# Keynote

# Sustainable energy development status (2020) with key lessons from the pandemic

***Noam Lior***

*University of Pennsylvania, Philadelphia, PA, USA,* *lior@seas.upenn.edu*

**Abstract:**

This invited keynote paper is the most recent among energy reviews in the sustainability (economic, environmental and social impacts) framework published by the author, updated to year 2020 and is augmented by discussions on the effects of the Covid-19 pandemic on sustainable energy development, emphasizing reminder of the need for integrating and employing resilience planning and analysis with sustainable development, and by identifying some of the currently main game-changing developments, as well as introducing some of the planning status for countering the energy-related pandemic impacts in the extremely dynamic and transient energy field. This dynamic transience often results in significant consequences for humanity and can seldom be foreseen or recognized early enough to allow timely correctional reactions. A brief description of the recent estimates and forecasts of the energy resources, uses and the dizzy, and hence ruinous, volatility of their prices is presented. Some of the main ongoing and high probability energy game-changers discussed are:

1. Proof of the mandatory need for multi-generational global sustainability and resilience planning and implementation
2. Ultimatum for lowering the critical global warming temperature limit by 25% (to a maximal increase of 1.5°C)
3. Postponement of “Peak Oil”
4. Significantly increasing use of unconventional fossil fuels: shale and tight gas and oil
5. Ruinous effects of strong fluctuations (≤ 1:7) of fuel prices,
6. Decoupling of energy consumption from economic growth
7. Criticality of the future of coal
8. The nuclear disaster in Japan and nuclear power future
9. Transition to energy independence of the USA
10. Market entry impact of electric cars
11. Criticality of the transition to renewable energy use
12. Worrisome portents of critical policy changes
13. Accelerated entry of the sharing energy economy
14. Important increase of support by organized religion for sustainable development.

**Keywords:**

Energy, Sustainability, Resilience, Energy game-changers, Covid pandemic.

# 1. Introduction

This invited keynote paper is the most recent among energy reviews in the sustainability (economic, environmental, and social impacts) framework published by the author, updated to year 2020. It is augmented by discussions on the effects of the COVID-19 pandemic on sustainable energy development, emphasizing a reminder of the need for integrating and employing resilience planning and analysis with sustainable development.

Section 2 contains an abridged revew of the current global energy status, Section 3 contains brief decription of the current effects of the COVID-19 pandemic on sustainable energy development, Section 4 presents the author’s view of of the current main energy game-changers, and Section 5 describes some proposed immediate and general sustainable and resilient energy paths to the future.

Some of the basic references include the latest (2020) energy statistics annual report of British Petroleum (BP) [1], the USDOE Energy Information Administration (EIA) [2], the International Energy Agency (IEA) [3], and REN21 [4]. The analysis, interpretation, and comments are entirely the author's and do not represent any institutional or government views. Reviews of similar nature were published by the author in 2002 [5], 2006 [6], 2008 [7], 2010 [8], and 2011 [9,10], to keep updating the information about this very dynamic field.

The information about COVID-19 and its related energy, economic, and environmental impacts changes continuously, and the data in this paper are for the beginning of July 2020.

## 2. Selected energy data for 2020 (mostly from [1-4], till the end of 2019)

While the COVID crisis has unprecedently severe global impact in many aspects, and reduced energy use, especially for transportation, the near-past energy trends did not change much. Primary energy consumption growth slowed to 1.3% last year, less than half the rate of growth in 2018 (2.8%). That increase was driven by renewables and natural gas (its share rose to a record high of 24.2%), and all fuels use, apart from nuclear, grew at a slower rate than their 10-year averages. China was by far the biggest driver of energy, accounting for more than three quarters of net global growth, followed by India and Indonesia.

Renewable energy, especially electricity, had another record-breaking year in 2019, as installed power capacity grew more than 200 GW (mostly solar PV) – its largest increase ever, but less than the global increases in final energy demand. Net additions of renewable power generation capacity strongly outpaced net installations of fossil fuel and nuclear power capacity, combined.

By the end of 2019, installed renewable energy provide an estimated 27.3% of global electricity generation.

Investment in all new renewable power capacity again far exceeded investment in coal, natural gas and nuclear power capacity in 2019, continuing to focus on wind and solar power, with wind outweighing solar PV for the first time since 2010.

While coal consumption fell for the fourth time in the past six years, with its global share falling to its lowest level for 16 years, it still remained the largest source of power generation, accounting for over 36% of global power. Investment in new coal-fired power plants, continued worldwide, and funding for fossil fuel projects from private banks has increased each year since the signing of the Paris Agreement in 2015, totaling \$2.7 trillion between 2016 and 2019. Energy-related $CO_2$ emissions remained stable in 2019, mostly due to improvements in energy efficiency, rising share of renewable energy, and to fuel switching from coal to gas. This stabilization is welcome, but especially when noting that the average annual growth in carbon emissions over 2018 and 2019 was greater than its 10-year average, is, however, starkly insufficient for limiting global warming to the critical value of 1.5 °C recommended by the UN for avoiding the climate change catastrophe.

