave of projects approved from September 2014 to March 2016". In that period, the Global Energy Monitor study points out, "the central government delegated the authorizations to the provincial authorities which, for their part, had strong incentives to approve and build coal-fired power plants to achieve economic objectives".

At the same time, China is also the leading market for solar panels, wind turbines and electric vehicles, producing about two-thirds of the solar cells installed worldwide.

"We are seeing many contradictions in China's energy development," said Kevin Tu, a Beijing member of the Center on Global Energy Policy at Columbia University. "It is the largest coal market and the largest clean energy market in the world."[92]



Also, according to BloombergNEF, China's investments in renewable energy in 2019 went down by 8%. Therefore, with $83.4bn of investments in the renewable sector, China in 2019 had the worst performance since 2013. The sector most decreased in terms of investments was solar energy, precisely by 33% to $25.7bn, less than a third of the total in 2017[93]. For this contradiction, China is alternately presented as the

[92] Larson, C. (2019). *Il paradosso cinese: il leader delle rinnovabili punta ancora sul carbone*. [online] Fortune Italia. Available at: https://www.fortuneita.com/2019/12/03/il-paradosso-cinese-il-leader-delle-rinnovabili-punta-ancora-sul-carbone/ [Accessed 9 Sep. 2020].

[93] Grasso Macola, I. (2020). *China's renewable investments fall as US's rise: BloombergNEF report*. [online] Power Technology | Energy News and Market Analysis. Available at: https://www.power-technology.com/news/china-renewable-investment/.

world's worst climate criminal or the potential example of the implementation of clean energy, but the truth is that both superlatives could be somewhat out of place.

As a fast-growing economy, China's energy demands were bound to skyrocket; so, an increase in energy consumption, especially fossil, can hardly be surprising. The hope was therefore that the country could be powered by a large share of renewable energy, to curb the growth of emissions. To reinforce the expectations, there were the statements of the Chinese leader Xi Jinping, in 2017, that China had "taken a leading place in international cooperation to respond to climate change"[94].

Today the country's renewed attention to coal comes as a disappointment. "Now there is a sense that China has lost that leading role in the fight against climate change," said Lauri Myllyvirta, chief analyst at the Center for Research on Energy and Clean Air in Helsinki.

In November 2019, Premier Li Keqiang gave a speech emphasizing the importance of domestic coal for energy security. Once a new infrastructure is built, it is unlikely that it will not be used. Indeed, it will be politically difficult to demolish a new coal-fired power plant that employs people and supports an extraction operation. This will make China's transition away from coal more difficult.

The last hope of those who identified China as a leader in this emissions battle came from the lockdown caused by the Covid-19 pandemic. In the months that stopped Chinese production activities, as the Finnish Center for Research on Energy and Clean Air (Crea) states, in the same period but a year ago China released about 400 million tons of CO2. The quarantine reduced Chinese emissions by about 17%. The Crea researchers, however, had already warned, immediately after the publication of their study, that the drop-in emissions would probably be temporary, given the actions taken by Beijing to revive industrial activities. "As had already happened after the global financial crisis and the internal economic recession in the country of 2015", the report

[94] Il Post. (2017). *Xi Jinping come Mao Zedong - Il Post*. [online] Available at: https://www.ilpost.it/2017/10/24/xi-jinping-mao-zedong-cina-congresso/.

of the Finnish study center concludes, "the key factor that will determine the extent of this impact is the speed with which things will return to normal[95]".

Unfortunately, the forecasts of Crea did not take long to come true. In May, in fact, CO2 emissions in China returned to pre-Covid levels, recording an increase of 4-5% on an annual basis. According to data from Wind Information and the Chinese National Bureau of Statistics reported by Carbon Brief, to date CO2 emissions continue to be about 6% lower than in the same period of 2019. But it is a figure that will not last long[96]. The shutdown of factories and power plants and the freezing of road and air traffic have significantly improved air quality in the Asian giant. At the same time, however, this meant that for the first time in thirty years China was unable to achieve the economic growth targets it had set itself, prompting the government to set aside the "green line" in favor of the exploitation of fossil sources.

it is clear that, without China's contribution to the zero emissions goal (and the Chinese giant still seems far from this), the climate impact will be almost nil.

Second Limit: New Renewables

[95] Dall'Asén, M.J. (2020). *Coronavirus, in Cina la quarantena fa calare le emissioni di C02*. [online] Corriere della Sera. Available at: https://www.corriere.it/economia/finanza/20_febbraio_25/coronavirus-cina-quarantena-fa-calare-emissioni-c02-7e7569f2-57b2-11ea-a2d7-f1bec9902bd3.shtml.

[96] Millivyrta, L. (2020). *Analysis: China's CO2 emissions surged past pre-coronavirus levels in May*. [online] Available at: https://www.carbonbrief.org/analysis-chinas-co2-emissions-surged-past-pre-coronavirus-levels-in-may?utm_content=bufferd871f&utm_medium=social&utm_source=twitter.com&utm_campaign=buffer.

"Renewable energies, which should cover 60% of the energy needs ensured today by hydrocarbons, are not, economically speaking, a commodity". (Giuseppe Zollino)

Renewable sources dominated the energy market until the mid-nineteenth century. As can be seen from the first chapter of this thesis, in fact, the first sources of energy used by man were precisely the renewable ones, which were immediately supplanted when coal first and then oil entered the scene. Still in the first chapter, however, we also see that, after the 1973 shock, things seem to change with the expectation that the new renewables, especially solar energy, could be the solution to every problem. It was said that they were more democratic, because of their extraneousness to the logic of the market, and because they were widely and easily available.

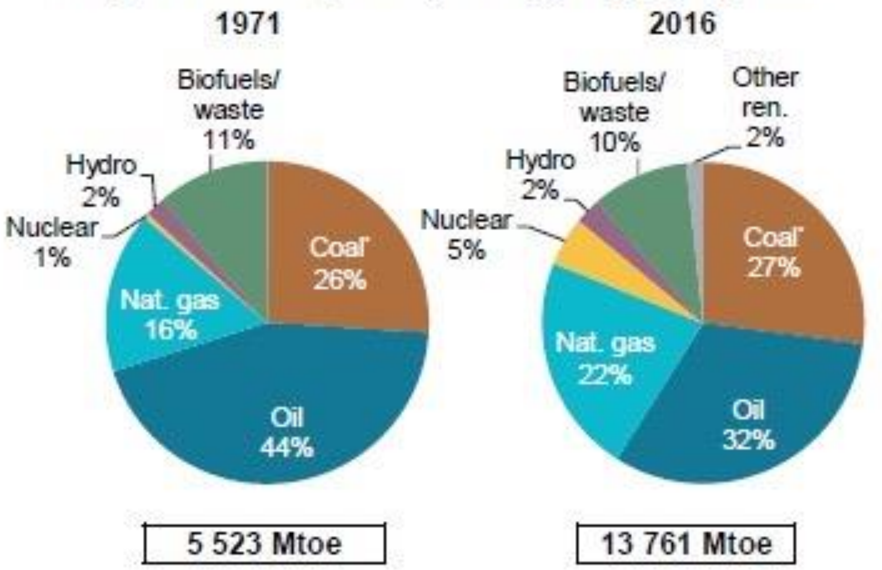
The enthusiasm with which renewables were accompanied in the 70s was not enough. In 2000, the share of solar energy in America did not exceed 0.4%, as Alberto Clò explains well in his book "Energy and Climate".

Still Clò, in an essay from 1989 in the journal “Le Scienze”, analyzes the various reasons (economic, technological, energy, environmental) for which the physical potential of renewables would not translate into effective commercial availability for a long time. In particular, Clò explains how their lower economic convenience compared to traditional sources, expressed by their respective monetary costs, was the exact reflection of a physical indicator of convenience: the energy produced compared to the energy used (directly or indirectly) to produce it, a figure commonly referred to as Energy Return on Investment (EROI).

"The higher its value, the less the amount of energy needed to produce an additional unit of each source (and vice versa). If lower than unity, that source could not be called such: it meant that it would have consumed more energy than it made available. Economic systems with access to higher quality resources (EROI ≥ 1) could do more work than those forced to use lesser quality and lower EROI resources. From the comparison, supported by numerous empirical findings, conventional sources showed values up to 100 - or 100 units of energy produced for each unit of energy used - against levels for renewable energy close to or below 1. The conclusion was that a quantitatively significant penetration of the new renewables could only have taken place following strong advances in technology. " (Alberto Clò)

It is then explained that, in the 1970s, the times for renewables were not yet ripe. However, from the 70s huge investments and public funds were reserved for new renewables, with the approval of the US president Jimmy Carter who, in response to the OPEC embargo, said: "no one can embargo the sun from us"[97]. This period in the United States lasted relatively shortly, given the arrival of Ronald Reagan who decided that when and how much to invest, even in energy, had to be indicated only by the invisible hand of the market and not the contribution of the public. Regarding the physical contribution of renewables, it remained very low.

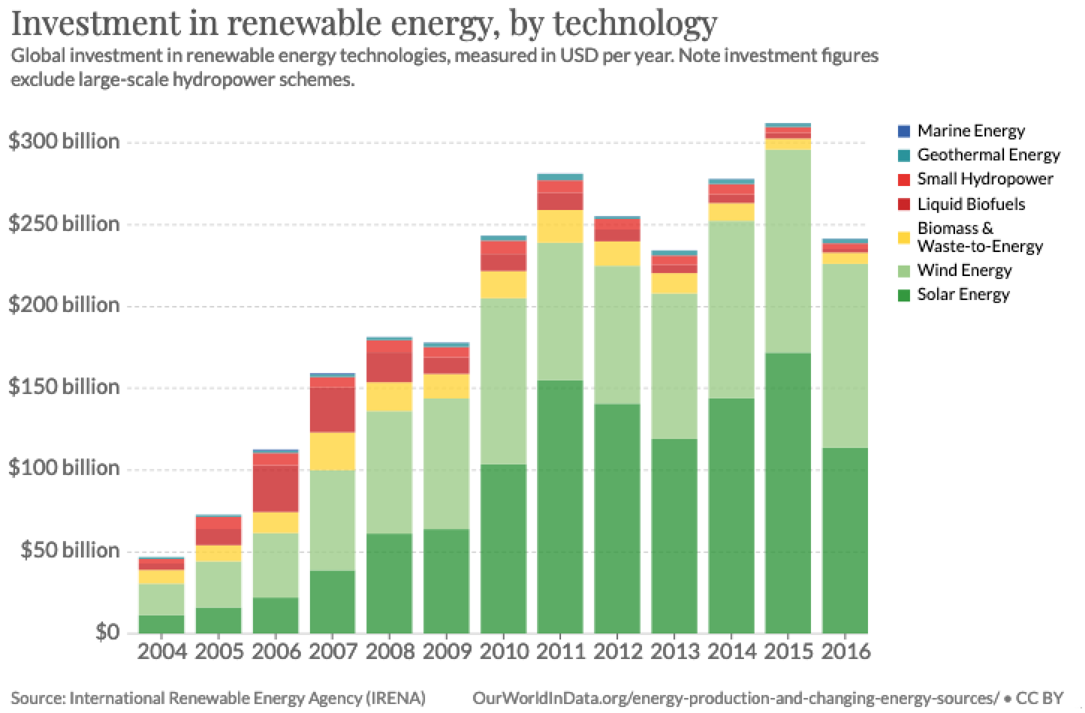
Figure 6. Total primary energy supply by fuel



* In this graph peat and oil shale are aggregated with coal

The history of new renewables finds new life with the emergence of the climate issue, when it becomes a priority on the political agenda. As it was introduced in the second chapter, this new lymph seemed "injected" by the support provided to them by public policies, which were not in any case able to solve the technical limits of renewables, always present and which we will see shortly.

97 don (2016). *Solar Flashback – The White House – June 1979*. [online] Energy Matters. Available at: https://www.energymatters.com.au/renewable-news/solar-white-house-em5535/



The penetration of new renewables, as we can see in the graph, was dictated by huge investments from 2004 onwards, but which had nothing to do with a mere replacement of primary sources (an energy transition from fossils to renewables) but in the affirmation of a new technological paradigm which, from reliable and economic sources that had to be exploited by maximizing outputs and aiming to reduce the amount of input needed, replaced a generation of (renewable) plants of greater capital intensity but of small size , low programmability, much lower utilization rates in a ratio of up to one to five compared to the traditional plants they were replacing.

The more the new renewables "were imposed" on the market, the more the electricity systems had to respond to greater flexibility, due to the unpredictability of the supply of these sources. In fact, solar and wind provided a floating baseload[98].

From the beginning of the new millennium, this second phase of industrial footprint has started worldwide with an extraordinary growth in investments and an increase in electrical power, especially wind and solar, by more than ten times, from 51 to 551 GW, becoming the dominant component in the realization of the new electric power in various areas of the world.

[98] Baseload in an electrical network is the minimum level of demand on the network in a given time interval.

However, the contribution of renewables to the global energy market has always remained limited, due to their underlying technical limits.

The first technical limit represented by renewable energy sources is discontinuity, the problem that humans had overcome with fossil sources. Renewable sources, in fact, always depend on the amount of sun (for a solar power plant) or wind (for a wind power plant) that is present at the moment. The unpredictable discontinuity of sun and wind leads to unpredictable variability in the input of electricity from these points, with sudden peaks and falls in production.

The second limit, directly linked to the first, is obviously the uncertainty. The uncertainty and discontinuity of energy sources such as wind and solar, and their extreme fragmentation in small power plants, are factors that complicate their integration into the grid. In order to absorb the energy generated by these numerous plants (in Europe there are now millions, mainly photovoltaic), allowing their further development, it is necessary both to strengthen the grid, to modify it conceptually and renew it technologically. However, even this would not be enough. To fully exploit renewable generation, which by its nature is typically non-programmable, it is also necessary to provide adequate storage capacity: it can happen, for example, that wind farms reach their maximum production at night, when demand is more scarce or that there are strong intermittences in the generation (gusts of wind) such as to complicate the work of balancing between consumption and generation.

The ability to "store" energy produced from renewable sources is one of the most significant and complicated fronts in the use of renewable resources.

The third major limitation of renewable resources, in fact, is the difficulty of accumulating the energy they produce. Unlike other resources or products, producing electricity and storing it is not possible, but there must be a balance between energy consumption and production at all times.

