

Towards responsible circular fossil carbon industries: Upstream proposals to reduce demand and control supply - A working paper

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While emissions from energy production are rising sharply (see [IEA announcement of 20/04/2021](#)), the proximity of COP26 in Glasgow is pushing governments and private companies, particularly in the hydrocarbons industry, to announce strong commitments to reduce their emissions. These announcements are themselves generating a lot of reactions as to their feasibility and real impact (see, for example, the [Carbon Tracker article on major oil companies' strategies](#)) and they stimulate debate on the rules for implementing Article 6 of the Paris Agreement, which allows Parties to finance more effective mitigation measures in other countries in order to reduce their own commitments. They also highlight the accounting difficulties of the current emissions tracking framework - see, for example (Andrew 2020) or (Thunder Said Energy 2021).

This paper proposes a different approach, based on one hand on setting up an indicator quantifying the quantities of carbon that have a fossil origin and on the other hand on empowering the fossil carbon producers about the fate of the extracted carbon . This would contribute to the setup of a supply side control system. .

After a reminder of the emission control mechanisms currently in place or under discussion, we recall the relevant time scales and orders of magnitude of the carbon cycles and the impact of extractive activities since the industrial revolution on greenhouse gas (GHG) emissions and the quantities of formerly "fossil" carbon now circulating outside the geosphere.

In a second part, we propose an fossil carbon indicator" that is simpler to monitor and more relevant than the monitoring of emissions.

In the third part, we propose a method based on this indicator that could lead the actors involved to reduce their emissions more effectively and give the Parties to the Paris Agreement better tools to honour their commitments.

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Preface by the Association of Oil and Energy Consultants

The Association des Consultants Pétrole Energie (www.acp-france.org), which brings together independent specialists in the oil and gas professions, is a creative force for proposals to the profession and to society in general about the changes that the oil and gas industries are undergoing driven by the low-carbon transformation of the economy. The article below, written by Mr Nicolas and Mr Portolano as part of a citizens' initiative, fully meets the Association's objectives and the Association strongly recommends that it be widely circulated, in particular to a circle of decision-makers who can influence the resolutions that will be taken at the forthcoming COP 26 climate conference in Glasgow in November.

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1. Current mechanisms to account for carbon emissions

Several schemes have emerged to control and then reduce GHG emissions (these are described in more detail in Annex 1 and in the recently published IFRI review (Mathieu 2021)):

- Emissions Trading Scheme (ETS) in which a decreasing volume of emission rights is allocated each year to participants, who can trade them in the market and bring out the most economical emission reduction solutions
- carbon contributions or taxes where participants pay a contribution proportional to the volume of GHG they emit
- clean development instruments that allow certain participants to finance projects unrelated to their activities but that reduce emissions in exchange for carbon 'credits' or emission allowances.

More recently, to reduce the "carbon leakage" created by the establishment of the ETS in Europe vis-à-vis the rest of the world, the EU is contemplating the introduction of a carbon tax at the frontiers to compensate for the distortion of competition for European players.

Ineffectiveness of current means of accounting for carbon

To date, these mechanisms have not been able to reduce emissions overall. As they are based solely on the voluntary participation of States, they are not binding enough. In fact, they only cover a portion of emissions (16% of GHGs by the end of 2020, according to World Bank (World Bank 2021)) and even if the "cost" of carbon emitted has increased in recent years, it is far from being a deterrent.

Moreover, although theoretically optimal, the emissions market mechanism has for a long time led to an extremely low carbon value in the EU-ETS due to an imbalance between the volume of rights and the emissions themselves, not to mention financial malpractice (VAT fraud between 2008 and 2009). The Carbon Credits (CERs) set up under the Kyoto agreement have also been under-valued for a very long time

The various carbon credits set up to help finance development projects are not comparable, being built on different criteria. Some are used to promote multiple sustainable development objectives, which is desirable, but does not facilitate the monitoring of the impact on emissions. In this regard, it is worth noting that the SBTi criteria (Science Based Targets initiative 2021) for validating a company's emissions reduction trajectory exclude the use of credits ("offsets").

The difficulty for the parties in knowing how to implement Article 6 of the Paris Agreement illustrates the complexity of the mechanisms in place. Indeed, while this article allows priority to be given to financing the most effective actions in terms of GHG reduction, the inclusion of all the carbon credits initiated by countries or private entities, inherited from the Kyoto Protocol or committed more recently using different approaches, makes the monitoring of national commitments (NDCs) extremely complex.

2. Carbon cycling

a. Natural fluxes

The carbon cycle takes place over the entire globe and involves the **atmosphere**, the **hydrosphere**, the **terrestrial and marine biospheres**, and the **geosphere** (the upper part of which is the **lithosphere**). The figure below summarises the cycle:

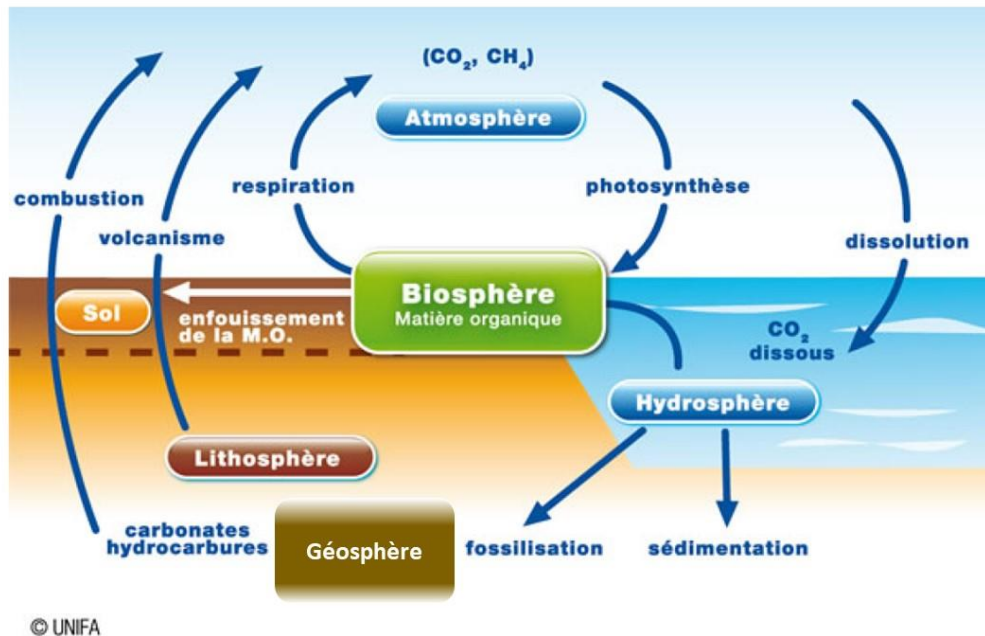


Figure 1: carbon cycle - UNIFA

The carbon cycle is one of the most important cycles on earth and, together with the water cycle, is responsible for the very existence of the biosphere.

To summarize, there is an **endogenous carbon cycle** within the geosphere that operates on time scales of a million years or more and regulates more than 99.9% of the Earth's carbon. Therefore, the atmosphere, biosphere, and hydrosphere - where the so-called **exogenous carbon cycle** takes place - contain only a tiny fraction of the carbon stock and, in the present geological time, receive carbon from the geosphere at a rate of less than 0.4 Gt/yr (mainly through volcanism and metamorphism).

