Sustainability and decarbonization: can we afford it?

Some implications for management

Jacques Martin, ESOE, jma.martin@wanadoo.fr
Claudio Baccarani, University of Verona, Italy, claudio.baccarani@univr.it
Federico Brunetti, University of Verona, Italy, federico.brunetti@univr.it

"I work all night, I work all day to pay the bills I have to pay…"
ABBA *Money, money, money*

Abstract: 'Sustainability' is the topic of the day. Hundreds, if not thousands, of studies and papers have already been published about it. However, the huge majority of them adopt a political or macro-economic approach. The social aspects are rarely deeply investigated, and the issue of the cost of sustainability is largely overlooked. This paper aims at evidencing some of the links between the macro-economic dimension and the micro-economic one, through the question of decarbonization, which is probably the key element for sustainability, considering the main social consequences such a dramatic change implies and trying to tackle the tricky problem of the cost of decarbonization both at the macro and micro levels. After trying to clarify the concept of sustainability and the central part played by decarbonization, we examine the question of the global cost of decarbonization and analyze some examples of companies in this respect.
Findings: Even allowing for large margins of error due to the incomplete data available and the parameters that cannot be controlled, or even known, the estimates that can be made show that the cost of decarbonization is absolutely baffling and beyond what the common citizens and managers, not to speak of politicians, can imagine, which can be a big reason why the subject is largely overlooked as it would surely create social upheavals round the world.
Methodology: The study is based on data extracted from various reports on sustainability, climate change and decarbonization, notably by the IPCC, for the macro-economic dimension, and from the Annual Reports (2020) of the companies studied. These data are processed so as to calculate an estimate of the cost of decarbonization.
Originality: This paper is an attempt at filling part of the gap in the scant number of studies about the cost of decarbonization.
Keywords: sustainability, decarbonization, cost of decarbonization, corporate and consumer behaviour

Introduction:

Sustainability is not a new concept. We can trace back its infancy in the second half of the 19th century when some individuals or groups raised the issue of the harmful consequences of the Industrial Revolution which started an era, which is not yet finished, of extensive use of coal as a source of energy for feeding the operations of industrial plants. We can mention for example the creation of the *Society for the Prevention of Smoke* in 1892 in Chicago (Christine Meisner Rosen 1995) or the report to the Royal Commission on River Pollution in 1897 (UK). The word 'sustainability' had not been invented yet (the word was first used in 1907 in a legal context, and only in 1972 with the meaning that interests us here), and the focus was on the negative consequences of industrial pollution; but right from the start a number of people were aware of the negative externalities of the Industrial Revolution, and almost everybody suffered from them.

However, these warnings were not heeded and all kinds of pollution with their harmful consequences developed throughout the 20th century.
It is only in the 1970s that the concept of sustainability, as we know it today, was formulated by the Club of Rome (1972) and the United Nations Conference on Environment in 1972 in Stockholm. The standard definition of sustainability appeared in 1987 with the Brundtland Report entitled *Our Common Future*. Although the first COP ('Conference Of the Parties' under the auspices of the United Nations) took place in 1995 in Berlin, it is only at the COP 21 (2015) that a big majority of States committed themselves to acting in order to combat the negative effects of climatic change.
All these Conferences, and similar ones like the Johannesburg Summit in 2002 or the Rio Summit in 2012, but to name two significant ones, deal with the issue of sustainability at a macro-economic level, something that does not necessarily help, and often makes it confusing, for action and operations at the micro-economic level, that is the level of firms. Globally speaking, climatic changes and their consequences impact the management of firms. All firms, big and small, local or international, today are urged to adopt strategies and policies of sustainable development (Baccarani, Brunetti, Martin, 2021) under the double pressure of governments and markets.
The concept of sustainability covers a wide range of issues. A key one is the question of decarbonization. Any sustainable strategy cannot dodge this question of decarbonization as carbonization is the main cause of climate change.
Although there are thousands of research papers and official reports about the stakes of and the roads to decarbonization, only sparse information, using different evaluation methods each time, can be found on the cost of decarbonization for companies.
Within the framework of sustainability, the specific aim of this paper is to raise the question of the ability of companies, and subsequently of consumers, to bear the cost of the radical transformation of their processes implied by decarbonization. A definite answer can of course not be given as the conditions of this decarbonization evolve and change all the time. Our aim is to shed some light on this management upheaval and show, albeit in a limited way, that the general public is not aware of the cost that societies at large will have to bear for decarbonization and that probably a majority of managers are not aware of it either. So, we may even wonder if decarbonization is not a lost battle before it has really started. What has happened, or not happened, since the COP 21 cannot make us very optimistic.
We will consider in a first part the key issues raised by the concept of sustainability and the specific issue of decarbonization. What do they mean? What do they imply?
In a second part, we will adopt both a macro-economic and a micro-economic view to set the global scene and take the example of some companies to illustrate the stakes and challenges of decarbonization that companies are faced with and have to take up, using a rather simple but at least uniform methodology to apprehend the question of cost.

Part 1: The concept of sustainability and the issue of decarbonization:

1.1 The concept of sustainability:

Our purpose here is not to look deeply into this concept. There are already thousands and thousands of studies and papers on the subject (*Google* returns nearly 5 billion answers for *sustainability* and 36 million for *decarbonization*!). We may even wonder if there is anything new to say about it. We would like to highlight first the fundamental elements of this concept of sustainability and second specifically consider how they impact the management of companies.

1.1.1 The tenets of sustainability:

Although the concept of sustainability has been around now for more than fifty years, it remains rather polysemic and it is still not quite clear what it means. There is no consensus beyond the general principles. “the concept of sustainability, now also declined in sustainable development, is difficult to define due to its intrinsic multidimensionality – economic, social and environmental aspects– and its dynamic nature” (Nigro, Ianuzzi, Spallone, 2021). Indeed, the multi-disciplinary nature of sustainability, which is evidence of its very wide scope, can have the disadvantage of somewhat blurring the concept (Billi, Mascareño, Edwards, 2021). The classic definitions of sustainability state general principles, with which one is inclined to promptly agree, and the objectives set by international bodies remain at a macro-economic level. The *WHAT* should be done is clear enough, albeit of little help for managers, but the *HOW* it should be done cruelly lacks specificities, notably in terms of measuring sustainability, which is the key at a micro-economic level (firms) for evaluating the progress made by firms in sustainability (Isaksson, Ramanathan, Rosvall, 2021).

It is always useful when studying a concept to look at where the words for expressing it come from.

The noun ‘sustainability’, originally coined in 1907 in its legal sense and in 1972 in the sense we use it here, is made up of ‘sustain + able +ity’, literally meaning the ‘capacity of sustaining’. The verb ‘sustain’ from old French ‘sostenir’ means to ‘keep up an action’, defined as ‘enable to last out’ by the *Oxford English Dictionary*. We clearly see here two fundamental dimensions of ‘sustainability’ that we will find in the recent definitions of it: the action dimension and the time dimension. The verb ‘sustain’ comes from the Latin ‘sustinere’ made up of ‘su(b)s or susum + tenire’. ‘Tenire’ means ‘hold’ and ‘susum’ means ‘high’ or ‘up’. This shows that the time dimension and even the qualitative dimension are at the root of the word. Interestingly Cicero sometimes uses it in the sense of ‘keeping in good shape’, which is very close to the present sense of the word in its socio-economic meaning (e.g. *De Officiis*). So, we could use a paraphrase and say that ‘sustainability’ is the ‘capacity to keep something in good shape over time’.

The standard definition of ‘sustainability’ is found in the Brundtland Report entitled *Our Common Future* published in 1987. The definition is concise and *prima facie* straightforward: Sustainability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In other words, the satisfaction of the needs TODAY must not jeopardize the satisfaction of the needs TOMORROW. We do have the two dimensions made out above. But immediately we are faced with a number of problems.

What are these needs? The needs of whom? What is tomorrow? And even what is today? There is nothing quite explicit about the ‘needs’ in the report. The report speaks of **basic** needs which **include food, clothing, shelter, jobs**, which is an unexpressed reference to the first level of Maslow’s pyramid, of which we know today that it does not correspond to the psycho-sociological situation of today. It says that they are ‘the essential needs of the world’s poor, to which overriding priority should be given’. Consequently, the first objective of sustainable development is to eradicate (extreme) poverty in the world. This reflects the situation at the time of the writing of the report. Twenty-five years later, the situation is quite different. Millions and millions of people have been driven out of poverty. Of course poverty is not eradicated. But we can note that where it is still present, it is not due to intrinsic economic conditions but to political reasons. We can then say that to a very large extent ‘the needs of the present generations’ have been satisfied. But this approach implies that there are different needs for different people. So, what about the needs of the people whose ‘basic needs’ were already satisfied? The report states that ‘living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-

term sustainability', without giving a clue about the meaning of long-term sustainability. It is however suggested that some 'needs' beyond the basic ones will have to be forsaken, so, that they are not really needs ("Sustainable global development requires that those who are more affluent adopt life-styles within the planet's ecological means") . Moreover, needs evolve with time. A need that was not considered as basic thirty-five years ago, may be considered as basic today (e.g. a mobile phone). As a result, 'needs' change with each generation and we have to re-assess them all the time. As for the 'needs of future generations', we know near to nothing about them, by definition. All this makes the global objective of sustainable development non-operational (Isaksson, Ramanathan, Rosvall, 2021).

