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# Low Carbon Growth: Economic Progress from the Planet's Perspective

Sta. Romana, Leonardo L.

LSR Economic Associates, Manila, Philippines; and Vientiane, Lao PDR

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## A. Author's name and affiliation with e-mail

Leonardo L. Sta. Romana

Senior Economic Consultant (Independent)

Manila (Philippines), Vientiane (Lao PDR) and Southeast Asia; and

EmergingFrontierMarkets.com (Publisher)

Email: leonardo_staromana@post.harvard.edu

## B. Synonyms

Climate-friendly growth, Net-zero-emissions growth, Green growth

## C. Definitions

The term "low carbon growth" does not appear explicitly in any of the 17 Sustainable Development Goals, and the 169 associated Targets (UN General Assembly 2015). Instead, it is mentioned by means of a synonymous term in one of the associated Indicators, i.e. in SDG Indicator 13.2.1. The Paris Agreement mentions the phrase "low greenhouse gas emissions development" in two articles of the treaty (UN Framework Convention on Climate Change 2015). It seems likely then that the Paris Agreement was the source of the above phrase for SDG Indicator 13.2.1. Low carbon growth refers to a type of growth that relies on lower carbon emissions per unit of economic output, compared to the business-as-usual type of economic growth. The switch to a low carbon growth path is undertaken in order to become a low carbon economy.

## Main Body Text

### 1. Introduction

It has to be one of the biggest ironies of economic history that the principal reasons for the higher emissions of greenhouse gases over the past 150 years are associated with industrialization activities related to the Industrial Revolution and the spread of "Modern Economic Growth", i.e., the burning of ever increasing quantities of petroleum and coal and land use changes due to extensive urbanization (Uzawa 2003, Sachs and Someshwar 2015).

The formidable challenge of breaking the link between economic progress and higher standards of living, on the one hand, and the burning of ever increasing quantities of petroleum and coal and land use changes, on the other hand, is the topic of this contribution.

The preceding statements are, however, taking us ahead of our narrative. Before proceeding, there is a need to explain some basic concepts that will underpin the discussion that follows. The literature on this topic is both complex and voluminous. The aim of this contribution is to present a selective overview, highlighting a narrative based on a scientific consensus, that surprisingly is only quite recently coming to the fore in policy, as well as in media, discussion of the issues.

Firstly, the origin of the term “greenhouse” to describe carbon dioxide and other greenhouse gases merits a brief explanation. Radiation from the sun passes through the atmosphere and warms the Earth’s surface. In turn, the Earth’s surface re-radiates some of the energy from the sun toward outer space as infrared or thermal radiation. A portion of this escaping energy is absorbed by certain gases found in the atmosphere, in particular carbon dioxide, methane and nitrous oxide. In the process, heat is released that warms the lower atmosphere.

This process has become known as the “greenhouse effect”, since like the glass walls of a greenhouse, the atmosphere allows solar energy to pass inward while blocking its escape, thus keeping the space within it warm compared to outside conditions. Thus, it is the so-called greenhouse gases -- carbon dioxide, methane and nitrous oxide -- along with water vapour, that accounts for the Earth’s moderate climate.

Without its natural “greenhouse effect”, the Earth’s temperature would be below freezing, and all waters on its surface would be frozen (Schlesinger 2003). Much lesser concentrations of GHGs in the atmosphere of Mars explain its frigid conditions, while the intensely hot climate in Venus are attributable to much larger amounts of carbon dioxide (see, for example, Hsiang and Kopp 2018).

In this context, there is a related concept, as well as a key element in the Earth’s carbon cycle, namely, photosynthesis. It is a process by which land and sea plants use sunlight to consume atmospheric carbon dioxide and, together with water, convert it to oxygen and carbohydrates (for building new living tissue). Carbon is sequestered, and oxygen and water vapour are released in the process.

In the sections below, the narrative of this contribution  is organised in the following manner. Section 2 takes a look at the evidence on global warming, and its impacts on the planet's people, species and ecosystems. That points to the urgency of a response to the type of economic growth that has, and is leading, to global warming, hence the focus shifts in Section 3 to the need to switch to low carbon growth. Then, Section 4 follows with a discussion of the necessary transition to clean energy. Next, the role of one type of fossil fuel that is supposed to help bridge this transition, natural gas, is discussed in Section 5. This is followed in Section 6 by a focus on the much-neglected role of the forestry sector in limiting global warming. Section 7 looks at the threat of climate change crossing its planetary boundary, and relates low carbon growth to SDG12. The final section winds up with some concluding remarks.