The largest exchanges between the different compartments of the exogenous carbon cycle are between the atmosphere and the terrestrial biosphere (60 GtC/year in both directions, annual balance almost zero) and between the atmosphere and the ocean surface (70 GtC/year in both directions, annual balance almost zero). These large flows are due to the rapidity of the cycles concerned, which last from one day to several months (seasonal cycles) and whose very low annual balance controls climate variations over interannual to geological periods.

The smallest of these compartments, the atmosphere, is the real heart of the system as the concentrations of carbon compounds homogenise very quickly, in a few days to a few months, it

contributes to accelerating exchanges between these various compartments and it also reacts very quickly to their changes.

b. Anthropogenic emissions

Anthropogenic carbon emissions of fossil origin (mainly gas, oil, coal, and cement) exceeded 10 Gt of carbon (36 Gt of CO₂) in 2020 (Figure 2), i.e., 25 times more than natural emissions.

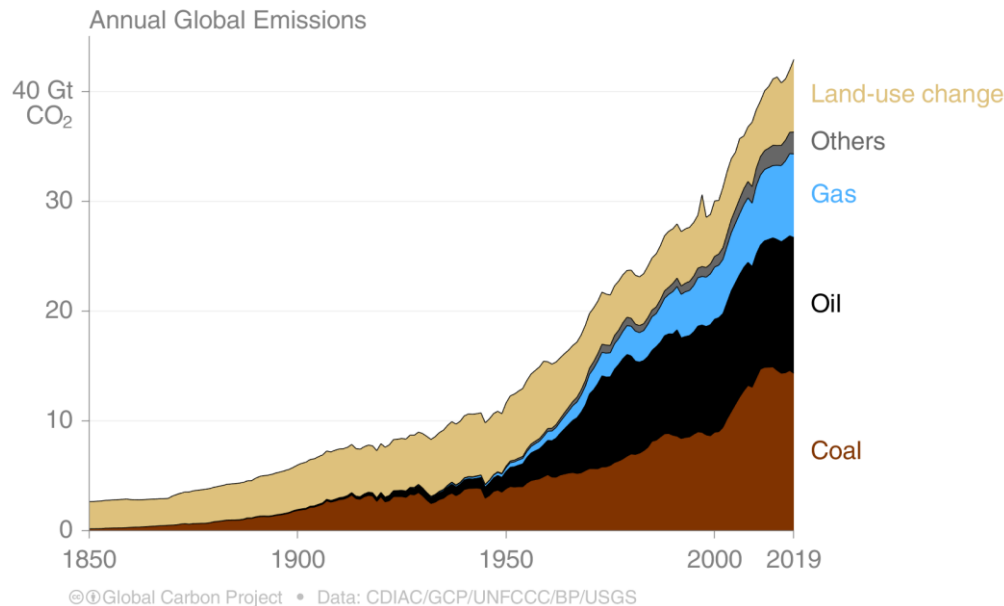


Figure 2: Distribution of emissions by category in GtCO_{2eq}, Global Carbon Budget 2020 (Friedlingstein 2020), the 'Others' sector includes cement and flaring emissions

(Note 40 Gt of CO₂ = 10,9 GtC)

This is a direct injection of fossil carbon from the geosphere into the external compartments of the biosphere, atmosphere, and hydrosphere.

It is therefore easy to imagine that an injection of more than 10 Gt of carbon per year from anthropogenic emissions of endogenous (fossil) origin strongly disturbs the natural flows and stocks of carbon between the biosphere, water, and atmosphere.

The effect of this direct injection of fossil carbon into the atmosphere has now been quantified as shown in Figure 3, which shows that in the past 4 years, a growth trend of about 2.6 ppm of CO₂ per annum is superimposed on the cyclical annual variations of 5 ppm amplitude linked to the homogenisation of the atmosphere due to its exchanges with the terrestrial biosphere and the oceans.

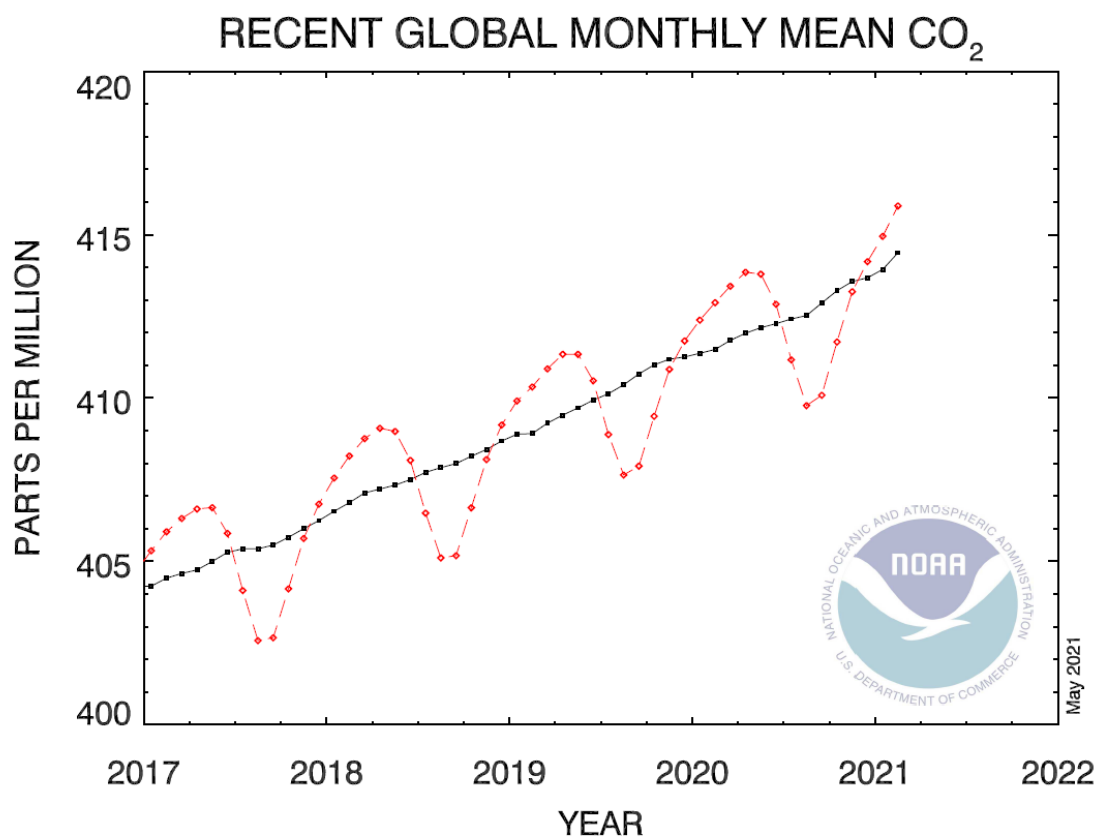


Figure 3: evolution of the carbon dioxide content of the atmosphere – source NOAA

Given that the carbon stock in the atmosphere is estimated at 874 Gt (year 2018) and its CO₂ concentration is 408 ppm, the observed average increase of 2.6 ppm/year (i.e. 0.6%) (period 2016 to 2018) amounts to introducing $874 \times 0.6\% = 5.2$ Gt of carbon. Between 2016 and 2018, average fossil emissions were 36 Gt/year of CO₂ (Figure 2), i.e. an emission of 9.8 Gt/year of carbon. This calculation, while greatly simplifying ongoing processes, attributes most of the annual increase in atmospheric carbon to CO₂ emissions from endogenous fossil carbon combustion. The balance of the 9.8 GtC emitted, i.e. 4.6 GtC, is mainly found in the biomass (photosynthesis) and in the oceans (acidification) (see Annex 2).

