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SCIENTIFIC REVIEWS

Current Environmental Issues and Emerging Global Challenges in the 21st Century for Environmental Protection and Sustainable Development

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Abstract

In 2016, a United Nations Environment Programme (UNEP) Frontiers report identified a series of global and emerging environmental problems that bring new challenges for the national and international environmental agencies and sustainable development organizations. In the last 50 years scientific research detailed monitoring and statistical records on a global scale prioritised environmental problems for their significance and the need for urgent action. These studies created greater awareness of the environmental problems and the urgent need to take remedial action. For example, urban air photochemical pollution from vehicular exhausts, the stratospheric ozone layer depletion in Antarctica, water pollution by agricultural runoffs and microplastics, soil erosion and desertification, industrial and municipal toxic sewage wastewater, damaging acid rain events in the lakes of Scandinavian countries, excessive population growth and urbanization in most continents, deforestation of vast areas of valuable tropical forests loss of biodiversity, climate change, were some examples that threatened natural resources, human health and sensitive ecosystems. But although some of these environmental problems attracted new and strict regulations, restriction of emissions, banning certain toxic and carcinogenic chemicals (microplastics, pharmaceutical and pesticide residues, etc), introduction of green chemistry processes and restriction of certain wasteful practices in industrial and agricultural sectors, novel emerging environmental problems appeared in the 21st century on a global scale that need new sustainable changes and the introduction of renewable energy sources and reduced use by mankind of non-renewable resources. At the same time old problems like overpopulation, urbanization, energy and food consumption trends, limits to continued unsustainable economic growth of developing countries need to be taken into account. The UN Environment's Sixth Global Environmental Outlook (GEO-6) in 2019 is the latest most comprehensive assessment of the state of the world's environment and emerging environmental problems. The report also offers a rigorous analysis of Earth's sustainable prospects and the most important environmental issues facing the Earth in the next decades. This review collected some important reports and scientific papers on the emerging environmental problems that will feature prominently in the future.

Introduction: Emerging environmental problems in the 21st century

Emerging environmental problems in the last decades have been accumulated to the old ones, bringing new challenges to international and national environmental protection institutions. The history of the emerging environmental problems facing advanced societies in the period 1950s-1970s is very revealing. At the same time there are new economic, social and technological changes on a global scale due to globalization. New forms of political, environmental and social mobilizations appear in developed and developing countries that promote new strategies for sustainable development.¹⁻⁵

Some of the most urgent and challenging environmental problems in the last decades were identified in the last 50 years creating greater awareness for the urgent need to take positive action. Examples, urban air photochemical pollution from vehicular exhausts (Los Angeles), the stratospheric ozone layer depletion in Antarctica, water pollution by agricultural runoffs and microplastics, soil erosion and desertification, industrial and municipal sewage wastewater in developed countries, damaging acid rain incidents in the lakes of Scandinavian countries, excessive overpopulation and urbanization in most continents, increasing solid waste disposal difficulties in big cities, deforestation of vast areas of valuable tropical forests and loss of biodiversity, were some examples that threatened human health and sensitive ecosystems before they were discovered. In some cases, solutions were very difficult to apply and certain conditions were expensive for remediation interventions.⁶⁻⁸

In the last decades, scientific endeavour and policy actions have led to innovative solutions and vital advancements in environmental protection. Yet these advances are frequently outpaced by overall economic growth. For example, as the fuel efficiency of cars has increased, the size of the global vehicle fleet continues to grow in urban areas. Some environmental pollution problems were discovered before substantial damage or threatening conditions developed in environmental resources and sensitive ecosystems.

But in some cases high concentrations of toxic pollutants appeared in the environment, in particular rivers, lakes and seas that proved to be very expensive for rementation actions. Some emerging environmental problems from anthropogenic activities appeared with serious toxic impact in humans and biological organisms or as diseases and premature deaths.^{9,-11}



Figure 1. The scientific literature in the last decades covered a variety of emerging and challenging environmental issues, toxic environmental pollutants, adverse impact of pollution on the natural resources, ecotoxicology, biodiversity and ecological actions to restore damage to sensitive ecosystems.

The key messages to environmental organizations and policy authorities are that human civilization will increasingly need access to timely, reliable environmental information from various locations around the world so that authorities can identify urgent environmental issues as they emerge and develop effective actions and policies to respond to them. Without this, the global community's efforts will be hampered.

National and international organizations facing challenging environmental issues

Environmental issues and in particular the most damaging to natural resources, biodiversity, sustainability, and human health are on the top on the list of priorities and concern of national and international environmental protection organizations. These organizations played important role in information and understanding of the threats, promoted investigations and follow up studies for environmental trends. Also, numerous publications and expert reports were directing scientific research not only for identification of emerging problems but also on practical solutions in the long term. A selection of environmental organizations (selection).

International: United Nations Environment Programme (UNEP, New York), Global Green Growth Institute (GGGI, Seoul, South Korea), Intergovernmental Panel on Climate Change (IPCC, UN New York), International Union for Conservation of Nature (IUCN, Gland, Switzerland), European Environment Agency (EEA, Copenhagen), Partnerships in Environmental Management for the Seas of East Asia (PEMSEA, Guezon, Philippines), etc .

Europe : Climate Action Network-Europe (CAN-Europe), European Association of Environmental and Resource Economists, European Environmental Bureau (EEB),

USA : Environmental Protection Agency (EPA), The Audubon Society (conserve and restore natural ecosystems), National Wildlife Federation (dedicated to preserving animals in the USA and works with local agencies), Rainforest Action Network (RAN) based in San Francisco and Tokyo,

UK, Green Alliance (1979) both a charity and a leading independent think-tank, Institution of Environmental Science (1971) on promoting sustainable development.

Germany. Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN), German Environmental Aid Association (DUH) in favour of sustainable technologies, Association for German Nature Conservation (DNR – Deutscher Naturschutzring, 1950),

Sweden Swedish Environmental Protection Agency (Natur Vards Verket).

Japan. Japanese Ministry of the Environment (Tokyo, 1971)

Non-governmental organizations (NGOs) : Confederation of European Environmental Engineering Societies, The Natural Resources Defense Council (USA), Earthwatch, Environmental Defense Fund, Friends of the Earth, World Resources Institute (WRI), World Wide Fund for Nature (WWF), Worldwatch Institute, Sierra Club (USA, Canada), Greenpeace, The Confederation of European Environmental Engineering Societies, etc.

UNEP Frontiers Report. Emerging issues of environmental concern (2016-2019)

The United Nations Environment Programme (UNEP) coordinates the organization's environmental activities and assists developing countries in implementing environmentally sound policies and practices. Every year UNEP publishes a Year Annual Book with global environmental problems for the last years (2016-2019). Also, the UNEP's scientific experts in the last years published annual Frontier reports identifying “emerging issues of environmental concern”. The reports provide analytical descriptions of emerging environmental issues and innovative policy interventions, new solutions and adapting existing practices. The 2018/19 Frontiers Report edition is accompanied by illustrative infographics and featuring the interactivity of links to videos on related research and information. The 2018/19 report covers five key emerging issues: the latest developments in synthetic biology; the critical advantages of landscape connectivity; the complex interactions and vulnerability of permafrost peatlands; the challenges of widespread nitrogen pollution; and the hazards of maladaptation in a world of climate change.[<https://www.unenvironment.org/resources/frontiers-201819-emerging-issues-environmental-concern>].¹²

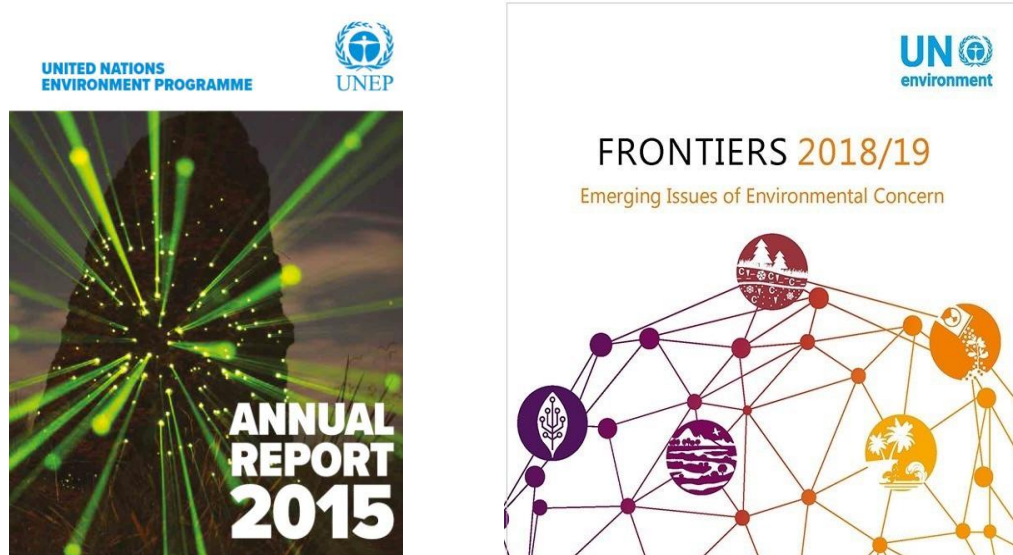


Figure 2. UNEP publishes annual environmental reports with experts addressing emerging environmental issues. Frontiers 2016, 2017, 2018/2019 include important environmental challenges facing the planet Earth.