The dizzy out-of-control fuel price fluctuations, ruinous to sustainable development, are worsening significantly (Fig. 1), but momentarily somewhat justified by the consequences of the pandemic.

Oil prices (Brent) dropped up to 3-fold (from about \$40/b to \$11/b!), each month of full lockdown reduced electricity demand by 20%, global electricity demand decreased 2.5% in the first quarter of 2020, and demand for coal and oil fell by 8% and 5%, respectively. Natural gas price dropped in all hubs, and stayed lowest, down to \$1.69/millionBtu, at the Henry Hub (US) [1,2].

It is very noteworthy that many of the "unconventional" oil and gas sources, such as tight and shale oil and shale gas, which are the main sources of the U.S. fuel, may become unprofitable to the owners once their prices drop to such low levels.

Renewables were the only source of electricity to record demand growth over this period, due to low operating costs and preferential access to electricity networks.

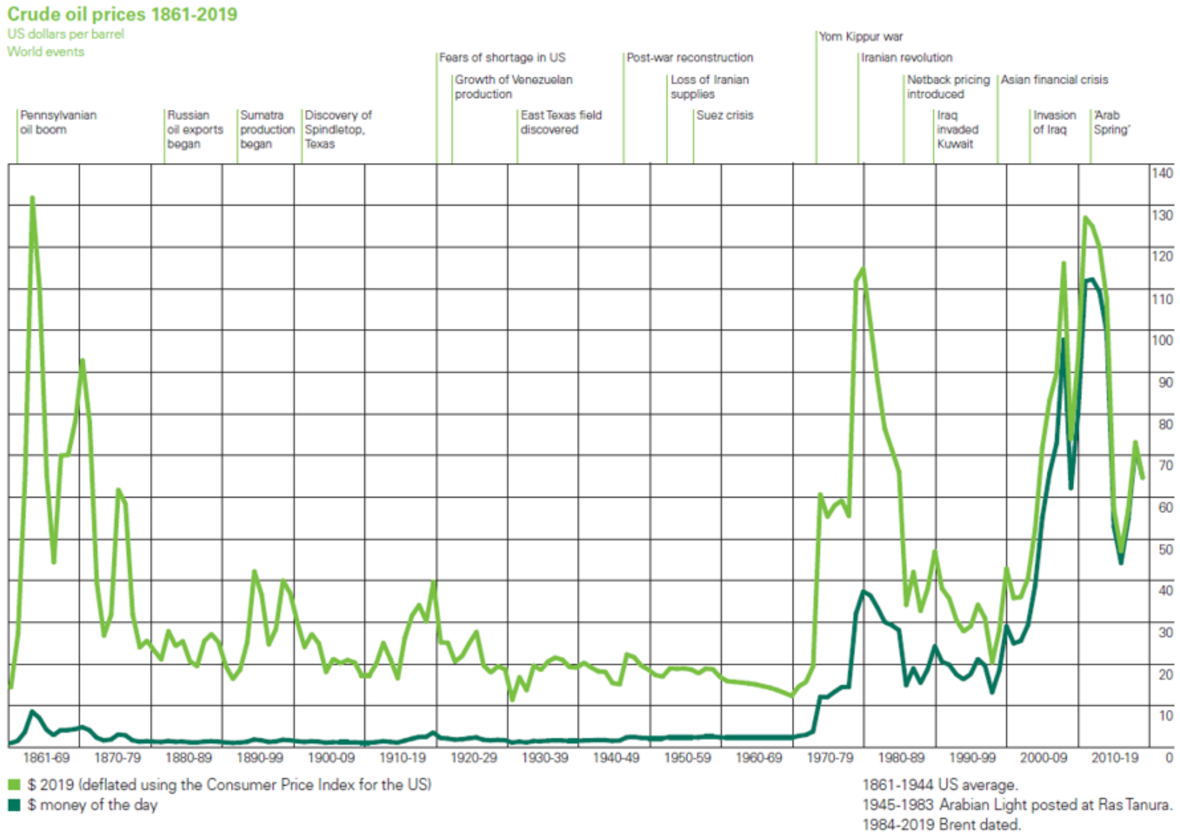


*Fig. 1 Crude oil prices 1861-2019 [1]*

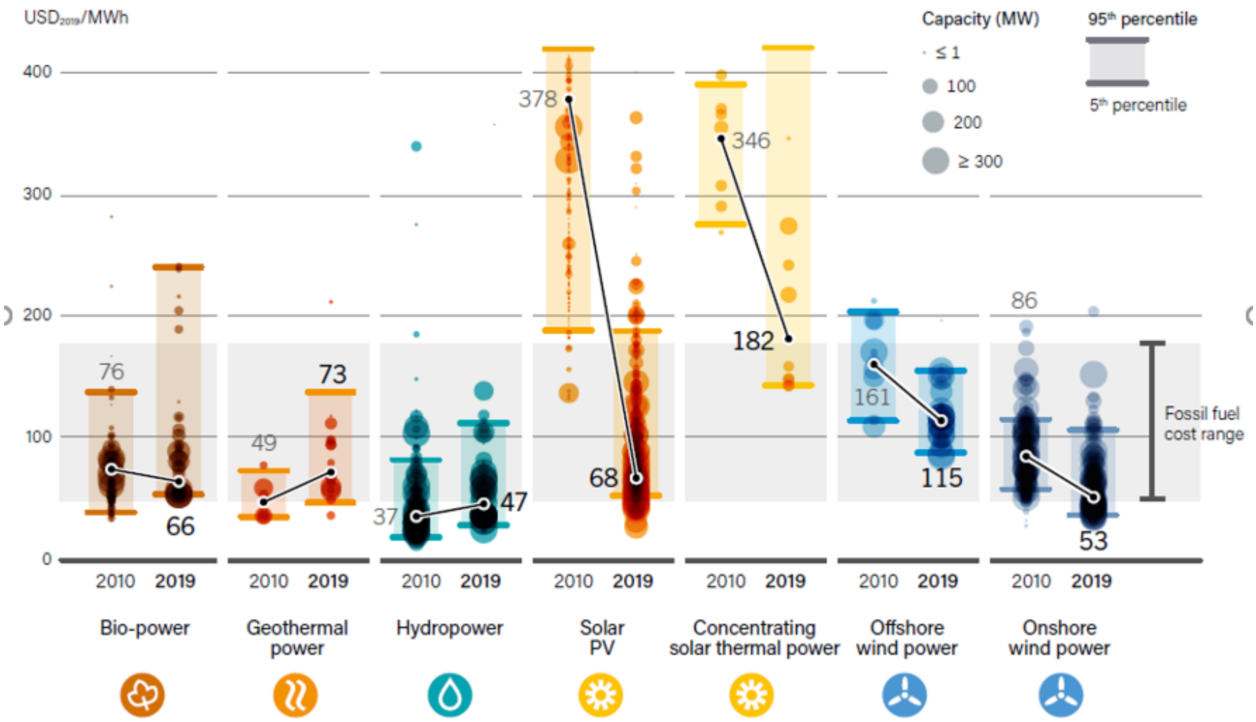


*Fig.2 Global levelized cost of electricity from newly-commissioned, utility-scale renewable power generation technologies, 2010 and 2019 [4]*

It is encouraging that electricity networks in major markets were able to accommodate huge changes in the energy mix as of mid-2020, and that renewable electricity prices continue to drop, and, as shown in Fig. 2, are competitive with those of fossil and nuclear generation using all renewable resources except solar.

It is noteworthy that the fossil fuels Reserves/Production ratio ($R/P$) remains nearly steady for 3 decades, at the values of about $50, 49.8 and 132 for oil, gas and coal, respectively.