These cumulative emissions since the beginning of the industrial era, in an extremely short period of time on a geological scale, mean that the CO₂ content of the atmosphere now exceeds 400 ppm, whereas it has remained between 180 and 300 ppm for the last 300,000 years, according to measurements taken in the ice (Uemura, et al. 2018).

The work of the Deep Carbon Project (Cin-Ty A. Lee 2019) estimates that **such disturbances, if not stopped quickly, could have effects over periods of tens of thousands to hundreds of thousands of years.**

Finally, as the IPCC reminded policymakers in its 2014 Synthesis Report, climate change is directly related to the increase in GHG content of the atmosphere.

3. Proposed Fossil Carbon Indicator to create downstream demand reduction signals

Based on these considerations, it is proposed that all economic agents (corporations, retailers, consumers) be informed of the nature of the carbon they are dealing with carbon of endogenous origin (also known as fossil carbon) should not be treated in the same way as carbon of exogenous origin.

To this end, we propose the definition of an **Fossil Carbon Indicator**, which will be built on the volumes of carbon extracted from human-controlled geological sources, i.e. extraction sites, to measure the quantities that in the short (days, months) or medium (years) term will disturb the atmospheric balance. *This includes all primary production of geological (fossil) resources whose transformations will systematically generate greenhouse gas emissions in the biosphere.*

Several academic sites, including the US (EPA - AVERT 2018) and the IPCC emissions factors database (IPCC 2021), provide estimates of the quantities of greenhouse gases generated by from the combustion or industrial processing of various fossil resources. Precise coefficients can be obtained for each extraction site, given that the content is essentially linked to the chemical composition of the resources.

Table 1: indicative GHG¹ content per unit of geological resource, sources (EPA - AVERT 2018) and (IPCC 2021)

Geological resources (fossils)	Production unit	GHG emissions per unit of production in t CO ₂ eq
Oil	Barrel	0.43
Coal	Ton	2.44
Gas	mmBTu	0.05
LPG	Barrel	0.25
Calcite/Aragonite (calcium carbonate)	Dry ton	0.44
Dolomite		0.48
<i>for lime or glass production</i>		

The aggregated quantities produced by all operators and converted into **tCO₂eq** form the **Fossil Carbon indicator**. This indicator is de facto unambiguously defined for each primary material when it is extracted.

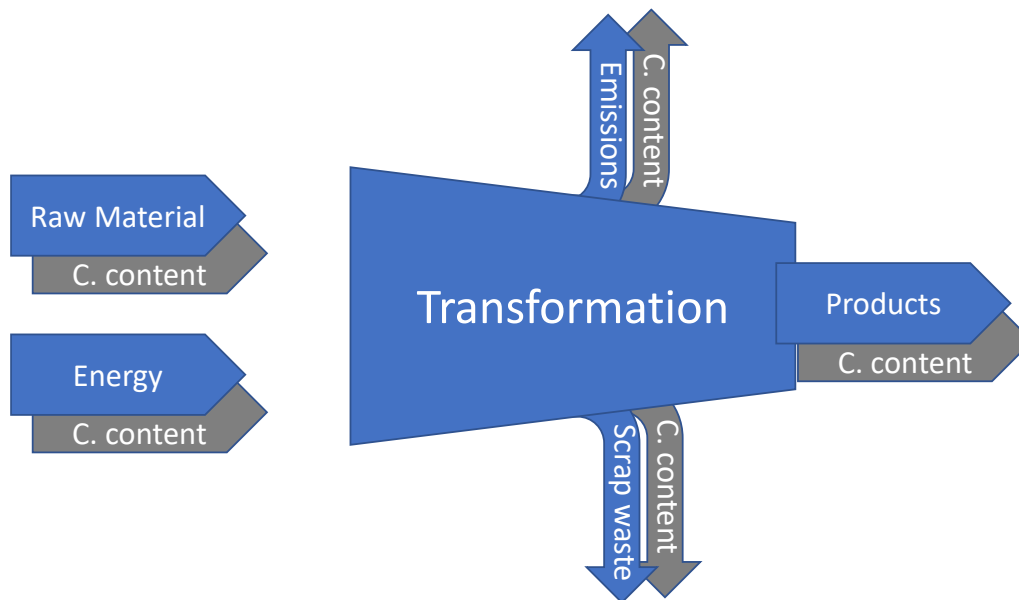
In this approach, it is no longer necessary to differentiate between fossil carbon uses in separate 'scopes'² since all the emissions potentially generated by the products are accounted for in the **well/ mine/ quarry output** Fossil Carbon Indicator measure. It may be possible to consider in the emission coefficients the fact that some carbon-rich products have no short- or long-term impact on the atmosphere, while bearing in mind that many manufactured products end up generating greenhouse gases during their destruction (decomposition, incineration, etc.) and thus increase the stock of carbon circulating in the biosphere or atmosphere in short cycles on a geological scale.

¹ GHG: greenhouse gases

² GHG emissions assessments are divided in international standards (World Business Council for Sustainable Development, World Resources Institute) into three categories, called "scopes": Scope 1 covers direct emissions, Scope 2 indirect emissions associated with energy consumption, and Scope 3 other indirect emissions generated using the products sold.

Displaying these quantities in tonnes of CO₂ equivalent (tCO₂ eq) would make it possible to compare them with the carbon 'budget' put forward by the IPCC (Meinshausen 2009), (C. McGlade 2015) to estimate the quantities of 'burnable' fossil resources that could be used in order to keep global warming below 2°C.

It may also be possible to track this carbon indicator over the life of the products, via an accounting of inputs and stocks at each point of transformation that can be reconciled with emissions to the atmosphere as shown in Figure 4



$$\sum_{\substack{\text{Raw Material} \\ + \text{Energy}}} \text{Carbon} = \sum_{\text{Products}} \text{Carbon} + \sum_{\text{Emissions}} \text{Carbon} + \sum_{\text{Scrap}} \text{Carbon}$$

Figure 4: Accounting for carbon flows in product processing

For any given product, a **Fossil Carbon Footprint Indicator** will be calculated by dividing the Fossil Carbon Indicator by its Carbon Footprint. As the ultimate beneficiaries of products and services produced with fossil carbon are usually unaware of the total amount of fossil carbon that has been mobilised in the transformation steps, posting this indicator may change their attitude into preferring the less fossil carbon intensive products. This may also be used by the authorities in order to modulate a carbon tax aimed at discouraging the use of fossil fuel-based products. The development of certificates or tracking solutions (blockchain type) as already exists in some food industries (see solution crystalchain³) may also have to be considered.

With a view to reducing the demand for fossil carbon resources, these indicators derived from the Fossil Carbon Indicator are necessary tools for characterising the products and services that use the most of these resources, such as fuels, energy sources, steel, aluminium, cements, petrochemical products, etc., and those covered by carbon taxes or markets.

³ <https://crystalchain.io/>

Qualitative valuation of the Fossil Carbon Indicator:

Let us recall at this point that the objective agreed in the Paris Agreement is to halt as quickly as possible the increase in GHG content in the atmosphere, which we have seen is linked to the quantity of fossil carbon mobilised by human activities.