Sixth global United Nations environmental outlook (GEO-6)

The UN Environment's Sixth Global Environmental Outlook (GEO-6) in 2019 is the most comprehensive assessment of the state of the world's environment. The report also offers a rigorous analysis of Earth's prospects for a healthy future. It contains chapters on the most important environmental issues facing the Earth in the next decades. The most important problems: [<https://www.unenvironment.org/interactive/global-environment-outlook/>].¹³

Overpopulation, urbanization and consumption. There are about 7.7 billion people living on Earth in 2019. At the same time these people will be increasingly drawn to life in cities (50% now). It is estimated that by 2050, roughly 68% of the population will live in urban areas. Urbanization increases energy consumption by raising the demand for housing, food, public utilities, land use, transportation, use of more electric appliances, etc.^{14,15}

Food production and waste for growing population. Earth encounters a rapid global population growth and in addition climate pressures that will affect agriculture. The result will be high demand of more food to feed the additional population. Countries have to use greater efficiency and resilience in food production and to encourage people everywhere to adopt diets that are more sustainable (reduce meat consumption). Food waste is a huge part of the problem. About 1/3 of all food produced for human consumption is ultimately lost or wasted.^{16,17}

Climate change and rising temperatures, Floods, droughts, forest fires and other climate disasters are already disrupting Earth's food supply, natural resources and human health. Such threats will probably become more frequent in the future.^{18,19}

Biodiversity is under serious threats as a result of human activities in exploiting natural resources (air, soil, marine environment, forests, aquatic resources). The main dangers worldwide are population growth and resource consumption, climate change and global warming, habitat conversion and urbanisation, invasive alien species, over-exploitation of natural resources and environmental degradation. The three greatest proximate threats to biodiversity are habitat loss, overharvesting, and introduction of exotic

species. Toxic pollution, have specific targeted effects on species, but are not generally seen as threats at the magnitude of the other causes.^{20,21}



Figure 3. GEO-6. Global Environmental Outlook-6. Healthy Planet Healthy People. UN publs, 2019. Report identifies among other issues that food waste will cause negative environmental impacts. At present 56% of all food waste is generated in high-income countries, while 44% comes from poorer.

Overexploitation of natural resources and ecosystems. Throughout of the history of established human societies their survival dependent on exploitation of natural resources. Even primitive humans have manipulated natural resources to produce the materials (food, energy. construction materials, medicinal products) they needed to sustain their growing populations. Natural resources are an important material basis for a stable natural economy and social development. With industrialization and urbanization mankind's demands for natural resources increased substantially and large scale exploitation and consumption resulted in deterioration and exhaustion of non-renewable natural resources. The overexploitation of natural resources (air, water, soil, forests, minerals, etc) and Earth's ecosystems by humans has long-lasting consequences for the future provision of natural resources and ecosystem services. Inevitably if this trend continues there will be problems in the provision of food, increase health hazards and risks of natural disasters. Emission of greenhouse gases (GHG) may affect the global climate for centuries, the non-sustainable harvest of fisheries and forests may leave these systems degraded for decades. The limitations of natural resources has

been widely recognized by the scientific community and the transition to sustainability constitute the focus of an ongoing debate.^{22,23}

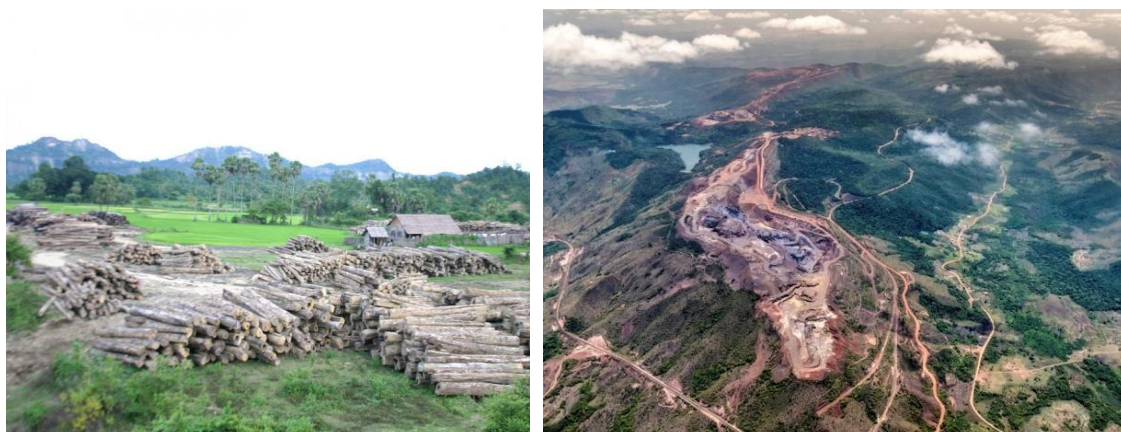


Figure 4. Environmental exploitation of natural resources increased drastically in recent years. Tropical forests in the Amazon, Indonesia, and Mesoamerica face multiple threats from mining, oil, and gas extraction and massive infrastructure projects over the next two decades. Bebbington J, et al. Resource extraction and infrastructure threaten forest cover and community rights. *Proc Natl Acad Sci USA* 115 (52):13164-13173; 2018.

Global energy demand and renewable energy production. Global energy demand is increasing substantially in the last decades and although renewable energy production is on the increase, electricity generated from coal and fossil fuels is also on the rise. Latest statistical evidence shows that about 2/3 of global electricity production still comes from fossil fuels which produce CO₂. Renewables have grown significantly over the past ten years. It is now at a record high. Renewable power capacity is set to expand by 50% between 2019 and 2024, led by solar PV (PhotoVoltaic systems) and installation of wind turbines. This increase of 1,200 GW is equivalent to the total installed power capacity of the USA today. Solar PhotoVoltaic panels (PV) account for almost 60% of the expected growth, with onshore wind turbines representing 25%. Hydropower remains the leader with 1,712 MW, wind turbines generated 564 GW, solar PV parks 480 GW. Bioenergy capacity is 121 GW (2018) geothermal power was 13 GW and marine energy capacity 500 MW. [Renewables Now, 2018 <https://renewablesnow.com/news/global-renewables-capacity-reaches-235-tw-in-2018-649118/>].

Renewable energies are expected to meet 40% of the projected demand and capture 2/3 of global investments in power plants between now and 2040. Looking even further ahead (2050 or 2060) the renewable energy

production will reduce substantially the CO₂ production from thermoelectric stations using fossil fuels. Similar reduction of GreenHouse Gases (GHGs) will be achieved with the expansion of use of electric vehicles. This dramatic transformation and the replacement of fossil fuels with Li-ion batteries can be beneficial to future climate changes and rising temperatures. All efforts at global scale to reduce energy consumption, increase efficiency and reduce energy loss, and subsequently reduce GHGs in the energy sector is hoped to contribute substantially in keeping Earth warming to well below 2°C.

[International Energy Agency (IEA) <https://renewablesnow.com/news/renewables-supply-25-of-global-power-in-2017-iea-606070/>].

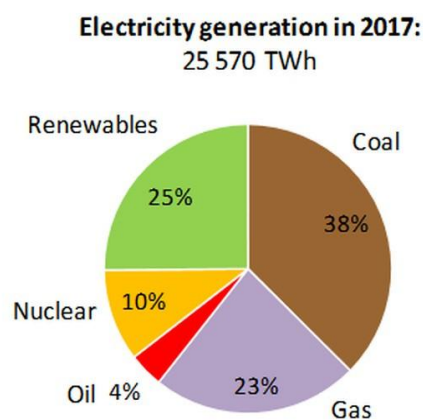


Figure 5. Global renewable power production (2017) increased substantially in the last 10 years. Hydropower, bioenergy, geothermal, wind turbines and solar photovoltaics panels covered around 25% of the world's power demand.

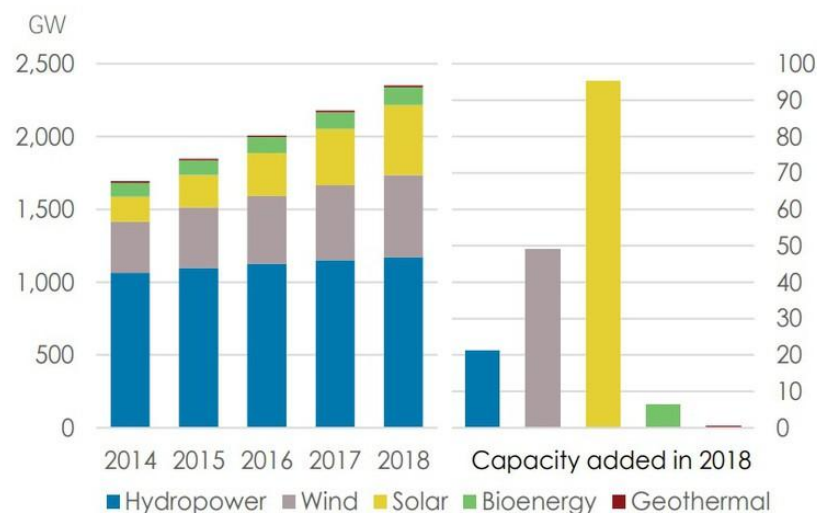


Figure 6. International Renewable Energy Agency (IRENA). In 2019 the global renewable energy generation was 2,351 GW (gigawatt) representing 33% of global installed power capacity. Hydropower leader with 1,712 MW, wind turbines 564 GW, solar PV 480 GW. Global bioenergy capacity was 121 GW (2018), geothermal power was 13 GW and marine energy capacity 500 MW. [<https://renewablesnow.com/news/global-renewables-capacity-reaches-235-tw-in-2018-649118/>].

In the last decade offshore wind power increased substantially. Wind power turbines have the capacity to meet all of the world's electricity demand, and is set to be a “game-changer” for energy systems, according to the International Energy Agency (IEA, Paris). The IEA estimates falling costs of offshore wind would make it competitive with fossil energy within the next decade, forecasting that the global average cost of power generated by offshore wind would drop 40% by 2030. In 2019 most of the world's offshore windpower was in Europe, but recently China has seen a surge in offshore wind installations. [Financial Times 25.10.2019, <https://www.ft.com/content/7c36dd38-f69b-11e9-a79c-bc9acae3b654>].



Figure 7. China with 221 GW installed capacity is the world leader in wind energy (2/3 of the world's capacity, 2018). The USA is 2nd with 96.4GW of installed capacity. Germany is 3rd and has the highest installed wind capacity in Europe with 59.3GW. India is 4th and the only Asian country apart from China to make the list, with a total capacity of 35GW. Spain is 5th and a strong performer in wind energy, with a capacity of 23GW covering 18% of Spain's electricity supply. The United Kingdom (UK) is 6th the with a total capacity of just over 20.7GW. France (7th), Brazil (8th), Canada (9th), Italy (10th). [Global Data. Top 10 countries by wind energy capacity (2018), 14.3.2019 [<https://www.power-technology.com/features/wind-energy-by-country/>]].

The global problem of hazardous/toxic waste. Hazardous or toxic wastes (liquid, solid and sludge) are discarded materials that can cause substantial threats to environmental resources (air, water, soil) and to human health. Hazardous waste is dangerous byproduct of a wide range of activities, including manufacturing, farming, water treatment systems, construction, automotive garages, laboratories, hospitals, and other industries. Hazardous

waste contains chemicals, heavy metals, carcinogens, pathogens, radioactive or other toxic materials. Hazardous waste are also municipal and households generated waste, from items such as discarded food, plastics, furniture, batteries, used computer equipment, and leftover paints or pesticides. On a global scale humans produce every year more than 400 million tons and the amount is increasing. Statistical data showed that in 2016 each European citizen produces 5-6 tonnes of hazardous waste per year, of which 45% were landfilled and 37% were recycled in the European Union (EU) in 2016. [Eurostat Waste Statistics, 6.11.2019 https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics].

