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Decoupling and green growth*

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Summary

The term "decoupling" is usually used to mean the possibility of economic growth, measured by rise in GDP, that takes place simultaneously with a fall in resource consumption and environmental impact.

This definition of decoupling must satisfy several criteria to meet climatic urgency.

In particular, it must be:

•**absolute:** GDP and environmental damage must go in opposite directions – in opposition to a smaller increase in environmental damage when GDP rises;

•**total:** in the case of climatic damage, is GDP decoupled with all greenhouse gas emissions rather than only some of them (e.g.: effects of combustion of fossil fuels, not to mention those from deforestation);

•**world:** it must not be limited to one or a few geographical areas;

•**sustainable:** it must be maintained over time, in the long term;

•**and fast:** some environmental damage is irreversible if it is not dealt with very fast (e.g.: observation of the 2°C limit under the Paris Agreement).

Many reference prospective scenarios focus their approach on the concept of decoupling. These energy-climate scenarios are proposed by international agencies, NGOs, companies, research laboratories: they provide the vision of easy, fast, "painless" decoupling.

This vision is not exempt from shortcuts and strong hypotheses, sometimes inherent to this kind of modeling, and of which we must be aware. In fact, to

generally focus on very strong hypotheses of energy efficiency, the use of CO_2 capture, and reducing the carbon intensity of energy. Their credibility may be argued, especially in terms of technical progress made in the past.

Furthermore, the current construction of these prospective scenarios reserves for growth in GDP an “exceptional regime.” This growth is exogenous, and neither rising temperatures, nor depletion of natural resources, nor more generally, a possible future event has the capacity to moderate it or eliminate it. This construction must be reviewed as it gives the false impression that GDP will continue to rise according to our mere desires, independently of any physical constraint.

So it seems necessary to reconnect these scenarios with the limitations of the planet by integrating physical determinants on which economic activity and the resulting endogenous change in GDP rely.

This exercise also makes absolute sense when it comes to the prospects of economic players: it gives them a more developed and robust “spectrum of possibilities.”

This helps them to be ready or “better prepared” when the time comes, in a context in which we must compose with increasing uncertainty to make decisions.

Introduction

The ecological crisis and climate shift require a detailed review of our economic system, to make it compatible with the physical limits of the planet. The desire to reconcile preservation of resources, the limitation of global warming, and world economic growth finds in the concept of “green growth” the ideal theoretical solution: the ecological transition would in practice become “sustainable growth,” within which the economy and ecology would develop without compromising each other.

Having been a central theme of government policies since the Rio +20 conference in 2012, the concept of green growth thus seeks to make the preservation of the planet’s habitability and sustained economic growth coexist.

concerns and warnings of the scientific sphere faced with the threat of global warming and generalized harm to the environment.

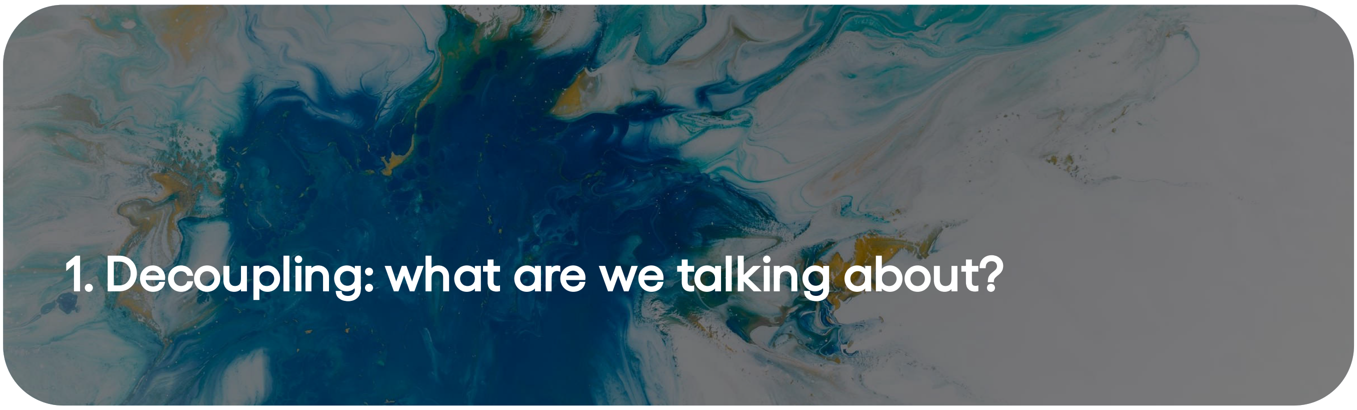
This publication will try to provide an initial response to the following questions:

•What exactly are we talking about when we discuss decoupling or green growth?

•What decoupling do we need to meet the challenges of the ecological crisis, both in terms of resource consumption and environmental impacts?

•Concerning global warning, how can “reference” prospective scenarios drastically reduce CO2 emissions without compromising sustained GDP growth?

•What are the impasses of current forecasts and how can we work on alternative forecasts?



1. Decoupling: what are we talking about?

“Coupling” designates the dependent behavior of one variable relative to another.

Variables are thus referred to as coupled if they are in a relationship of causality, and any variation in one implies variation in the other. The relationship that links the two variations may take a multitude of forms.

The most familiar one is linear: for example, the price paid for carrots on a market is proportional to the weight bought. In the situation of decoupling, each of the two variables may change independently. Owing to misuse of language, people also use this term to describe a situation in which a rise in one implies a drop in the other.

What variables are we talking about?

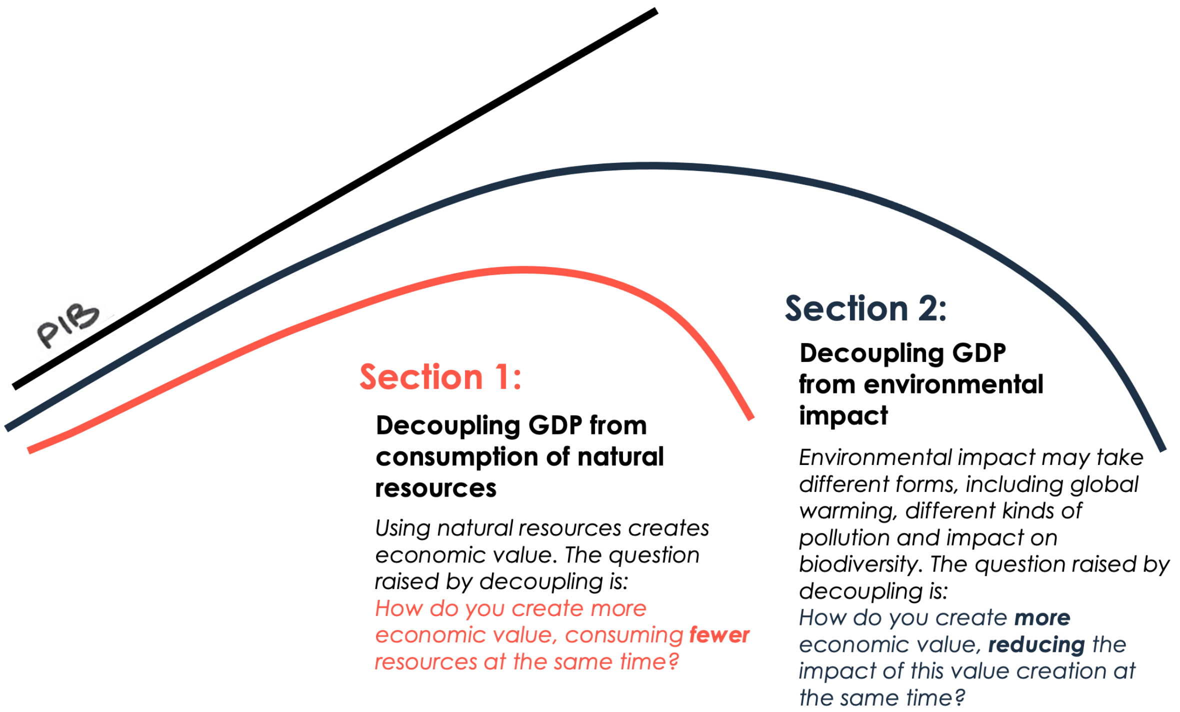
What do we want to decouple?

On the basis that our society is faced with an unprecedented ecological crisis, it would mean, in the words of the OECD's, “breaking the link between environmental bads and economic goods"[1]. In fact, it is the need for double decoupling that must be stressed. In a context of economic growth, or rise in gross domestic product (GDP[2]), it would mean:

1. upstream, to reduce the use of "finite"[3] natural resources;
2. downstream, to reduce the environmental impact of the use of these resources.