In the long term, therefore, we must reduce the use of new fossil carbon resources as much as possible and promote the recycling of resources already extracted or alternative resources and establish as an ecological principle that any new fossil carbon resource produced should be compensated tonne for tonne by extracting carbon from the surface (atmosphere, soils, or oceans) and immobilising it for the long term in the geosphere.

Transition period

Given the universal use of fossil energy resources, their complete replacement overnight by often less efficient resources is not an option.

Wherever possible, the aim is to pursue and to accelerate the use of renewable and low carbon resources rather than mobilizing new fossil carbon resources. When there will be no alternative to the use of such resources, capture and geological sequestration should offset their GHG emissions.

By informing the economic agents with an indicator of the nature of the carbon (content of fossil carbon vs biogenic carbon), they will be able to deliberately reduce their fossil carbon impact by comparing their purchase with possible alternatives.

A tax levied by consuming countries and built on this Fossil Carbon Indicator rather than on emissions alone will be more effective. It will be used to finance alternative solutions, carbon sequestration and part of the funds needed to adapt to climate change.

For example, if this contribution were valued at €40/tCO₂ (order of magnitude of the carbon price needed to have a profitable CCS operation at the beginning of 2021), this would result in an additional cost of around €0.10 per litre of petrol at the pump in France (current selling price €1.40 per litre).

The failure to implement the Kyoto agreement has shown that voluntarism is not sufficient to mobilise states and institutions to reduce GHG emissions. Thus, as modelled by (Nordhaus 2015), the creation of a club of developed countries promoting a significant carbon tax and penalising non-members is probably the most effective approach to obtain increasing adherence to this policy and to achieve binding international agreements involving all countries.

Limiting demand within groups of voluntary countries, although essential to initiate emission reductions, will not be sufficient if there is no reduction in supply by producers. Otherwise, as explained for example by (Pellegrini et Muñoa 2021), the drop in demand will lead in the short term to a drop in prices and an increase in demand in the consumer countries not subject to the limitation. Moreover, for fear of seeing their assets becoming stranded, some producing countries will accelerate their production, which will also lower prices in the short term.

It is therefore necessary to involve at least some major producers in a supply reduction agreement. The trade association within a single 'climate club' of willing consumer and producer countries,

penalising trade with countries outside the club, could provide sufficient incentive to convince other countries to join.

Subsequently, and subject to the conclusion of appropriate agreements, depending on their geology, some producing countries may be interested in developing CO₂ sequestration solutions and thus benefit from exemptions for the sale of their fossil fuel production if they are able to compensate for the same emissions. These producers who can 'neutralise' the emissions associated with their production of fossil fuels will be able to levy a contribution directly 'upstream' (at the sink) to remunerate the sequestration operations.

4. Desired end game for the fossil carbon industries - responsible circular approach

We are not aware of any precedent for this approach at this stage. The proposal here is to draw out some general principles for economic management of fossil carbon, based on the understanding of the biogeochemical carbon cycle outlined at the beginning of this paper and in Annex 2.

The objective would be for these principles to be brought to the debate at the next COP 26 so that supranational legal provisions can be rapidly adopted to bring carbon taxation and markets in line with natural carbon cycles as soon as possible.

Environmental principles

- From a certain date onwards, the sole and final responsibility for managing fossil carbon lies with the person or entity which extract it from the geosphere: its liability consists of re-immobilising an equal quantity of carbon in the geosphere for millions of years

Examples:

- Geological sequestration of CO₂ (CCS⁵), e.g. in non-usable aquifers or in depleted hydrocarbon reservoirs
- Geochemical carbonation reactions (above or below ground) such as the transformation of CO₂ and silicate rocks into carbonate rocks.
- Storage on the surface (e.g. old quarries) or in mines of carbon obtained by pyrolysis (in the absence of oxygen) of carbon-rich materials
- Onshore or offshore bioproduction of organic material (kelp, algal mats, shellfish, foraminifera, etc.) trapping organic matter or carbonates in sediments while decomposing in lake/sea bottoms.
- *or any other solution allowing the reintegration of carbon into the endogenous cycle*

Ensuring that these processes will isolate the captured carbon from current biospheric processes, and that the necessary energy will be available.

- If the producers of fossil carbon cannot take care of this process, they must entrust it to another economic agent, or pass down the responsibility to buyers who will be obliged to take care of the geological sequestration of the carbon at the same rate as it is extracted by the producer.

⁵ CCS : Carbon Capture & Storage

Results:

- The price of carbon storage is thus considered by economic players at source. Operations that are too carbon-intensive (in terms of costs) are thus naturally eliminated in favour of low-carbon operations.
- Atmospheric emissions are being reduced very quickly, as no more fossil carbon is emitted than is stored geologically each year.
- Carbon capture from the air fulfils its primary purpose of reducing carbon content, not offsetting fossil carbon emissions.
- The use of biocarbon sources is not penalised.
- The reduction of fossil carbon levels in the atmosphere is achieved through appropriate ecological management of forests, soils and oceans left to the initiative of each territory. There is no longer any risk of setting up planetary processes that could ultimately result in the decay of ecosystems which would be used to geologically store excess biospheric carbon. Nor that any supra-territorial authority imposes unwanted policies locally, other than the obligation to locally manage the circularity of fossil carbon extractions.

Implementation

- These principles are to be adopted at an international assembly (COP26) and incorporated into international laws that will lead to local regulations
- The parties commit to a limited duration of the transition period.

Examples

An oil company such as TOTALENERGIES is on the right track since it has announced that it will monitor all its Scope² 1+2+3 emissions. It must now be ensured that the extracted fossil carbon will return to the fossil state at the same rate as its hydrocarbon production. It must also be ensured that biospheric storage systems (forests, soils, oceans in which the extracted fossil carbon remains in the biosphere) are only temporary and are accompanied by long-term immobilisation (BECCS). It must finally be ensured that carbon credits are not just informational mirages (virtualisation of fossil carbon that ultimately remains in the biosphere through trading operations on the carbon markets).

But much more needs to be done, both by hydrocarbon and by coal producing companies and states.

Some companies, such as ARAMCO, the world's leading oil company, are already taking the lead and implementing a business model based on a circular carbon economy by experimenting with full-scale solutions such as the use of carbon carriers (ships that transport CO₂, bringing the CO₂ from their hydrocarbons to fields where it can be stored); or the local production of hydrogen, which is then transformed into ammonia with on-site sequestration of the co-produced CO₂. (ARAMCO 2021)

Others will benefit from the first experiences of the oil groups that are currently the most enterprising in this area.

5. Discussion of alignment with other proposals for upstream interventions

This approach is in line with that advocated by Charles Komanoff's [Carbon Tax Center](#) in the United States since 2007.

The concept of an upstream carbon tax was proposed as early as 2009 by (Metcalf et Weisbach 2009) (University of Chicago) where they showed that *“a well-implemented carbon tax imposed*

upstream can easily cover 80 percent of U.S. emissions and can likely cover almost 90 percent with a modest additional cost. The benefits of the broad base and lower compliance costs are likely to be significant."

Also in 2009 also, Myles Allen, David Frame and Charles Manson, from Oxford University ()published in Nature a call for *"a mandatory link between carbon sequestration and fossil fuel extraction"*.