The global market for waste is worth \$410 billion, and not all of it is legal. Safely disposing of hazardous waste is an expensive undertaking, so some people decide to just ship it to other (usually poorer) parts of the world. Humanity used an estimated 90 billion tons of resources in 2017. More than 50% of that was dispersed or emitted as waste, while less than 10% was put back into the economy. In the last decades electronic waste (discarded telephones, computers, etc) amounted to about 50 million tons in 2018, nearly a 50% increase in under a decade. [Statista. Electronic waste generated worldwide from 2010 to 2018, in million metric tons. 8.11.2019 <https://www.statista.com/statistics/499891/projection-ewaste-generation-worldwide/>].

The imperative to build a Circular Economy. The dramatic increase of the global population (estimated to 9 billion by 2030 of which 3 billion will be middle-class consumers) is expected to put unprecedented pressure on natural resources to meet future consumer demand (new houses, vehicles, furniture, clothes, food, electrical equipments, etc). Recent scientific research argued for the imperative need of a circular economy that will support sustainable development, where industrial systems and materials from natural resources are used in a restorative and regenerative mode by design and intention. The fundamental principle of a circular economy is that there is no waste, but recycling and production of new useful materials, moving away from the current wasteful economy, called linear ‘take-make-dispose’ economy. The circular economy’s potential for innovation, job

creation and economic development is huge with estimates indicating a trillion-dollar opportunity on a global scale. [World Economic Forum (WEF). The Circular Economy imperative, 2019, <https://www.weforum.org/about/circular-economy-videos>].

Global emerging and challenging environmental issues

International and national environmental organizations in the 21st century are projecting their research to new and emerging environmental problems which introduce challenging situations and solution. Some of these challenging issues are in recent reports and environmental analyses that follow megatrends in continued economic growth, population urbanisation and ageing, global diseases burdens, accelerating introduction of new technologies (artificial intelligence, robots, deep learning), alternative energy sources, depleted natural resources, worrying signs of climate change, tropical forest degradation, and the need for introduction of sustainable goals, and circular economy solutions for the future.

The debate for continued unsustainable economic growth and inevitable exhaustion of natural resources

The relationship between economic growth and the environment has multiple aspects and is a complex problem. Most of the key natural resources and ecosystems services are scarce or under pressure. Thus, achieving sustained economic growth will require absolute decoupling of the production of goods and services from their environmental impacts. This means consuming environmental resources in a sustainable manner – whether by improving the efficiency of resource consumption or by adopting new production techniques and novel technological product designs. It means avoiding breaches in critical thresholds beyond which natural assets cannot be replaced and can no longer support the desired level of economic activity in developed and developing countries.²⁴

For the last 200 years planet Earth has seen an incredible rise in the world's average standard of living and personal wealth. This increase in living

standards is a result of an unprecedented level of economic growth (as measured by the GDP, Gross domestic product is the most basic indicator used to measure the overall health and size of a country's economy) and inevitably competition among countries for important natural resources.²⁵

The report of the Club of Rome on the predicament of humankind in 1972 “The Limits to Growth” was a clarion call for unsustainable growth and inevitable exhaustion of natural resources. The Club of Rome with the help of a research team from the Massachusetts Institute of Technology (MIT) began a study of the effects and limits of continued worldwide economic and consumption growth. The study concluded that even under the most optimistic assumptions about advances in technology, the world cannot support economic and population growth for more than a few decades. The report created headlines worldwide (9 million copies) and remained as first reference source for humankind awareness on unsustainable economic growth.²⁶

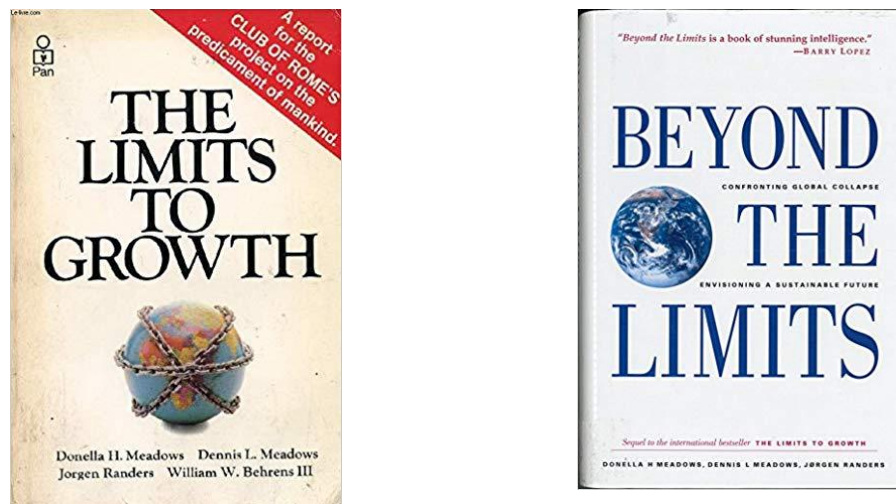


Figure 8. In 1972 “The Limits to Growth”, sponsored by the Club of Rome and produced by a research team on a MIT computer programmed with a World3 model, created a stormy global book sensation (sold 9 million copies). A sequel “*Beyond the Limits. Confronting Global Collapse, Envisioning a Sustainable Future*” (1992) used again an advanced and sophisticated computer modeling program to project into the next century the consequences of current rates of resource consumption and population growth.

Although 20 years later the same research team retracted some of the main assumptions for the time limits of natural resources, in the new book “Beyond the Limits” (1992). The new global data collected in the 20 years period and development trends gave to the scientific team a better outlook.

Their new analysis found that the world has already overshoot some of its limits and, if present trends continue, mankind will face certain prospects of a global collapse in the near future because of environmental degradation.²⁷

A number of studies were published in the last decade for the effects of economic growth on environmental quality indicators in countries that witnessed economic crises. There is a wide empirical literature verifying the relationship between economic activity and environmental degradation, in particular the relationship between economic growth, energy consumption and carbon dioxide (CO₂) emissions.²⁸⁻⁻³¹

The scientific literature has many investigations analysing environmental quality indicators associated in the immediate aftermath of economic crises. The results suggest that in the short term, economic crises generally result in positive environmental impacts (reduced consumption, decreased energy use, reduced emissions, etc). A study investigated changes in air and water pollution in Asia following the economic crisis of 1997, finding that the crisis resulted in short-term environmental benefits, due to contractions in manufacturing outputs. Also, the study found that the crisis led many Asian countries to cut back their investment into environmental protection in the long term (negative effect on sustainability).³²

2



Figure 9. Unsustainable development affect environmental quality and natural resources. Mayere SH. *Exploring Impact of Economic Growth on Environmental Sustainability*. Lambert/Academic Publs, 2017. Tietenberg T, Lewis L. *Environmental and Natural Resources Economics*. 11th edition, Routledge/Taylor & Francis, 2018. Hoffman AR (Ed). *Water, Energy and Environment: A Primer*. IWA (International Water Association), London, 2019.

Another study examined the impacts of the 1997 and 2008 financial crises on the environment in East Asia, which was negative on the whole.³³ The Greek financial crisis (2009-2015) is another case of economic downgrading that affected environmental quality indicators. A study assessed changes in air and water pollution, in order to analyse the impact of austerity policies on the environment in Greece, and noted that levels of sulphur dioxide (SO₂), carbon dioxide (CO₂), phosphorus and nitrogen fell between 2007 and 2010, in line with reductions in economic productivity. But these environmental short gains were reversed from unexpected smog in Greek cities (burning of old furniture and biomass for winter heating).^{34,35}

Any global reduction in CO₂ emissions as a result of the financial crisis in the last decade had ended a year after the crisis, as developing states rapidly increased their emissions again. Studies provided data for assessing changes in environmental quality and economic growth downturns.^{36,37}

The arguments for decoupling and compatibility between economic growth and environmental limits

American economist Kenneth Boulding famously quipped, “Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist”.³⁸ He was giving evidence to the U.S. Congress in 1973, in the wake of the Club of Rome's first, enormously influential and provocative (book) report ***The Limits to Growth***. The remark has survived as a somewhat satirical comment on the economics profession, but it also has a certain internal logic and provides a useful starting point for thinking about the “decoupling wars” that tend to be fought around the compatibility between economic growth and environmental limits.³⁸

When economists contend that growth can continue indefinitely, it is because in their view, growth is something measured in terms of economic value rather than material throughput. The preferred measure of output for economists—the gross domestic product (GDP)—is denominated in monetary value rather than in material weight. Economists argued, that these things are separable: By decoupling one from the other, economies ought to be able to escape the dominion of finite limits at least to any relevant degree.^{39,40}

Professor Paul Krugman (Nobel Prize for Economic Sciences, 2008) goes as far as to suggest that physical scientists simply have a false conception of economic growth: “They think of it as a crude, physical thing, a matter simply of producing more stuff, and don't take into account the many choices—about what to consume, about which technologies to use—that go into producing a dollar's worth of GDP”. His conviction that these “many choices” will allow for even the most stringent ecological goals to be achieved without ever compromising economic growth leads him to denounce growth skeptics as “prophets of despair.”⁴¹

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Krugman's argument (which is supported by other economists) is essentially an appeal to technology (including Green Chemistry and Green Engineering). Novel technological developments include more efficient industrial processes, lighter and less polluting products, or a structural shift from materially intensive goods to materially light services. The importance of this kind of decoupling is not disputed, even by those who maintain that growth may not be feasible nor even necessarily desirable on a finite planet. What divides opinion, rather, is the question of whether a continuous decoupling might allow economic expansion to go on indefinitely.⁴²⁻⁴⁵

Scientists agree that to reduce drastically the degradation of the natural environment and the exploitation of non-renewable natural resources there must be changes in the organization of human society and the present economic outlook supporting a high consumer and energy expansive society. They propose as a sensible solution, a new term under the direction of Green Growth, that has been increasingly criticized by academic thinkers. Also, the offered alternative by other scientists of degrowth has remained a marginal undertaking in academia and in practice. A comparative analysis of the

normative foundations of green growth and degrowth using frameworks from critical social theory shows that Green Growth and Degrowth work toward different normative ideals that are justified in different ways. The analysis shows that degrowth has a stronger normative justification than green growth and therefore, should be preferred.⁴⁶

How economic growth affects competition for non-renewable natural resources

Studies on the global use of renewable and non-renewable natural resources showed that their exploitation increased 10 times (ten-fold) since 1900. Also, estimates with recent trends expect that their exploitation will double again by 2030 jeopardising their availability in the future and causing extensive environmental pollution and severe shortages of valuable or strategic non-renewable natural resources.