## 3. The pandemic as the best demonstration of the vital need for resilient sustainability

Defining sustainability in a qualitative way as the ability to meet the current needs without destroying the ability of future generations to meet theirs, by applying its balanced environmental, economic, and social pillars is well-known, reasonably quantified and rather widely applied by many authors in analysis and planning (e.g., [11-13]). The need for multi-generational global planning is part of the definition, but often ignored, as evidenced by the fact that only a few countries have sustainability planning beyond a few years at a time (e.g., Holland, Germany, Norway), and there is no such obligatory global planning, nor even effective voluntary coordination, among most countries. The existing short-term planning is usually a victim to time-varying immediate needs and politics, and is thus disabled from preparing for unforeseen needs and emergencies, whether they be major environmental events, major social upheavals, wars small or large, pandemics, climate change, and such.

***Resilience*** of a system is its *ability to prepare for threats, survive after absorbing impacts, recover and adapt quickly following persistent stress or disruptive events, and thrive under disorganized change and uncertainty; toughness.* It is well recognized and even quantified as an important attribute, if not often- or well-enough implemented in planning at any scale, and there is much scholarly debate on whether resilience is part of *sustainability* or whether it should be treated separately [14-17]. While the debate contributes to knowledge and methodology, it is fundamentally obvious that only resilient systems will "have the ability to meet the current needs without destroying the ability of future generations to meet theirs" (i.e., be sustainable by definition), and, in turn, systems designed to be sustainable based on the three pillars usually contribute to their resilience. One way or another, resilience planning must be tightly integrated with sustainable development, and such combined analysis can be accomplished by proper and careful choice of indicators, weights, and their correlation coefficients.