In September 2015, just before COP21, scientists from Oxford University, Edinburgh University and Tyndall Center (Allen, et al. 2015) made the proposal to the British Government to setup a Carbon Certificate scheme which:

"Would remove the burden of funding CCS of Government support, and spread the cost of CCS development and deployment across the entire fossil fuel sector through a Certificate scheme that would rely only on data already reported to Government"

Their approach *"places the burden of CCS development and deployment where it should be, on the owners of fossil fuel assets"*.

and is fairly simple:

"The proposed mechanism is as follows: to introduce a Certificate system to identify any person extracting, or importing, oil or gas for sale or use as fuel or feedstock or reagent within the economic jurisdiction of the UK. The Certificate carries an obligation to demonstrate permanent storage of a percentage of the fossil carbon content of that oil or gas in the form of carbon dioxide that would otherwise, under normal business practice, have been vented into the atmosphere. The percentage will be set by the Oil and Gas Authority in consultation with independent scientific advice and increase over time to be commensurate with the UK's long-term climate goals. Permanent storage may be provisionally defined as an expected storage lifetime of 10,000 years".

The same scheme was also proposed for Norway and reiterated in 2019 by Oxford University (Mitchell-Larson 2019).

A few days after the closing of COP 21 in Paris, Romain Ferrari, President of the 2019 Foundation (France), made a proposal of levying an Excise Duty on the extraction of fossil fuels that would be paid to a redistributive "Climate" fund at world level (Ferrari, Blogs-COP21 2015) and (De Gerlache et Ferrari 2015). His proposal was reiterated with Christian de Perthuis, founder of the Chair of Climate Economics at the University of Paris Dauphine and Serge Orru, advisor to the mayor of Paris Anne Hidalgo, in an article in the economic magazine Les Echos (Ferrari, Orru et De Perthuis, COP21: transformer les bonnes intentions en actions 2016).

In March 2018, in a special issue of "Fossil Fuel and Climate Policy", two authors from the London School of Economics and the Australia Institute, (Lazarus et van Asselt 2018) reminded that *"the most efficient point of regulation for a carbon tax (or cap-and-trade system) would be upstream at the point of fossil fuel extraction. Doing so would ensure maximum coverage and results in lower administrative costs as there are far fewer entities that produce rather than process, distribute, or consume fossil fuels.*

In the same issue, the Stockholm Environment Institute (Green et Dennis 2018), remarked that the *"evaluation of instruments aimed at restricting the upstream supply of commodities or products whose downstream consumption causes greenhouse gas emissions—such as fossil fuels—has largely been neglected ... given the widespread use of restrictive supply-side policies in other policy domains, their relative neglect in the climate policy domain seems anomalous"* and stressed that

“restrictive supply-side policy instruments (targeting fossil fuels) have numerous characteristic economic and political advantages over otherwise similar restrictive demand-side instruments (targeting greenhouse gases) ; economic advantages include low administrative and transaction costs, higher abatement certainty (due to the relative ease of monitoring reporting and verification), comprehensive within-sector coverage, some advantageous price/efficiency effects, the mitigation of infrastructure “lock-in” risks (sending clear signal to investors and avoiding inefficiently high levels of investment), and mitigation of the “green paradox” (i.e. rebound effect of increased demand driven by lower prices) . “Political advantages include the superior potential to mobilize public support for supply-side policies, the conduciveness of supply-side policies to international policy cooperation, and the potential to bring different segments of the fossil fuel industry into a coalition supportive of such policies”.

In the letter published in Nature in March 2019 "Tax Fuel Production, not Emissions", Emil Roduner (University of Stuttgart) reiterated the concept of an upstream production tax (Roduner 2019).

In July 2019, nine specialists from various Universities of Norway and the Toulouse School of Economics (Asheim, et al. 2019) published in Science a call for “a supply-side climate treaty”.

In January 2021, five specialists from institutions or universities in Germany, Saudi Arabia (KAPSARC), and UK as well as from SHELL (Zakkour, et al. 2021) presented “a supply-side approach aimed at balancing rates of carbon extraction from the geosphere and rates of carbon deposition in stable geological reservoirs so as to achieve net-zero emissions”.

Also in January 2021, a report (Kuijper, Holleman et van Soest 2021) for the Dutch Ministry of Economy recommended that “A Carbon Takeback Obligation (CTBO) “ be implemented; it is “a scheme to ensure that hydrocarbons placed on the market are, on balance, employed in a CO₂-free manner by the time net zero needs to be reached”. “The essence is that a producer or importer placing such carbon compounds on the market must ensure that the CO₂ that would be released during their use will be sequestered/stored rather than be released into the atmosphere. It is not, by definition, incumbent upon the producer or importer to carry out the sequestration/storage themselves, although it is permitted; their primary responsibility is to arrange for the possibility of storage/sequestration. This can be achieved by contracting storage and/or sequestration facilities upon the production or import of (fossil) hydrocarbons; by purchasing carbon storage units (CSUs) from third parties; or by (collectively) setting up a storage company that generates sufficient CSUs.” This very detailed approach would allow a rapid implementation of her proposed CTBO by Dutch authorities.

As the climatic issue becomes more pressing year after year and has been accelerating these last 10 years, the inefficiency of measures targeting only emissions is getting more and more evident. The climatic situation has now reached a point where entities not related to the hydrocarbon world are proposing more drastic solutions, using the concept of “Fossil Fuel non-proliferation treaty” for supply-side control of global extraction of fossil fuels (Newell et Simms 2020). This proposal which has a high mediatic coverage has been signed by more than 100 Nobel prizes and personalities such as the Dalai Lama⁶, Gael Giraud, Naomi Klein as well as by more than 1300 scientists⁷, 12 000

⁶ <https://edition.cnn.com/2021/04/21/world/earth-day-dalai-lama-climate-letter-intl/index.html>

⁷ These scientists belong to organizations , mainly research centres and universities from the following countries: Australia, Austria, Belgium, Canada, Chili, Costa Rica, Denmark, France, Germany, Holland, Hong Kong, Ireland, Italy, Japan, Malaysia, Mexico, Nepal, New Zealand, Norway, Pakistan, Peru, Philippines, Portugal, South Africa, Sweden, Switzerland, Spain, UK, US

individuals, 13 cities or regions ⁸and 600 organizations, mainly NGO⁹. Only a handful of researchers who signed are employed in the private sector, mainly in renewable energy SME such as Atlantic Energy, or Hy-Energie as well as in the French utilities majors such as EDF, Enedis or Engie. It is also worth noting the absence of any signature from fossil carbon producing organizations or from carbon intensive or carbon producing countries such as India, Russia, African countries, Middle Eastern or East European countries. This separation in 2 groups correspond to a greater or lesser extent to the historic split between the colonizing vs colonized world, or to a split between the countries that will bear most of the climate change vs those where less effects will be felt. This will certainly reactivate old and persistent fracture lines during the debates at COP26.

We certainly agree as claimed on the site "<https://fossilfuel treaty.org/home>" that "*The main cause of the climate emergency is fossil fuels*" and that "*Phasing out fossil fuel production, and fast-tracking progress towards safer and more cost-effective alternatives, will require unprecedented international cooperation*", but should we compare fossil fuels to disseminated nuclear weapons ? Some may argue that these 2 last years have seen tens of climatic bombs exploding in all parts of the world: such bombs are hurricanes coming with stronger force in Louisiana, Texas, Florida, Bahamas, Philippines or China, the stationary storms creating unimaginable flash floods in France, Germany, Turkey, Tennessee, the very long dry spells creating wildfire over areas of thousands of km² in Australia, Canada, US, Russia. We should note though that the analogy is undermined by noting that proliferation of fossil fuel extraction and use is already practically universal.