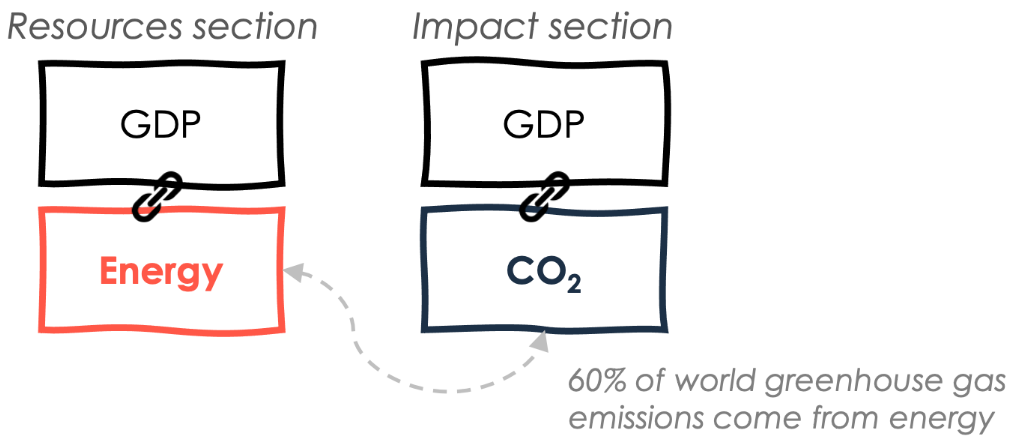
This concept of double decoupling has been evoked by the European Commission since 2005[4] and has been cited in many reference publications on the subject[5]. We ourselves are going to cite it in this publication, as it is worth focusing on both entrants into the economy (natural resources, some of which are non-renewable) and its impact on the environment.

Double decoupling



It should be noted that there are bridges between sections 1 and 2, with environmental impacts being for example the consequences of consumption of natural resources. This is especially the case with man-made global warming, mainly caused by the consumption of fossil fuels (oil, coal and natural gas) and deforestation. In the rest of this publication, we will focus on this impact in particular and the consumption of fossil fuels which is its main cause. Nevertheless, we wil try to avoid overlooking the other dimensions of decoupling, and in particular the "resources" section, whether they be energy related or not.

Decoupling protagonists



Following on from this introduction, why focus on GDP as the variable to be decoupled from consumption of resources and environmental impact? Thought of as a monetary aggregate of everything that is physically produced through human productive activity, GDP is considered the reference indicator for quantifying the economy as a whole.
However, it is not an indicator of the good health of societies and ecosystems.

In the US for example, life expectancy has been decoupled from GDP for 4 years[6]. As far as ecosystems are concerned, the increase in world GDP over the last 50 years has been accompanied by a biodiversity crisis.

As this indicator is generally used in debates on decoupling between economy and environment, it is the one we will use in this publication[7].

Let us consider the problem in terms of the climate emergency we are faced with.

What decoupling would we need to respond to this major[8] crisis?

We need decoupling that combines several additional criteria. They are described below and some are described in the report *Decoupling debunked*[9] by the European Environmental Bureau (a network of European environmental associations).

1. We need absolute decoupling, not just relative

In practice, the term decoupling is used whenever there is loss of proportionality between the two variables considered.

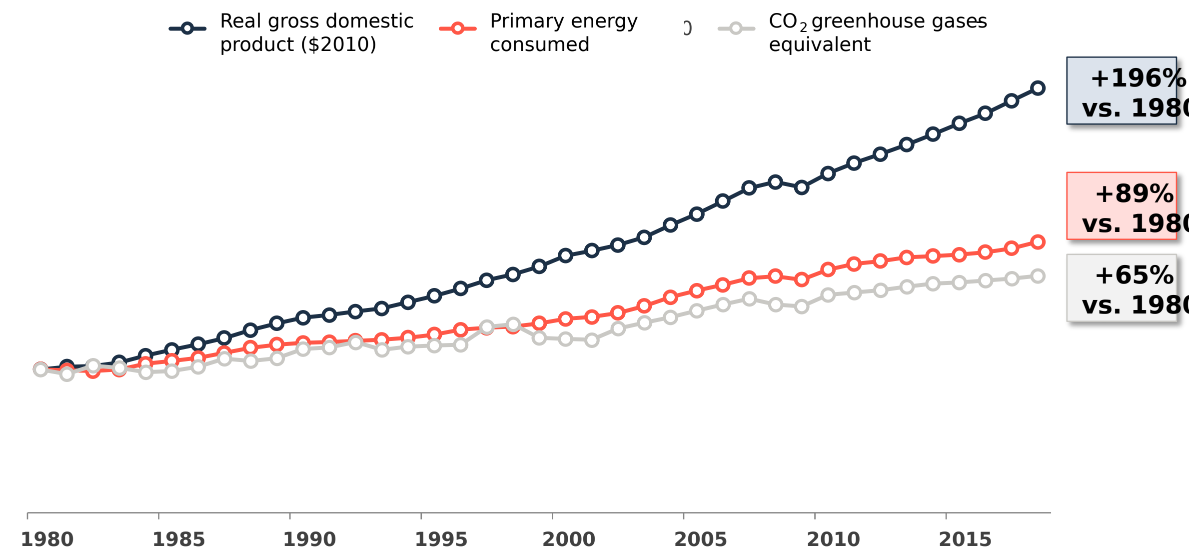
- **Relative** decoupling means that the two variables remain coupled, but “to a lesser extent” than the historical trend, an increase in GDP therefore meaning “just” *a lower-than-before rise in consumption of resources and environmental pollution*[10].

Today, concerning global warming, the level of greenhouse gas emissions is such that we could not stop at mere relative decoupling: the annual flow of emissions must fall, rather than rise at a slower rate. As far back as there are statistics, the only phenomenon that has been observed on a global scale is relative decoupling of GDP variables and energy consumption or greenhouse gas emissions.

Graph 1 below illustrates what relative decoupling is, both for energy and emissions versus GDP. Over the period 1980-2018, the three variables increase, but the energy and emissions increase more slowly than GDP. Each unit of GDP thus required less energy, and generated fewer greenhouse gases. Therefore, the 2018 GDP is higher than in 1980 for the same quantity of energy. However, for the overall climate system, it is the total quantity of greenhouse gases emitted that counts:
As long as this quantity continues to increase, it affects the climatic balance a little more, and increases the Earth's temperature.

Symmetrically, the only times when emissions and energy decrease is times when GDP falls (in 2009, and again in 2020).

Graph 1 – Change in primary energy consumption, greenhouse gases and GDP on a world scale | 1980 - 2018



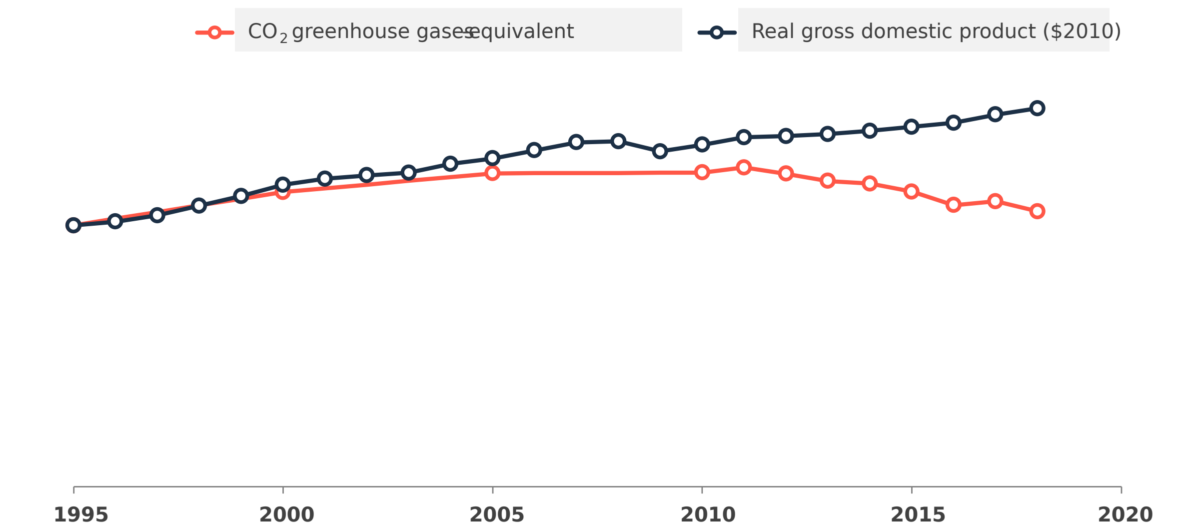
base 100 in 1980, greenhouse gases including LULUCF emissions[11]

Sources: World Bank (2020), Our world in data (2020), UN (2019)

- **Absolute** decoupling means that the variables become independent of one another, and are therefore free to go in opposite directions. If one rises, this does not prevent the other from falling and vice versa; an increase in GDP could arise at the same time as a sufficient - even massive - fall in resource consumption, or environmental impact.