While global demand for natural resources (in particular the so called critical or strategic, or scarce) is set to grow significantly in coming decades, the outlook for supplies is more uncertain. Geographic concentration of reserves in a limited number of countries is a concern since it affords suppliers considerable influence over global prices and supplies. Uncertainty regarding access to commodities increases if reserves are concentrated in politically unstable regions (especially in Africa). Certain non-renewable resources deserve particular attention because of their economic relevance, including their role in green-energy technologies. In 2014, the European Commission identified twenty critical raw materials (mostly scarce or strategic metals), based on the risks of supply shortage and their economic importance to industrial countries. Global production of these materials is quite concentrated in some countries in Africa and Asia.⁴⁷

Metals are essential for a wide range of industries like mechanical engineering, transport, aerospace, construction, packaging, electricity and energy, consumer electronics, medical devices, etc.. The European Commission identified the most critical metals : Heavy rare earths, Light rare earths, Magnesium (Mg), Antimony (Sb), Tungsten (W), Magnesite (MgCO₃, magnesium carbonate), Gallium, (Ga), natural graphite (C), Germanium (Ge),

Indium (In), Silicon metal (Si), Lithium (Li), Fluorspar (CaF_2 , calcium fluoride), Coking coal (C), Phosphate rock (P_2O_5), Niobium (Nb), Beryllium (Be), Platinum Metal (Pt), Chromium (Cr), Cobalt (Co), Borates (B, large number of boron-oxygen compounds usually containing oxyanions).⁴⁷

Economists have divided natural resources into renewable and non-renewables but also resources can be subdivided into “strategic” or “scarce” “critical natural capital”, “keystone resources”, and “critical raw materials” natural resources, which can become very important in the future and cause disputes among countries.⁴⁸⁻⁵²

For example, the most recent dispute among countries (2019) is about the Nile waters between Egypt and Ethiopia. Ethiopia is building an upstream Nile dam that has escalated into a heated war of words of the two countries over the hydropower barrage. The dam is a \$4 billion construction on the Blue Nile, a tributary of the Nile River, near the border with Sudan. Ethiopia is saying the project is necessary to provide the country with much needed-electricity. But Egypt fears that the dam could stem the flow of the Nile, on which it depends for around 90% of its water supply (agriculture and fresh drinking water). After several months of negotiations between the two countries have failed to make any breakthrough, spurring fears of a military conflict between Egypt and Ethiopia. The prime minister of Ethiopia (Abiy Ahmed, Nobel Peace Prize for 2019) said “no force can stop Ethiopia” from building the dam and Egypt responded by saying it was “shocked” by the remarks, amid calls in local media for launching a war to stop Ethiopia from building the dam.

[AA. Nile dam spurs fears of Egypt-Ethiopia “water war” 30/10/2019, <https://www.aa.com.tr/en/africa/nile-dam-spurs-fears-of-egypt-ethiopia-water-war/1630981>].

In the last decades international organizations keep a tight statistical overlook regarding the depletion of non-renewable natural resources and the rates of discovery of new sources or alternative materials. But the real picture of depletion of some very important natural resources, such as fresh water, fertile agricultural land, soil erosion, marine fish commodities, forests-timber, etc, is startling.

For example, extraction of minerals from the Earth’s crust, were 40 billion tons in 1980 and around 100 billion tons in the end of the 2020s. The

increased extraction of metal ores indicates the continued importance of this resource category for industrial development. Although depletion of mineral resources is a good example for worrying trends, there is depletion of other non-renewable resources that are equally very challenging for future developmental prospects. A typical example, during more than a century the use and extraction of mineral resources increased exponentially with an average between 3-4% annually. Scientists are questioning the trends of exploitation given that there are limited amounts of mineral resources in the Earth's crust? ⁵³

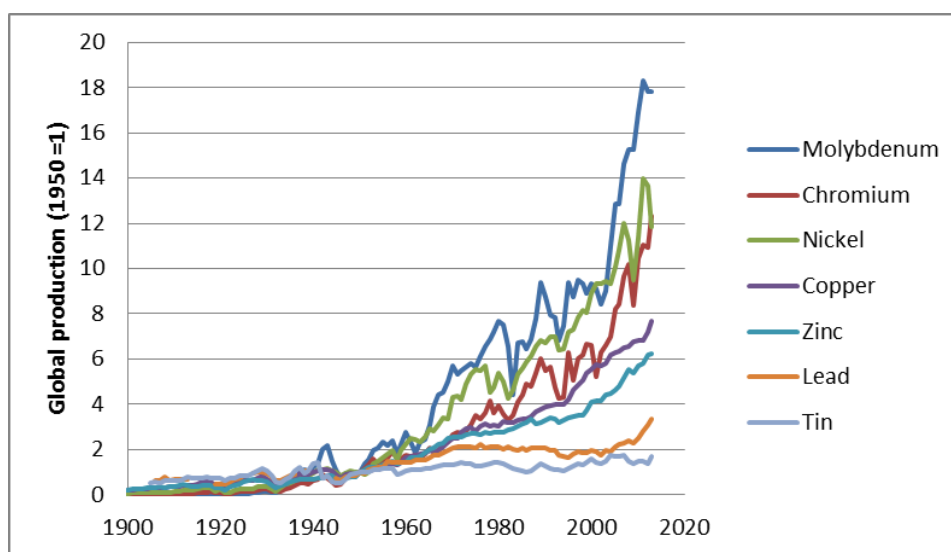


Figure 10. Trends in the annual extraction of seven strategic mineral commodities that are used in many industrial and commercial industries. Reference 42. Henckens T. An update on mineral depletion: do we need mining quotas? 17.1.2017. Resilience [<https://www.resilience.org/stories/2017-01-17/an-update-on-mineral-depletion-do-we-need-mining-quotas/>].

The effects of depletion of non-renewable natural resources will have widespread consequences not only on the human life but also for many environmental quality indicators. When natural resources become scarce, food, fossil fuel, minerals and energy prices will rise. But many examples in the past show that increased prices force human to change to alternatives or conserve scarce natural resources and start recycling. The future availability of natural resources is critically important for human societies. Current and future natural resource availability is therefore a political, economic, social and environmental issue that can impact all stakeholder groups, often with disproportionate and indirect consequences. Given that resource-related

supply chains are often global in nature, these consequences may easily be underestimated in both scale and scope. Future natural resources availability is highly contested among scientists because natural resource supply and demand are hard to predict and complex in nature.^{54,55}

Can Green Growth improve efficient use of natural resources?

In the last decade there is, relatively, a new concept of “**Green Growth**” for economic studies associated with scarcity of natural resources and increasing prices. Green growth can be fruitfully connected to concepts and theories in neoclassical economics including market externalities. With equilibrium concepts and models scientists investigated how resource depletion and environmental degradation are affecting the economy, and how efforts to reduce the impact of these environmental and resource constraints could improve economic growth and performance.⁵⁶

Green growth is not a replacement for the process of sustainable development, but it provides a practical and flexible approach for achieving concrete, measurable progress across its economic and environmental pillars, while taking full account of the social consequences of greening the growth dynamic of economies. Green growth strategies must ensure that natural resources can deliver their full economic potential on a sustainable basis. That potential includes the provision of critical life support services – clean air and water, and the resilient biodiversity needed to support food production and human health. Natural assets are not infinitely substitutable and green growth policies take account of that. The OECD (Organization of Economic Cooperation and Development, Paris) published a package of reports “*Towards Green Growth*” (25/5/2011) in respond to a request from Ministers of the 34 industrial countries who signed a Green Growth Declaration in 2009, committing to strengthen their efforts to pursue green growth strategies as part of their responses to the crisis. They agreed that green growth tools and indicators can help expand economic growth and job creation through sustainable use of natural resources, efficient use of energy, and valuation of ecosystem services. Ministers noted that innovation, supported by a strong

intellectual property rights system, is a key to countries' abilities to achieve green economic growth, create green jobs, and protect the environment. There are now 46 Adherents to the 2009 OECD Declaration on Green Growth. Bulgaria has joined Costa Rica, Colombia, Croatia, Georgia, Kazakhstan, Latvia, Lithuania, Morocco, Peru, Tunisia, as well as OECD members in having adhered to the Declaration. Latest reports are now available on Brazil, New Zealand, Slovak Republic, Slovenia, Korea, Latvia and Zambia.^{57,58}



Figure 11. The OECD (Organization of Economic Cooperation and Development, Paris) published a package of reports “*Towards Green Growth*” (25/5/2011). The *Green Growth Indicators 2017* uses a range of indicators covering land use to CO₂ productivity and innovation to show where 46 countries rank on balancing economic growth with environmental pressures over 1990 to 2015. The report shows that no country is performing well on all green growth dimensions, to fully disconnect economic growth from fossil fuel use and pollutant emissions. Progress has often been insufficient to preserve the natural asset base or relieve pressure on ecosystems and on natural environmental services such as water purification and climate regulation.