The presentation of the climatic situation in the last report released by IPCC in August 2021 (IPCC (AR6 working Group I) 2021) would indeed call for such type of measures and it is now long overdue that producing companies and producing countries act seriously and rapidly to control the supply side of their emissions.

⁸ Australia: the Australian Capital Territory, City of Darebin, Moreland, Yarra and Sydney;
US : Cities of Los Angeles, Hayward and Yakima;
Canada : Cities of Toronto and Vancouver;
UK : Valley Borough Council and Lewes Town Council
Spain : Barcelona;

⁹ including Carbon Tracker Initiative, Centre for International Environmental Law (CIEL), David Suzuki Foundation, Extinction Rebellion, Friends of the Earth, Global Witness, Greenpeace

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Annex 1

Current mechanisms to account for carbon emissions

Mechanisms

Since the signing of the Kyoto Protocol at the end of 1997 at COP3, several mechanisms have been put in place to reduce GHG emissions (CO₂, CH₄, N₂O, SF₆, HFC, PFC and perfluorocarbons).

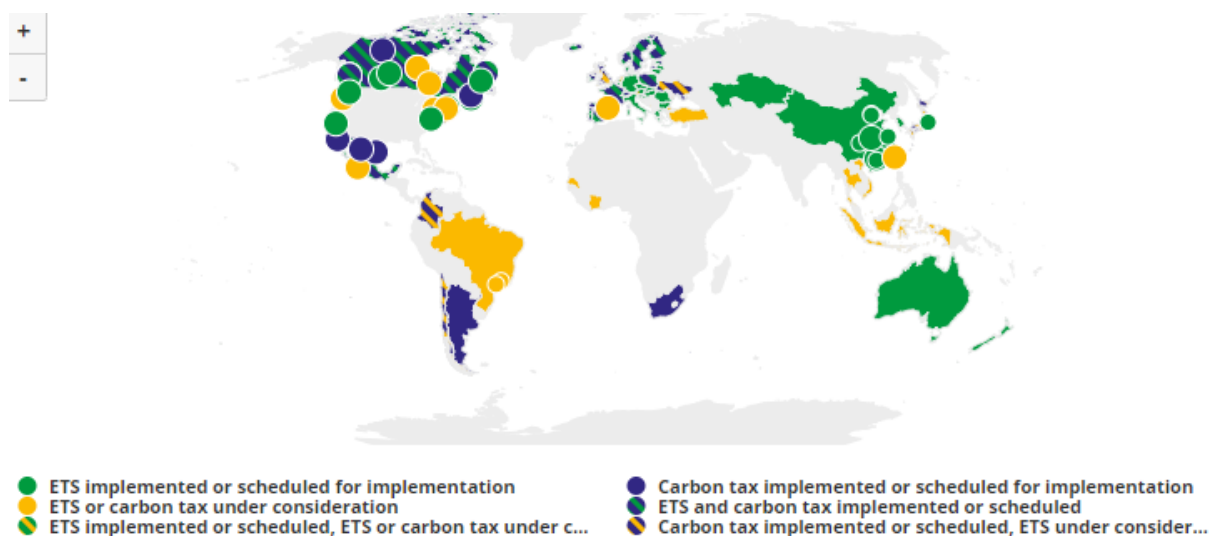
The first mechanism is the **Emissions Trading Scheme (ETS)**, which was originally intended to be global. In fact, several regional markets have been created, including the European Emissions Trading Scheme (EU-ETS), which was launched in 2005 and is the largest to date. ETs also exist in California, Australia, and Korea. The Chinese ETS is due to start operating in 2021. Where they are in operation, they cover the highest emitting industries and where emissions are measurable

These markets operate in two ways:

- « *Cap and trade* » in which the cap is set to decrease year by year and allowances are distributed for free or auctioned up to the cap
- « *Baseline and credit* » where a baseline is charged to each entity and credit is given to those issuing less

The other mechanism implemented in several regions is the **carbon tax**, most often calculated on fossil fuels per tCO₂eq on the volume of emissions.

By the end of 2020, ETs and carbon taxes are in place in 45 countries and cover 9 GtCO₂eq representing just over 16% of GHGs according to the dashboard published by the World Bank (World Bank 2021). Below is a map of countries that have organised or are planning to launch an emissions market or carbon tax:



The Kyoto Protocol also allowed for the emergence of **Clean Development Mechanisms (CDMs)** to allow Annex I countries (those committed to reducing their emissions) to invest in projects in developing countries by generating emission credits that can, under certain conditions, be used to meet the investors' emission reduction obligations.

Following the same approach, but outside the control of the United Nations (UNFCCC), other independent initiatives have developed which allow companies and other organisations to voluntarily finance development projects certified by organisations such as the Verified Carbon Standard (VCS) to materialise their commitment. The volume of these credits has increased significantly in recent years, accounting for 65% of credits issued in 2019, largely for projects aimed at restoring natural areas and forests ("nature-based solutions").

Finally, to deter the most carbon-intensive activities from relocating to regions not subject to a carbon cost, the European Union is studying the possibility of setting up a border adjustment mechanism (**CBAM**) and limiting the distortion of competition between products manufactured within the Union and those imported. According to current discussions, this mechanism could be effective from 2023.

ANNEX 2

Carbon Cycle (more details)

Natural fluxes

The carbon cycle in the **atmosphere, hydrosphere, terrestrial biosphere and geosphere** is detailed in Chapter 11 (Cin-Ty A. Lee 2019) of the synthesis « *Deep Carbon : past to present* » published in 2019.

The carbon cycle is one of the most important cycles on earth and, together with the water cycle, is at the origin of the very existence of the biosphere, about which some concepts are reminded below:

- The biosphere is the domain of living organisms. These are essentially made up of combinations of carbon and water molecules, and their chemical composition in the soil and in the oceans can be summarised by the formula CH_2O . Other elements are involved (N, P, K, Fe, Si, Al, Ni, etc.) but in much smaller proportions.
- The thermodynamic range of existence of life corresponds to temperatures from -15°C to 120°C and pressures from 0.01 atmospheres to 10 000 atmospheres. The biosphere is therefore present up to an altitude of a few km in the atmosphere, throughout the hydrosphere (up to 11 km deep) and down to an unknown depth, below 10 km in the lithosphere.
- The size of the lithospheric biomass has been known for a short time and is estimated at 13% of the planet's biomass.

The boundaries between the different compartments in Figure 1 are complex exchange surfaces (fractals) allowing biological and physico-chemical processes, the development of which spans over several order of magnitude of time and space scales.

Research such as the Deep Carbon Project provides insight into the different time and space scales of natural carbon streams on Earth.

Over short time scales (<100 years), the most significant processes concern only a fraction of the carbon that resides in the atmosphere, the terrestrial biosphere, and the oceans:

- Respiration of living beings and oxidation of organic matter (slow degradation or combustion) between the terrestrial and marine biosphere and the atmosphere, of the order of 60 GtC/year
- photosynthesis, which tends to balance annually the previous natural fluxes between the atmosphere and the terrestrial and marine biosphere
- balancing the partial pressure of CO_2 between the atmosphere and the colder or warmer surfaces of the oceans, of the order of 70 GtC/year in both directions.