Electrical energy storage systems allow to convert energy into an accumulated form, store it in this form and then reconvert it to solve the energy storage problem. The main problem of them is that they have characteristics and costs that are not very adaptable to distribution networks or consumer plants (for example, the large hydroelectric generation and pumping plants)[99].

These characteristics, combined to the fact that the power of renewable sources is closely linked to territorial morphology, do not make renewable energy today definable as a commodity, if by commodity we mean an asset for which there is demand but which is offered without qualitative differences.

Case Study: Italy and the Photovoltaic investments

The decisive point in the policy in favor of renewables were the subsidies, aimed at promoting their use, which cost Italy about 16 billion euros in 2016 alone.

As explained in the GSE 2019 report, there is currently a competition mechanism in Italy to encourage the production of electricity powered by renewable sources based on elements of technological neutrality.

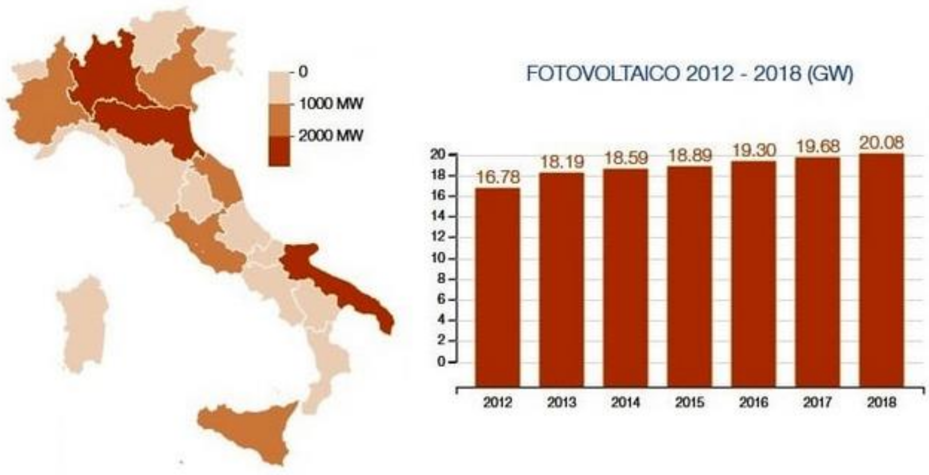
The renewable source on which, from 2007 until 2013, most has been invested in Italy was photovoltaics. Photovoltaics directly transforms sunlight into electricity thanks to panels made up of semi-conductor cells. It uses the photovoltaic (or photoelectric) effect, guessed by the physicist Edmond Becquerel (1839) and explained by Albert Einstein in 1905, who won the Nobel Prize (1921) for that discover. The first industrial application realized in 1954. In summary: when an electromagnetic radiation strikes a material, under certain conditions (specific frequencies of the emitted radiation), release to the outermost electrons of the material's atoms, the sufficient energy to move the electrons hit in away from the atom of origin. The movement of the electrons released, into an electrical circuit, gives life to an electric current. This, in summary, the photoelectrical effect in solar panels.

In 2013, as Chicco Testa, Giulio Bettanini and Patrizia Feletig put it in "Chi ha ucciso le rinnovabili?", the cumulative cost of the incentives given to photovoltaic energy was 6.5 billion. This investment undoubtedly had positive implications, such as the

[99] E-distribuzione (n.d.). *Stoccaggio dell'energia | e-distribuzione*. [online] www.e-distribuzione.it. Available at: https://www.e-distribuzione.it/progetti-e-innovazioni/smart-grids/stoccaggio-dell-energia.html].

fact that in Italy there are about 24 GW of photovoltaic production, one of the largest shares in the world, but it is also true, as always underlined by Testa, Bettanini and Feletig, that this type of success does not certify anything.

In fact, this investment has not translated into a huge amount of energy demand (clearly electricity) covered by photovoltaics in 2019 (7,6%). On the other hand, the money dedicated annually to incentives was not used for other purposes, for example to increase the technological advancement of panels, which would have allowed Italy to get a sort of independence from Chinese production.



Source: [Qualenergia]

As shown in the graph, At the moment in our country there are almost 818 thousand photovoltaic systems which have made it possible to exceed the threshold of 20 GW of installed power.

Of these, 83.7% are related to PV systems below 12 kWp (684,844) for a total power of approximately 3 GW.

Going up in size (12-20 kWp) the plants, in terms of number, reach 62,289, that is 7.6% of the total. The installed power for this specific size is just over one gigawatt[100].

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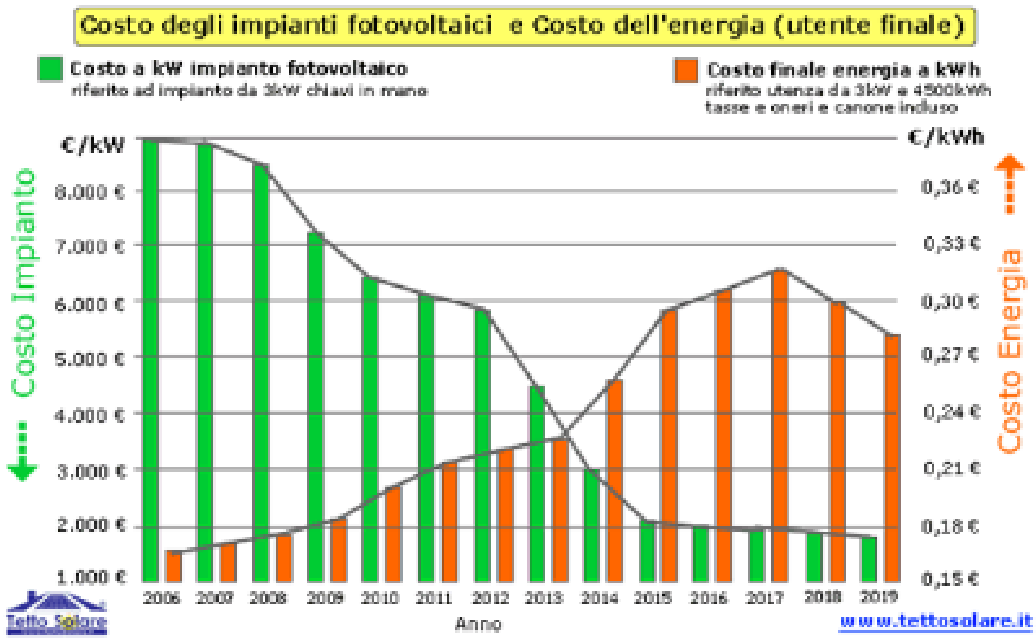
100 Redazione (2018b). *Quanti impianti fotovoltaici ci sono in Italia?* [online] QualEnergia.it. Available at: https://www.qualenergia.it/articoli/quanti-impianti-fotovoltaici-ci-sono-in-italia/.

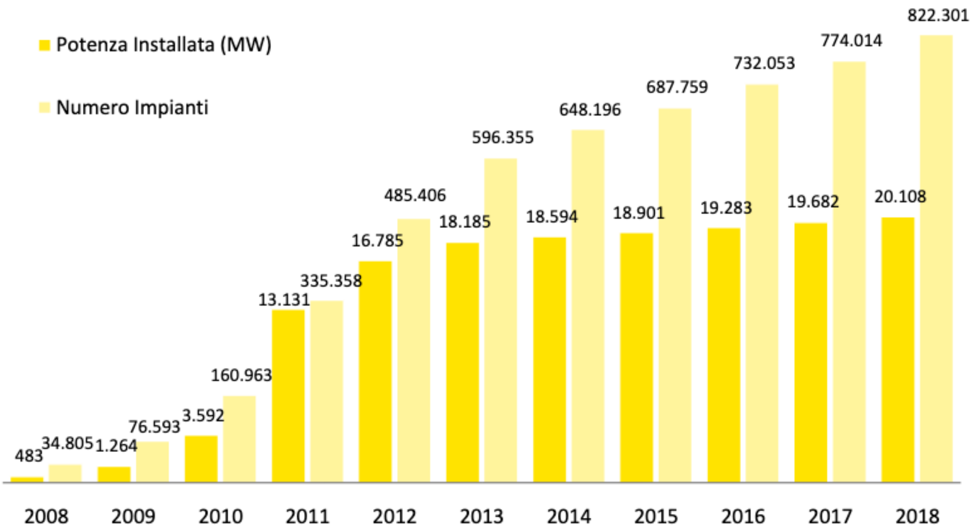
For many, the new renewables market in Italy, with particular reference to photovoltaics, has been defined as "distorted". The point is that in the process of authorization and construction of the photovoltaic plant, the investor regained the investment into a quasi-integral form. In fact, from the moment of entry into operation of the plant, the owner of the business perceived a quota of the GSE through the bolt of Italian branches.

All the gain is very easy to predict. the value of the incentive established by law is multiplied with production, which in turn is easily predictable because it is enough to know the hours of sunshine in the different areas of Italy. What will be obtained is the total turnover; at that point it will be enough to understand how much must be given to those who sell the authorizations, how much to the builder and how much to the bank that financed the investor.



This great predictability is the reason why the price of the photovoltaic, over the years, has dropped dramatically. The suppliers knew exactly how much Italian investors could pay, and the expected revenue. For this reason, a high price was kept as long as the incentive was high, and then lowered when the incentive itself fell.

Of all this investment, little is left. In fact, in Italy there are no companies that produce solar panels capable of competing with Chinese production.



Source: GSE Report Solar Photovoltaic 2018

As GSE explains in its 2018 report, The graph shows the evolution of the number and installed power of photovoltaic systems in Italy; as can be seen, after a phase of rapid growth favored, among other things, by incentive mechanisms called Conto Energia, starting from 2013 the dynamics evolved into a more gradual development. The plants that entered into operation during 2018 - mostly service installations of household users - have an average power of 8.8kW, almost in line with the values recorded for the two-year period 2016-2017. The cumulative average size of the photovoltaic systems gradually decreases, reaching 24.5kW in 2018[101].

The story of the "Conto Energia" is important to understand the reason why from 2013 onwards the photovoltaic incentive system ceased to be predominant.

The first "Conto Energia" came into force in 2005 and established an incentive rate of 0.445-0.460 Euro / kWh, to which were added the benefits of the electricity sold to the grid or the self-consumption of the energy produced.

[101] Studi, A.D., Di Sistema, M., Statistiche, F., Target, M., Cura Di, A., Agrillo, A., Surace, V., Liberatore, P. and Benedetti, L. (2019). *Gestore dei Servizi Energetici*. [online] Available at: https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20statistici/Solare%20Fotovoltaico%20-%20Rapporto%20Statistico%202018.pdf.

The second "Conto Energia" came into force in 2007 and provided for limits to the incentivable power: 3 MWp[102] should have been reached by 2016 and a limit to the incentivable power of 1200 kWp. The incentive rate was between 0.36 Euro / kWh for large ground-mounted systems and 0.49 Euro / kWh for domestic systems with a power of 3 kWp[103].

The third "Conto Energia" remained in force for only five months, in 2011, and was dictated by the need to respond to the drop in the prices of photovoltaic panels. It established an installable power target of 8 GWp by 2020 and an incentivized power limit of 3 GWp by the end of 2013. The problem with this latest "Conto Energia" was the Salva-Alcoa decree, which provided that the plants who's the works had been completed in 2010 and had entered into activity in June 2011, they would have been able to access the tariffs of the Second "Conto Energia". The consequence of this decree, as the GSE warned, was that the requests of the owners of the plants who wanted to be included in the decree made it clear that the power of 8 GWp would be reached already in 2011. It was for this reason that in June 2011 a fourth "Conto Energia". The fourth brings installable power to 23 GWp by 2020 and introduced a limit on the annual cumulative cost of incentives, equal to 6 billion euros. The Fourth "Conto Energia" was responsible for a huge reduction in incentive tariffs and a revolution in the system, with the introduction of an all-inclusive tariff (instead of the incentive) and a bonus for self-consumed energy. The all-inclusive tariff would have been equal to the sum of the commercial value of the energy fed into the grid by the plant and the actual incentive, which was therefore no longer calculated as fixed and supplied on the energy produced but for difference.

The fifth and last "Conto Energia" was issued by the Monti government in 2012 and introduced heavy limits to the plants that could access the incentive and a precise figure indicated as the limit of the cumulative annual cost of the incentives: 6.7 billion euros, at the end of which incentives will no longer be granted and the Conto Energia will cease to be applied.

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[102] MWp is an abbreviation for Megawatt peak – a unit of measurement for the output of power from a source such as solar or wind where the output may vary according to the strength of sunlight or wind speed. MWp is a measure of the maximum potential output of power. A Megawatt is 1,000 kilowatts. A kilowatt is 1,000 watts.

[103] The peak kilowatt (symbol: kWp) is a unit of measurement of the maximum theoretical power that can be produced by an electric generator or vice versa the maximum theoretical power that can be absorbed by an electric load.

The choice was perhaps dictated by arrogance. The 6.5 billion euros of incentives, which we talked about earlier, are the result of an investment of 50 billion euros which assumed an average cost per MW of 3 million euros. Then the price per MW dropped and the yield of photovoltaics instead improved. This would have made it so that if it had been decided to spread the investment over a longer period of time, the economic impact would be greatly reduced and at the same time the technological innovations that took place would have been captured.

The debate then shifted to the name of the incentives for photovoltaic systems, which were considered by many to be almost more than subsidies. In fact, if an incentive translates into perennial support for a sector unable to compete on the market alone, it assumes a "drug effect" which takes the subsidiary form.

In fact, an innovation must be able to be chosen for reasons of convenience. This stage has never been reached by photovoltaics, since, as we have seen, as soon as the incentives disappear it slows down, showing that it is unable to walk alone.