Increasing global divergence in population trends: populations ageing, growing and migrating

In the last decades statistical evidence show that Earth’s population is increasing at about a billion people every 12 to 15 years. Lately, scientists have turned their attention to issues of new population projections, population longevity and ageing, migrations and other aspects affecting environmental sustainability. The population explosion affects virtually every environmental aspect of the Earth upon which humankind rely to survive: lands in five

continents, oceans, fisheries, forests, wildlife, biodiversity, grasslands, rivers and lakes, groundwater, air quality, atmosphere, weather, and climate. United Nations researchers' projections (indicators of infant mortality, total fertility rate, and life expectancy) indicate that by 2045, world population is likely to reach about 9 billion and begin to level off soon after.⁵⁹⁻⁶²

The Organisation for Economic Co-operation and Development (OECD, founded in 1961, Paris) is an international organization shaping policies that foster economic prosperity, equality and trade opportunities in 36 of the most developed countries. The OECD estimates that over the next 50 years, its member 36 countries (with 18% of world population) will see a steep increase in the share of elderly persons in the population, as well as a steep decline in their prime working-age populations. Researchers in the International Labour Office (ILO, Geneva, tripartite United Nations agency, founded 1919, 187 member states, set labour standards, and promote decent working conditions) calculated that with these demographic trends and longevity by 2050, there will be two billion people aged 60 or over, a proportion that brings with it many implications for humankind and the environment. These population transitions mean that there will also be a change in the labour force supply in the global scale. Many industries and agriculture will have to adjust either by bringing more of the youth population into its workforce with increasing salaries or by attracting more workers from the older population segment.⁶³

Between 2000 and 2050, the proportion of the world's population aged 60 years and older will double, from about 11% to 22%. The absolute number of people 60 years and older is projected to increase from 900 million in 2015 to 1.4 billion by 2030, to 2.1 billion by 2050, and to 3.2 billion in 2100. However, longer life expectancy is also a source of concern for policymakers; income growth may become harder to realize in countries with large populations of older people, and meeting the medical and housing needs of a large elderly population will be especially difficult in low- and middle-income countries. It will be necessary to create economic and social institutions that provide income security, adequate health care, and other needs for the aging population. Inevitably, many aspects of these changes in population will affect the quality of environmental indicators.^{64,65}

Environmental sustainability and the ageing population are two of the most important challenges facing national authorities around the world today. There is a debate among scientists for the influence of an ageing population to environmental resources. Birth rates have been falling across much of the world in recent years, and OECD countries (36 of the most developed industrial countries, including Greece) are no exception. In 1970, the average woman in an OECD country had 2.7 children in her lifetime. In the last years (2016-19), the figure was around 1.3-1.9 and decreasing. That number is significant because it now means that OECD countries birth rates have dipped below the replacement rate of 2.1 children that is needed to maintain a stable population size (excluding any impact from migration). A smaller and older population may not only be more productive than expected but even cause less environmental pollution. Also, individual consumption patterns and their ecological consequences are better for old people. It is a fact that younger individuals travel and consume more commodities and cause higher CO₂ emissions than individuals at retirement age because of their involvement in family formation and extra needs for children, education, housing, car ownership, etc. This implies that if today's consumption behaviour prevails, older and smaller populations may generate substantial CO₂ reductions and decreased consumption.⁶⁶⁻⁶⁸

Urbanization: spreading cities and effects on environmental quality and ecosystem services

In 1800 the majority of the world population 98% lived in rural areas (villages and small towns), and only about 2% of the world's population lived in urban areas. But in the last 200 years the growth of urban areas was inevitable because of steady increase in migration to the cities and the increased fertility of urban populations. Urban migration is the result of rural populations' desire for the advantages that urban areas offer (schools, hospitals, transport, services, entertainment, new housing). In only 200 years, the world's urban population has grown to nearly 55% of the population and is expected to increase to 68% in 2050. The most striking examples of the urbanization of the world are the megacities of 10 million or more people. In

1975 only four megacities existed; in 2000 there were 18. In 2016 it is estimated that 4 billion people lived in urban areas, and 3.4 billion in rural areas. Most of the investigations of urbanization and its impact on environmental indicators showed that cities and high density urban populations created major environmental problems ranging from substantial air and water pollution, increased consumption of fresh water resources, deforestation for housing needs, motorways, parking spaces, public amenities etc. Urbanization played a significant role in increasing CO₂ emission in some countries (from studies in China).⁶⁹⁻⁷²



Figure 11. An international team of more than 200 scientists conducted a global assessment of urbanization and the environment, called the City Biodiversity Outlook (CBO), finding widespread degradation of ecosystem service provision for urban residents and a substantial loss of biodiversity in urban and urbanizing areas.

There is in recent years a vigorous debate on the role of urbanization on the adverse effects on **Ecosystem Services**. They are grouped into four broad categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and oxygen production; and cultural, such as spiritual and recreational benefits.^{73,74}

An international team of researchers gathered by the Secretariat of the Convention of Biological Diversity (CBD, Montreal, Canada) contacted an

extensive study on the impact of urbanization on the degradation of ecosystem services. The Report: “*Cities and Biodiversity Outlook. Action and Policy*” (CBO, 2012) found that ecosystem services are beneficial to humans through particular characteristics of the natural environment and from properly-functioning ecosystems.⁷⁵

The report argues that while there are many different causes of ecosystem services degradation, including loss of habitat, climate change, and regulatory and institutional barriers, one fundamental underlying problem was identified in several of the chapters of the CBO: many ecosystem services, in particular regulatory and cultural services, are common or public goods. That is, these ecosystem services are non-excludable goods, in that the benefits they provide are not easily limited to only those who can pay for them, but are freely available to a large set of people. For instance, a large forested patch in an urban region helps to maintain and regulate air quality and temperature locally and potentially regionally, yet these benefits are available to essentially all those near the forested patch, regardless of whether they have paid for their provision.⁷⁶

In the last decades big cities were transformed into an essential element of a prosperous national economy in most industrial-developed countries. All statistical evidence showed that cities are huge drivers of economic growth. With more than 80% of global Gross Domestic Product (GDP) generated in cities, inevitably inhabitants of rural areas migrated to big cities. Urbanization can contribute to sustainable growth if managed well by increasing productivity, allowing innovation and new ideas to emerge.

Cities have a large share of the educated citizens, both public and private institutions and advanced infrastructure. In 2007, just 380 cities contributed 50% of global Gross Domestic Product (GDP). Researchers project that by 2025, 600 cities will account for 60% of global GDP. For example, In the United Kingdom, London accounts for almost 50% of Britain’s GDP. In the biggest global economy of USA (20.5 trillion GDP in 2018), the Boston-New York-Washington corridor and greater Los Angeles together combine for about 33% of USA’s GDP. In Japan, there are some of the most densely populated urban areas, 2/3 of Japan’s population is in the Tokyo-

Nagoya-Osaka megalopolis belt with some of the biggest industrial, banking and commercial companies.

In China, Shanghai, Beijing, Southern cities Shenzhen and Guangzhou, Central Chinese stronghold Chongqing and its neighbour Chengdu as well as Shanghai satellite cities Suzhou and Hangzhou were some of the biggest cities in China in 2018 by GDP. The 8 cities' growth exemplifies the meteoric ascent of the Chinese economy. A typical example of explosive GDP increase for Shanghai's GDP was a mere 27.3 billion yuan Renmin in 1978, the city posted a GDP of CN¥3.3. trillion in 2018, a 12,000% increase in the period of 40 years.[1 Renminbi = 0.14 US\$].

[World Economic Forum. The explosive growth of 8 miracle Chinese cities, <https://www.weforum.org/agenda/2019/09/infographic-the-explosive-growth-of-chinese-cities/>]

The gathering of economic and educated human resources in one place stimulates innovation and development in business, science (universities and research institutes), technology and industry. Access to education, health, communication, transport networks and social services (hospitals, medical centres, pharmacy shops, private biomedical services and private doctors) help the urban population to feel more prosperous and safe. Lately the concept of “smart cities” and environmental sustainability has appeared in the scientific literature. The density of urban populations makes it easier and less costly for the government and utilities to provide essential goods and innovative services and the supply of basic facilities such as fresh water, sewage, solid waste disposal and electricity can be achieved with less effort and less cost per person.⁷⁷⁻⁷⁹

Big Cities with high populations in many countries have always been associated with transformative ideas, novel social initiatives, scientific and technological innovations. Some scientists argue that the innovative activities are the products of cities and urban regions. The urban environment initiates innovative activities that help in the generation of new ideas, new organisational forms and new enterprises. Most of the environmental and social challenges that modern societies face today are exacerbated within urban areas; this is both one of the underlying reasons for greater innovation in cities, and one which can eventually be overcome by harnessing this same,

vital innovation. The high level of provision of education, services and leisure activities, combined with a high population density and the very high frequency of interactions notably found in cities, favour technological and social innovation, entrepreneurship and creativity.⁸⁰

Despite the many benefits of urban life compared to rural life, some of the benefits do not apply to all people. Rapid population increases and unplanned growth create an urban sprawl with negative economic, social, and environmental consequences (air and water pollution, untreated waste, cost of life, etc), congested traffic roads, high crime rates, urban noise. Urbanization can contribute to sustainable growth if managed well by increasing productivity and allowing innovation. However, the speed and scale of urbanization brings challenges, including meeting accelerated demand for affordable housing, well-connected transport systems, and other infrastructure, basic services, as well as jobs, particularly for the nearly one billion urban poor who live in informal settlements to be near opportunities. Conflicts are on the rise, resulting in 60% of forcibly displaced people living in urban areas. Big Cities also play an important role in tackling climate change, as they consume close to 2/3 of the world's energy and account for more than 70% of global greenhouse gas emissions (GHG). As cities develop, their exposure to climate and disaster risk also increases. Almost half a billion urban residents live in coastal areas, increasing their vulnerability to storm surges and sea level rise. In the 136 biggest coastal cities, there are 100 million people – or 20% of their population – and \$4.7 trillion in assets exposed to coastal floods. Around 90% of urban expansion in developing countries is near hazard-prone areas and built through informal and unplanned settlements.⁸¹

The United Nations Human Settlements Program has already established the worsening situation in urban unplanned settlements in the last decades with overcrowding, homelessness, hazardous air and drinking water conditions, and environmental health problems. This global rise of urban poverty and insecure occupancy status takes place in a context of accelerated globalization and structural adjustment policies in many developing countries in the five continents of the Earth.

Accelerating adoption of emerging/disruptive technologies and their risks: are we racing into the unknown?