Over longer periods of time, other phenomena regulate the whole carbon budget of the planet, but on much longer geological timescales:

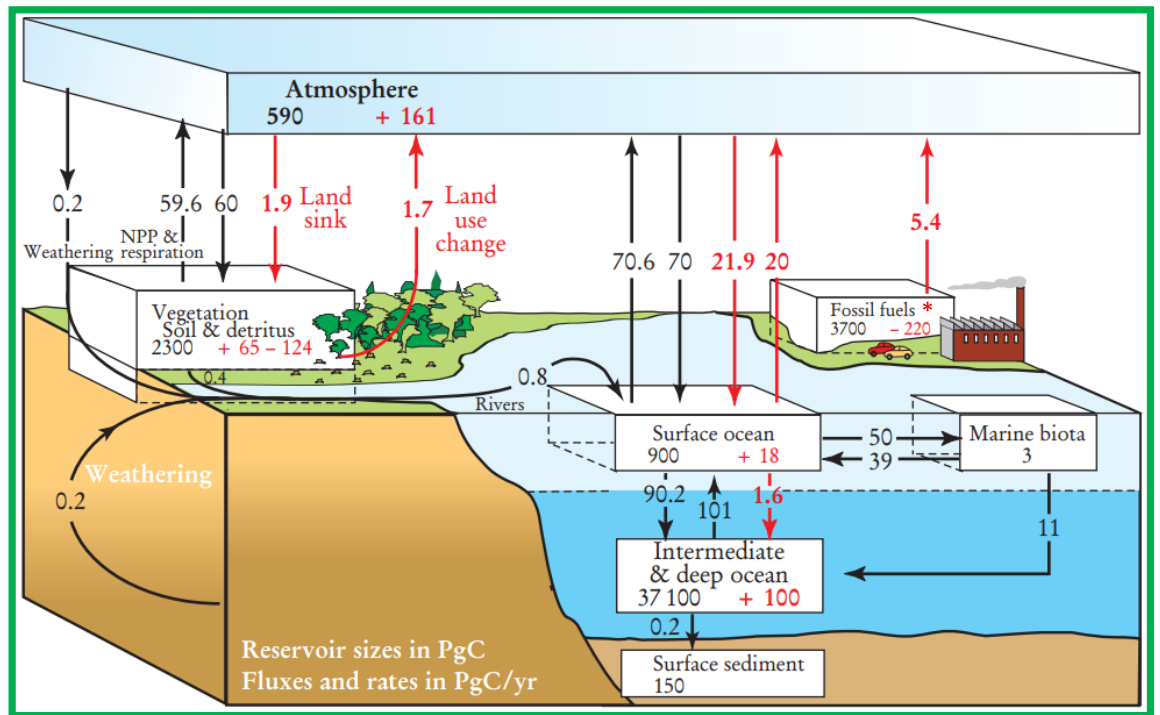
- erosive processes, which are slower and carry sediments into rivers and then to the bottom of the oceans

- the absorption of carbon via carbonate or organic deposits at the bottom of oceans and lakes
- aerial or underwater volcanic carbon emissions, metamorphic related emissions
- the subduction of carbon in the lithosphere and then in the mantle.

These fluxes are of the order of 0.4 GtC/year.

Since the beginning of industrial-scale exploitation of fossil resources at the lithosphere boundary, human activities have been increasing the stock of carbon circulating in the atmosphere, terrestrial biosphere, and oceans.

The next figure reconstructed from articles by (Cin-Ty A. Lee 2019) and (Sarmiento et Gruber 2002) represents the natural fluxes quantified on a pre-industrial basis and those related to anthropogenic activities based on data collected in the years 1980 to 2000 (the figures shown need to be updated for 2021 but nevertheless give a good estimate of the orders of magnitude involved).



Details of **natural carbon fluxes** (in GtC/year) and **stocks** (in GtC) - in black - between the atmosphere, the oceans and the terrestrial biosphere with the addition of **fluxes and stocks linked to anthropogenic activities from the pre-industrial period to the 1980s** - in red - including those linked to emissions of fossil origin (included in the lithosphere carbon stock (*) in the lower diagram)

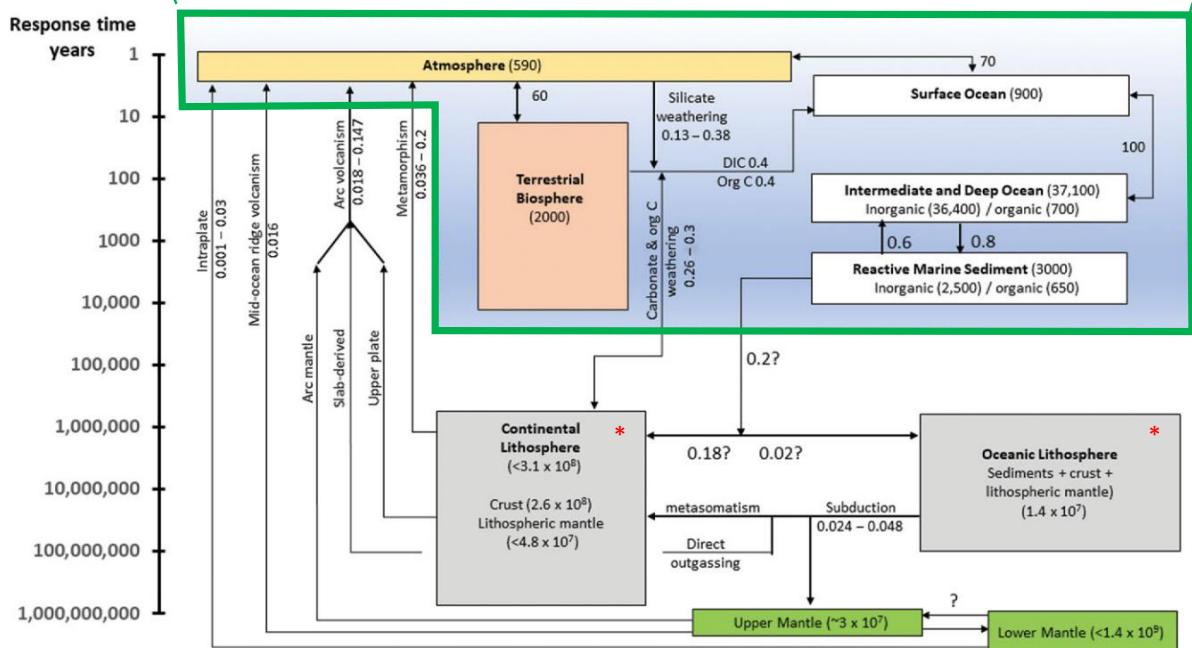


Figure 5: Earth-scale carbon cycle model, fluxes in GtC/year, taken from (Cin-Ty A. Lee 2019) : fluxes between green-framed blocks constituting the exogenous cycle are detailed in the upper part, taken from (Sarmiento et Gruber 2002) the other blocks represent the reservoirs located within the globe and constituting the endogenous cycle. The numbers in brackets indicate the mass of carbon (GtC) in each reservoir; the vertical size of the blocks gives the order of magnitude of the residence time

This analysis is in line with that of the IPCC in 2001 (Prentice report):