It took the unexpected and sudden ongoing COVID-19 pandemic to unequivocally and bluntly demonstrate how tragically unprepared the world, including its wealthiest and most scientifically-advanced countries, was in all respects, from toilet paper shortages to inadequate ability and knowledge to anticipate the viral breakout, to treat the infected, and provide vaccines. We did not invest in even nearly-adequate multi-generational sustainable and resilient development and the penalty is so high that it might become intolerable; globally so far (12 July 2020), due to the pandemic nearly 13 million people were infected and 600,000 died, 300 million became unemployed, governments' economic stimuli alone amounted to $9 trillion, the global economy estimated to shrink by 6% in 2020, and global energy investment foreseen to shrink by an unparalleled 20% in 2020.

While it seems very likely that humankind would eventually survive the COVID-19 pandemic and continue its progress, it may not be the last catastrophe, especially when considering the steadily nearing critical climate change, which is predicted to cause much more harm than this pandemic. Effective global cooperation, development of and reliance on science and effective technology including scientific development of sustainability with resilience, fostering and education of human kindness, and election of competent compassionate leaders, must be our immediate priority.

## 4. Some recent and lasting key game-changers

GC1. Proof of the mandatory need for multi-generational global sustainability and resilience planning and implementation
GC2. Ultimatum for lowering the critical global warming temperature limit by 25% (to a maximal increase of 1.5°C)
GC3. Postponement of "Peak Oil"
GC4. Significantly increasing use of unconventional fossil fuels
GC5. Ruinous effects of strong fluctuations (≤ 1:7) of fuel prices
GC6. Decoupling of energy consumption from economic growth
GC7. Criticality of the future of coal
GC8. The nuclear disaster in Japan and nuclear power future
GC9. Transition to energy independence of the USA
GC10. Market entry impact of electric cars
GC11. Criticality of the transition to renewable energy use
GC12. Worrisome portents of critical policy changes and use of "alternative facts"
GC13. Accelerated entry of the sharing energy economy
GC14. Important increase of support by organized religion for sustainable development.

**GC1: Proof of the mandatory need for multi-generational global sustainability and resilience planning and implementation**

The ongoing COVID-19 pandemic is the best uncontroversial evidence demonstration of the vital need for resilient sustainability, providing a unique opportunity for drawing optimal fact- and science-based conclusions from it, and for implementing them urgently. Further details are presented in Section 3 of this paper.

**GC2: Ultimatum for lowering the critical global warming temperature limit by 25% (to a maximal increase of 1.5°C)** [18]

The Paris Agreement (2016) was to keep global temperature rise this century to "well below two degrees Celsius above pre-industrial levels", which was deemed to avoid global catastrophe.

The IPCC 2018 report was created as a response to this, seeking to understand the impact of 1.5°C warming compared to 2°C, and it is an ominous wake-up call. It finds that based on ongoing developments such catastrophes are likely to take place already at 1.5°C. There is a high degree of confidence that global warming is likely to reach 1.5°C between 2030-52 if it continues to increase at the current rate. Predicted rapid, far-reaching and unprecedented changes make it clear that it is vital to limit global warming to 1.5°C, and a list of pathways to that objective are presented, all of them drastic. It is highlighted by the statement "The next few years are probably the most important in our history." A global response is developing much too slowly, and stymied by some "sceptic" governments, such as those of the US and the Russian Federation.

**GC3: Postponement or "Peak Oil".**

In the 1970-s and 1980-s it was widely believed that fossil fuels, especially oil, will become depleted beyond availability for their current uses within perhaps 50 years. It is now clear that "Peak oil" was significantly postponed, perhaps till the end of this century, because the last decade experienced discoveries of large amounts of fossil fuels and of developments in their economical exploitation technology, that include to some extent additional already exploitable conventional oil, gas, and coal, but to large extent "unconventional" fuels including tar (oil) sands, "extra heavy" crude oil, coal bed natural gas (CBNG), "Tight Gas", and more recently shale gas and oil, as well as large (but also very difficult) resources of methane hydrates. The quantities of these "unconventional" hydrocarbons are estimated to be significantly larger than those of the conventional ones. It must be noted, however, that the "unconventional" hydrocarbon resources pose significantly higher negative environmental impacts than the conventional ones. Furthermore, accelerated use of renewable energy and conservation measures are reducing the demand for fossil fuels.