Over the past twenty years (2000-2019) emerging technologies, also known as “*disruptive technologies*”, have fueled innovation that has transformed entire industries, and given birth to over 100 unicorns [**a unicorn company refers to any technological startup enterprise that reaches a \$1 billion dollar market value as determined by private or public investment, a term coined in 2013 by venture capitalist Aileen Lee]. In the USA alone there are a high number of unicorn companies with a combined value of \$360 billion, and enabled the platform in the global economy with a total market value of over \$4.3 trillion! In 2018 there were 266 unicorn enterprises with total US\$861 capital: China (125), USA (121), India (27), South Korea (10), UK (10), Israel (5), Sweden (5) and others⁸²

Some of the innovative technologies have been commercialized for years and their introduction have initiated dramatic developments in industries, marketing and commercial practices. Disruptive technologies breach new territory in a particular field. At the same time they promote globalization of trade, storage of data, personal communications, and other innovative activities. There are many examples of emerging or disruptive technologies:

- a. **Cloud computing** (large numbers of information and data stored on physical or virtual servers, maintained and controlled by a cloud computing provider, such as Amazon and their AWS product),
- b. **Mobile networking** (mobile networking refers to technology that can support voice and/or data network connectivity using wireless, 1G-5G),
- c. **Social media:** websites and applications that enable users to create and share content or to participate in social networking. (Facebook, Instagram, Twitter, Google, etc). There are also some other disruptive technologies are immature and not established yet to a large extent:
- d. **IoT (Internet of Things)**, an emerging topic of technical, social, and economic significance. Consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects are being combined with Internet connectivity and powerful

data analytic capabilities that promise to transform the way we work, live, and play,

- e. **3D Printing** (three dimensional printing), a process that builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material (plastic) layer by layer,
- f. **Cognitive automation** (artificial Intelligence techniques applied to automating specific business processes, such as machine Robotic Process Automation), and
- g. **Blockchain** (originally block chain) is a growing list of records, called blocks, that are linked using cryptography. Blockchain was invented by a person (or group of people) using the name Satoshi Nakamoto in 2008 to serve as the public transaction ledger of the cryptocurrency bitcoin. Blockchain enables fully decentralized databases, resistant to censorship and potentially allowing for system adoption in critical applications like money and identity,
- h. **Artificial intelligence** (AI) and **Robots** are arguably the most exciting recent fields of research and technological applications. Also, AI is certainly a controversial subject: Everybody agrees that a robot can work in an assembly line, but there's no consensus on whether a robot can ever be intelligent. Like the term "robot" itself, artificial intelligence a man-made machine with human intellectual abilities. This would include the ability to learn just about anything, the ability to reason, the ability to use language and the ability to formulate original ideas. Roboticists are nowhere near achieving this level of artificial intelligence, but they have made a lot of progress with more limited AI. AI machines can replicate some specific elements of intellectual ability.

Furthermore, the pace at which new disruptive technologies are introduced in accelerating rate making decision to apply them and replace old techniques very risky. For established industrial and commercial enterprizes these technologies present some formidable challenges. While there are significant opportunities to be realized by exploiting them to innovate and create new sources of value, there are also significant risks that could more than offset any benefits. Furthermore, not all of these

technologies are equal. The process by which organizations evaluate, select, invest, and deploy these technologies can make the difference between competitive differentiation and market growth or monetary losses, write-downs, and reputational damage. Artificial Intelligence (AI) and robotics are advancing very fast and their applications are causing problems of trust and challenging situations in enterprises.⁸²⁻⁸⁴

Intensified global competition for natural resources and decreasing stocks. UNEP Global Resources Outlook, 2019

The International Resource Panel (United Nations Environment Programme, UNEP) was established to provide independent, coherent and authoritative scientific assessments on the use of natural resources and their environmental impacts over the full life cycle. The Panel aims to contribute to a better understanding of how to decouple economic growth from environmental degradation while enhancing well-being. Benefiting from the broad support of governments and scientific communities, the Panel is constituted of eminent scientists and experts from all parts of the world, bringing their multidisciplinary expertise to address resource management issues. The information contained in the International Resource Panel's reports is intended to be evidence based and policy relevant, informing policy framing and development and supporting evaluation and monitoring of policy effectiveness.

The report by UNEP "*Global Resources Outlook 2019 – Implications for Business Leaders*" highlights the key findings of the Global Resources Outlook 2019 (GRO) for leaders in business and policy [https://wedocs.unep.org/bitstream/handle/20.500.11822/27519/GRO_2019_I_BL.pdf?sequence=1&isAllowed=y]. The basic aim of the report was to provide a starting point for strategic decision-making for successful businesses in a sustainable economy that takes into account the emerging environmental issues of the 21st century. In 2015, countries around the world agreed on the key parameters of a sustainable economy in the Sustainable Development Goals (SDGs), aiming to create a world of growing prosperity for all in a healthy environment. Global intergovernmental commitments further specify

the most urgent environmental agendas, including the Paris Agreement to limit global warming to 'well under' 2°C, the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (UNCCD).



Figure 12. Global Resources Outlook 2019, prepared by the UNEP International Resource Panel, examines the trends in natural resources and their corresponding consumption patterns since the 1970s to support policymakers in strategic decision-making and transitioning to a sustainable economy. Over the past five decades, the population has doubled, and global domestic product has increased four times. The report finds that, in the same period, annual global extraction of materials grew from 27 billion tonnes to 92 billion tonnes (by 2017). This will double again by 2060 on current trends.

The report focus on the following Natural resources – biomass (wood, crops, including food, fuel, feedstock and plant-based materials), fossil fuels (coal, gas and oil), metals (such as iron, aluminium and cooper), non-metallic minerals (including sand, gravel and limestone), water and land.

According to the report these natural resources provide the foundation for the goods, services and infrastructure that make up our current socio-economic systems on Earth. The use of these natural resources is also a key cause of the most urgent impacts on planetary and human well-being: the extraction and processing of natural resources alone cause over 90% of global biodiversity loss and water stress, and more than 50% of global greenhouse gas emissions. Also, extraction of natural resources and use causes environmental pollution through waste and emissions, including particulate matter (PM) and toxic chemicals (gases, liquids, solid dusts). Resource use is also closely related to economic stability. Global growth has

become more dependent on commodity trading, while price volatility has become a determining factor for trade and manufacturers around the world. Natural resource use and impacts also play an important role in many conflicts among countries and migration of populations from underdeveloped countries to industrial developed countries. Global resource use and its resulting impacts are growing: resource use more than tripled from 27 billion tons in 1970 to 92 billion tons in 2017.

The Global Resources Outlook 2019 report emphasises that current natural resource use exceed the planetary boundaries and, if left unchecked, will inevitably change the world economy in a fundamental way. This means shifting away from traditional strategies and take action for “embracing decoupling” and preparing for discontinuities and disruptions. Traders and manufacturers must take “sustainability” into account and integrate implications of decoupling into regular business practices and strategies of industrial; development.

- a. **Metals extraction** has increased 3.5 times between 1970 – 2017. The **iron-steel production** chain has the largest climate change impacts, with about two thirds of the overall metals group. • **Aluminum production** has the second highest climate change impacts, with about one quarter of the group. • In the **processing of copper and precious** metals toxicity impacts are the major concern, (representing about 30-45% of toxicity impacts of the metals group).
- b. **Non-metallic minerals** extraction was 4.9 times higher in 2017 than in 1970, which represents the highest growth rate of all resource groups. **Cement production** has the highest climate change impacts (with over 80%) and particulate matter health impacts (with over 50 per cent of the non-metallic minerals group). • **Sand/gravel** and limestone have a minor impact on the global average. Nevertheless, mining activities may have severe local impacts on ecosystems. • **Phosphorus fertilizer** application has high toxicity impacts that are more significant in the usage phase.
- c. **Fossil fuel extraction** was 2.5 times higher in 2017 than in 1970. **Methane emissions** during fossil fuel extraction have a large climate impact, with more than 1/3 of the material group (fossil extraction and processing) and 60% of fossil extraction (the latter without processing). **Coal extraction** alone contributes about half to these methane emissions. • **Oil and gas extraction** and processing are responsible for 26 per cent and 27% of the material group’s climate change impact. Mostly, they arise from venting, flaring and local energy supply, as well as from leaks and other sources of fugitive emissions. • Most climate

change impacts of the group's emissions are caused by the refining of crude oil into useful products (for example chemicals, various fuels and intermediate products) and chemical production (together >60 per cent of impacts of the material group). • Both coal combustion and oil and gas extraction release significant amounts of mercury into the environment (for coal this is 35% of global anthropogenic emissions; for oil/gas extraction mercury is emitted with waste water and solid waste streams). These emissions are major contributors to mercury contamination in oceans.

- d. **Biomass extraction** has increased 2.7-fold between 1970-2017. **Cattle farming** has the highest share of climate change impacts with 26% of the biomass group, mainly from enteric fermentation (i.e. CH₄ emissions) and N₂O emissions. • **Rice production** includes the highest CH₄ emissions besides livestock and has the highest impacts from crop production. • Climate impacts of **land use change** are difficult to allocate to sectors, potentially doubling the climate change impacts of biomass production.

Key approaches on the demand side include the improvement of diets to **lower global meat consumption** and reduce overconsumption of food. **Crop-based biofuels** must be largely phased out as they compete for agricultural land. From the production perspective, yields must be increased in many developing countries by using state-of-the art crop management, including optimized fertilization and irrigation practices. **Genetically modified organisms (GMOs)** must be assessed further, as they can have benefits including enhancing yields or increase resistance but can be perceived as a potential risk to humans and ecosystems. Precision agriculture, new breeds, and drone applications are promising technologies to increase biomass production efficiencies.

- e. **Water withdrawal.** Global water withdrawal for agriculture, industries, and municipalities increased sharply in the second half of the 20th century. During that period, water withdrawal grew at a faster rate than human population. From 1970 to 2010, the growth rate of withdrawal slowed, while, nevertheless, growing from 2,500 km³ per year to 3,900 km³ per year. In addition to the water withdrawal by those three sectors, water was lost by evaporation from artificial lakes or reservoirs with dams.
- f. **Land-Use Change.** Between 2000 and 2010 the continents cover 134 million km². In 2010, these were mainly covered by forest (31.7%); grassland, shrubland and savannah (19.1%); intensively managed pastures (12%), cropland (11.4%); and barren land (14%). Built-up areas covered by settlements and infrastructure account for 1 to 3% of the total area. Between 2000 and 2010, total global cropland area increased by 1.3% from 15.2 million to 15.4 million km². While **cropland area** declined in Europe and North America, there were increases in Africa, Latin America and, more moderately, in Asia. **Global pasture area** has decreased slightly from 31.3 million to 30.9 million km². While slight increases can be observed in North America, Latin America and Africa, there was a decrease in Europe and more significantly in Asia. Globally in 2000, 53% of this area was intensively managed pasture, 47% were

grassland, savannahs, shrubland and barren land that were extensively grazed. Up to 2010, these proportions hardly changed. Net forest losses can be observed in Africa (-1.3%) and Latin America (-1.6%). The other world regions show slight net increases in forest areas. The overall forest area in Asia appears fairly stable, while a more detailed spatial analysis shows that South Asia is a deforestation hotspot. Shrinking forests in that region are compensated by forest expansion in East Asia in terms of land cover. About 2/3 of world forests are extensively used, 6% are intensively managed (for example, fast-growing plantations), while 28% remain largely intact.