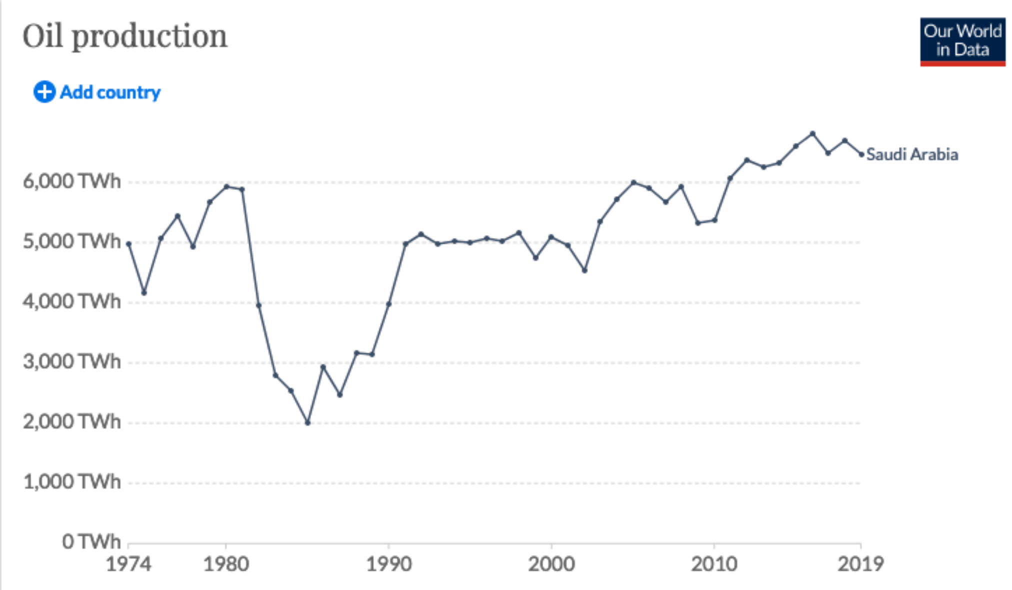
Finally, as an effect of the incentive policy, the mechanism of the Power Exchange must be considered. The power exchange is an organized system of offers, sales and purchases of electricity. The power exchange, provided for by legislative decree no. 79/1999 for the liberalization of the electricity market, was established in Italy starting from April 1, 2004 and is managed by the Electricity Market Operator, which later became the Energy Market Manager in November 2009. The sale of electricity is carried out every day for the following day by resorting to bargaining on an hourly basis where the meeting between supply and demand is carried out through the marginal price system. Put simply, the mechanism remunerates producers by paying the equilibrium price between supply and demand. A perfect competitive mechanism, however, is altered by the rule, valid for the entire European Community, which gives to renewables priority for dispatching, the entry of the various plants on the distribution network (grid).

Third Limit: Export Countries

A decarbonization policy must also be able to take into account the various geopolitical balances at stake. It is clear that, in a possible energy transition, the countries that should face the greatest consequences are precisely the main exporting countries. The decrease in exports, which would consequently be accompanied by a lowering of prices, would have heavy repercussions on various economic systems. It is therefore evident that the countries producing fossil energy sources, faced with a decrease in demand, will have to review their economic system from the ground up. The consequences for countries such as Saudi Arabia and Russia, for example, could be far-reaching, even affecting the role of these countries in the international scenario.

Case Study #1: Saudi Arabia

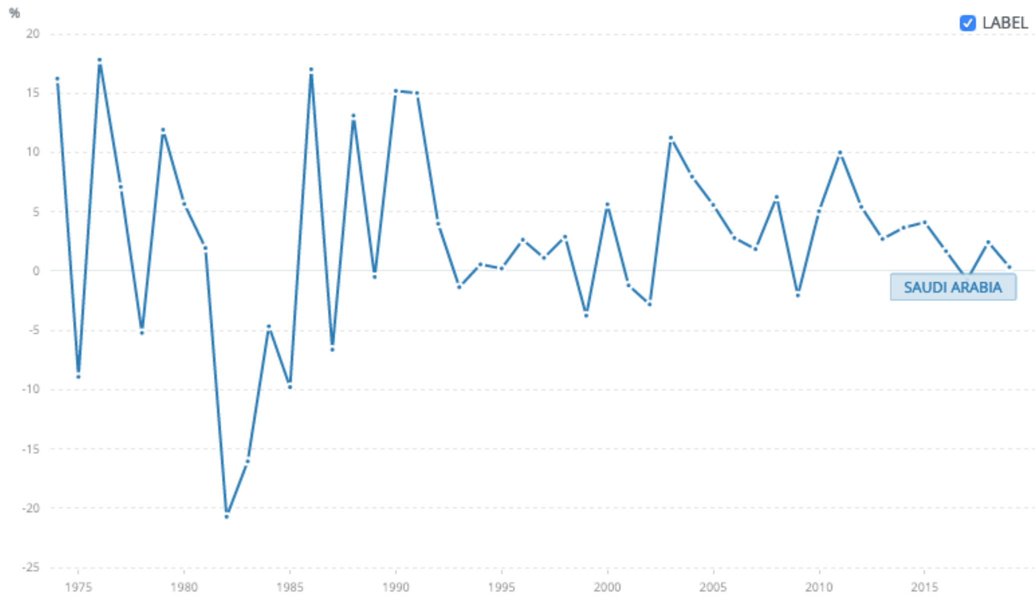
Saudi Arabia is one of the largest oil exporters: the oil sector accounts for nearly 90% of Saudi budget revenues, 90% of exports and 42% of GDP. In fact, 10% of world oil production comes from the Saudi Kingdom. But Riyadh is also the sixth largest consumer of crude oil in the world, with around 3.5 million barrels used per day. The population is constantly increasing, with an annual rate of 1.6%, and with an expectation for a higher quality of life.



As can be seen in the graph, the oil production trend in Saudi Arabia has grown from the 2000s onwards. The boom of the 1980s, due in part to the Iranian revolution of 1979 which led to the blockade of production for the latter, was soon followed by a cut in production by Saudi Arabia. In fact, from 1982 to 1985 OPEC tried to set production quotas at a level low enough to stabilize the price of oil. These attempts failed as many members of the organization ended up producing in excess of their commitments. During this period Saudi Arabia played the role of "swing producer", cutting its production to contain the free fall in prices. In August 1985, the Saudis got tired of performing this function. They tied their prices to those of the marketplace and in early 1986 increased production from 2 to 5 million barrels / day, with the result that the price of crude oil plummeted to $ 10 in the middle of the year[104].

As already stated, Saudi Arabia is a “swing producer” in the global oil scenario, meaning that it is capable of rising production sharply with a minimum increase in internal costs and, thanks to its position, of affecting global market prices, providing medium and short-term downward protection. This illustrates how the high amount of oil reserves and production has greatly contributed to the country's economic development and stability.

In fact, Saudi Arabia's economy is almost entirely linked to oil exports, so a potential decline in exports and a decrease in prices could have a very negative impact.



The very clear link between Saudi Arabian GDP and oil production is explained by the second graph, which analyzes GDP growth (%). As we can see very clearly, the periods of decline in oil production also correspond to a significant decline in GDP in percentage terms. In 2015, for example, following the collapse in oil prices, GDP fell by 0.1%, while the state budget deficit was 15% of GDP in 2015 and 12.6% in 2016.

It is therefore clear that a policy of decarbonization by Europe risks having a strong impact on the Saudi economy.

104 Galeotti, M. *1986-2006: VENT'ANNI DI PREZZI DEL PETROLIO.* [online] Available at: https://www.ice.it/it/sites/default/files/inline-files/Rapporto%20Ice%202006%20-%20Galeotti.pdf

Indeed, in 2017, more than half (55.1%) of the EU-28 gross available energy was covered by imports[105]. Of these imports, only Italy covers large quantities of oil and semi-finished products from the Middle East for a total of over 27.6 million tons, according to data updated to 2017 in the "Unione Petrolifera" Data Book: 6 million tons arrive from Saudi Arabia, along with 2.2 million semi-finished products[106].

In order to reduce its dependence from oil exports, Saudi Arabia faced an important economic challenge. Upon ascending to the throne the following year, King Salman bin Abdulaziz Al Saud and his son Mohammed bin Salman Al Saud (now the crown prince) developed an ambitious economic and social reform plan, Saudi Vision 2030, which was presented in 2016 and designed to reduce the country's dependence on oil by facilitating the emergence of a robust private sector.

Vision 2030 is a response to the oil prices, which were $115 a barrel in June 2014, plummeted steadily in the summer of 2014, reaching $28 a barrel in January 2016. In January 2018, it stabilized at $68 a barrel after Saudi Arabia and OPEC agreed to cut production in 2017, a decrease of 41 percent from its 2014 peak.

The effect was profound on Saudi government finances and, by extension, on the economy. In 2016, government revenue declined precipitously to about $133 billion (SAR 500 billion), less than half of the nearly $320 billion (SAR 1200 billion) in 2013. Economic growth plummeted from 6 percent (annual year-on-year) in the first quarter of 2014 to 2 percent in the third, then somewhat recovered in 2015, then lacklustered in 2016, and finally turned negative in 2017. Between mid-2014 and 2016 the stock market in the country fell by half in value. As oil revenues dropped, the government budget dropped into deficit, hitting 14.8 per cent of GDP in 2015. Government debt increased from 1.6 percent of GDP in 2014 to 5.8 percent in 2015 and 13.1 percent in 2016 and continues to rise today (25% of GDP, which it is still small, compared to

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105 ec.europa.eu. (n.d.). *Produzione e importazioni di energia - Statistics Explained*. [online] Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_production_and_imports/it#L.27UE_e_i_suoi_Stati_membri_sono_tutti_importatori_netti_di_energia

106 Unione Petrolifera (2019). *Databook 2019*. [online] Available at: https://www.unionepetrolifera.it/wp-content/uploads/2019/04/UP-Data-Book-2019-compresso.pdf.

international standards). Official foreign reserves dwindled from a peak of approximately $730 billion (SAR 2,745 billion) in 2014 to approximately $600 billion (SAR 2,300 billion) at the beginning of 2016, hovered around $500 billion (SAR 1,900 billion) at the end of 2019, and fell sharply to $464 billion (SAR 1,745 billion) in March 2020[107].

In December 2015, McKinsey Global Institute, a research arm of McKinsey and Company (which has advised Saudi leaders for years along with Boston Consulting Group and Booz Allen Hamilton), published a study evaluating the Saudi economy in the aftermath of the oil slump[108]. The study made grim forecasts for the economic future of Saudi Arabia. Even with some policy adjustments, the consultancy estimated that "unemployment will grow quickly, household income will decrease and the national government's fiscal situation will be dramatically detected." Their advice to avoid economic stagnation was a "productivity-led economic transition." Generally, McKinsey established an urgent need to move from an oil-based economy.

Saudi Vision 2030 is the answer: it aims to draw on Saudi Arabia's three perceived competitive advantages: its central place in the Arab and Muslim worlds as the custodian of the Holy Mosques, its financial strength as a potential investment powerhouse and its geographical location at the crossroads of three continents.

In the section "Building a thriving economy" a passage declares: "building renewable energy systems", with a 200 billion investment in Solar project.

Vision 2030 immediately had to clash with the reality of Covid-19. In April 2020, the iMF estimated a 2.3% economic slump in Saudi Arabia and a 3% economic contraction worldwide. this will have a significant impact on every aspect of Saudi Arabia's economic life. The government has already stated that, while appealing to its reserves and debt markets to finance the budget, it will slash spending in the 2020

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107 Barbuscia, M.R., Davide (2020). Saudi foreign reserves fall at fastest for two decades. *Reuters*. [online] 29 Apr. Available at: https://www.reuters.com/article/us-saudi-budget/saudi-foreign-reserves-fall-at-fastest-for-two-decades-idUSKCN22B0W5.

108 Mckinsey & Company (2015). *Moving Saudi Arabia's economy beyond oil*. [online] McKinsey & Company. Available at: https://www.mckinsey.com/featured-insights/employment-and-growth/moving-saudi-arabias-economy-beyond-oil.

budget[109]. The finance minister also said budgets might be cut "sharply" and told Saudis "the path ahead is long."[110]

Riyadh's state revenues are still heavily dependent on energy revenue. The post-hydrocarbon economic transformation, as described in the "Vision 2030" plans, is not based on oil but is made possible by oil and the income generated by it: one example is the Saudi sovereign fund, the Public Investment Fund (Pif), and that 5% of Saudi Aramco now listed on the Riyadh stock exchange. Therefore, the shock of the pandemic and the shock of the oil market have a profound impact on the timing and ambitions of "Vision 2030". The socio-economic reform, and from the aspirations of identity, on which MbS has bet the throne had not been elaborated (in 2016 when it was made public) assuming the barrel of oil at (approximately) 40 dollars, as it is today: in December 2019, the spending budget presented by the kingdom fixed the barrel of crude oil still at 60 dollars.

For this reason, the ambition of a Non-Oil Saudi Society is in tatters.

On 3 September 2020, Aramco of Saudi Arabia said it will shelve a multi-billion-dollar investment in the Port Arthur LNG terminal of Sempra Oil. It also said that it will postpone investments at its Yanbu hub in a $20 billion refining and petrochemical project at home[111].

Instead, the 200 billion Solar Project is in trouble: government sources in Riyadh told the Wall Street Journal that Saudi Arabia was not pursuing its solar farm project it had conceived in collaboration with the SoftBank of Japan. No one worked on the project,

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[109] Staff, R. (2020). Saudi government agrees on cutting 5% of 2020 budget. *Reuters*. [online] 18 Mar. Available at: https://www.reuters.com/article/health-coronavirus-saudi-budget/saudi-government-agrees-on-cutting-5-of-2020-budget-idUSL8N2BB9C6.

[110] Turak, N. (2020). *Saudi Arabia hit with Moody's downgrade, prepares for "painful" measures — but can likely weather the storm*. [online] CNBC. Available at: https://www.cnbc.com/2020/05/04/coronavirus-oil-shock-saudi-arabia-gets-downgrade-painful-measures-ahead.html.

[111] Slav, I. (2020). *Low Oil Prices Force Aramco To Delay LNG, Petchem Ambitions*. [online] OilPrice.com. Available at: https://oilprice.com/Energy/Energy-General/Low-Oil-Prices-Force-Aramco-To-Delay-LNG-Petchem-Ambitions.html.

the sources said, and Riyadh was talking about a replacement with many smaller solar projects[112].

The push for energy diversification was focused precisely on the materialization of oil revenues. And now that the effects of the coronavirus pandemic on oil demand have drastically decreased these revenues, Prince Mohammed 's vision is under pressure.

Irina Slav, a writer for Oilprice.com with over a decade of experience writing about the oil and gas industry, says: "There was always some questions about Saudi Arabia able to pull all these ventures off. They were just too costly, even for its huge sovereign fund. Naturally, it was never thought that the Kingdom would finance all these big initiatives on its own, but it did rely on Aramco."

The fall in oil prices, however, contributed to Aramco 's collapse. This spring, almost all the oil stocks collapsed, so Aramco was not the only one. But what was unique about it is that it is hinged on by a whole program of economic diversification.