The answer to the question 'the needs of whom' is clear in the report. They are the needs of 'ALL', but as seen – and acknowledged in the report – ALL is so multi-facetted that it does not help in any operational way.

Concerning the time dimension, there is nothing in the report to help us. None of the 12 chapters of the report tackles it head on. This is not surprising in fact as there is no answer to this question. As the saying goes 'the future is written nowhere' (freely derived from Descartes).

The Brundtland report is not anti-growth, as the Club of Rome was to a large extent, but advocates a new type of growth. This growth must be geared to the 'ability of the biosphere to absorb the effects of human activities'. But here again this ability is not defined, as it cannot be. It depends on 'the present state of technology and social organization'. 'The accumulation of knowledge and the development of technology can enhance the carrying capacity of the resource base'. In the end sustainable development is something relative ("The concept of sustainable development does imply limits - not absolute limits…"). But we are warned that "Many of these will manifest themselves in the form of rising costs and diminishing returns", which will be the focus of the second part of this paper.

Quite rightly, we think, the conclusion in I.3.30 of the report ("Yet in the end, sustainable development is not a fixed state of harmony, but rather a **process of change**") is quite apt. So, the details given in the report, though limited, mitigate the general principle stated in the definition.

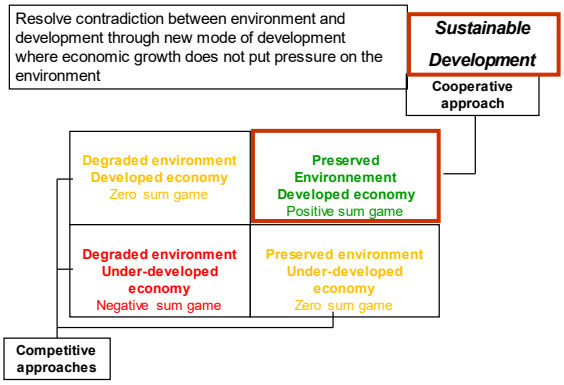
We can try and find help in some other definitions commonly quoted to complement the Brundtland Report. Some years after the publication of the report, a somewhat different definition stated that sustainability is a "requirement of our generation to manage the resource base such as the **average quality of life** that we ensure ourselves can **potentially** be shared by all future generations… Development is sustainable if it involves **a non-decreasing average quality of life**" (we underline) (Asheim, 1994). 'Needs' are replaced by 'average quality of life', which can be measured according to objective criteria, in the sense that they can be universal and be used in comparative evaluations, like, for example, the Human Development Index (HDI calculated and published under the auspices of the United Nations). 'Present generations' is replaced by 'our generation' normally implying that there is an adaptation of the 'average quality of life' from one generation to the next. And, more importantly to our mind, the imperative drafting of the Brundtland Report ('without compromising') is replaced by 'can potentially', which leaves the door open to scientific innovations and social behaviours that cannot be known today and can significantly alter the sustainability equation in the future. So, this definition by the World Bank can help overcoming some of the logical shortcomings of the Brundtland Report's definition.

More recently, Amartya Sen (2009, The idea of justice) added the freedom of future generations to choose what they want for their life. We can indeed raise this question of freedom of choice. Can we accept that operational decisions made today, of which some may be drastic and irreversible, limit the freedom of choice of the generations of tomorrow?

This is another way of approaching the crux of the matter in the understanding of sustainability.
All definitions of sustainability first profess a general principle which is of an ethical nature. Second they propose some ways and means to apply this principle, which are of an operational nature. The question is then how do we link the principle to the operations? And this is where we (especially as managers) get stuck. Is sustainability an aporia?
We can analyze the situation with the help of Aristotle. Aristotle distinguishes between two steps in the reasoning; the first step is the ἀρχή (arkhè) referring to the principle (what is at the beginning: *princeps*) and the προαίρεσις (proairesis) referring to the action or resolution (Aristotle: Nicomachean Ethics). There must be a necessary link between the two. The link is the λόγος (logos : discourse, reason, relation), and Aristotle tells us that "for the action/resolution to be good, the λόγος must be true." That is the whole ethical chain. When we apply this to management, we have the principle of sustainability (step 1) which is expressed in the firm's strategy, and the action which is expressed in the firm's operations within a certain structure (step 2). There must be a match between strategy and structure/operations for success. Twenty-five centuries after Aristotle, this is what Chandler tells us in management with his phrase "Structure follows strategy", and even more what Kaplan and Norton extensively develop in the Execution Premium (2008).
The question is then 'where is the logos?' in management. How should organizations act (operations) in order to attain the objective of the principle (sustainability)?

This overview of the concept of sustainability shows that it is fraught with pitfalls (see for example Mayer A., 2008, or Bell S. and Morse S., 1999) although at first sight it seems straightforward and it is not seriously challenged by anybody today. Therefore, it must be dealt with with precautions, always keeping in mind that there is nothing definite and absolute and consequently that an open-minded and adaptive attitude needs to be adopted.
One example that can be referred to, to illustrate this state of things is the notion of 'peak oil'. In the early 1970s, at the time of the Club of Rome, much talk started about the 'peak oil' and lasted for decades. One of the reasons advocated for, eventually, putting an end to the use of oil, leaving aside its polluting properties, was that one day there would be no oil available. The reasoning was that the quantity of oil extracted was higher than the quantity of new oil found so that one day there would be a peak after which oil production would decline and one day the resource would be depleted. In the early 1970s this moment was set around the year 2000. And it did not happen, quite the contrary. In the second half of the 1990s, it was set between 2010 and 2020, and it has not happened. In the early 2000s, it was set as 'far' as beyond 2050 (one estimate – Lynch -, wisely, set none). And we know now, thanks to sustainability (!), that there will never be a peak. When we have stopped using oil, and it will not be in a near future, there will still be plenty of it in the ground (not to speak about coal). Prudence is the mother of all virtues.

In any case, the search for sustainability implies a cooperative approach and not a competitive one.
This can be illustrated in this way:



Source: authors

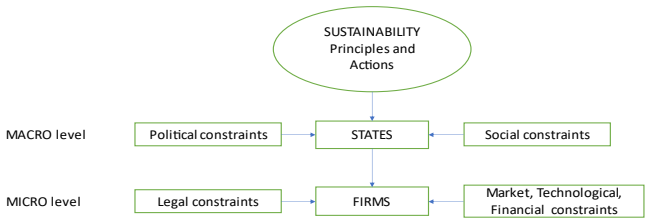
We can now examine the impacts on management of the adoption of a strategy of sustainability, with all the limitations that we have underlined.

1.1.2 Management impacts:

The concept of 'sustainability' has for sure a philosophical dimension. The question for the manager is how to translate this concept into shared actions.
We have seen the conundrum raised by the notion of 'needs'. If the needs, from one generation to another, are pre-defined, they may, and most probably will, conflict with the freedom of choice of the successive generations.
Therefore, it seems that the thought of Cicero about sustainability as the 'capacity to keep something in good shape over time' is an apt approach of the issue as there is a clear goal but no specific constraints imposed on successive generations, thus securing the freedom of choice of each, while remaining conscious that the decisions made by one generation necessarily impact the following ones as, by definition, sustainability operates over a long time.
The 'good shape' is when all the components work together well both at the individual level and above all, from a social management point of view, for the whole community. Using a modern phrase, we could say that the 'good shape' can be equated with the 'well-being' of society; the latter not being defined *ex ante*, but left to the choices thought to be appropriate of society as it evolves. The end must be shared by everyone: ensure the availability of the resources necessary to guarantee the 'good shape', but the means are left to the successive generations at the political level and at the level of enterprises, which will evolve and be different over time, if only because of the technological advances.
Fundamentally, we need to combine a thought founded on a purely anthropological social ethic with a thought also taking into account the 'rights of nature' in a sort of universal ethic. The implementation of such a vision requires a revision of an economy entirely based on the notion of growth, in its classical sense, and of the use of capital focused on the maximization of (financial) profit with an overwhelming short-term view whereas sustainability *per se* requires a (very) long-term view (the long-term orientation of Confucianism).
The contribution of enterprises in the implementation of this vision can be fostered by adopting Environmental, Social and Corporate Governance indicators (ESG) and producing a Corporate Sustainability Report, which a number of them already do. Enterprises need to be careful, however, to select indicators in keeping with the general goal (well-being) and not

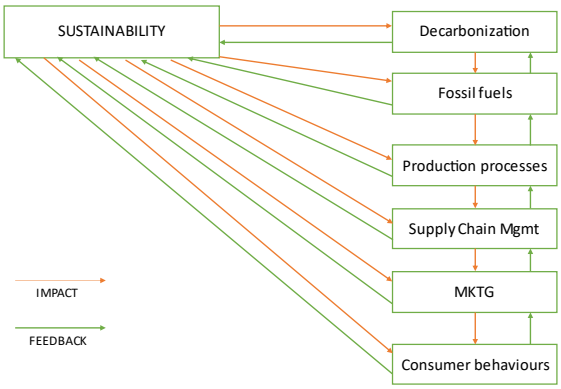
influenced, explicitly or implicitly, by purely financial motives, so that ESG actions simply become an alibi for 'doing business as usual'.