[UNEP. Global Resources Outlook, 2019. https://www.resourcepanel.org/sites/default/files/documents/document/media/unep_252_global_resource_outlook_2019_web.pdf].

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Climate Change. Increasing severity of the consequences of climatic changes, rising sea levels and temperatures

Climate changes and rising temperatures are known to have multiple impacts on worldwide environmental parameters in the future. Scientists use various models to simulate future changes (land-cover, rising sea levels, river floods, biodiversity, agriculture, human health, etc) on Earth.

Climate change and land-cover change will have major impacts on biodiversity persistence worldwide. These two stressors are likely to interact, but how climate change will mediate the effects of land-cover change remains poorly understood. Scientists used empirically-derived model of the interaction

between habitat loss and climate to predict the implications of this for biodiversity loss and conservation priorities at a global scale. Risk analysis was used to estimate the risk of biodiversity loss due to alternative future land-cover change scenarios and to quantify how climate change mediates this risk. The results showed that climate change with land-cover change could increase the impact of land-cover change on birds and mammals by up to 43% and 24% respectively and alter the spatial distribution of threats. Ranking of global biodiversity hotspots by threat depends critically on the interaction between climate change and habitat loss. Scientists argued that global conservation efforts must take this into account if we are to develop cost-effective conservation policies and strategies under global change.⁸⁵

A research assessment (2016) calculated the implications of climate change for global river flood risk in various regions. Estimations were based on the flood frequency relationships at a grid resolution of $0.5 \times 0.5^\circ$, using a global hydrological model with climate scenarios derived from 21 climate models, together with projections of future population. The study used 4 indicators of the river flood hazards. Under one climate model, emissions and socioeconomic scenarios in 2050, the current 100-year flood would occur at least twice as frequently across 40 % of the globe, approximately 450 million flood-prone people and 430 thousand km^2 of flood-prone cropland would be exposed to a doubling of flood frequency, and global flood risk would increase by approximately 187 % over the risk in 2050 in the absence of climate change. The models showed a strong regional variability (most adverse impacts would be in Asia), and considerable variability between climate models.⁸⁶

One of the most urgent problem, concerning climate change and rising sea levels, are the inhabitants of atolls in the Pacific Ocean. Observations show global sea level is rising due to climate change, with the highest rates in the tropical Pacific Ocean where many of the world's low-lying atolls are located.. Research showed that that sea-level rise will result in larger waves and higher wave-driven water levels along atoll islands' shorelines than at present. Numerical model results revealed waves will synergistically interact with sea-level rise, causing twice as much land forecast to be flooded for a given value of sea-level rise than currently predicted by current models that

do not take wave-driven water levels into account. It appears that many atoll islands will be flooded annually, salinizing the limited freshwater resources and thus likely forcing inhabitants to abandon their islands in decades, not centuries, as previously thought.⁸⁷



Figure 13. Atolls (called also coral atoll, is a ring-shaped coral reef including a coral rim that encircles a lagoon partially or completely) are only found in the tropical and subtropical warm waters of the oceans and seas. Most of the world's great atolls are located in the Pacific Ocean, especially in the islands of Tuamotu, Caroline, Marshall, and the Coral Sea. Sea levels are rising, with the highest rates in the tropics, where thousands of low-lying coral atoll islands are located threatening populations living in the big atolls.

Studies investigated the impact of changes in temperature, precipitation, sea level, and coastal storms will likely increase the vulnerability of infrastructure (roads, bridges, etc) and coastal properties and urban drainage infrastructure. Recently a study investigated the problem of coastal areas and infrastructure in the USA. Researchers used 4 models that analyze vulnerability, and adverse impacts to roads, bridges, coastal properties, and urban drainage infrastructure in US cities. They investigated sensitivity to varying greenhouse gas emission scenarios, climate sensitivities, and global climate models. The results suggest that the impacts of climate change in this sector could be large, especially in the second half of the 21st century as sea-level rises, temperature increases, and precipitation patterns become more extreme and affect the sustainability of long-lived infrastructure.⁸⁸

The European coastline is especially vulnerable to flood risks due to climatic changes. Scientists estimated that rising extreme sea levels and continued socioeconomic development in coastal zones will lead to increasing

future flood risk along the European coastline. A group of researchers (2018) prepared a comprehensive analysis of future coastal flood risk for Europe that separates the impacts of global warming and socioeconomic development. In the absence of further investments in coastal adaptation, the present expected annual damage of €1.25 billion is projected to increase by two to three orders of magnitude by the end of the century, ranging between 93 and €961 billion. The current expected annual number of people in Europe exposed to coastal flooding of 102,000 is projected to reach 1.52–3.65 million by the end of the century (2100). Their models calculated that climate change is the main driver of the future rise in coastal flood losses, with the importance of coastward migration, urbanization and rising asset values rapidly declining with time. They argued that to keep future coastal flood losses constant relative to the size of the economy, flood defence structures need to be installed or reinforced to withstand increases in sea levels that range from 0.5m to 2.5 meters.⁸⁹



Figure 14. Europe's coastline stretches to more than 100,000km. Many of its coastal zones are highly populated and developed. The economic damage from coastal flooding in Europe could reach almost €1 trillion per year by 2100 without new investment in adaptation to climate change. Research observations showed that rising sea levels and continued socioeconomic development will affect future coastal flood risk in 24 European countries. Severe flooding in Venice (November 2019) has left much of the Italian city under water is a direct result of climate change, the mayor says. The highest water levels in the region in more than 50 years would leave "a permanent mark", Venice Mayor Luigi Brugnaro tweeted. Venice closed St Mark's Square as the city suffered a third major flooding in less than a week, while rain lashed the rest of Italy and warnings were issued in Florence and Pisa..

Trends and challenges in emerging renewable energy technologies

In the last decades there is a worldwide accelerating increase in installations and use of renewable energy sources. Statistical evidence in 2019 revealed a dramatic increase in sustainable renewable energy sources spreading worldwide in most countries, regions and energy enterprises.

The future of renewable energy sources depends on modern and safe storage facilities for balancing power supply and demand. Pairing a storage technologically advanced system with a renewable energy source ensures a smooth and steady power supply, even when weather conditions are not optimal for energy generation. Batteries are the most common storage devices used in renewable energy systems and their use is increasing on both the residential and grid-wide scale. Energy storage technologies are expected to continue to improve, making their use more viable and affordable. Lithium-ion batteries will likely be the dominant technology for the next five to 10 years, according to experts, and continuing improvements will result in batteries that can store 4-8 hours of energy – long enough, for example, to shift solar-generated power to the evening peak in demand.

Although scientists talk about exciting new innovations in renewable energy technologies, we can forget that a significant percentage of the world's population remains without access to energy at all. A billion people live without electricity and hundreds of millions have unreliable or prohibitively expensive energy sources. Achieving universal access to energy is a critical component of addressing global development challenges

The most important renewable energy trends and emerging technologies to watch in the coming years comprise of:

Hydropower. Hydropower is fueled by water and is a clean fuel source without pollution. In addition to a sustainable fuel source, hydropower installations produce a number of benefits, such as flood control, irrigation, and water supply. Hydropower facilities can quickly go from zero power to maximum output and can generate power to the grid immediately, providing essential back-up power during electricity outages or disruptions.

Geothermal energy, Geothermal energy is renewable and sustainable energy because once water or steam is used, it can be pumped back into the ground. Recent technological advancements (e.g. enhanced geothermal systems) have made more geothermal resources exploitable at lower costs.

Wind energy, Harvesting wind power is a clean, non-polluting way to generate electricity. Wind energy does not emit air pollutants or greenhouse gases. Major disadvantages of wind power is the initial cost. Many people are concerned with the visual effects that wind turbines have on the beautiful scenery of nature. Wind turbines may be dangerous to flying animals.

Solar energy, Solar panel positioning robots: Solar energy is radiant light and heat from the Sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic panels, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis. Solar panel positioning robots are small-scale robots able to re-position solar panels depending on weather conditions. More efficient than attaching each panel to motorized tracking assemblies.



Figure 15. Trackers direct solar panels or modules toward the sun. These devices change their orientation throughout the day to follow the sun's path to maximize energy capture. Single-axis **solar** trackers rotate on one axis moving back and forth in a single direction.

Offshore floating solar panels. Offshore floating solar panels have the potential to be the next frontier, but there are still challenges to overcome within the inland floating solar arena. China outshines Europe in 2017 clean power investment ranking. China is accounting for more than 50% of the world's new capacity on solar power. China as the nation with the largest carbon footprint, is also the largest producer and buyer of solar panels.



Figure 16. The most powerful floating solar PV plant in Europe was inaugurated in southern France (October 2019), marking another milestone in the development of solar energy. The O'MEGA1 project is a 17 megawatt (MW) solar plant situated in Piolenc, a commune in the Vaucluse department, near Orange and Avignon. The project is the largest in Europe based on floating solar technology. According to its promoters, the floating structure helps reduce conflicts over land use because it can be installed on drinking water reservoirs, industrial pools, flood plains or quarry lakes.

Concentrated solar photovoltaics. Concentrator photovoltaics (CPV) (also known as concentration photovoltaics) is a photovoltaic technology that generates electricity from sunlight. Unlike conventional photovoltaic systems, it uses lenses or curved mirrors to focus sunlight onto small, highly efficient, multi-junction (MJ) solar cells



Figure 17. Concentrated Photovoltaics (CPV) is been recognized as the technology which holds the greatest promise in meeting the energy challenges facing the world. But is has higher maintenance needs: High precision tracking of the sun (up to 0.1° angular precision) needs constant attention from dedicated personnel. Also, the washing of the panels can be harder due to the height of the trackers. Clouds degrade performance, .CPV can only work with direct sunlight.The CPV is usually aimed to be installed in a sunny location with over 80% of clear days per year.

Biomass energy, Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.