## 2. Global Warming, Climate Change and Its Impacts

This section begins our discussion of one of the defining issues of the 21st century, namely, global warming and climate change.

This segment first takes a look at the evidence on global warming. The evidence for human influence on the climate system has increased since the last assessment in 2007 by the Intergovernmental Panel on Climate Change, or IPCC, which is the source for policy makers of authoritative and objective scientific assessments in this field.

It points out that “human influence has been detected in the warming of the atmosphere and the ocean, in changes in the global water cycle, in reductions in snow and ice, and in global mean sea level rise; and it is extremely likely to have been the dominant cause of the observed warming since the mid-20th century” (IPCC 2014a).

The human influence has been in the form of emissions of greenhouse gases, with carbon dioxide, nitrous oxide, and methane among the main ones. However, carbon dioxide is the principal greenhouse gas that affects the Earth’s climate. It is a by-product of burning fossil fuels (such as coal, oil, and gas), of burning biomass, of land use changes, and of industrial processes (e.g. iron and steel production) (IPCC 2014b)

As a background note, fossil fuels are carbon-based fuels from fossil hydrocarbon deposits, such as coal, petroleum/oil, and natural gas, derived from the buried remains of plants and animals that lived millions of years ago (UN Statistics Division 2001, IPCC 2014a and 2014c)

Supposing the global economy were to continue with the business-as-usual type of economic growth, what are the risks posed by the resulting continued global warming and climate change? The increase in warming raises the chances of severe, pervasive and irreversible impacts for people, species and ecosystems. The IPCC enumerates the key risks across regions and sectors:

1) Due to storm surges, coastal flooding, and sea level rise, the risk of death, injury, ill-health, or disrupted livelihoods in low-lying coastal zones and small island developing states and other small islands.
2) Due to inland flooding in some regions, the risk of severe ill-health and disrupted livelihoods for large urban populations.
3) Due to extreme weather events, the systemic risks leading to breakdown of infrastructure networks and critical services such as electricity, water supply, and health and emergency services.
4) Due to periods of extreme heat, the risk of death and ill-health, especially for vulnerable urban populations and those working outdoors in urban or rural areas.
5) Due to warming, drought, flooding, and variability and extremes in rainfall, the risk of food insecurity and the breakdown of food systems.
6) Due to insufficient access to drinking and irrigation water, and reduced agricultural productivity, the risk of loss of rural livelihoods and income, especially for farmers and pastoralists with minimal capital in semi-arid regions.
7) The risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods in inland communities.

8) The risk of loss of marine and coastal ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for coastal livelihoods, especially for fishing communities in the tropics and the Arctic (IPCC 2014b).

The indicated risks above are generally greater for disadvantaged people and communities in both developed and developing countries.

It will be recalled that the main aim of the Paris Agreement is to keep a global average temperature rise this century well below 2 degrees Celsius (3.6 Fahrenheit) and to drive efforts to limit the temperature increase even further to 1.5C (2.7F) above pre-industrial levels (UN Framework Convention on Climate Change 2015).

In an updated special report, the IPCC gathered evidence on the tougher target of 1.5C demanded by countries on the frontlines of climate change impacts. The report validates their concerns, showing that the difference between 1.5C and 2C – the upper limit governments committed to in the Paris Agreement – is critical to millions of people's homes, jobs and lives (IPCC 2018).

## 3. The Transition to Low Carbon Growth

After having seen (in Section 2) that the current type of economic growth fueled mainly by the burning of fossil fuels is responsible for the ever increasing amounts of emissions of greenhouse gases, mainly, carbon dioxide, that has, and is leading, to global warming, the focus shifts to the need to switch to low carbon growth.

The term "low carbon growth" does not appear explicitly in any of the 17 Sustainable Development Goals, or SDGs, and the 169 associated Targets (UN General Assembly 2015; see also Kanbur, Patel, Stiglitz 2018). Instead, it is mentioned by means of a synonymous term in one of the associated Indicators, that is, in SDG Indicator 13.2.1: ". . . the establishment or operationalization of an integrated policy/strategy/plan which increases their [the countries'] ability to. . . *foster climate resilience and low greenhouse gas emissions development*. . ." [italics added].

After the UN General Assembly had approved the 2030 Agenda for Sustainable Development in September 2015, with the 17 SDGs and associated targets, an Inter-Agency and Expert Group on SDG Indicators was set up and tasked to develop a global indicator framework for reviewing and monitoring the progress toward the SDGs.