Management is one of the main areas of human activity on which the search for sustainability has a major impact. Management is where the action takes place to make the economy tick. Globally speaking, the search for sustainability operates at two big levels; a macro-economic one and a micro-economic one. States, governments and (governmental) international organizations operate at the macro-economic level. They set general objectives, advocate global policies, decide on rules and devise incentives for economic actors. Firms operate at the micro-economic level. Through their management, they work out their specific sustainability strategies and organize their operations in accordance with the general objectives. There are constant interactions between the two levels. Therefore it is necessary to have a systemic view of the relations between the macro-economic level and the micro-economic one. They are not separate but intertwined. And neither States nor firms are free to do what they want.
States are constrained by political and social factors and firms are constrained by States, the market (their customers), technological and financial factors.
The situation can be illustrated in this way:



Source: authors

For a firm, a strategy of sustainability involves working on a number of fields of management that need to be totally or largely re-engineered.
As our focus is on decarbonization, which is nowadays accepted as the *sine qua non* condition for sustainability (see below) whatever the specific definition of it is given, we can start with decarbonization as the touchstone of a strategy of sustainability. Once this has been accepted, it triggers a series of management policies that all together contribute to sustainability.
This chain can be illustrated in this way:



Source: authors

Our view is that of the firm. We assume that a strategy of sustainability is first and foremost founded on decarbonization. Decarbonization implies stopping, eventually, the use of fossil fuels which are the main source of greenhouse gases causing a rise in temperatures on planet earth and jeopardizing or destroying ecosystems necessary for life. Putting an end to the use of fossil fuels implies a re-engineering of production processes (in a general sense, i.e. both industrial and service processes), and consequently of products. The re-engineering of production processes implies a re-engineering of supply chains, both inside the firm and between firms. New processes, products and supply chains call for a new marketing approach. This new marketing must induce new consumer behaviours. Sustainability impacts all the elements individually and collectively in a chain reaction. All the elements retroact on the others in iterative feedback loops, and contribute to the sustainability strategy.

It can be said that decarbonization gives the impetus to the system. Once this goal has been adopted, all the rest necessarily follows. Therefore all the aspects of the management of a company are impacted by this goal. That is the reason why we can use decarbonization as the key element, for the transformation of management practices. But, as "there is no free lunch", according to the common say, this will lead us to tackle the question of the cost of this decarbonization.

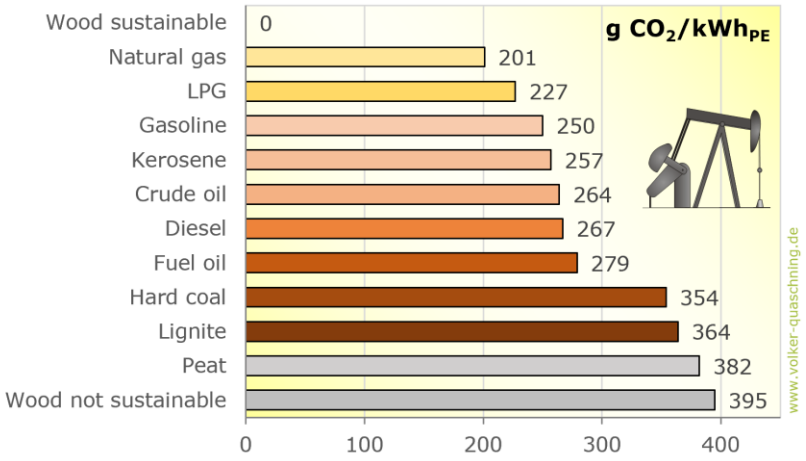
1.2 The issue of decarbonization:

Decarbonization is commonly defined as "the reduction of carbon dioxide emissions through the use of low carbon power sources, achieving a lower output of greenhouse gasses into the atmosphere" (TWI, 2022). First of all, we must be aware that 'decarbonization' means reducing carbon (*de-* means *down*). 'Decarbonization' tends to refer to the process of **reducing** 'carbon intensity', **lowering** the amount of greenhouse gas emissions produced by the burning of fossil fuels" (TWI, 2022 – we underline) not suppressing it. It is not sure that the general public understands the word correctly. We will expand on that further down about the notion of 'carbon neutrality'. And this is the only scientific path as there will always be carbon produced by human activities (we ignore here natural carbon emissions as nature globally maintains a balance between carbon emission and carbon absorption – outside exceptional events such as huge and long volcanic eruptions) . The goal will then be to have carbon emissions which are 'sustainable' in the sense that will be examined below.

Although we speak about ‘carbon’ generically, the carbon we are interested in is ‘carbon dioxide – CO^2’. First we need to dissipate a common misunderstanding. CO^2 is not a (air) pollutant *stricto sensu*. It is a necessary for the human breathing system. It is not poisonous and lethal, although at high concentrations it affects the working of the brain. It becomes an asphyxiant by simply replacing the oxygen that the body needs. If it were lethal, millions of people would have died from drinking *Coca Cola* and the like! Carbon monoxide (CO) on the contrary is quickly lethal, as it blocks the breathing system, without people realizing it because the gas has no colour, no smell and does not irritate. CO is classified among ‘primary pollutants’.

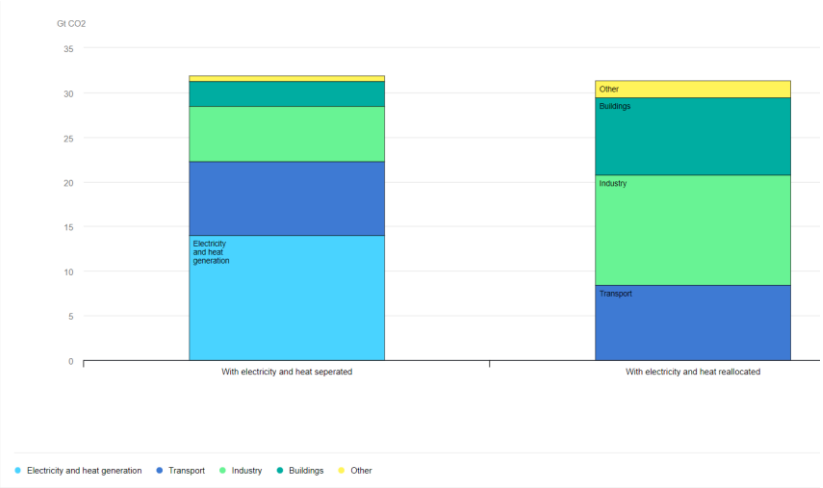
CO^2 is a sort of double-edged sword. It is necessary for the earth’s atmosphere to be livable. Without it, the atmosphere would be too cold. But when there is too much of it, the atmosphere becomes too warm making it uncomfortable to live in it, and at high concentrations (above 5000 ppm) it has harmful effects on health. We are at 417 ppm (CO^2.earth, Jan 2022). So there is absolutely no imminent danger of being asphyxiated. But the danger is elsewhere.

CO^2 comes from the combustion of fossil fuels. The quantity of CO^2 released into the atmosphere varies with the type of fossil fuel which is burnt, but also with sub-categories within a type of fuel. The chart below shows that, for fuels used for industrial purposes, coal is the worst and natural gas the best:



Source: Volker Quaschning, 2021

The intensity of the use of these fossil fuels varies depending on the economic activity, and consequently the volume of CO^2 emitted by these activities. Different breakdowns are possible. The most common one is a pie chart with ‘energy, transport, industry, agriculture and other’. Sometimes ‘buildings’ is shown separately. But this presentation does not help us for our purpose as energy is not produced for itself but is used in industry, transport, buildings and agriculture. It is therefore better to look at figures which reallocate energy, like in this chart:



Source: IEA, 2021

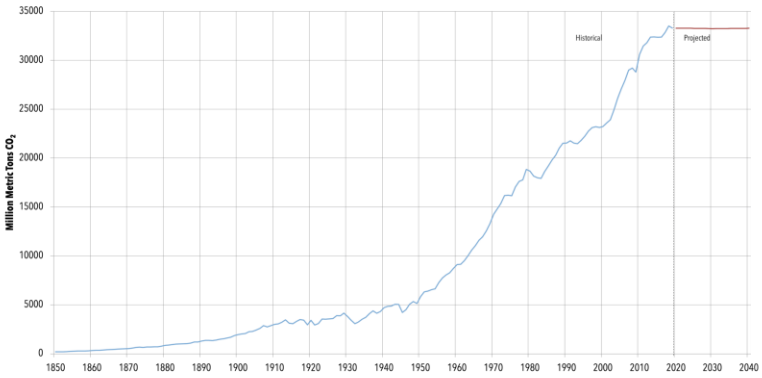
With the reallocation of energy, we have the following picture of CO^2 emissions (percentage of emission by big sector of economic activity):

- Industry = 39.28 %
- Buildings = 27.81%
- Transport = 26.18%
- Other (inc. agriculture) = 6.53%
  (figures rounded to the 2nd decimal)

However, all the graphs and charts that we can find have, to our mind, a big shortcoming. They do not make 'services' appear. So one might think that services do not contribute to CO^2 emissions, which is totally wrong. The *Internet*, for example represents 3.7% of carbon emissions - expected to double by 2025 - (carboncare.org, 2021), already more than the airline industry. Every e-mail produces 4 grams of CO^2.