With all these stressors, Vision 2030 is still in play, but it risks remaining just a mirage. The big problem, in analogy with what the Green Deal could present, is the thunderous nature of the announcements made that have little response in reality. The Covid-19 pandemic may only have exposed an already existing problem faster.

As for the European Green Deal, however, it must be taken into account that, despite the attempts to detach from oil that Saudi Arabia has been operating in recent years, its economy is still strongly based on exports of this fossil source, a factor that Europe must consider to keep the geo-political balance intact in the Saudi area.

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[112] Slav, I. (2018). *$200 Billion Saudi Solar Megaproject Might Never Happen*. [online] OilPrice.com. Available at: https://oilprice.com/Alternative-Energy/Solar-Energy/200-Billion-Saudi-Solar-Megaproject-Might-Never-Happen.html.

Case Study #2: Russia

Russia exported nearly US$ 33.7 billion worth of crude oil to China, the highest export value of this commodity among other importers in 2019.

It is also facing heightened competition, however. The 'silent revolution' of shale gas in the United States caused a change in export-import routes and, more significantly, put the United States in the position of a net exporter[113]. As a result, competition among exporters of natural gas has increased significantly, leading to a drop in the price of natural gas and even price wars, especially in the European natural gas sector[114]. In the United States, the shale gas boom has also led to a reorientation of natural gas import-export routes[115], as well as a massive expansion of liquefied natural gas (LNG) trade, generating gas-to-gas competition. Other producers are also raising their shares in the natural gas market. For example, China and Australia account for the significant increase in natural gas exports[116].

A 'transition fuel' into a safer, more efficient and more environmentally sustainable source of energy is known to be natural gas. Natural gas production and usage are expected to increase steadily in all energy scenarios, and continued growth in the consumption of natural gas in the Asian markets is projected to remain steady and long-term; higher demand for natural gas is expected[117], although the source of this growth is different from what anyone thought (replacement of coal with natural gas due to environmental and natural gas).

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113 Statistical Review of World Energy (BP) 68th edition (2019)

114 Rystad Energy (n.d.). *Lowest European gas prices in a decade*. [online] www.rystadenergy.com. Available at: https://www.rystadenergy.com/newsevents/news/press-releases/Lowest-European-gas-prices-in-a-decade/

115 IEA. (n.d.). *The US shale revolution has reshaped the energy landscape at home and abroad, according to latest IEA policy review - News*. [online] Available at: https://www.iea.org/news/the-us-shale-revolution-has-reshaped-the-energy-landscape-at-home-and-abroad-according-to-latest-iea-policy-review

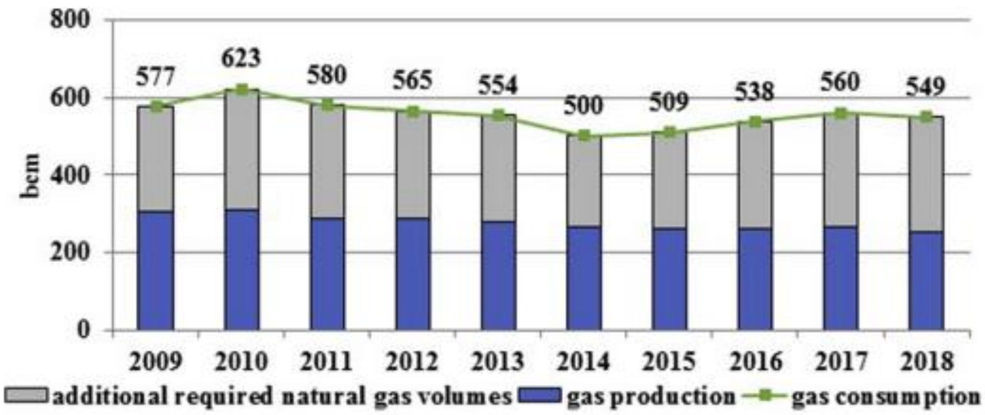
116 IEA. (n.d.). *Market Report Series: Gas 2019 – Analysis*. [online] Available at: https://www.iea.org/reports/gas-2019

117 Statistical Review of World Energy (n.d.). *BP Energy Outlook 2019*. [online] Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2019.pdf.

Russia is the world's second-largest natural gas producer after the United States, followed by Iran, Canada, and Qatar. In recent years, global natural gas output has reached the highest level of 3868 billion cubic meters (bcm), and that of Russia in 2018 was 669 bcm[118]. The presence of enormous natural gas resources in Russia, irrespective of the domestic market situation, gives the possibility of growing gas exports. In Russia, over 30 percent of the total supply of natural gas is exported.

During the USSR era, a vast system was developed for the export of natural gas, including pipelines, pump stations and other related infrastructures, mainly aimed at European consumers[119]. The infrastructure 's capacity still ensures the regular delivery of natural gas to the CIS countries and Europe[120]; it must be stated that the pipeline system is not flexible in nature and is connected to unique markets or customers.

For this reason, for Russia, the European Gas Market is genuinely strategic.



Natural gas production, consumption, and additional required volumes in Europe

Source: Kutcherov, V., Morgunova, M., Bessel, V. and Lopatin, A. (2020). Russian natural gas exports: An analysis of challenges and opportunities. *Energy Strategy Reviews*, [online] Available at: https://bit.ly/3kBvcTR.

[118] Statistical Review of World Energy (BP) 68th edition (2019)

[119] Country Analysis Brief: Russia. (n.d.). [online] Available at: https://www.eia.gov/international/content/analysis/countries_long/Russia/russia.pdf.

[120] Vatansever, A. (2017). Is Russia building too many pipelines? Explaining Russia’s oil and gas export strategy. *Energy Policy*.

Europe is a net importer of natural gas, where demand far exceeds the estimated proven reserves of the country. The graph shows summarized data on the production, use, and additional volumes required for natural gas. In numerical terms, the energy dependence rate, which indicates the percentage of energy that must be imported by the economic system and, in particular, determines the ratio between the value of new net energy and the gross internal energy consumption, is 58% for Europe, which means that net imports meet more than half of the EU's energy needs. In terms of natural gas, these imports are due to two thirds of the two main countries, Russia and Norway, which are thus verified as the most energy-dependent countries in the EU. Russia accounts for 40.5 percent of the supply share, in particular. The structure of European natural gas imports is especially significant. The gas sector in Europe has a more comprehensive export-import structure than the U.S. market, with natural gas being supplied to European consumers through pipeline networks and LNG, due to the presence of a variety of exporters (Russia and Central Asian countries). Today, Russian export prospects are mixed in the European economy. The European Green Deal ventures, the shift in export-import flows of natural gas due to the dramatic increase in shale gas output in the United States and the global increase in LNG demand have had an immense impact on the European gas sector, where many more exporters are vying for market access. Russia will therefore face significant difficulties in achieving a higher share of imports or even maintaining current levels as a result of higher competition and over-supply of natural gas (from other LNG suppliers such as Qatar, North African countries and the US) to the European market. But the geopolitical dimension is the key aspect. First, as Poland did in September 2019, political decisions limit Gazprom's use of European gas transport networks[121]. In addition, at the end of December 2019, US President Donald Trump signed a law which provides for sanctions against companies involved in the Nord Stream 2 pipeline construction, hampering the diversification of Russian natural gas export routes to Europe[122]. Completing the Nord Stream 2 development, now implemented at 94 percent, is currently the greatest challenge for Gazprom. To understand the delicate geopolitical balances at stake, the history of what preceded Nord Stream 2 is very important. As far as Russia is concerned, two fundamental guidelines are followed by the Kremlin: one aimed at seeking routes for exports of natural gas to Europe, while avoiding transit through Ukraine, and the other, with particular attention to the

[121] Gazprom is a partially State (Russia) owned energy company focused on geological exploration, production, transportation, storage, processing and sales of gas, gas condensate and oil, sales of gas as a vehicle fuel, as well as generation and marketing of heat and electric power.

[122] Trump signs off sanctions on Russia gas pipeline. (2019b). *BBC News*. [online] 21 Dec. Available at: https://www.bbc.com/news/world-europe-50875935.

increasing Asian demand for gas, towards non-European markets. As for the objective of diversifying away from Kiev, in the wake of the initial success of the first, Nord Stream was first developed by Russia and a second project, the so-called South Stream, was established. This pipeline, if built, would have allowed Russian gas to be exported across the Black Sea to Bulgaria and Central Europe, with a capacity of 63 billion cubic meters per year. Construction works, which had already started in 2012, were then stopped and the project abandoned following some key concerns raised by the European Commission itself, mainly of a regulatory nature[123]. It would have resulted in a massive European dependence on Russian gas, putting the EU and its Member States at higher security risk. Moreover, Europe had previously attempted to cope with the geopolitical risk arising from Moscow's excessive reliance on energy through the Nabucco gas pipeline, a project to build a new route for importing natural gas via a southern area dominated by Russia. The hypothesized path actually involved importing gas from the area of the Caucasus and, potentially, from the area of the Mid-Caucasus. The project was therefore of great strategic importance because, by-its diversification, it would have contributed to improving the protection of the EU's energy supply, a goal which was also highlighted in the Third Energy Package[124], entered into force in September 2009. The loss of South Stream did not, however, lead to a halt to the Kremlin 's strategy, which merely changed its scheme by turning to a new partner: Turkey. Indeed, an MoU was signed between Gazprom and the Turkish company Botaş in December 2014 for the construction of a new offshore gas pipeline, the so-called TurkStream, shortly after the announcement of the termination of the South Stream project. Although Turkstream has received less media attention than Nord Stream 2, in shaping the geopolitical balance between Russia and Europe, it is equally significant. Bulgaria, in fact, is stuck between the EU and Russia; on the one hand, it seeks to orient itself among the European rules on the internal energy market, but on the other hand, it seeks to optimize the potential benefits of becoming a transit country. Sofia is highly involved in being a center for gas and TurkStream is an important component of this strategy. This last point seems even more true if we remember that the latest pipeline has begun to supply gas from the beginning of 2020

[123] European Commission - European Commission. (n.d.). *Press corner*. [online] Available at: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_14_505

[124] HJ (2019). *Third energy package*. [online] Energy - European Commission. Available at: https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/third-energy-package_en.

in Bulgaria, North Macedonia and Greece[125]. The geopolitical risks resulting from such a scenario are easily apparent, moving beyond the pure numerical significance of the data and heading through a broader analysis, all the more so if the political tensions that have shaken Moscow-Brussels relations in recent years are considered. Firstly, the unilateral seizure of Crimea by the Kremlin in 2014 and the consequent Western sanctions against Russia. As a result, relations between the two parties have deteriorated, making the introduction of European policies aimed at securing the supply of energy an absolute priority, which is, however, connected to climate policy. In the light of what has been studied so far, it is clear that Russia will not abandon its attempt to join the European market, despite all its peculiarities and complexities, and this is a fact for which the EU and its Member States must be prepared so that a clear and secure role can be taken in the future, based on a broad consensus. International energy supply elements are important, and, like many other economic and political dynamics, they form relations between states by altering their power balance[126]. Instead of staying within the same import logic, the decision to follow a course of energy diversification is mostly a risk, which is then destined to unfold its consequences from a commercial, economic, legal and geopolitical point of view. Russia's supplies are also no exception, and indeed, considering the potential energy security ramifications, they have much greater global reach.

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[125] Staff, R. (2019). Bulgaria to get Russian gas supplies via TurkStream. *Reuters*. [online] 30 Dec. Available at: https://www.reuters.com/article/us-bulgaria-russia-gas/bulgaria-to-get-russian-gas-supplies-via-turkstream-idUSKBN1YY0SW

[126] Ciaboco, S. (2020). *La vexata quaestio circa la dipendenza energetica dell'UE dalla Russia*. [online] Eurobull.it. Available at: https://www.eurobull.it/la-vexata-questio-circa-la-dipendenza-energetica-dell-ue-dalla-russia?lang=fr#nb2-5

4TH CHAPTER: Zero Emissions Strategy

Nuclear Energy

Referring to the forecasts made by IPCC, even if we managed to completely stop emissions today, the current CO_2 concentration is above 410 ppm, that will remain in the atmosphere for, at least, another century. To reach decarbonization fast enough to be achieved by 2050, and mitigate the effects of the global warming, the world will need to halve emissions for each of the next decades.

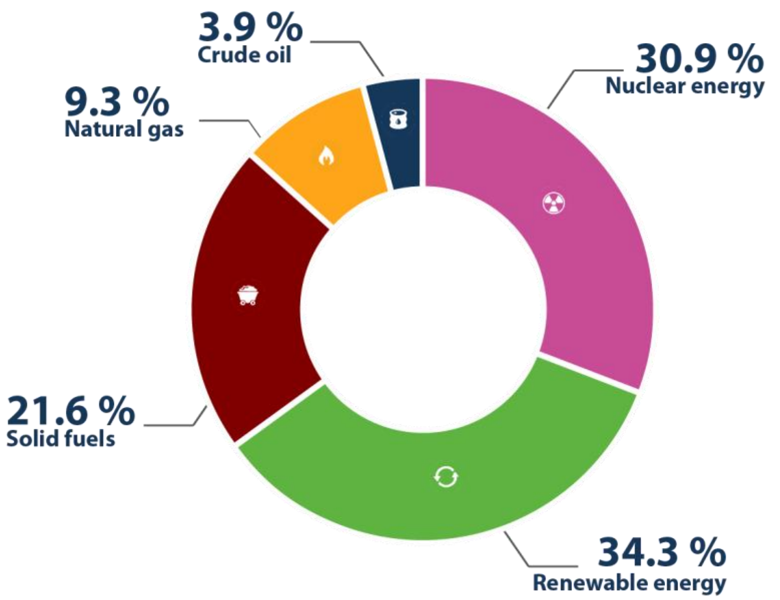
The difficulty is clear, but it is made more difficult if the European energy mix of non-emission system does not consider the Nuclear energy.

Nuclear energy was officially born in 1934 with experiments carried out by a group of Italian scientists under the guidance of physicist Enrico Fermi. The group is also known by the name of "boys of Via Panisperna" where the headquarters of the institute resided. The studies were carried out in 1938 by the German chemist Otto Hahn who for the first time was able to demonstrate the principle of nuclear fission by which the functioning of a power plant is still based today.