In France, if we consider all greenhouse gases in the footprint (in other words, greenhouse gases induced by final demand[12]), we see a reduction in this footprint from 2010 onwards. In parallel, GDP rises (with the exception of 2009, due to the economic crisis). From 2010 onwards, the variables "*GDP*" and "*greenhouse gas footprint*" go in opposite directions: **thus, there is absolute decoupling between these two variables in France over the 2010-2018 period.**

Graph 2 - Change in greenhouse gas footprint and GDP in France | 1995 - 2020

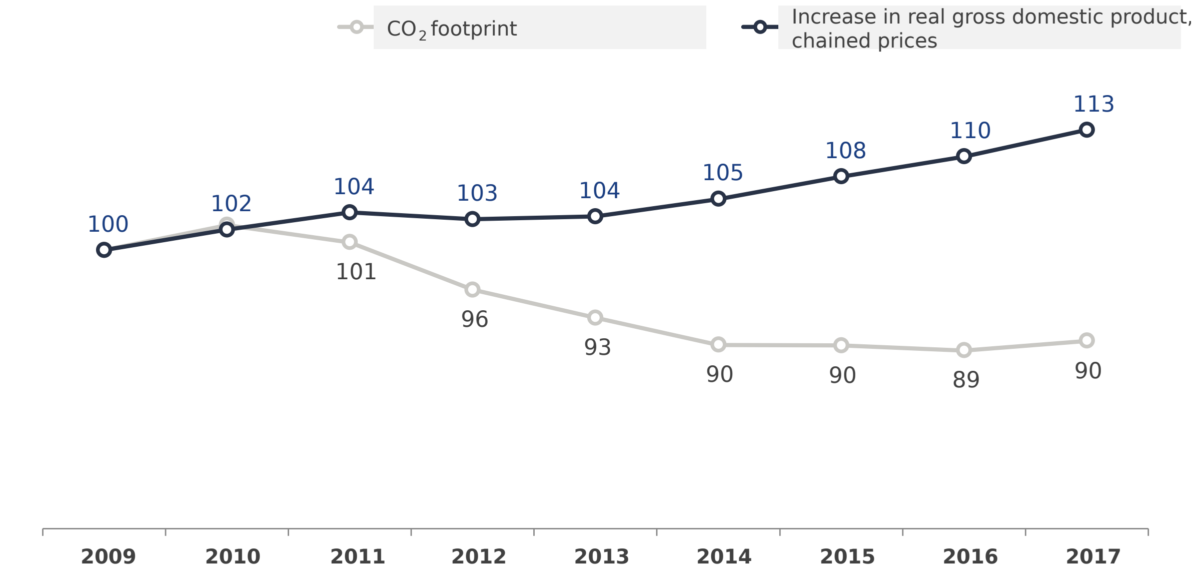


(base 100 in 1995)

Sources: World Bank (2020), Data and Statistical Surveys Service (SDES) (2020)

In Europe, graph 3 below shows absolute decoupling of CO2 emissions (in footprint view) and GDP between 2010 and 2016.

Graph 3 - Change in CO2 footprint and GDP in the European Union (EU28) | 2009 - 2017



(base 100 in 2009)

Sources: Eurostat and DGEC, I4CE, SDES (2021) [13]

Note [13]

2. We need total, not just partial, decoupling

In practice, decoupling is total when GDP rises independently of the consumption of any finite resource and environmental damage. It is partial when GDP is decoupled from one or more indicators whilst coupling persists with other indicators of environmental damage or consumption of finite resources.

For example, we could imagine decoupling of GDP and fossil fuel consumption, but if that leads to a rise in deforestation, environmental pressures will persist. Therefore, it is a matter of not shifting the problem of one challenge to another. In practice, it is extremely difficult to guarantee that decoupling is complete, as that requires a holistic view of impacts and extraction.

Focus

"What to make of the stagnation of CO2 emissions due to energy use, despite global growth of 2.9% in 2019?"

In February 2020, the International Energy Agency announced the stagnation of global emissions due to energy use, despite 2.9% economic growth. As encouraging as these figures may seem, the concept of decoupling does not apply here.

Firstly, CO_2 emissions due to energy only account for ~60% of world greenhouse gas emissions[14]: It is therefore necessary to examine the relative change in greenhouse gas emissions and GDP across the full spectrum of greenhouse gases in 2019 when the data are available. We already know that concentrations of CO_2 and methane (CH_4) continued to rise in the atmosphere in 2019 when considering all emission sources[15].

More fundamentally, the stagnation of emissions in a single year is not sufficient for us to talk about absolute decoupling, that is a situation sought "in its permanent state."

As seen previously, emissions would need to fall continuously whilst GDP would rise as continuously to be able to apply this term.

In 2020, CO_2 and GDP figures give a very different perspective because of the pandemic. Estimates reveal a fall in GDP (of some -4%[16]) concomitant with a fall in CO_2 emissions (of some -8%[17]), which does not call into question the issue of coupling of these two variables.

3. We need world decoupling

A situation of decoupling may be defined on different geographical scales. Local decoupling is observed within a restricted geographical area. Indeed, climate change arises from a global phenomenon: the decoupling that we need must therefore take place on a global scale.

Restricting the analysis to a local scale leads to asymmetry between the consideration of emissions and that of value added (which constitutes GDP). In fact, a great many activities lead a country – or group of countries – to benefit from value added within its/their borders, with emissions produced elsewhere. International tourism is one of many examples: visitors spend their money in the country visited, but the emissions produced from them coming take place in another country or "by no-one" for international air travel. The same applies to trade (the margin is made at the trader's registered office, the associated emissions wherever the goods or raw materials being traded are produced) and financial activities.

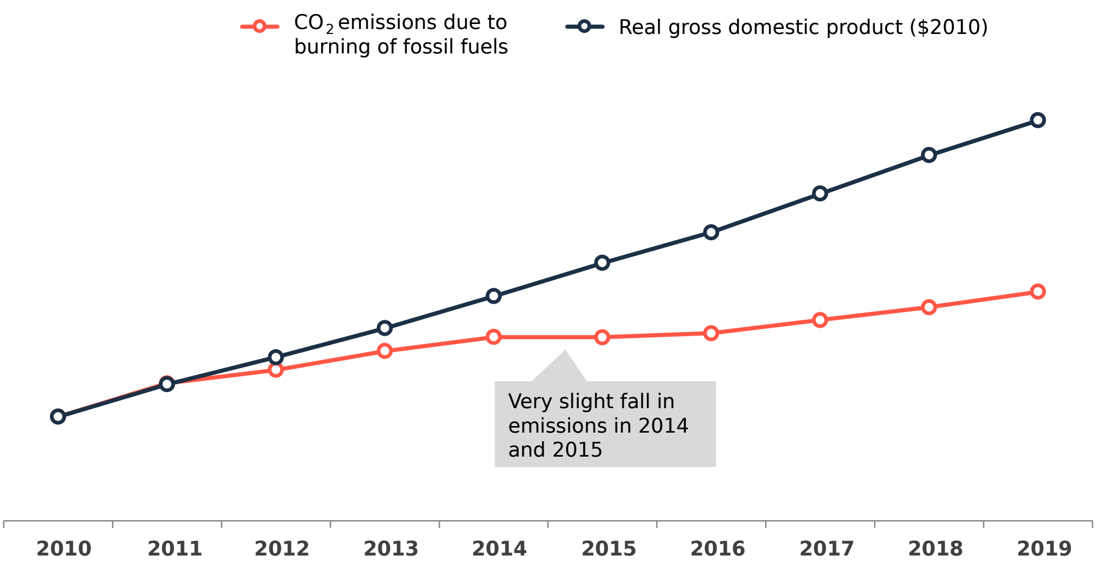
Countries that import a lot of manufactured goods may note absolute not necessarily be the case in a "carbon footprint" vision. Conversely, exporting countries produce within their borders emissions that do not correspond to their final consumption: in the "carbon footprint" vision, their decoupling improves faster than in the "domestic emissions" vision.

4. We need sustainable decoupling

As with the geographical scope, the time period studied is important. It is in fact possible to observe one-off decoupling, followed by rebound effects (which could be qualified as recoupling). However, to meet the challenges posed by climate deregulation, we need to maintain this decoupling over time, until we reach a sustainable balance between greenhouse gas emissions and sinks (natural or technological).

For example, in 2014 and 2015, global CO2 emissions due to the burning of fossil fuels fell very slightly, whilst GDP rose between these two milestones. The two trends are represented below, with the fall in emissions almost imperceptible (and therefore likely to be within the margin of error). This one-off absolute decoupling was not maintained over time since emissions began to rise again the following year[18].