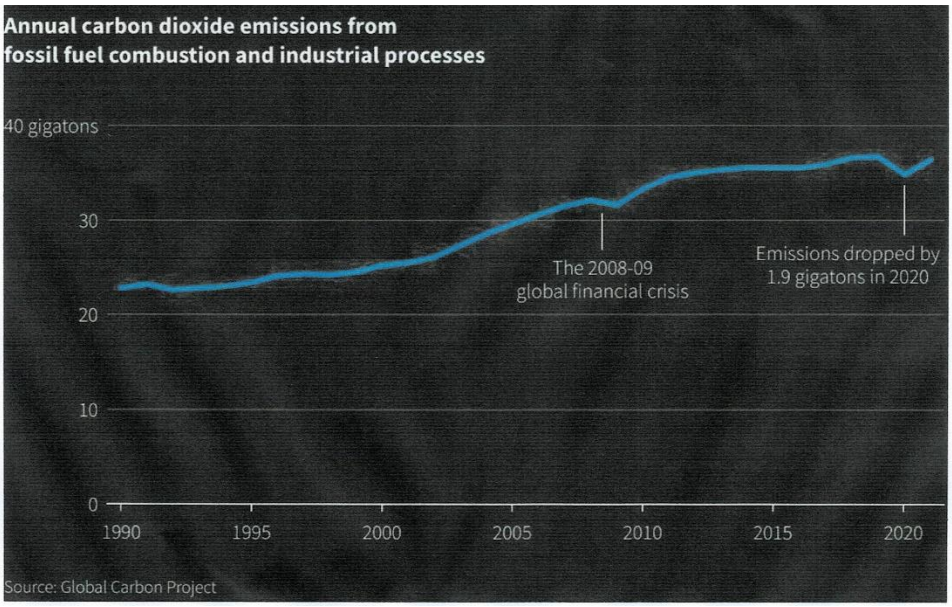
Carbon emissions can be traced back thousands of years by analyzing carrots of ice in which bubbles are encapsulated. For the recent period, i.e. since the Industrial Revolution of the 19th century, direct observations and measurements have been made. We can notice that since the Industrial Revolution there has been a constant and sharper and sharper increase of carbon emissions. This increase is due to the more and more extensive use of fossil fuels. A look at the evolution of these emissions does not require any comments, striking as it is.

Carbon emissions 1850 – 2020



Source: IPCC

We only see a small decline at periods when there was an economic downturn. This means that no voluntary action, if any taken, has had any impact on the level of emissions. A closer look at the very recent period clearly shows it:

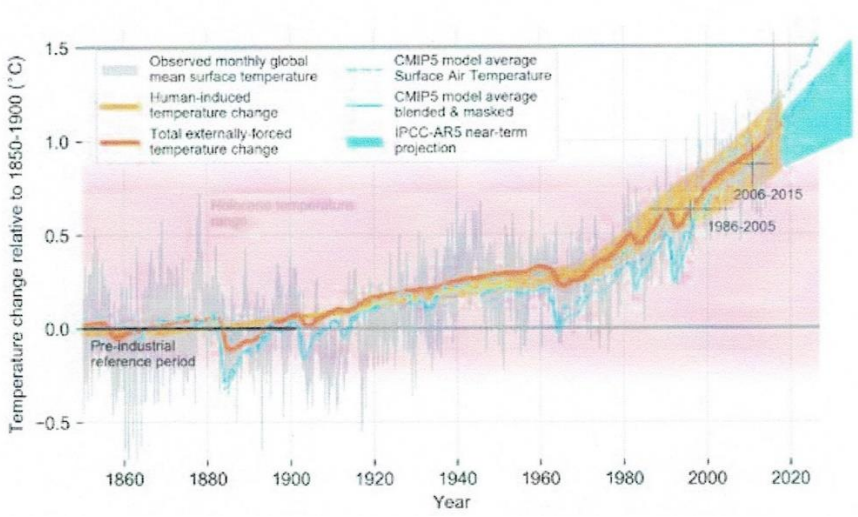


Source: Global Carbon Project

As CO^2 is not a pollutant *stricto sensu*, why should it be a source of worry?

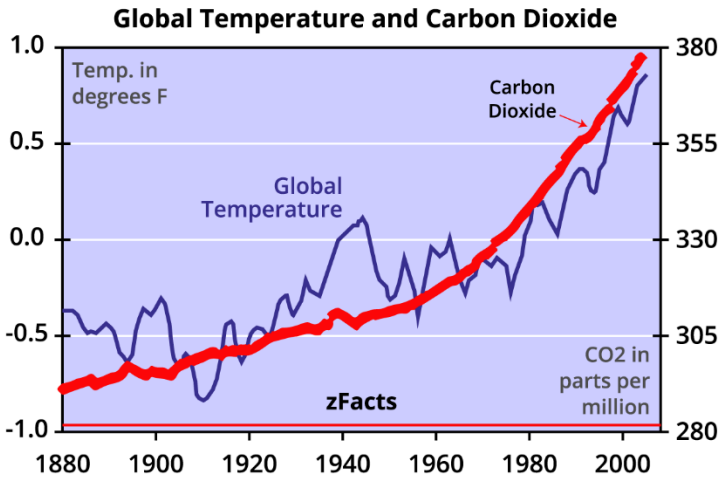
CO^2 belongs to this group of gases labelled 'greenhouse gases'. There are four main greenhouse gases: carbon dioxide, methane, nitrous oxide and fluorinated gases. Among them CO^2 represents around 80% of emissions. Methane comes second with about 15%.

The effect of these gases is to trap heat in the atmosphere and consequently cause an increase in temperature, a phenomenon commonly called 'global warming'. This graph shows that the temperature has steadily increased since the end of the 19th century, with an acceleration from the 1960s.



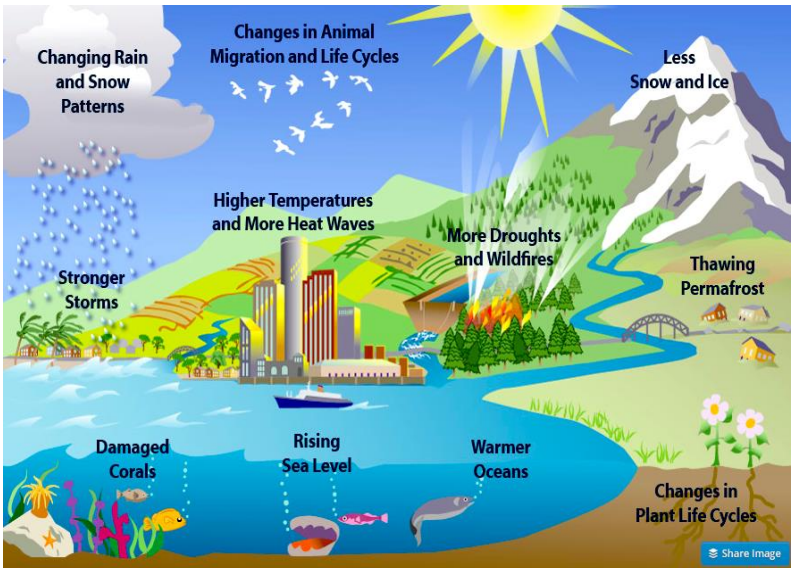
Source: IPCC

And there is a clear correlation between CO^2 emissions and temperature:



Source: zFacts

The consequences of global warming are many and are linked with one another as illustrated in this image from joboneforhumanity.org:



More frequent climatic extremes (storms, heatwaves, droughts, floods) adversely affect most aspects of life: a reduction in agricultural production, a destruction of industrial and services means of production, a disruption of supply chains, a degraded health, just to mention a few that are directly linked to management issues.

As we are nearing irreversible thresholds, drastic action is required to strongly reduce the emissions of greenhouse gases, primarily CO^2, and limit the increase in temperature. The huge majority of scientists consider that an increase of more than 2°C above preindustrial levels will cause irreversible consequences. On the present trend, this will happen in a couple of decades. The rise should be limited to 1.5°C, the target set out at the COP 21 (2015), to keep the situation under control. However, the COP 21 commitments have not been followed by real improvements as CO^2 emissions have continued to rise since 2015.
At the COP 26 in Glasgow (2021), 153 countries representing 90% of the world GDP have committed themselves to carbon neutrality in 2050, with gas emissions around 5 billion tonnes lower by 2030.
But we must not be fooled by the phrase 'carbon neutrality'. It does not mean that the volume of CO^2 in the atmosphere is reduced, it means that the volume of carbon emitted (from 2050) is equal to the volume absorbed, either by natural phenomena (the role of forests and oceans for example) or through human action (carbon capture for example). For the global volume of carbon to decrease, 'negative emissions' are necessary (McKinsey, 2022) meaning that a certain volume of CO^2 is removed from the atmosphere. So, in fact 'carbon neutrality', with far from a probability of 1 to be achieved by 2050, is only a **first** step in decarbonization.
The task is then a huge one, and certainly the majority of people, including entrepreneurs, managers and of course politicians are not aware of it. Most of the technological tools to mitigate and then reduce carbonization are already available. But there are two big obstacles to overcome; the first one is political and the second one is financial.
The political obstacle is certainly the hardest to overcome. In spite of nice speeches, governments do not say the truth to the people for fear of electoral backlashes and social unrest, and consequently do not act as they should. It has been known for centuries and centuries that politicians have a short-term horizon whereas combatting climate is a (very) long term horizon. They will all be long gone (including autocrats and dictators) when significant tangible results are achieved.