It is noteworthy that the fossil fuels Reserves/Production ratio (*R*/*P*) remained nearly steady for **3** decades, at the values of about 50, 49.8 and 132 for oil, gas and coal, respectively [1]. At this moment in earth history we are running out of environment much faster than out of reasonably usable energy resources.

**GC4: Significantly increasing use of unconventional fossil fuels: shale and tight gas and oil.**

The above mentioned "unconventional" hydrocarbon resources can compete with conventional ones if their price is lower, for example currently they cease to be competitive if conventional oil price is lower than $30-40/b, which the case became recently. At the same time, advanced extraction and treatment technology can lower their price. They also pose significantly higher harmful environmental impacts than the conventional ones, and typically not only do not reduce global greenhouse gas emissions via fuel substitution, but even increase them. These problems may be alleviated with proper technology but the product cost is then likely to be higher, and governmental regulation must be properly formulated and enforced prior to commercial exploitation and use.

**GC5: Ruinous effects of strong fluctuations of fuel prices.**

Energy planning, especially planning for sustainable development, suffer ruinously from the unpredictability and presently uncontrollability of fuel prices, accompanied by their extreme fluctuations of magnitude and also of abruptness (Fig. 1). These often appear to be largely unrelated to either supply-and-demand forces or to the actual cost of the fuel. The fluctuations are increasingly understood to be significantly controlled by speculation inherent in the world "free" market system, which, in addition, also often gives undue significance to oil as a fuel because it indexes prices of other fuels to that of oil even when they do not compete for the same customers. An example of that is linking gas price to that of oil in the Asian-Pacific markets even though oil is principally used for transportation fuels while gas serves completely different customers such as those engaged in power generation and heating.

Both such price rises and drops severely impair planning, disable competition, affect conservation, and create significant impacts on tax revenues to municipalities, states and countries.

Since energy is a commodity of vital importance, its prices and supply need (regrettably) much more regulatory protection than most other commodities.

**GC6: Decoupling between energy consumption and economic growth.**

It was a common belief by economists and politicians that economic growth (measured by GDP) needs similar growth in energy consumption, but this is increasingly found to apply only to poorest countries, so it is neither true, nor is the use of GDP an appropriate general measure for economic growth or overall quality of life. This belief is obviously extremely damaging to sustainable development because it assigns major weight to the GDP at the expense of the environmental and social pillars, which are often are assigned zero weight. Decoupling between energy consumption and economic growth and $CO_2$ emissions are due to reduced energy intensity and increased use of lower-emissions energy sources. The main drivers for this decoupling are market forces, technology cost reductions, and concerns about climate change and pollution. It is extremely helpful to sustainable development when such decoupling occurs, as it did during several recent years (2006-2016, but not in 2017) in many countries [1]. $CO_2$ emissions are also often decoupling from economic growth both due to reduced energy intensity and increased use of lower-emissions energy sources [1].

**GC7: Criticality of the future of coal.**

Compared with fluid fossil fuels, coal has important disadvantages including its mining, preparation, transportation, use, and all its species and quantities of specific emissions, but on the other hand comprises about 27% of the globally used primary energy, has a global R/P > 130 and serves as a major supply of energy to countries that have inadequate or unaffordable other energy resources. Important examples are China and India that currently have 36% of the world population and use coal for 60-70% of their total energy demand [1]. Most of the deficiencies of coal as fuel can be resolved by proper management, regulation, and existing technology, estimated to raise the price of coal-generated electricity by 50% at most. This increase includes the estimated costs for $CO_2$ capture and sequestration, and the primary obstacle is that the technology for acceptable and safe sequestration is still unavailable. "Clean coal" should be a major objective of governments, industry, and society in general. It needs to be a relatively inexpensive and relatively harmless, abundantly available, source of energy, noting also that the processes for its realization would create a huge market for the "cleaning" equipment developers and manufacturers.

**GC8: The nuclear disaster in Japan and nuclear power future.**
The still-contaminating 2011 Fukushima disaster has largely contributed to discouraging further major global reliance on nuclear power, and it may be necessary to wait till a new generation of proven nuclear reactors is available, which can withstand extreme natural upheavals, produce only safe-level short-term manageable radioactive waste (using transmutation?), are proliferation proof, and, practically incredibly, at the same time also produce electricity at a competitive price when considering all externalities and the advancements in the power generation competition using gas and renewables. Japan's government is increasing the R&D funds for renewables, energy efficiency and fossil fuel power, and reducing those for nuclear.

**GC9: Transition of the USA to energy independence.**
From around 2006 the US oil imports started dropping significantly [4], in small part because of lower consumption but mostly because of increased domestic production, especially from tight/shale oil. Furthermore, the main imports increasingly came from the nearby countries, such as Canada, Mexico, and Venezuela, reducing political complexities and transportation costs, as well as trade deficits. In 2018 it passed (but not necessarily permanently) both Saudi Arabia and Russia to become the worlds' largest oil producer for the first time since 1975, and is no longer the world's largest oil importer. The associated economic benefits are probably surpassed by the benefits of much higher energy security and much less need for political or other interventions needed to secure necessary energy imports.