Graph 4 - Change in CO2 emissions and GDP on a world scale | 2010 - 2019



(base 100 in 2010)

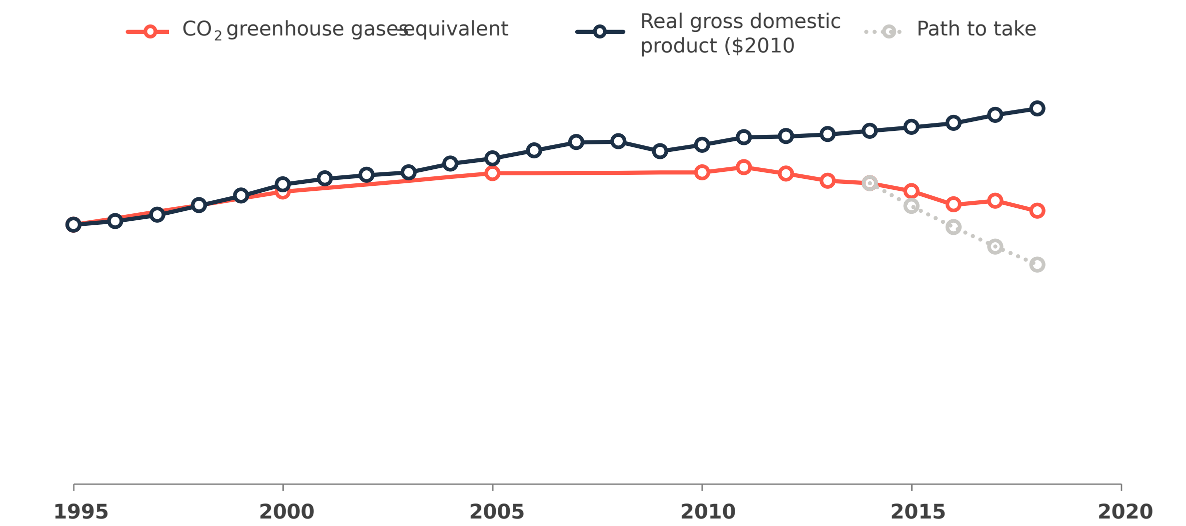
Sources : DGEC, I4CE, SDES (2020), Banque mondiale (2020), UN Emissions Gap Report (2019)

5. We need rapid decoupling

Strictly speaking a 2% rise in GDP per year concomitant with an 0.01% annual fall in greenhouse gas emissions would meet the definition of absolute decoupling proposed in the first part of this publication: GDP would rise whilst the annual emissions flow would fall. But to limit global warming below 1.5°C compared to pre-industrial temperature levels, we need to reduce our emissions massively and quickly by some -7 to -8% starting now, every year and at least until 2030 on a global scale under the United Nations Environment Program[19]. If we do not keep up with this pace, the scientific community believes that we will be unable to cope with the magnitude of the consequences of global warming and may reach certain points of no return[20], That is to say trigger certain feedback loops[21] such as forest fires and thawing permafrost.

In this respect, France is reducing its carbon footprint at an insufficient pace[22]. Graph 5 shows actual reduction in the carbon footprint since 1990 and the "path to follow." This is consistent with the average annual rate of reduction used by the United Nations: it is up to France to reduce the emissions induced by its final consumption at the correct pace, whether produced in France or elsewhere.

Graph 5 - Change in greenhouse gas footprint and GDP, compared to the desired decrease in emissions from 2015 (-7,6%/year) | 1995-2020



(base 100 in 1995)

Sources: World Bank (2020), SDES (2020)

Concerning the consumption of finite natural resources, decoupling must also take place at a sustained pace; also, reducing our consumption of fossil fuels whether electric vehicles, production of renewable electricity or biomass, lead, all other factors being equal, to a rise in extraction of minerals and water[23]. Hence, replacing fossil fuel thermal technologies with less carbon-intensive technologies must necessarily be accompanied by a reduction of our consumption of materials, through gestures or sobriety measures (for example: opting for a light vehicle rather than an SUV), while bearing in mind that recycling alone is not a sufficient response[24]. For some metals such as copper and cobalt, the level of geological criticality is assessed as high in relation to available reserves, in a 2°C scenario that would not activate any sobriety lever[25].

Key information

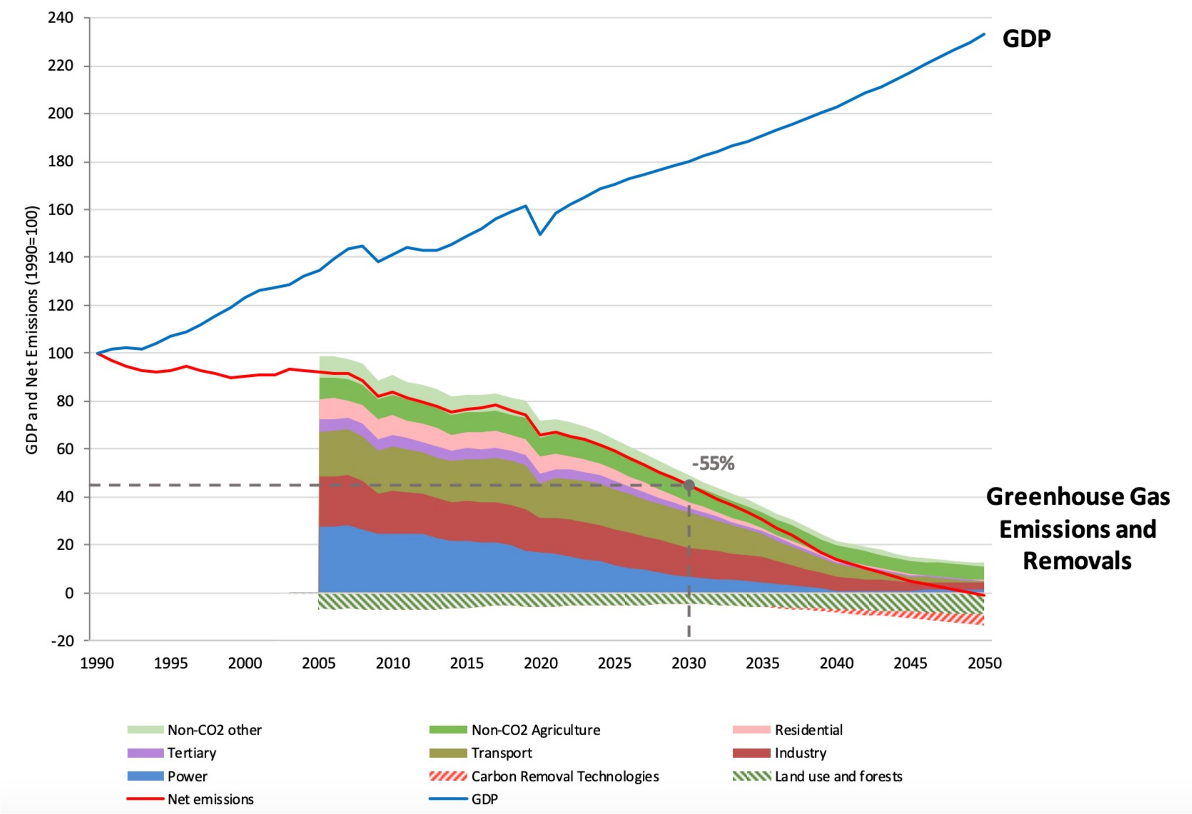
- Decoupling breaks or attenuates the connection between economic growth and environmental impact.
- This decoupling must be **absolute, total, global, sustained and swift** to respond fully to the environmental crisis we are faced with and whose consequences our societies are only experiencing the premises. This effort at decoupling should also be **fairly spread**, developed countries having more leeway to change their uses. Therefore, they bear the historic responsibility for quickly producing models of sustainable and carbon-neutral economies.

We need decoupling:	Description	Example	Downgraded versi
...absolute →	The variables are independent of one another, so are **free to go in the opposite direction**.	A rate of **GDP growth** of 2% is accompanied by **absolute reduction** in greenhouse gas emissions of 3%.	***Relative decoupling:*** *GDP growth is accompanied by an ever-smaller rise in emissions*
..total →	GDP is uncorrelated with consumption of **all** finite resources and **all** environmental damage	GDP manages to rise by consuming **every finite resource** at a sustainable level, not leading to **any ecological (or humanitarian) damage**	***Partial decoupling:*** *Coupling persists with some indicators of environmental damage or consumption of finite resources*
..global →	Decoupling takes place worldwide.	**World** consumption of fossil fuels falls whilst GDP continues to rise.	***Local decoupling:*** *A given economy sees its GDP rise whilst its consumption of fossil fuels falls.*
...sustained →	Decoupling takes place in a timescale sufficient for us to say that it is **structural** rather than **short-term**.	**In the last 5 years, GDP has risen while greenhouse gas emissions have fallen.**	***Decoupling over time:*** *Very much one-off decoupling takes place (e.g. a given year), but it is not maintained over time*
...swift →	Decoupling takes place quite fast to prevent irreversible environmental damage	Rising GDP will be accompanied by **absolute reduction in greenhouse gas emissions of 7.6% per year by 2030**	***Decoupling that is too sl*** *Absolute decoupling, worldwide and sustainable, is taking place but is not fas enough to respect the Paris Agreement*

2. Understanding the challenge of decoupling from energy-climate scenarios

In the spheres of economic and governmental decision-making, decoupling is advocated, targeted, displayed, without being subject to a shared definition and without the underlying implications being explained. The UN brings it to the forefront of its Sustainable Development Goals [26], France cites it in its Law on Energy Transition for Green Growth, passed in 2015[27]. More recently, in 2020, the European Commission made it a cardinal principle in the first paragraph of its draft climate bill[28]. Graph 6 below illustrates the historical pace until 2020 and the goal of European decoupling over the 2020-2050 period: historical (and absolute) decoupling of GDP and greenhouse gases must be considerably deepened to achieve carbon neutrality by 2050, maintaining a significant rise in GDP at the same time.