The financial obstacle is, maybe paradoxically, easier to overcome but this requires adopting proven management strategies, policies and operations for the objectives set, and having of course a long-term perspective.
Decarbonization being inescapable for survival at all levels, we can examine in a second part the question of its cost. This question was largely ignored for years (when browsing papers about decarbonization over the last twenty years – using Google Scopus for example – the issue of cost is absent or incidental) and recently although there are a number of studies at the macro-economic levels, there are few at the level of individual firms.

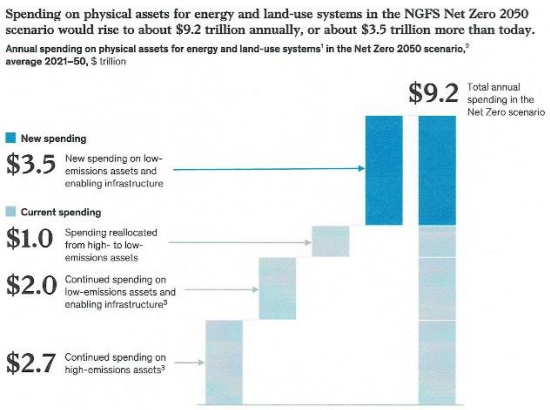
Part 2: The global cost of decarbonization and some examples of cost for firms:

A key aspect of decarbonization within the framework of sustainability, which is often simply ignored or rather superficially taken into account, is the question of the cost of this decarbonization for firms, for economies and for societies. The huge majority of studies focus on the analysis from a chemical point of view of carbonization and the technological solutions that can be envisaged to mitigate this carbonization and maybe eventually to get rid of it as far as human carbonization is concerned. The question of the cost of decarbonizing human activities is largely overlooked although quite recently it has come more to the forefront with the formal commitment of more and more countries, and consequently of individual firms, to decarbonate economic activities.
This question of the cost of decarbonization can be approached at two levels. The most spoken about level is the macro-economic level, most of the time on the basis of the analysis of national economies. The less spoken about, maybe because it is more difficult to apprehend, is the micro-economic level, that of individual firms. We can venture some reasons for this state of things. Data about carbonization, and *per force* decarbonization, about individual firms are sparse, incomplete, unstandardized, or simply absent, requiring to re-process accounting and financial information using methods without a high reliability, so that a wide margin of error must be accepted. When an estimate has been reached about a particular firm, it is then very difficult to make comparisons due to the nature of the data just mentioned. Most often, we are comparing oranges with bananas. When we try to aggregate the results obtained, we can but extrapolate from a limited number of cases and consequently only be able to propose an order of magnitude of the cost of decarbonization.
The total cost of decarbonization can be split into two components. There is first the cost of getting rid of carbonizing processes and second the cost of putting in place decarbonated processes. The main hitch is that classic accounting techniques, whether it is at the level of a country or that of a firm, do not permit to evidence them.
With all these limitations, calculating the cost of decarbonization looks like one of Hercules' works. Nevertheless, as will be seen, the magnitude of this cost is such that, even with a big margin of error, we can get an idea of the task that lies ahead of governments and managers if the goal of 'carbon neutrality' in 2050 is to be reached. The magnitude of the cost and its consequences are not realized by the general public. And it is not publicized by governments and politicians (as far as they know something about it), including the so-called 'Green' parties for the simple reason that they would lose all support. Like any cost it has to be borne by someone. Who is going to bear the cost of decarbonization? The answer is simple: everybody.
In this unsure methodological environment, we will attempt to shed some light on the cost of decarbonization, first by looking at the macro-economic level and second at the micro-economic one.

2.1: The global cost of decarbonization:

As we are entering the heart of the matter, now more studies come out about the macro-economic cost of decarbonization. We should keep in mind that decarbonization is only one aspect of sustainable development, meaning that the cost of sustainability is going to be much higher.
It is interesting to note that the communication of governments on decarbonization is not made in terms of cost, which would be too frightening for people, but in terms of investment, which is more presentable to electors (see for ex.: Commission action plan on financing sustainable growth, 2018, ec.europa.eu; Plan France 2030, gouvernement.fr). However, from an accounting point of view, an investment is first a cost. When the investment produces an income, this income will, everything going well, offset the cost of the investment, and, if everything goes pretty well, generate a profit. In the case of decarbonization, estimating the 'profit' it will eventually generate (through the cashflows generated to speak in financial terms) is very adventurous.
The most recent and complete study published is that of McKinsey (Jan. 2022) entitled *The net-zero transition* with this interesting subtitle, illustrating in a subdued way what we have just expressed, *what it would cost, what it could bring.* This clearly shows that the 'cost' is real but the 'bring' is hypothetical (We have *would* and *could* because the study has been carried on the assumption of 'carbon neutrality in 2050' and 1.5°C increase in temperature). We will therefore base ourselves on these findings to give the order of magnitude.
Global capital spending on physical assets is estimated to be $9.2 trillion per year on average over the 2021-2050 period. The part devoted to low-emissions assets is estimated at $3.5 trillion.

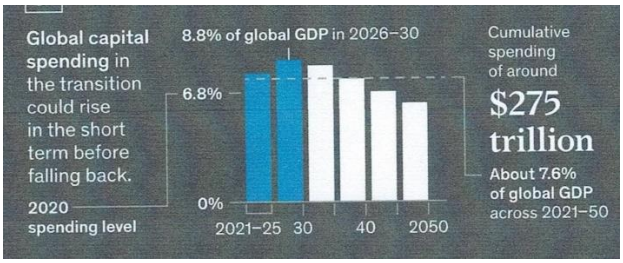
Spending on physical assets



Source: McKinsey, 2022

To give an idea of the size of this amount, the study states that 'the $3.5 trillion is approximately equivalent, in 2020, to half of global corporate profits, one-quarter of total tax revenue, and 7 percent of household spending.' The cumulative amount represents around 7.6% of the world's GDP over the period:

Global capital spending



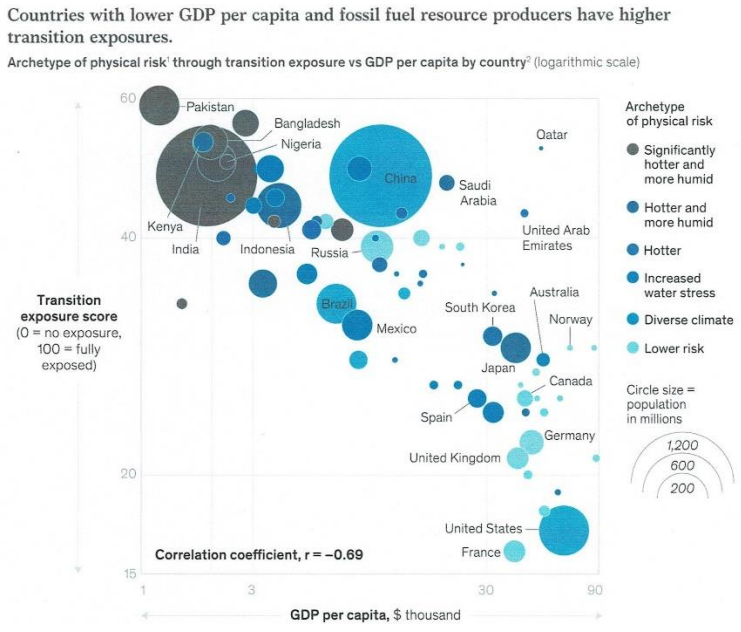
Source: McKinsey, 2022

As usual an average can give a general picture but hides time variations. According to the study, the distribution of this spending, which represents 6.8% of GDP in 2020, would go up to 8.8% between 2026 and 2030, and then decrease to around 6% as the measures taken have started producing their effects. The study adds that 'an additional $1 trillion of today's annual spending would, moreover, need to be reallocated from high-emissions to low-emissions assets.'

As stated above, we must not forget that decarbonization implies the obsolescence of existing assets whose value is reduced to zero. The study estimates that $2.1 trillion in value will be lost for power assets alone, meaning that the total amount of impaired assets will be much higher.