In a nuclear fission power plant, uranium is used as a raw material. Uranium is formed from a mixture of three isotopes: U-235, U-238 and U-234. U-238 is the most abundant, present for about 99.3%, while U-235 is the only one, of the three, fissile. Bombarded by a beam of slow neutrons, U-235 splits, releasing neutrons which slowed down by a specific moderator (light, graphite, other materials), hit other nuclei of U-235, giving rise to the so-called “chain reaction”. Together with neutrons, each fissioned nucleus release a considerable amount of energy. It heats the water, which in turn vaporizes. The steam moves a turbine, which by turning creates kinetic energy. At the end, a transformer converts this kinetic energy into electrical energy, sending it to the network. In order to have the necessary quantity of U-235, the isotopes of uranium are separated to increase the concentration of U-235 compared to U-238; this process is called uranium enrichment. Uranium is considered "enriched" when the U-235 fraction is considerably higher than the natural level (approximately 0.7204%), typically on values between 3% and 7%.

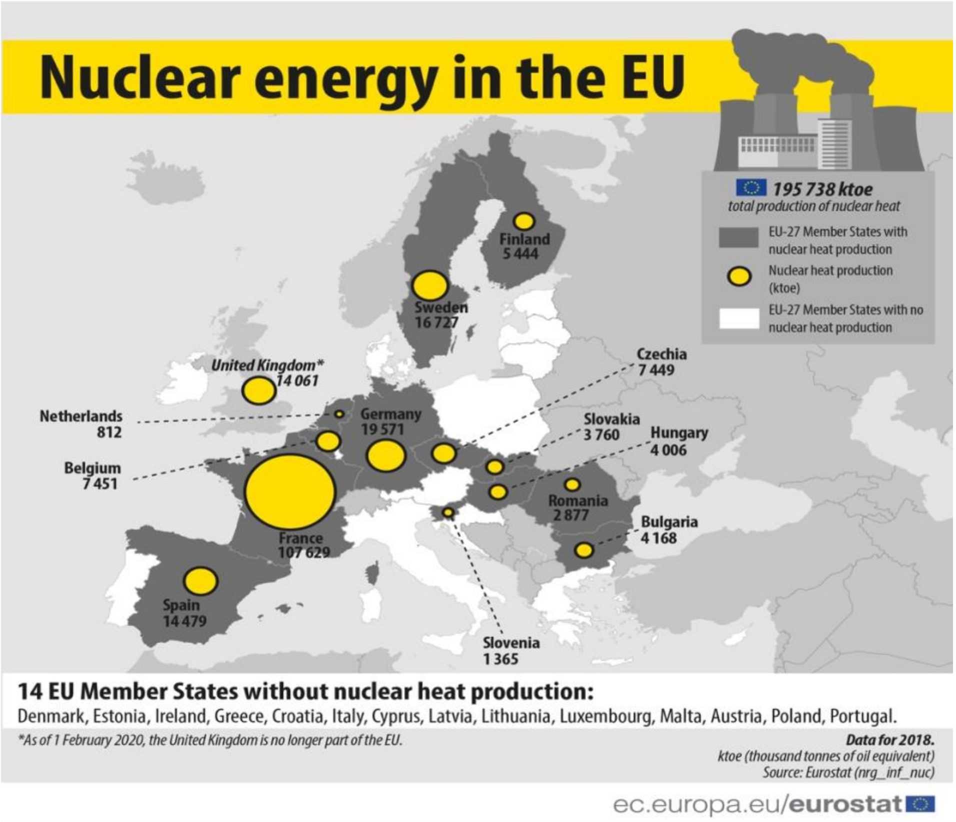
A total of 119 billion Watts (GWe) of nuclear power is provided by European nuclear power plants, but more than half of these come from the 58 French power plants. With the fission of the atom, Paris produces over three quarters of its electricity. Another element is the fact that another 56 nuclear power plants operating in non-European states (Russia, Ukraine and Switzerland) account for as much as 17% of our energy needs within the Union.

Share of EU energy production by source, 2018



Source: Eurostat

A Brief History of Nuclear Energy



Born in 1951, the first six founding states of the Coal and Steel Community (ECSC) agreed that nuclear power was the perfect way to accomplish energy independence and thus dealing with fuel shortages and major industrialization. For this reason, the European Atomic Energy Community (Euratom) was founded in 1957 by those same six members, including Italy, with the goal of contributing to the research and development of nuclear fission power plants.

Since then, Europe has undertaken the construction of various nuclear power plants, also in Italy, without specific critical problems. However, after the Chernobyl disaster in 1986, Italy called on its citizens to express themselves with a referendum in 1987 on the nuclear option that led to the definitive closure of the reactors already in service (Caorso, Garigliano, Latina, Trino Vercellese). In 2011, another nuclear accident (Fukushima in Japan) brought Europe and Italy back into doubt, and a second referendum in Italy just three months later resulted in a definite renunciation of nuclear power, while Belgium temporarily shut down two plants following the discovery of cracks in the center of the reactor, and Germany shut down eight plants, announcing plans to dismantle them by 2022.

A turn around appears to be very difficult for the countries that have renounced nuclear power, in particular Italy. First of all, since Italy does not have reusable facilities, it is unimaginable to bring back into operation the power stations that were scrapped in the 1990s, since they are outdated. There is also a shortage of technicians, physicists and engineers. Others, geared towards renewable energy, appear to be the programs. In fact, even the historic National Nuclear Energy Committee (CNEL) has been renamed as the National Alternative Energy Agency (ENEA).

Nuclear and new renewables: the comparison

As was partly stated earlier, investment in the construction of new nuclear plants is steadily falling.

In 2011, Germany launched a program for the gradual dismantling of its reactors to be completed by 2022, Belgium approved a similar plan that should start shortly[127] and in the USA the long-awaited draft of the Democratic Green New Deal proposes a real transition energy based only on wind, solar and geothermal to be realized by 2030, with nuclear excluded, as noted James Temple, senior editor of the MIT Technology Review[128].

The paradox, however, is that countries such as France, the United Kingdom, Slovakia and Hungary are preparing to build new reactors at the same time. And the role nuclear power can play in the energy transition has also been welcomed by a significant part of the scientific community. Above all, this path is pursued for comparison with the new renewables.

It has already been clarified in the third chapter that new renewables have proven to be inadequate on their own to satisfy our increasing energy needs, despite their popularity.

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[127] World Nuclear News (2018). *Belgium maintains nuclear phase-out policy - World Nuclear News*. [online] www.world-nuclear-news.org. Available at: https://www.world-nuclear-news.org/Articles/Belgium-maintains-nuclear-phase-out-policy

[128] Temple, J. (2019). *The Green New Deal has been released. Here are four key tech takeaways*. [online] MIT Technology Review. Available at: https://www.technologyreview.com/2019/02/07/137532/the-green-new-deal-has-been-released-here-are-four-key-tech-takeaways/

This is because, as we have already said, modern renewables, unlike atomic energy, remain connected to uncontrollable natural phenomena, such as the sun, the wind and the availability of water, all seasonal features. For example, solar and wind power have abrupt and unexpected drops that require us to use solutions such as natural gas to serve as a backup to the daily demand for electricity, nullifying part of the efforts made to curb polluting emissions.

Then there is the problem of land consumption caused by solar panel fields, a topic that is very close to the heart of those involved in habitat conservation. Finally, hydroelectric and geothermal are necessarily linked to particular landscape and geological formations, which not all countries have[129].

To manage the growing energy demand, it has become clear to many experts the need to add a reliable energy source to the new renewables, if we were to exclude fossil sources. Nuclear energy, which could have been a valuable player in the fight against emissions, is suffering hostility from the European Green Deal.

The art. 5 of the Just Transition Fund, in fact, provides for not support the decommissioning or construction of nuclear power plants[130].

Yet nuclear power is an option that is already available, low-carbon and basically limitless. In addition, it costs much less to build a reactor today than it once did. Through the energy provided by the fission of uranium-235 and plutonium-239 isotopes, electricity is still created in the same way, but the new plants being tested are smaller and simpler to construct than the big and costly ones from the past.

They are the so-called *small and modular reactors* (SMR) which are of smaller power (ranging from few MW to 300/400 MW) than the current large plant (on average of 1600 MW). SMR are feasible in shorter periods and at lower costs[131]. Modularity and

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[129] Saltori, M. (2019). *Perché abbiamo ancora paura dell'energia nucleare?* [online] The Vision. Available at: https://thevision.com/scienza/energia-nucleare-cambiamento-climatico/

[130] Redazione (2020). *Fonti fossili (gas compreso) e nucleare esclusi dai fondi Ue per la transizione energetica | QualEnergia.it*. [online] Qualenergia.it. Available at: https://www.qualenergia.it/articoli/fonti-fossili-gas-compreso-e-nucleare-esclusi-dai-fondi-ue-per-la-transizione-energetica/

[131] Philips, L. (2019). *The new, safer nuclear reactors that might help stop climate change*. [online] MIT Technology Review. Available at: https://www.technologyreview.com/2019/02/27/136920/the-new-safer-nuclear-reactors-that-might-help-stop-climate-change/.

smaller dimensions of SMR plays down one of the biggest issues of current nuclear plant: location and related infrastructural equipment. Technically SMR plays down, further, important criticism of the current nuclear power (radioactive waste, safety). Once SMR will enter series production will reduce the fixed investment costs typical of existing nuclear plants. Modularity is a key factor. For instance, in the case of a reactor built by Portland's NuScale Power, the capacity of a single reactor (module) is 60 megawatts of power, just around 6% of the power generated by a conventional reactor. But other modules (reactors) can be added each time the energy demand increases or need it. Several SMR projects are underway. However, as regards the development of nuclear technology, the problem remains social consensus, especially in Italy, and questions in public opinion still consideing nuclear energy dangerous.

Nonetheless, study published in the Lancet in 2007 showed that nuclear energy is the safest source both in terms of emissions and in terms of health consequences. Main problem, in current nuclear energy, remains that of exhausted waste. The solution used up to now is that of confinement in adequate underground deposits continuously monitored[132]. This solution, widely practiced, for safe storage of the large part of nuclear waste produced by the process in a nuclear plant, is particular only for a very small percentage (just 3% of the total) of the waste: spent fuel and a series of by products with very long decay, as testified by projects such as that of Yucca Mountain, in Nevada[133]. According to the US Department of Energy, however, all the exhausted material accumulated in sixty years by the United States would cover an area of about 7 thousand square meters by 9 meters high[134].

This does not suggest that even the hypothetical risks of an accident can be reduced, but it remains a fundamental challenge to explicitly balance global energy needs with the risks associated with the technologies that we use. The time available to make these choices continues to decrease.

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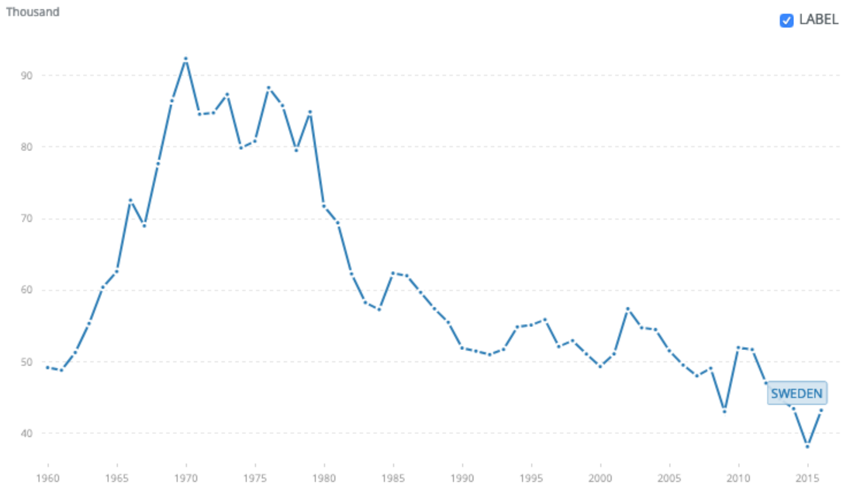
[132] Gibney, E. (2015). Why Finland now leads the world in nuclear waste storage. *Nature*.

[133] Tollefson, J. (2011). Battle of Yucca Mountain rages on. *Nature*, 473(7347), pp.266–267.

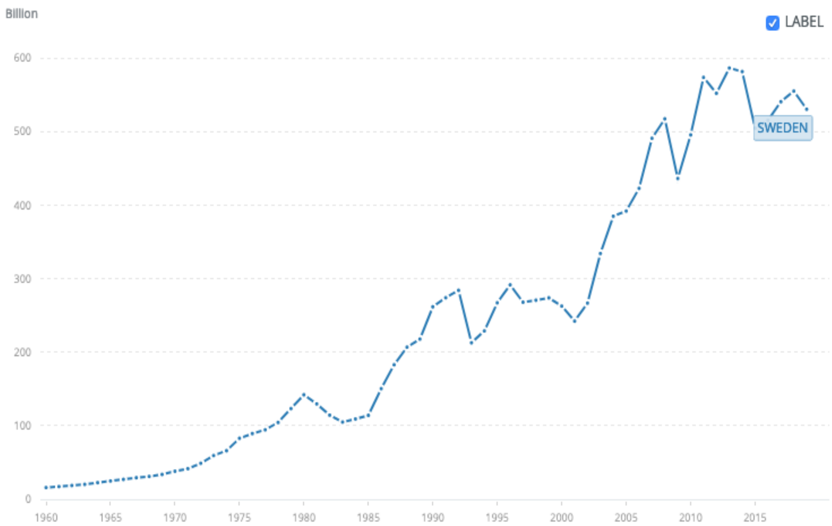
[134] Mueller, M. (2018). *5 Fast Facts About Nuclear Energy*. [online] Energy.gov. Available at: https://www.energy.gov/ne/articles/5-fast-facts-about-nuclear-energy.