The group drew up an initial list of indicators, after extensive consultations with various stakeholders. It was made clear that the list of indicators may need to be subject to further technical refinement on a periodic basis.

After a number of refinements (as of March 2018), the list now includes 232 indicators on which general agreement has been reached. In fact, the total number of indicators is 244; however, since nine indicators repeat under two or three different SDG targets, the actual total number of individual indicators in the list is 232.

Returning to the initial list of indicators, this was presented to the UN Statistical Commission in

March 2016 (UN Economic and Social Council 2016). This timeline is relevant to the specific mention in SDG indicator 13.2.1 of "low greenhouse gas emissions development". It will be recalled that the Paris Agreement on Climate Change was reached in December 2015, three months after the 2030 Sustainable Development Agenda, with the SDGs and Targets, was approved.

The Paris Agreement mentions the phrase "low greenhouse gas emissions development" in two articles of the treaty, i.e. Articles 2 and 4 (UNFCCC 2015). It seems likely then that the Paris Agreement was the source of the above phrase for SDG Indicator 13.2.1, especially since SDG Goal 13 pertains to climate change.

Low carbon growth refers to a type of growth that relies on lower carbon emissions per unit of economic output, compared to the business-as-usual type of economic growth. The switch to a low carbon growth path is undertaken in order to become a low carbon economy. This explains the use of the expression "low carbon" as part of the mitigation strategy against climate change.

To provide first an overview of the task of transition from the business-as-usual high carbon economy to a global low carbon economy, the discussion begins with the IPCC's definition of the mitigation of climate change: "a human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC 2014c). A source is any process, activity or mechanism that releases a greenhouse gas, while a sink is any process, activity or mechanism that removes a greenhouse gas.

To transition then into a global low carbon economy involves addressing the issue of mitigation of climate change on two fronts:

1) How to reduce the sources of greenhouse gases; and
2) How to enhance the sinks of greenhouse gases.

In the Paris Agreement, there is no mention of the term (carbon) neutrality. Instead, the treaty's Article 4 called on countries "...to undertake rapid reductions [of greenhouse gas emissions]...so as to achieve a *balance between anthropogenic emissions by sources and removals by sinks* of greenhouse gases..." [italics added] (UNFCCC 2015).

In Section 2, it was noted that carbon dioxide is the greenhouse gas that is mainly responsible for the global warming of the planet. And the principal source of carbon dioxide is the burning of fossil fuels (oil, coal, and natural gas) to generate electricity and to power our transport.  The next section turns to the need for a transition to clean energy sources.

## 4. The Transition to Clean Energy

Firstly, with regard to fossil fuels (discussed in Section 1), an important point to recognise is that not all fossil fuels are created equal. A million btu (British thermal unit) of coal results in 80 percent more carbon dioxide than a million btu of natural gas. Petroleum involves 37 percent more carbon dioxide than a million btu of natural gas (US Energy Information Agency 2016).

It would seem to follow then that the formidable task of reducing the sources of greenhouse gases, i.e., the use of fossil fuels for the world's energy needs, will have to involve two phases:

1) The transition from high carbon fossil fuels (coal and oil) to the relatively low carbon fossil fuel (natural gas); and
2) The transition from all fossil fuels to non-fossil-fuel energy sources that are very low or zero carbon.

The above two transitions will not necessarily be in sequence (i.e., one after the other), but can also occur in parallel.

This section continues with a presentation of the various clean energy alternatives to the use of fossil fuels. It provides a concise overview of the zero or low carbon energy options facing the world economy. The discussion begins with energy derived from sunlight, wind, and water.

### 4.1 Solar energy

This is direct radiant energy from the sun that can be converted directly into electricity using a panel of semiconductor materials called photovoltaic (PV) cells. The PV cell is the basic building block of a PV system. The smallest PV systems power pocket calculators and wrist watches (Global Energy Assessment 2012, US EIA 2018b).

### 4.2 Wind energy

This is energy available in the wind that is converted to mechanical energy that can be used to power machinery (grain mills, water pumps) and to operate an electric generator. The wind energy conversion device that produces electricity, called a wind turbine, is typically three blades rotating about a horizontal axis and positioned up-wind of the supporting tower. The blades are connected to a drive shaft that turns an electric generator, which produces the electricity (GEA 2012, US EIA 2018b).