**GC10: Accelerated market entry of electric cars** [1-4, 19]**.**
Plug-in electric vehicles (PEVs) are a very attractive option relative to conventional ones for many reasons, including usually high overall energy efficiency, no local emissions and typically reduced ones overall, reduced dependence on oil imports, lifecycle GHG emission reduction by at least 30% (for the current European electricity generation mix), quietness, low operating cost and maintenance, and their high acceleration ("Insane" and "Ludicrous"…). The electricity for charging the batteries can be generated by any type of power plants (fossil and nuclear fuelled, and by renewable energies), the batteries energy density, price, and charging infrastructure are improving rapidly. The extent of market capture will also depend on (1) the extent to which any PEV advantages, primarily emissions but also low noise, will be monetized, and (2) an adequate infrastructure for battery charging and/or swapping, and for service.
PEV economic success would rise if smartly integrated with the electric grid, by realizing their large electricity storage potential for utilities when used in a "vehicle-to-grid" (V2G) mode in which PEVs charged during off-peak hours can then dispatch some electricity back to the grid during peak load, thus reducing the need for operating the utilities' expensive peaking systems and reducing the need for capital investment to meet an increasing electric load growth, and consequently potentially reducing electric rates to participating customers.
There globally are at least 5.3 million electric 4+wheelers including 300,000 (and growing fast) municipal buses (mostly in China). Most major vehicle manufacturers, and new ones focusing just

on PEV, are offering or planning to offer a PEV for sale soon. There is also huge growth in the number of electric 2-3 wheelers, with more than 12 million in use [19].

**GC11: Criticality of the transition to renewable energy use.**
Renewable energy is well recognized by society, many governments are renewables-supportive, and the last decade has witnessed an exponential growth of its use at a rate higher than of any other energy source. So far it is used to supply only about 15% (including hydro) of the world primary energy, and to attain a much higher contribution it must attain and maintain price parity advantage relative to conventional sources of energy; which is a function of technological advancement, favorable government intervention via monetization of avoided emissions and all externalities, and subsidies, both extremely sensitive to ever-erratic local and world politics,
Currently foreboding potential game changers in the progress of renewable energy are new islands of skepticism (e.g., the current US administration) about the anthropogenic origins of global warming as well as of the enormity of the consequences of its other violations of the environment, subtle (but real) opposition by part of the fossil fuel industry and by all greedy developers, and recent abundance of cheap natural gas and oil from shales. This abundance is especially in North America, but huge reserves, yet unused, were found in many parts of the world.
Subsidies to renewable energy, estimated at about $200 billion so far, often criticized by opponents, are rather transparent, yet those to fossil fuel and nuclear tend to be obfuscated. IMF estimated that global fossil fuel subsidies in 2015 were $5.3 trillion and the elimination of "subsidies would have reduced global carbon emissions in 2013 by 21% and fossil fuel air pollution deaths 55%, while raising revenue of 4%, and social welfare by 2.2%, of global GDP" [3]. REN21 [4] estimated in 2019 that global subsidies for fossil fuel consumption reached $300 billion in 2017, IEA [3] stated the elimination of fossil fuel subsidies worldwide would be one of the most effective ways for reducing greenhouse gases, G7 nations set a 2025 deadline for ending most fossil fuel subsidies, and OECD stated that subsidies supporting fossil fuels represent greater threats to the environment than subsidies to renewable energy. Subsidies to nuclear power [3] contribute to shifting untold future risks, perhaps for generations, away from investors to taxpayers and ratepayers, including a million years (?) nuclear waste management one. Another type of subsidy is given by often not taxing "windfall profits", which periodically occur when fuel suppliers make huge profits due to large fluctuations in the prices. Decision on subsidies should consider national and global sustainable development, and appropriate support for sustainable renewable energy development and use should not be at risk.

**GC12: Worrisome portents of critical policy changes.**
The world was gradually unifying in recognizing the need for sustainability, (e,g., Montreal Protocol, COP 21), and increased efforts are made by China and India to relieve their severe environmental problems, but recent political changes in some countries' administrations, including the U.S., were at least partially created by revival and strengthening of scientifically-unfounded scepticism about anthropogenic effects on the environment, and sometime better founded statements that they are over-regulated in environmental protection, at the expense of their economy and employment. Sustainable development indeed requires additional investment and thus diversion of some resources from often-stressed national budgets, as well as recognition of the fundamental need for effective global cooperation, and thus vitally depends on national policy. These political changes have reflected themselves indeed in administrative actions that threaten the prospects for global sustainable development. The most outstanding examples of these recent changes is the new US and Brazil administrations, and possibly BREXIT that may weaken the outstanding efforts of the EU towards sustainable national and global development.