We must also be aware that the effort needed to decarbonate will be unevenly distributed among countries. The general picture is that countries with lower per capita GDP will have to bear higher costs of decarbonization. Two countries particularly stand out, as could be expected, India and China. On an exposure scale of 0 (no exposure) to 100 (full exposure), for example, we find Pakistan at 60, India and China at 50 , Japan at 30, Germany and the UK around 25, The USA around 18 and France around 16. This reflects of course the structure of the economy. Countries relying heavily on industrial activities, especially those using a lot of fossil fuels, are more exposed than countries relying on services and using less fossil fuels. As the most exposed countries are those with the lower per capita GDP, and the bigger populations, we can have a glimpse of the social impact of decarbonization (which is not our focus here).

Country exposure



Source: McKinsey, 2022

There are evidently significant variations depending on the type of economic activity.
For example, the production cost of electricity on the basis of 100 in 2020 would be 120 in 2030 and 2050; the production cost of steel would be 105 in 2030 and 130 in 2050; the production of cement would be 105 in 2030 and 145 in 2050. The cost of sustainable aviation fuel would be between 180 and 460 in 2050.
Although this aspect is not the focus of this paper, decarbonization would have a big impact on the structure of employment, with all the consequences that can be anticipated, on the management of human resources in terms of competencies and training (cf. Patrick Artus, *Le Monde*, 19-20 December 2021). According to the McKinsey calculations, there would be a gain of around 200m jobs and a loss of 185m, with big variations according to the activity, for example +16m in power, +4m in the auto industry, -33m in fossil fuels.
As is known, in the end everybody has to bear the cost of anything in one way or another. Assuming that the increase in production costs are entirely passed on to the final consumer, which is most probably not acceptable in social and political terms but which has the merit of being straightforward (in reality the costs will be in part borne by firms, but this reduces their profit and consequently their investment capacity, and in part by governments, but which means an increase in taxes eventually borne by firms and individuals), we get the following picture.
Using the examples above, customers will have to pay 20% more for electricity, 30% more for steel and 45% more for cement in 2050. Another striking example that is not widely publicized to say the least, is the cost of owning a medium size electric car, presented by the majority of politicians relayed by the media as a sort of miracle solution. Compared to the cost of an internal combustion engine car today, the cost of an electric car is 50% higher in the USA and 25% higher in Europe, and will be 23% higher in the USA and the same in Europe in 2030 (internal combustion engine cars are supposed to be phased – in production - out in those countries from 2030). We need to keep in mind that all these assumptions are made on the hypothesis of a 1.5°C increase in global temperature, a goal that, in the light of what has happened since the COP 21 is very unlikely to be attained. Any supplementary increase in temperature significantly increases the cost of decarbonization in a non-linear way.
If we consider the household spending (keeping in mind that it is an average), which is a measure that can show the contribution of consumers well, this means that Americans will have to devote about $969 bn/year to decarbonization, that is about $11744 year for a household of 4 persons. If we make the hypothesis of a household of 4 persons with one bread earner on the Federal minimum wage ($7.5/hour), 'decarbonization' will cost it 40 weeks of earnings. No comments are needed. EU citizens will have to devote about €123.5 bn/year, that is about €1141 year for a household of 4 persons. Due to wide disparities in consumption within the EU (the ratio between Bulgaria and Germany is more than 1 to 40), we can take some specific examples (the three biggest economies in the EU). In the case of Germany the 'cost' is about 20276 €/year for a household of 4; for France 18792 €/year; Italy 16896 €/year. (figures are for 2020 for populations and 2021 for consumer spending, sources from various statistical offices). Even allowing for a big margin of error and significant variations from one country to another, it is obvious that the amounts are absolutely huge.

It is undeniable that consumers will be significantly impacted in a negative way as regards their purchasing power (we can only anticipate in a dream that incomes will increase by 20 to 50% in the next 30 years!) by decarbonization, and lower-income households more than the others. Although this is not our main focus here, inevitably consumption habits will have to

change radically affecting energy uses, nutrition, transport, housing among the most important. It is therefore necessary to examine the role of consumers.
Consumers' predominant attitude is to turn to businesses to actively take the initiative and act concretely to tackle the problem of sustainability. The logic of consumers is that businesses are responsible for what is offered on the market. They do not see themselves as primarily responsible.
Their claims towards businesses are not merely generic but also in a number of cases precise requests which, if not taken into consideration, can affect their purchasing behaviour by switching to other products and services or boycotting them. They take the cost-quality-delivery tryptic as granted and demand purpose, commitment and accountability on the part of businesses.
There are multiple surveys revealing a change in consumers' attitude towards businesses. For example a survey of nearly 30,000 consumers by Accenture Strategy shows that 62% of customers want companies to take a stand on issues like sustainability, transparency or fair employment practices, or in the Havas Meaningful Brands 2021 Report 79% of customers think that brands must act for the good of society and the planet.
Consumers also claim that they are willing to act personally and change their habits in favour of sustainability (64% prefer buying from companies that have another purpose than making profits, but a thin majority -53%- are ready to pay more for a brand environmentally and socially responsible – Havas 2021 report). According to the McCann The Truth about Sustainability report, 90% of people globally are willing to change something to live more sustainably, particularly among younger people.
This attitude is logical in the sense that these younger generations are the ones which will be confronted head-on with the consequences of climate change and unethical behaviours by companies. In a survey by McKinsey ('True Gen': Generation Z and its implications for companies, 2018), 70% of respondents say they try to purchase products from companies they consider ethical and 65% search for information about the origins of products.
However, there is paradox among consumers in the sense that there is a discrepancy between their intentions and their behaviours. This is a common phenomenon in social psychology (uncertainty avoidance). Any process of change involves risks for individual and groups as it implies a modification of one's habits and way of life. The literature has focused on the explanation of the gap (Govind et al., 2019; Park, Lin, 2020), its antecedents, on mediating and moderating factors (Casais, Farias, 2022), on actual buying behaviour (Testa, Sarti, Frey, 2018).
Adherence to sustainability is therefore much more an attitude than a behaviour, as a result the consumers' response to the sustainability offer of companies is lacking, which, obviously, constitutes a serious problem, given that issues as broad as sustainability cannot be resolved - or at least improved - without the participation of all the players involved.
Nevertheless, the conversion of intention into behaviour seems destined to grow making the choices of companies in the same direction easier, for different reasons.
Firstly, the issue of sustainability is now so publicized and pervasive that many feel they cannot help but respond positively. Secondly, the ethical problems that the consumption of environmentally and / or socially unsustainable products raises in the consumer's psyche can give the decisive push to switch to more acceptable consumption practices. Thirdly, the loss of meaning that mass consumption is experiencing among many consumers can finally induce them to consume less and devote more resources to more expensive but more sustainable options. Fourthly, the sense of self-efficacy and self-realization derived from feeling part of a great commitment and challenge can act as a strong motivation.

As is commonly said, it is the first step that is difficult. Consumers and businesses must forsake the -easy but potentially lethal- preference for the *status quo* and overcome their risk aversion. The cost will be in the end much lower, to say the least, than doing nothing.
To be successful the process of change should integrate three elements: reciprocity, transparency and simplicity.
Reciprocity means that all parties must commit themselves. Transparency means that businesses – and also consumers- should not have opaque processes and should make their motivations and actions clear. Transparency is necessary to establish trust between stakeholders. Simplicity is required to facilitate consumers' understanding and not scare them away with complex and abstruse communication.

The macro-economic picture is truly mind-blowing and probably not realized particularly in its implications for common citizens. We can now have a look at the micro-economic level by examining some examples of companies and give an evaluation of the costs of decarbonization that they are facing.

2.2: The cost of decarbonization for companies: some examples

Trying to estimate the cost of decarbonization for a company is a quasi-insurmountable task. The structure of classic financial reporting does not take into account at all the environmental, in a wide sense, aspects of the activities and the use of assets of a company (Camelia Iuliana LUNGU, Chiraţa CARAIANI, Cornelia DASCALU, Raluca Gina GUSE, Daniela Nicoleta SAHLIAN, August 2009), although the issue was raised and discussed long ago already (for example: Gray, R., Owen, D., Adams C. (1996) or PH Gray, R.H., Kouhy, R., Lavers, S. (1995). IAS 1 in its classic drafting ignores these aspects, although a revision in 2007 added 'other explanatory information' where environmental elements can be expressed. The environmental policies of the company are now a common feature of the Financial Statements, but the information is more or less complete, tends, of course, to embellish the image the company wants to give of itself, and are difficult to compare. It is then necessary to dig into the financial information to try and mine relevant information.

2.2.1: Methodology:

The cost of getting rid of carbonizing processes in a wide sense (i.e. encompassing all the activities in the diagram in 1.1.2) is a tricky, in many respects impossible, operation due to the number of parameters to take into account and the problems of quantification. It can, however, be approached in a rather simple and same way for all companies in order to have an order of magnitude of this cost. We will basically follow the same methodology as McKinsey to have an estimate of the capital spending the companies selected will need to decarbonate their production processes. For doing so, we will use the financial reports of the companies for the year 2020. Decarbonating production processes first means that existing (carbonated) processes become obsolete and consequently lose their value. We will only consider tangible assets although intangible assets such as patents are also at stake. However, it is not possible to identify the relevant intangible assets unless we have the full list of them and their content. Second, the assets that have become obsolete must be replaced by decarbonated ones, as has been seen. The cost of putting in place these new assets is much trickier as a number of the parameters to do so are unknown or cannot be used in a very reliable way since we do not know the state of the technologies available and the cost of implementing them at a given time in the future as the McKinsey study acknowledges. If we follow the McKinsey report, the cost of decarbonated assets is on average 20% higher (with

significant variations) than they are as of today. In order to have a rough estimate, we can then use this 20% markup. Land and buildings, when figures are available, can reasonably be excluded as they can serve several purposes.