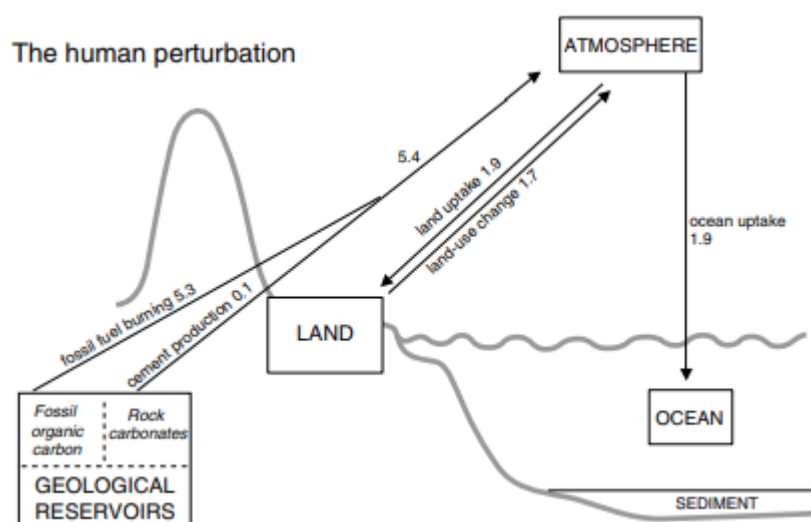


Figure 6: Carbon fluxes in GtC/year, taken from (Prentice 2001) due to human activity based on data from the 1980s.

It was updated in 2015 by the World Meteorological Organization (Canadell report) which gives the following carbon fluxes:

Table 2: carbon fluxes in GtC/year due to human activities, extracted from (J. Canadell 2017)

9.9 ± 0.5	1.3 ± 0.5	=	6.2 ± 0.2	3.0 ± 0.5	2.0 ± 0.9
Fossil fuel emissions (includes cement production)	Land use change, primarily desforestation		Growth in atmospheric concentration (6.2 GtC = 2.9 ppm)	Uptake by the ocean	Uptake by land

The measurements of atmospheric CO₂ concentration since the 1980s below show how this trend continues and its magnitude in relation to annual cycles related to photosynthesis and respiration.

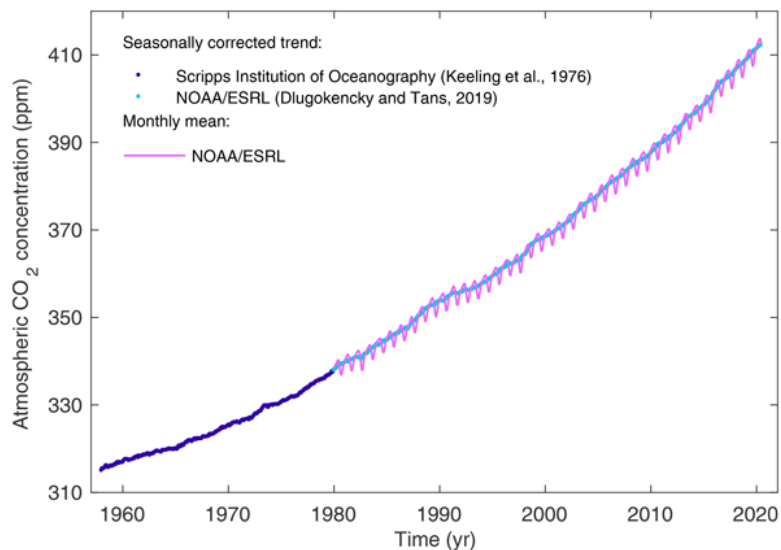


Figure 7: evolution of the atmospheric concentration of CO₂, taken from (Friedlingstein 2020)

This overview clearly shows that more than 90% of the fossil carbon extracted from the geosphere is being permanently injected into the hydrosphere and the atmosphere. In the atmosphere, this translates into a continuous increase in the content of its carbon components (methane, CO₂, volatile organic compounds), all of which have a strong greenhouse effect. In the hydrosphere, this translates into an acidification of the water masses (equilibration between the partial pressure of CO₂ in the atmosphere and the content of bicarbonate ions in the water).

In the biosphere, the increase in the mass of living organic matter (increased plant growth) and that potentially stored in soils is unfortunately offset by emissions from urbanisation and land-use change, as shown in Figure 8 below, using the more recent figures from the Global Carbon Budget 2020 (Friedlingstein 2020) : the effects of land-use change and deforestation (in light brown) are offset by the increase in fluxes to the soil (in light green).

These also show how the trend is accelerating for emissions from fossil sources (grey) and the impact on the content of carbon containing elements in the atmosphere (blue).

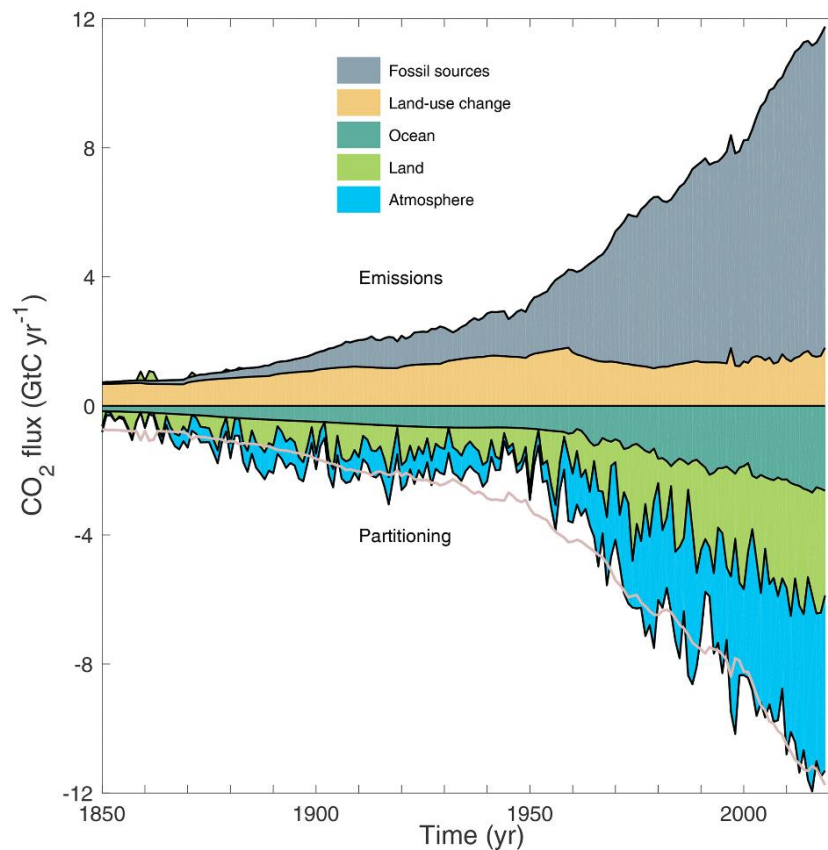


Figure 8: reconstruction of CO₂ fluxes in GtC/year from 1850 to 2020, Global Carbon Budget 2020 (Friedlingstein 2020) : top chart - the evolution of anthropogenic emissions, bottom chart - the distribution of these emissions in the oceans, land, and atmosphere. As the top and bottom profiles are constructed with different methods and accuracies, the total of the partition calculated year by year is not the same as that of the emissions reproduced by the small grey line; however, the two sets are globally coherent, which makes it possible to consider that the analysis gives a good idea of the reality of the quantities at stake

The same report indicates that until the beginning of the 20th century, emissions from land use change were dominant and have remained at about the same level until today (Figure 2). Since the middle of the 20th century, fossil emissions have been dominant: in 2019, they are 8 times higher than those from land use change; coal accounts for 39%, oil 33%, gas 21% and cement 4%.