On June 1, 2017 President Trump announced that the U.S. would cease all participation in the 2015 Paris Agreement on climate change mitigation (leaving the US as the only country that is no longer a signatory); a majority of the US public and many businesses oppose this, and the United States Climate Alliance (currently governors of 24 states and Puerto Rico) [20] was formed against this cessation.

By 10 July 2020 the Trump administration applied to introduce about 100 rules, most of them directly to reverse (roll back) environmental protection aspects, and the others new ones for the same purpose [21].
All of the annual DOE budget proposals by this administration include a cut of about 50% in some of the main R&D topics of the civilian USDOE budget, and leave the energy science budget nearly unchanged [22].
For comparison, the reported policy of China is now focusing increasingly on the environmental and sustainability aspects rather successfully, showing that all related energy and environmental improvement goals for the 12th 5-year plan (2010-2015) have been exceeded, and further improvement goals were included in the 13th 5-year plan (2016-2020*)* [23].
As to BREXIT, after several years of arguments, it was approved by the UK, starting on 31 January 2020 the process of withdrawal from the EU. The preceding discussions and public reviews indicated that it is likely to have negative effects on global and local sustainable development, and on UK's leadership role in these issues. It revealed a deep division between inward- and outward-facing worldviews, counter to the need for international collaboration that recognizes the interconnected and increasingly interdependent world. Significantly, the Brexit discussions seem to have had very insufficient emphasis on sustainability.
The UK's close involvement and cooperation would still be very important for the sustainable development of the EU, and indeed the world.

**GC13: Accelerated entry of the sharing energy economy.**
The energy field is increasingly affected by the advent of various forms of shared markets, which are modern descendants of millennia-old cooperatives for agricultural and generally commercial buying, selling, and bartering, which made it possible for many small units to have higher control of their economy, higher profits, and also effectively compete with large traders and land-owners, including governing states. Examples of some of the largest most recognized sharing services are Airbnb, TaskRabbit, Uber, Lyft, Zip-car, Waze, EBay, Poshmark, Freecycle, and even Wikipedia; Some are direct 2-way sharing, and others just facilitating the commerce. Benefiting from systems or goods that are not used much, by sharing rather than owning them, is considered to be a good path to sustainability (on all economic, social and environmental pillars); e.g., considering transience of energy supply and demand, a properly designed solar energy system is very likely to have a higher capacity factor and lower specific cost when shared. The increased introduction and rapid growth of such activities are a consequence of having the internet, allowing expanded and facilitated electronic networking. With the rising emergence of renewable energy generation and the deregulation of the electricity market, SE becomes a part of the electricity market [24], e.g., there are at least 1,000 energy sharing cooperatives in the US alone.
One of the SE expositions is in the "Peer-to-Peer" (P2P) economy, which is a decentralized model whereby two individuals interact to buy or sell goods and services (here electricity) directly with each other, without intermediation by a third-party, or without the use of a company of business. P2P electricity trading is expected to contribute to expanding small-scale distributed resources and creating new markets: the main advantages are that the energy they generate on their own can generate profit instead of discarding it; the power generation can be made to meet the requirements of the end-users; and the utilization of the resources can be optimized through the cooperative network between producers and consumers. The significant and rising interest in P2P electricity trading is also evidenced in part by related European Commission legislation and very encouraging economic and technology assessments, which predict that adoption of new "grid-edge" technologies in OECD countries could bring more than $2.4 trillion of value creation for society and the industry over the next 10 years, and improved electric generation and use efficiency. It also identified major related challenges facing the electricity sector, including the need to develop proper regulation.
A survey of the existing literature and assessment of the sharing electricity concept generally concludes that it is not only synergistic to sustainability and human well-being, but that SE offers an important and socially favourable improvement of the path to sustainable development. Since sharing

electricity is a very important aspect of electric markets, which is bound to increase in importance, a commensurate increase in well-focused research, both theoretical and empirical, by all stakeholders, is needed urgently

**GC14: Important increase of support by organized religion for sustainable development.**
The increasing support for sustainable development by religious organizations as exemplified explicitly by Pope Francis' 18 June 2015 Encyclical on climate and other ecological change *Laudato Si' (Praise be to you) On the Care of our home*, addressed to the whole world, and by Ecumenical Patriarch Bartholomew I, renowned for his significant faith-linked contributions to preserving the environment, who has on 1 September 2017 joined Pope Francis in issuing a joint declaration from the Vatican and from the Phanar *"On the world day of prayer for creation*", that includes their joint similar sentiments, such as "*…The human environment and the natural environment are deteriorating together… The impact of climate change affects, first and foremost, those who live in poverty in every corner of the globe…We are convinced that there can be no sincere and enduring resolution to the challenge of the ecological crisis and climate change unless the response is concerted and collective, unless the responsibility is shared and accountable, unless we give priority to solidarity and service"*
The declarations have shaken religions' common indifference that was so far largely guided by decreed human unrestrained exploitation of nature (e.g., Genesis 1;26,28,29,31).
This support extends well beyond that by the about 1.5 billion Catholics and Orthodox Christians, and is creating hope that many more religions, as well as the nonreligious, will unite in their active support for sustainable development.