We must also not be intoxicated by a sort of magic of decarbonization. A decarbonated process or product does not mean that it is free of carbon.
To illustrate this point, we will borrow two examples from Vaclav Smil, *Numbers don't lie,* (Penguin Random House UK, 2020).
The first example is wind turbines. Wind turbines are lauded as an ideal source of non-carbon energy generation in as far as they use a non-carbon fuel which is indefinitely renewable at zero cost in itself. That is the reason why many of them are already installed and many projects of installation are on their way. But, when looking at the full production process of wind turbines, we see that they need steel, concrete, resins, plastics, fiberglass, lubricant, all of which for now and many years to come are produced by using fossil fuels. The production of 25% of global demand (2.5 terawatts) by 2030 would require about 450 million tons of steel, for example, using more than 600 m tons of coal equivalent (Smil, pp. 147-150).
The second example is electric cars. 'Western' governments have decided to ban cars with internal combustion engines from 2030 and consequently are heralding electric cars as the miracle solution to cut transport carbon emissions. This miracle may well be a mirage. Smil plainly states that 'the rational case for accepting them (electric vehicles) has been undermined by unrealistic market forecasts and a disregard for the environmental effects involved in producing and operating such vehicles'. The main issue is the origin of the electricity on which the cars run. Even in 2030 primary non-carbon energy is forecast to be around 40% (McKinsey 2022) – 70% in 2050. Many EVs will still be coal, oil or gas cars. Then there is of course the manufacturing processes of EVs that will remain significantly dependent on fossil fuels. 'The Arthur D. Little management consultancy estimates that – based on a vehicle life of 20 years – the manufacture of an EV creates three times as much toxicity as that of a conventional vehicle' (Smil, pp. 201-203).

There is another type of cost, that we will not examine; the cost of training the human resource to use these new decarbonated assets. We have seen that a big displacement of jobs will take place. Globally around 185 m carbonated jobs will disappear and 200 m decarbonated jobs will appear. The equation in terms of training is easy: training costs for carbonated jobs will disappear and new training costs for decarbonated jobs will appear. If we can know the cost of 'carbonated training', we cannot know the cost of 'decarbonated training' *ex ante* due to the same limitations as for production processes. Nevertheless, we must not forget that these training costs will add up to the bill for companies.

2.2.2 Some examples of decarbonization costs:

Bearing in mind all the limitations such calculations suffer from, we can examine a few companies which can serve as emblems of the decarbonization issue.
We will first examine industrial companies which are the highest producers of CO^2: TOTAL Energies, Arcelor Mittal, Lafarge Holcim. Then we will look at two companies in the transport domain (Volkswagen Group and Air France-KLM). Finally, we will look at a 'pure' service company in the telecommunications sector: Orange.

2.2.2.1 TOTAL Energies:

TOTAL Energies is a company that was created and developed around the exploitation, transformation and commercialization of oil and gas. Significantly, the name of the company was recently changed to TOTAL Energies to signify the shift the company is operating from fossil fuels to renewable energies. (all figures derived from 2020 Annual Report)
The company's investment policy is in line with the resolutions of the COP 26, reaching carbon neutrality in 2050. In the 2022-2025 period investments in renewables is set to represent more than 20% of net investments. For example the capacity of renewable electricity generation has more than doubled between 2019 and 2020.
The total of tangible assets for 2020 is $33,528 m (the breakdown between fossil fuels and renewables is not given in the consolidated balance sheet). If we exclude the value of land and buildings ($6,420 m) which can be used for different purposes, then the assets' value is $27,108 m. The value of technical installations, the first item affected by decarbonization, is $12,125 m.
The value of the assets as adjusted above represent around 2.3 times the average yearly profit for 2018-2019 (we exclude 2020 when the company made a loss due to the Covid pandemic). If we apply the 20% markup for the new assets, we get a value of $32,529. The total cost is then $59,637 m, that is 5.2 years of profit.
This proportion clearly shows the magnitude of the financial cost of decarbonization. Of course, these assets will not be written off and replaced in one go. Still, this writing off and the cost of replacement spread till 2030, is about 64.5% of the yearly profit (assuming that the average profit remains roughly similar).

2.2.2.2 Arcelor Mittal:

Arcelor Mittal is the biggest steel maker in the world. It produced 89.8 million tonnes of crude steel in 2020 and 71.5 mt in 2020. The SD policy is aligned with the Paris Agreement. In 2015 it launched the SD framework which is aligned with the UN SD Goals. (all figures derived from the 2020 Annual Report).
The total for tangible assets for 2020 is $30,622 m. If we exclude the value of land and building, it is $19,884 m. The value of equipment is $36,559 m.
The value of the adjusted assets represent around 6.5 times the average profit (before tax) of 2017 and 2020 (we exclude 2019 when the company made a loss due to the Covid situation). If we apply the 20% markup (which is lower than the reality concerning steel production), we get a value of $23,861 m. The total cost is then $43,745 m, that is nearly 14.5 times the average profit for 2018 and 2020. Spread till 2030, the cost represents 180% of the yearly profit (assuming that the average profit remains roughly similar). As things stand at present (but of course, they will not, and we do not know what they will be like), decarbonization looks like bankruptcy for the company. But, carbonated or decarbonated, we will still need steel.

2.2.2.3 Lafarge Holcim:

Lafarge Hocim is the biggest concrete producer in the world. We know that cement is the biggest emitter of CO^2. So it is an emblematic example of the drive towards decarbonization. The company's sustainable policy is a 'net zero pledge for 2030', notably thanks to what it calls the 'ECOpact green concrete'. The net CO^2/ton emission of cement has gone down by 4.8% between 2016 (the year after the COP 21) and 2020. The target is a reduction of 14.4% between 2020 and 2030. This will be done by reducing the clinker content (the highest emitter of CO^2), using recycled fuels and developing carbon capture. (all figures derived from 2020 Annual Report)

The total for tangible assets for 2020 is CHF24,220 m. If we exclude land and buildings (including mineral reserves), it is CHF 12,816 m. The value of equipment is CHF29,747m. The value of the adjusted assets represent around 5.7 times the average profit (before tax) for 2019 and 2020.
If we apply the 20% markup (which is lower than the reality concerning cement production), we get a value of CHF15,379 m. The total cost is then CHF28,195 m, that is 12.5 times the average profit 2019 and 2020. Spread till 2030, the cost represents 156% of the yearly profit (assuming that the average profit remains roughly similar). We are in a situation which is similar to that of Arcelor Mittal. But likewise, carbonated or decarbonated, we will still need cement.

2.2.2.4 Volkswagen:

The Volkswagen group is the biggest producer of vehicles in the world. The group is committed to carbon neutrality in 2050. The average CO^2 emission of its vehicles (except for Lamborghini and Bentley) has already been reduced to 99.9 g CO^2/km (NEDC) in line with the EURO 7 standard to be effective in 2025. (all figures derived from 2020 Annual Report)
The total tangible assets for 2020 are valued at € 63,884 m. If we exclude land and buildings, it is €37,875 m. The value of technical equipment is €12,158 m. The value of the adjusted assets represent around 2.5 times the average profit (before tax) for 2019 and 2020. The value of the technical equipment alone represents 0.8% of the profit. If we applied the 20% markup, we would have €45,450 m, and a total of €83,385 m, that is 5.5 times the yearly profit. Spread till 2030, the cost would represent about 70% of the yearly profit (assuming that the average profit remains roughly similar). We have kept the same references as for the three companies above for reasons of coherence in a comparison, but in reality the cost for Volkswagen Group is lower due to the fact that significant efforts have already been made toward decarbonization. Nevertheless this cost remains sizeable.

2.2.2.5 Air France-KLM:

Air France-KLM is one of the biggest Airline company in the world. The objectives for 2030 are a reduction of 50% in CO^2, compared to 2005, a reduction of 50% in non-recycled waste, compared to 2011, and 0 emissions from ground operations. (all figures derived from 2020 Annual Report)
The total tangible assets of the company are valued at €12,579 m. If we exclude land and buildings, it is €11,714. The value of aeronautical assets is 11,031 and that of equipment is €248 m. It is impossible to calculate a somewhat meaningful ratio between tangible assets and profit as the company incurred a huge loss (€6928 m) in 2020 and a profit of only €346 m in 2019. In fact in 2020 the company was technically bankrupt due to the Covid crisis, and it could survive only thanks to governmental grants. The cost of having zero emission airplanes cannot be estimated as there will not be zero emitting planes even in 2050, and maybe never. In any case, this cost would be enormous.