The wind turbine evolved from, and evokes the memory of, the windmills used by mankind for centuries that Miguel de Cervantes's knight-errant Don Quixote made famous with his "tilting at windmills".

### 4.3 Hydroelectric power

This refers to the electrical energy derived from turbines being spun by flowing water as it moves downstream. This can be from rivers or from man-made installations, where water flows from a high-level reservoir down through a tunnel and away from a dam. (GEA 2012, US EIA 2018b).

### 4.4 Geothermal energy

This is the energy available as heat transferred from the earth's molten core to underground deposits of hot water or steam. By drilling deep wells and pumping the hot water or steam to the surface, the thermal energy may be used to supply heat or to generate electricity in a thermal power plant. It is a renewable energy source because heat is continuously produced inside the earth (GEA 2012, US EIA 2018b, International Energy Agency n.d.).

### 4.5 Bioenergy

This is energy derived from any form of biomass. Biomass is material from living (or recently living) plants and animals used for fuel. Traditional biomass refers to biomass, such as fuelwood, charcoal, agricultural residues, and animal dung, used in stoves with very low efficiencies.

Modern biomass refers to all biomass used in high efficiency conversion systems, an example of which are biofuels derived from biomass or waste feedstocks, such as biodiesel and ethanol (GEA 2012, IPCC 2014c, US IEA 2018b)

### 4.6 Nuclear energy

This refers to the energy in the core (or nucleus) of an atom. Atoms are held together with great force, and in a process called fission, atoms are split apart, and the energy released can be used to generate electricity. Uranium is the fuel most widely used by nuclear plants for nuclear fission (GEA 2012).

Nuclear energy is a low carbon source of energy, yet it is not a renewable energy source. This points to the fact that while all fossil fuels are non-renewables, not all non-renewables are fossil fuels. Uranium ore, though a mineral extracted from the ground, is not a fossil fuel, but is classified as a non-renewable fuel (US EIA 2018a).

Nuclear energy could contribute more to low carbon energy supply, but a variety of "barriers and risks exist, which include: operational risks, and the associated (safety) concerns, uranium mining risks, financial and regulatory risks, unresolved waste management issues, nuclear weapon proliferation concerns, and adverse public opinion" (IPCC 2014c)

To wind up the discussion of clean energy options, it bears pointing out that while the energy literature cites a few other sources of low carbon energy (e.g., ocean/marine energy), the discussion in this section has been confined to the technology options that are currently commercially available.

**5. The Role of Natural Gas in the Transition**

In discussing the transition to clean energy, and thereby to low carbon growth, it was noted (in Section 4) that there has to be a transition from high carbon fossil fuels (coal and oil) to the relatively low carbon fossil fuel (natural gas). In this section, the discussion shifts to take note of an ongoing debate regarding the role of natural gas in the transition.

First, this section begins with the case for natural gas as an alternative to other fossil-fuels, i.e., coal and oil. Natural gas has the reputation of being the "bridge" fuel, a cleaner-burning, low-cost alternative to coal until solar, wind and batteries became cheap enough to generate the world's electricity needs.

It was that premise that enabled the natural gas boon in the US. Recent experience in the US suggests that increasing natural gas supply has the potential to deliver multiple wins: lower energy costs, improved energy security, reduced air pollution, and a significantly less carbon-intensive electricity supply. Over the past decade, the US shale gas revolution has dramatically increased supplies of low-cost natural gas, upended US coal markets, and led many electric utilities to switch from coal to natural gas (Lazarus, Tempest, Klevnäs et al 2015).

The US experience has heightened interest in whether natural gas can serve as a “bridge” fuel on the path to a global low carbon future. While building out new infrastructure for the supply and use of natural gas can support climate goals by avoiding the “lock-in” of new coal power plants, it also poses risks, for example, of “locking-out” other, lower-emission alternatives. Achieving one while avoiding the other will require careful policy design.

The research by Lazarus et al (2015) indicates, firstly, that countries should not count on natural gas as a "climate bridge". Recent US experience was unique in terms of delivering significant benefits to both the climate and the economy. Yet, a more enduring climate-economy “win-win” based on increased natural gas supply is far from guaranteed, even in the US.

Secondly, public policy needs to create the enabling conditions if gas is to make a positive contribution. In order for the “climate bridge” to assist in a sturdy transition to a climate-compatible future, certain “guardrails” are necessary.