Graph 6 – “The EU’s pathway to sustained economic prosperity and climate neutrality, 1990-2050”



Source: European Commission[29] (2020)

Note [29]

One way of better understanding the ins and outs of decoupling is to focus on prospective scenarios and their underlying assumptions.

The International Energy Agency (IEA) publishes reports on the medium-term development prospects of our energy consumption and supply. De facto, it occupies a prominent position to propose energy transition scenarios leading to a low-carbon economy.

In March 2016, it published an article entitled “*Decoupling of global emissions and economic growth is confirmed*,”[30] based on the observation that emissions due to the use of energy had stabilized between 2013 and 2015, during economic growth. The same phenomenon was observed in 2019, when stagnation of CO2 due to the use of energy coincided with 2.9% global growth.

As mentioned above, this is not what is needed to resolve the climatic crisis as this decoupling is one-off and only concerns a fraction of greenhouse gases

Beyond these historical analyses, let us focus on the projections proposed by the scenario publishers (one of them the IEA) and in particular low-carbon scenarios, those constructed to be compatible with the Paris Agreement.

Definition

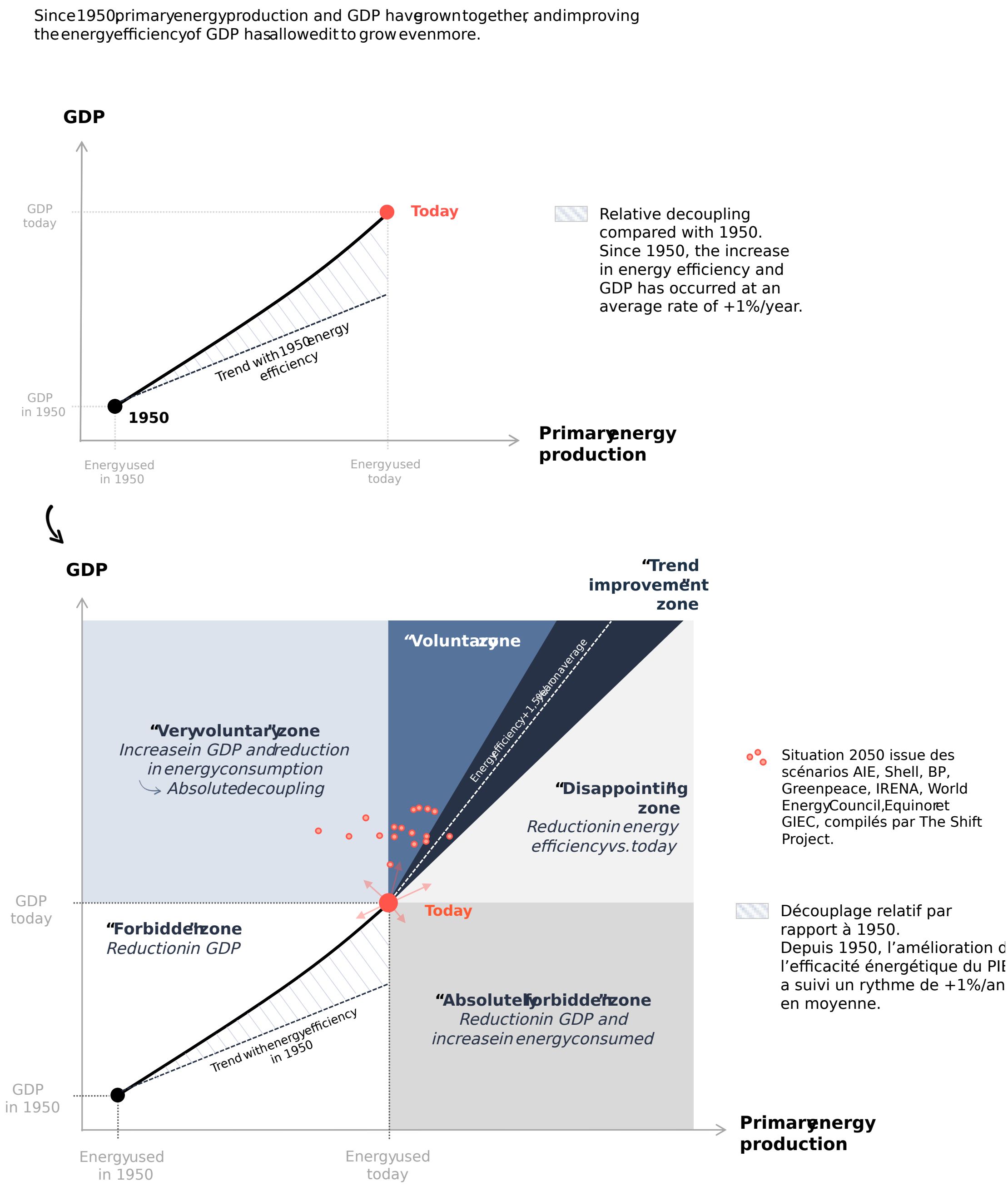
A prospective scenario refers to a possible future for society as a whole. It is constructed from a set of variables, input – which we call hypotheses – and output – which we call results – that are related through modeling. All of these hypotheses and results suggest possible change in our societies over a given time period. The results likely to change in a scenario are for example, population size, GDP, demand for or supply of energy and materials, CO2 emissions, technologies, machines and infrastructures, geopolitical contexts, governance, etc.

The scenarios are used by world economic players, both public and private, to project an activity or a sector into different futures and to understand the potential changes to be prepared for. So-called "low-carbon" scenarios have the characteristic that they add a finite carbon budget to input data, in other words, an accumulated emissions cap not to be exceeded to be compatible with the Paris Agreement.

The evolution of physical flows (for example traffic of goods, fleet of vehicles and even quantity of steel produced, etc.) and the associated energy and technology mix (evolution in industrial processes, modal transfers, etc.) is then modeled with the imperative to respect this carbon budget. Similarly, the constraint most often focuses on CO2 alone, sometimes accounting for other greenhouse gases, but it is very rare for the scenario to have to respect an availability limit for other finite natural resources (metals, ground space, etc.).

Graph 7 (taken from a Shift Project publication) shows, for several public decarbonization scenarios, the evolution over time of the variables "world primary energy consumption"[31] and GDP (following the curve from the point "today," we read, year on year, the value of primary energy consumed on the *x* axis and the value of GDP on the *y* axis). The 17 scenarios analyzed include those of the IEA, Shell, BP, Greenpeace, IRENA, the World Energy Council, Equinor and finally, the different scenarios presented in GIEC reports that emanate from research centers[32].

Graph 7 – Paths of reference scenarios and scope of decoupling considered, Shift Project adapted, simplified diagram (2019)



With one exception, none of the scenarios are in the "trend improvement" zone, which raises the historical rate of energy efficiency gains. This means that almost all scenarios assume that we will do very significantly better in the future than in the past. Is this a robust assumption on which to base a global strategy?

Graph 7 legend

Several zones may be identified in this graph:

• **"Very voluntary" zone:** several traditional scenarios (4 of the 17 studied) suppose that it will be possible, in the not-too-distant future, to generate an increasing amount of GDP and reduce primary energy consumption simultaneously. Therefore, this is absolute decoupling of both variables.

• **"Voluntary" zone:** other scenarios (12 of the 17 studied) bet on a moderate rise in primary energy consumption. This time, it is relative decoupling.

• **"Trend improvement" zone:** the *Shift Project* considers that energy efficiency could possibly change in this zone, in view of the progress that has been made to date and the scope of the ambition of current government policies. This zone is not defined physically, but only arbitrarily, in trend logic. On average, a hypothesis of increases in efficiency of +1.5%/year in the future is considered possible by the Shift Project (which represents +50% compared to the historical pace). The only scenario that is on the left fringe of this range is Shell's *Sky* scenario, that foresees a pace of energy efficiency gains of about 2%/year between 2017 and 2050.

• **"(Very) forbidden" zones:** named thus by the Shift Project as they are generally considered inadmissible in the eyes of the political and economic world since they imply a fall in GDP.