## 5. Some immediate and general sustainable and resilient energy paths to the future

Obviously, of most immediate interest and need at this time is to plan sustainable paths with focus on the pandemic, so this section of the paper starts with that objective in mind, and then continues with comments/suggestions about main sustainable paths in general.

Considering the enormous global damage that the pandemic is wreaking even just in the last few months, causing so far infection of nearly 13 million people, 600,000 deaths, 300 million unemployeds, governments' economic stimuli spending of $9 trillion, (primarily for emergency financial and economic relief to prevent an even deeper crisis), as well as huge private spending, with the global economy estimated to shrink by 6% in 2020, and global energy investment expected to shrink by an unparalleled 20% in 2020, and not abating, it is obvious that enormous and inestimable further investments would be needed.

Wise and creative planning could diminish the associated global damage by using the needed investments and efforts as an opportunity to also restructure and modernize the energy economy and its environmental drivers of climate change, by channelling some of the money to create more efficient and less polluting systems and activities, and reduce wastes. The IEA has recently developed and published such a *Sustainable Recovery Plan* [25] for joint government-private actions that can be deployed over the next three years in six key sectors – electricity, transport, industry, buildings, fuels and emerging low-carbon technologies, proposed to cost 1$ trillion per year. These sectors are planned to be focused on (1) accelerating the deployment of low-carbon electricity sources and expansion and modernization of electricity grids; (2) cleaner transport such as more efficient and electric vehicles, and high-speed rail; (3) improving the energy efficiency of buildings and appliances; (4) enhancing the industrial efficiency; (5) making the production and use of fuels more sustainable; and (6) boosting innovation in crucial technology areas including hydrogen, batteries, carbon capture utilization and storage, and small modular nuclear reactors.

It is expected by IEA that this plan would create nearly 9 million new energy related jobs in construction and manufacturing over the next three years, increase global GDP by 1.1% in each of them, boost energy resilience and sustainability, and contribute significantly to the prevention of global warming,
This plan is a very timely largely sensible framework in general and may be regarded as a first draft that of course would need much more detailed work and analysis in close consultation with stakeholders before implementation.

**Some proposed general main sustainable energy development paths to the future**

- Development and application of integrated sustainability and resilience science.
- Individual, national, and global long-term/multi-generational sustainable planning and conduct.
- Constitutional adaption of the political governance system to support rapid and effective progress along the new sustainable paths, and to plan beyond its tenure, rather than its common preference to solutions that are primarily supportive of its own survival: popular support for such legislation should be sought/educated.
- Recognition that sustainable development can't take place without proper measures for population control.
- Conservation, as long as it meets the sustainability objectives
    - Higher efficiency with controlled rebound
    - Substitution for lower energy intensity products and processes
    - Recycling
    - More modest lifestyles
- Curbing the large fluctuations in fuel prices that are unrelated objectively to supply and demand or cost, and that are deadly to the development of alternative and/or efficient energy systems.
- Imposing a price on externalities, including of imports if not paid by the exporting country
- Sustainable renewable energy
    - Highest growth rate: solar and wind,
    - High potential: inedible biomass, hydro, especially small, geothermal.
- More efficient and cleaner use of fossil fuels (for this century); "Clean coal"; shale gas, tar sands, shale oil; reliable & economical $CO_2$ sequestration, partially by increased planting.
- More efficient transport, with attention to its management; electric vehicles with grid synergy.
- Enabling energy saving in the building sector by using free market forces.
- Nuclear energy if breakthroughs in fusion or in element transmutation, beyond-Gen-IV reactors.
- Significantly improved and smart energy distribution grids.
- Much better and sustainable energy storage and its significantly expanded use.
- Superconductivity, in the longer term.
- Space power generation for terrestrial use?
- Effective and equitable government subsidies.
- Legislation that forces and rewards long-term planning well beyond the tenure of political leaders.
- Morality: corruption, institutional to individual, is a major enemy of sustainable development.
- Benevolent innovation!
- Many of the innovative solutions require very long periods of time; It is of vital importance to start intensively now, so we wouldn't be too late. Maybe we already are…

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