Case Study: Sweden



Co2 emissions (Sweden)

Source: data.worldbank.org



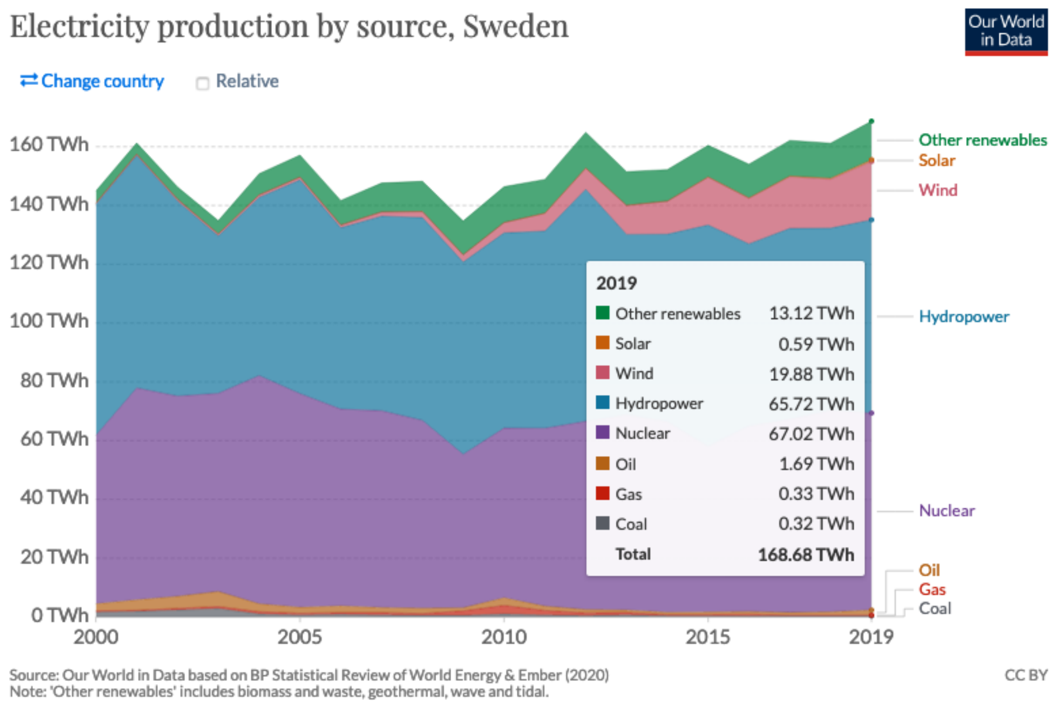
GDP Growth (Sweden)

Source: data.worldbank.org

Sweden is a model for the success it has achieved in reducing its emissions. In fact, between 1970 and 1990 the country cut its total CO2 emissions by half, and its per capita emissions by more than 60%. At the same time, however, the Swedish economy has grown by 50% in recent years, and its electricity generation has more than doubled[135]. In fact, Sweden has achieved decoupling, if we understand it as a breaking the link between "environmental bads" and "economic goods."

[135] Qvist, S. and Brook, B. (2015). *Potential for Worldwide Displacement of Fossil Fuels Electricity by Nuclear Energy in Three Decades Based on Extrapolation of Regional Deployment*. [online] Available at: https://www.researchgate.net/publication/276280493_Potential_for_Worldwide_Displacement_of_Fossil-

In the late 1960s, Sweden, to preserve the last remaining rivers, decided to stop the growth of the hydropower. Oil was the top candidate to cover the electricity needs the country needed. A few years later, however, precisely in 1973 first and then in 1979, the oil crisis caused major supply disruptions, thus convincing the Swedes to seek a viable alternative to imported fossil fuels. Sweden therefore decided to invest in nuclear energy; the choice was made above all by the energy density of the nuclear fuel, uranium, capable of producing, with just one pound, the same amount of energy as more than 2 million pounds of coal. Of course, secondly, it was also important that the amount of toxic waste generated by nuclear energy was much less than that produced by both coal and natural gas.



Nuclear power has given Sweden access to an inexpensive electricity system, also allowing it to expand the use of its energy very quickly and remove its pre-existing part of the supply covered by fossil fuels. The total energy supply of oil-based products dropped 40% rapidly, while the use of electricity for heating rose fivefold.

Sweden, after having indicated nuclear power as its primary energy source, has built several units of plants, grouped in 4 sites. Eight of the plants built at that time still

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Fuel_Electricity_by_Nuclear_Energy_in_Three_Decades_Based_on_Extrapolation_of_Regional_Deployment_Data
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operate today, and together they make up 40% of Swedish electricity, such as hydropower, with the rest coming mainly from biofuels and wind. The plants can run about 90% capacity on average over the year, producing electricity reliably around the clock. The largest nuclear site in Sweden is Ringhals, 150 acres, which produces more than 4 gigawatts of electricity, 24 hours a day, 7 days a week. In a full year, it alone produces 24 TWh of electricity[136].

The same amount of energy but produced for example from coal would require at least 11 million tons of coal per year, which would cause enormous environmental damage.

The same quantity produced from oil would be much more expensive and less polluting than coal, but only in part. To replace Ringhals, Sweden would have to pump and transport more than 30 million barrels of oil annually[137].

Finally, methane would undoubtedly produce the cleanest energy, among fossil sources, but it would still emit a very high quantity of CO_2 compared to that emitted by a nuclear power plant.

If the comparison shifts to new renewables, as we have already said, wind turbines could produce the same amount of electricity only with a plant with a power capacity three times higher than Ringhals, given the unpredictability, discontinuity and low energy productivity of wind farms. Replacing Ringhals, therefore, would require double the capacity of Markbygden[138], the Swedish wind farm which is also one of the largest in Europe.

Finally, solar panels would not be able to replace Ringhals. Even if solar power were not intermittent (and it is) it would still require more than 20 Gw produced by solar energy to replace 4 Gw produced by Ringhals, because the sun shines only during the day (and not every day, especially in swedish winters).

The great success of nuclear power plants is therefore explained by the enormous benefit of Sweden, which has become an example in the expansion of a low-carbon electricity generation and the implementation of decoupling.

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[136] Joshua Goldstein, Staffan Qvist, *A Bright Future*, Public Affairs Books (2019)

[137] Ibidem

[138] https://www.power-technology.com/projects/markbygden-ett-windfarm/

The Energy of the future, but patience is needed: Hydrogen

Hydrogen is the simplest element in existence from a molecular chemical point of view: it only consists of a proton and an electron, but it is a very interesting source because of its great energy density. In fact, the energy content of a hydrogen molecule is around 44,000 watts. A carbon molecule (a core element in coal, oil and gas) contains just 250. The first and the most common element in the Universe is hydrogen: stars are almost entirely composed of it. Hydrogen requires a large cosmic vacuum to remain and grow due to its simplicity and lightness. It is almost impossible to find it in its purest form on Earth and in the atmosphere. We only find hydrogen in a compound combined with other elements: the most common example is water, which consists of two atoms of hydrogen and one of oxygen (H2O). The other is hydrocarbons: methane gas, for example, is made of four molecules of hydrogen and carbon (CH4). Therefore, we have to separate it from the compounds where it is found, in order to produce hydrogen on Earth. The method of extraction from water is called electrolysis, steam reforming from hydrocarbons. In both examples, it requires spending energy. In many manufacturing processes, hydrogen is used: in the pharmaceutical and electronics industries, and in aeronautics. It must be said that Hydrogen is not a suitable source, but a carrier of energy. This implies that it is a type of secondary energy which, as described by Alberto Delbianco, head of Eni's Downstream Research and Development Operation, can be stored and transported to the place of use[139]. A carrier is a material which can release the energy it contains quickly. For example, electricity, which can be transported to be used where it is required, is the best-known energy carrier. The same thing happens with hydrogen: the rich energy gas (H) is processed and transported by reforming processes (a chemical process that breaks the carbon-hydrogen bonds of hydrogen-releasing methane) or by water electrolysis. Hydrogen, therefore, is a vector that enables not only the transport of energy but also its storage, unlike the electricity that is lost if it is not used when it is generated[140]. We apply to grey hydrogen extracted from fossil fuels, such as natural gas, blue hydrogen extracted from fossil fuels, but with the addition of an emission

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[139] Casini, S. (2020). *Idrogeno da grigio a verde nel futuro scenario energetico: l'intervista ad Alberto Delbianco di Eni*. [online] Tech Economy 2030. Available at: https://www.techeconomy2030.it/2020/08/11/idrogeno-da-grigio-a-verde-nel-futuro-scenario-energetico-lintervista-ad-alberto-delbianco-di-eni/

[140] Ibidem

capture mechanism, carbon capture storage (CCS), and green hydrogen, made by electrolysis.

Grey hydrogen is the most commonly used hydrogen to date, but significant amounts of CO2 are released by the thermochemical conversion of natural gas required to produce it. There is no emission in green hydrogen, since it is derived from renewable sources.

This distinction is important because, according to a study by Wood Mackenzie analysts[141], the current production of hydrogen is almost entirely (99 percent) dependent on fossil sources with high CO2 emissions; on the other hand, due to its high production costs, green hydrogen, the only one that could really contribute significantly to decarbonization and combating global warming, will take a long time, because it requires large-scale electrolyzers to minimize their costs, rendering green hydrogen production affordable.

The most optimistic outlook is about ten years. According to recent research by Bloomberg New Energy Finance, green hydrogen production costs could drop by 70 % over the next ten years, rendering the green option entirely affordable as compared to other solutions[142]. The cost of green hydrogen will be competitive by 2030, a projection true only for Italy and Germany, according to the Snam and McKinsey report, where it will be possible to break even with grey hydrogen 5-10 years earlier than in other countries, thanks to the greater presence of renewable energy and a gas transport capillary network[143].

On the other hand, however, the timing for the need for (green) hydrogen to establish itself in the electricity market is not entirely positive.

In spite of this, a correspondence from the European Commission, entitled 'A Hydrogen Plan for a Climate-Neutral Europe' was drafted on 8 July, positions hydrogen as a key element of a zero-emission economy by 2050.

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[141] Mackenzie, W. (n.d.). *Hydrogen production costs: is a tipping point near?* [online] Available at: https://asvis.it/public/asvis2/files/News/Report_Brochure_Hydrogen_Costs_Is_A_Tipping_Point_Near.pdf.

[142] Henze, V. (2020). *'Hydrogen Economy' Offers Promising Path to Decarbonization*. [online] BloombergNEF. Available at: https://about.bnef.com/blog/hydrogen-economy-offers-promising-path-to-decarbonization/

[143] www.snam.it. (2019). *Il potenziale dell'idrogeno in Italia*. [online] Available at: https://www.snam.it/it/hydrogen_challenge/potenziale_idrogeno_italia/

According to IRENA (International Renewable Energy Agency), as stated above, 96 percent of the current global supply of hydrogen comes from fossil fuels (methane 48 percent, oil 30 percent, coal 18 percent) with substantial CO2 emissions and accounts for less than 2.5 percent of the world's primary energy with approximately 115 million tons / year in 2019 (equal to 345 million TOE).

The existing cost of global development of grey hydrogen from fossil sources is suggested in September 2019, during the World Energy Congress, in the 'Hydrogen, Bridging Sectors and Regions' session, without measuring the CO2 penalties, between 1.25 and 2.5 dollars per kilogram, which corresponds to 37.50-75.00 dollars/ MWh[144].

On the other hand, Hydrogen Europe[145] explains that the hydrogen produced today will cost approximately EUR 7.80 / kg, corresponding to EUR 235 / MWh, which undoubtedly represents a very high value, with German onshore wind at EUR 60 / MWh and 2,000 equivalent hours of operation at full power (load factor).

In order to make green hydrogen competitive, the European Union is preparing to make substantial investments, primarily to increase energy efficiency to 75% and electrolyzer capacity to more than 100 MW by 2030 and to 1000 MW by 2050. Nevertheless, as defined by Alessandro Clerici, WEC Italia's Honorary President, the price of hydrogen will remain high for electrolyzers in the coming years, even given a clear decrease in investment costs[146]. According to the statement by Vaclav Smil, which explains that the source of energy most used by countries will be available and cheaper, green hydrogen might still not be able to compete with conventional energy sources on a price basis by 2050.

Carbon Capture Storage (CCS) & Utilization of Carbon (CCUS)

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[144] Clerici, A. (n.d.). *www.nuova-energia.com - Idrogeno, tecnologia interessante ma adelante con juicio*. [online] www.nuova-energia.com. Available at: http://www.nuova-energia.com/index.php?option=com_content&task=view&id=5770&Itemid=113

[145] Hydrogen Europe represents the European industry, national associations and research centers active in the hydrogen and fuel cell sector. The association partners with the European Commission in the innovation programme Fuel Cells and Hydrogen Joint Undertaking (FCH JU).

[146] Alessandro Clerici (2020). *L'era dell'idrogeno è davvero alle porte? |1*. [online] Rivista Energia. Available at: https://www.rivistaenergia.it/2020/08/una-nuova-era-per-lidrogeno-ma-con-quali-tempi-e-costi/#_ftn2

CCS is a device that is capable of carbon dioxide capture and storage. In practice, it is a matter of subtracting the emissions produced by the combustion of petroleum products and, in particular, coal, until they are dispersed into the air.

When it leaves the chimneys, the CO2 is then chemically extracted, and then pumped into the underground rocks. Instead of trying to discharge it into the environment, the aim is to bury CO2 underground.

The CCS dream is put at risk by countless obstacles. Significant environmentalists, arguing that technology only distracts from renewable energy, are opposed. And above all definitions, technical dilemmas remain. One of these is how the cost of capturing CO2, a process that remains too expensive to operate without subsidies, can be reduced.

In short, for heavy industry and all those who benefit from it, carbon capture reflects the prospect of moving from "criminals" in the ecological vision to climate saviors in the population's eyes. This without abandoning dependency on fossil fuels, and relying on the public sector in any event. At a time when markets-far more than policymakers themselves-are forcing polluters to clean up their businesses, it is a possible new lease on life. BlackRock, the world's largest fund manager, announced in January 2020 that it will steer its investments towards reducing climate risk and reducing fossil-fuel exposure. British oil giant BP said in February that its aim is to reach net zero carbon emissions by 2050, a target that relies largely on the CCS[147].

The biggest technological challenge that any CO2 capture and reuse process would face is the fact that the carbon dioxide molecule is the most stable of the carbon compounds, so it still takes a lot of energy to break its bonds or bind it to any other material. There is no single solution for dissolving this chemical-dictated restriction, but study studies reaction paths that require the lowest energy consumption possible.

A second issue, often of a technological nature, is the capacity of the underground caverns in which the CO2 is stored to maintain it indefinitely.