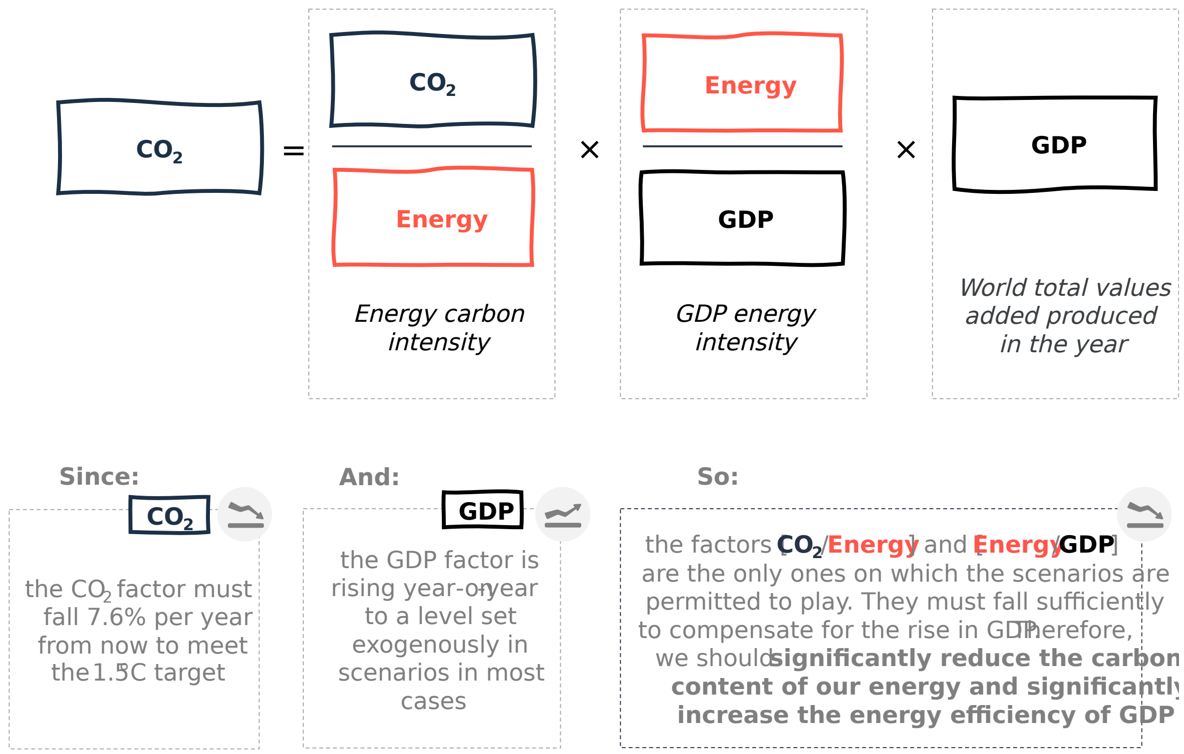
What conclusions can be drawn from this representation?

Firstly, note that these scenarios all project a continuous rise in GDP in the next 20-30 years. It is essential to remember that it is not a forecast, but an input hypothesis.

In fact, growth is postulated by principle, and is not in any way the result of the economic activities modeled. Accordingly, the rise in GDP is exogenous (in other words, it is input data rather than output data from the model) in all "reference" scenarios available.

Secondly, note that all scenarios studied are based on the principle that increases in energy efficiency on a global scale must be significantly greater in the future than they have been in the past. In other words, all scenarios believe that energy efficiency will go "beyond" the dark green zone, which is already significantly faster than the historical pace of improvement.

The second point actually follows from the first: assuming that GDP rises 3% per year[33], and that CO2 emissions must fall 7 to 8% per year (in order to respect the +1,5°C limit set by the Paris Agreement), two levers (or factors) may be used to satisfy the equality[34] below (known as Kaya's equation). These two levers are the carbon intensity of energy on the one hand, and the energy intensity of GDP on the other.



Therefore, the underlying movement in the scenarios is that the carbon intensity of energy and the energy intensity of GDP must fall sufficiently for the carbon budget to be met, without this preventing GDP from rising. Therefore, it is up to these two factors to make absolute decoupling of CO2 emissions and GDP possible.

Key information

- Decoupling is the norm for reference public scenarios, proposed by international agencies, NGOs, companies and some research laboratories. It should be noted that this decoupling is absolute when it concerns a scenario for achieving carbon neutrality.
- These reference scenarios focus on economic growth as exogenous data, or an input hypothesis rather than output data from the model. This specifically implies that the rise in GDP is a *sine qua non* condition for efficiency gains.
- To be able to reconcile a fall in emissions and a rise in GDP, these scenarios are based on hypotheses of an increase in energy efficiency of GDP, and a pace of energy decarbonization, that are on average much higher than we have managed to achieve to date.
- In these scenarios, the energy efficiency of GDP and the carbon intensity of energy are in fact the two levers that are used to “close the equation” of decoupling, but the likelihood of the results being obtained is never questioned.

3. The limits of current prospects

The Current low-carbon scenarios combine an exogenously rising GDP with a carbon constraint that is respected. This poses the question of the possibility of absolute *and fast* decoupling of GDP and CO2 emissions. The question is also raised in many texts and speeches of political policies[35] that state a target for decoupling (decoupling of GDP-impact and/or GDP-consumption of resources).

However, some of the conceptual assumptions of the reference scenarios are problematic, in particular the consideration of an exogenous GDP with a constant growth rate over time (that would mathematically result in exponential growth).

The hypothesis of a continued historical trend in terms of economic growth, but also the consistency of this growth, is an extremely strong bet. In fact, we are nearing the planet’s limits, which are likely to prevent the pursuit of growth and contribute to a strong “unpredictability” of the economic future. Disturbances will be particularly due to the multiple physical impacts of global warming, even limited to +1.5°C or 2°C[36]. It should be noted that some scenarios propose changes in GDP breaking away from historical trends[37].

Consequently, it is the exogenous nature of GDP that is problematic.

First of all, this rise in GDP does not consider stocks and the paces at which natural resources are renewed (minerals, biomass, halieutic resources, etc.). Economic growth is therefore uncorrelated with the physical world. However, the underlying elements necessary for this rise in GDP are material[38]. In the models used for the scenarios evoked here, it is the rise in global GDP – exogenous – that leads to rising consumption of energy (endogenous), items produced (for example, tons of metal, m^2 of homes and the tertiary sector) and flows of transport (for example, passenger-kilometers).

In practice, this assumption leads to a major simplification, namely that infinite material growth is conceivable in a finite world. In fact, it is unimaginable that increases in material efficiency should be sustained indefinitely: they necessarily reach a ceiling. In other words, to make a car, you need a minimum thickness of steel: therefore, after the first efficiency gains, more steel will be necessary to make evermore cars.

Furthermore, this posture of exogenous growth of GDP imposes compliance with the carbon budget compatible with the Paris Agreement using two levers whose sources and speeds of activation are limited: (i) the energy efficiency of GDP and (ii) the carbon content of energy.

i.Meeting the carbon budget relies on the **strong hypotheses of energy efficiency gains in GDP**. These hypotheses clash in particular with the **rebound effect**: increases in energy or material efficiency incite us to consume more energy and materials.

This rebound effect is valid at the scale of an individual, a company or an economic sector. It may also have direct or indirect effects[39]:

• Direct: a less energy-hungry car will save on fuel, and that, at constant budget, allows you to travel further or be offered a more spacious, heavier vehicle.

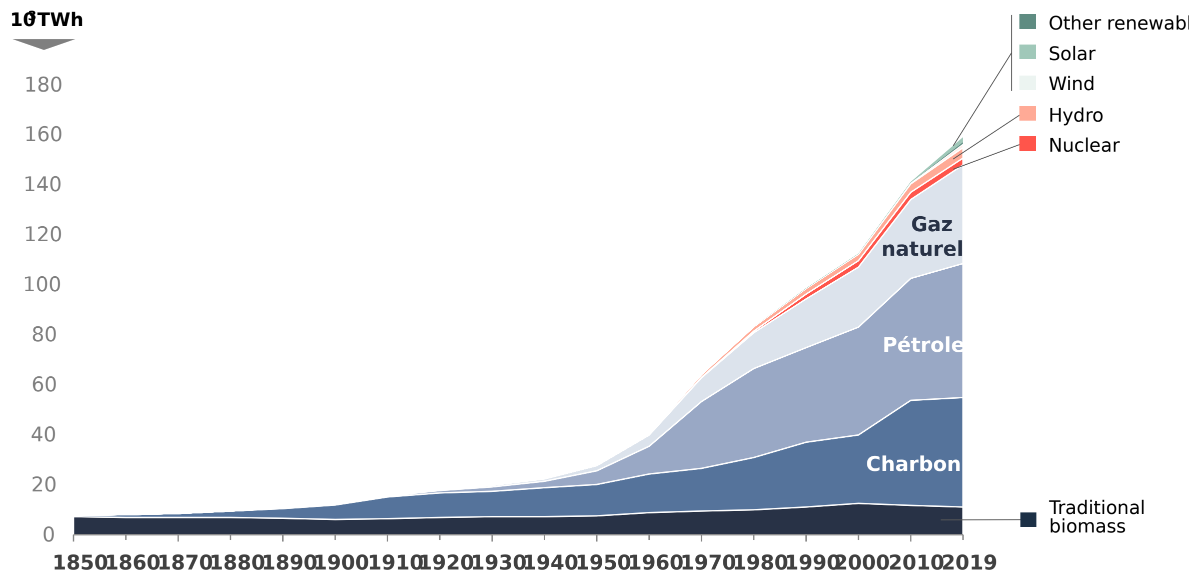
• Indirect: petrol saved over several months will help you, for example, to buy a plane ticket.