2.2.2.6 Orange:

Orange is a major actor in the field of telecommunications with 259 million customers in 26 countries in 2020. In its strategic plan called ‘Engage 2025’, it is committed to net zero carbon for 2040 with its ‘Green’ programme for information systems networks consuming less energy and using renewable energy sources, but there is no specific information about the

estimated cost. Interestingly, Orange gives its global carbon imprint which is 1,287,809 tonnes of CO^2. It gives an idea of the effort to make.
It is of course even more difficult for a service company to estimate the cost of decarbonization as the number of parameters is bigger than for a purely industrial activity and they are harder to control due to the role played by the customers who are all different. But as a company like Orange relies on a big infrastructure of an industrial nature, we can venture to apply the same method as with the industrial companies and get an order of magnitude for the cost of decarbonization.
The total tangible assets of the company are valued at €29,075 m. If we exclude land and buildings, it is €27,057. The value of the adjusted assets represent around 5.5 times the average profit (before tax) for 2019 and 2020. If we apply the 20% markup, we would have €32,468 m, and a total of €59,525 m, that is 12.2 times the yearly profit. Spread till 2030, the cost would represent about 153% of the yearly profit (assuming that the average profit remains roughly similar). Like for the case of Volkswagen Group, this amount is somewhat over-estimated as part of the activities are already decarbonated.

As we have warned, all these calculations, though based on actual figures, contain many parameters, variables and data that cannot be under control. Consequently, the results can only be broad estimates of the cost of decarbonization for countries and firms. But the size of the amounts is such that, even allowing for a tolerance of several million dollars or euro or any other currency, it is obvious that the cost of decarbonization is well beyond anything that common people, politicians and even top managers can imagine. The figures are so scary that no one wants to face them and communicate about them, and thus are a sort of taboo. It is significant to notice that in all official documents there is never any information about the cost of decarbonization. For example, in the 28 pages document about the COP26 entitled 'The Glasgow climate pact', there is hardly anything about costs. The word itself does not appear. We read such things as 'Over $20 billion of new public and philanthropic finance has been committed to support developing countries to scale up clean power and make the transition away from coal' (page 9). But, as noted above, this is but a pledge of financing the energy transition. Why $20 bn? Nobody knows. The cost aspect is totally ignored. And we have seen, drawing from the McKinsey study, that this amount is ridiculous. Not in one of the Annual Reports of the companies that we have examined, do we find any information about costs, only general pledges or partial information about investments to reduce carbon emissions. No Annual Report (except Orange) gives any specific information about the amount of CO^2 that their operations produce.
Even if we look at the issue from the point of view of financing, we do not have specific information about how fighting climate change will be financed.
At the level of States, where will the money come from? There are only two possible sources: taxes or debt. No need to stress that both are subjects better not to talk about.
At the level of firms, there are four possible sources of finance: retained earnings, capital increase, debt, government grants and subsidies. We have seen that retained earnings can only marginally contribute to covering the cost of decarbonization. Capital increases imply that the markets are ready to invest in the firms for something with a long-term and largely unknown return, so we can expect them to be somewhat reluctant. Debt is limited by the level of indebtedness of companies, which is already quite high for a number of them. Government grants and subsidies are an 'easy' way for companies. But where will governments find the money? And we are back to square one.

The costs of decarbonization as estimated above, are gross amounts. They will be, to a certain extent, offset by benefits such as a reduction in diseases and natural disasters. However, these

benefits will only materialize years after the costs of decarbonization have been borne, that is after 2050 when carbon neutrality will have been reached, if the target is reached, and over many years afterwards when a real reduction in the amount of carbon accumulated since the Industrial Revolution will be effective. It is consequently absolutely necessary to adopt a very long-term perspective to have a chance of overcoming the problem. It is also absolutely necessary to adopt a cooperative strategy between States, between companies, among consumers and between States, companies and consumers.

Conclusion:

In the search for sustainability, the decarbonization of human activities is the touchstone of any strategy both for countries and firms and also for individual human beings. Sustainability will not come for free. And in the array of actions required for sustainability, decarbonization is probably the action which is the most costly. In this study we have attempted to tackle this question of the cost of decarbonization both at the macroeconomic level and the microeconomic one. This issue is rarely dealt with in studies about sustainability and decarbonization, which mainly focus on scientific aspects and technical and technological possible solutions, and is simply almost totally ignored, willingly – probably - or unwillingly, in official documents from governments, international organizations or companies. The task of estimating (nothing else than an estimate is possible) the cost of decarbonization in an accurate way is insuperable as many parameters cannot be controlled. Our aim has been to give an order of magnitude of this cost.

In spite of all the methodological limitations, the results clearly show that this cost is extremely huge and that it cannot be financed by companies under 'classical financial conditions'.

Decarbonization will also have a very significant impact on consumers whose reactions cannot be really anticipated.

In any case, decarbonization entails a radical change in the way companies operate and consumers behave.

In front of this Sisyphean mountain, what can we image will happen?

In the light of what has been done, or not done, and what has happened since the COP 21, it is very doubtful, and impossible according to the latest IPCC Report (2022), that the high income countries will reach the goals set for 2030 and 2050, and definitely impossible for middle and low income countries.

Some companies will simply not decarbonate in absolute terms, but eventually disappear (?) at one point or another. Some will partly do it and do it over a very long period, longer than the official pledges (20, 30 years?). For some it could be 50 to 70 years (e.g. in India). The deadlines officially set are very unlikely to be met. And when they are, we must not forget that 'carbon neutrality' is not real decarbonization. We may wonder if real decarbonization is an attainable goal, or really, as suggested in the 1st part, an aporia. The likely higher probability is that we will have to live with higher temperatures, sharp climatic variations, cataclysms and bear their negative effects: migrations, destruction of assets, deaths..

(Everybody sings: ABBA song: *money, money, money*)

References:

Meisner Rosen C. (1995): Businessmen against Pollution in Late Nineteenth Century Chicago, The Business History Review, Vol. 69, No. 3 Autumn, 1995

Report to the Royal Commission on River Pollution, UK (1897).

Club of Rome (1972): *The limits to* growth,
Brundtland Report (1987): O*ur Common Future*.
Baccarani C., Brunetti F., Martin J. (2021) : Climate change and organizational management: toward a new paradigm, TQM Journal, vol. 33, n° 3
Nigro C., Ianuzzi E., Spallone S. (2021): Towards a motivational model to understand the managerial coping with sustainability issues into the university system, 24th EISIC
Billi M., Mascareño A., & Edwards J. (2021): Governing sustainability or sustainable governance? Semantic constellations on the sustainability-governance intersection in academic literature. *Journal of Cleaner Production*, *279*, 123523
Isaksson R., Ramanathan S., Rosvall M. (2021): Sustainability Opportunity Study – Diagnosing, 24th EISIC
Asheim G. B. (1994): "Sustainibility", The World Bank
Sen A. (2009): The idea of justice
Aristotle (5th cent BC): Nicomachean Ethics
Mayer A (2008), "Strengths and weaknesses of common sustainability indices for multidimensional systems", *Environment International* Vol: 34, p. 277–291
Bell S., Morse S. (1999) *Sustainability Indicators: Measuring the Immeasurable*, Earthscan, London
Mc Kinsey (2022): *The net-zero transition, what it would cost, what it could bring,* McKinsey Global Institute, McKinsey & Company
Artus P. (2021) : Pas de transition verte sans croissance, *Le Monde*, 19-20 December 2021
McKinsey (2018): 'True Gen': Generation Z and its implications for companies, McKinsey & Company
Lungu C. I., Caraiani C., Dascalu C., Guse R. G., Sahlian D. N. (2009): Corporate Social and Environmental Reporting: Another Dimension for Accounting Information, SSRN Electronic journal, August 2009
Gray R., Owen D., Adams C. (1996): Accounting and accountability, Hemel Hempstead, Prentice Hall Gray P.H., Kouhy R.H., Lavers S. (1995): Corporate social and environmental reporting: A review of the literature and a longitudinal study of UK disclosure, Accounting, Auditing and Accountability Journal, Vol. 8, No. 2: 47-77
Havas Meaningful Brands Report (2021)
Smil V. (2020): Numbers don't lie, Penguin Random House UK
TOTAL Energies (2020): Annual report
Arcelor-Mittal (2020): Annual report
Larfarge Holcim (2020): Annual report
Volkswagen (2020): Annual report
Air France – KLM (2020): Annual report
COP 26 (2021): 'The Glasgow climate pact'
IPCC (2018): Global warming of 1.5°
IPCC (2022): Full report
Govind, R., Singh, J. J., Garg, N., & D'Silva, S. (2019). Not walking the walk: How dual attitudes influence behavioral outcomes in ethical consumption. *Journal of Business Ethics*, *155*(4), 1195-1214.
Park, H. J., & Lin, L. M. (2020). Exploring attitude–behavior gap in sustainable consumption: Comparison of recycled and upcycled fashion products. *Journal of Business Research*, *117*, 623-628.
Casais, B., & Faria, J. (2021). The intention-behavior gap in ethical consumption: mediators, moderators and consumer profiles based on ethical priorities. *Journal of Macromarketing*, 02761467211054836.

Testa, F., Sarti, S., & Frey, M. (2019). Are green consumers really green? Exploring the factors behind the actual consumption of organic food products. *Business Strategy and the Environment*, *28*(2), 327-338.