The IPCC certifies that 99 percent of CO2 for more than 100 years can safely be stored by a well-structured site. Possible incidents, such as the one that occurred in Cameroon in 1986, where a naturally sequestered Co2 bubble erupted due to volcanic causes, also

[147] Ball, J. (2020). *Cos'è il carbon capture, la grande speranza delle big del petrolio*. [online] Fortune Italia. Available at: https://www.fortuneita.com/2020/07/15/cose-il-carbon-capture-la-grande-speranza-delle-big-del-petrolio/

concern the risks associated with the burial of Co2, causing the death of more than 1,700 individuals by asphyxiation.

The CCS is not much loved by a number of NGOs and other environmental movements for these reasons and for the fear that, as predicted, the CCS may distract focus from other energy policies.

For this reason, in its position paper, the WWF requires that the CCS credits should not be counted in order to achieve the objectives laid down in the Kyoto Protocol, because they were not considered at the time when the objectives for the first commitment period were set.

Reacting to this position, the International Emissions Trading Association argued that the exclusion of CCS from Clean Development Management is the product of an obviously arbitrary and politicized cause, rather than a position guided by any objective analysis.

As Alessandro Lanza describes, the debate sees, on the one hand, opinion movements, including environmental movements, on the other businesses, especially oil companies[148].

The emphasis is not only on capture and storage, but also on carbon utilization (CCUS) for applications such as increasing oil well production (enhanced oil recovery or EOR) or as an input for useful products to be produced.

There are currently 23 large-scale CCS / CCUS projects in service and growth worldwide, with a capacity to extract 40 million tons of CO2 per year (Mtpa). Most of these projects are focused on highly concentrated CO2 stream technologies, such as the refining of natural gas and chemical production facilities, and 70% of the capture capacity is accounted for by North America. In the world, only two coal power plants, one in Canada and one in the United States (US), have been retrofitted to trap carbon. In addition, coal-fired power plants are used in six of the world's 20 projects under construction (4 in China and 2 in South Korea). There is one project under feasibility study in Canada already. Overall, CCS / CCUS projects focused on coal power plants have a CO2 capture capacity of 12.4 Mtpa and require some 4 GW of coal capacity.

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[148] Lanza, A. (2011). *CCS e Carbon Credit: le implicazioni dell'ingresso della CCS nell'ambito dei progetti di Clean Development Mechanism*. [online] Available at: https://www.enea.it/it/seguici/pubblicazioni/pdf-eai/gennaio-febbraio/SpecialeCSS.pdf.

From a global perspective, while CCS / CCUS may provide a solution for the decarbonization of the coal-fired power sector, especially in emerging Asia, market and policy design as well as technological progress will ultimately determine the viability of CCS / CCUS in coal-fired power generation. The current lack of success means that if it is to be one of the mitigation options, efforts to help CCS / CCUS become commercially viable must be stepped up. [149]

Conclusion

One of the reasons, perhaps the most important, that makes the fight against global warming dictated by policies uncertain is the fact that since the first Berlin Climate Conference in 1995, but also in the endless literature on the subject, substantially no account has been taken of the reality on which policies should intervene. The paradox occurs above all in the field of energy, where there is a constant detachment between "virtual" reality painted in environmental rhetoric and "real" reality.

As proof of this, there is the fact that the Paris Agreement called for an energy transition in the period of the Shale Revolution, capable of increasing the American energy supply much more than any Green Revolution has been able to do. The script of the numerous climate conferences remained the same: taking note of the scientific updates of the IPCC (CO2 concentration, emissions trend, temperature increase) and political negotiation on the timing of the reduction of emissions. But the theme of the feasibility of what was proposed has always been avoided, continuing to reiterate the same actions regardless of whether the external context changed, due to economic crises or the rise in international tensions. This has meant that the Paris Agreement found itself in an implementation vacuum, the same one in which the Green Deal risks ending.

Nor can reality be confused with dialectics; the results of the Paris Agreement or the Kyoto Protocol, in terms of reducing emissions, have often been a consequence of recessions, rather than virtuous actions.

[149] Cornot-gandolphe, S. (2019). *Carbon Capture, Storage and utilization to the reSCue of Coal? Global Perspectives and Focus on China and the United States études de l'Ifri Sylvie Cornot-gandolphe Center for Energy*. [online] Available at: https://www.ifri.org/sites/default/files/atoms/files/etude_cornot_carbon_coal_2019.pdf

The most neglected condition by Paris Agreement and European Green Deal is that any intervention useful to reduce emissions has an obvious monetary cost. This is important to understand, if we consider that in the following year in Paris, spending on new renewables collapsed, at nominal level. Even adhering to the hypothesis that monetary resources are sustainable within a framework of macroeconomic compatibility and justifiable in a global perspective in the comparison between costs and benefits, the discourse on "who really pays" remains, or rather on the effective provision of disposal of these resources by the market, which cannot be simplistically deduced from the global costs avoided. In other words, it is not enough that what is spent has full economic justification or even general ethics if it is not able to ensure profitability for those who employ money. Economic sustainability, in essence, is not a sufficient condition, but a necessary one for the investments necessary to achieve the energy transition to be made.

On this point, a series of questions arise: from which subjects - public or private - can transition projects be implemented and financed? Are these projects compatible with other needs? how do its profitability is guaranteed?

These questions assume importance above all if we take into account the fact that emissions are expected to grow in emerging countries and to remain stable in advanced countries, that benefit from high living standards acquired thanks to use of fossil sources. Most investments, also in order to maximize their effectiveness, should therefore move towards emerging countries where the financial markets are, however, less equipped, liquid, stable and the political and regulatory risks are greater. Private investors may therefore not have sufficient motivation to make such complex investments in an unstable situation.

Who pays then?

As for the European Green Deal, unfortunately the first steps suggest that it is slipping into an implementation vacuum too. The Covid-19 pandemic, with the consequent collapse in the price of oil, has been framed by many as an opportunity to speed up the transition process. Christopher Kaminker, head of Lombard Odier's Sustainable Investment Research & Strategy, called this event an assist for the zero-emission transition. According to Kaminker, with the fall in demand, at the root of the fall in prices, governments should have been less reluctant to give up black gold. The same line of thinking was shared by Alexandra Ocasio-Cortez, a member of the United States House of Representatives, who with a tweet (later removed) celebrated the collapse of the oil price by writing: "You absolutely love to see it", then describing how this is the right moment for mass investments in the Green sector. Again, the risk is that energy policies are more ideological than practical. The question, according to many, should not be to what extent or in what time frame an energy transition is feasible, but rather how it should be governed, to ensure that the new, not yet mature, takes the place of the old in a wrong moment, without therefore leaving everything to the game of the markets or the combination of detached and uncoordinated national policies. In a similar scenario, it is even clearer that until the technologies have reached a level of maturity such as to overcome, for example, the technical limits of the new renewables, old and new must at least coexist. The Deadline to 2050, for this reason, appears uncertain and impractical. For an unpredictable amount of time, fossil and renewable sources will have to be managed within a framework of integration; To put them in antithesis is counterproductive even before it is wrong. Decarbonization policies will proceed at different rates in different areas and sectors of the economies. Part of the emissions will be unavoidable where hydrocarbons cannot be replaced as in chemical production, in air transport, in heavy manufacturing. CCS or CCUS will be able to capture a significant amount of CO_2 in an unpredictable timeframe if there is no adequate commitment to research and development.

The more the new low-carbon technologies penetrate, the more the demand for traditional sources will decrease. The investments to guarantee the flow, even if still necessary, risk becoming increasingly unstable.

In the same way, however, ignoring the role that oil and methane will still have to play increases the risks of market instability and security, if we consider the geopolitical balances we have faced earlier. From this emerges an uncomfortable position for the fossil industries, which is placed between the possibility that climate policies cause a gradual marginalization and the need, on the other hand, of these industries to adopt strategic choices today on which the future of energy markets as a whole, and of the world economy, will depend.

Paris and the Green Deal have indicated to the fossil industry that the international community no longer considers them essential to the future of energy. The support they have received so far from the states is destined to run out if not to change sign with growing legal barriers.

the risk is that the oil and methane industry, faced with uncertainty about its future caused by aggressive climate policies, will decide to reduce its investments, creating the conditions for a strong market imbalance. The transition to new energy sources does not relieve the world of the responsibility of guaranteeing full coverage of energy needs in the future. Hence the need for climate policies to be carefully calibrated and for the energy transition to be governed.

The thesis carried out so far, therefore, makes it clear that the energy transition is a complex, long, costly path that is unlikely to be completed in times compatible with the objectives set by the Green Deal. In fact, decarbonization will require the replacement of the entire existing capital stock on both the supply and demand side of energy. Claiming otherwise is one of the causes of the failures of previous climate agreements. Saying how things are, overcoming the politically correct view and substituting the analysis of facts for emotions is a necessary prerequisite for acquiring the necessary consensus in public opinion on which the costs of the energy transition will fall.

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Executive Summary

Climate change, which is the subject of an extensive international debate, is due, according to a shared opinion, to the growth of carbon dioxide emissions into the atmosphere. This growth is principally traced back to the emissions of the fossil sources of energy, which, still today, accounts the 80% of the energy generation. In order to contrast the climate change, the necessity of an energy transition is indicated that is substantially identified in the goal of a rapid decarbonization.

The paper aims to analyze the energy transition. What, most of all, can teach us what the future will be is the past, and that is why defining the concept of energy and then analyzing what caused the other energy transitions in history, recognizing their drivers

and the surrounding market conditions, is of vital importance. The paper combines an analysis of the political scenario with the technical explanations of energy sources, highlighting their limits but also the enormous impact, both economically and in everyday life, that it has had on human development. For each source that realized the transition, a graph will be shown, containing the main drivers and how they occurred.

The most important element to consider is the evolutionary nature of energy transitions. By analyzing the history of energy sources, we see that established sources and prime movers can be surprisingly persistent, and new techniques or new sources can only become dominant after a long period of time. The reason for this is explained by the drivers of an energy transition that we mentioned before.

The first driver is a *demand for energy services*. As we will see in the transition from wood to coal, the energy demand caused by massive deforestation, which had effectively dried up much of the wood available in developed countries, has (slowly) led to the use of coal as an energy source.

This happened because, linked to this first condition, there is the second: *supply constraints*. That simply happens when a resource cannot be expanded in step with increasing demand.

The third condition are the *cost advantages*, which include not only the actual fuel cost, but the associated labor costs, energy converter costs and other economic impacts.

The fourth condition are the *Performance benefits*; they include all advantages, from speed and acceleration to protection and cleanliness, that are not usually measured in terms of resource price. These are a subset of cost advantages, which definitely have an implied value shown by customer actions, although the attributes are not specifically priced in certain instances. They may be the product of a new fuel, but they are mostly connected to advances in energy converters[150].

An excellent example of a transition driven by Performance Benefits, even more than by the other drivers (however present) is agriculture. The birth of agriculture is not justified only by economic factors, given that, at least in the transition phase, foraging societies yielded more in terms of net energy returns, but also by factors that cannot be calculated at an economic level.

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[150] Energy Converters can be defined as the tool that converts energy into a useful form; a good example would be oil transformed into electricity thanks to a converter.

The final driver is the *Policy Decisions*. Tariffs, incentives, subsidies, codes, legislation, infrastructure growth, and other steps are among the acts taken by governments affecting energy supply. Cultural expectations frequently affect policy choices.

This driver, according to many, is seen as secondary, as it has never represented, in human history, the first to be realized, in the context of energy transitions. Indeed, when an attempt was made to impose a policy decision that in a certain way "forced" the transition, it never took place, as it is seen with OPEC supply decisions, in 1973 and 1979, and, from the 1980s onwards, with the policy of incentives and subsidies for new renewables.

It must therefore be assumed that, as long as the established sources or prime movers are present in an economic way, in terms of costs, abundant, in terms of quantity, and reliable, in terms of its use, their successors, even if they have attributes in certain higher realms, will advance very slowly. An example of this can be the Roman water mill, first used in the first century BCE, but which only became popular 500 years later.

The amount of time required is easily explained: before a source can be defined competitive on the market, a long period of research, experimentation and capital formation is needed.

The similar progress in global energy supply, in terms of time, that we saw with the transition to coal, oil and gas (almost 60 years for all of them) is another remarkable element to consider, because these three fuels require different production, distribution and conversion techniques. So, why the pace of these transitions is so similar? The two most important factors that explains these similarities are the prerequisites for enormous infrastructural investment and the inertia of massively embedded energy systems.

Although the pace of coal, oil, and gas transitions is not an indicator that can tell us whether the transition to 2050, envisaged by the Green Deal, should follow the same path, there is no element to make us think the opposite: apparently, the transition to renewable sources will require a long time. In 2015, the two major renewable energies for the electricity system, sun and wind, were still under 2% of the world's primary energy supply and in 2019 the level was still pretty low.

There is also another element to consider: the current structures of energy production, distribution and transformation are of an enormously higher dimension and are placed in a more complicated market than in the past; This means that there is greater resistance to any drastic transformation[151]. However, to better understand how an energy transition takes place, we must understand that it strictly depends also on the level of technology available at the given moment. Taking the transition to coal as an example. It took a very long time and was delayed by the decline in the quality of energy services that resulted immediately from its use as regards wood[152]. A century after Watt 's invention, the contribution of coal to energy consumption in English manufacturing in the mid-nineteenth century remained minimal relative to that of hydraulic and biological (human / animal) oil. The same was in America, whose wood consumption was still satisfied by more than 90 percent in 1850[153].

So, if we take technology as the driving force behind any transition, we understand that the transition is determined not so much by abundance or scarcity of the current source of energy, nor by the costs it requires, but by technology. Coal, and consequently oil, have entered the energy market forcefully as they are better suited to respond to the challenges that were imposed by technological advances at the time.

Therefore, if the penetration of coal, and consequently of oil, was connected to the confirmation of new technological paradigms, the same cannot be said for the other sources that have since the middle of the last century developed themselves on the energy scene: natural gas, and, mostly, new renewables (excluding traditional hydroelectric plants).

The thesis will then analyze the history that linked the climate to energy, with the first literary productions that formed the basis of the international climate meetings (COP), then analyzing the results, in terms of emission reduction, resulting from the protocol of Kyoto and the Paris Agreement.

Human-related global warming is, rightly or wrongly, the theory shared by much of the scientific community. It deserves to be highlighted that there is another slice of scientists, not indifferent in terms of reputation, who do not deny global warming, but who argue that further studies are needed to link anthropogenic activities to this result.

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151 This is what should be called "Path Dependency", in the sense that, owing to technological, infrastructural, institutional and behavioral lock-ins, energy systems are subject to strong and long-lived path dependency.