Examples of biomass and their uses for energy: Wood and wood processing wastes, Agricultural crops and waste materials—burned as a fuel or converted to liquid biofuels, Food, yard, and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills, Animal manure and human sewage—converted to biogas burned as a fuel

Biofuels, from first to third generation: The 3rd generation biofuels involve genetic modification of organisms to produce new fuels by unconventional means. Examples include direct production of hydrogen from highly efficient algae, and production of energy-dense furans for automotive use. Algal biomass has a very distinctive growth yield as compared with classical lignocellulosic biomass. Production of biofuels from algae usually relies on the lipid content of the microorganisms. Usually, species such as *Chlorella* are targeted because of their high lipid content and their high productivity. First-generation biofuels (derived from sources like starch, sugar, animal fats and vegetable oil, biogas, bioalcohols, syngas, etc)) are well implemented around the world, although they may come with certain restrictions such as energy consumption and utilization of arable lands, as well as the fuel versus food debate. Feedstock is getting increasingly expensive, leading to a growing interest toward second-generation biofuels. The 2nd generation is produced from a generally less expensive biomass such as forest, agricultural, animal, or municipal wastes. Numerous techniques are being investigated around the world for the production of energy. Third-generation biofuels are mostly related to algae, which are known to produce biomass faster and on reduced land surface as compared with lignocellulosic biomass, but production of algal biomass presents technical challenges such as lipid extraction and dewatering.⁹⁰

Marine energy, wave and tidal turbines: Among many of the current crop of 'cutting edge' renewable energy technologies, the concept of extracting energy from sea waves and tides is not a new one. What has

changed over the intervening years is the level of urgency and massive investment with which such projects are now being addressed and the technical achievements by some manufacturers which are making tidal and wave energy a reality. The United Kingdom (England, Wales and Scotland) has one the longest coastlines of any country in Europe, large tidal ranges and strong winds, it is perhaps obvious that as the home of one of the largest marine energy resources, the United Kingdom should also sport by far the largest concentration of marine power companies in the world. According to the IEA-OES, also known as the Implementing Agreement on Ocean Energy Systems which functions within a framework created by the International Energy Agency (IEA), by the end of 2008, more than 25 countries were involved in ocean renewable energy technology development activities. With the deployment of multi-unit wave technology in Portugal, and the commencement of construction of a 260 MW tidal power plant in South Korea standing out as noteworthy.[Renewable Energy World. Ocean energy development, 2019, <https://www.renewableenergyworld.com/2009/09/18/ocean-energy-developments/#gref>].

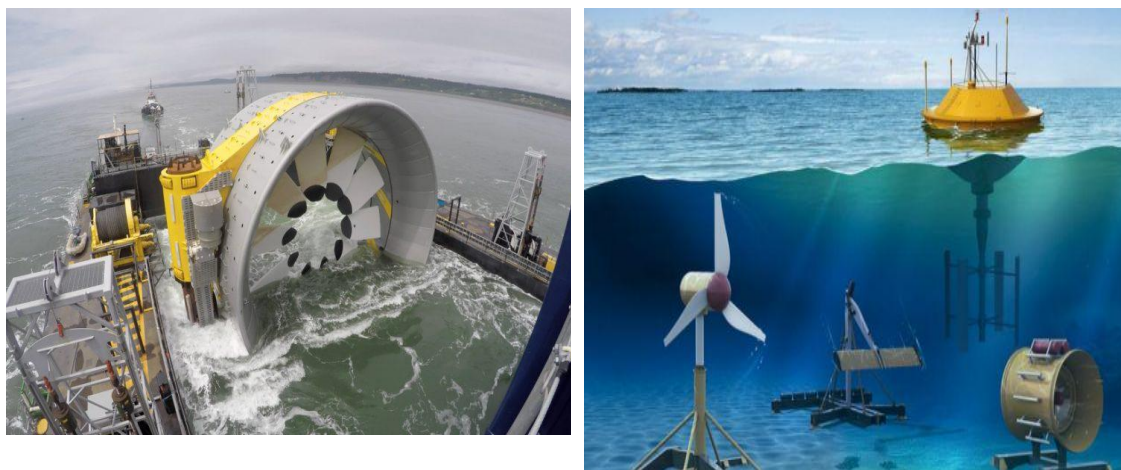


Figure 18. While the ocean energy sector is still at an early stage of development, there are more than ten future emerging technologies to generate energy from the ocean tides and waves. Wave and Tidal Energy Market is expected to grow substantially in the coming decades. In Europe a large variety of concepts have been developed for ocean energy conversion, with more than 200 different devices proposed. [EU Science Hub. New technologies in the ocean energy sector, 2018, <https://ec.europa.eu/jrc/en/news/new-technologies-ocean-energy-sector>].

Green hydrogen. Renewably produced hydrogen (H₂) is fast moving from the category "emerging" to "established" renewable energy source.. Green hydrogen produced from water electrolysis through the use of electricity from renewable energy sources (solar and wind power) is distinguished from grey hydrogen obtained from fossil fuels, thus non-renewable energy sources, such as natural gas. Hydrogen as an energy source is environmentally friendly, but unlike electricity, it can be easily stored and converted back to electricity or heat at later times. At least 10 countries are already jostling for leadership positions in what some see as the next big thing in energy. Green hydrogen contains up to 3 times more energy per unit mass than diesel, and 2½ times more than natural gas.

[International Renewable Energy Agency, IRENA, Hydrogen: a Renewable Energy Perspective. Report from the 2nd Hydrogen Energy Ministerial Meeting, Tokyo, Japan, Sept. 2019. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf].

Cellulosic ethanol. First generation biofuel ethanol is produced predominantly from sugar- and starch-based feedstocks for blending with gasoline. The US and Brazil are the largest fuel ethanol producers in the world (US produces fuel ethanol mainly from corn (maize) and Brazil produces fuel ethanol from sugarcane juice or molasses]. **Cellulosic ethanol**, is a second-generation biofuel that is manufactured by converting vegetation unsuitable for human consumption into ethyl alcohol (ethanol). Whereas first-generation biofuels use edible feedstock (corn or maize), cellulosic ethanol can be produced by using raw materials such as wood, grass, or nonedible plant parts. All biofuels are renewable, but cellulosic ethanol has a lesser impact on the food chain than first-generation biofuels.⁹¹

Microgrids with Artificial Intelligence (AI). Microgrids are local energy grids that can operate either autonomously or while connected to a larger traditional grid. Using the machine learning capabilities of Artificial Intelligence (AI) with microgrid controllers allows for continuous adaptation and improvement of operation]. The U.S. federal government is also investing in a so-called **smart grid** that employs digital technology to more efficiently manage energy resources. The smart grid project also will extend the reach of

the grid to access remote sources of renewable energy like geothermal power and wind farms.

Smart cities of the future need smart electricity distribution that adapt according to supply and demand. The increasing availability of renewable energy is effectively moving power generation closer to where it is needed, and this has led to the rise of microgrids: small-scale power grids that operate independently or in conjunction with an area's main electrical grid. Microgrids typically have their own power resources, generation, metering and loads, as well as definable boundaries that essentially make them small-scale localized stations that are separate from, yet interconnected with, the main electrical grid. Smart cities apply the most advanced technological developments to enhance existing services, including cloud computing, Internet of Things (IoT), smart grid, edge computing and smart systems. Implementing microgrids in smart city processes through renewables, efficient generation, smart metering and optimal loads augments the capabilities of the platform with minimal additional costs. Microgrids facilitate numerous key operations, such as resiliency, distributed generation, efficient use of resources and dependability, all of which ultimately shape the future of electricity usage and trading.⁹²

Emerging chemical pollutants in the last decades

In the last decades monitoring in air, water, sediment and soil detected a large number of emerging chemical pollutants in high concentrations. These chemical pollutants are synthetic or naturally occurring chemicals that have the potential to enter the environment and cause specific ecological damage and adverse human health effects. The catalogue is very extensive but the most important are pesticide residues, fertilizers, cosmetics and personal care products, industrial waste chemicals, surfactants, disinfectants, additives perfluorinated compounds, and cleaning products. Analytical studies have detected water pollutants with endocrine-disrupting properties, analgesics, antibiotics, hormones, veterinary medicines, and a whole range of other pharmaceutical compounds including antiinflammatory, antidiabetic, and antiepileptic drugs. Also, plastics, microplastics and nanoplastic materials

have been found in all aquatic sources and in particular in the open sea and oceans.⁹³⁻⁹⁵

With advances in analytical techniques, such as high-performance liquid-chromatography-mass spectrometry (HPLC–MS), liquid chromatography-mass spectrometry tandem mass spectrometry (LC–MS/MS), a wide array of previously undetected chemical compounds in a complex environmental matrix have been identified and quantified at low microgram (μg) or nanogram (ng)-per-litre (l^{-1}) concentration. These substances have collectively been called chemical pollutants or contaminants of emerging concern and have attracted significant research interest among the major international organisations such as World Health Organization (WHO), United States Environmental Protection Agency (EPA) and the European Environment Agency (Copenhagen) and aother EU agencies. Some previously used, harmful chemicals such as polychlorinated biphenyls (PCBs), dichlorodiphenyl, DDT, trichloroethane, chlordane, chloroform, carbon tetrachloride, and other polychlorinated pesticides, have being phased out of circulation.⁹⁶⁻¹⁰⁰

Despite the Stockholm Convention known as the Persistent Organic Pollutants Treaty of 2001 and the Berlaymont Declaration of 2013 to protect humans and aquatic species from risks associated with exposure to these chemical pollutants/contaminants, the number of synthetic chemicals in the environmental is on the increase.

Conclusions

Environmental issues and emerging global challenges in the 21st Century have changed dramatically in the last years. Humankind has witnessed urgent pressures from the climatic changes and environmental pollution challenges by emerging pollutants. There is overwhelming evidence in the last decades that anthropogenic activities drive global environmental change in what has been come to be called the ‘Anthropocene’ Era. Modern human societies have engaged in increasingly disruptive modes (increasing non-renewable energy use, consumption and waste of food, increasing exploitation of natural resources). Overpopulation and urbanization caused immense changes in the

water cycle, imbalances and degradation in the marine and terrestrial ecosystems, acidification of the oceans and degradation of forested area. Despite the increasing numbers of international treaties, national and international regulations to reduce air pollution and water contamination by toxic and hazardous chemicals, a high proportion of pollutants are still discharged in air, sediment, rivers, lakes and open seas, oceans. The majority of scientists and environmental state agencies understand now that chemical pollution needs to be dramatically reduced because it is destroying the environment, contaminate food and water, causing diseases in humans and wildlife. Protecting the environment is a long and daunting task, requiring continuous planning, governmental policies, and public and industrial participation.

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