In particular, approaches for addressing substitution, methane leakage, and scale effects will be required to achieve any significant climate benefits. Therefore, if policy-makers want to use gas as a “bridge”, they need to add “guardrails”, to:

1) Limit energy demand growth (the scale effect);

2) Manage and reduce methane leakage;

3) Direct added gas supplies to the applications that yield the greatest substitution benefit (displacement of coal in the power sector); and

4) Restrict the extent of lower-carbon technology lock-out.

## 6. Forestry's Role in the Transition

In Section 3, it was noted that the major goal of slowing (or mitigating) climate change involves the twin tasks of reducing the sources of greenhouse gases, on the one hand, while enhancing (or increasing) the sinks of greenhouse gases, on the other hand. In that context, this section discusses how forests play a major role as a sink of greenhouse gases, mainly, carbon dioxide.

Because trees take up carbon dioxide from the atmosphere as they grow (the process known as photosynthesis, as discussed in Section 1), planting more trees means boosting how much carbon dioxide forests absorb and store.

That indicates that when measures related to forestry are implemented to slow climate change by reducing the amount of carbon dioxide in the atmosphere, these can have socio-economic and environmental co-benefits. This pertains to these separate, though related, steps (IPCC 2014c):

1) Reducing the clearance of forests (deforestation) and forest degradation;
2) The planting of trees on degraded forests or lands where the trees have been cut down and converted to some other use (reforestation);
3) The planting of trees on lands where there were previously none (afforestation).

The three measures above can, in turn, have the following co-benefits:

1) Improve local climatic conditions;
2) Promote conservation of biodiversity and water resource;
3) Reduce soil erosion; and
4) Help to restore degraded or abandoned land.

It is worthy of note that the most cost-effective options in forestry in slowing climate change by reducing the amount of carbon dioxide in the atmosphere are the planting of trees on lands where there were previously none (afforestation), reducing the clearance of forests (deforestation) and forest degradation, and sustainable forest management, with large differences reported in their relative importance across regions (IPCC 2014c, Griscom, Adams, Ellis et al 2017).

## 7. Planetary Boundaries, Low Carbon Growth and SDG 12

The planetary boundaries concept presents a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come. In 2009, a group of 29 internationally renowned scientists identified the nine processes that regulate the stability and resilience of the Earth system. The scientists proposed quantitative planetary boundaries, and crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes. Planetary boundaries define, as it were, the boundaries of the "planetary playing field" for humanity if we want to be sure of avoiding major human-induced environmental change on a global scale (Rockström, Steffen, Noone et al 2009).

Since its publication, the planetary boundaries framework has become influential in international policy discussions on global sustainability, and it is cited repeatedly in the UN Environment Programme's world assessment reports GEO-5 and GEO-6. The former UN secretary-general Ban Ki-moon endorsed the concept following a report from the High Level Panel on Global Sustainability. The draft document presented for world leaders at the Rio+20 Summit endorsed the approach. In 2015 the updated findings were presented in the World Economic Forum in Davos. It has also been featured in a number of prominent media outlets such as the New York Times, Washington Post and The Economist, to name a few (Engström, Gars, Kiran et al 2018).

Due to its intuitive appeal (of "safe operating space" within the specified boundaries of system-critical processes) and its anchor on consensus on the underlying scientific evidence, the framework has generated greater interest than other earlier, alternative approaches. These include the safe minimum standards, critical loads, carrying capacity, limits to growth, and tolerable windows or guardrails (Häyhäa, Lucas, van Vuuren et al 2016)

The planetary boundaries are for nine key processes that determine the state of the Earth system, together with quantitative boundaries for these processes inside which the risk of triggering a destabilizing shift is acceptably low. The nine processes are (Steffen, Richardson, Rockström et al 2015):

1) Climate change
2) Loss of biosphere integrity (e.g. marine and terrestrial biodiversity loss)
3) Land-system change
4) Freshwater use
5) Biogeochemical flows (e.g. effluents that interfere with nitrogen and phosphorous cycles)
6) Ocean acidification
7) Atmospheric aerosol loading
8) Stratospheric ozone depletion
9) Novel entities (new substances, new forms of existing substances, and modified life forms that have the potential for unwanted geophysical and/or biological effects, e.g., chemical pollution)

Although the exact positions of planetary boundaries are uncertain, policies are motivated by the risk of crossing them. Appropriate policy design and stringency level will depend on the distance to each planetary boundary. Crossing one or more planetary boundaries may have serious consequences for human well-being due to the risk of crossing thresholds or tipping points that can trigger abrupt or irreversible environmental changes.