152 When we think about energetic transition today, we should keep it in mind

153 Vaclav Smil, *Energy and civilization: a history*, The Mit PRESS (2018)

The paper will analyze the literary history and the moment in which fossil sources were indicated as responsible for significant climate impacts, first in Global Cooling, then in Global Warming.

As already said, transitions require a very long time. This happens because, even if technology is a driver of a transition, there is no immediate link between technological progress and energy policies. It's very important to understand that, in order to evaluate the "sustainability" of an energy transition to a no-carbon system. The proof is the experience of 90's in the Western world. In order to face conflicts and tensions on oil front, that shook the economy world between since the 70's (first oil shock 1973) until the end of the 90's (continuous fluctuations of oil and gas prices and supply, financial and industrial crises, social reluctance to austerity policies, the URSS collapse, the explosion of Middle eastern conflicts, terrorism) a massive deployment of existing renewable energy sources into western electricity system was forced, in order to alleviate dependence on oil importation. This political orientation was in line with the suggestions of environmental policy of the two decades from the Club of Rome Report (1971) and Rio Conference (1992). Massive incentive policies were set up to support displacement of wind and solar plants in national electricity system. Perhaps even then Western governments had evidence of a thorny reality: current renewable sources were not ready, for technological reasons, to replace oil extensively. This problem will come back at the end of this quarter of the new century, when the replacement of oil is demanded for environmental reasons and no longer for economic and geopolitical ones. The fact remains that, in order to deploy renewables, in the 70's and 90's, investors gave credit to short term technologies. To cope with an enthusiastic expectation on existing renewables technologies, first of all wind and photovoltaic, States decided to support heavily the renewables deployment. Despite notable financial support for this policy, the share of fossil fuels in western energy portfolios was only slightly scratched. To force renewables to be compatibles with energy markets, strict internal regulation of energy activities by States was necessary. The freedom of choice of companies was therefore decreasing, and this was not at all smoothed out by the choice of the States to internalize negative externalities in energy policies. At first, political externalities related to oil were internalized, as dependence on imports had consequences on national security and sovereignty, later also environmental externalities, with oil seen as harming the environment. These problems still drag on. With both internalizations, the States have directed investors towards the new renewables, first of all for the zero content of CO_2 emissions, but above all for the possibility that these energies had to reduce compatibility with mere market logic and therefore to make greater leverage on public policies. From the political point of view, this initially translated into a Command And Control approach, with also important results such as the limitation of acid rain or the reversal of the trend regarding the ozone hole, then the approach moved towards an imposition on energy systems, mostly electric ones, to convert to renewable energies with rather evident contradictions: the most important was undoubtedly the claim that this could "get stuck" in the logic of the market. The interventionist spiral that followed this approach was evidently unsuccessful and frantic.

Regulatory father Alfred Kahn argued that the option would not be between perfect market competition and perfect state control, but rather between an imperfect version of the two. Thus, Paul Joskow added, the liberalization of certain sectors like electricity will take the "worst of both worlds." “A view” wrote John Mott, former president of the American Federal Energy Regulatory Commission “that we are continually facing in regulated energy markets where tariffs produce a volatile combination of incomplete competition and flawed control that reinforce one another. We can rationally disagree about the degree of harm it has done, but not about whether it is actual and increasing…”.

Oil, in its statement on coal and old renewables, led to three important changes: the first was the overcoming of the localization rigidities, simply due to the fact that the greatest development took place where that energy source was close and easily accessible. It must be said that this is very true for wood and water courses, while coal broke up, but only partially, this trend. At a substantial level, however, the fact that countries with large quantities of coal mines could guarantee themselves greater development remained true, leaving behind those who did not, such as Italy.

Oil drastically breaks these stiffnesses, thanks to its great abundance but above all for the ease of carrying it. With its advent, the development and power of nations detach themselves from the close ownership of the energy they feed on.

The second improvement linked to the becoming of the sources is the increase in the dimensional scale of their output, also known as power density: energy generated per unit of space, or the capacity to concentrate large quantities of energy in confined spaces supporting large scales of output, which in effect would stimulate advances in electricity, chemistry and transport, leading to the affirmation of the growth model based on consumption[154].

An increase in energy density that went hand in hand, supporting each other, with the processes of urbanization or, in either case, with the population densification in increasingly restricted spaces. During the transition from forest to hydraulic or wind energy, land usage per unit of energy was decreased by 10 times, but by another 100 times with the advent of fossils, and even more with nuclear power[155].The third change was the reduction in real energy prices.

At this point, three questions come automatically: which energy systems are consistent with development models capable of revolutionizing societies? If such systems other than the current one existed today, would they be able to give a positive boost to economies? Third, compared to the three changes we have seen from oil, will renewables be able to achieve the same results?

The analysis of what in fact led to the birth of environmentalism that contrasts fossil fuels with renewable sources is fundamental to be able to answer Epstein's question, contained in the final part of the second chapter: what value do we give to human life?

In the following, the European Green Deal will be analyzed, presented by Ursula Von Der Leyen on 11 December 2019, which, for the first time in history, establishes a deadline for the energy transition, 2050. In a period in which only doubting the feasibility of the energy transition, at least in the ways in which it is prophesied, is sufficient to be qualified at best as ignorant and at worst as "morally reprehensible", an analysis of the limits underlying the Green Deal (the low climate impact of Europe alone, the technical limits of the New Renewables and the fragile geopolitical balances based on the oil market) is indispensable. For this reason, each limit will be accompanied by a case study, to make understand the interests at stake of the main countries in the global scenario and to find empirical confirmation of what is explained in theory.

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[154] Alberto Clô, *Energia e clima. L'altra faccia della medaglia*, Il Mulino (2017)

[155] Bravo, P. and Debecker, D. (2016). *Combining CO 2 capture and catalytic conversion to methane*. [online] Available at: https://dial.uclouvain.be/pr/boreal/object/boreal%3A216172/datastream/PDF_01/view [Accessed 24 Aug. 2020].

China will be the first case study analyzed. A climate deal that sees China marching in the opposite direction can only have counterproductive results. At the same time, it is difficult to believe that China can or wants to move in the direction indicated by the European Union, due to the growing demand for energy in its borders, which can be met (for now) in large part by coal. CO_2 has the great limitation of being global, it knows no borders and does not need a passport to move from one country to another. The reduction of emissions by Europe alone is not sufficient to achieve a significant climate impact, a limit that the Green Deal must consider.

The second case study, linked to the limits of New Renewables, will be Italy. The history of Italy, characterized by massive investments and incentives in the photovoltaic sector, is of fundamental importance to understand how the massive policy decisions made in favor of renewable energy in recent decades have not obtained the result of pushing them towards an impact, in terms of energy requirement, significant. This is due to the technical limits that renewables present, which are difficult to overcome in the short term.

The third case study will be Saudi Arabia and Russia, to frame the fragile geopolitical balances between Europe and these two countries and the role that fossil fuels play from a purely economic but also political point of view.

Saudi Arabia is functional in demonstrating how the export of oil is able to form and maintain an entire economy, which, driven by the low-carbon pulsations of Europe, its major importer, but also by the characteristic volatility and uncertainty of the oil price, has decided to make an attempt to detach from it, through the Saudi Vision 2030, which, however, is not achieving the desired results. Russia, on the other hand, serves to present the current natural gas market, seen by many as transitional energy (including from Europe, which recently decided to include it in the investments accepted by the Green Deal to encourage decarbonization) but which it still has some limitations, one of which is the need for large and expensive infrastructures, impossible to limit within its borders and which therefore require agreements with neighboring countries.

Finally, the thesis will analyze zero emission technologies, and the possible impact they can have in a transition to zero CO_2 emitted. The first, more than a technology, is an alternative energy source, nuclear energy, capable of having a major impact on the energy needs of countries. France could have been an excellent case study, but

Sweden was chosen, a country also defined by numerous environmental movements as one of the most virtuous in terms of low-carbon emissions.

Nuclear energy, demonized by a large part of public opinion, is moving towards important technological advances, which promise to limit the problem of radioactive waste and increase its safety, already very high.

Then, the hydrogen will be analyzed to understand its potential and feasibility. Today the Green Deal is very much linked to hydrogen defined as "green", produced by electrolysis from renewable sources. But the risk is that we are focusing on a source (for hydrogen the term "energy vector" would be more correct) that is not yet mature at the technological level.

Finally, the CCS (Carbon Capture Storage) and CCUS (Carbon Capture Utilization Storage) system will be presented, analyzing their technical nature and the investments necessary to produce a significant impact on the environment.

Europe is preparing to face an enormous challenge, perhaps too great, which will have to be realized by 2050. There are many areas that will require major commitments, and it is necessary to understand if the technology will be available in this time limit.

One of the reasons, perhaps the most important, that makes the fight against global warming dictated by policies uncertain is the fact that since the first Berlin Climate Conference in 1995, but also in the endless literature on the subject, substantially no account has been taken of the reality on which policies should intervene. The paradox occurs above all in the field of energy, where there is a constant detachment between “virtual” reality painted in environmental rhetoric and "real" reality.

As proof of this, there is the fact that the Paris Agreement called for an energy transition in the period of the Shale Revolution, capable of increasing the American energy supply much more than any Green Revolution has been able to do. The script of the numerous climate conferences remained the same: taking note of the scientific updates of the IPCC (CO2 concentration, emissions trend, temperature increase) and political negotiation on the timing of the reduction of emissions. But the theme of the feasibility of what was proposed has always been avoided, continuing to reiterate the same actions regardless of whether the external context changed, due to economic crises or the rise in international tensions. This has meant that the Paris Agreement found itself in an implementation vacuum, the same one in which the Green Deal risks ending.

Nor can reality be confused with dialectics; the results of the Paris Agreement or the Kyoto Protocol, in terms of reducing emissions, have often been a consequence of recessions, rather than virtuous actions.

The most neglected condition by Paris Agreement and European Green Deal is that any intervention useful to reduce emissions has an obvious monetary cost. This is important to understand, if we consider that in the following year in Paris, spending on new renewables collapsed, at nominal level. Even adhering to the hypothesis that monetary resources are sustainable within a framework of macroeconomic compatibility and justifiable in a global perspective in the comparison between costs and benefits, the discourse on "who really pays" remains, or rather on the effective provision of disposal of these resources by the market, which cannot be simplistically deduced from the global costs avoided. In other words, it is not enough that what is spent has full economic justification or even general ethics if it is not able to ensure profitability for those who employ money. Economic sustainability, in essence, is not a sufficient condition, but a necessary one for the investments necessary to achieve the energy transition to be made.

On this point, a series of questions arise: from which subjects - public or private - can transition projects be implemented and financed? Are these projects compatible with other needs? how do its profitability is guaranteed?

These questions assume importance above all if we take into account the fact that emissions are expected to grow in emerging countries and to remain stable in advanced countries, that benefit from high living standards acquired thanks to use of fossil sources. Most investments, also in order to maximize their effectiveness, should therefore move towards emerging countries where the financial markets are, however, less equipped, liquid, stable and the political and regulatory risks are greater. Private investors may therefore not have sufficient motivation to make such complex investments in an unstable situation.

Who pays then?

As for the European Green Deal, unfortunately the first steps suggest that it is slipping into an implementation vacuum too. The Covid-19 pandemic, with the consequent collapse in the price of oil, has been framed by many as an opportunity to speed up the transition process. Christopher Kaminker, head of Lombard Odier's Sustainable Investment Research & Strategy, called this event an assist for the zero-emission transition. According to Kaminker, with the fall in demand, at the root of the fall in prices, governments should have been less reluctant to give up black gold. The same line of thinking was shared by Alexandra Ocasio-Cortez, a member of the United States House of Representatives, who with a tweet (later removed) celebrated the collapse of the oil price by writing: "You absolutely love to see it", then describing how this is the right moment for mass investments in the Green sector. Again, the risk is that energy policies are more ideological than practical. The question, according to many, should not be to what extent or in what time frame an energy transition is feasible, but rather how it should be governed, to ensure that the new, not yet mature, takes the place of the old in a wrong moment, without therefore leaving everything to the game of the markets or the combination of detached and uncoordinated national policies. In a similar scenario, it is even clearer that until the technologies have reached a level of maturity such as to overcome, for example, the technical limits of the new renewables, old and new must at least coexist. The Deadline to 2050, for this reason, appears uncertain and impractical. For an unpredictable amount of time, fossil and renewable sources will have to be managed within a framework of integration; To put them in antithesis is counterproductive even before it is wrong. Decarbonization policies will proceed at different rates in different areas and sectors of the economies. Part of the emissions will be unavoidable where hydrocarbons cannot be replaced as in chemical production, in air transport, in heavy manufacturing. CCS or CCUS will be able to capture a significant amount of CO2 in an unpredictable timeframe if there is no adequate commitment to research and development.

The more the new low-carbon technologies penetrate, the more the demand for traditional sources will decrease. The investments to guarantee the flow, even if still necessary, risk becoming increasingly unstable.

In the same way, however, ignoring the role that oil and methane will still have to play increases the risks of market instability and security, if we consider the geopolitical balances we have faced earlier. From this emerges an uncomfortable position for the fossil industries, which is placed between the possibility that climate policies cause a gradual marginalization and the need, on the other hand, of these industries to adopt strategic choices today on which the future of energy markets as a whole, and of the world economy, will depend.

Paris and the Green Deal have indicated to the fossil industry that the international community no longer considers them essential to the future of energy. The support they have received so far from the states is destined to run out if not to change sign with growing legal barriers.

the risk is that the oil and methane industry, faced with uncertainty about its future caused by aggressive climate policies, will decide to reduce its investments, creating the conditions for a strong market imbalance. The transition to new energy sources does not relieve the world of the responsibility of guaranteeing full coverage of energy needs in the future. Hence the need for climate policies to be carefully calibrated and for the energy transition to be governed.

The thesis, therefore, makes it clear that the energy transition is a complex, long, costly path that is unlikely to be completed in times compatible with the objectives set by the Green Deal. In fact, decarbonization will require the replacement of the entire existing capital stock on both the supply and demand side of energy. Claiming the opposite of it is one of the causes of the failures of previous climate agreements. Saying how things are, overcoming the politically correct view and substituting the analysis of facts for emotions is a necessary prerequisite for acquiring the necessary consensus in public opinion on which the costs of the energy transition will fall.