In the last 30 years, the weight of brand new vehicles sold in France has risen 30% on average, that has contributed towards canceling out energy savings enabled by high performance motors[40]. Another example, thermal restoration of buildings does not necessarily lead to an anticipated reduction in energy consumption, as a better insulated home will help to increase its comfort

Thus, we cannot imagine making very significant progress in energy efficiency merely by extending current trends, in other words, by continuing the current trends of access to consumption and distribution of innovation. Achieving this will demand significant changes in public policies and in individual and collective behavior. Politically, the rebound effect requires incentives not to focus just on energy performance, but also volumes. In France, this is the reason behind the penalty for cars over 1,400 kg proposed by the Citizens' Convention on the Climate[42]. In fact, this measure has been weakened since it will only concern vehicles over 1,800 kg from 2022[43].

ii. The second lever that the scenarios heavily rely on is that of reduction in the **carbon content of energy.** It is very difficult to reduce the **CO2/Energy**[44] factor below a certain threshold and in the time available, especially if energy requirements increase. Every year since the mid-19th century, energy consumption has increased on a global scale and this increase has always been accompanied by an increase in consumption of fossil fuels, despite the progressive and fairly slim introduction of renewables (see graph 8 below).

Graph 8 - Annual world consumption of primary energy | 1850 - 2019



Sources : Our world in data[45], Carbone 4

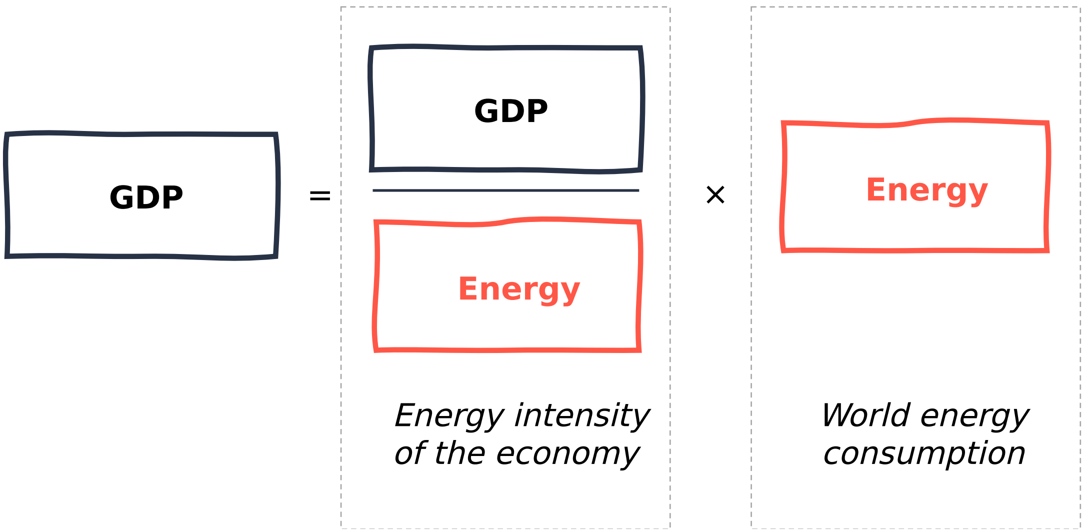
Note [45]

Even in a very optimistic scenario, in which global energy needs fall whilst GDP rises, a dramatic reduction in the carbon intensity of energy would be necessary, something easier said than done. Long-distance means of transport and certain industries may find it difficult to switch from solid or liquid fuels[46] (with very high energy density), such as oil, gas or coal. Less carbon-intensive alternatives, such as solid biomass, liquid biofuels and biogas are, of course, in short supply. Therefore, we can focus on reducing this CO2/Energy factor, but only to a certain extent and at a certain pace.

Some scenarios bet on a more significant reduction (albeit always limited) of this factor thanks to **carbon capture and sequestration**[47]. This hypothesis again leads us to question the credibility and massive deployment of these solutions. One of the key difficulties posed by this option is that it is energy-hungry. The logistic chain which goes from CO2 capture to storage in a geological tank, not to mention pressurized gas transport, requires a further energy contribution compared with a no-CCS chain. It is estimated that a power station with a capture system produces 15 to 30%[48] less energy than a power station that emits its CO2 into the atmosphere. The energy penalty variable depends on the type of power station and capture system.

This additional energy consumption implies that for the same quantity of energy entering a factory or power station, a smaller final quantity of energy will be produced, which – all other factors being equal – means lower GDP.

Therefore, in the equation below, this means that the GDP/Energy factor may deteriorate:



Unless we compensate for this deterioration with equivalent increases in efficiency in the energy chain[49], it will only be possible to keep GDP at its current level by contributing more energy to the economy.

Key information

Public energy/climate scenarios propose the vision of “painless” GDP-CO2 decoupling. This vision is not free of shortcuts and strong assumptions, that are, however, sometimes inevitable in this type of modeling, and which we must be aware of.

In general, these scenarios:

- Represent continuously growing economies. This hitch-free horizon is not particularly credible: even a world limited to +1.5°C will suffer climatic crises that will have an impact on economic growth, not to mention put other planetary limits to the test,
- Bet on major breakthroughs that will result in considerably improve the energy efficiency of GDP and the carbon content of energy.
  - These very strong hypotheses must be taken for what they are, i.e. desirable hypotheses rather than forecasts.
  - It is up to the public authorities (and, ultimately, each and every one of us) to ensure the conditions for making these hypotheses a reality.
- Do not consider stocks of natural resources available and rates of renewal. Thus, the implicit hypothesis is that it is possible to grow endlessly in a finite world.
- Omit a lever of attenuation, indeed an essential one: that of sobriety, in the energy and/or carbon sense.
  - This lever could lead, as a global average, to a fall in GDP/person as currently defined and calculated.
  - It must also be treated with the necessary caution due to consumption disparities per person worldwide.

New energy-climate scenarios

Therefore, the key imperative is to propose an alternative prospective approach, capable of providing a more complete and realistic vision of the world, or rather of the possible *worlds* that meet the challenges described in this publication. Thus, the aim is to catalyse ambitious considerations and their implementation through specific actions, whether it be through public policies or corporate strategies.

In particular, this renewed prospective approach should:

- Natively integrate physical determinants on which economic activities rely:
  - the physical limits of the planet: stocks, and rates of renewal of energy and material resources, capacity to absorb waste, and disturbance of the climatic system by recording all emissions of greenhouse gases due to human activity (not just CO_2), etc.;
  - realistic hypotheses concerning change in technologies (limits of recycling and material-energy efficiency);
  - retroactions of the physical impacts of climate change on economic activities.
- Explore contrasted futures:
  - Avoid any dependence on technique such as increases in energy efficiency and CO_2 capture and storage;
  - Integrate behavioral levers such as sobriety, coordinated with varied societal associations;
  - Integrate shocks of a climatic nature, varying in intensity, frequency and nature.
- Rely on a dynamic modeling approach (rather than the current “return to equilibrium”), again giving GDP an endogenous dimension, more consistent with reality.

Carbone 4 is now working on the IRIS initiative[51] with academic partners and sponsors. This initiative seeks to rekindle strategic considerations in companies: it focuses on an unprecedented physical-economic modeling approach to produce alternative scenarios.

Conclusion

Everything starts with the idea that GDP, seen as an indicator of prosperity (that it is, at best, only partially), must continue to increase, even in mature economies such as the European Union. The question is therefore whether it will be possible to achieve that while sustainably reducing our environmental impact and our consumption of finite resources.

In other words, it is essential to assess the feasibility of decoupling, a phenomenon that must combine several criteria simultaneously in order to rise to the challenge.

Although forms of decoupling do indeed exist (part I.1), the chances of achieving decoupling at the right level appear compromised without radical changes (parts I.5 and II). Indeed, to do this, decoupling must be absolute, total, global, sustained and swift.

Reference prospective scenarios provide a partial vision of GDP-CO2 decoupling enabled through an unprecedented increase in energy efficiency and decarbonization of energy mixes. These hypotheses are not forecasts: although these paths towards decarbonization are considered desirable and possible, it is up to public authorities and private bodies, at all levels of society, to take serious, unprecedented measures to make them a reality.