What the planetary boundaries framework highlights is that the threats of crossing planetary boundaries are global, long-run, interconnected, uncertain and potentially irreversible, and they need to be analysed together to avoid conflicts and take advantage of synergies. To design suitable policies that are effective at both international and local levels requires careful analysis of the underlying mechanisms across scientific disciplines and approaches, and must take politics into account.

As it happens, a recent workshop attended by senior academics from the sciences -- biology, ecology, climate science, and earth's systems modeling -- and the social sciences, like anthropology, sociology, and economics, identified seven guiding principles on the design of policy and governance structures in response to the risks of crossing these planetary boundaries (Sterner, Barbier, Bateman et al 2019). These are as follows:

1) Inherent complexities necessitate interdisciplinary collaboration in the design of appropriate policies and governance systems.
2) To identify the appropriate strength and type of policy, it is important to ascertain how serious the environmental problems are. If possible to measure, this could be given by the distance to the various boundaries.
3) Links across planetary boundaries often necessitate considering two or more of them together—both because policy approaches tackling one boundary may lead to 'ancillary' benefits elsewhere, and because of potential conflicts, where a policy that mitigates human impacts on one dimension exacerbates threats to another.
4) Despite the novelty and complexity of the task, several well-known policy instruments exist. The challenge thus is not to invent entirely new approaches, but to select and design appropriate policies given specific scientific, societal and political contexts.
5) Instrument selection depends on a proper diagnosis of the socioeconomic cause(s) underlying the problem, focused on the most important points of leverage.
6) Effective policy choice and design needs to be based on efficiency, achieving desired outcome at lowest costs, but must also consider "political" criteria such as the distribution of costs and resistance by powerful vested interests.
7) Finally, global problems need policy instruments and agreements that are operational at both international and local levels, to ensure not only efficient outcomes but also effective jurisdiction and governance.

To provide an example of policy design relevant to the topic of this contribution, the planetary boundaries for climate change and ocean acidification are closely linked because they share a common pollutant -- carbon dioxide -- which, in turn, is linked to fossil fuel use and land-use changes (in turn drivers for several other planetary boundaries). Thus, the appropriate set of policy instruments would be to reduce subsidies on fossil fuels; introduce or expand RD&D (research, development and dissemination) policies for renewable energy; and put in place better policies for land use and freshwater management.

Taking the above example one step further, the global characteristic of the pollutant identifies carbon dioxide emissions “leakage” as a concern, which occurs when businesses or consumers in one jurisdiction increase pollution in response to abatement elsewhere. Preventing leakage requires international action, hence the need for two-tier policy instruments such as international treaties concerning the two jurisdictions’ policy instruments aimed at the identified pollutant.

It has to be pointed out that the driving forces behind the unsustainable use of environmental resources, which threaten to cross these planetary boundaries, are principally economic, i.e. the patterns of unsustainable consumption and production by the human population. These patterns have led to the extraction and use of natural resources at a rapidly increasing rate, leading to unprecedented environmental degradation.

This then connects the planetary boundaries framework -- which includes a planetary boundary for climate change -- to the SDG Goal 12 (the focus of this volume). By the same token, a significant message of the planetary boundaries approach is that the global environmental and sustainability challenge is much more than climate change.

It will be recalled that SDG Goal 12 is: “Ensure sustainable consumption and production patterns”, which UN communication experts opted to shorten to “Responsible consumption and production”, presumably as a parallel, in a sense, to the concept of corporate social responsibility, or CSR.

## 8. Conclusions

Can the global economy break the link between economic progress and higher standards of living, on the one hand, and the burning of ever-increasing quantities of fossil fuels and land use changes, on the other hand?

In this contribution, the case of "where we are now" -- dependent on energy from coal, gas and oil -- was contrasted with that of "where we should be" -- powered by clean energy sources -- in order to guard against unchecked emissions of greenhouse gases. The path to low carbon growth is through a balanced view of the two separate, but related, tasks of reducing the sources of greenhouse gases, and enhancing the sinks of greenhouse gases. As the latest IPCC report (2018) suggests, the new term for low carbon growth is economic growth with net-zero emissions. However, as the title of a recent article asks (though focusing only on one of the two tasks above): Will we ever stop using fossil fuels? (Covert, Greenstone, Knittel 2016).

## Cross-References

Decarbonization

Global energy

Greenhouse gas emissions

Sustainable production practices to address climate change

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