In this context, the variety of possible futures would benefit from being broadened to give energy and carbon sobriety all of the room that it needs as a lever for attenuation on the one hand, and to integrate future climate shocks on the other.

The current construction of reference prospective scenarios must be reviewed: it reserves for GDP growth an "exceptional regime," as an exogenous factor, over which neither the rise in temperatures, nor the depletion of natural resources, has any influence.

This construction gives the false impression that GDP will continue to rise, independently of any physical reality.

Beyond the place of GDP in our economy, the following noteworthy issue arises: "*what do we want to give value to?"* Is it appropriate to consider decoupling from an indicator that is not, as it stands, an indicator of prosperity? The ambition of decoupling is also the opportunity to foresee an indicator (or more than one) of good health in our societies and our ecosystems that is more robust than GDP to guide our choices. This would help to rise to the challenge of the century: to invent socio-economic systems for living a stimulating life within planetary limits.

[1] Indicators to measure decoupling of environmental pressure from economic growth, OECD Environment Program, 2002.

[2] According to the INSEE's definition, Gross Domestic Product (GDP) is "the aggregate representing the end result of the activity of production of resident producing units." It is the sum of the values added produced in the year by a given economy.

[3] A (non-fossil) natural resource may be renewed but is finite if it is used too intensively, in other words, if the pace at which it is renewed is not maintained.

[4] "The strategic approach to achieving more sustainable use of natural resources should lead over time to improved resource efficiency, together with a reduction in the negative environmental impact of resource use, so that overall improvements in the environment go hand-in-hand with growth." Source: Themed strategy on sustainable use of natural resources, European Commission Communication, 2005.

[5] Growth without economic growth - European Environment Agency - 2020.

[6] Life expectancy at birth fell in the US between 2014 and 2018 (post-2018 data are not yet available). Source: World Bank.

[7] Populations of wild mammals have fallen 82% since prehistory; 25% of animal species studied by the scientific community are threatened with extinction. Source: *Global assessment report on biodiversity and ecosystem services*, IPBES, 2019.

[8] A crisis that, let us stress, presents zones of significant overlap with other ecological crises such as reduction in biodiversity or air pollution in urban areas.

[9] *Decoupling debunked – Evidence and arguments against green growth as a sole strategy for sustainability*, European Environmental Bureau, 2019.

[10] In other words, the proportionality ratio between the two variables reduces over time.

[11] LULUCF: Land Use, Land-Use Change and Forestry.

[12] "The footprint comprises direct emissions from households (homes and cars), emissions from national production (non-export) and emissions from foreign economic activities, production from which is intended for the country's imports." Source: *Key climate figures – France, Europe and the World*, DGEC, I4CE and SDES, 2021.

[13] This report does not present years after 2017.

[14] *2019: The year of the stagnation of world emissions?*, César Dugast, 2020.

[15] *Greenhouse gas concentrations*, Climate Change Service, 2019.

[16] International Monetary Fund, 2021.

[17] *The impacts of the COVID-19 crisis on global energy demand and CO2 emissions*, IEA Global Energy Review 2020. This report foresees a 7.8% in CO2 emissions induced by worldwide energy consumption.

[18] And partial since not all greenhouse gases are represented here. Total greenhouse gas emissions did not fall over the period.

[19] *Emissions Gap Report, United Nations Environment Program, 2019. The 1.5°C scenario highlighted in the report is consistent with GIEC scenarios that foresee that the 1.5°C carbon budget will be met throughout the 21st century (the so-called "with no or limited overshoot" scenario). This scenario requires an annual reduction of greenhouse gas emissions of 7.6% between 2020 and 2030.*

[20] IPCC - Work group II. Climate change 2014 – Consequences, adaptation and vulnerability. Decision-makers' summary: "[…] any delay in taking attenuation measures could reduce possible choices of development profits favorable to resilience in the future."

[21] A point of no return means an effect of global warming that contributes towards increasing it.

[22] We are of course talking about the carbon footprint rather than territorial emissions. For the latter, assessment is more contrasted, with the initial carbon budget not met over the 2015-2018 period, but met for 2019 and 2020, partly for short-term reasons (mild winter, the pandemic). Indeed, SNBC's aim is to reach an average of 3% structural reductions per year over the 2019-2023 period.

[23] *Towards a more complex energy geopolicy?*, IFP Energies nouvelles and IRIS, 2018.

[24] "*The disillusion of a start-up in the circular economy,*", La Boucle Verte, February 2020.

[25] For the GENERATE project (2017-2020), IFPEN has shown that in a "business as usual" 2°C scenario, accumulated consumption of cobalt over the 2005-2050 period could reach 93% of resources available (resources assessed in 2011). As for copper, by 2050, we could consume 96% of resources available.

[26] seek to 'do more and better with less.' They also entail decoupling economic growth and environmental damage by reducing efficiency in use of resources."

[27] Article 1 defines the expression green growth: "[...] is defined as an economic development method respectful of the environment, both simple and effective in energy and consumption of resources and carbon, socially inclusive, supporting potential for innovation and guaranteeing competitiveness amongst companies."

[28] European draft climate act, 2020: "The communication entitled "The green agreement for Europe" marked the launch of a new growth strategy for the EU, [...] the net greenhouse gas emissions from which will have become zero in 2050 and in which economic growth will be dissociated from use of resources."

[29] *Communication from the Commission to the Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition Investing in a climate-neutral future for the benefit of our people,* European Commission, 2020.

[30] *Decoupling of global emissions and economic growth confirmed,* International Energy Agency, 2016.

[31] Gross energy, such as you find it in nature before any transformation or transport.

[32] The scenarios are described in greater detail in the publication *Climate energy scenarios: assessment and use* written by the think tank The Shift Project for the AFEP in 2019.

[33] This is the average rate of growth used in the scenarios studied by the Shift Project (minimum 2% and maximum 4%) for the 2015-2050 period.

[34] The construction of this equality is inspired by Kaya's equation. Kaya's equation was developed by Yoichi Kaya, a Japanese energy economist, in his work *Environment, Energy and Economy: strategies for sustainability* (published in 1997). It is founded on the fact that you can always multiply or divide by the same number on each side of an equality.

[35] A few key examples have been cited previously: internationally, the United Nations Sustainable Development Goals; at European level, the draft climate act (2020); at French level, the Act on energy transition for green growth (2015).

[36] On this subject, see the conclusions of the GIEC in its *Special Report on the impacts of global warming of 1.5°C,* 2018.

[37] The Shift Project writes on this subject: "This is especially the case for scenarios relying on detailed narratives and describing a future in which economic activity is affected by political and social elements (Equinor scenarios, WEC and SSP scenarios). Therefore, change in GDP (up or down) is illustrated in the narrative." Source: *Climate energy scenarios: assessment and use,* The Shift Project and AFEP, 2019.

[38] Remember that this aggregate was created to calculate, using a single unit – money – products and services as a whole – material goods – from human activity: so it is not very surprising that there is a need to be "fed" by extractive flows of resources and energy.

[39] *Does the rebound effect doom transition to failure?, Louis Daumas, 2020.*

[40] On this subject, see the Carbone 4 article *Cars must lose the weight they have gained recently*, November 2020.

[41] *What is the impact of energy restoration works on homes on energy consumption?, G. Blaise, M. Glachant, 2019.*

[42] Penalty of €10 per kg for every kg over the 1,400 kg limit. Source: Proposals of the Citizens' convention on the climate, *corrected version dated* 01/29/2021 .

[43] In an interview granted by Carbone 4 on November 30, 2020, Nicolas Meilhan stated that "a weight penalty from 1,800 kg [...] [would concern] only 2 to 3% of sales of brand new vehicles."

[44] In other words, the average carbon intensity of the energy that we consume.

[45] Primary source: *Energy Transitions: Global and National Perspectives* Vaclav Smil, 2017 et *Statistical Review of World Energy*, BP, 2020.

[46] Electrification is not always possible or appropriate, and even if it was, we do not have the resources to produce low-carbon electricity, steerable and that would lead to social adhesion. Nuclear and carbon capture and sequestration (CCS) technologies do not meet these three criteria fully. In addition, these two options would not enable total decoupling since they lead to rise in consumption of finite resources. We will see this a little further on with the case of CCS.

[48] *Bridging the gap: improving the economic and policy framework for carbon capture and storage in the European Union*, CCCEP in conjunction with The Grantham Research Institute on Climate Change and the Environment, and The Grantham Institute at Imperial College, 2015.

[49] We would need ~10 years to compensate an energy penalty of 15% at the current pace of GDP/Energy factor improvement.

[50] The IEA's NZE2050 scenario is a notable exception, since it introduces significant behavioral changes. See, for example, table 4.1 of WEO 2020. It is not part of the scenarios examined in the second part of this publication.

[51] www.carbone4.com/lancement-iris-initiative/

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